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Dr. Pietro Paolo Falciglia

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FOREWORD

I am honoured to introduce this latest issue to the International Journal of Environment, Agriculture and Biotechnology (IJEAB). Our journal is dedicated to disseminating high-quality research and innovative findings that contribute to advancing knowledge in these critical fields.

In this issue, we present a collection of papers that exemplify the diversity and depth of contemporary environmental, agriculture, and biotechnology research. The articles include various topics, from sustainable agricultural practices and environmental conservation strategies to cutting-edge biotechnological innovations. Each contribution has undergone a rigorous peer-review process, ensuring the publication of only the most significant and original research.

Our commitment at IJEAB is to provide a robust platform for researchers, academicians, and practitioners to share their work and engage with a global audience. By fostering an interdisciplinary approach, we aim to bridge the gaps between different areas of study and promote holistic understanding and solutions to the challenges we face in these domains.

We are grateful to our dedicated authors, whose hard work and intellectual rigour are the backbone of our journal. We also extend our appreciation to our reviewers and editorial board members, whose expertise and diligence ensure the high standards of our publication. Finally, we thank our readers for their continued support and engagement.

We hope you find the articles insightful and inspiring as you explore this issue. We encourage you to contribute your research to future issues and join us in our mission to advance knowledge and drive positive change in the environment, agriculture, and biotechnology fields.

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Quality Analysis of Orange Varieties in the Mekong Delta and Kontum, Vietnam

Lang Thi Nguyen*, Phuong Hoang Le, Hieu Chi Bui, Khoa Anh Bien

High Agricultural Technology Research Institute for Mekong Delta
Web: hatri.org
*Corresponding author's email: ntlang.prof@gmail.com

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***Abstract*— *In the present study results, Orange were successfully produced and analysed for physical, chemical and sensory properties. It was observed that the resultant orange juice samples had a pH range of between 3.50 – 4.81 for samples for samples. A reversed case occurred on these samples for titratable acidity with a range of 1.47 – 3.18%. Cam Sanh (7) showed the highest concentrations of citric acid (3.18), The Total soluble sugar (TSS), Titratable acids (TA), TSS were also important parameters, related to orange quality, where Cam Canh(9) had the highest TSS value (17.8), and Cam Sanh (7) had the lowest TSS value (6.70). According to the above results, noticeable differences were observed among orange varieties.Oranges reduced the sugar content and increases the vitamin C content of the juice,and also has very high nutritional value. It is a very good source of vitamins, minerals and amino acids. Products were formulated and sensory evaluation was done by selected panel members. The results showed that there were significant differences in quality attributes, nutrients, and functional components among different orange varieties, which might be affected by the species, origin place, growing season, environmental factors, ripening, and changes in the storage process. The results of this study will provide valuable guidance for the identification and utilization of growing orange.*

***Keywords*— Orange, sensory properties, titratable acidity(TA), Total soluble sugar(TSS), valuable**

I. INTRODUCTION

Citrus belongs to the *Rutaceae* family and is one of the most important fruit trees in the world. (FAO.2020) ,Oranges provide a source of macro- and micronutrients and fiber (Marín et al., 2007). They are also rich in antioxidant compounds (Liu et al., 2012), report anti-cancer and anti-inflammatory properties (Ma et al., 2020), and are effective in reducing the risk of cardiovascular disease, osteoporosis, and type 2 diabetes (Sugiura et al., 2016). Orange is a distinct fresh fruit, widely consumed and especially appreciated for its aromatic taste. Orange powder is an excellent source of vitamin C, providing 64% of an individual's daily needs [USA.2014]. In addition to the vitamin C content in orange juice, it is also rich in folic acid, potassium, and an excellent source of bioactive antioxidant phytochemicals, and they are important commercial commodities in most countries (Vasavada .2003). Its juice has a composition of nearly 81.2 – 86.2% moisture, 13 – 19% of total solids of which sucrose, glucose... Collagen synthesis in the body. Significant differences among different citrus varieties were found. In particular, the total soluble sugar content of Mingrijian was higher than that of other citrus, suggesting its potential for fresh consumption and food processing(Huan et al.,2023).Recently, more and more research has focused on the domestication of Citrus of Mekong delta and KonTum province , helping us to shed light on the origins of cultivated species. This provides a comprehensive resource on how wild resources can contribute to improving existing varieties (Ahmed et al., 2019). Traditional variety selection is one of the main strategies used to improve agronomic characteristics. In many citrus species, some varieties have evolved through conventional methods, such as mutagenesis, mid-and-in-specific hybridization, and asexual selection (Caruso et al.

2020). Therefore, to compare the quality of oranges is the goal of this study and to compare the physical, chemical and sensory properties of the product in order to select the orange variety in the direction of the best quantity.

II. MATERIALS AND METHODS

Site selection

The study on the effect of altitude and fruit bearing positions on fruit quality attributes was conducted at three villages *viz.*, KonTum , Hau Giang (Vị Thuy) , Ben Tre (Giong Trom)and Can Tho(Phong Dien, O Mon) Vinh Long(Binh Minh)

Sample collection

30 orange fruits representing the single tree were collected and a replica containing 4 organces of each bearing positions were packed in sealed plastic bags and collected for physiochemical analysis. Fruits were harvested in first week of May 2023.

Table 1. The sites selected orange

Number	Lines	collected in Province	Sites: Latitude and longitude
1	Cam Xoan	Phong Dien Can Tho	Can Tho, latitude 9.9968° N, 105.6687° E, and the longitude is 105.6687
2	Cam Đuong	Phong Dien Can Tho	Can Tho, latitude 9.9968° N, 105.6687° E, and the longitude is 105.6687.
3	Cam Mat CT	Omon, Can Tho	Can Tho, latitude 10.1165° N,, and the longitude is 105.6326° E.
4	Cam MatBT	Giong Trom , Ben Tre	Latitude and longitude — 10.1719° N, 106.4641° E
5	Cam SanhBT	Giong Trom , Ben Tre	Latitude and longitude — 10.1719° N, 106.4641° E
6	Cam Sanh HG	Long My,HauGiang	Latitude 9.6696° N, longitud105.5650° E
7	Cam Sanh VL	Binh Minh Vinh Long	Latitude10.0705° N, longitude 105.8229° E
8	Cam Sanh KT	KonTum	Latitude14.3497° N, longitude 108.0005° E
9	Cam Canh	KonTum	Latitude14.3497° N, longitude 108.0005° E

Quality attributes assessment

Determination of quality attributes, total soluble sugar, and titratable acids in citrus fruits

Ingredients Fully ripe, ripe and fresh oranges are available at Kontum. They were transferred to the laboratory at the Mekong Delta High-Tech Agricultural Research Institute for further research. The chemicals and reagents used in this study belong to the analytical category.

Preparation of orange juice :Quality characteristics such as uniformity in size, color, shape have been considered in the selection of oranges. The selected ones are sorted and thoroughly washed under running water, after which they are washed with a 5% hypochlorite solution to remove surface bacteria and contamination.

- The fruit shape index (d/h) was calculated by dividing the transverse diameter by the vertical length of the fruit. After being peeled and deseeded, the fruit samples were weighed and then the edible proportion (%) was calculated as the percentage of the fresh weight of the edible tissues to the weight of the whole fruit.

Different chemical parameters i.e. Total soluble sugar (TSS), Titratable acids (TA), pH and ascorbic acid content were scored. TSS was measured by hand held refrac-tometer, pH was measured by digital pH meter at 27°C and TA and ascorbic acid were measured as per the methods outlined in AOAC (2016) and (Li et al.2021)

-Total soluble sugar (TSS) was measured with a hand-held digital refractometer (precision of ±0.01, PAL-BX/ACID F5, ATAGO Co., Ltd., Tokyo, Japan) at 25°C, and the data was expressed as "°Brix." The refractometer was cleaned with distilled water after each measurement.

- Titratable acids (TTA) were measured using the Phenolphthalein indicator method according to (Li et al.2021).

Ten (10ml) of the juice was pipetted into a conical flask and 25ml of distilled water added as described by AOAC [2016]. Two hundred metres (200ml) of 0.1M NaOH was powered into a burette and was titrated against the sample in the flask using three drops of phenolphthalein as indicator. It was titrated until a pink colouration was observed and the corresponding burette reading taken using the following formula.

Titratable acidity % = Titreblanknormality of base xml equivalent of citric acid / Weight of sample

ML equivalent of citric acid(meq) = 0.06404

Total Sugar Content (o Brix) The hand held sugar refractometer was used. The prism of the refractometer was cleaned and a drop of the juice was placed on the prism and closed. The total sugar content (o Brix) was read off the scale of the refractometer when held close to the eye according to the method of AOAC [2016].

-pH The pH of the juice was determined using a digital pH meter (pHs-2F, Harris, England) according to AOAC (2016) method. Fifty (50ml) of the juice was transferred into a beaker and the pH was determined after the meter was calibrated using standard buffer solutions of pH 4.0 and 7.0. Sufficient time was allowed for equilibration before readings were taken.

Determination of the contents of main nutritional compositions in citrus fruits

After the fruit was washed, the flesh and peel portions were separated by hand. The flesh portion was chopped, and homogenized using a Polytron blender for 1 min. Afterward, a weighed portion (100 g) was oven-dried and finely ground for further nutritional analysis. The content of moisture was determined using the hot-air drying method. Ash, protein, fat, and crude fiber were determined according to previously reported methods (Janati et al .,2012). Briefly, the fruit sample (1.0 g) was placed in a muffle furnace. The furnace temperature was gradually raised to 550°C and maintained for 30 min. After cooling the sample for 30 min, the furnace temperature was slowly raised to 550°C again and maintained for 30 min until the ash sample was obtained with a constant weight.

-The protein content (nitrogen × 6.25) was estimated by the Kjeldahl method, and a nitrogen analyzer was applied. Total dietary fiber content was measured by enzymatic digestion with thermostable 50 µL amylase (300 U), 100 µL protease (30 U), and 100 µL amyloglucosidase (400 U) in 40 mL 4-Morpholineethanesulfonic acid-Tris buffer (MES-Tris, pH 8.2).

-The lipit content was measured using petroleum ether as the extractant in a Soxhlet apparatus, and the carbohydrate content was measured by the difference method (Ani et al .,2018). The carbohydrate content was estimated according to the formula: carbohydrate (%) = 100 − ash−moisture−fat−protein−dietary fiber. Moreover, the content of ascorbic acid was determined according to a previous report (Sigmann et al.,2004). Briefly, citrus samples (100 g) were weighed and mixed with 100 mL of the extractant solution (8% acetic acid and 3% metaphosphoric acid). Thymol blue was selected as the indicator, and the fluorescence intensity was measured at an emission wavelength of 350 nm and an excitation wavelength of 430 nm. All nutritional compositions were presented in wet weight.

-Vitamin C was determined by a dye solution of 2, 6 – dichloroindophenol (DCIP) titration method described by (Mazumdar and Majumder 2003).

-Macro elements, such as phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na), as well as trace elements such as iron (Fe) and zinc (Zn), were analyzed using an inductively coupled plasma-optical emission spectrometry (ICP-OES; Varian ICP 720-ES, Varian Inc., Palo Alto, CA, United States) according to a previous study with appropriate modifications (Altundag et la.,2011). The sample (1.0 g) was added with 1 mL of $HClO_4$ and 5 mL of HNO_3 and treated on a hot plate. Where necessary, more acid was added to facilitate the dissolution of the residue, and a colorless and transparent digestion solution was prepared. Finally, the digested samples were cooled, fixed to volume, and filtered. Blanks were prepared in the same way as samples. The ICP-OES was calibrated using standard solutions of various elements prior to the analysis of citrus samples.

Sensory Evaluation

Sensory evaluation was carried out by nine trained panelists aged 24–45 years, following approval by HATRI .All the panelists had been trained for more than 6 months in citrus sensory evaluation, and they discussed a series of taste reference solutions, including sucrose (8%) for sweetness, citric acid (0.3%) for sourness, quinine (0.0025%) for bitterness, and tannins (0.2%) for astringency. Purified water was provided between evaluations to eliminate any residual taste from the tongue. Each taste intensity was marked on a 15 cm line scale with 0.5 cm anchors, labeled “very weak” on the left and “very strong” on the right (Kim et la.,2023).

Statistical Analysis Results were expressed as mean values and standard deviation of three (3) determinations. Data were analysed using a one-way analyses of variance (ANOVA) using Statistical Package for Social Science (SPSS) version 20.0 software 2011 to test the level of significance at 5% probability (p)

III. RESULT AND DISCUSSION

3.1. Analysis of citrus fruit quality attributes, total soluble sugar, titratable acids and pH

The quality attributes (fruit weight, and edible proportion) and juice properties (TSS, TA, and TSS/TA) and pH of citrus fruits are shown in table2. The appearance and cross-section photographs of different citrus varieties were displayed in figure 1. The mean fruit weight, was a significant difference among different citrus varieties. Cam Canh , a relatively small variety, had the lowest mean fruit weight (152.1 g). Marked differences were found in organic acid composition (Table 2), in which citric acid was the main organic acid, followed by malic and ascorbic acids. Cam Sanh (7)and Cam Sanh (8) showed the highest concentrations of citric acid (3.18 and 3.05 %,respectively), The TSS, TA, and TSS/TA were also important parameters, related to citrus quality, where Cam Canh(9) had the highest TSS value (17.8), and Cam Sanh (7) had the lowest TSS value (6.70). According to the above results, noticeable differences were observed among citrus varieties. The quality parameters of citrus samples varied with varieties and growing regions(Tounsi et al.,2011).Moreover, a citrus metabolomic pathway associated with the cultivation methods is proposed, and the correlations of the phytochemical profiles and sensory and soil characteristics are discussed by (Sung et al.,2024). Notably, among the selected citrus varieties, the Cam Xoan, Cam Canh , Cam Duong higher attention was given to it. This is confirmed by the TSS/TA ratio, an important indicator of commercial and sensory ripeness. This is used widely for citrus fruits because it helps define their characteristic flavour (Pilla et la.2022)The TSS/TA value of Cam Canh , Cam Xoan produced in KonTum , Cam Mat was higher than other varieties, even higher than Cam Xoan Can Tho (a variety famous for its high sweetness), indicating its potential for fresh consumption and food industrial processing. Maturity index was another important parameter related to the qualitative characteristics of citrus fruit and is linked to fruit ripeness. Cam Mat had the highest value as a result of its low citric acid content.

The physical properties' result showed that the pH of the juices ranged between 3.50 – 4.81 for samples , as presented in Table 2. This falls within the range of 3.50 – 3. for fruit as reported by (Ohwesiri et al .,2016). There were significant difference ($p<0.05$) in the pH values for samples 3(Cam Mat and 4 (Cam Mat)the reference sample (4.81, and 4.22), respectively. The pH value for sample 1: Cam Xoan (4.51) was significantly higher while samples 5,7,6 (3.50,3.51 and 3.63) respectively was significantly low compared to other samples.

1.Cam Xoan 2: Cam Duong 3: Cam Mat 4: Cam Mat 5 : Cam Sanh BT

6. Cam SanhHG 7. Cam Sanh VL 8. Cam SanhKT 9. Cam Canh

Fig.1. Appearance morphology of different citrus fruits. 1: Cam Xoan ;2: CamDuong PD;3: Cam Mat OM ;4: Cam Mat BT ;5 Cam Sanh BT; 6: Cam Sanh HG; 7: Cam Sanh VL;8: Cam SanhKT 9: Cam Canh

Table 2: Quality attributes, total soluble sugar, and titratable acids , pH of organe fruits.

No.	name	Weight(g)	Seed	TA(%)	TSS(Brix)	TSS / TA	pH
1	Cam Xoan	180.1d	1	1.56e	16.5b	10.58b	4.51a
2	Cam Đuong	253.5b	12	1.87d	15.6c	8.34c	4.32a
3	Cam Mat CT	156.7f	10	1.95c	14.6d	7.48d	4.81a
4	Cam MatBT	189.5d	12	1.75d	13.5e	7.71d	4.22a
5	Cam SanhBT	264.7a	14	2.89b	8.2f	2.83e	3.50b
6	Cam Sanh HG	256.3b	6	3.02a	7.6g	2.51e	3.63
7	Cam Sanh VL	212.7c	10	3.18a	6.7h	2.13e	3.51b
8	Cam Sanh KT	166.5e	13	3.05g	13.4e	10.72b	4.56a
9	Cam Canh	152.1f	15	1.47f	17.8a	12.10a	4.15a

Note: Numbers that follow the same character are not statistically significant at 5%.

3.2. **Nutritional composition analysis**

The health-promoting effects of organe fruits are largely attributed to their abundance of nutrients. Organe fruits are rich in a variety of other nutritional compositions, including protein, carbohydrates, fat, dietary fiber, and ascorbic acid. The nutritional compositions of different organe varieties were shown in Table 3. The protein content of the orange was low, ranging from 0.91 – 1.45 % for samples. Sample 5 (Cam Sanh) was observed to have significantly higher value compared to other 6 and 7 samples while sample 3 and 4 (Cam Mat) had no significant difference as compared to sample 2 (Cam Duong). The total lipid content of organe fruits was determined to be 0.20–1.15 g/100 g wet weight. The carbohydrate content of organe fruits was determined to be 7.21–11.08 g/100 g wet weight and The carbohydrate was the main component that gives organe its sweetness (Lu et al.2021). The dietary fiber of the organe fruits varied significantly among different varieties, ranging from 1.89 to 3.60 g/100 g wet weight. Cam Xoan was the variety with the highest dietary fiber content. Cam Duong (2) also had elevated dietary fiber content at about 3.03 g/100 g wet weight, while Cam Canh (9) (1.94 g/100 g wet weight) and Cam Mat (1.89 g/100 g wet weight) had the lowest dietary fiber content. These organe fruit quality parameters are under the influence of environmental factors (Chelong et al.,2013). The maturation of organe fruit is then impacted by climatic factors such as relative humidity, solar radiation and especially temperature. In fact, organe fruit maturation is closely related to thermal summation (Stenzel, et al.,2006). Depending on the plant investigated, degree days provide estimations of rates of activity of biochemical processes as well as plant growth. As shown in Table 3, Cam Sanh: sample 5,7, and 6 (36.3;35.75 and 30.2mg/mL) respectively and had the highest ascorbic acid content .Furthermore, the lowest ascorbic acid content was found in 8(20.6 mg/mL) and line 9 (21.49 mg/mL). Table 3

Table 3. Nutritional composition and elemental composition of orange fruit.

	1	2	3	4	5	6	7	8	9	
Protein(g/100g)	1.39b	0.91d	0.98d	0.95d	1.45a	1.36b	1.22c	0.86e	0.95d	
Lipit (g/100g)	1.15a	0.75c	0.85b	0.54d	0.52d	0.56d	0.54d	0.20e	0.78c	
Carbohydrade(g/100)	11.08a	10.32b	9.25c	7.89d	7.21d	7.23d	7.25d	9.86c	9.75c	
Acid ascorbic(mg/100g)	23.93f	25.61e	22.77f	32.18c	36.31a	30.2d	35.75b	20.62h	21.49g	
Vitamine C	61.2b	58.7c	63.7b	66.5b	72.8a	72.9a	73.0a	66.2b	60.4b	
Fiber(G/ 100g)	3.60	3.03	2.17	1.89	2.69	3.01	2.58	2.56	1.94	
Na(mg/100g)	3.2	3	3	3.1	3.1	2.95	2.95	2.74	3.0	
P(mg/100g)	188.5b	125.7b	189.6b	130.5c	114.7d	185.2	210.56a	200.45a	204.2a	
K(mg/100g)	2.06a	1.18d	2.04a	1.28c	1.25	1.47b	2.14a	2.25a	2.45a	
Mg(mg/100g)	119.8e	145.3b	120.5s	125.8s	118.5	155.7a	145.7b	114.5e	132.5c	
Canxi(mg/kg)	256.7c	321.4b	342.1b	415.2a	321.4b	241.2c	215.6c	224.1c	225.7c	
Fe(mg/Kg)	3.2	3.1	3.25	3.21	3.2	3.2	3.5	3.2	3.2	
Zn(mg/Kg)	2.12	2.15	2.13	2.14	2.01	2.03	2.14	2.10	2.25	

Note : 1: Cam Xoan ;2: CamDuong PD;3: Cam Mat OM ;4: Cam Mat BT ;5 Cam Sanh BT; 6: Cam Sanh HG; 7: Cam Sanh VL;8: Cam SanhKT 9: Cam Canh.

3.3. Elements analysis

Orange juice is a good source of minerals, such as P, K, Mn, Ca, Mg, F, Cu, etc. The types and contents of elements in different varieties of orange were shown in Table 3. The contents of Na in the citrus samples were lower than 3 mg/100 g, and the contents of K were determined to be 1.18–2.45 mg/kg. The contents of Ca in the pulp of orange fruits were determined to be 194.2–446.9 mg/Kg. Ca, which plays an important role in building strong bones (Czech et la.2020). The contents of P in the pulp of orange fruits were determined to be approximately 114.7–210.56 mg/kg. The contents of Mg in organe samples were determined to be 114.5–155.7 mg/kg.These essential phytonutrients played important roles in various enzymatic reactions, but their contents were not shown in this study due to low levels. In conclusion, the orange fruit variety had a significant effect on the content of mineral elements in citrus pulp. This result might attribute to the mineral composition of the soil in which they are grown, the types and amounts of fertilizers used, weather conditions, and the composition of irrigation water (Czech et la.,2020).

3.4. Sensory Properties of Orange

The statistical analysis revealed that there were significant difference ($p>0.05$) in the tasted of all the orange juice samples as shown in Figure 2. Some fruit orange that have been produced reported by researchers to obtain high sensory value are cashew juice with sensory score range of 1 .5(Cam Sanh VL – 5 (Cam Duong) on a 5 – point hedonic scale . Citrus flavor is a combination of various metabolites involved in the basic taste (sugars, acidic compounds, phenolic compounds, and limonoids) and volatile compounds (Lado et la., .2023). In particular, acidic compounds play a dominant role in orange taste by stimulating bitterness and suppressing or partially masking sweetness (Jiang et la.,2019).

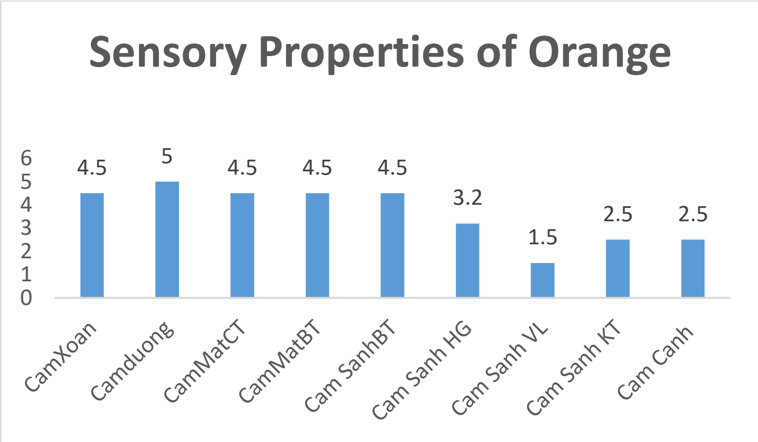

Fig.2: Sensory properties of orange

IV. CONCLUSION

The total soluble sugar content of Cam Xoan and Cam Canh produced in Can Tho and KonTum in this study was higher than those of other orange varieties, suggesting its potential for fresh consumption and food industrial processing. Orange were successfully produced and analysed for physical, chemical and sensory properties. It was observed that the resultant juice samples had a pH range of between 3.50 – 4.81 for samples for samples. A reversed case occurred on these samples for titratable acidity with a range of 1.47 – 3.18%. Oranges reduced the sugar content and increases the vitamin C content of the orange. Its moisture value falls within the acceptable range and presented no significant difference compared to the reference sample. The dietary fiber of the organe fruits varied significantly among different varieties, ranging from 1.89 to 3.60 g/100 g wet weight. Cam Xoan was the variety with the highest dietary fiber content. Cam Duong (2) also had elevated dietary fiber content at about 3.03 g/100 g wet weight, while Cam Canh (9) (1.94 g/100 g wet weight) and Cam Mat (1.89 g/100 g wet weight) had the lowest dietary fiber content. All the sensory attributes of the orange reference sample. The results showed that there were significant differences in quality attributes, nutrients, and functional components among different orange varieties, which might be affected by the species, origin place, growing season, environmental factors, ripening, and changes in the storage process. The results of this study will provide valuable guidance for the identification and utilization of growing orange.

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Wind speed's impact on the distribution uniformity of sprinkler irrigation system in Haryana

Raj Kumar[1]*, Ram Naresh[2]

[1]Research Scholar, Department of Soil & Water Engineering, CCSHAU, Hisar
[2]Assistant Professor, Department of Soil & Water Engineering, CCSHAU, Hisar
*Email: rajkumarhau9@gmail.com

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Abstract**—** *This study investigated the impact of varying wind speeds on water distribution uniformity using a 6 m × 6 m lateral spacing configuration with rotating sprinklers at the field of the village Luhana located in Western Haryana, India, during 2019-20. Three replications were conducted under different wind conditions: 0-4 km/h, 4-8 km/h, and 8-12 km/h. For wind speeds ranging from 0 to 4 km/h, observed speeds averaged 3.0 km/h, with distribution uniformity ranging from 79.17% to 86.33% in the northwest direction (average 82.46%). Wind speeds between 4 and 8 km/h yielded an average of 6.4 km/h, with distribution uniformity varying from 81.42% to 84.22% (average 82.88%). At wind speeds of 8-12 km/h (average 10.8 km/h), distribution uniformity ranged from 79.73% to 83.57% (average 81.42%). Variations in the uniform distribution of water were less prominant at wind speeds between 0-4 km/h. But it was observed that a range of wind speed 8-12 km/h, significant deviation from the uniformity distribution of water was observed.*

Keywords**— *Distribution uniformity, Irrigation, Sprinkler, Sprinkler spacing, Wind speed***

I. INTRODUCTION

The Green Revolution in India, which significantly transformed agricultural productivity post-independence, was largely driven by the development and expansion of irrigation systems. Unirrigated regions in India, barring a few exceptions, did not experience the same agricultural advancements, underscoring the critical role of irrigation [1]. Despite having only 4% of the world's water resources, India supports 17% of the global population, highlighting the country's intense water resource management challenge [2]. Out of the annual 3700 BCM of water resources derived from precipitation, approximately 850 BCM are used for evapotranspiration, and 1850 BCM are lost to runoff [3].

Pressurized irrigation techniques, such as drip, sprinkler, center-pivot, and traveler irrigation systems, offer high water application efficiency [3], [4]. These methods enhance soil health, provide precise irrigation, and mitigate issues related to water scarcity, salinization, labor shortages, and waterlogging. This is particularly crucial in arid and semi-arid regions where best management practices are essential for optimal results [5].The primary objective of sprinkler irrigation systems is to achieve high distribution uniformity (DU). Several factors, including design parameters, environmental conditions and management practices, influence the uniformity of sprinklers [6]. Sprinkler irrigation disperses water in the form of tiny droplets over the irrigated surface using pressurized systems. The goal is to maintain high water uniformity and achieve a good crop yield. The system includes numerous laterals that are easily disassembled and reassembled, making it suitable for irrigating large areas efficiently. Unlike traditional irrigation methods, sprinkler systems minimize water losses due to seepage, evaporation, and evapotranspiration, leading to improved crop productivity.

The design of the sprinkler irrigation system significantly impacts crop yield. An ideal system ensures even water distribution across the entire irrigated area. Enhanced water productivity is achieved when optimal water supplies result in higher crop yields. Conversely, excess water can reduce yields by leaching plant nutrients, increasing disease prevalence, and failing to promote the growth of commercially valuable plant parts. Insufficient water leads to weaker plants and lower crop yields [7].

II. MATERIAL AND METHODS

An experiment was conducted on a low-pressure portable rotating sprinkler system installed in the village of Luhana, located in Western Haryana at 28° 15' 33.84" N latitude and 76° 24' 4.68" E longitude, with an elevation of 246 meters above mean sea level. The field was leveled and free from obstacles to ensure accurate measurement of water distribution. The region experiences an annual rainfall of 569.6 mm. Relative humidity ranges from 36-45% in winter to 78-84% during the summer and monsoon seasons. The sprinkler system utilized was a solid set, semi-permanent hand-move type. The soil texture is sandy loam. Wind speed was measured using an anemometer, and water distribution was collected using catch cans placed uniformly across the irrigated area.

Table 1: Different treatments combinations to study the effect of sprinkler spacing and average wind speed on distribution uniformity

S. No.	Treatment	Abbreviation
1	6 m × 6 m sprinkler spacing with the range of 0-4 km/h wind speed	T1
2	6 m × 6 m sprinkler spacing with the range of 4-8 km/h wind speed	T2
3	6 m × 6 m sprinkler spacing with the range of 8-12 km/h wind speed	T3

The primary water resource in the area was alkaline groundwater, with levels ranging from 6.67 m to 26.31 m during the pre-monsoon period and from 6.79 m to 25.14 m during the post-monsoon period. To lift and supply this water to the sprinkler irrigation system, a 15 HP submersible pump was installed in the bore well. The water was conveyed through a network of mains and sub-mains consisting of 6 m long aluminum pipes with a diameter of 75 mm, achieving a measured discharge of 4.5 l/sec in the main line. The sprinkler system was designed to distribute water uniformly across the field, preventing runoff and significant deep percolation losses.

For this experiment, rotating sprinklers were selected due to their adaptability to a wide range of application rates and spacing configurations. Each sprinkler nozzle, with a size of 4.5 mm and a coverage diameter of 12 m, was connected to risers and positioned to cover a 360° angle. To measure wind velocity during the experiment, a digital anemometer was employed, capable of recording wind speeds from 1.4 to 180 km/h. Additionally, a pressure gauge was used to monitor the system's water pressure. The discharge of the sprinklers was measured using a bucket and stopwatch method. The sprinklers were operated for 30 minutes, and the water collected in catch-cans was measured with a measuring cylinder to determine the discharge rate.

2.1 Distribution Uniformity (DU)

DU = 100 * (Avg. low quarter depth of application/Overall avg. depth of application) (1)

2.2 Uniformity Coefficient (UC)

Christiansen equation [8] was used.

$$UC = 100 * \{1-(\Sigma X/mn)\} \quad (2)$$

Where,

m = Average value of all observation (average application rate), mm

n = Total number of observation points

X = Numerical deviation of individual observation from the average application rate, mm

2.3 Methodology

A suitable location was chosen for the test area layout, ensuring it was free from obstacles that could hinder the even distribution of water. The field was clear of obstructions, and the area where catch cans were positioned was leveled evenly in a horizontal plane. The laterals were laid out in the test area according to the required spacing, with the risers kept vertical. Rotating sprinkler heads were mounted on the risers, ensuring compatibility with the connecting thread on the sprinklers.

Catch cans were arranged on a grid with a 1 m × 1 m spacing to test water distribution patterns for different sprinkler spacings (6 m × 6 m, 6 m × 9 m, and 9 m × 12 m). Water was supplied to the sprinklers through 75 mm aluminum lateral pipes by a 15 HP submersible pump. Before starting the test, all catch cans were emptied.

The test commenced by simultaneously operating all the sprinklers surrounding the test site, with the start time recorded. Wind velocity and direction were noted every 5 minutes using an anemometer, along with the ambient temperature. The sprinklers ran for 30 minutes before the test was terminated by stopping the sprinklers, and the end time was noted. The volume of water collected in the catch cans was measured with a measuring cylinder, and the readings were recorded. Additionally, the discharge of the nozzles was measured by collecting water in a bucket, with the duration noted using a digital stopwatch.

III. RESULTS AND DISCUSSION

3.1 Distribution uniformity for range 0-4 km/h wind speed with spacing 6 m × 6 m in different directions (T_1)

Three replications were conducted for lateral spacing of 6 m × 6 m under wind speeds ranging from 0 to 4 km/h. The observed wind speeds ranged from 2.46 km/h to 3.83 km/h, with an average speed of 3.0 km/h. In the northwest direction, distribution uniformity ranged from 79.17% to 86.33%, averaging 82.46%. Table 2 presents detailed data on the distribution uniformity of water influenced by wind speeds within the 0-4 km/h range.

Table 2: Distribution uniformity and average wind speed in different directions calculated from observing data of treatments T_1

Experiment no.	Avg. wind speed (km/h)	DU (%)	CU (%)
1	2.46	86.33	91.79
2	2.86	81.89	90.85
3	3.83	79.17	90.20
Average	**3.0**	**82.46**	**90.94**

3.2 Distribution uniformityfor range 4-8 km/h wind speed with spacing 6 m × 6m in different directions (T_2)

Three replicates were carried out for a lateral spacing of 6 m × 6 m under wind speeds ranging from 4 to 8 km/h. Throughout these trials, wind speeds ranged from a minimum of 4.67 km/h to a maximum of 7.73 km/h, with an average of 6.4 km/h recorded. In the northwest direction, the distribution uniformity of water varied between 81.42% and 84.22%, with an average value of 82.88%. Detailed results depicting the impact of wind speeds within the 4-8 km/h range on water distribution uniformity are provided in Table 3.

Table 3: Distribution uniformity and average wind speed in different directions calculated from observing data of treatments T_2

Experiment no.	Avg. wind speed (km/h)	DU (%)	CU(%)
1	4.67	84.22	89.49
2	6.81	83.02	88.93
3	7.73	81.42	87.88
Average	6.4	82.88	88.76

3.3 Distribution uniformityfor range 8-12 km/h wind speed with spacing 6 m × 6 min different directions (T_3)

Three replicates were performed for a lateral spacing of 6 m × 6 m under wind speeds ranging from 8 to 12 km/h. During the experiments, wind speeds ranged from a minimum of 9.74 km/h to a maximum of 11.91 km/h, averaging 10.8 km/h. In the northwest direction, the distribution uniformity of water varied between 79.73% and 83.57%, with an average of 81.42%. Table 4 provides detailed findings on how wind speeds in the 8-12 km/h range influenced the distribution uniformity of water.

Table 4: Distribution uniformity and average wind speed in different directions calculated from observing data of treatments T_3

Experiment no.	Avg. wind speed (km/h)	DU (%)	CU (%)
1	9.74	83.57	87.36
2	10.93	80.98	86.94
3	11.91	79.73	86.17
Average	**10.8**	**81.42**	**86.82**

3.4 Effect of different Wind Speed at Spacing 6 m * 6 m on Water Distribution

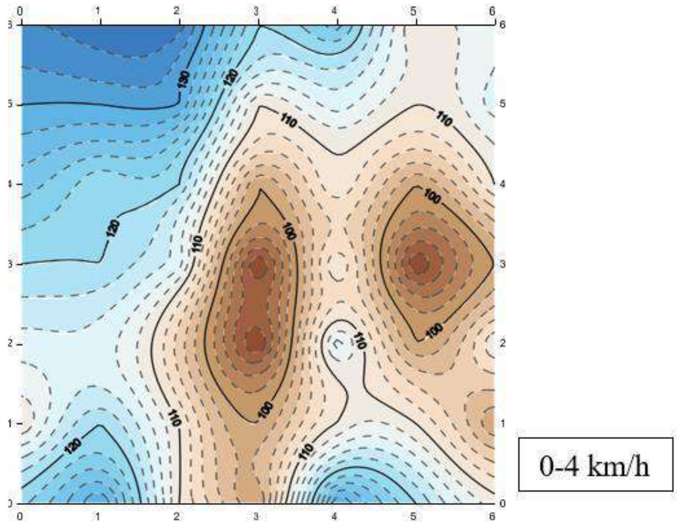

Fig.1: Effect of wind movement *on water distribution at treatment combination T_1*

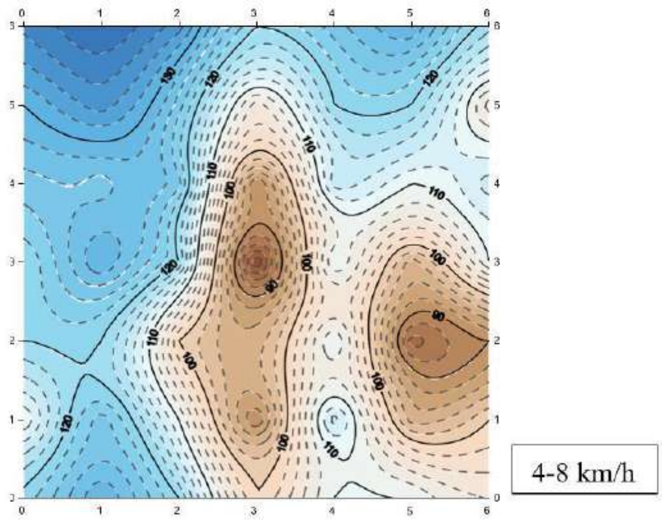

Fig.2: Effect of wind movement on water distribution at treatment combination T_2

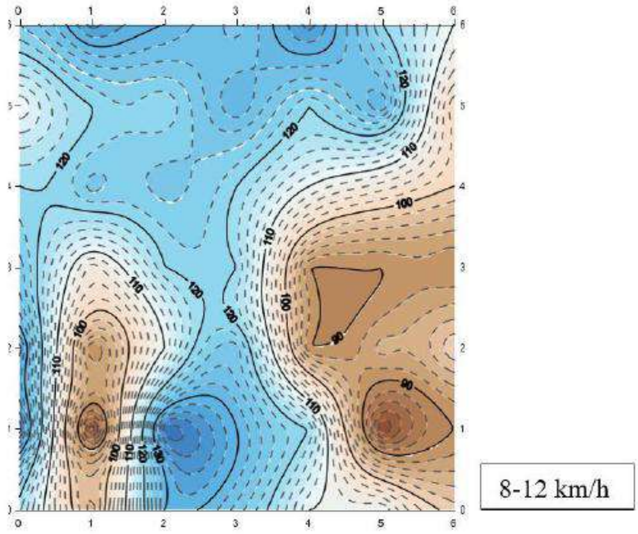

Fig.3: Effect of wind movement on water distribution at treatment combination T_3

Comparing treatment combinations (T_1, T_2, and T_3) across varying wind speeds (0-4 km/h, 4-8 km/h, and 8-12 km/h) with a sprinkler spacing of 6 m × 9 m revealed that T_1 exhibited the most effective water distribution pattern. This was attributed to significant overlap between sprinklers, ensuring uniform water coverage. However, higher wind speeds, particularly in T_2, and T_3, caused minor deflection of spray towards the field's center, potentially reducing water reach at the sides and corners. Implementing wind breaks in the windward direction could mitigate this issue.

In contrast, treatments T_2, and T_3demonstrated more pronounced deflection in water distribution patterns as wind speed increased. The multi-directional impact of wind led to uneven water coverage and reduced overlap between sprinklers. These observations underscore the importance of considering wind effects in optimizing sprinkler system performance and uniformity of water application.

3.5 Impact of Wind Speed on Average Distribution Uniformity and Uniformity Coefficient

Based on the findings presented in Fig. 1, it is evident that as wind speed increases from 0-4 km/h to 8-12 km/h, both distribution uniformity and uniformity coefficient decrease. This indicates that higher wind speeds result in less uniform distribution of applied water across the field, leading to lower overall uniformity. For instance, distribution uniformity decreases from approximately 82.46% at wind speeds of 0-4 km/h to about 81.42% at wind speeds of 8-12 km/h. A similar trend is observed for the uniformity coefficient, illustrating a reduced consistency in water application with increasing wind speeds. These results highlight the significant influence of wind speed on the performance of sprinkler irrigation systems. Higher wind speeds disrupt the trajectory of water droplets from sprinkler nozzles, causing them to drift and resulting in uneven water distribution. This can potentially impact crop growth and yield, as certain areas may receive more water than others, leading to water stress or nutrient leaching in some parts of the field.

In conclusion, managing wind effects is crucial for optimizing the efficiency of sprinkler irrigation systems. Strategies such as adjusting sprinkler design, spacing, or operating schedules based on prevailing wind conditions can help mitigate the negative impact of wind on distribution uniformity.

IV. CONCLUSION

As wind speeds increase, the uniformity of airborne particle distribution decreases, resulting in lower distribution uniformity and coefficient of uniformity. This phenomenon is likely due to the turbulent nature of wind at higher velocities, which disrupts the consistent distribution of particles.

For sprinkler systems operating under wind speeds of 8-12 km/h, a spacing of 6 m × 6 m appears suitable to achieve a distribution uniformity of 75%. Similarly, this spacing maintains a coefficient of uniformity of 85%. These findings underscore the importance of considering wind conditions in optimizing sprinkler system performance to ensure uniform water application and effective agricultural irrigation practices. Adjusting sprinkler spacing and other system parameters according to prevailing wind speeds can mitigate the adverse effects of wind turbulence on water distribution uniformity.

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Investigating Biochemical Characteristics of Key Finger Millet (*Eleusine coracana* L.) Varieties/ Genotypes

Neelesh Mishra*, Lalit Kumar Singh, V. B. Gore, Kundan, Amit Deep Mishra

[1,3,4]Ph.D. Scholar, Division of Biochemistry, Indian Agricultural Research Institute, New Delhi,110012.
[2]Professor And Head Department of Biochemical Engineering, HBTI Kanpur, UP.
[5]MSc Agri.Vegetable Science, CSAUA&T Kanpur.
Email: neelesh4dolu@gmail.com

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***Abstract*— *During the 2022-23 research conducted at the Department of Agricultural Biochemistry, C. S. Azad University of Agriculture and Technology in Kanpur, a comprehensive investigation was undertaken to analyze the physical parameters, functional properties, and biochemical parameters of 20 varieties/genotypes of finger millet. The study employed a Completely Randomized Design (CRD), and all findings were deemed statistically significant. Among the varieties assessed, IC0321712 exhibited the highest value in terms of test weight, indicating its potential for robust grain yield. Notably, IC0475978 demonstrated exceptional functional characteristics, particularly in dispersibility and water absorption capacity, suggesting its suitability for various food applications. Furthermore, variety IC0476418 emerged as biochemically superior, boasting elevated levels of carbohydrates and proteins. Additionally, it contained significant amounts of essential amino acids such as methionine and tryptophan, which are crucial for human health. These findings hold significant implications for breeding programs and the promotion of finger millet consumption. By identifying varieties/genotypes with superior nutritional profiles and specific health-promoting properties, this research contributes to the advancement of agriculture and the diversification of nutritious grain sources.*

***Keywords*— Dispersibility, millets, Tryptophan, ragi, seed colour**

I. INTRODUCTION

The grass family *Poaceae* encompasses a remarkable member known as finger millet (Eleusine coracana) with a chromosome count of 2n=36. Around 5000 years ago, a wild variant of finger millet, flourishing in the highlands of Ethiopia and Uganda, underwent the transformative process of domestication. Subsequently, domesticated finger millet found its way to the lowlands of Africa. Roughly three millennia in the past, this invaluable grain journeyed to India, establishing the nation as a secondary hub of finger millet diversity (FAO, 2023). Widely recognized as "ragi" in India, it stands as a dietary cornerstone for many in economically disadvantaged segments of society. In the Indian context, finger millet ranks as the third most vital millet. Its primary consumption base lies within underdeveloped regions globally, often earning the monikers "crop for the poor" or "famine food." Yet, its nutritional and therapeutic prowess has elevated it to the status of a "super cereal" (Vietmeyer, 1996).

According to the World Food Programme, almost 1.2 billion people are estimated to routinely consume millet. The production of millet has been relatively stable in the past several years, and in 2020, 28 million metric tons are expected to be produced. Asia is the second-largest producer of millet, behind Africa. The top three nations in the world that produce millet are China, Niger, and India. Further notable millet-producing countries are Senegal, Mali, and Burkina Faso. India ranks among the top 5 exporters of millet worldwide. Millet exports increased from $400 million in 2020 to $470 million in 2021, based on the ITC trade map. India exported $64.28 million worth of millets in 2021–2022, compared to $59.75 million in 2020–2021.

The mature plant may grow up to 150 cm in height. Among other things, the seeds—which might be white, light brown, or dark brown—are used to produce unleavened bread from milled flour. With many tillers and nodule branches, the leaves are grass-like and thin. The panicle is composed of fingers, which are a group of digitally ordered spikes.

A culture of "refined" eating and growing worries about lifestyle illnesses have led to a gradual but steady shift in consumer behavior toward nutrient-rich millets as a viable alternative to wheat and rice. Customers in both urban and rural regions are increasingly favoring millets to improve their immunity and nutrition as a consequence of the COVID-19. The Government of India designated certain millets as Nutri-Cereals in April 2018 to promote the production and consumption of millets. These include Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Ragi/Mandua), and Minor Millets, such as Foxtail Millet (Kangani/Kakun), Proso Millet (Cheena), Kodo Millet (Kodo), Barnyard Millet (Sawa/Sanwa/ Jhangora), Little Millet (Kutki), and two Pseudo-millets, Buckwheat (Kuttu) and Amaranthus (Chaulai). In an effort to boost demand for millets both domestically and internationally and to provide people with nutrient-dense meals, the Indian government has asked the UN to declare 2023 the International Year of Millets (IYoM-2023). The United Nations General Assembly (UNGA) declared March 20, 2023, to be the International Year of Millets after 72 countries granted India's proposal. Consequently, the Honourable Union Finance Minister declared the following budget on February 1st, 2022: It has been announced that 2023 will be the International Year of Millets. Post-harvest value addition, increasing local consumption, and national and international branding of millet products will all receive support. (NABARD 2023). It is also a nutritious grain that is high in fiber and other minerals. These elements will guarantee millet's continued importance as a food crop in the years to come. Most Indian millets are cultivated in arid and semi-arid regions and belong to a class of nutrient-rich, drought-tolerant cereals. They are an essential part of India's economic and ecological security and a major source of food and fodder for millions of farmers who lack resources. They are ideal for anyone with diabetes or celiac disease because they are also gluten-free and have a low glycemic index.

All other millets have at least twice as much calcium as rice, but finger millet contains thirty times more than rice. Rice is not even in the race since foxtail and little millet are so rich in iron. Millets contain large amounts of Carotene, a vitamin that most of us only find in pharmaceutical tablets and capsules. Additionally, ragi contains a sizable amount of essential amino acids (EAA), which are necessary for human health. Eleusine coracana, the primary protein portion of finger millet, has strong levels of valine, methionine, isoleucine, tryptophan, and threonine, making it a biologically valuable food. In addition to aiding in the body's nitrogen balance, valine is necessary for metabolism, muscular coordination, tissue healing, and muscle balance. Additionally, it enhances and maintains mental vigor and tranquility. Isoleucine has a critical role in maintaining blood formation and controlling blood sugar levels. It also helps to mend and rebuild skin, bones, and muscular tissue. The body uses threonine to maintain its levels of protein. It also inhibits the production of fat in the liver and aids in the development of tooth enamel. Tryptophan is a naturally occurring relaxant that helps prevent anxiety, melancholy, and sleeplessness. They also lessen overindulgence in food and produce growth hormones, which aid in the treatment of migraine headaches. Methionine is an amino acid with a sulphur base that the body needs for a number of functions. It's said to support healthy skin and hair growth. Finger millet is consumed to fulfil customary needs and as a dietary supplement. The food items are given to sick people, infants, breastfeeding mothers, and expecting women as a nutritious supplement. Leprosy is treated internally in southern Africa by drinking a mixture of finger millet leaves and leaves.

In addition to the primary nutrients, 100 grams of finger millet includes 290 mg of phosphorus, 410 mg of calcium, and 12.6 mg of iron. Patients with diabetes are also advised to consume it due to its high fiber content and low glycaemic index. Eating finger millet reduces cholesterol and keeps constipation at bay. The seed of finger millet is used medicinally as a dysentery prophylactic. Ragi has the highest levels of phytic acid (685 mg/100g), total polyphenols (298 mg/100g), tannins (18.75 mg/100g), flavonoids (23.68 mg/100g), and trypsin inhibitors (102.6 mg/100g). Its high carbohydrate content (72%), proteins (7.3%), fat (1.4%), and minerals (2.7%) account for its nutritive value. (Kumar et al., 2013).

finger millet's medical applications and its well-known therapeutic qualities, even for the average person. gives the body elasticity and strength, allows for the preservation of strength without fatigue, raises body warmth, and causes increased urine; for these reasons, it is typically used in heavy physical labor. Finger millet bran causes indigestion, thus in order to avoid this issue, it must be soaked, pulverized, and the bran/husk removed before drying and eating. Additionally, millets include folic acid and the vitamins "B" complex, particularly niacin. Minerals including calcium, iron, potassium, magnesium, and zinc are also present in finger millet. It has been shown that eating enough calcium helps to regulate blood-lipid levels and guards against osteoporosis, colon cancer, and kidney stones. For youngsters to gain bone, the ideal calcium to protein ratio is required. Patients with diabetes are given finger millet grain to help lower their blood glucose levels. Those with heart problems can also benefit from this grain. (Et al., Rajalakshmi 2014). The United Nations Organization is observing 2023 as International Millets Year to encourage the use and processing of millets in light of their utility, at the request of the Indian government. Coarse grains can also significantly lessen the prevalence of hunger and malnutrition in African nations. Given the significance of this, the current study has been designed to accomplish the goals. The study seeks to identify those with superior biochemical profiles, which could potentially contribute to enhanced nutritional value, health benefits, or other desirable characteristics. The research may also explore correlations between biochemical composition and agronomic traits to provide insights into the underlying genetic and physiological mechanisms governing these traits. Additionally, the findings could inform breeding programs aimed at developing improved finger millet varieties with optimized biochemical attributes for food, nutrition, and agricultural sustainability.

II. MATERIALS AND METHODS

The current study was conducted at the laboratories of the Department of Agricultural Biochemistry at Chandra Shekhar Azad University of Agriculture and Technology in Kanpur, India, during the 20222–2023 season. The Chandra Shekhar Azad University of Agriculture and Technology in Kanpur's Department of Genetics and Plant Breeding will provide the seed sample for each of the twenty finger millet varieties/genotypes listed below. The Department of Agricultural Biochemistry, Laboratory of Biochemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India is the site of all experiments and research. Longitude: 80.307251, Latitude: 26.491150.

Seed colour:

Seed coat colour of ragi millet germplasm was determined on the bases of visual observation

Test weight:

The weight of a thousand seed was calculated by weighing, writing down the weight, then manually counting the samples. With a precision of 0.01 g, the grain samples were weighed using a digital electronic balance.

Dispersibility: -

A total of 10 g of the flour sample was weighed into 100 mL measuring cylinder and distilled water was added. The set up was stirred vigorously and allowed to stand for 3 h. The volume of settled particle was recorded and subtracted from 100. Olopade, *et.al*., (2014).

$$\% \text{ Dispersibility } = 100 - \text{volume of settled particles}$$

Water absorption capacity: -

One gram of flour was divided into three identical 50 mL centrifuge tubes, to which 10 mL of distilled water was added. The mixture was then thoroughly mixed with a glass rod and allowed to sit in a water bath at 30 degrees Celsius for half an hour. A centrifuge was used to centrifuge the centrifuge tubes for 15 minutes at 3,000 rpm. After discarding the supernatants, the remnants were weighed. Sawant et al. (2013) used Equation 11 to determine the water absorbance of two distinct centrifuge tube weights.

$$\text{Water absorption capacity} = \frac{V1-V2}{V2} X100$$

Where: V1 = initial volume of the liquid

V2 = final volume of the liquid

Carbohydrate

Estimation of carbohydrate is done by anthrone method. (Ludwig & Goldberg 1956)

Protein content:

Protein content of the sample was determined by biuret method as described by Williams P. C. (1961).

Methionine content:

Methionine content of the sample was determined by Calorimetric method as reported by Horn et al., (1946).

Tryptophan content:

Tryptophan content of the sample was determined by the Spies and Chambers (1949).

III. RESULT AND DISCUSSION

Seed colour:

Table 1 provides information on the color of the seed in several ragi Millet germplasms. There have been reports of radish brown, dark red, light brown, and brick red colors in different germplasm. One of the main elements influencing the color of the ragi millet grains is the presence of pigments, which improve the product's visual quality. Color variation within the germplasm is prevalent and evident in nearly all minor millets. (2011) Krishna et al. Variations in the color of ragi millet seeds might be due to the genetic composition of the germplasm. According to reports, the dehulled ragi millet grain ranges in colour from drab cream to chocolate. while the colours of the grains of ragi millet are light brown, dark brown, dark red, brick red, and purple. **(Rajasekharan 2004).**

Test weight:

Results on finger millet test weight as impacted by certain finer millet varieties/genotypes is shown in table 1 and visually represented in fig 1. The data made it clear that finger millet test weights varied between 2.22 and 4.23 grams depending on the variety and genotype. In variety IC0321712, the significantly highest test weight of 4.23g was obtained. 2.22g was the lowest in IC0475978. The test weight varied from 2.22 g to 4.23 g in different ragi millet grains. The germplasm of all the ragi millets was found to be significant in terms of test weight. Ramappa *et al.* (2010) showed a similar range of test weight in Ragi Millet germplasm when obtaining the yield factors.

Table 1. Physical characteristics of certain varieties/genotypes of finger millet.

S.N.	Varieties/Genotypes	Colour of seeds	Test weight (gm)
1	**VL324**	Dark red	3.35
2	**VL379**	Dark red	3.37
3	**VL376**	Radish brown	2.45
4	**VL352**	Dark red	3.02
5	**IC0475654**	Light brown	2.38
6	**IC0474887**	Radish brown	3.05
7	**IC0475697**	Light brown	3.21
8	**IC0478760**	Dark red	2.99
9	**IC0321712**	Brick red	**4.23**
10	**IC0475457**	Dark red	4.03
11	**IC0283451**	Radish brown	3.03
12	**IC0476418**	Light brown	3.81
13	**IC0476092**	Brick red	2.32
14	**IC0474910**	Dark red	3.97
15	**IC0476818**	Radish brown	3.76
16	**IC0475654**	Light brown	2.47
17	**IC0474887**	Dark red	3.12
18	**IC0475978**	Brick red	**2.22**
19	**IC0347251**	Light brown	3.16
20	**IC0474089**	Dark red	3.04
	Mean		**2.48**
	S.E.(d)		**0.075**
	C.D. at 5%		**0.152**

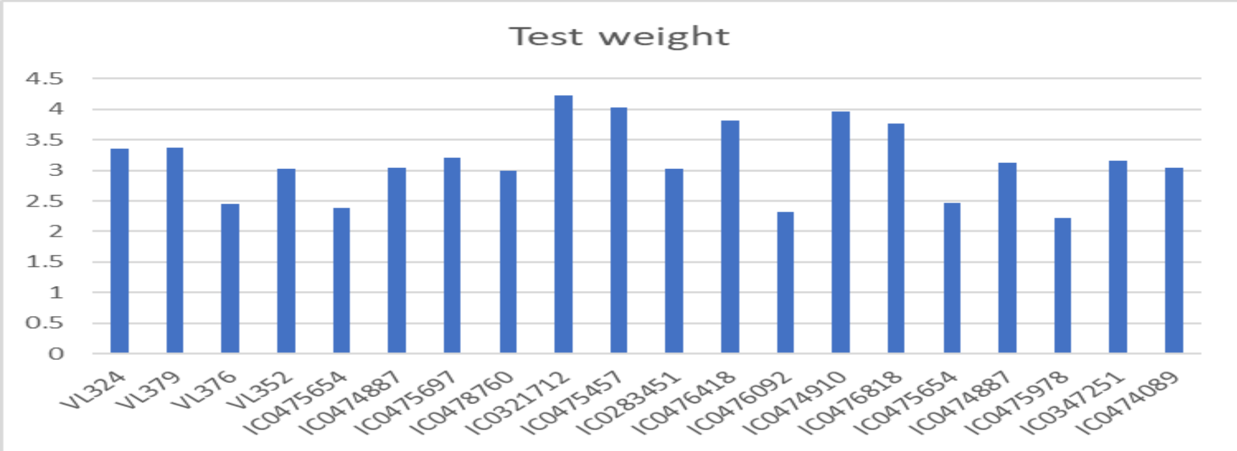


Fig.1 .test weight of finger millet

Dispersibility:

Table 2 presents data on the dispersibility of several finger millet varieties and genotypes, whereas Figure 2 provides a visual representation of the data. The data made it clear that finger millet's dispersibility varied between 75.66% and 90.66% depending on the variety and genotype. In variety IC0475978, the dispersibility was much higher at 90.66%. Finally, 75.66% in IC0475697 was the lowest.The dispersibility of different ragi millet grains varies from 75.66% to 90.66%. It was discovered that all ragi millets have high dispersibility. The results of this investigation were in line with those of Ramashia et al. (2017), who found that finger millet flours had dispersibilities ranging from 87% to 92%. When mixing, the dispersibility levels could contribute to the production of fine component dough.

Water absorption capacity:

Table 2 provides information on the water absorption capacity of several finger millet varieties and genotypes, whereas Figure 3 provides a visual representation of the data. The chart made it clear that finger millet of various kinds and genotypes had a water absorption capacity ranging from 0.91 to 1.15 milliliters per gram. Significantly, variety IC0475978 had the highest WAC of 1.15 mg/g. And in VL352, the lowest were 0.91 ml/g. The results of this investigation were in line with those of Ramashia et al. (2017), who found that finger millet flours had dispersibilities ranging from 0.93 to 1.23 ml/g.

Table 2. Functional characteristics of certain varieties/genotypes of finger millet.

S.N.	Varieties/Genotypes	Dispersibility (%)	Water absorption capacity (ml/g)
1	**VL324**	86.33	1.02
2	**VL379**	90.33	0.99
3	**VL376**	80.66	0.96
4	**VL352**	90.65	**0.91**
5	**IC0475654**	85.00	0.97
6	**IC0474887**	82.33	1.01
7	**IC0475697**	**75.66**	1.04
8	**IC0478760**	82.33	0.94
9	**IC0321712**	82.00	1.05
10	**IC0475457**	87.33	1.02
11	**IC0283451**	84.66	0.97
12	**IC0476418**	87.33	1.08

13	**IC0476092**	89.66	0.95
14	**IC0474910**	85.66	0.90
15	**IC0476818**	85.66	0.98
16	**IC0475654**	85.33	0.93
17	**IC0474887**	83.00	1.05
18	**IC0475978**	**90.66**	**1.15**
19	**IC0347251**	84.33	0.94
20	**IC0474089**	88.66	0.95
	Mean	81.091	0.99
	S.E.(d)	2.095	0.032
	C.D. at 5%	4.250	0.065

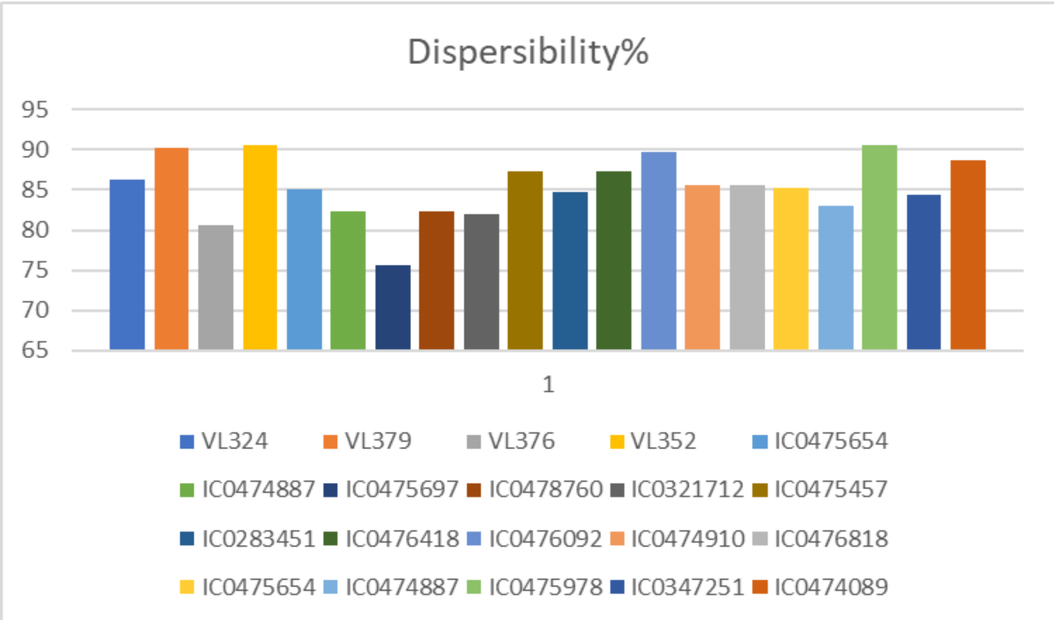


Fig.2. Dispersibility of finger millet.

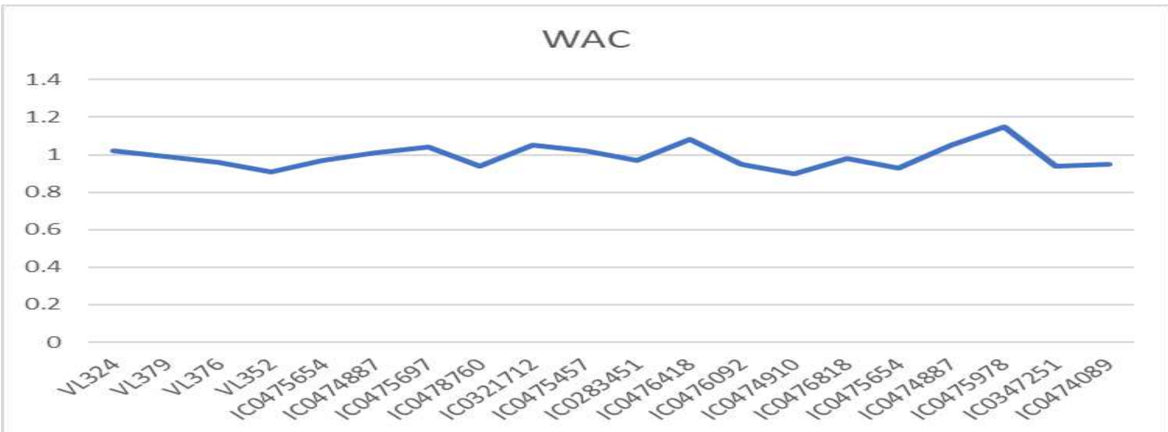


Fig.3. Water absorption capacity (ml/g) of finger millet.

Biochemical characteristics:

Carbohydrate content

Table 3 presents statistics on finger millet's performance with regard to its carbohydrate content, while Figure 4 provides a graphic illustration of the data. The chart made it clear that finger millet of various kinds and genotypes had a carbohydrate content that ranged from 69.87% to 74.78%. The variety IC0476418 had the significantly greatest carbohydrate content (74.78%), whereas IC0474910 had the lowest (69.87%). Depending on its genetic composition, different germplasms may have greater or lower carbohydrate levels. In 2013, Amadou et al. observed a similar range of carbs in their study on the nutritional value of several genotypes of ragi millet.

Protein content

Table 3 presents statistics on the protein content of finger millet, while Figure 4 provides a visual illustration of the same. The table showed that the protein content of finger millet varied in varieties and genotypes, ranging from 7.14% to 9.23%. In variety IC0476418, the protein content was found to be much higher at 9.23%. And in IC0474887, the lowest were 7.14. It was discovered that the protein composition of the germplasm was all significant. Verma and Patel (2013). The protein content and energy value were assessed using actual digestibility, biological value, net protein utilisation, and the observation of a similar range of protein. When Bhosale et al. (2020) examined the biochemical properties of finger millet, they discovered that the protein range was comparable, ranging from 5.78 to 10.96%.

Methionine content

Table 3 presents the data on the methionine content of finger millet, while Figure 4 provides a graphic illustration of the same. The data showed that the methionine concentration of finger millet varied in varieties and genotypes was between 22.15 to 30.13 mg/g protein. The variety IC0476818 had the significantly highest methionine content (30.13), while IC0475654 had the lowest (22.15). superior quality of vital amino acids, particularly cysteine and methionine.

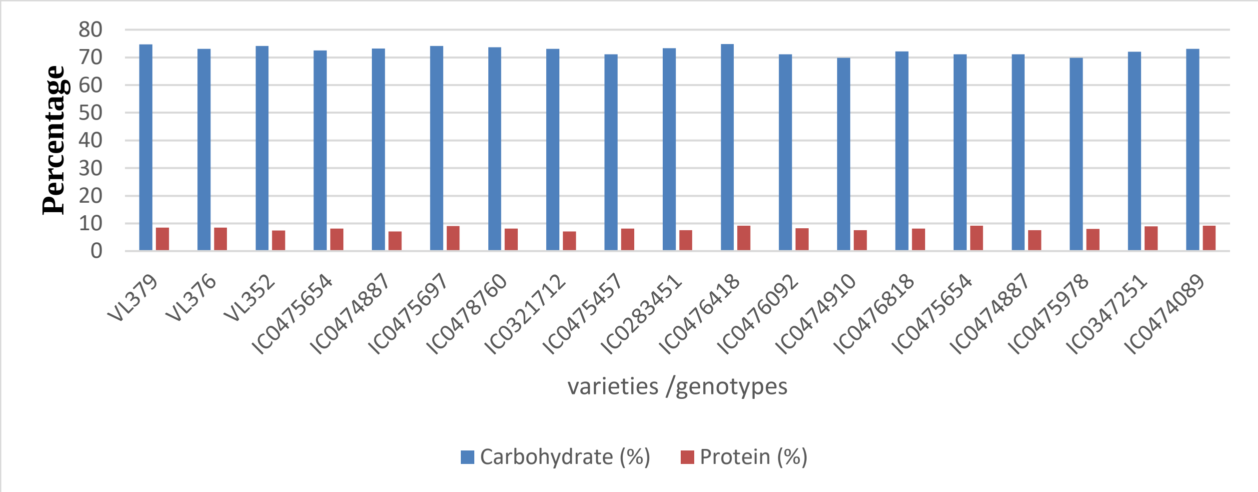
Tryptophane content

Table 3 presents the facts on the tryptophane content of finger millet, while Figure 4 provides a graphic illustration of the same. The data made it clear that the tryptophane content of finger millet varied in varieties and genotypes was between 11.27 and 19.87 mg/g protein. Variety IC0475654 had the noticeably highest tryptophane concentration, 19.87 mg/g protein. And 11.27 in IC0475457 was the lowest.Tryptophan is an essential amino acid that is involved in several metabolic activities, chief among them being the production of nicotinamide, a vitamin B6. Every germplasm has a noticeable distinction from one another. Obilana and Manyasa (2002) suggested that the variation in tryptophane content between finger millet germplasm was probably caused by changes in protein synthesis and its function in the production of aromatic amino acids. Amadou et al. (2013) provided information on the tryptophan content of several finger millet germplasm samples.

Table 3. Biochemical characteristics of certain varieties/genotypes of finger millet.

S.N.	Varieties/Genotypes	Carbohydrate (%)	Protein (%)	Methionine (mg/g protein)	Tryptophane (mg/g protein)
1	**VL324**	70.88	7.54	26.33	19.54
2	**VL379**	74.65	8.53	27.14	17.12
3	**VL376**	73.11	8.51	26.13	18.42
4	**VL352**	74.11	7.46	28.03	13.52
5	**IC0475654**	72.53	8.13	**22.15**	**19.87**
6	**IC0474887**	73.16	**7.14**	26.33	14.52
7	**IC0475697**	74.15	9.09	22.50	17.47
8	**IC0478760**	73.69	8.11	23.02	16.96
9	**IC0321712**	73.04	7.05	28.31	19.34
10	**IC0475457**	71.12	8.14	27.16	**11.27**
11	**IC0283451**	73.30	7.53	26.19	16.69
12	**IC0476418**	**74.78**	**9.23**	29.47	18.97
13	**IC0476092**	71.07	8.21	27.52	16.53

14	**IC0474910**	**69.87**	7.54	26.54	14.97
15	**IC0476818**	72.15	8.14	**30.13**	17.57
16	**IC0475654**	71.15	9.21	24.54	18.49
17	**IC0474887**	71.08	7.52	27.03	17.23
18	**IC0475978**	69.90	8.03	25.17	16.69
19	**IC0347251**	72.10	8.95	24.15	15.98
20	**IC0474089**	73.14	9.15	23.16	17.83
	Mean	68.76	8.16	26.04	16.94
	S.E.(d)	0.124	0.069	0.135	0.075
	C.D. at 5%	0.252	0.141	0.274	0.152



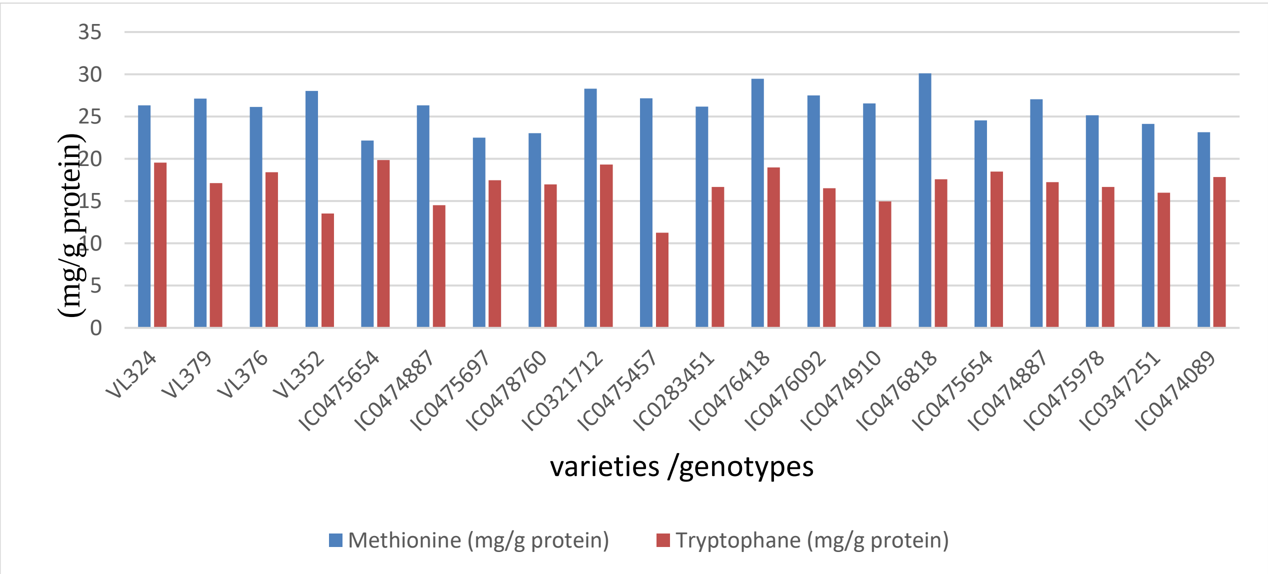


Fig.4. Biochemical properties of finger millet.

IV. CONCLUSIONS

The variety IC0321712 delivered the greatest value in test weight based on physical attributes, according to the aims and conclusions of the experiment. Dispersibility and water absorption capacity are two functional attributes where the variation IC0475978 excels greatly. Biochemically, the variety IC0476418 is outstanding. It has the greatest protein and carbohydrate content along with a sizable dose of tryptophane and methionine. Variety ICO476418 was discovered to be superior in biochemical parameters and to have important physical and functional features based on the overall observation. The findings underscore the importance of genetic diversity in finger millet and the potential for targeted breeding efforts to develop improved varieties with enhanced nutritional value, health benefits, and agronomic traits. These insights have practical implications for food security, nutrition, and agricultural sustainability, providing a foundation for further research, breeding programs, and the promotion of finger millet as a valuable crop for human consumption and agricultural development.

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Role of Active Packaging for Food Freshness and Quality Maintenance

Priyanka*, Raveena Rani, Rekha Yadav, Neha Bajal, Balwan Singh Mandal, Ajay Kumar

CCS Haryana Agricultural University, Hisar-125004, India
Corresponding*: priyankarohilla234@gmail.com

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***Abstract*— *Active packaging is developed as a favorable method to address the challenge and prolong the shelf life of perishable foodstuffs while maintaining their freshness and quality. This abstract provides an overview of the active packaging systems and their roles in preserving food quality and safety. Active packaging incorporates various technologies, oxygen scavengers, moisture absorbers, antimicrobial agents, and flavor-release systems, within the packaging materials. These technologies actively interact with the food product to create a modified atmosphere or inhibit microbial growth, resulting in improved preservation and quality retention. Active packaging provides many benefits, including its ability to reduce food waste, enhance product safety, and meet consumer demands for convenience and sustainability. In inference, active packaging offers a favorable opportunity to enhance the shelf's life of food products and maintain their freshness and quality.*

Keywords*— *Active packaging, Shelf life, Products, Technologies, Antimicrobial agents, Atmosphere, Sustainability, Freshness.

INTRODUCTION

The food packaging industry, on a global scale, was characterized by the active participation of developing nations, constituting approximately 50 per cent in this area (Dainelli *et al.*, 2008; Pereira *et al.*, 2020; Robertson, 2013). In the context of the food processing industry, packaging was a critical component with the primary objectives of containment, protection, and preservation of the end product to fulfill customer requirements. It should be noted that packaging served a triad of functions: firstly, safeguarding the product; secondly, conveying essential information; and thirdly, facilitating transportation (Young *et al.*, 2020). The temporal stability of packaged food was assessed through a comprehensive analysis, incorporating intrinsic factors such as water activity (Aw), pH, redox potential, nutritional composition, antibacterial agent presence, inhalation rate, and organic structure. Simultaneously, extrinsic variables include storage temperatures, relative humidity, and the compositions of the ambient gas were taken into account (Day, B. 2008). In the past, the primary objective of food packaging resided in safeguarding food items from the detrimental effects of oxygen, water vapor, UV radiation, as well as chemical and microbial pollutants. In accordance with data furnished by the World Health Organization, the United States bore witness to approximately 48 million instances of foodborne infections annually, culminating in an approximate tally of 3000 fatalities. Spain, during that timeframe, was estimated to have experienced an incidence rate of 60 cases of foodborne illnesses for every 100,000 residents yearly, thereby necessitating the emergence of biosensors engineered for pathogen detection within food matrices. Consequently, efforts were undertaken to enhance the preservation of food items and implement continuous quality control through the adoption of active packaging materials. (Pan American Health Organization, PAHO 2009). "Packaging was deemed a pivotal source of information capable of significantly influencing consumer perceptions and purchasing choices in the past." In recent years, an array of scientific publications and studies elucidating novel technologies within the realm of food packaging, particularly those pertaining to active packaging, garnered attention, driven by the increasing the consumers demand for convenient food management or prolonged product shelf-life (Jeantet *et al.,* 2016; Nur Hanani *et al.,* 2014; Rehman *et al.,* 2020) (Wyrwa & Barska, 2017). "In the earlier, active packaging constituted a system where in the packaging go through modification to enhance the preservation, sensory attributes, safety, and quality traits of the enclosed food product" (Robertson, 2013).

Food Packaging

Food packaging that is effective serves several functions. It preserves the nutritional and structural integrity of food by servings as the protective barrier against external factors like water, light, odors, dust, bacteria, and machine-driven damage. "Additionally, it functions as a receptacle for the transportation and storage of food items." Packaging may incorporate barriers to uphold stable gas composition or moisture levels within the product. Accessibility considerations are pivotal in packaging design, with a growing consumer preference for swift original, dispensing, or resealing mechanisms ensure sustained manufactured goods quality till consumption complete (Gupta, R. K. & Dudeja, P. 2017).

Materials used in the food packaging

Paper, plastic, metal, and glass have emerged as predominant materials for the packaging of food items in contemporary contexts. Glass and metal demonstrated exceptional barrier qualities and showed little contact with the contained food goods. Contrastingly, plastic materials had features that caused interactions with the packaged food products, including poor barrier properties and a lack of inertness. Nonetheless, the used of the plastics material for packaging improved exponentially in the years before then. Comparing plastics to other materials, it became clear that they were more cost-effective due to their lower energy content, reduced weight, and comparable structural robustness. (Mtolo, *et al.*, 2020).

"In numerous scenarios, the amalgamation of multiple materials was employed to attain the prescribed barrier properties of the packaging." Exemplary layers encompassed foil, diverse plastic varieties, paper, and adhesive substances. The prevalent plastics utilized in food or beverage packaging includes polypropylene, polyethylene, polyethylene terephthalate, polyamide, polystyrene, and ethylene vinyl alcohol. (Risch, S. J. 2000). Polyvinyl chloride, polyethylene (PE) emerged as the most ubiquitously manufactured plastic globally, with polypropylene (PP) ranking as the third most abundant bulk plastic

Active food packaging

It was observed that packaging played a crucial role in enhanced the shelf lives and the economic worth of food products. Along with the entire supply chain, suitable food packaging functioned mainly as a vessel for foods, safeguarding it against unfavorable biochemical and microbiological alterations (Yu *et al.,* 2019). The Active packaging systems, beyond their fundamental roles, were found to offer supplementary functionalities meant at enhancing their quality and safeties of the food products (Kra'sniewska *et al.,* 2020). In order to enhance the cleanness, quality, and safety, of the certain active packaging materials were employed in the past to impede respiration rates, hinder microbiological growth, and constrain moisture migration. The utilization of active antimicrobial treatments was explored as a means to extend the shelf's life of food products, concurrently sustaining their nutritive integrity and safeties through postponement of microbial proliferation. The incorporation of active substances abundant in antioxidants was studied for its capacity to forestall food oxidation (Realini & Marcos, 2014). The active packaging material's nature or working principle was ascertained by its active substance (AI), which exhibited properties of release, absorptions, blocking and buffering (Kuswandi & Jumina, 2019; Rehman *et al.*,2020). However, any of the active packaging material possessed either non-migratory (i.e., scavenging) and the migratory (i.e., producing) characteristics. (Kuswandi & Yu *et al.*, 2019). The Active packaging involves incorporation of additives or "freshness enhancers" across diverse packaging applications, aimed at augmenting the preservation capabilities inherent in the fundamental packaging system.

In a broader context, active packaging was divided into the two main categories: non-migratory active packaging, which refers to the scavengers considered to remove undesirable mechanisms from the internal packaging surroundings lacking intentional movement, and active discharging packaging, which is mainly concerned with emitters facilitating the controlled migration of the desired substances into the packaging milieu, thereby conferring beneficial influence upon food product. (Dainelli *et al.*, 2008; Barska *et al.*, 2017). It was observed that the majority of non-migratory active packaging systems in food products exhibited the capacity to function as oxygen scavengers, moisture scavengers, and ethylene absorbers. Conversely, active release packaging systems were found to encompass carbon dioxide-emitting mechanisms, antioxidant packaging, and antimicrobial packaging. (Yildirim *et al.*, 2018).

In the past, due to advancements in technology, active packaging systems underwent a significant expansion. The alterations engendered concomitant elevation of benchmarks pertaining to alimentary quality and safety, concomitant with an unequivocal emphasis on the imperatives of sustainability and the amelioration of waste. Among these developments, edible films and coatings became active packaging innovations that, at the time, showed they could meet strict criteria, were mainly made from natural sources, and had built-in biodegradability. (Han, 2005; Stoleru *et al.*, 2021).

Methods of Active Packaging (Mane, K. A. 2016**)**

System of active packaging	**Methods**	**Uses for food**
Oxygen scavengers	They are ascorbate, an iron-based or acid metal catalyst, and enzymes. Examples of these include platinum.	Rice that has been cooked, cake, biscuits ,cured meats and fish, pizza, pasta, cheese, and drinks, coffee, snack snacks, and dried goods.
Carbon dioxide scavengers/emitters	Sodium bicarbonate, ascorbate, and activated charcoal Calcium hydroxide ferrous carbonate, iron oxide, and calcium oxide containing metal halides.	Fresh meats, coffee and other snack food products and sponge cakes.
Ethylene scavengers	Carbon- and potassium-permanganate-activated clays and zeolites.	Fruits, vegetables, and other goods from horticulture
Preservative releasers/ Antimicrobial agents **Preservative releasers/ Antimicrobial agents**	Naturally occurring acids Herb and spice extracts in silver zeolite BHA/BHT antioxidants, vitamin E, and sulfur dioxide and volatile chlorine dioxide	Meats, seafood, cheese, breads, snacks, and fruits and vegetables
Ethanol emitters	Alcohol spray encapsulated ethanol	Cakes,bread,biscuits pizza, fish and bakery product
Moisture absorbers	Mineral silica gel and PVA blanket activated clays	Fish, cereals,sandwiches,meats,vegetables and fruits
Flavors/-odour absorbers	Ascorbate activate carbon, zeolites, ferrous salt and cellulose triacetate acetylated paper.	Dairy products,fruits,fruits juices,poultry,fried snack foods
Temperature control Packaging	Water ammonium nitate, non-woven plastic double walled container.	Fish,meats,poultry and beverage, ready meals

Oxygen Scavengers

Packaged food products typically contain specific volumes of headspace gases and trapped oxygen. Additionally, there's a significant focus on preventing the ingress of oxygen into plastic containers. While it's preferred to limit the headspace gases to ensure secure sealing, it's equally vital to reduce the oxygen that could potentially act in response with the substances inside the container (C.J *et. al.*, 1985). Molecular oxygen (O2) is capable of being reduced in electron density via one to four to produce a range of intermediate species, such as superoxide, hydroxy radicals, hydrogen peroxide, and water. Notably, superoxide, hydroxy radicals, and hydrogen peroxide exhibit high reactivity, with a particular affinity for carbon-carbon double bonds. In contrast, O_2 and water display comparatively low reactivity. These reactive oxygen species are naturally free radicals, which makes the oxidative reactions they participate in autocatalytic. Assuming that products comprising complex organic constituents are likely to contain carbon-carbon double bonds and other oxygen-reactive components, the possibility of oxidative reactions increases. (Zenner, B.D. et al., 2002). Undesirable oxygen content can arise from several factors during the packaging process, including insufficient evacuation, inherent oxygen in the food or packaging materials, leakage into the headspace, permeation through the packaging, poor sealing allowing air entry, or microscopic holes in the packaging material. Elevated oxygen levels have adverse effects on food, diminishing its nutritional quality and shelf lifespan (Mohan, C. *et al.,* 2008)

Certain food yields, including meats, milk powder, and herbs and spices, can be rapidly depleted due to reactions between oxygen in atmospheric gases and sensitive food items. Furthermore, it feeds bacteria and causes rancidity in oily, fatty, and nut foods and also causes vitamin deterioration. Methods like vacuum sealing, introducing inert gases either carbon dioxide (CO2) or nitrogen (N2), even combining the two methods can all be used to remove oxygen from food packing. These approaches find applications in packaging for items like orange juice and within the brewing industry, as well as in artificial-atmosphere packaging for various food products. This technology is capable of reducing approximately 85-95% of the oxygen originally present in the surrounding appearance before or during the packaging process. However, removing the remaining traces of oxygen becomes a costly endeavor. In order to control the packaging's residual oxygen content, oxygen-absorbing materials are utilized, which helps to slow down the rate at which food goods deteriorate and degrade (Zerdin, K. *et.al*., 2003) Promptly removing oxygen has been shown to be essential for maintaining increased ascorbic acid levels in orange juice during long storage periods. Vegetables and orange juice browning are also related to oxygen content. Additionally, using oxygen scavengers in cakes led to a substantial rise in the amount of cakes which retained their mold-free mantelshelf life. (Guynot, M.E. *et al.,* 2003).

Oxygen scavengers offer several advantages:

- They hinder oxidation processes, preventing the development of issues such as the rancidity of fats and oils, resulting in undesirable odors and flavors, as well as alterations in the natural colors of food items. They also protect substances like unsaturated fatty acids and vitamins A, C, and E that are susceptible to oxygen.
- They prevent aerobic microbes from growing.
- Buying "fresh" or "natural" things becomes increasingly desirable as they reduce or eradicate the need for preservatives and antioxidants in food.
- They provide an effective and affordable alternative for vacuum packaging and controlled environment processes.
- By impeding the metabolic processes of food, these systems facilitate preservation, consequently extending the commercial lifespan of food products, whether utilized independently or in conjunction with conventional packaging technologies.

The various mechanisms by which oxygen scavengers operate include:

1. The most common and effective process now in use is the corrosion of iron and iron salts. The oxygen scrounger methods reliant on iron rust reactions can be elucidated through the following calculation:
   $4Fe(OH)_2 + O_2 + 2H2O \rightarrow 4Fe(OH)_3$
2. Photophobic colorants undergo oxidative reactions.
3. Oxidation occurs in the unsaturated fatty acids ascorbic acid, oleic acid, and linoleic acid.
4. Enzymatic oxidation employs specific enzymes like alcohol oxidase, glucose oxidase, and catalase. For example, glucose oxidase, an oxidoreductase, catalyzes the conversion of two hydrogen atoms from glucose's CHOH group to oxygen, yielding hydrogen peroxide and glucono-δ-lactone. (Vermeiren, L *et al.,* 2000).

The process involves the oxidative transformation of iron and ferrous salts within systems, wherein interaction with aqueous food results in the hydration of iron within product packaging, leading to its irreversible conversion into a stable oxide. To prevent direct contact with the food, iron powder is encapsulated in minute, permeable pouches. In contrast to conventional residual oxygen-modified environment packaging, which typically achieves a range of 0.3–3.0%, the notable benefit of employing that kind of oxygen absorber lies in its capability to reduce oxygen levels to less than 0.01%. This diminished oxygen concentration can be sustained over prolonged durations, contingent upon the oxygen absorbency of the packing material. But, the utilization of the saccharides bags presents drawbacks, such as the introduction of additional steps in the packaging process that may compromise the visual presentation of the food. (Ohtsuka, S. *et al.,* 1984).

Ethylene Scavengers (encompassing both ethylene absorbers and emitters, serve as efficacious agents in mitigating the presence of ethylene.)

The modulation of ethylene concentrations in storage environments markedly enhances the postharvest longevity of diverse classes of perishable agricultural commodities. (Terry, L. A. *et al*., 2007). Ethylene, a phytohormone, emanates from metabolic pathways within the living cells of climacteric fruit varieties, including but not limited to tomatoes, avocadoes, mango, banana, pears and kiwi. In contrast, non-climatic fruits like lemon, pineapples, oranges, grapes and strawberries do not exhibit similar ethylene-dependent responses (Brody, A. L. *et al.,* 2001). It has been established for an extended period that even trace amounts of ethylene elicit the hastening of ripening in all types of vegetables and fruits, encompassing both climatic and non-climatic varieties, by provoking an augmentation in their respiratory activity. For instance, ethylene is harnessed industrially to expedite the ripening of bananas and tomatoes, and also to induce the characteristic orange coloration in oranges. The mitigation of ethylene exposure within the proximate surroundings of these produce items leads to a deceleration in their respiratory rates, consequently yielding delayed ripening and thereby an extended period of postharvest viability (Vermeiren, L. *et al.*, 2003). The management of ethylene levels within storage environments assumes a pivotal role in the extension of the postharvest longevity of numerous categories of fresh agricultural produce. The majority of fruits and vegetables release ethylene following harvest, initiating and accelerating the ripening process, causing softening, and promoting the degradation of chlorophylls. Ultimately, these processes lead to the weakening of fresh and minimally handled fruit and vegetables.

Action of mechanism:

a. Different approaches depend on which materials can absorb ethylene on their own or in combination with a reactant. Palladium, for example, has shown better ethylene adsorption capability than scavengers based on permanganate, particularly under high relative humidity settings (Smith, A. W. et al., 2009). Ethylene can be adsorbed by packaging materials such polymer films made of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). In the food industry, substances like ethyl acetate, hydrogen sulfide, and ethanol are employed for ethylene adsorption, providing a dual function of extending the freshness of food products and mitigating undesirable odors.

b. A primary mode of operation for ethylene scavengers involves the utilization of potassium permanganate; this makes ethylene easier to oxidize into carbon dioxide and water. These scavengers typically contain potassium permanganate concentrations ranging from 4 percent to 6 percent (ABE, K. & WATADA *et al.*, 1991). As potassium permanganate interacts with ethylene, it undergoes a visible transformation from purple to brown, thereby serving as an indicator of its remaining capacity to absorb ethylene. However, it is important to note that due to its toxicity, direct contact with food is not permissible when using potassium permanganate.

Ethanol Emitters

Ethanol finds regular application in medicinal and pharmacological packaging, underscoring its prospective role as a vapor-phase inhibitor. Its utility encompasses the prevention of microbial contamination and the mitigation of the pace at which staling and oxidative alterations occur (Seiler, 1989). Scientific studies have demonstrated that applying ethanol to the surfaces of bread, cake, and pizza prior to packaging can effectively prolong their shelf life. This can be accomplished by the use of sachets that contain ethanol that has been encapsulated. These sachets allow for the regulated release of ethanol vapor within the enclosed packaging environment, maintaining the effectiveness of the preservative. The control of sachet permeability allows for the modification of the rate at which ethanol is released into the vapor. (Smith, J. P. 1995).

Emitters of Carbon Dioxide and Scavengers

Carbon dioxide emitters and scavengers play a pivotal role in modulating the antimicrobial impact of elevated carbon dioxide concentrations within packaging, particularly on surfaces of various commodities such as meat and poultry. This modulation contributes to the extension of shelf life. But since plastics are more permeable to carbon dioxide than to oxygen, in some cases it may be necessary to intentionally add carbon dioxide to the packaging in order to preserve the expected gas composition. (Lee, D. S. 2001)

Carbon dioxide adsorption is employed as a means to mitigate pressure escalation, expansion, and potential rupture of packages containing respiring foods, thereby diminishing the overall longevity of the product. Significant endeavors have been directed towards diminishing pressure levels within kimchi packaging. (Kimchi, a fermented vegetable product predominantly consumed in Korea, continues to generate carbon dioxide even during refrigerated storage.) Zeolite has demonstrated efficacy in adsorbing carbon dioxide, consequently resulting in decreased swelling of kimchi packaging. Due to the Strecker degradation reaction occurring between sugars and amino acids, roasted coffee manifests heightened carbon dioxide levels (Floros, J. D. 2000). To counteract this, a scrounger comprised of iron powder also CaOH is employed to decrease both oxygen and carbon dioxide concentrations. The resultant reduction in carbon dioxide content prevents package rupture, while diminished oxygen levels safeguard against oxidative flavor alterations, thereby extending the shelf life of products.

To avert the collapse of packages containing oxygen-scavenging agents, it is advisable to employ carbon dioxide-generating mechanisms. The prevalent systems predominantly employ ferrous carbonate or a blend of ascorbic acid and bicarbonate. Systems integrating both oxygen-absorbing and carbon dioxide-emitting components are primarily utilized for commodities demanding substantial packaging volume and aesthetic appeal, for example potato crisps and peanuts (Smith, J. *et al.*, 1995). Microbial growth is well-documented designate inhibited by CO_2. CO_2 concentrations inside the range of 70 to 80 per-cents effectively curtail microbial proliferation on surfaces, thereby prolonging the shelf life of products. As a result, adding a CO2 production mechanism to the packing structure and integrating it as a sachet serves as another approach to oxygen (O2) scavenging. Since most plastic films absorb CO2 three to five times more than they do O2, a steady supply of CO2 is required to keep the anticipated amount inside the package. There are several situations where a CO2 generator can be beneficial, such as during packaging cheese, fresh meat, fish, and livestock. For food substances somewhere package volume and visual appeal are crucial considerations, the combined use of a CO2 generator and an O2 scavenger represents a viable strategy (Smith, J. P. *et al.*, 1995).To forestall package collapse resulting from oxygen (O2) absorption, measures are taken. While carbon dioxide (CO2) exhibits a microbial inhibitory effect within the context of modified atmosphere packaging, an excess of CO2 can potentially detrimentally affect the product or even negate its inhibitory properties. Consequently, multiple food preservation packaging methodologies have been devised with the objective of CO2 removal (Brody, A. L. *et al.*, 2007).

Moisture Absorbers

Water originates from the metabolic breakdown of fats and carbohydrates during food respiration. Wet food, characterized by elevated water vapor pressure, frequently undergoes condensation within packaged items, especially fruits and vegetables. Temperature differentials, either internal or external to the packaging, result in water droplet formation on package walls or food surfaces. The presence of water droplets adversely affects packaging aesthetics, diminishing consumer appeal. Additionally, surface moisture on food facilitates mold growth, ultimately reducing the product's shelf life. To address these issues, desiccating films or sachets can be employed as effective solutions.

Pads containing cellulose fiber and propylene glycol are commonly used in direct interaction with fish and meat in packaging to absorb the moisture. Current research efforts focus on enhancing methodologies for integrating desiccants into packaging materials (Hurme, E. 2002).

Over-moisture acts as the main cause of food deterioration. Excess moisture can be removed utilizing several kinds of desiccants or absorptive agents, which is an extremely efficient method to preserve food quality and increase product shelf life. This stops the growth of bacteria and stops the loss of texture and flavor caused by moisture. Permeable plastic sachets with breaking strength are used to package dried food applications and desiccants such as calcium oxide, silica gel, minerals, and activated clays. These sachets may also serve dual purposes, incorporating stimulated carbon for odor absorption and iron powder for oxygen removal.

Flavors/Odour Absorbers

Intelligent packaging principles encompass various strategies to mitigate undesirable aromas and flavors. This includes the application of scavengers to eliminate noxious odors, addressing issues such as the removal of amines from oxidized protein-rich foods, elimination of aldehydes from products like biscuits and fried foods, and eradicating bitter-taste constituents like limning in fruit juices (Vermeiren, L. et al., 2003). Porous pads, initially researched for odor mitigation in products like diapers, have found application in food packing as well (Brody, A. L. et al., 2001).

There might be positive and negative effects from removing offensive substances from food packaging. Analyzing the advantages of odor/aroma reduction is now essential in the context of active packaging. Certain foods, such as newly cooked poultry and cereals, release "confinement odors" when they break down slightly. These items can release sulfurous compounds when protein molecules and amino acids break down, or they can release ketone and aldehyde compounds when lipids oxidize and anaerobic glycolysis occurs during transportation. Despite being generally harmless, these odors can lead to product rejection, emphasizing the need to eliminate them from packaging interiors. Additionally, incorporating odor-reducing agents helps mitigate odors originating from the packaging materials themselves, which may occur during plastic processing stages, requiring the inclusion of antioxidants in polyolefin processing (Brody, A. L. et al., 2001).

Antimicrobial Agents

Antimicrobial agents applied to food have a historical precedent, yet the utilization of antimicrobial interactive packaging represents a novel methodology for managing microbial surface contamination in food products. Two distinct categories of antimicrobial systems exist: those with migratory properties and those lacking such migration. Given their shared necessity for substantial interaction among the food products and packaging material, these applications have predominantly found utility in vacuum-sealed or skin-packaged food products (Vermeiren, L. *et al.*, 2002)

The introduction of ethanol into the packaging environment is exhibited efficacy in extending the shelf life of the bakery products. By reducing the amount of water on the food's surface, ethanol inhibits the growth of bacteria, mold, and yeast in particular. Moreover, ethanol's ability to prevent bread from stagnating has been observed.

Antimicrobial agents can be incorporating into food packaging material though either immobilization or by modifying and coating the package surface to activate the antimicrobial properties. According to current approaches, it is envisaged that naturally sourced antimicrobial agents could be integrated into packaging systems designed to protect various processed foods such as cheeses, meats, and other food products. This is especially the case for products with relatively uniform food product surfaces that come into direct contact with the inner packaging surface. This strategy is becoming more popular because it is thought to pose less of a danger to the consumer (Nicholson, M. D. *et al.*, 1998).

The two various kinds of antimicrobial films that are listed below:

- Films incorporating an anti-microbial (AM) agent that exhibits migration towards the food surface.
- Films that exhibit antimicrobial efficacy against surface microbial growth without the need for migration.

Temperature-Controlled Packaging

Temperature control in the context of active packaging includes the creation of self-heating and self-cooling containers as well as novel insulating materials. These approaches serve to address specific temperature control requirements. For instance, specialized insulating materials like insulate, constructed from nonwoven plastic with numerous air pore holes, have been engineered to safeguard refrigerated products from undesired temperature fluctuations while being transported and preserved. To strengthen the food packaging's capability to resist heat in response to temperature fluctuations, an effective strategy involves augmenting its thermal mass. Employing self-heating cans and containers, a technology predominantly favored in Japan, entails leveraging exothermic reactions. In this process, the amalgamation of water and lime at the base of the container induces heat production within self-heating steel and aluminum cans. This technology is widely applied in packaging various consumables such as coffee, tea, sake, and ready-to-eat meals, as documented by Day B.P.F. in 2003.

CONCLUSION

As a result, active packaging for preserving food freshness and quality represents a potential and cutting-edge strategy in the food sector. It provides a number of benefits, including prolonging shelf life, preserving taste and texture, and improving food safety, by incorporating different technologies such as oxygen scavengers, moisture regulators, and antimicrobial agents into packaging materials. Active packaging solutions' continual development has a lot of potential for lowering food waste, preserving product integrity, and satisfying consumer needs for high-quality, long-lasting food products. Food makers must balance functionality, affordability, and sustainability as this industry develops if they are to reap the advantages of active packaging while reducing its environmental impact.

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Polycystic Ovary Syndrome (PCOS): From Diagnosis to Treatment

Raveena Rani, Priyanka, Rekha Yadav, Neha Bajal, Balwan Singh Mandal, Ajay Kumar*

CCS Haryana Agricultural University, Hisar-125004, India
Corresponding*: ajayyadav62063@gmail.com

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***Abstract*— *Polycystic ovary syndrome (PCOS) is a common endocrine disorder affecting women of reproductive age. It is characterized by the presence of multiple cysts on the ovaries, menstrual irregularities, and hormonal imbalances. PCOS is a complex condition with a wide range of symptoms and varying degrees of severity. PCOS not only affects women of childbearing age but also adolescent girls and post- menopausal women. Most of the women affected by PCOS belong to the age group of 18-44 year. This condition affects about 5-10 percent of women of reproductive age and it is the most common endocrine disorder in women. Some of the most common symptoms include irregular periods, excessive hair growth, acne, and weight gain. PCOS is also associated with an increased risk of infertility, diabetes, and cardiovascular disease. The exact cause of PCOS is not fully understood, but it is believed to be a combination of genetic, hormonal, and lifestyle factors. Treatment for PCOS is focused on managing symptoms and reducing the risk of complications. Lifestyle changes, such as exercise and a healthy diet, are often recommended as the first line of treatment. Medications may also be prescribed to regulate menstrual cycles, reduce androgen levels, and improve insulin sensitivity. PCOS can be a challenging condition to manage, but with proper diagnosis and treatment, most women with PCOS can lead healthy and fulfilling lives. Regular medical check-ups, healthy lifestyle choices, and ongoing support from healthcare providers can help women with PCOS to manage their symptoms and reduce their risk of complications.*

***Keywords*— Polycystic ovary syndrome (PCOS), young women, health, lifestyle, healthy diet**

Polycystic ovarian syndrome (PCOS): Polycystic ovarian syndrome is a disorder suspected in patients with irregular menses and clinical signs of hyperandrogenism (Aswini and Jayapalan 2017, Lilhare and Pawar 2014). PCOS is a complex endocrine condition that affects the ovaries. It's linked to long-term metabolic problems like insulin resistance (IR), dyslipidemia and other disorders that predispose to cardiovascular risk, systemic inflammation and endothelial dysfunction. Elevated serum levels are another symptom of PCOS (Iervolino *et al.* 2021).

Polycystic Ovarian Syndrome (PCOS) is a prevalent endocrine disorder affecting up to 10% of women of reproductive age worldwide (Teede et al. 2018). It is characterized by a constellation of symptoms including hyperandrogenism, menstrual irregularities, and polycystic ovaries on ultrasound examination (American College of Obstetricians and Gynecologists [ACOG], 2018). PCOS is a complex condition with multifactorial etiology, involving genetic, environmental, and lifestyle factors (Teede et al. 2018). Diagnosis of PCOS typically follows the Rotterdam criteria, requiring the presence of at least two of the following: oligo- or anovulation, clinical or biochemical signs of hyperandrogenism, and polycystic ovaries on ultrasound. These criteria aim to capture the heterogeneous nature of the syndrome, which can manifest differently in affected individuals (ACOG, 2018).

Clinical manifestations of PCOS extend beyond reproductive health, encompassing metabolic disturbances such as insulin resistance, dyslipidemia, and obesity (Teede et al. 2018). These metabolic features contribute to an increased risk of developing type 2 diabetes mellitus and cardiovascular disease among women with PCOS (ACOG, 2018). Management strategies for PCOS focus on alleviating symptoms and reducing long-term health risks. Lifestyle modifications, including diet and exercise interventions, are recommended as first-line treatments to improve insulin sensitivity and regulate menstrual cycles (Teede et al. 2018). Pharmacological therapies, such as oral contraceptives and anti-androgen medications, may also be prescribed to manage symptoms like hirsutism and irregular bleeding (ACOG, 2018).

Recently, PCOS has been related to metabolic syndromes and patients may develop obesity, insulin resistance, keratoosis nigricans (acanthosis nigricans), Type 2 diabetes, dyslipidemias, hypertension, non-alcoholic liver disease and obstruction sleep apnea (Madnani *et al.* 2013). PCOS is a common endocrine disorder affecting women of reproductive age. PCOS is a diverse illness in which the ovary produces too many eggs. Mostly androgens derived primarily from the ovaries (Alshdaifat *et al.* 2021). This condition's complexity isn't due to its name; it's due to the fact that it's linked to a slew of other issues. In the sac of their ovary, PCOS patients develop many cysts measuring 8 mm in diameter. In the ovary, there are more than 12 cysts and because of this disease, around 70 percent of females are sterile (Ajmal *et al*. 2019).

Prevalence: According to the World Health Organisation (WHO), PCOS is affecting 116 million women worldwide in 2012, which is approximately 3.4 percent of world population (Bharathi *et al.* 2017). PCOS not only affects women of childbearing age but also adolescent girls and post- menopausal women. Most of the women affected by PCOS belong to the age group of 18-44 year (Ganie *et al.* 2019). This condition affects about 5-10 percent of women of reproductive age and it is the most common endocrine disorder in women. Obesity, hirsutism and infertility are all reported to have a significant impact on one's psychosocial well-being. Women with PCOS are more likely to have fertility issues (menstrual irregularities etc.), metabolic issues (insulin resistance, late menopause, endometrial cancer and infertility), failure to ovulate, late menopause, endometrial cancer and infertility resistance, type 2 diabetes, dyslipidemia, hypertension and cardiovascular illnesses (Thara and Divakar 2017).

PCOS) is one of the most common endocrine disorders among women of reproductive age, with prevalence estimates ranging from 6% to 12% globally depending on the diagnostic criteria used (March et al. 2010). In the United States, it is estimated that about 5 million women are affected by PCOS, which translates to a prevalence of approximately 6% to 10% among women of reproductive age (Centers for Disease Control and Prevention [CDC], 2023). Studies conducted in Europe and Australia have reported similar prevalence rates, generally between 8% and 13% (March et al. 2010). In some populations, particularly in South Asian countries, the prevalence of PCOS is even higher, with estimates ranging from 9% to 18% (Tehrani et al. 2011). The variability in prevalence rates is partly due to differences in the diagnostic criteria used, as well as genetic, environmental, and lifestyle factors that can influence the occurrence of PCOS (Azziz et al. 2016).

Symptoms: Polycystic Ovarian Syndrome (PCOS) is characterized by a range of symptoms that can vary in severity among affected individuals. One of the primary symptoms is irregular menstrual cycles, which may manifest as fewer than eight menstrual periods per year or prolonged intervals between periods (American College of Obstetricians and Gynecologists. This irregularity is often due to the lack of ovulation, a common feature of PCOS (ACOG, 2015). Hyperandrogenism is another key symptom observed in PCOS. This condition presents with clinical signs such as hirsutism (excessive hair growth on the face, chest, or back), acne, and male-pattern baldness. Biochemical signs of hyperandrogenism can include elevated levels of serum testosterone, free testosterone, or dehydroepiandrosterone sulfate (DHEAS) (ACOG, 2015; Escobar-Morreale, 2018).

Oligomenorrhea, hirsutism, severe acne and hair loss are some of the symptoms of PCOS. It produces major psychological disorders in adolescence, such as anxiety and depression. PCOS is the most common cause of infertility. Female infertility is a condition in which a woman is unable to conceive. Impaired glucose tolerance and type 2 diabetes are among the metabolic effects. Diabetes, obesity and a higher risk of cardiovascular disease are all linked to an increased risk of cardiovascular disease. Complications of metabolism and when compared to other PCOS types, the classic PCOS was found to have a higher rate of cardiovascular morbidity. PCOS is a condition that affects both obese and non-obese women. Obese women, on the other hand, have a higher prevalence of IR (Insulin resistance) indicators (Ganie *et al.* 2019).

PCOS promotes hirsutism and acne due to an increase in male hormones, specifically androgen. Insulin resistance is a condition that leads to obesity and type 2 Diabetes. This issue causes irregularities in the menstrual cycle, which leads to infertility. Sleep apnea affects 20 percent of females on a regular basis. Anxiety and depression are very frequent. The normal concentration of hormones in the body has a big impact on how healthy ovarian function and as a result, menstrual cycle regulation that sustains fertility (Ajmal *et al.* 2019).

In PCOS patients, Acanthosis Nigricans is a sign for hyperinsulinemia and insulin resistance darkening and thickening of the upper layer of skin in body folds and wrinkles characterize Acanthosis Nigricans, giving it a velvety look. Acanthosis Nigricans primarily affects the armpits, groin and neck (Shivaprakash *et al.* 2013). PCOS management is as difficult as the disorder itself. A nutritious diet, frequent physical activity and drugs that address the related symptoms and co-morbidities are all part of PCOS management and treatment. The four basic components of PCOS, including regular menstrual cycles, control of hyperandrogenism (acne and hirsutism), treatment of infertility and insulin resistance, as well as its related risk factors (T2DM, hyperlipidaemia and obesity) are the focus of PCOS management techniques (Ganie *et al.* 2019).

Other manifestations of PCOS include skin changes such as skin tags and darkened patches of skin, especially in body creases like the neck, groin, and underneath breasts. Psychological symptoms such as depression, anxiety, and mood swings are also commonly reported, impacting the overall quality of life for individuals with PCOS (ACOG, 2015).

Causes: Although the cause of PCOS is unknown, some genetic variables are thought to contribute to its pathophysiology, making those who have a genetic predisposition more likely to exhibit PCOS symptoms when exposed to particular environmental conditions (Alshdaifat *et al.* 2021). Several epidemiological studies have discovered a correlation between PCOS and lifestyle choices, as well as a link between food and the risk of polycystic ovarian syndrome (Eslamian and Hekmatdoost 2019).

The exact causes of Polycystic Ovarian Syndrome (PCOS) are not completely understood, but it is believed to result from a combination of genetic and environmental factors (Escobar-Morreale, 2018).

Genetic predisposition plays a significant role, as PCOS tends to run in families, suggesting a hereditary component (Goodarzi, Dumesic, Chazenbalk & Azziz, 2011). Studies have identified several genes that may be involved in the development of PCOS, highlighting the complex genetic basis of the disorder (Goodarzi et al. 2011).

Insulin resistance, where the body's cells do not respond normally to insulin, is a common feature of PCOS and can contribute to elevated androgen levels, leading to symptoms of PCOS (Dunaif, 1997). This insulin resistance is often accompanied by compensatory hyperinsulinemia, which exacerbates hyperandrogenism by stimulating ovarian androgen production and reducing sex hormone-binding globulin (SHBG) levels (Dunaif, 1997).

Elevated levels of androgens, or male hormones, are another critical factor in the development of PCOS, and these hormonal imbalances can disrupt the normal function of the ovaries (Azziz, Carmina, Dewailly, Diamanti-Kandarakis, Escobar-Morreale, Futterweit, Janssen, Legro, Norman, Taylor & Witchel, 2006). Hyperandrogenism, which manifests as hirsutism, acne, and alopecia, is a hallmark of PCOS and is linked to both ovarian and adrenal sources (Azziz et al. 2006).

Lifestyle factors, including diet and physical activity, can also influence the onset and severity of PCOS, particularly through their impact on insulin resistance and weight (Gambineri, Pelusi, Vicennati, Pagotto & Pasquali, 2002). Obesity, in particular, is closely associated with PCOS and can exacerbate symptoms and metabolic complications (Gambineri et al. 2002).

Chronic low-grade inflammation has also been linked to PCOS, as women with the condition often exhibit elevated levels of inflammatory markers (González, Sia, Shepard & Rote, 1999). This inflammation may contribute to insulin resistance and other metabolic disturbances associated with PCOS (González et al. 1999).

Diagnose: Diagnosing Polycystic Ovarian Syndrome (PCOS) involves a comprehensive evaluation of symptoms, physical examination, and laboratory tests. According to the American College of Obstetricians and Gynecologists (ACOG, 2015), diagnostic criteria include the presence of two out of three of the following features: irregular menstrual cycles, clinical or biochemical signs of hyperandrogenism, and polycystic ovaries on ultrasound.

Irregular menstrual cycles are often the first indicator, with women experiencing fewer than eight menstrual cycles per year or cycles that are prolonged (ACOG, 2015).

Hyperandrogenism can be assessed through clinical signs such as hirsutism, acne, and male-pattern baldness, or through elevated levels of androgens in blood tests, such as testosterone and dehydroepiandrosterone sulfate (DHEAS) (ACOG, 2015; Escobar-Morreale, 2018).

Polycystic ovaries are visualized via ultrasound, which reveals enlarged ovaries containing multiple small follicles arranged peripherally around a central stroma, giving them a "string of pearls" appearance (ACOG, 2015; Escobar-Morreale, 2018).

Laboratory tests may also include measuring fasting glucose and insulin levels to assess for insulin resistance, which is common in PCOS (Escobar-Morreale, 2018). Lipid profiles and thyroid function tests may be conducted to evaluate metabolic and hormonal status (Escobar-Morreale, 2018).

It's important to rule out other conditions that may present similarly to PCOS, such as congenital adrenal hyperplasia and androgen-secreting tumors, through additional hormonal testing and imaging studies if indicated (Escobar-Morreale, 2018).

According to the Rotterdam criteria, PCOS can be diagnosed if at least two of the following three criteria are present: oligoovulation or anovulation, clinical and/or biochemical signs of hyperandrogenism, and polycystic ovaries visualized on ultrasound (Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group, 2004).

Oligoovulation or anovulation is typically confirmed through a history of irregular menstrual cycles, characterized by intervals longer than 35 days or fewer than eight menstrual cycles per year. This criterion is essential, as it reflects the hormonal dysregulation that is central to the syndrome (Azziz et al. 2006).

Clinical signs of hyperandrogenism include hirsutism, defined as excessive hair growth in a male-pattern distribution, acne, and androgenic alopecia. Biochemical evidence of hyperandrogenism can be established through elevated levels of serum testosterone, free testosterone, or dehydroepiandrosterone sulfate (DHEAS) (Azziz et al. 2006).

Polycystic ovaries are visualized on ultrasound as ovaries with 12 or more follicles measuring 2-9 mm in diameter and/or increased ovarian volume (>10 cm³). The presence of polycystic ovaries is a supportive criterion but not necessary for diagnosis if the other criteria are met (Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group, 2004).

Laboratory tests are crucial in diagnosing PCOS and may include measuring fasting glucose and insulin levels to assess for insulin resistance, which is common in PCOS. Lipid profiles and thyroid function tests are also recommended to evaluate metabolic and hormonal status (Azziz et al. 2006).

Diagnostic evaluation should also aim to exclude other conditions that may mimic PCOS, such as congenital adrenal hyperplasia, androgen-secreting tumors, Cushing's syndrome, and thyroid disorders. This may involve additional hormonal testing (Azziz et al. 2006).

Risk Factors: Polycystic Ovarian Syndrome (PCOS) is influenced by several risk factors that contribute to its development and severity. These risk factors are crucial for understanding the pathogenesis of PCOS and for identifying individuals at higher risk for the condition.

1. Genetic Predisposition

Genetic factors significantly contribute to the risk of developing PCOS. Family history is a strong indicator, with first-degree relatives of women with PCOS having an increased likelihood of developing the condition themselves (Teede et al. 2018). Twin studies and familial clustering suggest a hereditary component, indicating that genetic predisposition plays a crucial role in the pathogenesis of PCOS (Dumesic et al. 2015).

2. Insulin Resistance

Insulin resistance is a common feature of PCOS and a significant risk factor for its development (Dunaif, 1997). Insulin resistance leads to hyperinsulinemia, which exacerbates hyperandrogenism by increasing ovarian androgen production and reducing sex hormone-binding globulin levels (Dunaif, 1997). This hormonal imbalance disrupts normal follicular development, contributing to the anovulation characteristic of PCOS (Teede et al. 2018).

3. Obesity

Obesity is both a risk factor and a consequence of PCOS, creating a vicious cycle that exacerbates the condition (Teede et al. 2018). Excess adipose tissue increases insulin resistance and hyperinsulinemia, which in turn aggravates hyperandrogenism and menstrual irregularities (Franks, 2008). Women with PCOS are more likely to be overweight or obese compared to the general population, and weight gain further complicates the metabolic and reproductive aspects of the syndrome (Teede et al. 2018).

4. Hormonal Imbalances

Hormonal imbalances, particularly elevated levels of androgens and luteinizing hormone (LH), are central to the pathophysiology of PCOS (Goodarzi et al. 2011). Elevated LH levels relative to follicle-stimulating hormone (FSH) lead to ovarian dysfunction, anovulation, and the development of polycystic ovaries (Franks, 2008). These hormonal disturbances are both a feature and a risk factor for the perpetuation of PCOS symptoms (Teede et al. 2018).

5. Environmental and Lifestyle Factors

Environmental and lifestyle factors also play a significant role in the risk of developing PCOS. Exposure to endocrine-disrupting chemicals, such as bisphenol A (BPA), has been associated with hormonal imbalances that may contribute to PCOS (Diamanti-Kandarakis et al. 2009). Additionally, diet and physical activity levels influence the risk and severity of PCOS. Poor dietary habits and sedentary lifestyles increase the risk of obesity and insulin resistance, thereby exacerbating PCOS symptoms (Teede et al. 2018).

6. Prenatal Factors

Prenatal factors, including maternal obesity and androgen exposure, have been suggested as potential risk factors for

PCOS. Animal studies have shown that fetal exposure to elevated androgen levels can lead to the development of PCOS-like symptoms in offspring, suggesting that in utero environment may influence the risk of developing PCOS later in life (Abbott et al. 2005).

Treatment: Pharmacological therapy and a lifestyle modification program are used in the management of PCOS, with a focus on behavioral change, a balanced diet, and frequent exercise. Menstrual irregularities, the impact of hyperandrogenism (acne and hirsutism), infertility and insulin resistance, as well as related long-term metabolic problems (T2DM, hyperlipidaemia and obesity) are the key components of PCOS that are the focus of the therapeutic plan (Ganie *et al.* 2019).

Women with PCOS are more likely to have mood disorders and psychiatric issues than women without the condition. The distress related with the symptoms commonly found in PCOS (obesity, hirsutism etc.) causes mood disorders (Barry *et al.* 2011). When compared to the urban population, the prevalence in rural areas is lower. However, the rural population may have fewer PCOS cases due to a lack of understanding and/or little or no exposure to junk foods, pollution and other endocrine disruptors. Furthermore, girls in rural areas do not rely on labor-saving technology or automobiles for home duties, which help them, maintain a healthy BMI. As a result of the constant health demands of globalization and economic liberalization, middle-class urban women are more vulnerable than rural women who live a traditional lifestyle. The higher prevalence of PCOS among India's higher socio-economic urban population has been attributed to sedentary lifestyles, access to high-calorie foods and machineries for all housework. The strongest and most significant link between the illness and family history has been discovered. As a result, further genetic research is needed to understand the hereditary pathophysiology of this complex condition (Bharathi *et al.* 2017).

The treatment of Polycystic Ovarian Syndrome (PCOS) focuses on managing individual symptoms and addressing the underlying hormonal imbalances (Legro, Arslanian, Ehrmann, Hoeger, Murad, Pasquali & Welt, 2013). Lifestyle modifications, including diet and exercise, are often the first line of treatment and can significantly improve symptoms by promoting weight loss and improving insulin sensitivity (Moran, Hutchison, Norman & Teede, 2011). Weight loss of even a small percentage can restore menstrual regularity and improve fertility outcomes in overweight women with PCOS (Moran et al. 2011).

Pharmacological treatments are also commonly used to manage PCOS symptoms. Metformin, an insulin-sensitizing agent, is often prescribed to improve insulin resistance and lower insulin and androgen levels, which can help restore ovulatory cycles (Banaszewska, Pawelczyk, Spaczynski & Duleba, 2011). Oral contraceptives are another mainstay of treatment and are used to regulate menstrual cycles, reduce androgen levels, and manage symptoms such as hirsutism and acne (Brown, Imran & Abbas, 2022).

For women who wish to conceive, ovulation induction medications such as clomiphene citrate or letrozole are often prescribed to stimulate ovulation (Legro et al. 2014). Letrozole, an aromatase inhibitor, has been found to be more effective than clomiphene in inducing ovulation and achieving live birth rates in women with PCOS (Legro et al. 2014).

In cases where pharmacological treatments are not effective, other options such as laparoscopic ovarian drilling (LOD) may be considered. LOD is a surgical procedure that can reduce androgen production and induce ovulation by destroying a portion of the ovarian tissue (Amer, 2009).

Managing metabolic issues is also critical in the treatment of PCOS. Statins may be used to address dyslipidemia, and antihypertensive medications may be required for those with high blood pressure (Diamanti-Kandarakis, Papavassiliou, Kandarakis & Chrousos, 2007).

Overall, pharmaceutical therapy combined with a lifestyle modification program focusing on behavioral management, a healthy diet and frequent physical activity is used to treat PCOS (Deeks *et al.* 2011).

CONCLUSION

Polycystic Ovarian Syndrome (PCOS) is a complex endocrine disorder affecting women of reproductive age, characterized by hormonal imbalances, irregular menstrual cycles, and metabolic disturbances. It involves genetic predisposition, insulin resistance, and lifestyle factors such as diet and physical activity. Management includes lifestyle modifications, pharmacological interventions, and sometimes surgical options, tailored to alleviate symptoms and reduce long-term health risks. Multidisciplinary care is crucial for addressing both physical and emotional aspects of PCOS, aiming to improve quality of life and fertility outcomes through personalized treatment approaches.

It is evident from the range of studies that early diagnosis and treatment of PCOS is pivotal for normal health, well-being and improved nutritional status of young women suffering from PCOS. There is great scope for improvement in the health and nutritional status of young women if they are advised timely about their health issues and emphasis is given on making them understand the importance of taking balanced diet, inclusion of protective foods in diet specially fruits and vegetable and role of physical activity in overall health. Nutrition awareness programmes aimed at women of reproductive age group are the need of the day for promoting utilization of available community and national level health and nutrition referral facilities.

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Morphometric Analysis and Gill Net Catch Results of Flying Fish in Lawallu Village, Soppeng Riaja District, Barru Regency, South Sulawesi, Indonesia

Nabilah Panti Ariqoh[1, *], Mahfud Palo[2], Muh. Afdal[3], Najamuddin[2]

[1] Fisheries Science Master's Study Program, Postgraduate Faculty, Hasanuddin University, Makassar, Indonesia
[2] Fisheries Resource Utilization Study Program, Department of Fisheries, Faculty of Marine Sciences and Fisheries, Hasanuddin University, Makassar, Indonesia
[3]Department of Marine Science, Faculty of Fisheries and Marine Science, Lambung Mangkurat University, Banjarbaru, Indonesia
*Corresponding author: nabilahariqah19@gmail.com

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Abstract**—** *This research aims to analyze fish morphometrics and analyze the results of gill net catches of flying fish such as the size suitable for catching flying fish. This research was carried out from December 2022 to April 2023 in Lawallu Village, Soppeng Riaja District, Barru Regency. The research method used is a case study, the unit of which is a fishing activity using one unit of flying fish gill net at the research location. Data collection was carried out by going directly to the field following the fishing operation, determining how the fish was caught and directly measuring the fork length, height, width, and body circumference of the flying fish. The parameters observed are the dimensions of the fishing gear which determines the performance of the flying fish gill net, and the size of the catch. Data was analyzed descriptively and quantitatively. The research results showed that flying fish were caught using gill nets with a mesh size of 3.81 cm. The total catch was 450 fish from the range of 13.0-23.2 cm, the highest size was in the range of 16.3-17.3 cm with 86 fish, while the lowest size was in the range of 22.2-23.2 cm. 17 heads. The percentage of flying fish that were worth catching was 76%, the total catch was 340 fish, in the size range of 15.2-23.2 cm & the percentage of flying fish that were not worth catching was 24%, the total catch was 110 fish, in the size range 13.0-15.1 cm.*

Keywords**— *Morphometrics, fish worth catching, gill nets, flying fish, Hirundichthys oxycephalus***

I. INTRODUCTION

Barru Regency is a fairly long coastal area. The coastline reaches 87 km so it is the district with the longest coastline in South Sulawesi (DKP Barru Regency, 2022). The fertile area means that Barru Regency has abundant potential and natural wealth, including the industrial, agricultural, plantation, and tourism sectors. One of the most prominent sectors is the maritime and fisheries sector. The coastline which stretches in the western region facing the Makassar Strait means that Barru Regency has enormous marine and fisheries potential and can be utilized optimally. This is supported by the marine fishing area, which is around 56,160 Ha, and the existence of various types of fishing equipment that have great potential. Fishing units in Barru Regency in 2011 were 2,174 fishing gear units and in 2012 the number of fishing gear units was 2,183 fishing gear units and 2,171 fishing gear units in 2013 (DKP Kab. Barru, 2015).

One of the fishing tools used by fishermen in Barru Regency is drift gill nets. Drift gill nets are gill nets that are operated by letting them drift in the water. This tool is operated in coastal waters or offshore waters intended for catching small pelagic fish or large pelagic fish. Nets operated in coastal waters are generally on a small scale where setting up/setting down and the number of settings in one trip will differ according to the fisherman who operates them

(Martasuganda, 2008). In general, gill nets are a type of fishing gear made from net material that has a rectangular shape where the meshes of the main net are the same size. The number of meshes in the horizontal direction (Mesh Length/ML) is much greater than the number of meshes in the vertical or inward direction (Mesh Depth/MD) (Manalu, et al. 2014).

One of the main targets for catching drift gill nets in Barru Regency is small pelagic fish, including flying fish that have elongated cigar-like bodies and the ability to float using long pectoral fins. The flying fish species, namely *Hirundichthys oxycephalus*, is known as the stained flying fish, which has a distinctive characteristic, namely its relatively long and large pectoral fin, resembling wings that can be used to fly above the water surface for a while. The ability of flying fish can hover in the air for 10 minutes and can reach a distance of 100 m (Najamuddin et 2 al., 2011; Ali, 2012).

The success of fishing operations cannot be separated from several influencing aspects. Several influential parameters include technical aspects and the composition of the catch which have a major influence on the success of fishing operations (Fauziyah & Afridanelly, 2011). The results of previous research related to gill nets were carried out by (Palo et al., 2019) regarding the Selectivity of Drifting Gillnet to *Hirundichthys oxycephalus* (bony flying fish) in the Southern part of Makassar Strait with the mesh size used by fishermen being 1.25 inch, design of flying fish gill nets in the waters of Takalar Regency, South Sulawesi which also uses a mesh size of 1.25 inches (Najamuddin et al., 2011) and analysis of gill net catches in fishing for flying fish (Exocoetidae) in the waters of the West Coast of Majene The Makassar Strait uses a mesh size of 1 inch (Palo et al., 2016), but for flying fish gill nets with a mesh size of 1.5 inches there is still very little research and until now there is no information about the technical aspects and catch results. Flying fish gill nets in Barru Regency waters.

The results of observations made in the field show that gill nets have been operated in the waters of Barru Regency for a long time and are often found, one of which is the flying fish gill net in Lawallu Village, there are two to three sets of gill nets that are operated and the catch is quite large, so there is the potential for overfishing in For this area, it is interesting to carry out research regarding flying fish catching in Barru Regency waters, such as technical aspects and catches from flying fish gill nets so that we can know the results of the catch, whether the fish are worth catching or not.

II. MATERIAL AND METHODS

2.1 Research Location

This research was carried out from December 2022 to April 2023 at Lawallu Village, Soppeng Riaja District, Barru Regency, South Sulawesi, Indonesia.

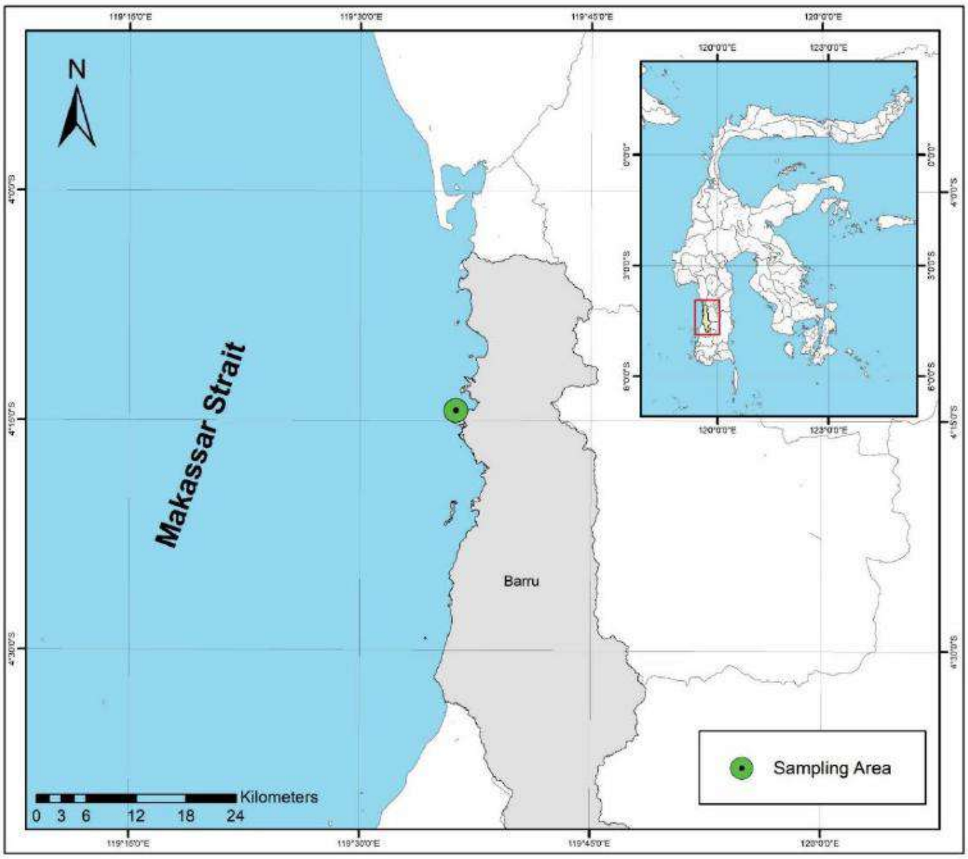

Fig.1. Sampling in Lawallu Village, Soppeng Riaja District, Barru Regency

2.2 Sample Collection

Data collection was carried out using the observation method. The observation method is a data collection method that is carried out directly in the field through systematic questions regarding any changes that occur in the object being studied. The data required in this research includes primary data and secondary data. Primary data is data obtained from direct measurements in the field. Secondary data is data obtained by conducting direct interviews with fishermen.

2.3 Data Analysis

Analysis of Flying Fish Sizes Worth Catching

The analysis of catch size is carried out by measuring the body length of the fish, using a ruler with an accuracy of 0.1 cm. The catch measured consists primarily of flying fish, and the measurement taken is the fork length. The fish length is measured from the tip of the snout to the outer edge of the fork in the caudal fin.

The body length of the predominantly caught flying fish is measured and categorized based on size classes by creating a fish length size table using Microsoft Excel. This measurement is carried out to determine the suitable catch size for flying fish caught with gill nets. According to Kholis (2018), the method to calculate the percentage of catchable fish is:

$$Percentage\ (\%) = \frac{Number\ of\ fish\ worth\ catching}{Number\ of\ samples}\ x\ 100\%$$

Determining the number of fish samples taken is based on size groups, where the size groups are adjusted to the results of the catch at the time of sampling, to determine the size suitable for catching or not suitable for catching flying fish caught in gill nets which are predominantly caught, by using references from journals, books or fish base which refers to the reference length of the fish when the gonads first mature or Length at First Maturity (Lm). It is said to be worth catching if the length of the fish caught in the gill net is greater than Lm.

Mesh Aperture Measurement

Measuring net mesh openings is an important aspect in determining the efficiency and effectiveness of fishing gear. Measurement of mesh openings based on parameters:

a. Mesh height at hanging ratio 62%

b. Width of mesh openings on shortening 38%

c. Bar

d. Mesh size

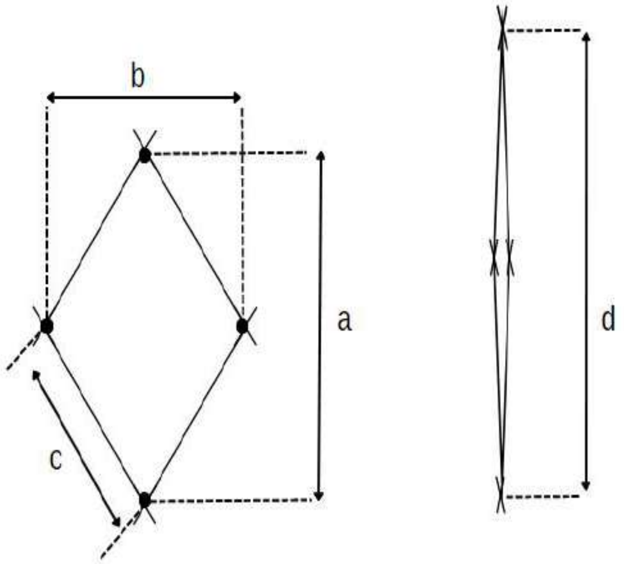

Fig.2. Design and dimensions of mesh size

How to Catch Fish in a Net

Analyzing data on the position of fish entangled in the net was carried out using fish size data (length, width and body circumference of the fish) which was linked to the position of the entangled fish.

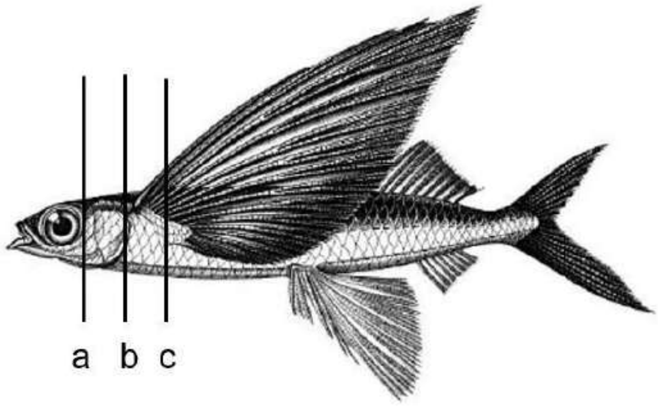

Fig.3. Proportion of entanglement area index in flying fish

Information :

a. Position of Fish entangled snagged (ij 0 – 33%)
b. Position of gilled entangled fish (ij 34 – 67%)
c. The position of the fish is wedged (ij 68 – 100%)

III. RESULT AND DISCUSSION

3.1 Gill Net Catch Results of Flying Fish

The catch of fishermen using flying fish gill nets operating in Lawallu Village, resulted in the flying fish species Hirundichthys oxycephalus. The local name for tuing-tuing fish. Flying fish obtained at the research location can be seen in Figure 3.

Fig.4. Flying fish (Hirundichthys oxycephalus)

Classification of flying fish (*Exocoetidae*) according to Parin (1999):

Kingdom: Animalia
Phylum: *Chordata*
Class: *Actinopterygii*
Order: *Beloniformes*
Family: *Exocoetidae*
Genus: *Hyrundicthys*
Species: *Hirundichthys oxycephalus*

The flying fish obtained based on the research carried out has an elongated round shape like a cigar, the skin color is dark bluish black on top with a silvery belly, the pectoral fins are very long and extend past the base of the anal fin, the base of the anal fin is parallel to the base of the dorsal fin and the tail fin is forked. where the lower branches are longer than the upper branches in a V shape. The eyes of flying fish are relatively large compared to other fish species.

3.2 3.2 Morphometrics of flying fish on the shape of the gill net mesh size

Flying fish morphometrics are ideal for gill net fishing, the proportion of the area index of the long entanglement so that measurements can be made of the morphometrics of fish caught in flying fish gill nets. These measurements include body height, body width and body circumference behind the eyes, operculum, and maximum height of the fish. Measurements were carried out to determine the relationship with the size of the mesh used in flying fish gill nets.

Fig.5. Area of entangled fish: (a) snagged, (b) gilled, (c) wedged

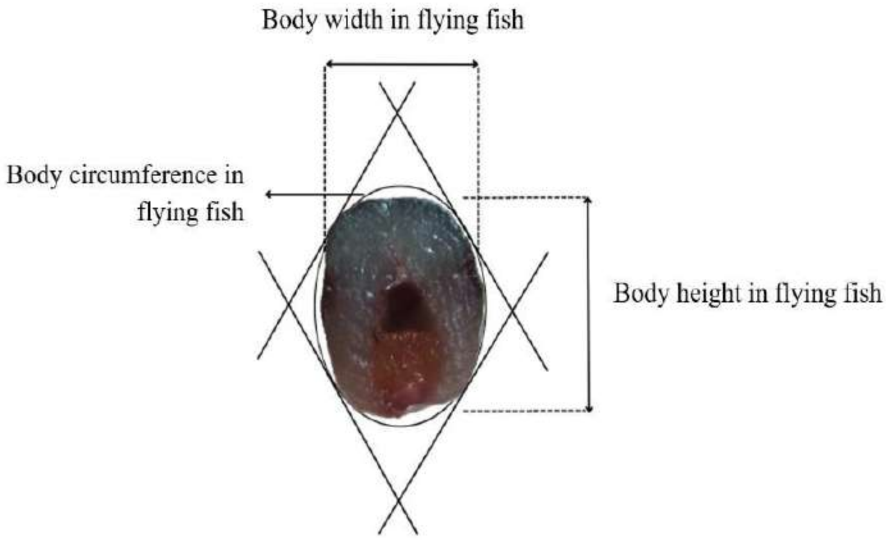

Fig.6. Measured body area of flying fish

The results of measurements of flying fish in the entangled area are:

a. Snagged : fish entangled in the area behind the eyes, body height 2.3 cm, body width 2, and body circumference 6.5 cm.

b. Gilled : fish entangled in the area behind the gill covers, with a body height of 2.7 cm, body width of 2.5 cm, and body circumference of 7.5 cm.

c. Wedged : fish is entangled in the area of maximum fish height, body height of 3 cm, body width of 2.5 cm, and body circumference of 8 cm.

Based on measurements of height, width, and body circumference in areas entangled in flying fish, it can be seen that there is a relationship between the mesh size of 3.81 cm in the flying fish gill net and the size of the flying fish that is the target catch so that the mesh size used is appropriate. The working principle of gill nets is to block the direction of fish swimming. With this obstacle, it is hoped that the fish will break through the net and become entangled (gilled) behind the gill covers or entangled (entangled) in the body of the net. Fishing in drift gill nets is the same as the principle of catching in gill nets in general. Generally, fish that are caught are entangled in the area around the operculum (gilled).

In Figure 6 we can see that the fish caught in gill nets with a mesh size of 3.81 cm have sizes in the area behind the eyes, operculum, and maximum height area that are much different from other fish. In part b (Figure 5) which is the operculum area, many flying fish are caught in this area because generally, fish that are entangled in the operculum area will find it difficult to escape, while in part c (Figure 5) which is the maximum height area, there are also many Flying fish are caught in this area because the entangled fish will be stuck at the maximum height. Based on these measurements, it can be seen that there is a relationship between mesh size and the size of flying fish caught in the gill net used because if the maximum height of the fish is smaller than the mesh size, the fish will escape.

Ikan terbang secara umum memiliki bentuk tubuh yang memanjang seperti cerutu, agak gepeng, garis rusuknya terletak di bagian bawah badan, kedua rahangnya hampir sama panjang kecuali pada ikan terbang yang masih muda dimana bentuk rahang bawah yang sedikit lebih panjang atau rahang bawah lebih menonjol terutama pada individu muda Oxymopharus dari family Oxyphoramphydae, dan atau rahang atas lebih menonjol daripada rahang bawahnya terutama pada jenis Cypselurus. Sirip pektoral panjang diadaptasikan untuk melayang dan terdiri dari duri lunak, dengan variasi ukuran dan jumlah ruas sirip bercabang pada masing-masing spesies. Sirip ekor bercagak dengan cagak bawah yang lebih panjang serta memiliki gigi-gigi kecil yang tumbuh pada kedua rahangnya. Sisiknya sikloid berukuran relatif besar dan mudah lepas. Pada beberapa spesies Hyrundichthys, sisiknya juga tumbuh pada bagian palatin, pada Fodiator dan Parexocoetus juga tumbuh pada vormer dan lidah. Ukuran-ukuran panjang kepala, tinggi, dan lebar juga tergantung pada umur (Hutomo et al., 1985).

This flying fish has an elongated round shape like a cigar, the pectoral fins are very long, usually reaching the back of the dorsal fin, the dorsal fin is slightly longer than the anal fin, it is dark or gloomy, and there are black spots. The caudal fin is branched where the lower branch is longer than the upper branch, and the long pelvic fin reaches the middle of the anal fin and sometimes even far back. Fin radius; D. 10-11; A.11; PI 14-15, on the lateral line there are 50-56 scales, between the dorsal fin and the lateral line there are 32-35 scales. On the back, it is bluish, while on the stomach it is silvery (Ali, 2012).

3.3 Appropriate Sizes to Catch Flying Fish

Based on the results of the measurements carried out, it can be seen that the fork length of the flying fish caught can be seen in Figure 6 showing that the total catch was 450 fish in the range of 13.0-23.2 cm, the highest size was in the range of 16.3-17. 3 cm as many as 86 individuals, while the lowest size was in the size range of 22.2-23.2 cm as many as 17 individuals. The percentage of fish suitable for catching and not suitable for catching can be seen in Figure 21 which shows that the percentage of flying fish that are suitable for catching is 76%. The total catch is 340 fish, in the size range of 15.2-23.2 cm & the percentage of flying fish that are not. catchable was 24%, and the total catch was 110 fish, in the size range of 13.0-15.1 cm.

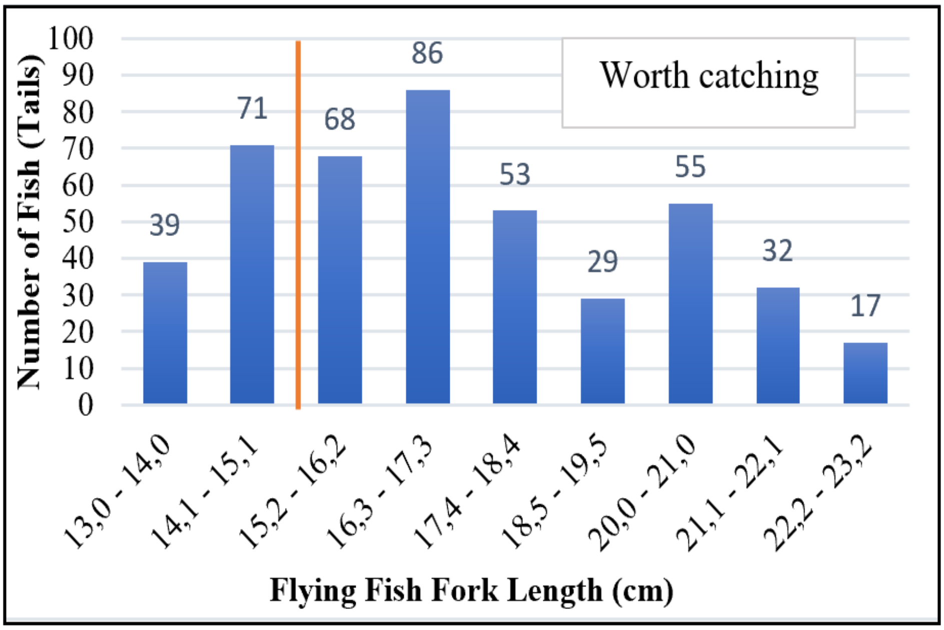

Fig.6. Fork length interval for flying fish

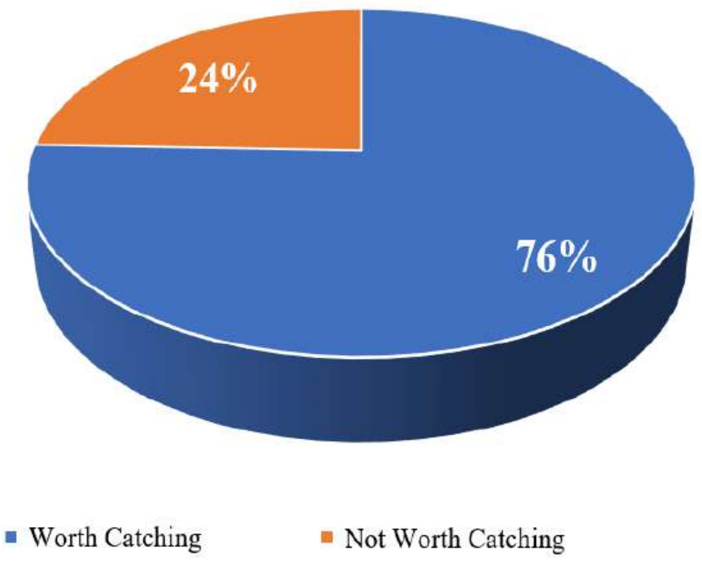

Fig.7. Percentage of catchable size of flying fish

The length of a fish can be used to determine whether or not the fish is worth catching by knowing the length at first maturity of the fish. Adult fish suitable for catching in fishing activities are fish that have entered the reproductive phase. Based on data from research on fish size, data on measuring the fork length of 450 fish was obtained.

The results of measuring the fork length of caught fish were identified based on Ali's (2005) research journal in the Makassar Strait with a catchable size or length at first maturity (Lm), namely 15.1 cm. This shows that flying fish that are worth catching have a size that exceeds L50%. Based on the results of observations made, the average fork length of flying fish caught in gill nets was measured at 17.3 cm, which ranged from 13.0-23.3 cm. The percentage of fish that are worth catching is 76% with a frequency of 340 fish, in the size range of 15.2-23.2 cm and fish that are not worth catching is 24% with a frequency of 110 fish, in the size range of 13.0-15.1 cm.

The relationship between the average size caught and the first time the gonads mature is a reference for determining whether the fish caught have matured gonads or not. Based on the analysis, the results obtained were that the dominant flying fish were caught after the gonads matured (Lc > Lm). This means that the fish are still worth catching and have the opportunity to spawn before being caught increasing the population in the waters. This was also stated by Laevastu & Hayes (1981) that a catch is declared worth catching if it provides an opportunity for fish to reproduce before being caught. Identification results can also be seen from the percentage and frequency that are considered suitable for catching. This is in accordance with Laevastu & Hayes (1981), that the size of the fish caught will have a maximum value or reach the optimum fish size. Similar results in research by Palo et al., (2019), the length of flying fish (*Hirundichthys oxycephalus*) caught with gill nets in the southern part of the Makassar Strait has an average size of 18.4-18.9 so it is a fish that is worth catching and Palo et al., (2016) flying fish caught in the waters of the west coast of Majene have an average length of flying fish in the class range of 15-25 cm so that they are also included in the fish that are worth catching with the highest frequency in the length class of 18-19 cm.

IV. CONCLUSION

From the results of the research that has been carried out, it can be concluded that flying fish were caught using gill nets with a mesh size of 3.81 cm. The total catch was 450 fish from the range of 13.0-23.2 cm, the highest size was in the range of 16.3-17.3 cm with 86 fish, while the lowest size was in the range of 22.2-23.2 cm. 17 heads. The percentage of flying fish that were worth catching was 76%, the total catch was 340 fish, in the size range of 15.2-23.2 cm & the percentage of flying fish that were not worth catching was 24%, the total catch was 110 fish, in the size range 13.0-15.1cm.

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A Novel UV-Vis Spectrophotometric Method for Quantifying Rifaximin: Method Development and Validation

Shibani Raut[1], Geetanjali Amat[1], Akshya Ku Mishra[2*]

[1]Dept. of Pharmaceutical Analysis, GCP Jamadarpali Sambalpur, Odisha, India
[2]Dept. of Microbiology, BKCP, Nuapada, Odisha, India
*Corresponding Author: akshyamicrobiologist@gmail.com

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***Abstract*— *This study evaluated the standardization and method validation of rifaximin using different acid and phosphate buffer conditions (pH 1.2, 6.8 and 7.4). Although all tested conditions showed excellent precision (less than 2% RSD), limitations in linearity and precision were observed. Although the correlation coefficients were high (0.9898 to 0.9972), they deviated from the ideal (1.0), indicating possible nonlinearities. Accuracy ranged from 89.45% to 94.16%, indicating slight under- or overestimation of rifaximin concentration. These limitations compromise the reliability of the rifaximin quantification method. Other optimization strategies are recommended, including exploring different pH conditions, refining the concentration range of the standard curve, and considering alternative analytical methods such as HPLC when possible. By addressing these limitations, a more robust and reliable method for rifaximin standardization can be achieved.*

***Keywords*— Rifaximin, Spectrophotometer, Standardization and method validation, Robustness, RSD**

I. INTRODUCTION

Rifaximin is an antibiotic that is semi-synthetic and produced from rifamycin. It is commonly used to treat gastrointestinal diseases, including hepatic encephalopathy, irritable bowel syndrome, and traveler's diarrhoea. Targeting pathogenic bacteria in the stomach is made easier by its broad-spectrum antibacterial action and low systemic absorption. The analytical techniques available for rifaximin's quantification and quality control are few and frequently intricate, despite its therapeutic importance. Thus, the development of an easy-to-use, trustworthy, and verified analytical technique is necessary for the regular analysis of rifaximin.

The majority of laboratories choose to use spectrophotometry, especially UV-Visible (UV-Vis) spectrophotometry, since it is an easy and affordable analytical technique. With this technique, the amount of medication present may be ascertained by measuring how much UV or visible light the analyte absorbs.

UV-Vis spectrophotometry has been shown in several studies to be useful in the study of different medicinal substances. For example, Bhavsar et al. (2015) demonstrated the sensitivity and specificity of their UV-Vis spectrophotometric approach for the accurate measurement of cefixime in pharmaceutical formulations[1]. Similar to this, Patel et al. (2017) proved the accuracy and strong linearity of a UV-Vis spectrophotometric approach for olmesartan medoxomil determination[2]. These investigations highlight UV-Vis spectrophotometry's promise as a trustworthy analytical instrument.

Prior analytical approaches for rifaximin have mostly relied on chromatographic techniques, such high-performance liquid chromatography (HPLC), which are accurate but need complex gear and thorough sample preparation. While HPLC techniques offer great sensitivity and specificity, Kumar et al. (2018) claim that they are frequently more difficult to use and require more time than spectrophotometric techniques[3]. Thus, the creation of a UV-Vis spectrophotometric technique provides a more useful substitute for regular analysis in resource-constrained environments.

The present study aims to develop and validate a UV-Vis spectrophotometric method for the quantitative analysis of rifaximin in bulk and pharmaceutical dosage forms. The method will be optimized and validated according to ICH guidelines, ensuring its accuracy, precision, linearity, and robustness. The successful implementation of this method will provide a valuable tool for the efficient and cost-effective analysis of rifaximin, contributing to better quality control and therapeutic efficacy.

II. MATERIAL & METHODS

1-Materials:

- Spectrophotometer: Systronics 117 UV-Vis Spectrophotometer
- Cells: 1 cm matched quartz cells

2-Methods:

2.1Preparation of Standard Stock Solution:

- A standard stock solution of Rifaximin was prepared at a concentration of 1000 µg/ml (micrograms per milliliter) for each of the following:
    - 0.1N HCL (hydrochloric acid), pH 1.2
    - Phosphate buffer, pH 6.8
    - Phosphate buffer, pH 7.4
- 10mg of Rifaximin was dissolved in 10ml of the respective solvent to obtain these solutions.

2.2-Working Standard Solution:

- A working standard solution containing 100 µg/ml of Rifaximin was prepared from the standard stock solutions. The specific method of dilution is not mentioned here.

2. **Selection of Wavelength for Analysis:**

- The standard stock solution (1000 µg/ml) was further diluted using the same three solvents (0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4).
- Each dilution was scanned in the UV-Vis spectrophotometer over a wavelength range of 200-800 nm.
- For each scan, the corresponding solvent (without Rifaximin) was used as a blank to account for background absorption.

2.3. Preparation for Calibration Curve:

- This section details how the researchers prepared a set of solutions for creating a calibration curve.
- The standard stock solution (1000 µg/ml) was further diluted with each of the three solvents (0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4).
- The goal was to obtain a series of solutions with concentrations ranging from 2 to 10 µg/ml.
- The absorbance of each solution was measured using the corresponding solvent as a blank (similar to step 2.2).
- To ensure accuracy, each concentration was measured three times.

2.4. Assay of Rifaximin in Tablet:

- This section describes how the researchers analyzed the amount of Rifaximin present in a tablet.
- Twenty tablets were weighed, and the average weight was determined.
- The tablets were then finely powdered.
- An amount of the powder equivalent to 50mg of Rifaximin was accurately weighed.
- This weighed powder was dissolved in a small amount of methanol in a 50 mL volumetric flask.
- The flask was then filled to the 50 mL mark with methanol, resulting in a solution with a concentration of 1000 µg/ml (assuming all the Rifaximin dissolved).
- From this initial solution (1000 µg/ml), 10 mL was pipetted and diluted to 100 mL with methanol in another volumetric flask. This dilution step creates a solution with a concentration of 100 µg/ml.
- Finally, 2 mL of the 100 µg/ml solution was diluted to 10 mL with methanol.
- The concentration of Rifaximin in this final solution was then measured using the UV spectrophotometer.

2.5. Method Validation

- This section details the experiments performed to ensure the analytical method is reliable and accurate for Rifaximin analysis.

- The validation is based on the International Council for Harmonisation (ICH) guidelines, a recognized standard for drug analysis.[4,5&6]

Here are the specific parameters evaluated:

- **Linearity:** Similar to section 2.3, solutions with concentrations ranging from 2 to 10 µg/ml were prepared using each solvent (0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4).
    - Absorbance was measured at a specific wavelength chosen based on the scans from section 2.2 (likely around 440 nm).
    - A linear calibration curve is obtained by plotting the absorbance values against the corresponding concentrations.
    - Linearity ensures a proportional relationship between absorbance and concentration within a defined range.
- **Accuracy:** This step verifies if the method provides a true reflection of the actual Rifaximin amount in the sample.
    - A standard addition method is employed. A known amount of Rifaximin standard is added to pre-analyzed samples at three levels: 80%, 100%, and 120% of the expected concentration.
    - The spiked samples are then reanalyzed, and the recovery of the added standard is calculated for each level (usually expressed as a percentage).
    - Good accuracy translates to consistent recovery close to 100% across these levels.
- **Precision:** Precision reflects how close repeated measurements are under the same conditions.
    - There are three aspects of precision evaluated here:
        - **Repeatability:** This measures the agreement between multiple measurements of the same sample within a short time frame (e.g., same day).
        - **Intra-day precision:** This assesses the variability of measurements within a single day using different aliquots of the same sample solution.
        - **Inter-day precision:** This evaluates the variation in measurements across different days, potentially involving different analysts or instruments.
    - Precision is typically expressed by statistical measures like standard deviation or relative standard deviation (RSD%). Lower values indicate higher precision.
- **Limit of Detection (LOD) & Limit of Quantitation (LOQ):**
    - LOD refers to the minimum concentration of Rifaximin detectable in a sample.
    - LOQ represents the lowest concentration that can be reliably measured with acceptable accuracy and precision.
    - Both LOD and LOQ are calculated using equations based on the slope and standard deviation of the calibration curve.
- **Robustness:** This step assesses how the analytical method is affected by slight variations in the experimental conditions.
    - The analysis is performed with deliberate changes, such as using a slightly different wavelength or altering the time between sample preparation and measurement.
    - Robustness ensures the method is not overly sensitive to minor changes and delivers consistent results.

By evaluating these parameters, the researchers can ensure the analytical method is suitable for determining the amount of Rifaximin in Rifaximin-containing tablets.

III. RESULTS

3.1-Selection of Wavelength for Analysis

The UV spectrum of Rifaximin showed the maximum absorbance at the wavelength 440 nm,441 nm & 445 nm respectively for 0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4 [Figure 1-3]. It was selected for the analysis of Rifaximin in bulk and tablet formulation.

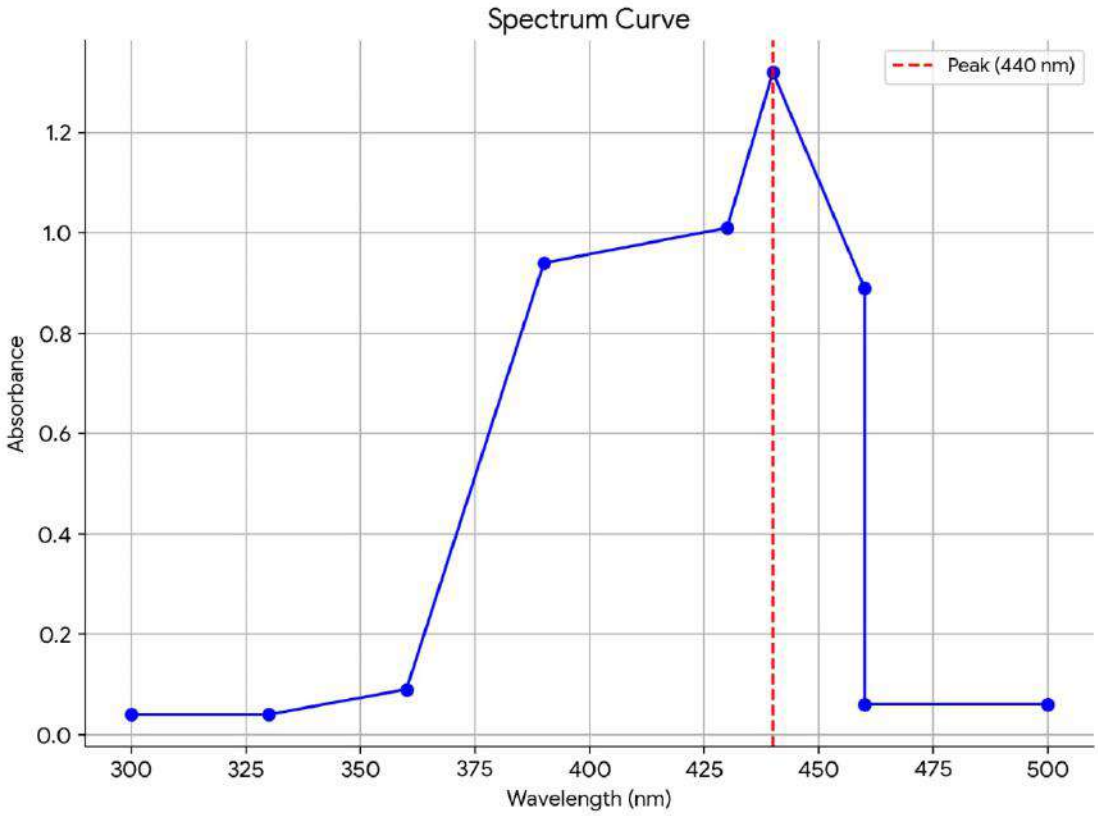

Fig.1: UV Spectrum of Rifaximin in 0.1N HCL (pH 1.2)

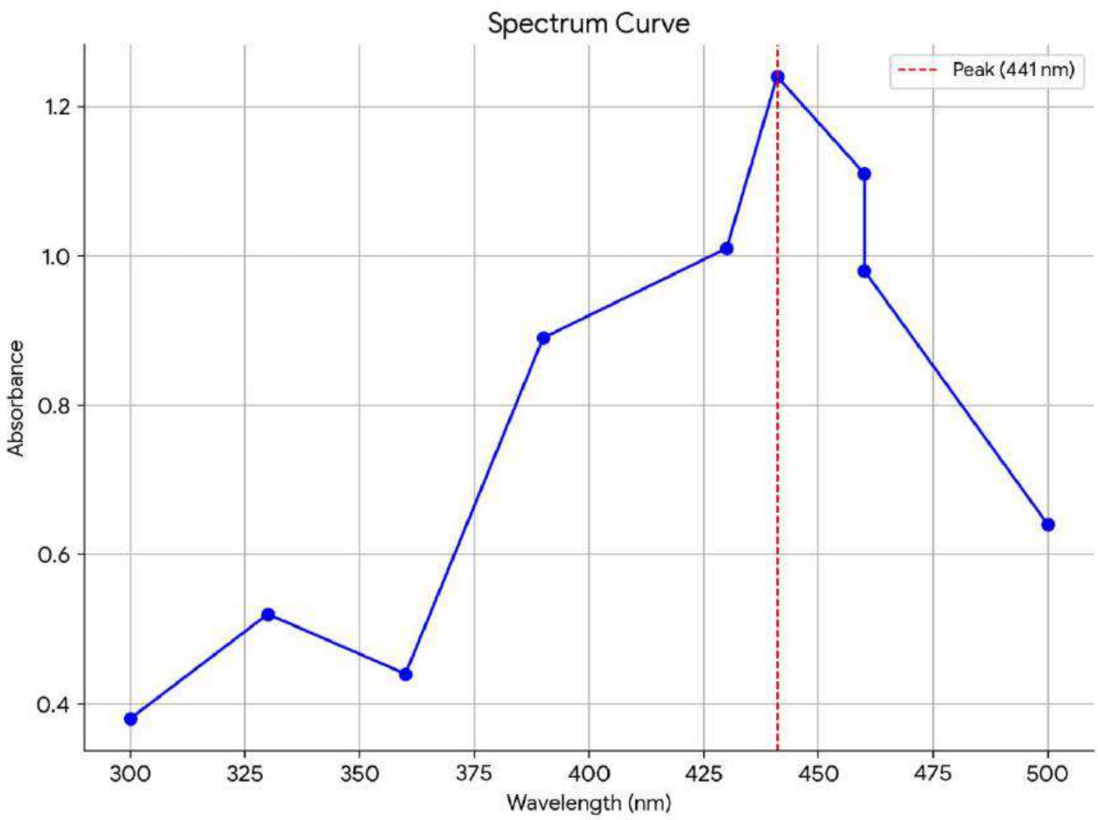

Fig.2: UV Spectrum of Rifaximin in Phosphate buffer (pH 6.8)

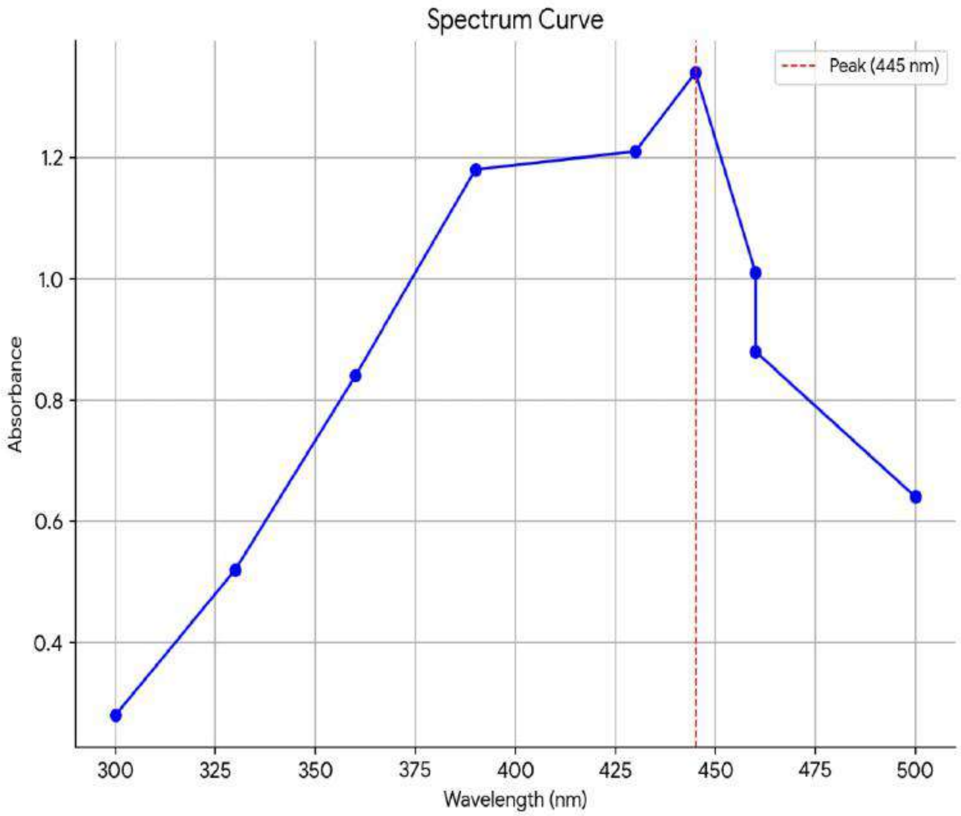

Fig.3: UV Spectrum of Rifaximin in Phosphate buffer (pH 7.4)

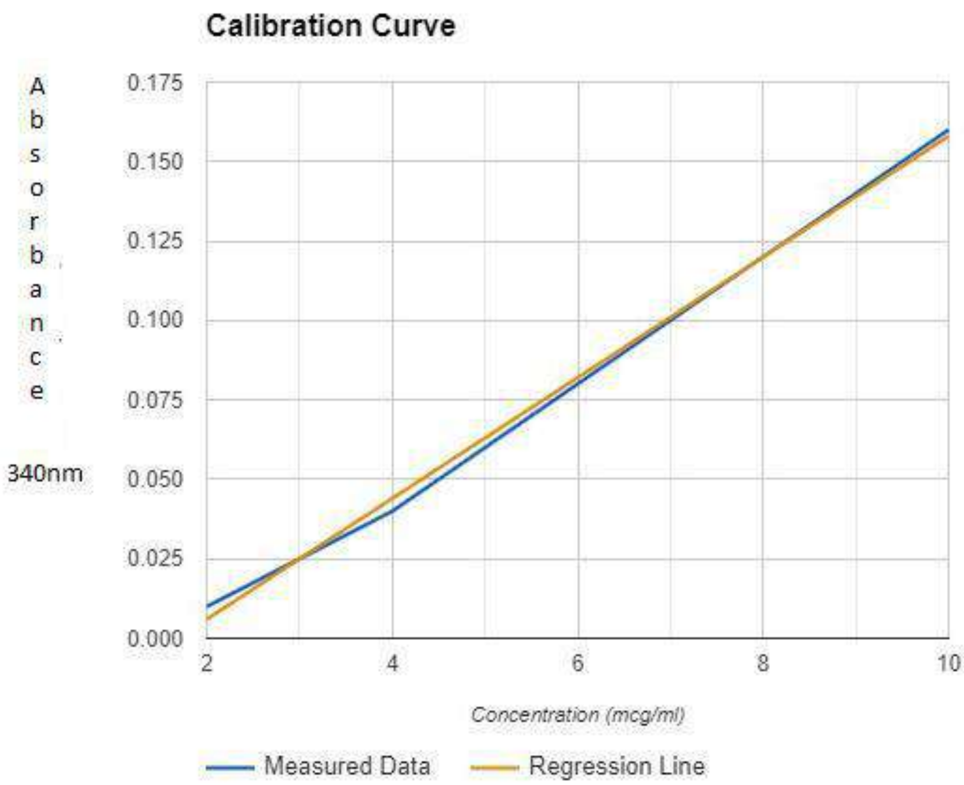

Fig.4: Calibration Curve of Rifaximin in 0.1N HCL (pH 1.2)

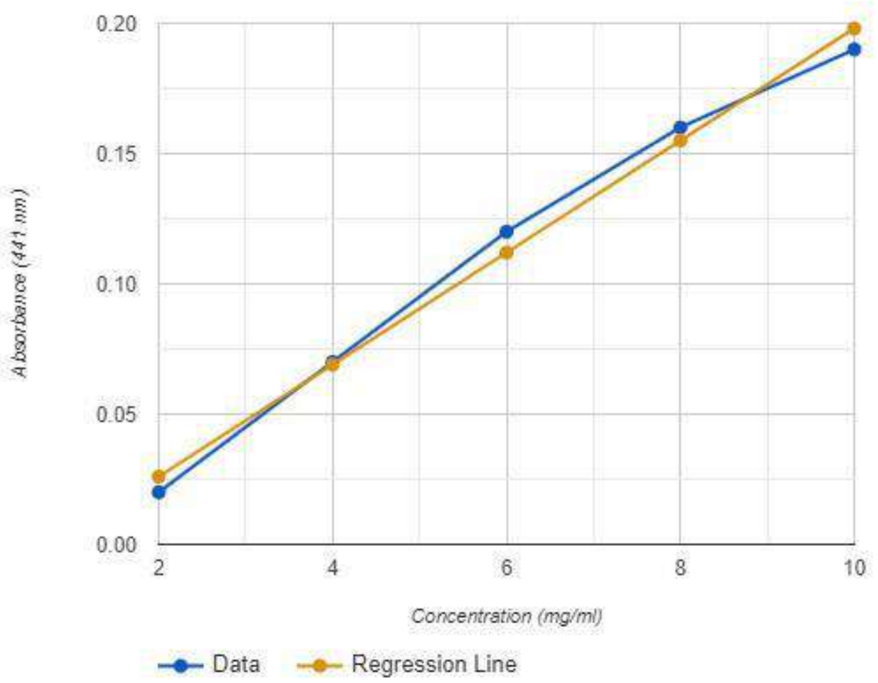

Fig.5: Calibration Curve of Rifaximin in Phosphate buffer (pH 6.8)

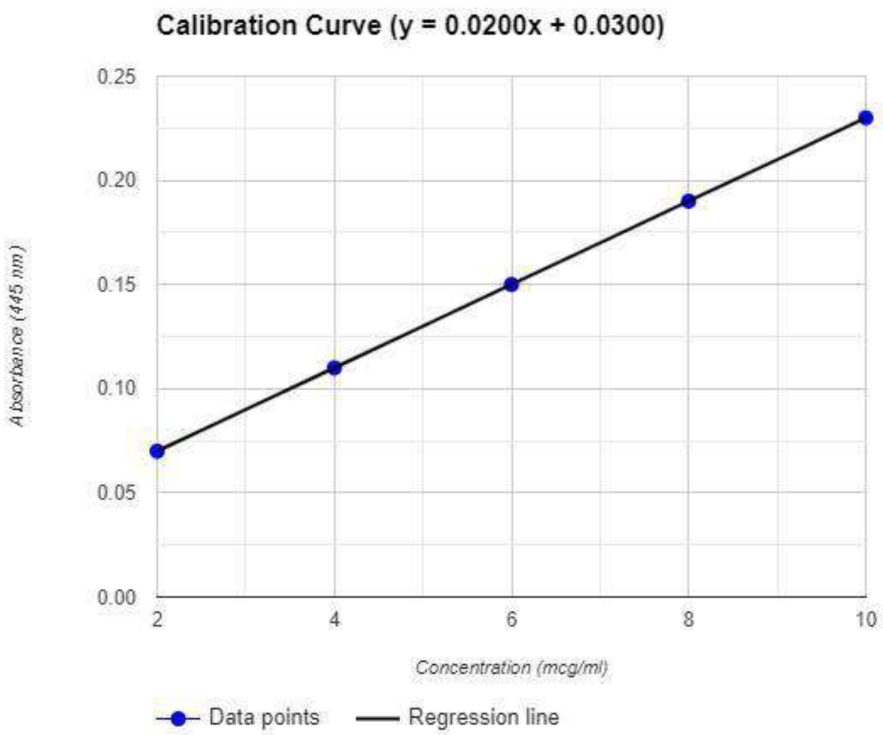

Fig.6: Calibration Curve of Rifaximin in Phosphate buffer (pH 7.4)

3.2-Preparation of the Calibration Curve

The calibration curve was constructed by plotting absorbance against corresponding concentration as shown in [Figure 4,5,&6] The calibration curve for Rifaximin. The drug obeyed Beer–Lambert's law in the concentration range of 2, 4, 6, 8, 10 µg/mL with coefficient of correlation (r2) of 0.998. [Table 1]

Table 1: Linearity data of Rifaximin in 0.1N HCL of 0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4.

PARAMETERS		**RESULTS**	
	0.1N HCL pH 1.2	**Phosphate buffer pH 6.8**	**Phosphate buffer pH 7.4.**
Linearity range	2-10 µg/ml	2-10 µg/ml	2-10 µg/ml
Regression line equation	y = 0.0190x - 0.0320	y = 0.0215x - 0.0170	y = 0.0200x + 0.0300
Slope	0.0190	0.0215	0.0200
Y-intercept	-0.0320	-0.0170	0.0300
Correlation cofficient	0.9972	0.9898	1

3.3-Assay of Rifaximin in Tablet

The amount of Rifaximin present in formulation was calculated by comparing the absorbance of sample with standard absorbance. Content of Rifaximin in tablet formulation determined by developed method was in good agreement with the label claim. [Table 2]

Table 2: Assay of Tablet Formulation by UV method

Labelled claim (mg)	**200mg**
Drug content ± SD (mg)	200±0.0028
% Assay	101.42
% RSD	0.41

3.4-Method Validation

3.4.1. Accuracy

The responses were reanalyzed using the suggested method, and the accuracy results are shown in [Table 3-5], which demonstrate that the percentage amount recovered was between 98.60%-99.96%, 95.12% - 95.59% & 98.17%-98.87% with % RSD less than 2.

Table 3: Results of Accuracy for Rifaximin in 0.1N HCL (pH 1.2)

		Observation table for accuracy (0.1N HCL pH 1.2)				
Levels	**Conc. In ppm**	**Absorbance**	**Conc. Found**	**Mean**	**SD**	**% Recovery**
80	18	0.0655	16.4982			
		0.0663	16.5807	16.6391	0.1449	92.43
		0.0688	16.8384			
100	20	0.0866	18.6735			
		0.0871	18.7250	18.7353	0.0552	93.67
		0.0879	18.8075			
120	22	0.1077	20.8487			
		0.1079	20.8693	20.7164	0.0351	94.16
		0.1085	20.9312			

Table 4: Results of Accuracy for Rifaximin in Phosphate buffer (pH 6.8)

		Observation table for accuracy (Phosphate buffer pH 6.8)				
Levels	**Conc. In ppm**	**Absorbance**	**Conc. Found**	**Mean**	**SD**	**% Recovery**
80	18	0.1141	16.1030			
		0.1138	16.0669	16.102	0.0283	89.45
		0.1147	16.1361			
100	20	0.1203	18.5669			
		0.1205	18.5823	18.5617	0.0192	92.80
		0.1199	18.5361			
120	22	0.1626	19.8207			
		0.1622	19.7961	19.8202	0.0195	90.09
		0.1629	19.8438			

Table 5: Results of Accuracy for Rifaximin in Phosphate buffer (pH 7.4)

		Observation table for accuracy (Phosphate buffer pH 7.4)				
Levels	**Conc. In ppm**	**Absorbance**	**Conc. Found**	**Mean**	**SD**	**% Recovery**
80	18	0.1452	16.6883			
		0.1459	16.7448	16.8442	0.182	93.57
		0.1503	17.0996			
100	20	0.1641	18.2125			
		0.1649	18.2770	18.2655	0.0374	91.31
		0.1652	18.3012			
120	22	0.1866	20.0270			
		0.1888	20.2045	20.4394	0.533	93.13
		0.2016	21.2367			

3.4.2. Precision

The developed method's precision was reported as a % RSD. These findings demonstrate the assay's repeatability. % RSD values less than 2 shows that the method for determining rifaximin is precise. [Table 6-8]

Table 6: Results of Precision for Rifaximin in 0.1N HCL (pH 1.2)

Conc. (ppm)	**Observation Table for Precision (0.1N HCL pH 1.2)**			
	Intra-day precision		**Inter-day precision**	
	Conc. Found ± SD (µg/ml)	**%RSD**	**Conc. Found ± SD (µg/ml)**	**%RSD**
10	9.92±0.005	1.44	9.98±0.005	1.41
20	19.92±0.003	0.51	19.91±0.004	0.59
30	29.48±0.001	1.21	29.94±0.004	1.10

Table 7: Results of Precision for Rifaximin in Phosphate buffer (pH 6.8)

Conc. (ppm)	**Observation Table for Precision (Phosphate buffer pH 6.8)**			
	Intra-day precision		**Inter-day precision**	
	Conc. Found ± SD (µg/ml)	**%RSD**	**Conc. Found ± SD (µg/ml)**	**%RSD**
10	9.03±0.004	0.04	8.42±0.006	1.7
20	19.42±0.003	0.85	19.40± 0.003	0.76
30	28.41±0.002	0.38	28.23± 0.004	0.51

Table 8: Results of Precision for Rifaximin in Phosphate buffer (pH 7.4)

Conc. (ppm)	**Observation Table for Precision (Phosphate buffer pH 7.4)**			
	Intra-day precision		**Inter-day precision**	
	Conc. Found ± SD (µg/ml)	**%RSD**	**Conc. Found ± SD (µg/ml)**	**%RSD**
10	9.21±0.002	0.72	9.62±0.004	0.89
20	19.31±0.002	1.65	19.83±0.003	1.82
30	29.42±0.004	1.73	29.63±0.001	1.95

3.4.3. LOD & LOQ

By using the given formula, the LOD & LOQ were calculated for rifaximin in 0.1N HCL pH 1.2, Phosphate buffer pH 6.8 & Phosphate buffer pH 7.4 respectively in [Table 9]

Table 9: Results of LOD & LOQ

Conc (ppm)	**Absorbance**		
	(0.1N HCL pH 1.2)	**(Phosphate buffer pH 6.8)**	**(Phosphate buffer pH 7.4)**
0.1	0.0123	0.0800	0.1219
0.2	0.0141	0.0801	0.2578
0.3	0.0160	0.0808	0.3786
0.4	0.0215	0.0810	0.1188
0.5	0.0310	0.0814	0.2580
0.6	0.0324	0.0845	0.3773

SD	0.00675	0.0171	0.1286
Slope	0.0328	0.1087	0.0589
LOD	0.0203	0.5207	7.17
LOQ	0.0675	1.0414	21.77

3.4.4. Robustness

This method's robustness was tested using variations in wavelength change. The experimental results demonstrated that the suggested UV technique is robust, with the change since% RSD being less than 0.9%. [Table 10-12]

Table 10: Results of Robustness for Rifaximin in 0.1N HCL (pH 1.2)

Wavelength	**Chamber Saturation Time(Min)**			**Time form application to development (min)**		
440	14	15	16	0	30	60
0.246	1.071	1.019	0.941	0.748	0.968	1.311

Table 11: Results of Robustness for Rifaximin in Phosphate buffer (pH 6.8)

Wavelength	**Chamber Saturation Time(Min)**			**Time form application to development (min)**		
441	14	15	16	0	30	60
0.429	1.220	1.239	1.225	1.025	0.656	0.335

Table 12: Results of Robustness for Rifaximin in Phosphate buffer (pH 7.4)

Wavelength	**Chamber Saturation Time(Min)**			**Time form application to development (min)**		
445	14	15	16	0	30	60
0.211	0.331	0.268	1.015	0.979	0.325	0.435

3.5 The Summary of Validation Parameters by UV Method

NO	**PARAMETERS**	**(0.1N HCL pH 1.2)**	**(Phosphate buffer pH 6.8)**	**(Phosphate buffer pH 7.4)**
1	ABSORPTION MAXIMA	440	441	445
2	BEERS RANGE (µg/ml)	2-10 µg/ml	2-10 µg/ml	2-10 µg/ml
3	STANDARD REGRESSION EQUATION	y = 0.0190x - 0.0320	y = 0.0215x - 0.0170	y = 0.0200x + 0.0300
4	CORRELATION COFFICIENT	0.9972	0.9898	1
5	PRECISION	Below 2%	Below 2%	Below 2%
6	ACCURACY	92.43-94.16%	89.45-92.80 %	91.31-93.57%
7	ROBUSTNESS	0.246	0.429	0.211

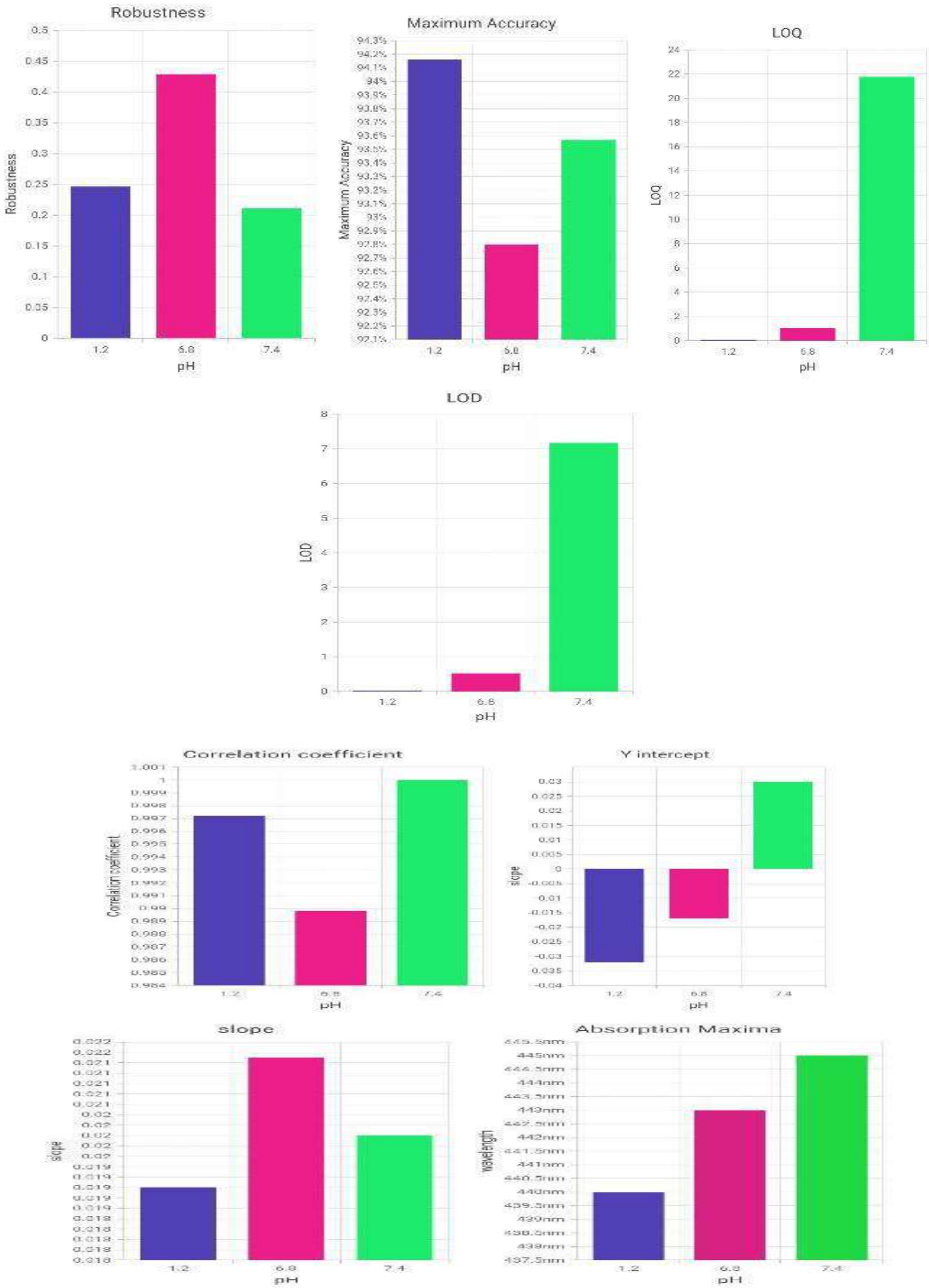

Fig-7 Graphical Representation Summary of Validation Method of Drug Rifaximin

IV. CONCLUSION

Validation of the rifaximin standardization method using different acid and phosphate buffer conditions (pH 1.2, 6.8 and 7.4) showed good accuracy (relative standard deviation less than 2%) but limitations in linearity and precision. Although the correlation coefficients were relatively high (0.9898 to 0.9972), they were below the ideal (1.0), indicating possible biases in concentration and absorption. In addition, accuracy ranged from 89.45% to 94.16%, suggesting a slight under- or overestimation of rifaximin concentration. Further optimization is needed to create a more robust method. This may include investigating different pH conditions, refining the concentration range of the standard curve, or even considering alternative analytical methods.

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Effect of Nitrogen Fertilization Dosage on Growth and Yield of Three Varieties of Glutinous Corn *(Zea mays var. ceratina)*

Ardian Tri Wahyu Ridha'i[1], Sudiarso[2] and Karuniawan Puji Wicaksono[2]

[1]Master Student at Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
[2]Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia
*Corresponding author Email : Ardiantri82@gmail.com

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Abstract— *Superior varieties are one of the technological components that are very important in achieving high production. The use of nitrogen fertilizer is the most important factor for plant growth and development. Chemical fertilizers in general and nitrogen fertilizers in particular are important determinants of productivity levels per unit area, and the importance of increasing the use of chemical fertilizers in soil conditions that lack organic matter. The research was carried out from February 2023 to May 2023 at Agro Techno Park, Jatikerto Village, Kromengan District, Malang Regency. The research was carried out in the form of a factorial experiment arranged in a Randomized Group Design (RGD). Consists of 2 factors, where the first factor is three varieties of glutinous corn and the second factor is the dose of nitrogen fertilizer. The first factor, varieties which consist of 3 levels, namely: Arumba Variety (V1), Srikandi Variety (V2), and URI 1 Variety (V3). The second factor, nitrogen fertilization dosage with 4 levels, namely: No fertilizer/Control (A0), Nitrogen 100 kg* ha^{1-} *(A1), Nitrogen 200 kg* ha^{1-} *(A2), and Nitrogen 300 kg* ha^{1-} *(A3). Overall, the variety treatment and N fertilizer dose showed a significant interaction effect on all growth parameters except for the number of leaves at 42 DAP, and leaf area at 14, 21, 35 and 49 DAP. The variety treatment and N fertilizer dose showed a significant interaction effect on all yield parameters except ear length. Variety treatment and N fertilizer dosage had an influence on the analysis of increasing starch, amylose and amylopectin content. The Srikandi variety had the highest yield in every growth and yield of glutinous corn followed by the Arumba and URI 1 varieties. In the treatment with a N fertilizer dose of 300 kg* ha^{1-} *had the highest yield in every observed parameter.*

Keywords— ***Maize, Nitrogen fertilizer, Varieties, Growth components, Yield components***

I. INTRODUCTION

Glutinous corn (*Zea mays var. ceratina*) is a type of corn that has a high amylopectin content, which causes the texture of the corn to become soft and fluffier. Glutinous corn is widely used for consumption, both in fresh form and in processed products because it has a sweet, soft taste and attractive appearance that other corn does not have (Tengah *et al*., 2017). Until now, Indonesia still relies on imports to meet demand for corn from the industrial sector. Corn imports throughout 2018 reached 737.22 thousand tons with a value of US$ 150.54 million.Increasing glutinous corn production needs to be done in line with increasing demand for glutinous corn.Variety is one of the many factors that determine plant growth and yield. Using the right varieties will increase glutinous corn production. Superior varieties are one of the technological components that are very important in achieving high production. Nitrogen fertilizer is the most important fertilizer for plant growth and development. Nitrogen fertilizer deficiency is a major factor limiting crop growth, yield and quality. Chemical fertilizers in general and nitrogen fertilizers in particular are important determinants of productivity levels per unit area, and the importance of increasing the use of chemical fertilizers in soil conditions that lack organic matter (Alamer and Alsharifi, 2020). Nitrogen is the main nutrient that is most important for increasing production, because corn plants respond very well to nitrogen fertilizer and about half of the nitrogen absorbed by grain is well accumulated (Alsharifi *et al.*, 2021). Jatikerto Village is included in the southern Malang region, it is a lowland with a height of 303 m. asl. and an average temperature of 23°C to 28°C. Jatikerto Village is a village with a agroecosystem type namely dry land planted with seasonal or annual crops, such as rice, secondary crops and horticulture. The moor is very dependent on rainwater. Therefore, appropriate management efforts are needed so that plant growth and production can be maximized. These efforts include providing balanced fertilizer and using corn varieties that suit land conditions.

II. MATERIALS AND METHODS

The research was carried out from February 2023 to May 2023 at Agro Techno Park, Jatikerto Village, Kromengan District, Malang Regency. Jatikerto Village is included in the southern Malang region, it is a lowland with a height of ± 300 m. asl. In carrying out this research, the tools used included a hoe, a stick, a sickle, a sprayer tank, measuring cups, buckets, scales, meters, rulers, label boards, cameras, and writing tools to record the results. The materials used in this research included glutinous corn seeds of the Arumba F1, Srikandi F1, and URI 1 varieties. Other materials used included Urea Nitrogen Fertilizer, NPK Phonska 15:15:15 Compound Fertilizer, pesticides and herbicides. The research used a design in the form of a factorial experiment arranged in a Randomized Group Design (RGD). Consists of 2 factors, where the first factor is three varieties of glutinous corn and the second factor is the dose of nitrogen fertilizer. The first factor, varieties which consist of 3 levels, namely: Arumba Variety (V1), Srikandi Variety (V2), and URI 1 Variety (V3). The second factor, nitrogen fertilization dosage with 4 levels, namely: No fertilizer/Control (A0), Nitrogen 100 kg ha^{1-} (A1), Nitrogen 200 kg ha^{1-} (A2), and Nitrogen 300 kg ha^{1-} (A3). Thus, for the entire experiment, 12 treatments were obtained with 3 replications so that there were 36 experimental plot units. Where each experimental plot consists of 40 plants and each experimental unit consists of 15 sample plants that are observed. The data from the observations were then analyzed using analysis of variance (F test) with a level of 5% with the aim of finding out whether the effect of the treatment was real or not. If there is a significant difference, then continue the BNJ test with a level of 5%. Parameters observed include plant height, number of leaves and leaf area, dry weight, plant growth rate (CGR), net assimilation rate (NAR), leaf area ratio (LAR), cob length, cob diameter, fresh weight of cob without husk , fresh weight of cob with husks, yield per hectare and starch, amylose and amylopectin content tests.

III. RESULT

Plant Height

Table 1. Average Height of Glutinous Corn Due to the Interaction Effect of Variety Treatment and N Fertilizer Dosage at observation ages 14, 21, and 28 DAP.

Day after planting (DAP)	Nitrogen dose (kg ha^{-1})	Varieties		
		Arumba	Srikandi	URI 1
14	0	19,83 b A	16,95 a A	16,61 a A
	100	21,44 b A	18,56 a A	17,83 a A
	200	21,72 b A	21,06 b B	18,33 a A
	300	22,06 b A	22,61 b B	18,61 a A
	HSD Varieties (5%)		2,43	
	HSD Nitrogen (5%)		2,20	
21	0	30 b A	29,17 b A	22 a A
	100	31,39 b B	30,42 b AB	24 a B
	200	31,92 b B	31,28 b B	25,25 a B
	300	32,39 b B	32,78 b C	26,83 a C
	HSD Varieties (5%)		1,28	
	HSD Nitrogen (5%)		1,16	
28	0	59,61 c A	54,06 b A	37,06 a A
	100	63,62 c AB	57,28 b AB	46,11 a AB
	200	65,44 b B	62,06 b BC	47,22 a B
	300	66,17 b B	63,59 b C	52,72 a C
	HSD Varieties (5%)		5,09	
	HSD Nitrogen (5%)		4,61	

The results of the analysis of variance showed that there was a real interaction between the application of nitrogen fertilizer to three different varieties at all ages of observing the growth of glutinous corn plants and this increased with increasing nitrogen doses. The dose of 300 kg ha^{1-} was significantly different from the control in all varieties. At each observation age, the Srikandi variety with a dose of 300 kg ha^{1-} had the highest value, followed by the Arumba and URI 1 varieties.

Table 2. Average Height of Glutinous Corn Treatment Varieties and N Fertilizer Doses at observation ages 35, 42, and 49 DAP.

Day after planting (DAP)	Nitrogen dose (kg ha^{-1})	Varieties		
		Arumba	Srikandi	URI 1
35	0	86,22 c A	76,22 b A	37,44 a A
	100	90,05 b AB	92,39 b B	54,44 a B
	200	97 b BC	94,97 b B	57,44 a B
	300	99 b C	97,42 b B	69,97 a C
	HSD Varieties (5%)		7,57	
	HSD Nitrogen (5%)		6,85	
42	0	109,7 b A	92,7 ab A	83,3 a A
	100	127,2 b AB	138,9 b B	86,7 a AB
	200	131,9 b AB	140,5 b B	99,5 a AB
	300	141,4 b B	151 b B	107,5 a B
	HSD Varieties (5%)		23,57	
	HSD Nitrogen (5%)		21,32	
49	0	134,7 b A	127,2 b A	81,7 a A
	100	139,8 b AB	164,4 c B	103,3 a B
	200	152,6 b BC	166,7 b B	107,4 a B
	300	165 b C	173,9 b B	108,7 a B
	HSD Varieties (5%)		16,28	
	HSD Nitrogen (5%)		14,73	

Number of leaves

Table 3. Average Number of Glutinous Corn Leaves Effect of Interaction Between Variety Treatment and N Fertilizer Dosage at observation ages 14, 21, and 28 DAP.

Day after planting (DAP)	Nitrogen dose (kg ha^{-1})	Varieties		
		Arumba	Srikandi	URI 1
14	0	19,83 b A	16,95 a A	16,61 a A
	100	21,44 b A	18,56 a A	17,83 a A
	200	21,72 b A	21,06 b B	18,33 a A
	300	22,06 b A	22,61 b B	18,61 a A
	HSD Varieties (5%)		2,43	
	HSD Nitrogen (5%)		2,20	
21	0	30 b A	29,17 b A	22 a A
	100	31,39 b B	30,42 b AB	24 a B
	200	31,92 b B	31,28 b B	25,25 a B
	300	32,39 b B	32,78 b C	26,83 a C
	HSD Varieties (5%)		1,28	
	HSD Nitrogen (5%)		1,16	
28	0	59,61 c A	54,06 b A	37,06 a A
	100	63,62 c AB	57,28 b AB	46,11 a AB
	200	65,44 b B	62,06 b BC	47,22 a B
	300	66,17 b B	63,59 b C	52,72 a C
	HSD Varieties (5%)		5,09	
	HSD Nitrogen (5%)		4,61	

The results of the analysis of variance showed a real interaction between the application of nitrogen fertilizer to three different varieties at the observation ages of 14, 21, 28, 35 and 42 DAP. At the observation age of 14 DAP, it showed an increase in the number of leaves of glutinous corn plants as the dose of nitrogen fertilizer increased. At the age of 49 DAP the arumba variety had the highest value.

Table 4. Average Number of Leaves for Varieties and N Fertilizer Doses at Observation Age 35 and 42 DAP.

Day after planting (DAP)	Nitrogen dose (kg ha^{-1})	Varieties		
		Arumba	Srikandi	URI 1
35	0	9,94 b A	10,83 b A	6,94 a A
	100	11,78 b B	11,67 b A	8 a AB
	200	13,61 b C	13,17 b B	9,06 a BC
	300	14,39 b C	14,17 b B	9,22 a C
	HSD Varieties (5%)		1,18	
	HSD Nitrogen (5%)		1,07	
42	0	9,11 b A	11,28 c A	6,39 a A
	100	11,06 b B	12,06 b AB	8,11 a AB
	200	13,94 b C	13,22 b BC	8,72 a B
	300	14,61 b C	14,28 b C	11,11 a C
	HSD Varieties (5%)		1,81	
	HSD Nitrogen (5%)		1,64	

Treatment	Number of leaves (leaves)
	49 DAP
Nitrogen dose (kg ha^{-1})	
0	6,78
100	7,70
200	9,11
300	9,94
HSD 5%	tn
Varieties	
Arumba	9,06
Srikandi	9,53
URI 1	6,57
HSD 5%	tn

At the observation age of 49 DAP, it showed an increase in the number of plant leaves as the dose of nitrogen fertilizer increased. At a dose of 300 kg ha^{-1} has the highest value of 9.94 strands tan^{-1}. The Srikandi variety has the highest value of 9.53 strands tan^{-1}.

Leaf area

Table 5. Average Leaf Area Due to the Effect of Interaction Between Variety Treatment and N Fertilizer Dosage.

Day after planting (DAP)	Nitrogen dose (kg ha⁻¹)	Varieties		
		Arumba	Srikandi	URI 1
28	0	251 b A	214,3 b A	113,8 a A
	100	259,5 b A	225,4 b A	119,3 a A
	200	273,6 b A	244,2 b AB	145 a A
	300	287,6 a A	289,7 a B	251,5 a B
	HSD Varieties (5%)		57,70	
	HSD Nitrogen (5%)		52,20	
42	0	376,4 b A	415,4 b A	177,6 a A
	100	449,7 b AB	421,1 b A	286,7 a AB
	200	481 a AB	474,6 a A	391,2 a B
	300	576 b B	740,5 c B	404,4 a B
	HSD Varieties (5%)		145,65	
	HSD Nitrogen (5%)		131,77	

The results of the analysis of variance showed that there was a real interaction at the observation ages of 28 and 42 DAP. At the observation ages of 28 and 42 DAP, it showed an increase in plant leaf area as the dose of nitrogen fertilizer increased for each variety. At the observation age of 21 DAP, it increased with the addition of nitrogen fertilizer doses but was not significantly different. The Srikandi and Arumba varieties are significantly different from the URI 1 variety at 105.3 cm² tang¹⁻ and 111.5 cm² tang¹⁻.

Treatment	Leaf area (cm² plant⁻¹) Day after planting (DAP)			
	14	21	35	49
Nitrogen dose (kg ha⁻¹)				
0 kg N ha⁻¹ ,	38,63 a	87,53	294,6 a	344,2 a
100 kg N ha⁻¹	53,59 ab	95,87	355,2 ab	438,3 ab
200 kg N ha⁻¹	53,13 ab	98,00	375,7 b	468,7 ab
300 kg N ha⁻¹	65,33 b	112,2	416,9 b	537,6 b
HSD 5%	17,92	ns	63,52	142,38
Varieties				
Arumba	56,68	111,5 b	427,7 b	477,8
Srikandi	58,48	105,3 b	406,9 b	473,1
URI 1	42,84	78,31 a	247,1 a	390,7
HSD 5%	ns	18,72	49,77	ns

Crop Growth Rate (CGR)

Observations show that the results are not significantly different for each observation parameter. Of the three varieties observed, the Arumba variety was the variety that had a growth pattern with a high value, followed by the Srikandi and URI 1 varieties. The Arumba and Srikandi varieties had the same growth pattern value at the age of 35-42 DAP. The URI 1 variety shows a growth pattern that tends to be constant and has a low value. It is known that varieties influence plant growth patterns and growth patterns increase during the initial phase of the plant and begin to decrease during the generative phase of glutinous corn plants aged 35-42 DAP.

Net Assimilation Rate (NAR)

The net assimilation rate shows that the treatment dose of N fertilizer is not significantly different to the net assimilation rate. At N fertilizer doses of 300 kg ha¹⁻ and 200 kg ha¹⁻ the net assimilation rate increased rapidly and was highest compared to N fertilizer doses of 0 kg ha100, ¹⁻ kg ha¹⁻, at the age of 21-28 DAP to 28-35 DAP and decreases at the age of 35-42 DAP. The net assimilation rate of glutinous corn in the treatment varieties was also not significantly different.

Leaf Area Ratio (LAR)

The leaf area ratio shows that the treatment dose of N fertilizer is not significantly different from the leaf area ratio at various ages of observation. At N fertilizer doses aged 21-28 DAP, 28-35 DAP, and 35-42 DAP there was a decrease in the leaf area ratio. The variety treatments showed no significant difference in observing the leaf area ratio and there was a decrease in values from the beginning of the observation to the end of the observation. The Arumba variety had the highest leaf area ratio per age of observation, followed by the Srikandi and URI 1 varieties. So it is known that the leaf area ratio has no significant effect on the variety treatment and N fertilizer dose.

Dry weight

The results of analysis of variance showed that dry weight had no significant effect on variety treatment and N fertilizer dose. It was known from each age of observation that increasing the N fertilizer dose resulted in an increase in plant dry weight. It is also known that the variety treatment shows that the Srikandi variety has a high dry weight value at each observation age, followed by the Arumba and URI 1 varieties.

Cob length

The results of the analysis of variance show that cob length has a significant effect on the treatment of the N fertilizer dose. It is known that each additional dose of N fertilizer increases the length of the plant cob. At a dose of 300 kg ha¹⁻ has the highest value, namely 18.81 cm. The variety treatments showed that there was no significant difference between each variety. The Srikandi variety has the highest cob length, followed by the Arumba and URI 1 varieties.

Table 6. Average Length of Glutinous corn Cobs in the Variety and N Fertilizer Dosage Treatments.

Treatment	Components of Glutinous Corn Results
	Cob length (cm)
Nitrogen dose (kg ha⁻¹)	
0 kg N ha⁻¹ ,	15,99 a
100 kg N ha⁻¹	17,62 ab
200 kg N ha⁻¹	18,13 b
300 kg N ha⁻¹	18,81 b
HSD 5%	1,96
Varieties	
Arumba	17,00
Srikandi	18,27
URI 1	17,65
HSD 5%	ns

Cob diameter

Table 7. Average Diameter of Glutinous corn Cobs Due to the Effect of Interaction Between Variety Treatment and N Fertilizer Dosage.

Observation parameters	Nitrogen dose (kg ha⁻¹)	Varieties		
		Arumba	Srikandi	URI 1
Cob diameter (cm)	0	4,09 b	3,83 b	2,61 a
		A	A	A
	100	4,22 a	4,7 b	4,14 a
		AB	B	B
	200	4,22 a	4,75 b	4,15 a
		AB	B	B
	300	4,52 a	4,78 a	4,46 a
		B	B	B
	HSD Varieties (5%)		0,41	
	HSD Nitrogen (5%)		0,37	

The results of analysis of variance show that cob diameter shows a significant interaction with variety treatment and N fertilizer dose. It is known that at a dose of 100 kg ha200 ¹⁻ kg ha¹⁻ the Srikandi variety has a significant effect on the arumba and URI 1 varieties. At a dose of 300 kg ha ¹⁻ The Srikandi variety has the highest value, followed by the Arumba and URI 1 varieties.

Fresh weight of cob with husks

Table 8. Average fresh weight of cobs with glutinous corn husks due to the interaction effect between variety treatment and N fertilizer dose.

Observation parameters	Nitrogen dose (kg ha⁻¹)	Varieties		
		Arumba	Srikandi	URI 1
Fresh weight of cob with husk (g plant-¹)	0	157,4 b	119,6 b	80,2 a
		A	A	A
	100	171,9 a	222 b	182,3 a
		AB	B	B
	200	183,3 a	228,1 b	185,2 a
		AB	B	B
	300	204,4 a	234,8 a	216,7 a
		B	B	B
	HSD Varieties (5%)		43,18	
	HSD Nitrogen (5%)		39,06	

The results of the analysis of variance showed a significant interaction with variety treatment and N fertilizer dose. It was found that as the N fertilizer dose increased, the weight of all varieties increased. Each dose of N fertilizer was significantly different between varieties, but at a dose of 300 kg ha¹⁻ it was not significantly different between varieties. The control and URI 1 sugar apple varieties were significantly different with each dose of N fertilizer. The highest value for fresh weight of cobs with husks was for the 300 kg ha¹⁻ dose of the sugar apple variety, namely 234.8 g tan-¹ followed by the URI 1 variety 216.7 g tan-¹ and arumba variety 204.4 g ton-¹.

Fresh weight of cob without husk

Table 9. Average fresh weight of cobs without glutinous corn husks due to the interaction effect between variety treatment and N fertilizer dose.

Observation parameters	Nitrogen dose (kg ha⁻¹)	Varieties		
		Arumba	Srikandi	URI 1
Fresh weight of cob without husk (g plant-¹)	0	124,8 c	79,6 b	40,2 a
		A	A	A
	100	131,9 a	188,1 b	149,6 a
		A	B	B
	200	143,3 a	190,9 b	151,2 a
		A	B	B
	300	164,4 a	194,8 a	176,7 a
		A	B	B
	HSD Varieties (5%)		41,22	
	HSD Nitrogen (5%)		37,29	

The results of the analysis of variance in fresh weight of cobs without husks showed a significant interaction with variety treatment and N fertilizer dose in Appendix 18. It was found that as the N fertilizer dose increased, the weight of all varieties increased. Each dose of N fertilizer was significantly different between varieties, but at a dose of 300 kg ha¹⁻ it was not significantly different between varieties. The control and URI 1 varieties of sugar apples were significantly different with each dose of N fertilizer. The highest value of fresh weight of cobs without husks for the sugar apple variety at a dose of 300 kg ha¹⁻ was 194.8 g tons, followed by the URI 1 variety 176.7 g tons. ¹ and arumba variety 164.4 g ton-¹.

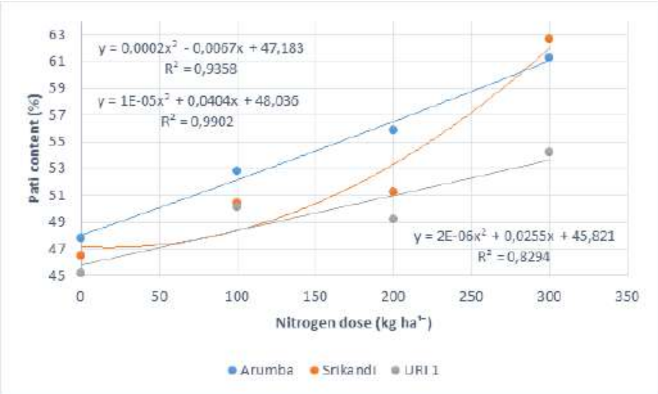
Yield per hectare

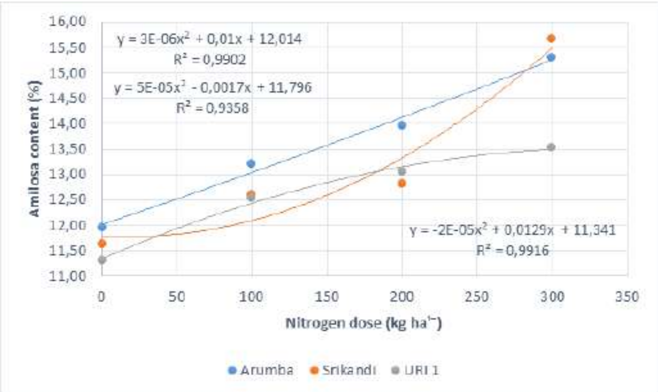
Table 10. Average Harvest Yield per Hectare Variety Treatment and N Fertilizer Dosage.

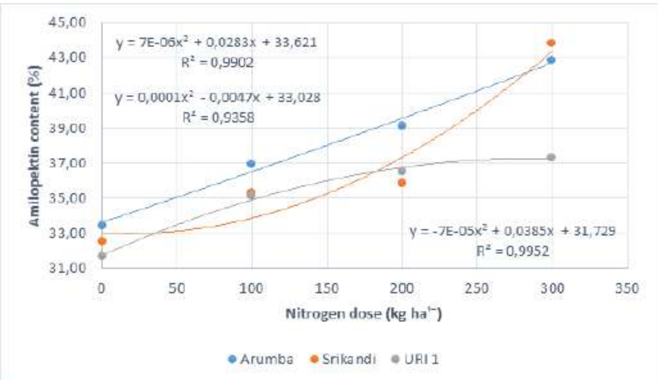
Observation parameters	Nitrogen dose (kg ha⁻¹)	Varieties		
		Arumba	Srikandi	URI 1
Yield (t. hec-¹)	0	6,54 c	4,97 b	3,33 a
		A	A	A
	100	7,14 a	9,22 b	7,57 a
		A	B	B
	200	7,62 a	9,48 b	7,69 a
		AB	B	B
	300	8,49 a	9,75 b	9 ab
		B	B	C
	HSD Varieties (5%)		1,09	
	HSD Nitrogen (5%)		0,99	

The average yield per hectare of glutinous corn is presented in table 16. The results of the analysis of yield variance show a real interaction with variety treatment and N fertilizer dose. It is known that as the N fertilizer dose increases, the yield increases in all varieties. The Srikandi and URI 1 control varieties were significantly different with each dose of N fertilizer. The highest value of yield per hectare for the Srikandi variety was at a dose of 300 kg ha^{-1}, namely 9.75t. hec^{-1} followed by the URI 1 9 t. hec^{-1} and arumba variety 8.49 t. hec^{-1}.

Starch, Amylose and Amylopectin content tests.







The quadratic effect shows that increasing the dose of N fertilizer increases the amount of starch content up to the optimum dose and then decreases at the highest dose. For the arumba variety, the regression value (R^2) of the two variables was obtained at 0.9358, for the Srikandi variety the regression value (R^2) for the two variables was 0.9902, and for the URI 1 variety, the regression value (R^2) for the two variables was 0.8294. , the greater the regression value or the closer the value is to 1, it shows that the two variables are related, which means that the dose of N fertilizer has an effect on the analysis of the starch content produced. Analysis of the highest starch content in the Srikandi variety with a N fertilizer dose of 300 kg ha^{1-} was 62.67%, followed by the Arumba variety 61.26% and the URI 1 variety 54.23%. The lowest starch content was found in the URI 1 variety with a control N fertilizer dose of 45.23% compared to other treatments.

For the arumba variety, the regression value (R^2) for the two variables was obtained at 0.9902, for the Srikandi variety the regression value (R^2) for the two variables was 0.9358, and for the URI 1 variety, the regression value (R^2) for the two variables was 0.9916. , the greater the regression value or the closer the value is to 1, it shows that the two variables are related, which means that the dose of N fertilizer has an effect on the analysis of the amylose levels produced. Analysis of the highest amylose content in the Srikandi variety at a N fertilizer dose of 300 kg ha^{1-}, namely 15.67%, followed by the Arumba variety 15.32%. The lowest starch content in the control dose URI 1 variety was 11.31% compared to other treatments. In each variety, the amylose content with additional doses of N fertilizer always increases with each dose. So it can be seen that differences in varieties also affect the amylose content in sticky corn plants.

For the arumba variety, the regression value (R^2) for the two variables was obtained at 0.9902, for the Srikandi variety the regression value (R^2) for the two variables was 0.9358, and for the URI 1 variety, the regression value (R^2) for the two variables was 0.9952. , the greater the regression value or the closer the value is to 1, it shows that the two variables are related, which means that the dose of N fertilizer has an effect on the analysis of the amylopectin levels produced. Analysis of the highest amylopectin levels in the Srikandi variety for nitrogen application of 300 kg ha^{1-}, namely 43.87%, followed by the Arumba variety for nitrogen application of 300 kg ha^{1-}, namely 42.88%. The lowest amylopectin level was in the control dose of the URI 1 variety, namely 31.66% compared to other treatments.

IV. DISCUSSION

The growth of glutinous corn plants increases with increasing doses of nitrogen fertilizer, which is related to the function of nitrogen fertilizer, namely to stimulate plant vegetative growth and is an important ingredient in the preparation of amino acids, amides, nucleotides, nucleoproteins, as well as for cell division and enlargement in plant tissue. Hammad et al. (2018), stated that different doses of nitrogen fertilizer had an effect on the growth and yield of corn plants. The maximum plant height at the observation age of 49 DAP (107.78 cm) was observed when a dose of 300 kg N ha^{1-} was given, while the minimum plant height (21.11 cm) was recorded in the control treatment.

Providing nitrogen fertilizer increased plant height 5 times higher when compared to the control treatment (107.78 vs. 21.11). According to research by Mohamed Yousif M. Alsharifi et al. (2022), nitrogen fertilization at a dose of 300 kg N ha^{1-} on corn plants with a spacing of 20 cm gave the highest growth and yield results compared to doses of 250 kg N ha^{1-} and 200 kg N ha^{1-}.

The ability of plants to absorb nutrients for plant growth and development needs is influenced, among other things, by genetic factors. Different types of varieties have different genetic characteristics. In this case, different varieties have different nutrient requirements. The growth rate of a plant is determined by the interaction of genetic factors of the plant variety itself with the growing environment such as sunlight, soil type, temperature, water availability and altitude (Adimihardja et al. 2013; Pithaloka et al. 2015). According to Hokmalipur and Darbandi (2011), chlorophyll content depends on the availability of N in the soil which can be utilized by plants. The wider the leaves and the higher the chlorophyll content in the leaves, the greater the rate of photosynthesis so that the photosynthesis process runs more effectively and the accumulation of photosynthesis which is directed towards the formation of dry matter and plant height increases. Leaf area is directly proportional to the amount of sunlight captured by the leaf. Therefore, more photosynthesis products such as carbohydrates and food reserves and energy sources are formed. The appearance of different growth in leaf area between glutinous corn varieties is caused by differences in the speed of division, multiplication, and cell enlargement.

From the differences in plant growth rates, it is known that CGR is significantly influenced by differences in N fertilizer levels in each growth period. Mian, Ahmed, and Matin (2002), also reported that the CGR value increased with increasing doses of nitrogen fertilizer along with the plant growth and development phase. This finding is in accordance with Khaleque (2005). Hossain and Shahjahan (2008), argue that the CGR value is slow at the beginning of growth due to the incomplete number of leaves and the low percentage of sunlight interception. Net Assimilation Rate (NAR) is the ability of plants to produce assimilated dry matter per unit leaf area per unit time. NAR is influenced by the amount of solar radiation, the ability of leaves to photosynthesize, leaf area index, light distribution, and the amount of plant respiration.

According to research by Ali et al. (2002), explains that the cob length value can be increased significantly by applying nitrogen. Junaid et al. (2009), cob length was significantly influenced by differences in nitrogen levels, namely 10-30% higher than the control. Negash et al. (2021), observed that the combination of varieties and N fertilizer doses had a large influence on the length of corn cobs. Research by Debele & Taressa (2023), shows that the weight of cobs per corn plant is greatly influenced by the interaction between varieties and the dose of nitrogen applied. Mosisa et al. (2022), found that differences in corn cultivars significantly influenced cob weight per plant. It is known that nitrogen plays an important role in plant growth and development. The observations in this study are fully consistent with the findings of Raven et al. (1999) in Mamudu et al. (2017), that nitrogen is one of the constituent components of a number of compounds (proteins and nucleic acids) which have an important role in plant physiological processes.

According to research by Huang et al. (2022), the amylose content in four sorghum varieties increased along with increasing nitrogen fertilizer content. In accordance with research by Kaplan et al. (2019), when the influence of processing factors (fertilizer and irrigation) on the starch fraction was investigated, it was determined that the lowest amount of amylose was determined from the I100:100% and N1:100 kg ha^{1-} treatments while the highest amylose content was obtained from the application of I50:50% and N3:300 kg ha^{1-}. The amylose content increased with increasing fertilizer concentration, while the amylose content decreased with increasing irrigation rate. From the analysis of the starch, amylose and amylopectin content studied, it is in line with research by Huang et al. (2022), who observed the effect of nitrogen fertilizer dosage on the structure and physicochemical properties of starch in four sorghum varieties, found that nitrogen fertilizer dosage influenced the physicochemical properties of sorghum. The particle size increases with increasing nitrogen fertilizer dosage. A similar trend also occurred in amylose content. However, the proportion of amorphous structures in starch decreased with increasing nitrogen fertilizer dosage. Peak viscosity, final viscosity, gelatinization temperature, initial temperature, final temperature, and enthalpy increased significantly with increasing nitrogen fertilizer dosage.

Application of nitrogen fertilizer significantly improved the above parameters, all of which peaked at N3 (300 kg/ha urea). However, excess doses of nitrogen fertilizer (N4: 450 kg/ha urea) can significantly reduce the above indicators, thereby changing the physicochemical properties and structure of sorghum starch. Overall, nitrogen had a significant effect on the structure and physicochemical properties of sorghum starch.

V. CONCLUSION

1. The variety treatment and N fertilizer dosage showed a significant interaction effect on all growth parameters, except for the number of leaves at 42 DAP and leaf area at 14, 21, 35 and 49 DAT.

2. The variety treatment and N fertilizer dose showed a significant interaction effect on all yield parameters, except for ear length.
3. Variety treatment and N fertilizer dosage had an influence on the analysis of increasing starch, amylose and amylopectin content.
4. The Srikandi variety has a higher response to nitrogen fertilization than the Arumba and URI 1 varieties.
5. In the treatment with a fertilizer dose of N 300 kg ha¹⁻ had the highest results in each observed parameter.

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Factors affecting on Knowledge of beneficiary Farmers about Project on Climate Resilient Agriculture

Rameshwar Chirde[1], Umesh Chinchmalatpure[2], S. P. Salame[3], A. M. Todkar[4]

[1]Ex. M.Sc. (Agri), Department of Extension Education, Dr. PDKV, Akola.
[2]Professor & CEEO, Directorate of Extension Education, Dr. PDKV, Akola.
[3] Assistant Professor, Directorate of Extension Education, Dr. PDKV, Akola.
[4] Ph.D. Scholar, Department of Extension Education, Dr. PDKV, Akola.
Corresponding email: rcumesh@rediffmail.com

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***Abstract*— *The study was carried out in two tahsils of Yavatmal district i.e., Darwha and Ner of Maharashtra state with the objective to study the knowledge about project on climate resilient agriculture (PoCRA) among the beneficiary and non-beneficiary farmers. For this study 60 PoCRA beneficiaries and 60 non-beneficiary farmers were selected on the basis of adoption of sprinkler irrigation system on subsidy. The data collected was analyzed and result of study revealed that (100%) of beneficiary farmers were belongs to high level of knowledge of sprinkler irrigation system under PoCRA Project. In case of non-beneficiary farmers, (63.33%) majority of farmers found to have medium level of knowledge about the sprinkler irrigation system, followed by (36.67%) of them having high level of knowledge whereas none of them was found in low level of knowledge.*

***Keywords*— Climate Resilient, PoCRA project, Knowledge, Beneficiaries**

I. INTRODUCTION

Agriculture is the back-bone sector of Indian economy and is largely depends on climate. Climate change poses a risk to the livelihoods of rural communities by negatively impacting agricultural output and raising production costs. Under such conditions, it is essential that the farmers be kept abreast of this dynamic agricultural through an equally dynamic system of extension education and also according to a report by Central Research Institute of Dryland Agriculture (CRIDA), Hyderabad the climate change also has an impact on Indian agriculture which results in a GDP loss of 1.5 per cent annually. Climate is constantly varying, on time scales that range from seasons to the lifetime of the Earth. We recently see effect of climate change then questions are arising in front of us that, what can we do for this? Then we move towards the technology. What kinds of Agriculture technology help us to conserve our atmosphere, our earth, and at last our life also? Climate resilient technologies are promising tool to guard a climate system from climatic variations.

In order to find out permanent solution to these changes in climate, Indian Council of Agricultural Research (ICAR) initiated National Initiative for Climate Resilient Agriculture (NICRA) to promote climate resilient practices over these climate change affected places.

The Project on Climate Resilient Agriculture (PoCRA) was conceptualised by the Department of Agriculture, Government of Maharashtra and the World Bank to develop a drought-proofing and climate-resilient strategy for the agriculture sector as a long-term and sustainable measure, to address the likely impacts of climate variabilities and climate change. The main purpose of this study was to get a clear-cut picture of the present situation of the knowledge of sprinkler irrigation system in Vidarbha region of Maharashtra especially in Yavatmal district with following objective: to find out the extent of knowledge of the farmers about sprinkler irrigation system, and to ascertain the association between the selected characteristics of the famers and their extent of knowledge of sprinkler irrigation system.

II. MATERIALS AND METHODS

For the present study, two talukas of Yavatmal district i.e. Darwha and Ner were selected on the basis of highest number of villages under PoCRA Project. From these tahsil 60 beneficiaries and 60 non beneficiaries were selected purposively who adopted sprinkler irrigation system. Ex-post Facto research design was used for the study. The primary data were collected using both structured and semi-structured interview schedule and focus group discussion was also conducted to collect qualitative data from the farmers. The quantitative data were analyzed using statistical tools like percentage, frequency, coefficient of correlation were used to analyze the farmers' responses to interpret and draw meaningful result.

III. RESULTS AND DISCUSSION

1. Profile of beneficiary and non-beneficiary farmers

The data related to profile of beneficiary and non-beneficiary farmers, reported that, more than half (53.33%) of beneficiary farmers belonged to middle age group i.e., 36 to 50 years of age, followed by old age i.e., above 50 years of age to the extent of 26.67 per cent. Remaining 20.00 per cent of beneficiary farmers were in the young age category i.e., 18 to 35 years. Regarding non-beneficiary farmers more than half (55.00%) of the farmers were belonged in middle age group i.e., 36 to 50 years of age group, followed by old age group i.e., above 50 years to extent of 30.00 per cent. Remaining 15.00 per cent of non-beneficiary farmers were in young age category i.e., 18 to 35 years. In case of education, 35.00 per cent of beneficiary farmers were educated up to higher secondary school level, followed by 26.67 per cent beneficiary farmers educated up to secondary school, 16.67 per cent educated up to college and 11.67 per cent of beneficiary farmers educated up to primary school. The remaining beneficiary farmers educated up to middle school level 08.33% and very few 03.33% per cent were found illiterate. In case of land holding, it was observed from 83.33 per cent beneficiary farmers possess semi land holding i.e., 1.01 - 2.00 ha, followed by 16.67 per cent possess marginal land holding i.e., below 01.00 ha, and None of the beneficiary farmer was found to be in semi-medium land, medium and large category of land holding i.e., 02.00 to 04.00 ha, 04.01-10.00 ha and above 10.00ha. respectively. Regarding the non-beneficiary farmers, 81.33 per cent of them possess small land holding i.e., 1.01 - 2.00 ha, followed by 18.33 per cent beneficiary farmers possess marginal land holding i.e., below 1.00 ha, None of the Non-beneficiary farmer was found to be in semi-medium land, medium and large category of land holding i.e., 02.00 to 04.00 ha, 04.01-10.00 ha and above 10.00 ha., respectively. It is revealed that, 50.00 per cent beneficiary farmers possess medium land holding i.e., 2.51 - 4.50, followed by 33.33 per cent possess large land holding i.e., above 04.50, and 16.67 per cent beneficiary farmer was found to be in small land holding. Regarding the non-beneficiary farmers, 61.67 per cent non-beneficiary farmers possess medium land holding i.e., 2.51 - 4.50, followed by 20.00 per cent possess large land holding i.e., above 04.50, and 18.33 per cent beneficiary farmer was found to be in small land holding. Further, it is evident that, 56.67 per cent of beneficiary farmers were having small family size having up to 4 members, followed by 36.67 per cent of respondents possessed medium family size i.e., 5 to 8 members, remaining 6.66 per cent of respondents were having large family size i.e., above 8 members. Regarding non-beneficiary farmers, 66.67 per cent were having small family size having up to 4 members, followed by 30.00 per cent of respondents possessed medium family size i.e., 5 to 8 members, remaining 03.33 per cent of respondents were having large family size i.e., above 8 members. It was, therefore, concluded that more than fifty per cent of respondents had small family size i.e., up to 4 members. It is revealed that, 66.67 per cent of the Beneficiary respondents had annual income between Rs. 50,001 to 1,00,000/-, Followed by the 18.33 per cent farmers possesses annual income up to 50,000/- And 15.00 per cent of the beneficiary farmer was found to be above Rs. 1,00,000/-. Regarding the non-beneficiary respondent, 60.00 per cent of the non-beneficiary respondents had annual income between Rs. 50,001 to 1,00,000/-, followed by the 35.00 per cent farmers possesses annual income up to 50,000/- And only 5.00 per cent of the non-beneficiary farmer was found to be above Rs. 1,00,000/-. Therefore, it could be concluded that, majority of beneficiary and non-beneficiary respondents had medium category of annual income between Rs 50,001 to Rs. 1,00,000/-. It is observed that, 65.00 per cent of beneficiary farmers were found to be in medium level of farming experience i.e., 13 to 24 years, followed by low level of farming experience i.e., up to 12 years 11.67 per cent and same 23.33 per cent of beneficiary farmers having high farming experience above 25 years. In case of non-beneficiary farmers, 60.00 per cent of them having medium level of farming experience i.e., 13 to 24 years, followed by low level of farming experience i.e., up to 12 years 20.00 per cent and only 20.00 per cent of non-beneficiary farmers having high farming experience. Thus, it could be concluded that the majority of beneficiary and non-beneficiary had medium level of farming experience. It could be seen that, 66.67

per cent of beneficiary farmers had medium level of extension contact, followed by 23.33 per cent farmers had high level of extension contact and only 10.00 per cent of beneficiary farmers had low level of extension contact. In case of non-beneficiary farmers, 61.67 per cent of non-beneficiary farmers had medium level of extension contact, followed by 35.00 per cent farmers had low level of extension contact and only 03.33 per cent of non-beneficiary farmers had low level of extension contact. It could be concluded that, most of the beneficiary and non-beneficiary farmers had medium level of extension contact. It could be seen that, more than half i.e., 80.00 per cent of beneficiary farmers having medium level of economic motivation, it was followed by high 18.33 per cent level of economic motivation and 01.67 per cent beneficiary farmers having low level of economic motivation. In case of non-beneficiary farmers, 65.00 per cent of farmers having low level of economic motivation, followed by medium 31.67 per cent level of economic motivation and only 03.33 per cent of non-beneficiary farmers found in high level of economic motivation. It could be concluded that, majority of beneficiary and non-beneficiary farmers had medium level of economic motivation. It could be seen that, more than half i.e., 65.00 per cent of beneficiary farmers having high level of attitude, it was followed by medium (35.00%) level of attitude and none of the beneficiary farmers having low level of attitude towards PoCRA technology. In case of non-beneficiary farmers, 68.33 per cent of farmers having medium level of attitude, followed by low 30.00 per cent level of attitude and only 01.67 per cent of non-beneficiary farmers found in high level of attitude. It could be concluded that, majority of beneficiary had high level of attitude and non-beneficiary farmers had medium level of attitude toward PoCRA technology. It could be seen that, 73.33 per cent of beneficiary farmers having medium level of risk orientation, followed by high level of risk orientation to the extent of 26.67 per cent. None of beneficiary farmers belonged to low level of risk orientation. In case of non-beneficiary farmers, 51.67 per cent of farmers found in medium level of risk orientation, followed by low level of risk orientation of non-beneficiaries to the extent of 48.33 per cent and none of non-beneficiary farmers belonged to high level of risk orientation. Further more than half i.e., 65.00 per cent of beneficiary farmers having high level of innovativeness, it was followed by medium (35.00%) level of innovativeness and none of the beneficiary farmers having low level of innovativeness towards PoCRA technology. In case of non-beneficiary farmers, 53.33 per cent of farmers having medium level of innovativeness, followed by low 46.67 per cent level of innovativeness and none of non-beneficiary farmers found in high level of innovativeness towards PoCRA technology.

2. Change in knowledge

Distribution of the beneficiary and non-beneficiary farmers according to frequency wise knowledge about sprinkler irrigation system has been furnished in Table 1 and Distribution of the beneficiary and non-beneficiary farmers according to their knowledge level about PoCRA project sprinkler technology has been furnished in Table 2.

It is evident from Table 1 that, in case of beneficiary farmers majority of farmers had knowledge subsidy structure under PoCRA (96.67), followed by sprinkler irrigation system saved water (96.67), type of soil suitable for sprinkler irrigation system (91.67), type of water cannot be use for sprinkler irrigation (91.67), labour requirements for the sprinkler system is less as compare to traditional method (90.00), sprinkler irrigation system depends on the topography of land (88.33), pumping system for sprinkler irrigation (85.00), irrigation scheme under PoCRA Project (83.33), area covered by single nozzle (76.67), spacing between two sprinklers (71.67), different components of sprinkler irrigation system (70.00), Very less number of beneficiary farmers had knowledge of cleaning with Acid treatment (60.00).

In case of non-beneficiary farmers, majority of farmers had knowledge of crops for which sprinkler irrigation system is suitable (98.33), followed by sprinkler irrigation system saved water (70.00), type of soil suitable for sprinkler irrigation system (66.67), sprinkler irrigation system depends on the topography of land (65.00), spacing between two sprinklers (63.33), type of water cannot be use for sprinkler irrigation (60.00), pumping system for sprinkler irrigation (56.67), area covered by single nozzle (56.67), whereas less than fifty per cent of non-beneficiary had knowledge about subsidy structure under PoCRA (46.67), different components of sprinkler irrigation system (40.00), labour requirements for the sprinkler system is less as compare to traditional method (33.33), Very small number of non-beneficiary farmers had knowledge of cleaning with Acid treatment (23.33).

Table 1. Distribution of the beneficiary and non-beneficiary PoCRA farmers according to frequency wise knowledge about sprinkler irrigation system

Sr. No.	Statements	Beneficiary farmers n=60		Non-beneficiary farmers n=60	
		Yes	No	Yes	No
1	The subsidy structure under PoCRA project for sprinkler system	58 (96.67)	02 (03.33)	28 (46.67)	32 (53.33)
2	Any two crops for which sprinkler irrigation system is suitable	60 (100.00)	00 (00.00)	59 (98.33)	01 (01.67)
3	Name different components of sprinkler irrigation system	42 (70.00)	18 (30.00)	24 (40.00)	36 (60.00)
4	Amount of water can be saved by sprinkler irrigation system	58 (96.67)	02 (03.33)	42 (70.00)	18 (30.00)
5	The area covered by single nozzle	46 (76.67)	14 (23.33)	34 (56.67)	26 (43.33)
6	Sprinkler irrigation system suitable for which type of soil	55 (91.67)	05 (08.33)	40 (66.67)	20 (33.33)
7	Water cannot be use under sprinkler irrigation	55 (91.67)	05 (08.33)	36 (60.00)	24 (40.00)
8	The use of sprinkler irrigation system depends on the topography of field	53 (88.33)	07 (11.67)	39 (65.00)	21 (35.00)
9	Spacing between two sprinklers	43 (71.67)	17 (28.33)	38 (63.33)	22 (36.67)
10	Name the pumping system use for sprinkler irrigation	51 (85.00)	09 (15.00)	34 (56.67)	26 (43.33)
11	Sprinkler irrigation system clean with Acid Treatment	36 (60.00)	24 (40.00)	14 (23.33)	46 (76.67)
12	The labour requirements for the sprinkler system are less as compare to traditional method	54 (90.00)	06 (10.00)	20 (33.33)	40 (66.67)

Table 2. Distribution of beneficiary and non-beneficiary PoCRA farmers according to their knowledge level about PoCRA project sprinkler technology

Sr. No.	Category	Beneficiary farmers (n=60)		Non-beneficiary farmers (n=60)	
		Frequency	Per cent	Frequency	Per cent
1	Low (Up to 33.33)	00	00.00	00	00.00
2	Medium (33.33 to 66.66)	00	00.00	38	63.33
3	High (Above 66.67)	60	100.00	22	36.67
	Total	**60**	**100.00**	**60**	**100.00**

Data with regards to the level of knowledge possessed by the beneficiary and non-beneficiary PoCRA farmers have been furnished in Table 2. It indicated that, 100.00 per cent of beneficiary farmers found to have high knowledge level about sprinkler irrigation system. No one beneficiary farmer was found in both medium and low knowledge level. In case of non-beneficiary farmers, 63.33 per cent of them found to have medium level of knowledge about sprinkler irrigation system, followed by 36.67 per cent of them having high level of knowledge whereas, none of them was found in low level of knowledge. It could be inferred from Table 2 that majority of beneficiary farmers were found in high level of knowledge whereas non-beneficiary farmers in medium level of knowledge.

3. Relation analysis

The coefficient of correlation between the selected characteristics of beneficiary and non-beneficiary farmers with the knowledge dimension has been presented in this section.

Coefficient of correlation between selected characteristics of beneficiary and non- beneficiary PoCRA farmers with their knowledge

The coefficients of correlation between selected characteristics of beneficiary and non-beneficiary farmers have been presented in Table 3.

Table 3. Coefficient of correlation between selected characteristics of beneficiary and non- beneficiary PoCRA farmers with their knowledge

Sr. No.	Characteristics	'r' value	
		Beneficiary farmers n=60	Non beneficiary farmers n=60
1	Age	0.062NS	0.065NS
2	Education	0.306*	0.130NS
3	Family size	0.291*	0.233NS
4	Land holding	0.219NS	0.360**
5	Annual income	0.398**	0.382**
6	Farming experience	0.275*	0.179NS
7	Extension contact	0.337**	0.477**
8	Economic motivation	0.404**	0.391**
9	Attitude	0.303*	0.193NS
10	Risk Orientation	-0.114NS	0.063NS
11	Innovativeness	0.381**	0.365**

**Significant of 0.01 level of probability NS – Non-Significant

*Significant of 0.05 level of probability

It was noted from the Table 3 that, in case of beneficiary farmers annual income, extension contact, economic motivation and innovativeness were found to be positive and highly significant with knowledge at 0.01 level of probability, whereas education, family size, farming experience and attitude were found to be positively significant at 0.05 level of probability. Whereas, age, land holding, family size and risk orientation were found non significantly correlated with knowledge. In case of non-beneficiary farmers, it could be seen that land holding, annual income, extension contact, economic motivation and innovativeness were found to be positive and highly significant with knowledge at 0.01 level of probability. No one was found to be positively significant at 0.05 level of probability. Whereas, age, education, family size, farming experience, attitude and risk orientation were found non significantly correlated with knowledge.

IV. CONCLUSION

Climate change is likely to affect all the natural ecosystems as well as socio-economic conditions of the farmers. Cent percent beneficiary farmers have the full knowledge of sprinkler irrigation system under PoCRA Project, however 63.33 percent of non-beneficiary farmers have medium level of knowledge about the sprinkler irrigation system. In terms of correlation, it can be concluded that, in case of beneficiary farmers annual income, extension contact, economic motivation and innovativeness were found to be positive and highly significant with knowledge at 0.01 level of probability. Whereas, education, family size, farming experience and attitude were found to be positively significant at 0.05 level of probability. Whereas, in case of non-beneficiary farmers, it could be seen that land holding, annual income, extension contact, economic motivation and innovativeness were found to be positive and highly significant with knowledge at 0.01 level of probability. It is therefore important that all the factors influencing farmer's perception be taken into consideration to improve their perception as these factors further influence the field level adaptation strategies to combat vagaries of climate change in agriculture.

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To assess the impact of imparting nutrition education on knowledge gain of young women with PCOS

Raveena Rani[1], Dr. Veenu Sangwan[2], Shikha[3], Priyanka[4], Meenu[5] and Dr. Varsha Rani[6]

[1]PhD scholar, Department of Foods and Nutrition, Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana, 125 004.
[2]Assistant Professor, Department of Foods and Nutrition, Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana, 125 004.
[3]MSc scholar, Department of Foods and Nutrition, Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana, 125 004.
[4]PhD scholar, Department of Foods and Nutrition, Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana, 125 004.
[5]PhD scholar, Department of Extension Education and Communication Management, Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana, 125 004.
[6]DES, Home Science, Dept. of Foods and Nutrition, CCS HAU, Hisar, Haryana, 125 004.
[1]Corresponding author: raveenajyani123@gmail.com

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***Abstract*— *The present study was conducted in Fatehabad district, Haryana to determine the impact of nutrition education on knowledge gain of young women with PCOS. Among PCOS respondents 52.0, 44.0 and 4.0 percent were in the age group of 19 to 25, 26 to 32 and 33 to 40 years, respectively. It was observed that 52.0 percent of the PCOS respondents were students, whereas 46.0 and 2.0 percent were housewife and in service, respectively. After imparting nutrition education to them there was increase in their knowledge scores. From the present study it is concluded that early diagnosis and treatment of PCOS is pivotal for normal health, well-being and improved nutritional status of young women suffering from PCOS.*

***Keywords*— Polycystic ovary syndrome (PCOS), young women, nutrition education, knowledge, diagnose.**

I. INTRODUCTION

Polycystic ovary syndrome (PCOS) is a widespread disorder with negative effects on both physical and mental health. It affects women throughout their reproductive lives and is linked to pregnancy issues such gestational diabetes, preeclampsia and large-for- gestational-age newborns. The health burden of PCOS is made worse by its association with excessive weight gain (Brennan *et al*. 2017). Menstrual cycle anomalies affect biochemical and anthropometric features in patients with PCOS (Christodoulopoulou *et al.* 2016). PCOS status continued to be independently correlated with an elevate body mass index (BMI). A 1000 kJ increase in energy intake was linked to a 0.44 kg/m2 increase in BMI, while a 1000 MET/min increase in physical activity was linked to a 0.42 kg/m2 drop in BMI. Age, glycaemic index, alcohol intake, smoking status and reduced BMI all remained independently related with each other (Moran *et al.* 2013). Comprehensive yoga programme is preferable in adolescent girls with PCOS for 12 weeks because it dramatically decreased AMH, LH, testosterone, the m F-G hirsutism score and monthly irregularity (Nidhi *et al.* 2011). Participants' knowledge of disease-related nutritional behaviors grew more in the intervention group has beneficial effect of educational intervention on increasing students' nutritional knowledge and positive behavioral changes (Amirjani *et al.* 2019). Consumption of low-glycemic load versus low-fat diets on biochemical hyperandrogenism and cardiovascular risk factors has a beneficial effect on BMI of overweight and obese PCOS women (Wong *et al.* 2016). There is increase in knowledge, attitude and practice score of respondents who participated in nutrition education and behavior modification programs and better manage and worked for mitigation of PCOS related symptoms (Katte *et al.* 2021).

II. MATERIALS AND METHODS

The study was carried out in city and villages of Fatehabad district, Haryana. The rural and urban areas of Fatehabad district were selected purposively depending on the availability of respondents and convenience of the researcher. For this study 50 young women with polycystic ovary syndrome (PCOS) above 18 years of age were selected purposively.

Imparting and assessing the impact of nutrition education on gain in knowledge of young women with PCOS

Knowledge is a collection of comprehended information that a person possesses. A questionnaire was developed and pre-tested on subjects before being modified and used for impact assessment. Nutritional education module was prepared for prevention of PCOS and imparting nutrition education to young women with PCOS and included 7 components and total 50 statements on nature of disorder, symptoms of disorder, diagnostic test of PCOS, complications of PCOS, recognize glycemic index of food and management of PCOS. The nutritional education was imparted to young women with PCOS on an interval of 15 days for 3 months. Pre and post knowledge scores were noted for assessing the impact of nutrition education on knowledge gain. The nutrition education was improved through lectures and distribution of leaflets, pamphlets and booklet on prevention and management of PCOS.

Statistical analysis

The qualitative and quantitative data were tabulated to draw meaningful inferences. The data was analyzed with the help of frequency, percentage and paired t-test using SPSS software.

III. RESULT

Personal and socio-economic profile of young women with and without PCOS

Personal and socio-economic profiles of young women with PCOS (50.0) were selected purposively. PCOS respondents 52.0, 44.0 and 4.0 percent were in the age group of 19 to 25, 26 to 32 and 33 to 40 years, respectively. Results highlighted that 46.0 percent of PCOS respondents were 10+2 followed by graduate (36.0%), PG (10.0%) and diploma holder (8.0%). It was observed that as many as 52.0 percent of the PCOS respondents were students, whereas 46.0 and 2.0 percent were housewife and in service, respectively. Maximum percentage (76.0%) of PCOS respondents belonged to nuclear families, whereas 22.0 and 2.0 percent were from joint and extended families, respectively. As far as family income was concerned, it was found that 68.0 per cent of PCOS respondents had family monthly income between Rs. 15,000 to 30,000 and 12.0, 12.0, 6.0 and 2.0 percent respondents had family monthly income between Rs. 31,000 to 45,000, 46,000 to 60,000, 61,000 to 75,000 and 76,000 to 90,000, respectively.

The impact of imparting nutrition education on knowledge gain of young women with PCOS

Information related to nutrition knowledge of women with PCOS has been presented in Table 1. Before imparting nutrition education, the 50.0, 72.0, 20.0, 88.0, 30.0, 60.0 and 88.0 percent respondents had adequate nutritional knowledge about the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complications of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS, respectively.

Table 1 Assessment of nutritional knowledge of the young women with PCOS before and after imparting nutrition education (n=50)

Characteristics	Pre knowledge scores			Post knowledge scores		
	Adequate (76% and above)	**Marginally adequate (50-75%)**	**Inadequate (Below 50%)**	**Adequate (76% and above)**	**Marginally adequate (50-75%)**	**Inadequate (Below 50%)**
Nature of disorder	25(50)	20(40)	5(10)	50(100)	-	-
Symptoms of disorder	36(72)	14(28)	-	46(92)	4(8)	-
Diagnostic test of PCOS	10(20)	36(72)	4(8)	50(100)	-	-
Complications of PCOS	44(88)	6(12)	-	45(90)	5(10)	-
Recognize glycemic index (GI) of foods	15(30)	14(28)	21(42)	47(94)	3(6)	-

Dietary guidelines for PCOS	30(60)	20(40)	-	45(90)	5(10)	-
Management of PCOS	44(88)	6(12)	-	46(92)	4(8)	-

Values in parentheses indicate percentage

It was found that 40.0, 28.0, 72.0, 12.0, 28.0, 40.0 and 12.0 per cent respondents had marginally adequate nutrition knowledge about the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complications of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS, respectively. As many as 10.0, 8.0 and 42.0 per cent of the respondents had inadequate knowledge about the nature of disorder, diagnostic test of PCOS and recognize glycemic index (GI) of foods, respectively. After imparting nutrition education to them with the help of media package, there was increase in their knowledge scores. It was noted that 100.0, 92.0, 100.0, 90.0, 94.0, 90.0 and 92.0 per cent of the respondents had adequate knowledge about the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complication of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS, respectively. It was observed that there was an increase in the number of PCOS women who had adequate and marginally adequate nutrition knowledge after imparting nutrition education.

Table 2 Gain in knowledge scores obtained by selected young women with PCOS (n=50)

Sr. No.	Component	No. of statements	Pre scores	Post scores	Gain in knowledge scores	t-value
1.	Nature of disorder	7	5.18±1.35	6.74±0.44	1.5	7.86*
2.	Symptoms of disorder	9	7.22±1.35	8.58±0.75	1.36	7.45*
3.	Diagnostic test of PCOS	2	1.12±0.52	2.00±0.00	0.88	11.95*
4.	Complications of PCOS	6	5.18±0.59	5.86±0.45	0.68	8.19*
5.	Recognize glycemicindex (GI) of foods	5	2.84±1.09	4.66±0.62	1.82	12.56*
6.	Dietary guidelines for PCOS	13	10.80±1.34	12.32±1.01	1.52	8.60*
7.	Management of PCOS	8	7.48±0.70	7.96±0.19	0.48	5.01*

Values are Mean ± SD *Significant at 5% level

The pre and post knowledge scores of with PCOS women before and after imparting nutrition education to them were calculated. Post-scores indicated a highly significant gain in the knowledge scores of respondents (Table 2). It was found that there was a significant gain in the knowledge of the respondents regarding the nature of disorder (1.5), symptoms of disorder (1.36), diagnostic test of PCOS (0.88), complications of PCOS (0.68), recognize glycemic index (GI) of foods (1.82), dietary guidelines for PCOS (1.52) and management of PCOS (0.48).

IV. DISCUSSION

Information related to nutrition knowledge of women with PCOS has been presented in Table 1. Before imparting nutrition education, the 50, 72, 20, 88, 30, 60 and 88 percent respondents had adequate nutritional knowledge about the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complications of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS, respectively. After imparting nutrition education to them with the help of media package, there was increase in their knowledge scores. It was noted that 100, 92, 100, 90, 94, 90 and 92 per cent of the respondents had adequate knowledge about, the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complication of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS, respectively. It was observed that there was an increase in the number of PCOS women who had adequate and marginally adequate nutrition knowledge after imparting nutrition education.

Garag and Malagi (2019) reported a similar study to evaluate the effects of education intervention on the knowledge and practices of PCOS-affected women. Prior to the intervention, the majority of the subjects fell into the category of knowledge and practice scores with less than 30 percent, but following the intervention, none of them achieved scores below 50 percent. The classification of the intervention group revealed that knowledge and practices significantly increased after the session. Therefore, nutrition education interventions are particularly efficient at enhancing PCOS women's awareness, habits, and management of the disease.

The pre and post knowledge scores of with PCOS women before and after imparting nutrition education to them were calculated. Post-scores indicated a highly significant ($p \leq 0.01$) gain in the knowledge scores of respondents (Table 2). It was found that there was a significant gain in knowledge of the respondents regarding the nature of disorder (1.5), symptoms of disorder (1.36), diagnostic test of PCOS (0.88), complication of PCOS (0.68), recognize glycemic index (GI) of foods (1.82), dietary guidelines for PCOS (1.52) and management of PCOS (0.48). Ding *et al.* (2016) also advocated that to overcome the prevalence of PCOS, there is need to create awareness among young women and strengthen the primary health care centers, diagnosis and treatment facilities. Kim *et al.* (2018) also reported that the education and treatment of PCOS improved the quality of life of young women. There was improvement in stress, infertility and menstrual problems associated with PCOS.

V. CONCLUSION

It was observed that there was an increase in the number of PCOS women who had adequate and marginally adequate nutrition knowledge after imparting nutrition education. It was found that there was a significant gain in the knowledge of the respondents regarding the nature of disorder, symptoms of disorder, diagnostic test of PCOS, complications of PCOS, recognize glycemic index (GI) of foods, dietary guidelines for PCOS and management of PCOS.

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Sustainable Management of Tomato Early Blight with Plant Extracts

Abarna R*, Jinisha Blessie J.P

Agricultural College and Research Institute, Vazhavachanur, Tamil Nadu, India
*abarnaravichandran03@gmail.com

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Abstract— *This study focused on developing eco-friendly management strategies for early blight disease in tomatoes, caused by Alternaria solani, through the use of botanical extracts from eight plants: Neem, Prosopis, Nerium, Senna, Lantana, Pungam, Coconut, and Calotropis. The research was carried out at the Agricultural College and Research Institute in Vazavachanur, Thiruvannamalai, to assess these botanicals in vitro and in vivo effectiveness against the pathogen. In laboratory conditions, the extracts were tested at a 10% concentration, and their ability to inhibit the pathogen's mycelial growth was evaluated. Neem leaf cold extract exhibited the highest inhibition at 77.8%, followed by Nerium at 75.9%, while Senna showed limited effectiveness. In a field trial using the PKM-1 tomato variety, the lowest disease index was observed with neem leaf extract spraying (28%) and Nerium extract (30.2%), indicating their potential as effective alternatives for managing early blight.*

Keywords— *Tomato, Alternaria solani, Botanicals, Early blight management, Inhibition*

I. INTRODUCTION

Tomato (*Solanum lycopersicum*), originally from the Andean region of South America, ranks among the most widely grown horticultural crops worldwide, flourishing in climates ranging from tropical to temperate zones (Knapp and Peralta, 2016). Its hardiness enables it to endure adverse outdoor temperatures. As the second most consumed vegetable globally after potatoes, tomato production is notable, with India producing 22,337 million metric tonnes from 801 thousand hectares (Cammarano *et al.*, 2022). In Tamil Nadu alone, tomatoes are cultivated on 38.78 thousand hectares, yielding 840.21 million tonnes, constituting 8.1% of India's total tomato production (NHB, 2018).

Tomatoes are consumed in various forms: fresh, in many culinary dishes, or processed into products such as sauce, ketchup, juice, salsa, paste, soup, and pickles. They are rich in vitamins A and C, and the antioxidant lycopene, which offers health benefits, including protection against cancer and heart diseases. The rising demand for both fresh and processed tomatoes underscores the need for increased production (Kaur *et al.*, 2004).

Despite their significance, tomato plants in India are susceptible to over 20 diseases. Early blight, caused by *Alternaria solani* poses a major global threat to tomato crops (Adhikari and Panthee, 2017). This disease is prevalent across India, leading to significant yield losses, with reductions of up to 63% reported in some cases (Christ Maczuga, 1989). Although *Alternaria solani* reproduces asexually, highly virulent isolates can overcome existing resistance genes (Meena *et al.*, 2017). This study explores the effectiveness of various botanicals, both in vitro and in vivo, as potential control measures against early blight caused by *A. solani*, and identifies the biologically active components of the most effective plant extract against the pathogen.

II. MATERIALS AND METHODS

Isolation of *Alternaria solani* from infected leaves

Infected leaf samples were collected from tomatoes grown at AC&RI, Vazhavachanur. The diseased sections were cut into small pieces and surface-sterilized with a 0.1%

mercuric chloride solution for one minute, followed by multiple rinses with sterile distilled water.

The sterilized pieces were placed on Potato Dextrose Agar (PDA) medium with 50 ppm streptomycin sulfate in sterile Petri dishes and incubated at 28±2°C for 48-72 hours. The mycelium that emerged from the pieces was aseptically transferred to Potato Dextrose Agar slants. The fungus was then purified using the single hyphal tip method (Ainsworth, 1981), and the stock culture was maintained on slants.

Pathogenicity test of the isolate

A seven-day-old culture of *Alternaria solani*, grown in three test tubes containing 5 ml of potato dextrose agar medium, was harvested and transferred into a blender with 250 ml of sterile water. The blender was run through cycles of high and low speeds for 3-4 minutes, vigorously slicing and beating the fungal mats. The mixture was then centrifuged intensely, reducing the fungal mats into small particles suitable for passage through the fine spray nozzle of an atomizer. The resulting mycelial suspension demonstrated high efficacy in mass inoculation experiments, effectively inducing disease outbreaks under field conditions.

Tomato plants aged between 60 and 70 days were selected for inoculation. These plants were exposed to a humid environment for 24 hours by covering them with polyethylene bags. Before inoculation, the plants were surface sterilized with 0.1% mercuric chloride and rinsed with sterile water. The mycelial suspension was sprayed onto the leaves early in the morning. As a control, other plants were sprayed with an equal volume of sterile distilled water. All plants were immediately covered with polyethylene bags containing water droplets and kept in this state for 48 hours. Regular observations were made to monitor the progression of disease development.

Disease development and re-isolation of the isolate

Seven days after inoculation, the leaves were examined for disease progression. The pathogen was re-cultured from the affected areas, and the new cultures were compared and validated against the original isolate.

In this study, eight botanical extracts were tested as treatments: T0 - Control; T1 - Neem; T2 - Prosopis; T3 - Nerium; T4 - Senna; T5 - Lantana; T6 - Pungam; T7 - Coconut; T8 - Calotropis (refer to Table 1). These botanicals were examined for their inhibitory effects on the pathogen under laboratory conditions. They were applied at a 10% concentration, with a control group without botanicals for comparison. The impact of these treatments on the linear growth of the pathogen was carefully monitored.

To evaluate their effects on the radial growth of the fungus, the botanicals were added to 20 ml of sterilized Potato Dextrose Agar medium in 100 ml conical flasks. After cooling, the medium was poured into sterile petri dishes. These plates were inoculated with 8 mm discs of the pathogen and incubated for 10 days at room temperature (28±2°C). Concurrently, a set of plates containing the medium without the botanical treatments was incubated as a control. The experiment was replicated three times, and the radial growth of the fungus, measured in centimeters, was recorded after the 10-day incubation period (refer to Table 2***)***.

Table 1: Treatment details

Treatment	Name of the plant botanicals	Botanical name
T0	Control	-
T1	Neem	*Azadirachta indica*
T2	Prosophis	*Prosopis juliflora*
T3	Nerium	*Nerium oleander*
T4	Senna	*Senna alexandrina*
T5	Lantana	*Lantana camara*
T6	Pungam	*Pongamia pinnata*
T7	Coconut	*Cocus nucifera*
T8	Calotropis	*Calotropis procera*

***In vivo* studies on the effect of botanicals on the growth of *Alternaria solani* at the field level**

The trial was conducted at the experimental farm of the Agricultural College and Research Institute in Vazhavachanur, Thiruvannamalai, using the PKM-1 tomato variety, recommended for the rabi/summer season.

The experiment followed a Randomized Block Design (RBD) with eight treatments and three replications, each plot measuring 2m x 2m. The land was prepared by plowing with a cultivator and using a rotavator to create a fine-textured bed. The plots were laid out according to the predetermined plan, and farmyard manure was applied during planting. The PKM-1 tomato seedlings, 27 days old, were planted 60 cm apart between rows and plants, following all prescribed farming practices.

Botanical materials were sourced from the college and nearby villages in Vazhavachanur and prepared at a 10% concentration. After washing and chopping into small pieces, the botanicals were ground using a pestle and mortar. The extracts were filtered through muslin cloth into glass beakers, repeating this process for all eight botanicals.

The botanical extracts were sterilized in an autoclave at 15 lb pressure and 121ºC for 20 minutes. These sterilized extracts were then sprayed on tomato plants at a 10% concentration, with three replications, on two occasions. For biometric observations, ten leaves per plant were examined to assess the intensity of blight based on the percentage of leaf area damaged, focusing on leaves affected by early blight. The disease index was calculated using McKinney's formula(1923).

$$\text{Infection Index or Disease Intensity of grading} = \frac{\text{Sum of all disease grade}}{\text{Total number of grade x Maximum disease grade}}$$

III. RESULTS

The use of botanicals to control various plant diseases is a well-established practice. In the pursuit of effective measures to control early blight in tomatoes, several botanicals underwent in vitro testing. Following this, a field trial was carried out as a follow-up to the laboratory studies.

Pathogenicity study

The pathogen was successfully isolated from plants exhibiting infection symptoms and subjected to pathogenicity testing on the PKM-1 tomato variety. Initially, the disease appeared as small, isolated, and scattered pale brown spots on the leaflets. As the infection progressed, these spots merged, causing the affected leaves to dry out. The infected leaves showed distinct concentric rings within the lesions. The infection began on the lower leaves and moved upward. Dark spots also appeared near the ground level at the base of the stem, gradually encircling it. Additionally, dark brown sunken spots developed on the fruits, leading to premature dropping of immature fruits and a reduction in overall fruit size.

***In vitro* studies**

The relative effectiveness of different botanicals was assessed in vitro using the poisoned food technique. The percentage inhibition of *Alternaria solani* growth at various botanical concentrations was determined and compared to the control, as outlined in the "Materials and Methods" section.

Effect of botanicals on the radial growth of *Alternaria solani*

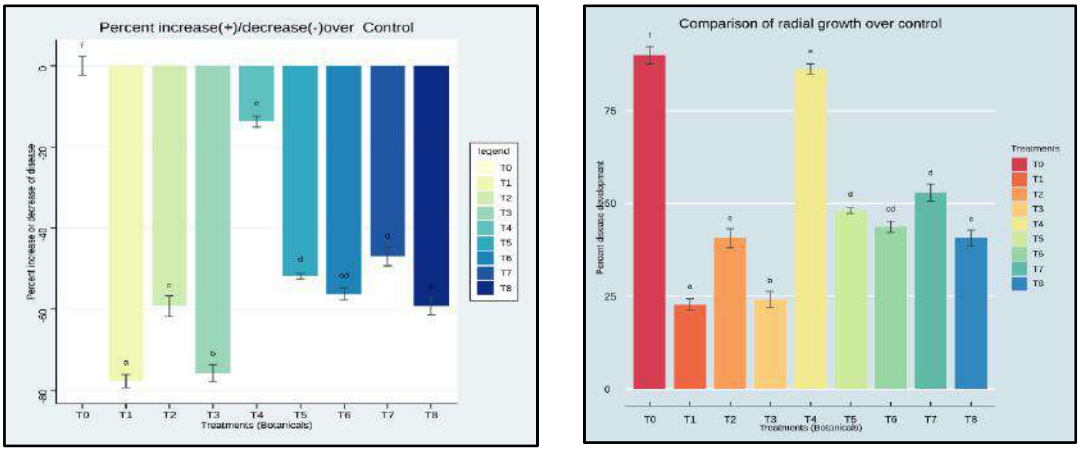
The effect of eight botanicals on pathogen growth was examined by incorporating them into Potato Dextrose agar medium at 10% concentrations. These cultures were incubated for 10 days, and the growth diameter of the pathogen was meticulously measured. A control group was also included, where no fungicide was added to the medium. The results averaged from three replications, are presented in Table 2.

Plate 1: Alternaria solani on Potato Dextrose Agar plate

Neem leaf cold extract demonstrated the highest level of inhibition among the botanicals tested, achieving a notable 77.8% reduction at a 10% concentration compared to the control. Following closely, Nerium showed significant inhibition at 75.9%, whereas the control group exhibited 0% inhibition. In contrast, Senna showed limited effectiveness in inhibiting the pathogen's growth, indicating relatively lower performance.

Table 2: Effect of different concentrations of botanicals on the radial growth of Alternaria solani

Treatment	Mean	Diameter of growth (mm) 10% concentration	
		Percent increase (+) or decrease (-) over control	Percent disease development
T0	90	0	0
T1	20.0	-77.8	22.8
T2	35.8	-59.3	40.7
T3	21.6	-75.9	24.1
T4	77.8	-13.7	86.3
T5	43.3	-51.9	48.1
T6	39.4	-56.3	43.7
T7	47.8	-47.0	53.0
T8	35.7	-59.3	40.7



(A) **(B)**

Fig.1: (A) Bar plot depicts the Percent increase (+) or decrease (-) over control, (B) Percent disease development

Efficacy of certain botanicals on the control of tomato early blight caused by *Alternaria solani*

Disease incidence

The field trial aimed to investigate the occurrence of early blight in the PKM-1 tomato variety, focusing on the impact of *Alternaria solani* and the application of botanicals. The findings, which include average values from three replicates, are outlined in Table 3.

Table 3: Effect of certain botanicals on early blight intensity in tomato cultivar PKM1 based on Grading of Alternaria solani affected leaves

Treatment	Name of the plant botanicals	Percent disease index (%)
T0	Control	40.8
T1	Neem	28.0

T2	Prosophis	36.2
T3	Nerium	30.2
T4	Senna	38.5
T5	Lantana	37.2
T6	Pungam	33.2
T7	Coconut	37.7
T8	Calotropis	31.7

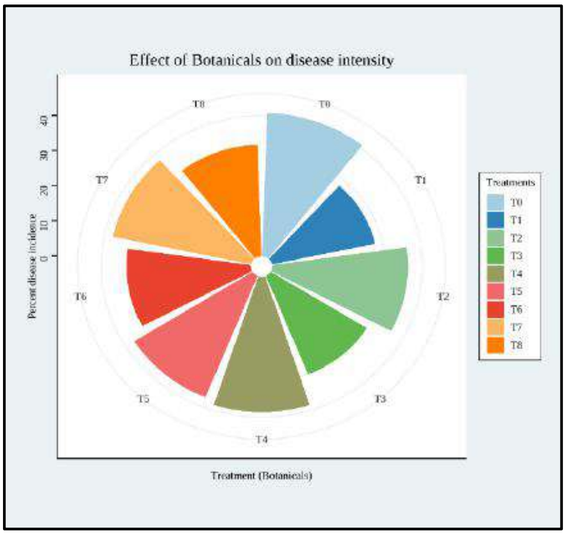


Fig.3: Circular bar plot depicts the effect of botanicals on disease intensity

IV. DISCUSSION

This chapter discusses the outcomes of the field experiment conducted at the Agricultural College and Research Institute, Vazhavachanur, focusing on the topic " Sustainable Management of Tomato Early Blight with Plant Extracts." Within this study, the causal agent of early blight, *Alternaria solani* were isolated and their pathogenicity was confirmed.

Throughout the investigation, *Alternaria solani* caused dark brown to black spots with concentric rings on leaves, petioles, stems, and fruits, resulting in yield losses ranging from 25 to 50 percent. Previous research by scholars Goussous *et al.,* (2010) extensively explored disease incidence and botanical control strategies. This study specifically focuses on evaluating various botanicals effectiveness against early blight in tomatoes, both in laboratory settings (in vitro) and real-world conditions (in vivo). The findings emphasize the efficacy of fungicides at different concentrations in inhibiting *Alternaria solani* under controlled and field conditions. Additionally, the study examines the impact of selected botanicals on disease incidence caused by *Alternaria solani* infection.

Effect of different concentrations of botanicals on the *in vitro* growth

In this study, the efficacy of botanicals in controlling the early blight of tomatoes caused by *Alternaria solani* was investigated under laboratory conditions. Eight botanicals such as Neem, Prosopis, Nerium, Senna, Parthenium, Pungam, Coconut, and Calotropis were tested at a concentration of 10 percent. The parameters selected to evaluate their fungicidal effectiveness included measuring the radial growth of *Alternaria solani.*

The results showed that all tested botanicals exhibited superior efficacy in inhibiting the radial growth of *Alternaria solani* compared to the control group. Among these botanicals, neem demonstrated the highest effectiveness in inhibiting radial growth.

V. CONCLUSION

In conclusion, the utilization of plant extracts presents a promising avenue for the sustainable management of early blight in tomatoes caused by *Alternaria solani*. This study demonstrated the efficacy of botanical extracts from eight plants: Neem, Prosopis, Nerium, Senna, Lantana, Pungam, Coconut, and Calotropis at a 10% concentration in inhibiting the radial growth of the pathogen. These botanicals not only showed significant fungicidal activity but also offered environmentally friendly alternatives to synthetic fungicides, aligning with principles of sustainable agriculture. Future research should focus on optimizing application methods and concentrations for different environmental conditions, as well as assessing their economic viability and scalability in commercial tomato production systems.

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Identification of heat tolerant, virus resistant candidate potato varieties for cereal based cropping system through participatory varietal selection approach

Pooja Pandey[1]*, Mohinder Kadian[2], PC Sindhu[3], Gaurav Kant[4], Neha Yadav[5]

[1,2]International Potato Center (CIP), NASC Complex, IARI Campus, New Delhi 110012, India,
[1*]p.pandey@cgiar.org, [2]m.kadian@cgiar.org
[3]Potato Technology Center Shamgarh, Karnal, Haryana 132116, India,
pcsindhu1969@gmail.com
[4]Center of Excellence for Fruits, Mangiana, Sirsa, Haryana 132116, India,
gauravkant.hort@hry.gov.in
[5]Integrated Horticulture Development Center, Sunderah, Narnaul, Haryana 132116, India
yneha.hort@gmail.com

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Abstract— *12 heat tolerant, low tropical virus resistant potato CIP clones were evaluated to select candidate varieties that can be planted 15-30 days earlier than normal season in north Indian plains of Haryana. Regarding this research trials were conducted in three districts Karnal, Narnaul and Sirsa in rabi (winter) season of 2021. Out of 12 clones, 11 are red skin whereas clone 4621 has white skin tubers. Kufri Pukhraj, Kufri Lima, Kufri Khyati and one red skin variety Kufri Uday were planted as control. The experiments were planted in randomized block design with three replications. Planting was done in the first week of October almost 20 days earlier than normal season planting. Trials were dehaulmed at 75 days after planting in all the locations. Morphological and yield parameters were recorded and statistically analysed. In all the locations, the highest marketable and total tuber yields were recorded in variety K. Lima. It was statistically at par to clone 4611, 4620, K. Pukhraj and clone 4613. Among the locations, Sirsa was found most suitable place for table potato cultivation followed by Narnaul and Karnal. Two clones 4614 and 4616 found suitable for processing. Participatory varietal selection for tuber yield and market acceptability was done at Sirsa however, organoleptic test was conducted at Sirsa and Narnaul. Based on yield and market acceptability, K. Lima was preferred by stakeholders followed by clone 4621 and 4611. Among clones, 4621 was preferred by stakeholders for its good taste.*

Keywords— ***Potato clones, locations, heat tolerant, Early maturity, Participatory varietal selection, organoleptic test***

I. INTRODUCTION

Potato is the third major food crops consumed in India. Farmers are shifting to intensive cropping system by growing short duration varieties of different crops. Besides this, they are always in search of early season varieties to fetch premium price by selling the produce early in the market. Early harvest also gives a window for another winter crop such as winter wheat or vegetables. Being a cash crop, potato generates good income in a short period. Most of the farmers cultivate potato for table purpose. Limited farmers go for seed production or contract farming. In the last few years the crop is facing climate challenges such as unseasonal rains and high temperature during planting. Development of climate resilient short duration potato varieties with high yield and disease resistance are the demands of farmers. Again, selection of the variety with stable performance over the locations is a challenge for a Breeder. Most of the genotypes behave differently over the environments. Therefore, it is essential to conduct location specific adaptation trial to identify suitable potato variety/varieties [1]. It is very important to identify and select location specific genotypes/clones, which have high yield potential with short growing period [26]. To assess the agronomic behavior of the genotypes, it is necessary to measure the relative stability of the genotypes submitted to all the predominant environments [25]. Knowing the magnitude of the Genotype x Environment interaction allows assessing the stability of the cultivars in the range of environments, in which they want to be introduced, as well as the productive potentials and limitations of these in the localities [4]. The interaction is a matter of relevance since it is one of the determining factors in the selection and recommendation of cultivars [2]. It highlights the importance of the environmental effect on adaptation and varietal behaviour, also increases the efficiency of genotype improvement [6]. Besides this, participation of stakeholders in the selection of candidate varieties facilitates acceptability of most suitable clones liked by stakeholders as per their choice [19]. Keeping all these aspects in view, 12 heat tolerant clones of potato were imported from International Potato Center (CIP), Lima (Peru) for evaluation under heat stress conditions.

II. MATERIALS AND METHODS

12 heat tolerant, low tropical virus resistant potato clones were evaluated at three Horticulture Centers of Haryana: Potato Technology Center, Karnal; Center of Excellence in Fruits, Sirsa and Integrated Horticulture Development Center, Narnaul during winter season of 2021. Among the locations, Karnal has mild climate with fertile soil. Sirsa and Narnaul are comparatively warmer but gets good sunny days with sandy-loam soil. 3 white skin (K. Lima, K. Khyati and K. Pukhraj) and one red skin (K. Uday) varieties were planted as standard checks. All the experiments were conducted in randomized block design with 3 replications. To assess the earliness of clones, planting was done in first week of October about 20 days earlier than the normal planting. Dehaulming was done at 75 days after planting (DAP). Plot size was 4.8 sqm; 40 tubers were planted in each plot with 60 cm spacing between rows and 20 cm between tubers. Recommended dose of NPK was given in the form of urea, DAP and MOP. Half dose of N and full dose of P and K were applied as basal and remaining N was applied 25 days after planting followed by earthing up. In Narnaul N was applied in three split doses: 3rd dose at 40 days after planting. Data for growth and yield were recorded and statistically analyzed. Sample tubers were supplied to PepsiCo lab for analysis of processing parameters.

Participatory varietal selection (PVS) exercise was conducted in Sirsa and Narnaul districts. Stakeholders including farmer, consumers and traders were invited for this exercise. Harvested tubers of each clone were heaped separately in the field,. A container is kept near each heap in which stakeholders put the grains. Each stakeholder was provided with six grains of kidney bean to select the best three varieties/clones. They were asked to put 3 grains in the jar for the 1st, 2 grains for 2nd and 1 grain for 3rd choice varieties/clone. After the exercise, grains were collected from the containers and counted separately for each variety/clone and ranking was given to clones/varieties based on number of grains. Clones/varieties having a greater number of grains was considered the preferred varieties.

Organoleptic test was also conducted to find out promising varieties based on taste. Under this test, 5 sample tubers of each clone were packed in hessian cloth bag separately and tagged to avoid mixing of clones. These tubers then boiled by putting all the bags in the water filled in a big container. Care was taken that the tubers were neither undercooked nor over cooked. Once the potatoes were cooked properly, tubers of each clone were kept in the plates, hiding the original number and an arbitrary number was marked on the plate. These tubers were peeled and cut into small pieces for tasting. Volunteer farmers/ stakeholders were involved in organoleptic evaluation of the clones. Each stakeholder was asked to taste the sample of every clone and the observations were classified as poor, good and excellent and were written down on a prescribed format, by the participants. Observations were presented through graphical data. The characteristics of the clones were compared separately for each location.

III. RESULTS

3.1 Morphological characters of clones

Morphological characters like plant vigour and plant habit were recorded at 60 days after planting and ranked into 1-5 scale. Based on the data depicted in Table 1, maximum vigour was recorded in clone 4609, 4620, 4621 and check varieties K. Lima and K. Pukhraj. Regarding plant habit clone 4613 showed compact growth followed by 4611, 4621 and K. Lima. Rest of the clones were showing medium to disperse plant growth.

3.2 Plant senescence

Plant senescence was recorded at 75 days, just before dehaulming to find out the early maturing clones. Data was recorded in 1-5 scale indicated very green to dry leaves.

Clones 4615 showed maximum senescence followed by K. Pukhraj and K. Uday.

3.3 Morphological characters of tuber

Tuber shape, skin colour, flesh colour and eye depth were recorded at the time of harvesting and presented in Table 1. The data reveals that most of the clones had red skin tubers except clone 4621 and variety K Lima, K Pukhraj and K Khyati. All the clones/varieties had shallow eyes except 4615 which had medium deep eyes. Regarding flesh colour, clones 4610, 4611, 4613, 4615 and 4617 contained white flesh whereas rest of the clones had yellow flesh colour.

Table 1 Morphological parameters of heat tolerant clones

CIP No.	CPRI No.	Plant Vigor	Plant habit	Senescence	Tuber Skin Colour	Tuber Shape	Tuber Eyes	Tuber Flesh Colour
302476.108	**4609**	5	2	1	R	OB	S	Y
304350.1	**4610**	4	2	3	LR	OB	S	W
304350.118	**4611**	4	4	1	R	O	S	W
304350.95	**4613**	4	5	3	R	OB	S	W
304366.46	**4614**	4	2	2	LR	R	S	Y
304380.19	**4615**	4	2	5	R	R	MD	W
309068	**4616**	3	3	3	R	R	S	Y
309105.41	**4617**	4	2	3	LR	OB	S	W
309117.115	**4618**	4	2	3	LR	O	S	Y
309118.5	**4619**	4	2	2	LR	OB	S	Y
396311.1	**4620**	5	2	1	R	O	S	Y
398208.505	**4621**	5	4	2	W	O	S	Y
	K Uday	4	2	4	R	OB	S	Y
	K. Lima	5	4	1	W	O	S	W
	K. Pukhraj	5	2	4	W	O	S	Y
	K. Khyati	4	2	3	W	O	S	Y

Legend: **Plant vigour:** 1-least,5-most; **Plant habit:** 1-disperse, 5-compact; **Senescence:** 1-least,5-most, **Skin Colour:** R-red, LR-light red, W-white; **Flesh colour**: Y-yellow, W-white, **Shape:** R-round, OB-oblong, O-oval; **Eyes:** D-Deep, MD-medium deep, S-shallow

3.4 Marketable and total tuber yield

The data presented in Table 2 indicate that significant differences were observed among the clones with respect to marketable and total tuber yield. In all the locations, the highest marketable and total tuber yields were recorded in variety K. Lima. It was statistically at par to clone 4611, 4620, K. Pukhraj and clone 4613. Significant difference was also recorded mong the locations for marketable and total tuber yield. Sirsa was found most suitable location for potato cultivation followed by Narnaul and Karnal. Similarly, interaction of clones and locations showed significant influence on marketable and total tuber yield. Maximum marketable tuber yield was recorded in clone 4611 followed by 4620 in Sirsa. However, the minimum yield was recorded in clone 4616 in Karnal. The total tuber yield was recorded highest in K. Lima followed by K. Khyati and clone 4620 in Sirsa, while it was found lowest in clone 4616 in Karnal.

Table 2. Marketable and total tuber yield of heat tolerant clones in Karnal, Sirsa and Narnaul districts of Haryana

Clones/Varieties	**Marketable yield (T/Ha)**				**Total tuber's yield (T/Ha)**			
Location	**Karnal**	**Narnaul**	**Sirsa**	**Mean C**	**Karnal**	**Narnaul**	**Sirsa**	**Mean C**
4609	20.2	22.8	26.7	**23.3**	20.8	27.3	29.9	**26.0**
4610	19.3	18.0	24.2	**20.5**	19.6	19.1	26.3	**21.7**
4611	24.6	31.0	31.7	**29.1**	24.8	32.1	32.6	**29.8**
4613	26.7	30.1	25.5	**27.4**	27.0	32.7	27.5	**29.1**
4614	19.6	18.7	22.3	**20.2**	20.1	19.4	24.0	**21.2**
4615	21.5	25.7	28.7	**25.3**	21.8	27.8	31.5	**27.0**
4616	15.9	19.1	24.4	**19.8**	16.0	19.8	25.8	**20.5**
4617	20.6	22.9	17.2	**20.3**	20.9	24.4	19.2	**21.5**
4618	21.8	18.9	21.0	**20.6**	22.0	21.0	23.4	**22.1**
4619	23.1	17.6	27.2	**22.6**	23.3	19.1	28.9	**23.8**
4620	26.9	27.7	31.6	**28.7**	27.3	30.3	33.0	**30.2**
4621	30.7	23.4	22.8	**25.6**	31.2	27.6	26.3	**28.4**
K. Uday	17.1	27.9	30.9	**25.3**	17.3	29.1	32.3	**26.2**
K. Lima	31.3	27.4	31.3	**30.0**	31.6	30.0	33.5	**31.7**
K. Pukhraj	28.7	25.0	28.5	**27.4**	29.2	27.5	30.8	**29.2**
K. Khyati	25.9	22.6	30.0	**26.2**	26.5	24.4	33.3	**28.0**
Mean L	**23.1**	**23.6**	**26.7**		**23.4**	**25.6**	**28.7**	
LSD @ 5%	**C- 2.6**	**L- 1.1**	**C x L- 4.5**		**C- 2.64**	**L- 1.10**	**C x L -4.6**	

Legend: L-Location; C-clone/varieties; T/Ha- tonnes per hectare; LSD- least significant difference

3.5 Processing test

To assess processing attributes of clones and varieties, sample tubers were given to the processing company PepsiCo. Cook test, solid content and sugars test were done. The data presented in Table 3 shows that clone 4614 had highest gross solid content followed by 4618, 4615, 4616, 4619 and 4621. Total potato defects (TPOD) were recorded minimum in clone 4616. All the clones/varieties showed acceptable sucrose content for processing, however, dextrose sugar was beyond the acceptable limit.

Table 3. Processing parameters of heat tolerant clones measured by PepsiCo.

Sample No.	Solid %		Cook Test				YSI Analysis			
	FL Solid	Gross Solid	UC%	ID%	ED%	TPOD%	Suc g/l	Suc %	Dex g/l	Dex %
4609	14.68	17.69	29.0	11.0	20.0	60.0	0.346	0.074	0.244	0.052
4610	0.00	0.00	60.0	10.0	7.0	77.0	0.235	0.051	0.596	0.128
4611	0.00	0.00	100.0	0.0	0.0	100.0	0.123	0.026	1.690	0.363
4613	14.47	17.43	100.0	0.0	0.0	100.0	0.240	0.052	0.381	0.082
4614	16.07	19.36	60.0	20.0	4.0	84.0	0.350	0.075	0.464	0.100
4615	15.00	18.07	65.0	15.0	0.0	80.0	0.246	0.053	0.695	0.149
4616	15.00	18.07	16.0	14.0	17.0	47.0	0.319	0.069	0.315	0.068
4617	14.82	17.86	40.0	20.0	8.0	68.0	0.337	0.072	0.528	0.114
4618	15.36	18.51	100.0	0.0	0.0	100.0	0.251	0.054	0.802	0.172
4619	15.00	18.07	56.0	14.0	10.0	80.0	0.293	0.063	0.487	0.105
4620	14.29	17.22	100.0	0.0	0.0	100.0	0.289	0.062	0.576	0.124
4621	15.00	18.07	100.0	0.0	0.0	100.0	0.320	0.069	1.190	0.256
K. Uday	0.00	0.00	100.0	0.0	0.0	100.0	0.145	0.031	0.173	0.037
K. Pukhraj	0.00	0.00	100.0	0.0	0.0	100.0	0.153	0.033	0.871	0.187
K. Lima	0.00	0.00	36.0	20.0	4.0	60.0	0.235	0.051	0.234	0.050
K. Khyati	0.00	0.00	100.0	0.0	0.0	100.0	0.211	0.045	0.568	0.122

Legend: FL- Frito-lay, UC- undesirable colour, ED- external defects, ID- internal defects, TPOD- total potato defects, Suc- sucrose, Dex- dextrose, YSI- yellow springs instrument

3.6 Participatory varietal selection (PVS) for yield and acceptability

PVS for yield and varieties acceptability was done in Sirsa by making heaps of harvested tubers. Stakeholders selected their choice varieties based on market acceptability and yield. The results of this exercise revealed that stakeholders preferred K. Lima followed by 4621 and 4618 based on their attractive shiny tubers.

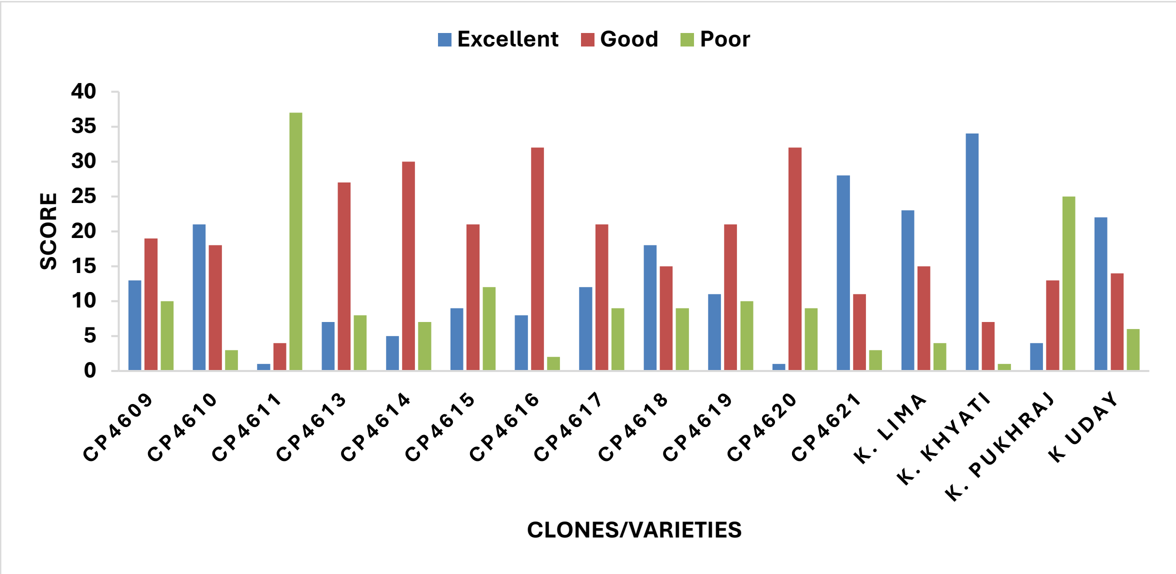
Table 4. Ranking of clones based on stakeholders' preference

Clone/variety	Score	Rank
4609	0	-
4610	11	IV
4611	18	III
4613	2	X
4614	0	-
4615	2	X
4616	0	-
4617	0	-
4618	5	VIII
4619	4	IX
4620	0	-

4621	24	II
K. Uday	8	VII
K. Lima	61	I
K. Khyati	5	IX
K. Pukhraj	10	V

3.7 PVS for organoleptic test

Organoleptic test was also done at farmer's fields in Sirsa and Narnaul to select the best variety based on taste. In Sirsa, K. Khyati received 1st rank by stakeholders followed by clone 4621 and K. Lima (Fig.1). However, in Narnaul clone 4621 was preferred followed by 4609 and 4618 (Fig. 2).



Fig, 1: Organoleptic test for taste of heat tolerant clones by stakeholders in Jodhka, Sirsa.

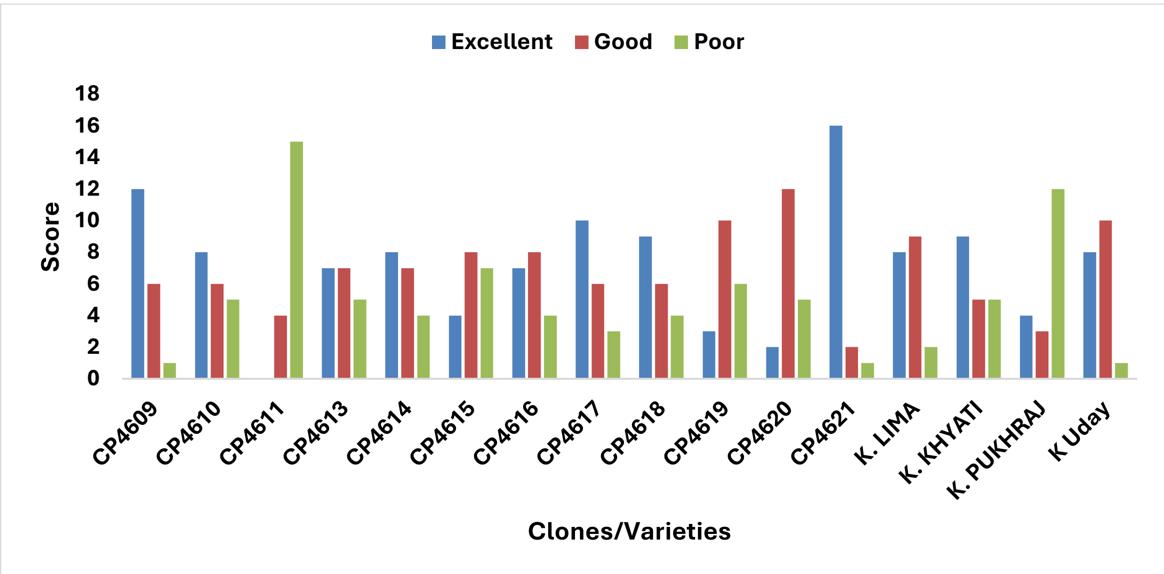


Fig. 2: Organoleptic test for taste of heat tolerant clones by stakeholders in Narnaul.

IV. DISCUSSIONS

4.1 Morphological characters of clones

Plant vigour and plant habit indicates the sturdiness of plant. However, it is not correlated with the tuber yield. Plants having more vigour translocate more food to the leaves rather than tubers consequently lesser yield. Compact growth is desirable as this prevent lodging in plants. Similar morphological variations on potato had been studied by previous researchers [9] and [10].

4.2 Plant senescence

Senescence of leaves defines crop maturity. It is a genetically governed character which also influences by management practices. Clones having early senescence indicated their earliness which is a most desirable character after yield as it enhances intensity of the cropping system. Senescence of leaf is an indicator of tuber bulking cessation and maturity [15] and [18].

4.3 Morphological characters of tuber

The shape, eye depth, skin and flesh colour of the tubers are genotypically governed and did not change much with the climate. However, soil impacts little on intensity of tuber colour, it becomes dull with the loose soil. The acceptability of tuber shape and colour of skin and flesh varies location to location. Similarly, deep eyes of tubers are not desirable as it requires more peeling. These distinctive quality parameters influence consumer's choice [19].

4.4 Marketable and total tuber yield

The significant variation in marketable and total tuber yield within the location might have been due to genotypic or varietal factor as reported by [7]. The moderate climate with maximum sunny days of Sirsa accelerate the photosynthesis and translocation of food consequently for fast bulking of tubers. In Karnal, foggy days during tuber bulking stage reduced photosynthetic rate and that reduced tuber yield. Similar finding of genotype-environment interaction was also reported by [3] and [12]. These reporting was also supported by [16].

4.5 Processing test

All the clones behaved differently with respect to processing parameters. Clones having high dry matter content, low sugars with good chip colour found suitable for processing. Similar findings were observed by [14] while evaluating different accessions for selecting parents for development of processing varieties. [13] were of the views that dry matter content determines the suitability of genotype for processing purposes and thus affecting chips yields, texture, flavour, oil content and processing efficiencies. Similar findings were recorded by [20] while evaluating potato clones for processing.

4.6 Participatory varietal selection (PVS) for yield and acceptability

PVS is an important exercise to assess and select the farmer's choice candidate varieties based on tuber appearance, taste and yield. Selection of a promising clone was strongly related to participant's decision on its organoleptic acceptance and probable logical decision for future adoption of a genotype for commercial cultivation [8] [17] and [5]. The choice can varies from location to location, in some region white skin tubers are preferred while in other areas consumers like red skin tubers. Processing industries demand big size round tubers for chips and oblong/long for french-fries. Farmers always need the varieties that show high performance for yield along with disease resistance, good storage and other essential agronomic traits having reliable superiority over a wide range of environmental conditions [21]. Stakeholders of Sirsa preferred clones having shiny white skin tubers with high yield. They do not like red skin tubers due to lesser acceptability in the market. The findings are in similarity with the findings of [12].

4.7 PVS for organoleptic test

The organoleptic test is important to avoid the failure of any high yielding variety at consumers' level based on taste. [11] were of the views that acceptability of the varieties varies region to region. This is consistent with the findings of [24] who evaluated the clones through organoleptic test by participation of stakeholders.

V. CONCLUSION

Based on above findings it can be concluded that on the basis of yield, variety K Lima and clones 4620, 4611, 4613 and 4621 performed well at selected three locations. Clone 4615 also had good yield with early maturity. Based on processing data, clones 4616 and 4614 were found to be within the acceptable limits. Considering the preferences of stakeholders under PVS exercise, clone 4621 and variety K Khyati were most preferred.

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Biological Control of Weeds

Dr. B. L. Meena[1], Kriti Sharma[2]

[1]Assoc. Professor (Agronomy) & SSH, KVK, Barmer, AU Jodhpur, Rajasthan
[2]Research Scholar, Department of Soil Science and Agricultural Chemistry, RCA, MPUAT, Udaipur, Rajasthan

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Abstract— *In response to the mounting environmental and anthropogenic challenges, there has been a notable shift towards adopting biological approaches as pivotal components of integrated and sustainable weed control strategies. Over the course of centuries, the efficacy of employing biological agents for weed management has emerged as a cornerstone in addressing these challenges. This review article aims to delve into the historical evolution and contemporary significance of biological agents in weed control, highlighting their pivotal role in modern agricultural and ecological practices. Our exploration begins with a classical perspective on the biological approach, shining a spotlight on arthropods, particularly insects. A unique angle introduced involves the redistribution of local arthropods as a nuanced method for effective weed control. Transitioning to the bioherbicide section, we delve into the realm of formulated natural products and their diverse formulations, recognizing their pivotal role in biological weed control. However, the landscape of biological weed control is not without its challenges. Financial constraints, side effects, and divergent opinions pose hurdles that warrant attention. Yet, despite these challenges, the narrative maintains an optimistic outlook. The underlying belief is that, in the future, biological methods will evolve to offer not only effective but also sustainable solutions for weed control practices. In essence, this abstract navigates through the historical successes of biological weed control, explores specific facets such as arthropods and bioherbicides, confronts existing challenges, and ultimately anticipates a future where biological methods emerge as more promising and sustainable players in the field of weed control.*

Keywords— ***Arthropods, Bioherbicides, Biological weed control, Sustainable agriculture, Weed control practices***

I. INTRODUCTION

Ever since the first cultivation systems were developed for food production, farmers of all generations and areas have been faced with the problems of non-crop plants growing amongst the crops. These non-crop plants, which compete with the crops for moisture, light, nutrients and space, have long been known as weeds. The weeds often cause many problems to farmers as they are difficult to control and are being used as an insult to other humans, inferring lack of courage or strength. Yet thin, spindly and pale weeds often have the resilience and ability to compete with the crop plants **(Briese, 1997).** A weed can be thought as any plant growing in the wrong place at the wrong time. In crops, weeds can cause problems of severely reduced yields and also affect the efficient use of machinery.

So effective weed control is therefore an essential part of crop husbandry and has traditionally been a labour-intensive operation of controlling the weeds. In less developed countries, the situation of labour shortage still exists where the peak labour requirement is often for hand weeding **(Rogers, 1979).** If this labour demand cannot be met, then the crop must be grown on a smaller area that would otherwise be economically viable. Some herbicides have also been developed which are a challenge worth combating as in methods of weed control in systems, herbicides are too expensive or ineffective to use. Thus, with the much greater public awareness of food and environmental issues, it is probably worth looking at weed control from a wider perspective especially non-chemical weed control.

II. WEED COMPETITION

At this stage it is worth considering some basic aspects of weed management, before looking in detail at the techniques available for non-chemical weed control. Awareness about the common weeds in the crop fields is important, so operations such as cultivations, sowing and weeding can be timed according to the peak germination periods of the predominant species.

Crop rotations, one option for weed control in the cropping system, should be designed such that the differences in the timing of seedbed cultivations prevent one weed species becoming dominant **(Lockhart *et al.*, 1990).**

III. WHY ARE WEEDS IMPORTANT?

In a review of crop losses due to pests, it was stated that: overall, weeds produced the highest potential loss (34%) with animal pests and pathogens being less important (losses of 18% and 16%) **(Oerke, 2005).** Worldwide, 40% of pesticide use is contributed to herbicides, 17% to insecticides and 10% to fungicides. **(Jamaludheen *et. al.*, 2022).**

The problem with weeds: Weeds compete with crops for essential resources such as space, light, moisture, and soil nutrients, consequently leading to yield reduction. It causes health problems to human beings. *For example, Parthenium hysterophorus.* Similarly, morning glory is beautiful in the garden, but when it entwines corn stalks, it can destroy a farmer's crop. Heavy infestation by perennial weeds makes the land unsuitable for cultivation resulting in loss in its monetary value. Aquatic weeds that grow along the irrigation canals, channels and water streams restrict the flow of water. Aquatic weeds form breeding grounds for obnoxious insects like mosquitoes. They reduce recreational value by interfering with fishing, swimming, boating, hunting and navigation on streams and canals. *For example,* water hyacinth is beautiful in floating gardens but can rapidly clog waterways, making navigation impossible.

So, there are many methods of destroying weeds either by burning, pulling out or chopping down and treating them with herbicides. Biological control holds much promise for long-term, economical and environmentally sensitive weed management **(Gharde *et al.*, 2023).**

IV. BIOLOGICAL WEED CONTROL

Origin: In ancient times, the Chinese discovered that increasing ant populations in their citrus groves helped decrease destructive populations of large boring beetles and caterpillars. That use of a natural enemy to control a pest marked the birth of biological control. Biological control research and implementation is even more relevant today. As a weed management method, biological control offers an environmentally friendly approach that complements conventional methods (This paragraph sheds light on the origins of biological weed control, which is why ancient techniques are mentioned.) It helps meet the need for new weed management strategies since some weeds have become resistant to certain herbicides. Biological control agents target specific weeds. Moreover, this technology is safe for applicators and consumers.

What is biological control of weeds?

Biological weed control involves use of living organisms, such as insects, nematodes, bacteria, or fungi, to control the weeds. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control. In nature, plants are controlled biologically by naturally occurring organisms called bio agents.

Qualities of bio-agent:

- The bio-agent must be host specific,
- Devoid of predators or parasites,
- Adaptable to environmental conditions with ample reproductive capacity,
- Capable of independent host-seeking,
- Able to either directly kill the weed or prevent its reproduction, in a direct or indirect manner (**Smith *et al.*, 2023**),

Merits:

- Environmentally benign/eco-friendly since it does not lead to environmental pollution,
- No residual effect,
- Preserves bio-diversity,
- Economical in the long run, although initially monetary investment is high,
- Will not affect non-targeted plants and safer in usage.

Demerits:

- Requires/incurs higher initial cost,
- Multiplication is costlier,
- Control is very slow,
- Weeds are not eradicated, but managed at a lower density,
- The span of activity of bio-agent in most cases is small/narrow, whereas weeds may grow all through the year. For example, *Parthenium hysterophorus*

grows all through the year, but *Zygogramma bicolorata*, the bio-agent is active only during rainy season for a period of 2-3 months starting from July.

How does it work?

- Roots provide plants with water and nutrients. Some bio-agents attach to roots and thereby stunt plant growth. Some bacteria release toxins that stunt root growth. Many fungi disrupt the water transport system, which reduces leaf growth. Beneficial insects and nematodes feed directly on the weed roots causing injury which allows bacteria and fungi to penetrate (**Khanna *et al*., 2021**).
- Plant leaves capture energy from the sun and store it as sugar. Insects feeding on leaves reduce the leaf area available for energy capture **(Mooney, 1972).** Fungi and bacteria infecting leaves reduce leaf ability to make sugars. In either case, there is less energy available for weed growth.
- Many weed species survive from year to year by producing seeds. Fungi or insects that attack seeds reduce the number of weed seeds stored in the soil, which in turn reduce the size of weed populations. This lowers the effort needed to control the remaining emerging weeds (**Barbercheck, and Wallace, 2021).**

Some bacteria and fungi applied as biological control agents do not survive from year to year. These organisms must be applied on an annual basis. This technique is called the "**bioherbicide**" strategy. With this tactic, biological agents are used in manner similar to chemical herbicides.

V. METHODS OF BIOLOGICAL WEED CONTROL

- Classical/Inoculative Biological Control
- Inundative/Augmentative/Bio-Herbicide Biological Control
- Broad-spectrum Biological Control
- Allelopathy
- Bio-dynamics

Classical/Inoculative Biological Control

Classical/Inoculative biological control involves the release of bio-agents (insects, pathogens) (**Evans & Ellison, 1990**) just for once in the belief that it will readily adapt to the prevailing climate and multiply enough to keep pace with the multiplication rate of weed in question. Therefore, repeated release of bio-agent is not advocated. No augmentation and large-scale mass production of the bio-agent are practiced. It has been suggested that some of the introduced, invasive perennial weeds such as giant hogweed (*Heracleumm antegazzium*), Himalayan balsam (*Impatiens glandulifera*) and the Japanese knotweeds (*Reynoutria* spp.) would be ideal candidates for classical biological control (**Child *et al*., 1993; Das *et al*., 2017; Evans & Ellison, 1990; Fowler *et al*., 1991**). The introduction of a classical bio-control agent may not be deliberate. In this approach, a small amount of inoculum (pathogen) or insects, based on the assessment of weed problem and prevailing situation, is initially released in the standing population of weeds and allow it to multiply and feed on the weeds. The rust (*Puccinia lagenophorae)* is of Australian origin where it attacks a range of *Senecio* spp. (*Senecio vulgaris*) (**Evans & Ellison, 1990**). The rust does not kill the weed but makes it less competitive. Higher yields have been recorded in lettuce experiments with rusted groundsel compared with rust-free plants (**Mishra *et al*., 2021; Paul & Ayres, 1986; Tewari & Chethan, 2018**).

Inundative/Augmentative/Bio-Herbicide Biological Control

Inundative/Augmentative/Bio-Herbicide biological control involves the culture and release of large numbers of a bio-control agent (inoculum) into the region or field where the target weed needs to be controlled. This inoculum is bio-herbicide. Bio-herbicides are native pathogens mostly fungi and hence called myco-herbicide. It has the advantage that native organisms can be used but there is the same requirement for host specificity (**Weidemann & Tebeest, 1990**). Several inoculums such as fungi, bacteria, parasitic nematodes, viruses can be applied as sprays in the same way as conventional herbicides. Bio-herbicides are sprayed in every season on the target weed in crop field **(Aneja *et al*., 2017; Keerthi *et al*., 2019).** The bio-agent generally remains active only on concurrent weed population. The specificity of a bio herbicide is increased where the susceptibility of the target organism can be enhanced. This may allow a selected area of a weed to be controlled without affecting nearby plants of the same species. *For example*, Isolates of *Xanthomonas campestris* pv. *Poae* have some activity against annual meadow grass, *Poa annua* (**Imaizumi *et al*., 1997**). In groundsel (*Senecio vulgaris*), plants naturally infected with the rust *Puccinia lagenophorae*, were killed by inoculation with the pathogen *Botrytis cinerea*, while healthy plants were not (**Hallett *et al*., 1990**).

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Table 1: Mycoherbicides (Bioherbicide) that have been registered and their targeted weeds, October 2008 (Kumar et al., 2018).

Product	Pathogen	Target weeds
Lubao	*Colletotrichum gloeosporioides f. sp. cuscutae*	Dodder in soybean
DeVine	*Phytophthora palmivora*	Strangler vine in citrus orchard
Collego	*Colletotrichum gloeosporioides f. sp. aeschynomene*	Northern joint vetch in rice and soybean
CASST	*Alternaria cassiae*	Sickle pod and coffee senna in soybean and peanuts
Dr Bio-Sedge	*Pucciniacanaliculata*	Yellow net sedge in soybeans, sugarcane, maize, potato and cotton
BioMal	*Colletotrichum gloeosporioides f. sp. Malvae*	Round leaved mallow in wheat, lentil & flax
Stumpout	*Cylindrobasidium leave*	Acacia species in native vegetation and water supplies
Biochon	*Chondrosteremum purpureum*	Woody weeds like black berry in plantation forests
Camperico	*Xanthomonas campestris pvpoae*	Turf grass in golf courses
Hakatak	*Colletotrichum acutatum*	*Hakea gummosis* &*H. sericea*in native vegetation
Woad Warrior	*Puccinia thlaspeos*	Dyers wood (*Isastistinctoria*) in farms, rangeland, waste areas and roadsides

Broad Spectrum Biological Control

The oldest example of broad-spectrum biological control is the use of grazing animals and birds to maintain pasture. In aquatic situations, the use of grass carp (*Ctenopharyngodon idella*) and other phytophagous fish has been investigated. In Australia, goats have been used to control blackberry (*Rubus fruticosus* agg.) **(Dellowet *al.*, 1988)**. In cereals, sheep grazing in spring is a traditional practice of many organic growers to aid weed control. Weeding increased grain yield but grazing reduced ear number. It is known that different breeds of livestock vary in their grazing or browsing preferences and abilities and should be taken into account for improved weed control **(Soil Association, 2002)**.

Allelopathy

Within the broadening perceptions of biological control, allelopathy is regarded as a component of biological control **(Lovett, 1991).** Allelopathy is derived from two Greek words, "allelon or allelo" means "mutual or each other" and "pathos or patho" means "suffering or to suffer." Molisch (1937) coined the term allelopathy, which includes all stimulatory and inhibitory reciprocal biochemical interactions among plants including microorganisms. The effect is exerted through the release of allelo chemicals by the growing plant or its residues. Allelopathy has been considered a defense mechanism in plants **(Lovett, 1982).** It makes a significant contribution to the process of plant succession **(Numata, 1982).** Allelo chemicals may be present in the mucilage around a germinating seed **(Kosemura *et al.*, 1993),** in leachates from the aerial parts of plants **(Tukey, 1966),** in exudates from plant roots, in volatile emissions from the growing plant **(Charron *et al.*, 1995),** and among decomposing plant residues **(Bewick *et al.*, 1994).** The effectiveness of living mulches, intercrops or smother crops may in part depend on their allelopathic ability. While allopathic crops or their residues inhibit the growth of certain weeds **(Steinsiek *et al.*, 1982),** weeds such as fat-hen (*Chenopodium album*) that has allelopathic ability, may also influence the growth of some crops **(Goel *et al.*, 1994; Qasem & Hill, 1989).** Weeds can also inhibit the growth of other weeds **(Anaya *et al.*, 1988).** Allelopathy could be used to manipulate the crop-weed balance by increasing the toxicity of the crop plants to the weeds **(Kostina-Bednarz *et al.*, 2023).**

There are two types of allelopathy :**(*True and Functional*)**

- ***True allelopathy*** involves the release of compounds into the environment and are toxic in the form they are produced.
- ***Functional allelopathy*** involves the release into the environment substances that are toxic as a result of transformation by microorganism.

Table 2: Allelochemicals and their functions (Vyvyan et al., 2002)

Chemicals	**Impact**
Sorgoleone and its hydroquinones	Inhibit chlorophyll formation and photosynthetic oxygen evolution
Coumarins and flavonoids	Blocks mitosis, seedling and germination inhibitor
Terpenoids	Germination and growth
Breviones	Etiolation of coleoptile (wheat)
Dehydroazulanin	Rapid leakage of plasama membrane and growth inhibitor
Strigolactones	Germination stimulants
Heliannauols	Enhance growth of monocots and restricts dicots

Biodynamic

The term biodynamic is taken from Greek word bios meaning life and dynamics meaning energy. Hence biodynamic farming refers "working with the energies which create and maintain life" **(Rai and Yadav, 2005).** There are two main characteristics of BD farming **(Dengel, 2004).** Firstly, by the use of particular farming inputs made from various herbal, mineral and raw materials processed in complex ways and finally applied in small and minimal doses on soil and crops. And secondly by the observation of rhythms in nature which go beyond the most obvious influences of sun, weather and season, but which include lunar, planetary and stellar constellations. Biodynamic differs from organic farming in a way that biodynamic farms aim to become self-sufficient in compost, manure and animal feeds and moreover an astronomical calendar is used to determine auspicious planting, cultivating and harvesting times **(Sharma, 2001).** Although not strictly part of biological control, bio-dynamics and related methods are included here because they rely on the use of natural materials for their effect. The control of perennial weeds by treating them with the potency ashes of those particular weed or their seeds is one area of particular interest to organic farmers. There is little scientific information on how these so-called weed peppers work. The principle is similar to the use of homeopathic medicines. **Scherrer (2000)** has begun testing the impact of weed peppers on *Solidago alissima* and S. *gigantean* but the treatments are expected to take several years of repeated applications to show an effect. Bio dynamically prepared compost applied to field crops reduced weed numbers but no more than non-biodynamic compost (**Carpenter-Boggs, 2000**).

Outstanding and Feasible Examples of Biological Weed Control (Hinz *et al.*, 2020)-

a. Larvae of *Coctoblastis cactorum*, a moth borer, control prickly pear *Opuntia* sp. The larvae tunnel through the plants and destroy it. In India it is controlled by cochinial insects *Dactylopiusindicus* and *D. tomentosus.*

b. *Lantana camara* is controlled by larvae of C*rocidosema lantana*, a moth bores into the flower, stems, eat flowers and fruits.

c. *Cuscuta* spp. is controlled by M*elanagromyza cuscutae.*

d. *Cyperus rotundus- Bactra verutana*a moth borer.

e. *Ludiwigia parviflora* is completely denuded by *Altica cynanea* (steel blue beetle).

f. Herbivorous fish- Tilapia controls algae. Common carp, a non-herbivorous fish controls submerged aquatic weeds. It is apparently due to uprooting of plants while in search of food. Snails prefer submersed weeds.

g. Weed like *Parthenium hysterophorus* completely controlled by a Mexican beetle

Larvae of *Coctoblastiscactorum*

Mexican Beetle
(*Zygogrammabicolorata*)

Table 3: Some examples of Biological Weed Control (Monteiro and Santos, 2022)

Bio agent	**Weeds**
Insect	
Beetles: *Octotomas cabripennis and Uroplatagiraldi*	*Lantana camara*
Scale insect:*Dactylopiu stomentosus.*	Prickly-pear weed - *Opuntia*
Flea beetle: *Agasicleshygrophyla*	Alligator weed – *Alternantheraphiloxeroides*
Fish	
Common carp and Chinese carp	Aquatic weeds
Mammals: Manetee or sea-cow	Water hyacinth
Snails: Marisa sp and other fresh water snails	Submerged weeds like coontail and algae
Fungi: *Rhizoctinia* blight.	Hyacinth
Mites	
Tetranychu ssp	Prickly pear
Plants: Cowpea as intercrop in sorghum	Effectively reduces the growth of weeds in sorghum

Table 4: Factors Affecting Biological Success (Monteiro and Santos, 2022)

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Biotic Factors	Abiotic Factors	Procedural Factors
Plant Community: Host density, Succession	**Climate:** Temperature, precipitation	**Before release:** Site selection, colony source, collection method, shipment, sex ratio
Interactions: Predation, parasitism, competition	**Site characteristics:** Soil, slope, aspect, shade, moisture	**Release:** Method, Wrong agent or host, timing, life stage, documentation
Biological Organism: Synchronization, physiology, fecundity, behavior, genetic diversity, emigration	**Elevation:** Temperature, precipitation	**After release:** Site management, agent detection, vandalism
	Latitude: Season, day length	**Personnel:** Training, experience, continuity, prioritization, follow-up
	Disturbance: Fire, flood	

Table 5. Exotic natural enemies' field-released for Classical biological control of weeds in India.

Weed (purported year of introduction)	Agents released (year)a	Establishment in the field and impact
Terrestrial weeds ***Ageratina adenophora*** **(Spreng el) R. King and H. Robinson (1900)**	***Procecidocha resutilis*** **Stone (1963)**	**Established - minimal control due to parasitoids**
Chromolaenaodorata **(L.) King and H. Robinson (1914)**	***Apionbrunneonigrum*** **BéguinBillecocq (1972)**	**Not established**
	Pareuchaetespseudoinsulata **Rego Barros (1973 and 1984)**	**Recently reappeared**
	Cecidochares connexa **(Macquart) (2005)**	**Established - too early to assess**
Lantana camara **L. (1809)**	***Ophiomyia lantanae*** **(Froggatt) (1921)**	**Established - not effective**
	Teleonemia scrupulosa **Stål (1941)**	**Established - provides minimal Control**
	Diastematigris**Guenée (1971)**	**Not established**
	Salbiahaemorrhoidalis**Guenée (1971)**	**Not established**
	Octotomascabripennis**Guérin-Méneville (1972)**	**Established - not effective**
	Uroplatagirardi**Pic (1972)**	**Established - not effective**
Mikania micrantha **H.B.K(1914)**	***Puccinia spegazzinii*****de Toni (rust pathogen,2005 Assam and 2006 Kerala)**	**Established in Kerala - too early**

Opuntia **spp. (unknown)**	***Dactylopius ceylonicus*****(Green) against** ***Opuntia vulgaris*** **Miller (1795)** ***Dactylopius confuses*** **(Cockerell) against** ***O. vulgaris*** **(1836)** ***Dactylopius opuntiae*****(Cockerell) against** ***Opuntia elatior*** **Miller and** ***Opuntia stricta*** **(Haworth) Haworth var.** ***dillenii*** **(Ker Gawler) L. Benson (1926)**	**Established and provided excellent Control** **Not established** **Established and provided completecontrol of both species**
Parthenium hysterophorus **L. (1955)**	***Zygogrammabicolorata*****Pallister (1984)**	**Excellent control in some areas**
Aquatic weeds		
Eichhornia crassipes **(Martius) Solms-Laubach (1900)**	***Neochetinaeichhorniae*****Warner (1983)** ***Neochetinabruchi*****Hustache (1984)** ***Orthogalumnaterebrantis*** **Wallwork (1986)**	**Established - provides good to variable control** **Established - provides good to variable control** **Established - alone not very effective**
Salvinia molesta **Mitchell (1955)**	***Pauliniaacuminata*** **(Degeer) (1974)** ***Cyrtobagous salviniae*** **Calder and Sands (1983)**	**Established - uncertain control** **Established - spectacular control**

VI. CONCLUSION

Techniques for non-chemical weed control have been developed to reduce chemical costs in conventional agriculture, in response to environmental pressures and to provide for the needs of organic food production. A wide range of equipment is available to cover the major crops grown. Successful non-chemical weed control requires a well-managed, integrated system and attention to detail. Future work is required to research the effects of heat from thermal techniques on soil microorganisms, weed seed germination and viability. The effects of the different soil/weed combinations on the success of the weeding operation and on the soil structure also needs merit attention.

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To study the effect of feeding of amla powder on growth performance of broiler chicks

Pradeep Nodal*, Siddhartha Mishra[1], Tetarwal J.M.[2], Chopra G.[3]

*Ph.D. Research Scholar Department of Animal Production Rajasthan College of Agriculture MPUAT Udaipur (Raj.) 313001
[1]Associate professor Department of Animal Production Rajasthan College of Agriculture MPUAT Udaipur (Raj.) 313001
[2]SMS (Subject Matter Specialist) Livestock production and Management CAZRI-KVK Pali (Raj.) 306401
[3]STO (Senior Technical Officer) Livestock production and Management CSWRI Malpura Tonk (Raj.) 304501
Corresponding author: Pradeep Nodal*, E-mail: pardeepnodal418@gmail.com

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***Abstract*— *As per 20th livestock census, the total poultry population in India has increased by 16.81% and the total poultry production recorded was 851.81 million during 2019. Out of total poultry population 37.8 % is under backyard production system in Rajasthan. However, the southern Rajasthan has about 16.3 % of total poultry of Rajasthan and it also has 41.2 % of total poultry of Rajasthan under backyard system. The total poultry population in Rajasthan has registered a phenomenal increase of about 80% over last livestock census and the current poultry population is 14.62 million, however, it is only 1.72% of poultry population of India (BAHS, 2019). The present study was conducted to assess the effect of feeding amla (Emblica officinalis) powder on performance and carcass characteristics of broiler chicks. One hundred sixty broiler chicks (day old chicks) were randomly allotted to 4 dietary treatments with 4 replicates of 10 chicks each. The treatment included the (T_1) control, (T_2) control group supplemented with amla powder @ 0.5%, (T_3) control group supplemented with Amla powder @ 1.0%, (T_4) control group supplemented with Amla powder @ 1.5%. The effect of supplementation was observed on the body weight, body weight gain, feed intake, FCR, nutrient utilization, nutrient balance, carcass traits viz., live weight, slaughter weight, eviscerated weight, dressing weight, weight of heart, liver, gizzard, and economics in broiler chicks.*

***Keywords*— performance, chicks, treatment, poultry**

I. INTRODUCTION

Over the last few decades, the health protection of birds and food safety were the priorities for poultry producers. Under the consumer pressure, the utilization of artificial feed additives is banned, and extreme solutions related to intensive rearing are mitigated to ensure the environment safety (Jachimowicz *et al.*, 2022). A complete ban or time bound decline in use of antibiotic growth promoters (AGP) has drawn the concerns of researchers for other natural substances like medicinal herbs, as a new class of additives to animal and poultry feeds growth promoters including herbal preparations for their use with myriad additional benifits (Ranade and Desai, 2005). The utilization of antibiotics in poultry and livestock production is advantageous to farmers and the economy due to improved poultry performance but at the same time, the likely dissemination of antibiotic resistant strains of pathogenic and non-pathogenic organisms into the environment and their further transmission to humans via the food chain could also lead to serious consequences on public health (Agyare *et al.*, 2019).

Amla or Indian Gooseberry (*Emblica officinalis*), with its origin in India has extensive adaptability to grow in diverse climatic and soil conditions (Pokharkar 2005). The fruits of the plants has early history of use in Ayurveda as a potant rasayana (revitalisers, biological response modifiers) in which the amla was added as anti-stress agent. Amla is one of the richest sources of ascorbic acid, minerals, amino acids, tannins, and phenolic compounds. Amla, richest source of vitamin-C and it's active tannoid principles have antimicrobial, antidiabetics, anticarcinogenic properties and enhances immune property

(Anjaria *et al.*, 2002). It is a great nutritional supplement with several medicinal benefits. Due to the abundance of phenolic compounds, Emblic fruit could be regarded as a plant source for natural antioxidants and nutraceuticals or medicinal components. In various animal and human investigations, amla has been proven to have anti-hyperglycemic, hypoglycemic, anti-inflammatory, anti-hyperlipidemic, and antioxidant activity that helps the body's immune systems and digestion (Gul *et al.*, 2022).

There are plenty resources of different kinds of medicinal herbs which can be explored as natural feed additives for poultry. Commonly known herbs are Aloe vera, Fenugreek, Ashwagandha, *Moringa oleifera*, Cinnamon, Tulsi, Garlic, Pepper etc. Herbal preparations help in the digestion process, safe, cost effective and environment friendly with no side effect (Vinus *et al.*, 2022). Herbal extracts are the powerful stimulators of the immune and animal digestive systems as well as highly beneficial effects in poultry nutrition due to their antioxidant, antimicrobial, antiviral, anticoccidial and anthelmintic properties (Akyildiz and Denli, 2016).

II. MATERIAL AND METHODS

The research work was undertaken to study the effect of feeding amla (*Emblica officinalis*) powder on growth performance and carcass characteristics of broiler chicks. The experiment was conducted for a period of 60 days including metabolism trial.

LOCATION

The experiment was conducted at Poultry farm, Department of Animal Production, Rajasthan College of Agriculture, MPUAT Udaipur, located in humid region at 24.35 North and Longitude of 74.42 East with height from the mean sea level 582.2 Meter.

1.1 Distribution of experimental Coloured broiler chicks under various treatments

Replications		Treatments		
	T_1	T_2	T_3	T_4
R_1	10	10	10	10
R_2	10	10	10	10
R_3	10	10	10	10
R_4	10	10	10	10

1.2 Details of experimental treatments

Groups	Treatments	No. of Chicks	Dose
T_1	Control/Conventional	40	Basal diet (Control)
T_2	Amla (*Emblica officinalis*)	40	Basal diet supplemented with 0.5% Amla powder
T_3	Amla (*Emblica officinalis*)	40	Basal diet supplemented with 1% Amla powder
T_4	Amla (*Emblica officinalis*)	40	Basal diet supplemented with 1.5% Amla powder

HOUSING AND MANAGEMENT

The chicks were reared under strict hygienic condition in the brooder house of the college poultry farm. Before housing the chicks, experimental brooder rooms, equipment's and utensils were cleaned and disinfected thoroughly with phenol and fumigated with formaldehyde gas. The chicks (day old) were weighed at the beginning of the experiment and divided into groups randomly. Rice husk was used as bedding material. The thickness of bedding material was kept 2 inches initially which was subsequently increased by 0.5 inch. The chicks were vaccinated against Ranikhet and Marek's disease.

FEEDING AND WATERING

Initially the chicks were fed by putting the feed in the trays up to the age of two weeks. After two weeks the chick feeders were used and continued during whole experimental period.

The birds were offered clean and fresh drinking water ad-libitum using chick waterers during the whole experimental periods.

LIGHTING

Proper amount of lighting condition was followed during brooding and in entire period of research work.

VENTILATION

The brooder house was properly ventilated. Adequate ventilation reduced dust, high moisture and excess ammonia from as improper ventilation affects growth and live ability of broiler chicks.

III. RESULT AND DISCUSSION

The results with respect to performance of broiler chicks fed amla powder will be discussed in this chapter under following subheads:

1. Body weight
2. Body weight gain
3. Feed intake
4. Feed conversion ratio
5. Nutrient utilization
6. Carcass traits
7. economics

The mean body weights in broiler chicks increased with the advancement age for dayold to 8^{th} week of age. The body weight was significantly higher in the group supplemented with amla powder @ 1.0% all ages. The mean body weights at 8^{th} week of age were significantly highest ($P<0.01$) in T3 followed by T2, T4 and lowest in T1 group (Table 4.1). Similarly, the overall mean body weight gains were also significantly highest in T3 followed by T2, T4 and lowest in T1. The weekly body weights observed in the present study are lower as compared to the body weights observed by Begum *et al*. (2019), Gaikwad *et al.* (2016) on supplementation of Amla powder and Sandeep *et al* (2018) on supplementation of Amla and synthetic vitamin c. The mean weekly body weights were recorded up to 7^{th} weeks of age i.e., for chick stage of growth. The lower body weights in broiler observed in the present study may be attributed to genetic constitution. The coloured broiler used in present study has shown slower growth as compared to commercial broilers.

The body weight at 6 weeks of age was significantly lower in present study as compared to the observation recorded by Kumari *et al.* (2012) and Gaikwad *et al* (2016) who reported higher body weights. Gaikwad *et al.* (2016) reviewed the effect of supplementation of Amla powder on growth performance of broiler chicks when supplemented with different levels of Amla powder i.e., 0.5, 1.0 percent along with the basal ration on the growth performance of broiler chicks up to 6 weeks of age. There is limited studies on the effect of amla powder on the performance of broiler up to 8 weeks of age. In the present study the experiment was continued until 8 the weeks.

It evidenced that the Amla powder was found to be beneficial when supplemented at 0.5 to 1.5% of total ration with varying proportions. However, in the present study the supplementation at 1.0% rate was found to be most effective in terms of weekly body weight or body weight gains. The body weight showed declining trend beyond 1.0% level of supplementation, however the supplementation of amla was found to be beneficial when compared to the control where there was no supplementation.

The mean body weight gains at different weeks of age on supplementation of Amla powder in the present study corroborates the findings of other research workers on supplementation of Amla alone or in combinations of other herbal feed additives / minerals / vitamins. Though the body weight gains at different weeks in present study were found to be lower than other studies which may be attributable to the fact that the present study was conducted on coloured synthetic female line against commercial lines in other studies and the birds are maintained as parent breeding stock in the AICRP on poultry breeding project.

The mean body weight gains at different weeks and overall body weight gain were significantly higher in T3 as compared to T2, T4 and lowest in T1 suggesting dietary supplementation of Amla powder at 1.0% resulted in increase in body weight gains in broiler chicks. Patel *et al* (2016) have also reported that the mean body weight gains up to 6 weeks of age was highest at supplementation level of 0.4% followed by 0.8% Amla powder. However, in the present study the higher mean body weight gains up to 8 weeks of age was found at 1.0% level of supplementation and it declined thereafter. Aljumaili *et al.* (2019) also reported higher body weight gains at 6 weeks of age on supplementation of Amla (1gm/kg) in combination with Vitamin c @ (250mg/km) each and support our findings.

Gaikwad *et al.* (2016) have reported higher 6^{th} week body weight at 2304.53 g and mean body gain at 6^{th} week of 502.15g on diet supplemented with 1.0% Amla powder on basal diet, however the body weight reported by Gaikwad and coworkers is lower than the mean body weights observed in the present study.

Weekly Body Weight

The data with respect to weekly body weights of broiler chicks up to 8^{th} weeks of age is presented in Table 4.1.
The initial body weight i.e., the day old weights of chicks were 42.43±0.58, 42.30±0.70, 41.55±0.58 and 41.28±0.55 g T1, T2, T3 and T4 respectively. The data revealed that the body weight at day old was did not differ significantly at 1^{st} to 8^{th} weeks of age except at day old, on which it was found non-significant.
The body weights at one week of age were 84.96±1.67, 90.02±1.74, 91.96±1.24 and 84.03±0.95 g in T1, T2, T3 and T4 groups respectively. The body weight at 1 week of age was significantly highest ($P<0.05$) in T2 and T3 as compared to T1 and T4. However, the difference between T2 and T3 and T1 and T4 was found statistically non-significant.
The mean body weights at 2 weeks of age were 175.65±6.67, 204.03±0.99, 224.94±1.82, and 190.08±1.13 g in T1, T2, T3 and T4 respectively. The perusal of data revealed that the body weight was significantly highest in T3 followed by T2, T4 and lowest in T1.

The mean body weights at 3rd week of age were 289.93±2.39, 350.06±2.49, 379.90±3.55 and 315.00±1.35 g respectively in T1, T2, T3 and T4 treatment groups. It was found that the body weight was significantly higher (P<0.01) in T3 followed by T2, T4 and lowest in T1.

The mean body weights at 4th weeks of age were 495.09±1.50, 579.93±2.30, 625.08±2.29 and 514.94±1.14 g in T1, T2, T3 and T4 respectively. The perusal of data revealed that the mean body weight was significantly highest (P<0.01) in T3 followed by T2, T4 and lowest in T1.

The mean body weights at 5th weeks of age were 740.05±2.39, 849.96±2.53, 910.05±2.96, 789.93±3.76 g respectively in T1, T2, T3 and T4 dietary treatment groups. The data revealed that the mean body weights at 5th weeks of age was significantly highest (P<0.01) T3, followed by T2, T4 and T1 suggesting that the supplementation of diets with amla powder has increased body weight as compared to control group.

The mean body weights at 6th week of age were 994.93±2.29, 1155.05±1.47, 1220.11±2.30 and 1089.87±1.81 g in T1, T2, T3 and T4 groups respectively. The mean body weight at 6th weeks of age followed the similar trend being significantly highest (P<0.01) in T3 followed by T2, T4 and lowest in T1 group.

The mean body weight at 7th weeks of age was 1295.11±3.14, 1490.07±3.84, 1559.88±5.27 and 1410.08±2.46 g respectively in T1, T2, T3 and T4 respectively. It was found that the mean body weights were significantly highest (P<0.01) in T3 followed by T2, T4 and lowest in T1.

The mean body weights at 8th week of age were 1680.11±4.58, 1849.83±3.81, 1995.11±3.23 and 1779.88±2.82 g respectively in T1, T2, T3 and T4. The perusal of data revealed that the mean body weights at 8th week of age was significantly highest (P<0.01) in T3 followed by T2, T4 and lowest in T1 group

IV. SUMMARY AND CONCLUSION

- To study the effect of feeding of amla powder on growth performance of broiler chicks
- Tassess the effect of feeding amla powder on feed intake and nutrient utilization in broiler chicks
- To study the effect of feeding amla powder on carcass characteristics of broiler chicks.
- To find out the economics of dietary supplementation of amla powder in broiler chicks.
- In the present study amla powder was supplemented with 0.5, 1.0 and 1.5 % of the diet and effect of supplementation was studied on the growth nutrient utilization and carcass traits of the broiler chicks. The results of the research work are summarized as under

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Increasing Solar Radiation Use Efficiency (RUE) of Maize (*Zea mays* L.) through Arranging the Layout of Several Intercrop Plants

Rizhanda Adi Fortuna[1], Agus Suryanto[2*], Sitawati[2]

[1]Department of Agronomy, Postgraduate Program, Faculty of Agriculture, Brawijaya Univesity, Malang, Indonesia
[2]Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang, Indonesia

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Abstract— *Maize plants grown in monoculture system that often cannot utilize sunlight optimally. Intercropping methods with several C3 intercrops such as rice, soybeans, and bambara groundnuts are expected to enhance the solar radiation use efficiency (RUE) of maize plants. This study aims to improve the solar radiation use efficiency (RUE) of maize (Zea mays L.) through the arrangement of various intercrops layouts. The experiment was conducted from July to November 2021 at the Faculty of Agriculture Experimental Field, Jatimulyo, Malang, East Java. The experiment consisted of Split Plot Design (SPD) with Orthogonal Contrasts for control treatments. The main factor consisted of the type of companion crops, such as rice, soybeans, and bambara groundnuts, while the second factor was the companion crop layout, consisting of three level: one row, two rows, and three rows. The results showed that the intercropping pattern with two rows of soybeans produced the highest land equivalent ratio (LER) value of 1.38 compared to other treatments. Additionally, the intercropping system generally provided the highest interception and solar radiation use efficiency of 94.07% and 6.19%, respectively, where the companion crop treatments in one and two rows each yielded the highest RUE values of 6.88% and 6.43%. Based on the research conducted, it was concluded that the arrangement of intercrop plant layouts in the intercropping system can enhance solar radiation use efficiency (RUE) and offer potential optimization of space and resources in agricultural systems.*

Keywords— ***Radiation use efficiency, intercropping, intercrop patterns, intercrop plant, maize.***

I. INTRODUCTION

Autotroph plants utilize solar energy in the photosynthesis process to convert it into chemical energy. The efficiency of solar energy conversion into chemical energy is measured as the percentage of solar radiation energy converted into chemical energy (Lawlor, 2001). The solar radiation use efficiency (RUE) of C3 plants reaches up to 9.4%, whereas C4 plants can achieve up to 12.3%. This efficiency is influenced by genetic and environmental factors, including the selection of superior varieties and optimal cultivation systems. Inadequate cultivation systems, such as suboptimal plant population and the use of varieties that are unresponsive to radiation intensity, can reduce solar radiation use efficiency (Zhu et al., 2010).

Maize (Zea mays L.) is a C4 plant that is more efficient in using CO2 for photosynthesis. Generally, maize is grown in monoculture, which leads to suboptimal utilization of sunlight. Increasing the efficiency of solar radiation energy conversion can be achieved through intercropping methods. This method increases plant population, reduces unused sunlight, and optimizes the space between main crops (Sugito, 2009). Additional benefits of this method include improved soil fertility and reduced plant pests (Aisyah and Herlina, 2018).

The selection of plant species in intercropping systems is crucial because the solar radiation requirements vary among plants. For example, the solar radiation use efficiency of maize reaches 1.6 g MJ-1, higher than sorghum, rice, and wheat (Aznur, 2017). Specific plant species selection and optimal layout are also necessary to enhance RUE, as reported by Suryanto (2018), where intercropping between potatoes and kidney beans increased RUE by 1.84% compared to monoculture, which was only 1.24%. Increasing plant population in kidney bean intercropping with higher companion crop density also improved RUE by 12-36% compared to lower densities.

Efforts to increase RUE can be made by intercropping between C4 plants like maize and C3 plants such as upland rice, edamame soybeans, and bambara groundnuts. This combination utilizes the solar radiation intensity transmitted by the taller maize morphology to lower C3 plants like rice. Additionally, the intercropping pattern between non-legume C4 plants and leguminous C3 plants like soybeans and bambara groundnuts, which have shrub-like and low habitus, can provide complementary effects. These include utilizing the transmitted solar radiation from maize and the addition of nitrogen nutrients from Rhizobium bacteria fixation in the roots of soybeans and Bambara groundnuts.

Based on the above explanation, it is expected that intercropping between C4 and C3 plants can increase the efficiency of solar radiation energy conversion on maize fields. The aim of this experiment is to obtain information on the types of companion crops that can enhance interception efficiency and solar radiation use efficiency in different intercropping layout.

II. MATERIALS AND METHOD

2.1 Experimental Detail

The experiment was conducted from July to November 2021 at the Faculty of Agriculture Experimental Field in Jatimulyo, Malang, East Java. The experiment utilized a Split Plot Design (SPD) and Orthogonal Contrasts for control treatments. The treatments consisted of the type of companion crops as the first factor and the companion crop pattern as the second factor, with the following details:

K = Maize monoculture (control)

Main plots were the three types of companion crops among the maize plants, which included:

T1 = Upland rice

T2 = Edamame Soybeans

T3 = Bambara groundnuts

Subplots were the population of companion crops among the maize plants, consisting of three levels of companion crop patterns:

P1 = One row

P2 = Two rows

P3 = Three rows

The combination of the two treatment factors resulted in 9 treatment combinations with 1 control treatment and 3 replications, which is obtained the total of 30 experimental units.

The data were analyzed using combined analysis of variance (ANOVA) (F-test) at a 5% significance level to determine the effects of the treatments. If significant effects were found, the analysis was followed by the Honestly Significant Difference (HSD) test at a 5% significance level.

2.2 Field Experiment

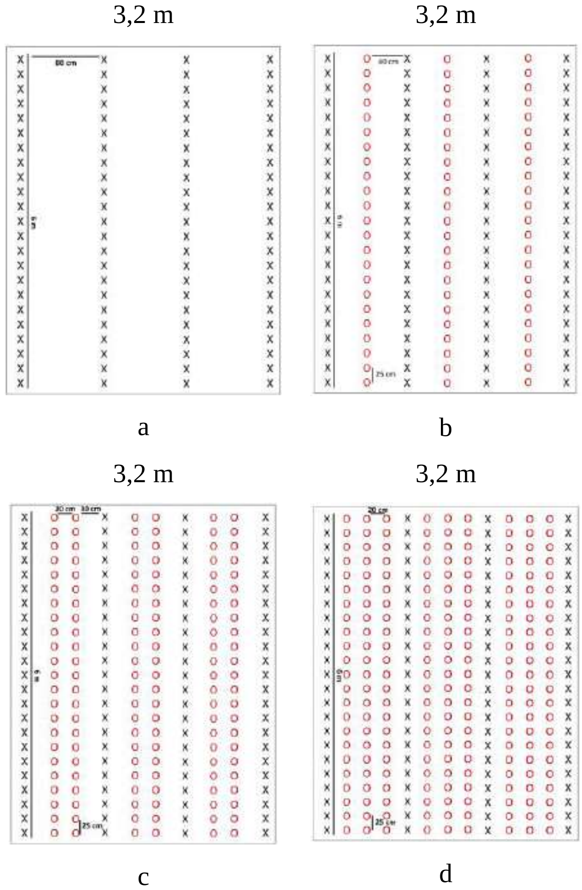

Fig.1: Layout of the number of intercrop plant rows (O) among maize plants (X): a. control (no intercrop), b. one row, c. two rows, d. three rows.

The experimental site was at an elevation of 450 meters above sea level, with an air temperature of 23°C - 25°C and regosol soil type. The annual rainfall was approximately 2447 mm.year^{-1}. Maize and companion crop seeds were planted using four planting layout methods according to the treatments. Maize was planted in monoculture (control) and intercropping systems as a main plant with a planting distance of 80 x 25 cm. Each companion crops were planted in planting holes prepared according to the following planting distances: one row at 80 cm x 25 cm; two rows at 20 cm x 25 cm and 60 cm x 25 cm; three rows at 20 cm x 25 cm, 20 cm x 25 cm, and 40 cm x 25 cm. The planting layout illustration presented in Figure 1.

The materials used in this experiment included BISI-18 maize seeds, Inpago 9 upland rice seeds, Edamame soybean seeds, Bambara groundnut seeds, urea fertilizer (46% N) at a dosage of 250 $kg.ha^{-1}$, and compound NPK fertilizer (15:15:15) at a dosage of 200 $kg.ha^{-1}$. Maintenance activities included weeding, replanting, watering, pest control, and fertilization. Daily solar radiation intensity data were obtained from the nearest climatology station (BMKG Karangploso, Malang, East Java), while daily solar radiation interception data were collected using a lux meter.

2.3 Observation

Plant observations included monitoring the maize growth observations, harvest observations, and solar radiation efficiency observations. The growth observation variables comprised plant height, number of leaves, leaf area, and leaf area index at 58 days after planting (DAP); total dry weight up to 72 DAP; and plant growth rate up to 58 DAP. Harvest observations included maize yield and land equivalent ratio (LER). The land equivalent ratio (LER), according to Guritno (2011), was used to determine land use efficiency in the intercropping pattern using the following formula:

$$\text{LER} = \frac{\text{Yi}}{\text{Yj}} + \frac{\text{Xi}}{\text{Xj}}$$

Explanation:

Yi: production of crop a in intercropping system a and b

Xi: production of crop b in intercropping system a and b

Yj: production of crop a in monoculture

Xj: production of crop b in monoculture

The solar radiation observations included interception efficiency at 58 days after planting (DAP) and radiation use efficiency at harvest. Interception efficiency (IE) indicates the percentage of solar radiation captured by the plant canopy (Sugito, 2009), which is calculated using the following equation:

$$\text{Ei} = \frac{\text{Ij} - \text{Il}}{\text{Ij}} \text{x } 100\%$$

Explanation:

Ij: Amount of solar radiation falling on a plant canopy

Il: Amount of radiation passing through the plant canopy

Radiation use efficiency (RUE) is the percentage of solar energy falling on the plant that can be converted into carbohydrate energy from photosynthesis, which is contained in the plants dry matter (Sugito, 2009). The equation for RUE according to Yoshida (1981) is as follows:

$$\text{RUE} = \frac{\Delta \text{W.K}}{\text{I.t.PAR}} \text{x}100\%$$

Explanation:

ΔW: Difference in plant dry weight (g) per m^2 over a given time period

K: Coefficient of heat combustion (4,000 cal g^{-1})

I: Daily solar radiation intensity (cal m^{-2} day^{-1})

t: A specific time period (days)

PAR: Photosynthetic Active Radiation (0.45)

III. RESULT & DISCUSSION

3.1 Growth Observation

Based on the analysis of variance results for the variables of plant height, number of leaves, leaf area, and leaf area index, there were no significant differences between the monoculture and intercropping treatment at 30-58 days after planting (DAP). The average plant height, number of leaves, leaf area, and leaf area index of maize plants due to the treatment of intercropping plant types and intercropping patterns at 58 DAP are presented in Table 1.

Observation results generally indicate that the variance analysis of each factor in the treatment of intercropping plant types and intercropping patterns did not significantly affect the height of maize plants from 30 to 58 DAP. However, the average height of maize plants under the treatment of intercropping plants and intercropping plant populations continued to increase up to 58 DAP.

Table 1. The Effect of Intercropping Plant Types and Intercropping Patterns on Several Growth Components.

Treatments	Plant Height (cm.plant^{-1})	Number of Leaves (sheet.plant^{-1})	Leaf Area (cm^2.plant^{-1})	Leaf Area Index
Monoculture	201,00	11,33	5822,83	2,91
Intercropping	202,22	11,37	6173,87	3,09
Intercrop Plant Type				
Rice	193,72±18,41	11,39±0,93	6319,17±897,69	3,16±0,45
Soybean	205,94±14,68	11,11±0,65	6176,22±738,89	3,09±0,37
Bambara Groundnut	202,67±15,93	11,61±0,65	6026,22±968,54	3,01±0,48
LSD 5%	ns	ns	ns	ns
CV (%)	8,73	9,54	12,05	12,05
Intercropping Pattern				
One Row	208,39±13,88	11,67±0,79	6672,00±721,19	3,34±0,36
Two Rows	197,44±20,64	11,39±0,55	6154,00±941,60	3,08±0,47
Three Rows	196,50±13,47	11,06±0,85	5695,61±628,11	2,85±0,31
LSD 5%	ns	ns	ns	ns
CV (%)	5,02	6,32	13,11	13,11

Note: Values are based on the mean ± standard deviation; ns = not significantly different based on the 5% LSD test.

Total dry weight variable of maize plants based on analysis of variance indicate that there are differences between monoculture and intercropping treatments with intercropped plants on the total dry weight of maize plants at 72 DAP. In the intercropping treatments, there is an interaction between the type of intercropped plant and the intercropping pattern affecting the dry weight of maize plants at 58 and 72 DAP. The average dry weight of maize plants due to the interaction between the type of intercropped plant and the intercropping pattern is presented in Table 2.

Table 2. Total Dry Weight of Maize Plants Average Due to the Interaction of Intercropping Plant Types and Intercropping Patterns

Treatments	Total Dry Weight of Maize Plants (g.plant^{-1})	
	58 DAP	72 DAP
Monoculture	258,01	324,33 A
Intercropping	252,79	425,18 B
Intercrop with Rice		
One Row	282,67 b	370,64 ab
Two Rows	311,78 b	446,59 abc
Three Rows	269,62 b	413,96 abc
Intercrop with Soybean		
One Row	244,09 ab	445,84 abc
Two Rows	255,99 b	441,48 abc
Three Rows	159,53 a	336,47 a
Intercrop with Bambara		
One Row	275,62 b	499,37 bc
Two Rows	229,97 ab	539,37 c

Three Rows	245,86 ab	332,91 a
LSD 5%	90,14	136,27
CV (%)	12,43	11,46

Note: Values followed by the same letter in the same column indicate no significant difference (uppercase letters for Orthogonal Contrast test and lowercase letters for 5% LSD test); DAP = Days After Planting.

The observations in Table 2 indicate that at 58 DAP, the dry weight of maize plants in the soybean intercropping treatment showed an increase of 60.47% in the two-row population compared to the three-row population, though there was no significant difference compared to the one-row population. At 72 DAP, the intercropping treatment with companion plants increased the dry weight of maize by 31.67% compared to the monoculture maize treatment. The total dry weight of maize in rice and soybean intercropping did not show significant differences among the intercropping patterns. The bambara groundnut intercropping treatment in the two-row and one-row populations did not show significant differences but resulted in a higher total maize dry weight of 62.02% and 50.00%, respectively, compared to the three-row population. Fewer plant populations and wider planting distances reduce competition among plants in terms of nutrient and water absorption. Kholid et al. (2023) stated that wider planting distances between soybeans and maize can reduce the level of competition in absorbing nutrients and light for the photosynthesis process. Xia et al. (2013) added that closer planting distances cause the roots of maize and legumes like soybeans to intermingle, leading to competition for utilizing the nitrogen fixation products from legume plants.

The results of variance analysis indicated that there were differences between monoculture maize treatments and intercropping with secondary crops in terms of maize growth rate at the ages of 30-44 days after planting (DAP) and 44-58 DAP. Additionally, among the intercropping treatments, there was no interaction between the type of secondary crop and the pattern of secondary crop planting at any observation age. The average growth rate of maize plants influenced by the type of secondary crop and the pattern of secondary crop planting is presented in Table 3.

Table 3. Growth Rate of Maize Plants Due to the Influence of Intercrop Plant Type and Intercropping Pattern.

Treatments	Maize Growth Rate ($g.m^{-2}.day^{-1}\ plant^{-1}$) at DAP	
	30-44	44-58
Monoculture	28,53 A	57,83
Intercropping	35,94 B	47,76
Intercrop Plant Type		
Rice	32,39 a	63,46 b
Soybean	36,83 ab	35,18 a
Bambara Groundnut	38,59 b	44,64 a
LSD 5%	4,83	11,69
CV (%)	8,16%	14,27%
Intercropping Pattern		
One Row	37,36	51,33 b
Two Rows	32,83	55,81 b
Three Rows	37,62	36,14 a
LSD 5%	ns	13,36
CV (%)	14,52%	22,78%

Note: Values followed by the same letter in the same column indicate no significant difference (uppercase letters for Orthogonal Contrast test and lowercase letters for 5% LSD test); DAP = Days After Planting; ns = not significantly different based on the 5% LSD test.

Maize growth rate at the age of 30-44 days after planting (DAP) in the intercropping treatment increased by 25.97% compared to the monoculture treatment. The treatment with bambara groundnut as the secondary crop did not differ from the treatment with soybean as the secondary crop, but it resulted in a 19.14% higher growth rate of maize compared to the rice secondary crop. Bambara, as a legume plant, supplies nitrogen to the soil through nitrogen fixation and increases light interception. Raza et al. (2022) showed that intercropping maize with soybeans also increases the maize growth rate through similar mechanisms.

The treatment with rice as the secondary crop also did not show any difference in the growth rate of maize compared to the soybean crop. The treatment with rice as the secondary crop resulted in a maize growth rate at the age of 44-58 DAP that was 80.39% and 42.16% higher than the treatment with soybean and bambara groundnut as secondary crops, respectively, likely due to lower competition for growing space. The one-row and two-row planting patterns are more effective in increasing the maize growth rate compared to the three-row pattern. Wider planting distances reduce competition for water and nutrient absorption, consistent with Marliah (2010), who stated that closer planting distances can decrease the growth and yield of sweet maize due to more intensive competition for necessary resources. However, there was no difference in the growth rate of maize between the soybean and bambara groundnut secondary crops. The treatment with single-row and double-row patterns of secondary crops resulted in maize growth rates that were 54.43% and 42.03% higher, respectively, compared to the single-row pattern treatment.

Based on the overall comparison results of intercropping treatment with monoculture, the intercropping system yields better results compared to monoculture in terms of maize dry weight and crop growth rate during the peak vegetative phase. This indicates a better influence of legumes and rice in intercropping, which fill the growing space between the main plants, inhibit weed growth, and contribute nitrogen availability to the maize plant roots. According to Rasool et al. (2021), the synergy between maize and intercrops can inhibit weed growth by reducing the sunlight available to weeds and providing nitrogen in the soil through nitrogen fixation by legume plants. The study by Raza et al. (2022) also supports that intercropping maize with soybeans increases the growth rate of maize by enhancing light use efficiency, water use efficiency, and the benefits of soybean's nitrogen-fixing ability.

3.2 Yield Observation

Based on analysis of variance results indicate that there are no differences between the monoculture and intercropping systems in terms of the average dry weight of maize kernels. Additionally, there was no interaction between the type of companion plant and the intercropping pattern on the average kernel production of maize plants. The average production of maize plants due to the treatment of companion plant types and intercropping patterns is presented in Table 4.

Table 4. Average Production of Dry Kernel Maize Crops Due to Treatment of Intercropping Types with Intercropping Pattern.

Treatments	Dry Yield of Maize Kernel per hectare (ton.ha^{-1})
Monoculture	9,24
Intercropping	8,92
Intercrop Plant Type	
Rice	8,82±0,86
Soybean	8,60±1,57
Bambara Groundnut	9,34±0,60
LSD 5%	ns
CV (%)	10,28%
Intercropping Pattern	
One Row	8,54±1,25
Two Rows	9,54±0,90
Three Rows	8,67±0,93
LSD 5%	ns
CV (%)	9,55%

Note: Values are based on the mean ± standard deviation; ns = not significantly different based on the 5% LSD test.

Based on observations from Table 4, the variance analysis of each factor shows that maize production did not show significant differences between intercrop types and planting patterns, nor between intercropping and monoculture systems. This is due to the dominance of maize plant growth compared to intercrops and the same maize plant population in each treatment. Fitriana (2014) found that planting maize with soybeans at different plant densities did not show differences in production per unit area. Although there were no differences in maize kernel production among the treatment factors, the type of companion plant treatment with different intercropping patterns can be beneficial when viewed from the Land Equivalent Ratio (LER). The production of monoculture and intercropped maize and companion plants, as well as the LER, are presented in Table 5.

Monoculture maize plant tends to produce higher dry seed yield compared to rice and soybeans in various populations, except for the soybean and also bambara treatments in the two-row population, which yielded higher results. LER calculations show that all planting patterns yield an LER greater than 1, except for the rice and soybean one-row planting pattern. Rice and soybean in the one-row pattern tend to gives lowest yield and LER compared to other treatments.

Most treatments resulted in an LER (Land Equivalent Ratio) of more than 1, indicating that intercropping systems are more productive and efficient in land use compared to monoculture. The highest LER was achieved by two-row soybean intercropping, followed by two-row bambara, which according to Sija et al. (2022), is due to the complementary effects on the canopy structure that increase solar radiation absorption and plant biomass accumulation. A decrease in LER occurred in three-row soybean and bambara intercropping, caused by higher intercrop density and closer planting distances to maize plants, leading to competition for growing space and suboptimal sunlight distribution. Parimaladevi et al. (2019) stated that the solar radiation received by legume plants is obstructed by the taller morphology of maize plants, reducing legume photosynthesis and yield.

Table 5. Average Production and Land Equivalent Ratio (LER) of Maize Crops and Intercrops Plant Due to Monoculture and Intercropping Treatment.

Intercrop Plant and Pattern	Average Dry Seed Yield per hectare (ton.ha^{-1})				LER
	Maize	Rice	Soybean	Bambara	
Monoculture	9,24	5,2**	6**	2,31**	
Intercropping					
One Row Rice	8,59	0,29	-	-	0,99
Two Rows Rice	8,87	0,31	-	-	1,02
Three Rows Rice	8,98	0,58	-	-	1,08
One Row Soybeans	7,67	-	0,79	-	0,96
Two Rows Soybeans	10,28	-	1,63	-	1,38
Three Rows Soybeans	7,85	-	1,23	-	1,06
One Row Bambara	9,36	-	-	0,25	1,12
Two Rows Bambara	9,46	-	-	0,71	1,33
Three Rows Bambara	9,18	-	-	0,53	1,22

**) Average monoculture intercrop plant dry seed yield is obtained from monoculture planting on the same field area.

3.3 Solar Radiation Observation

Results of the variance analysis indicate that there is a significant difference between the treatment of maize plants grown in monoculture and maize plants grown in intercropping systems to interception efficiency at 86 DAP (Days After Planting). However, in intercropping treatments, there is no interaction between the type of intercrop and the intercrop pattern on the interception efficiency of maize and intercrops. The variance analysis results for each factor show that the treatment of intercrop type and the treatment of intercrop pattern do not have a significant effect on interception efficiency. The interception efficiency data due to the treatment of intercrop type and intercrop pattern are presented in Table 6.

Tabel 6. Solar Interception Efficiency and Radiation Use Efficiency Due to Treatment of Intercrop Plant and Intercrop Patterns.

Treatments	Radiation Interception Efficiency (%)	Radiation Use Efficiency (%)
Monoculture	88,02 A	4,59 A
Intercropping	94,07 B	6,19 B
Intercrop Plant Type		
Rice	92,26	6,22
Soybean	95,97	6,05
Bambara Groundnut	93,98	6,30
LSD 5%	ns	ns
CV (%)	2,41%	22,61%
Intercropping Pattern		
One Row	93,75	5,25 a
Two Rows	94,56	6,88 b
Three Rows	93,89	6,43 b
LSD 5%	ns	1,13
CV (%)	1,49%	15,64%

Note: Values followed by the same letter in the same column indicate no significant difference (uppercase letters for Orthogonal Contrast test and lowercase letters for 5% LSD test); DAP = Days After Planting; ns = not significantly different based on the 5% LSD test.

Observations in Table 6 show that intercropping treatments of maize with several types of intercrops planted in various intercrop patterns can increase interception efficiency by 6.87% higher compared to the monoculture planting system, although there are no significant differences between intercrop types or planting patterns. Maize plants in intercropping systems show more optimal growth, with dominant plant canopies in receiving sunlight. Brooker (2015) stated that the top canopy layer in intercropping systems tends to dominate solar radiation interception, while shorter plants utilize the radiation transmitted to the ground. Liu et al. (2022) added that the larger leaf area of maize plants can increase solar radiation interception.

There is also a difference between monoculture maize treatment and intercropping treatment with intercrops plant on RUE at harvest time based the results of analysis of variance. Intercropping treatment can provide interaction between the type of intercrop and the intercrop pattern on solar radiation radiation use efficiency. The variance analysis results for each factor show that the intercrop pattern significantly affects the solar radiation radiation use efficiency of maize at harvest time. Intercropping treatment can provide an RUE (Radiation Use Efficiency) result of 34.86% higher compared to monoculture treatment. The two-row and three-row intercrop patterns can provide solar radiation use efficiency results of 30.86% and 22.44% higher, respectively, compared to the one-row treatment. RUE is higher in the intercropping system, especially in the two-row planting pattern, which shows an increase in plant biomass accumulation per unit area due to the more efficient use of solar radiation in intercropping and increased diffused light. Arina (2021) found that intercropping maize with legumes increases RUE compared to monoculture because the plant canopy covers the ground well, reducing escaping solar radiation. Raza (2019) also noted that planting distance arrangements in intercropping systems can increase dry weight accumulation and radiation use efficiency.

IV. CONCLUSION

This research indicates that the intercropping system can achieve higher values of solar Interception Efficiency (IE) and Radiation Use Efficiency (RUE), with increases of 6.87% and 34.86% respectively, compared to the monoculture system. Land Equivalent Ratio (LER) reached its highest value in the treatment with intercropped soybean and two-row bambara, which was followed by an increase in solar RUE of 31.05% higher in the two-row intercropping pattern compared to the one-row treatment.

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Forecasting of Dam Lake Water Level Using M5 Decision Tree and Anfis Models

Özden Nur Şentürk*, Fatih Üneş, Mustafa Demirci, Bestami Taşar

Department of Civil Engineering, Iskenderun Technical University, Türkiye
*Email: ozdennursenturk@gmail.com

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***Abstract*—Dam reservoir level prediction is important for dam construction, operation, design and safety. In this study, dam reservoir level change predictions were investigated using the M5 Decision Tree (M5 Tree) and Adaptive Neural Fuzzy Inference System (ANFIS) models. For modeling the daily dam reservoir water level (t), the lagged time of reservoir water level (t-1), stream flow (t) and precipitation heights in the dam basin (t) were used. The model results were compared with the results of conventional multiple linear regression (MLR) models. The models were analyzed with graphical and statistical results. The coefficient of determination (R^2), root mean square error (RMSE) and mean absolute error (MAE) performance criteria were taken into account when comparing the prediction models. The results showed that M5 Tree and Anfis model results gave a better performance in predicting the dam reservoir level change.**

Keywords*—Dam Reservoir Level, Fuzzy, Modelling, Prediction, Regression.

I. INTRODUCTION

The contents of each section may be provided to understand easily about the paper. Reservoirs and dams are essential to the management of water resources. In addition to providing water to cities, they are also employed in the production of hydroelectric power, flood control, and agricultural irrigation. A multipurpose water storage facility must have its reservoir or dam level regularly monitored in order to make the necessary modifications on time and to ensure maximum performance. In the field of water supply management, one of the most difficult jobs for planners and operators is forecasting water levels.

Control of water volume in the dam reservoir is achieved by accumulating and distributing water at the right time. Due to the precautions not taken in time and water-related problems, there may be loss of life and property. Therefore, proper dam reservoir management is a necessity not only in terms of freshwater supply but also in terms of preventing possible damages. One of the basic conditions for the most effective management of dam reservoirs is to determine the dam reservoir water volume and to be able to predict the ups and downs in this volume.

The first studies to determine the dam reservoir capacity were made by Ripple [1] and Sudler [2]. Since those studies, many researchers have used classical and traditional methods in dam reservoir studies. Sudheer and Jain [3] tried to explain the internal behavior of artificial neural networks with river flow models. Sudheer [4] tried to create river models with information extracted from trained neural networks. Üneş [5] and Unes et al [6] tried to determine the dam reservoir level changes with artificial intelligence techniques. In these methods, the reservoir volume is defined as the conservation of mass (continuity equation) at the macro scale in hydraulic research systems. In past studies on the water level and volume in lakes, the stability of the annual level of water was generally used by considering the mass-volume methods and statistical methods.

An earlier study used artificial neural networks (ANN) in conjunction with tree-based models, including decision trees (M5T), random forests (RF), and gradient-boosted trees (GB), to predict the dam intake into the Soyang River Dam in South Korea [7]. Research showed that an ensemble method, which merges the RF/GB forecasts with a multilayer perceptron (MLP), might outperform the use of a single individual model. The Upo wetland in South Korea serves as another example of the predictive power of tree-based approaches. In comparison to ANNs, DTs, and support vector machines (SVM), RF was found to have the best forecast accuracy [8].

To estimate the water level of Lake Erie, other techniques such as the Gaussian process (GP), multiple linear regression (MLR), and k-nearest neighbor (KNN) have also been compared to tree-based and ANN models [9]. Their findings demonstrate how machine learning techniques, particularly the MLR and M5P model tree, outperformed the process-based advanced hydrologic prediction system (AHPS) in terms of accuracy and training speed [10].

In this study, forecasting models were developed for the dam lake water level. In the forecasting models, stream flow, precipitation amount falling in the basin and shifted lake water level were used as independent variables. M5 Decision Tree (M5 Tree), which is one of the machine learning techniques that show superior performance in nonlinear problems, and Adaptive Neuro Fuzzy Logic (ANFIS) models, which is a hybrid method working with Fuzzy logic algorithm, were used.

II. MATERIAL AND METHODS

Study Area

The study location is Lake Tuscaloosa, which is located close to Tuscaloosa, Alabama, USA. (Figure 1) By damming the North River, a reservoir known as Lake Tuscaloosa was formed in west-central Alabama. Thornton Jones built it to supply water to Tuscaloosa citizens as well as for industrial purposes. At a cost of around $7,725,000, it was finished in 1970. The lake is a popular spot for outdoor enjoyment because it's close to Northport and Tuscaloosa. When Tuscaloosa's population grew and its two existing reservoirs, Harris Lake and Lake Nicol, could no longer hold enough water, the city built Lake Tuscaloosa. By building a dam on the North River, the region that would eventually become Lake Tuscaloosa was flooded.

Fig.1: Study area

The data used in this study were obtained by the United States Geological Survey (USGS). Streamflow (Q, m3/s), precipitation height in the basin (P, cm) and Lake Water Level (LWL, m) variables were used in the estimation models. The daily change in the LWL variable of the Tuscaloosa reservoir between 2018-2021 is given in Figure 2.

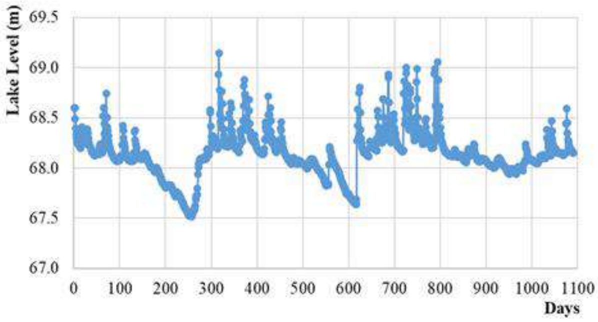

Fig.2: Daily lake water level change

Methods

Multiple Linear Regression (MLR)

Multiple Linear Regression analyses are among the methods used to model the relationship between two or more variables according to the cause-effect relationship. If a single independent variable is used as an input in the model established to estimate the dependent variable, it is called single regression, and if more than one independent variable is used, it is called multiple regression analysis. In the MLR method, the effect of independent variables on dependent variables is expressed with the regression coefficient in the equation. This coefficient shows the degree of effect of independent variables on the dependent variable in the regression equation. Multiple Linear Regression is given in Equation 1

$$Y_i = (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n) + \varepsilon_i \qquad (1)$$

This equation contains linear expressions. In this equation, Xi (i = 1, …, n) independent variables, Yi dependent variable, β regression coefficient and ε represents the error.

M5 Decision Tree (M5 Tree)

M5 Tree was first proposed by Quinlan [11] This method results in the estimated value of the dependent variable in a fast, practical and understandable way. It is a versatile logical model. It is a guide on how to deal with numerical data and missing data values. It is quite fast and produces understandable outputs that are very accurate at very high rates. This situation is explained by the robust and versatile operation of decision tree learning that can cope with the demands of real-world data sets. (Witten et al. [12]). The M5T algorithm creates a regression series by repeatedly dividing the sample space using tests on a single feature that maximizes the variance in the target space. The mathematical equation for calculating the standard deviation reduction (SDR) is given in Equation 2

$$SDR = sd(T) - \sum \frac{|T_i|}{|T|} sd(T_i) \quad (2)$$

Adaptive Neuro Fuzzy Inference System (ANFIS)

An adaptive network-based fuzzy inference system (ANFIS) is used as an artificial neural network method based on a fuzzy inference system. ANFIS model was developed by Jang since the early 1990s and is used in modeling nonlinear functions and estimating chaotic time series [13-14]. ANFIS consists of nodes directly connected and each node represents a processing unit [15]. Since ANFIS uses both artificial neural networks and fuzzy logic inference methods, it uses a hybrid learning algorithm [16]. There are two approaches to fuzzy inference systems. These approaches are the approach of Mamdani and Assilian, Takagi and Sugeno [17]. To apply an adaptive neuro-fuzzy inference system (ANFIS), data sets with input and output are generally needed. The ANFIS method finds the best values for the membership functions of fuzzy sets by training the model with the principle of reducing errors. It also creates fuzzy rules for FIS. The structure of the Adaptive Neural Inference System (ANFIS) is shown in Figure 2. Here; "x, y, z, t" are our independent variables, "a1, a2, b1, b2, c1, c2, d1, d2" are the input parameters, "∏ (pi)" are the membership functions, "N" are the rules and "wi" are the weights of the parameters.

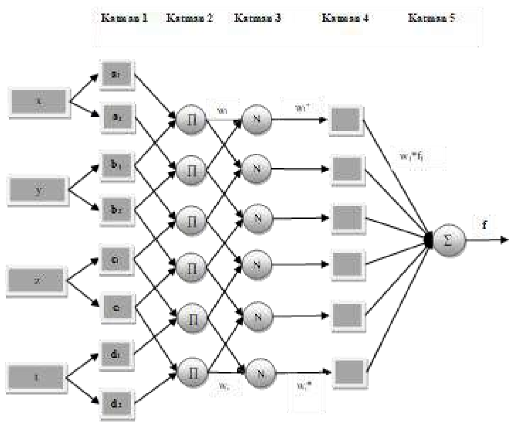

Fig.4: ANFIS model with four inputs and one output.

In Figure 4; in the 1st layer, the membership function is selected, and the membership levels of the linguistic variables are determined. In the ANFIS model of this study, the number of membership functions is two for each independent variable. In the 2nd layer, all nodes in the second layer are fixed nodes indicated by the symbol "∏". The products of the outputs of the first layer represent the resulting fuzzy rules. In the 3rd layer, here too, the nodes in the layer are fixed nodes and indicated by the symbol "N". ANFIS normalizes the values in the network structure. These values are taken as output. In the 4th layer, all nodes in this layer are normalized nodes and the weight values (w) coming from the third layer are multiplied by the first-degree polynomial equation. "w1*f1" is the layer output. In the 5th layer, there is only one fixed node in this layer. It gives the total result of all the operations coming as "Σ".

III. RESULTS

In the model analysis, the first 75% of the total data set (1091) was used as training data and the last 25% (273) as test data. For the 273-day test data; MLR, M5 Tree and Anfis model's performances were evaluated using statistical criteria (RMSE, MAE and R^2). For each model, mean absolute error (MAE), root mean square error (RMSE), and coefficients of determination (R^2) between model predictions and measured values were used and the statistical criteria used are given in the equations below. Table 1 shows model performance comparisons as a result of the analysis.

$$RMSE = \sqrt{\frac{1}{N}\left(\sum_{i=1}^{N} LWL_{measurement} - LWL_{prediction}\right)^2} \quad (3)$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|LWL_{measurement} - LWL_{prediction}\right| \quad (4)$$

Table 1. Error information and correlation changes of the models.

Model	Model Inputs	MAE (m)	RMSE (m)	R^2
MLR	Q(t), P(t) ve LWL(t-1)	0.024	0.030	0.957
M5 Tree	Q(t), P(t) ve LWL(t-1)	0.010	0.018	0.965
Anfis	Q(t), P(t) ve LWL(t-1)	0.009	0.016	0.971

MLR Results

In the MLR model, stream flow rate (Q(t), m^3/s), precipitation height in the basin (P(t), cm) and offset lake water level (LWL(t-1), m) parameters were used in LWL estimation. The results of the test phase of the MLR method are given as distribution and scatter graphs in Figures 5-6, respectively.

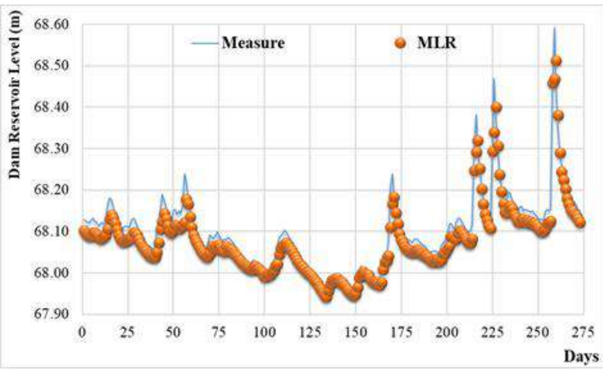

Fig.5: Distribution graph of MLR model

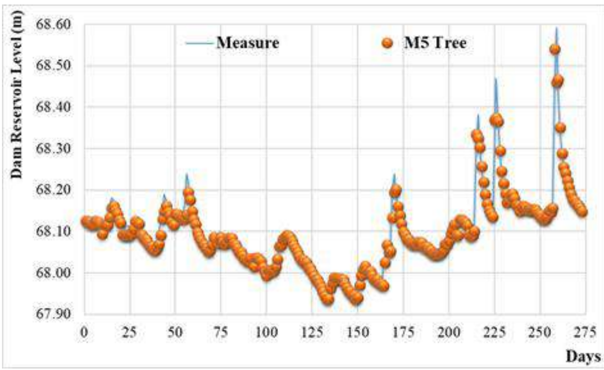

Fig.7: Distribution graph of M5 Tree model

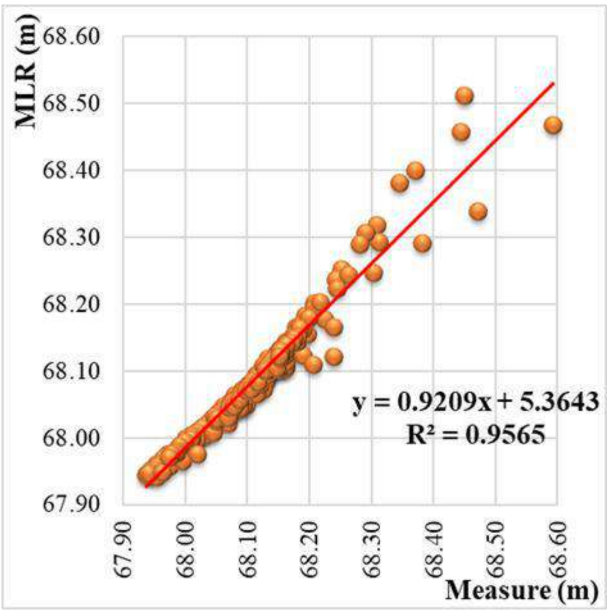

Fig.6: Scatter graph of MLR model

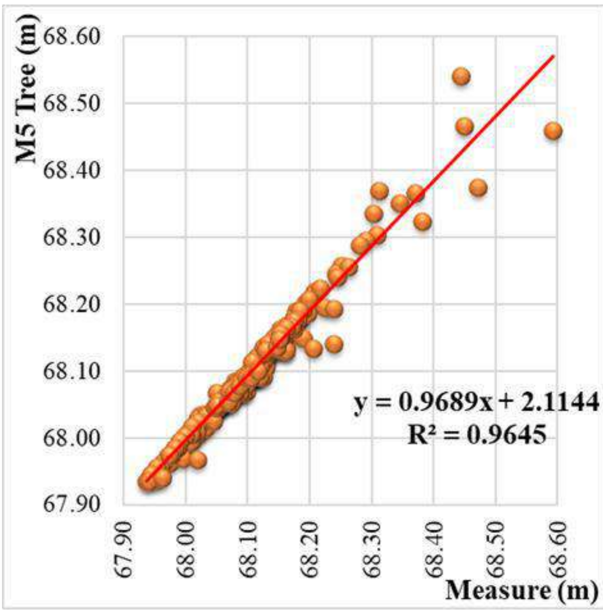

Fig.8: Scatter graph of M5 Tree model

According to the scatter graph (Figure 6) and Table 1, it was seen that the coefficient of determination obtained was R^2 = 0.957. When the MLR model in the test phase was examined, it was determined that it had the lowest determination value. It was determined that some peak LWL amounts gave lower estimates than the actual LWL values in the MLR model. Therefore, it is seen that there is a decrease in the determination values.

M5 Tree Results

In the M5 Tree model (as in the MLR method), LWL was estimated using the stream flow rate (Q(t), m^3/s), precipitation height in the basin (P(t), cm) and offset Lake Water Level (LWL(t-1), m) parameters. The distribution and scatter graphs in the test phase results of the M5 Tree model are given in Figures 7-8, respectively.

According to the distribution and scatter graphs given in Figures 7 and 8, it was obtained that there was a good agreement between the real LWL and M5 Tree estimation results. It was seen from Table 1 and Figure 8 that the coefficient of determination R^2 = 0.965. The M5 Tree method performed better than the MLR method in LWL estimation.

Anfis Results

In the Anfis model (as in the MLR and M5 Tree models), the LWL was estimated using the stream flow rate (Q(t), m3/s), precipitation height in the basin (P(t), cm) and offset Lake Water Level (LWL(t-1), m) parameters. The distribution and scatter graphs in the test phase results of the Anfis model are given in Figures 9-10, respectively

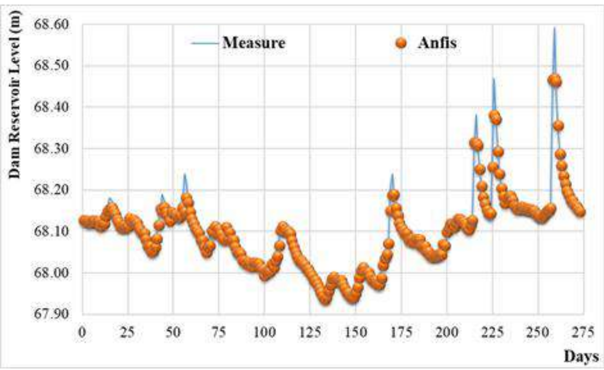

Fig.9: Distribution graph of Anfis model

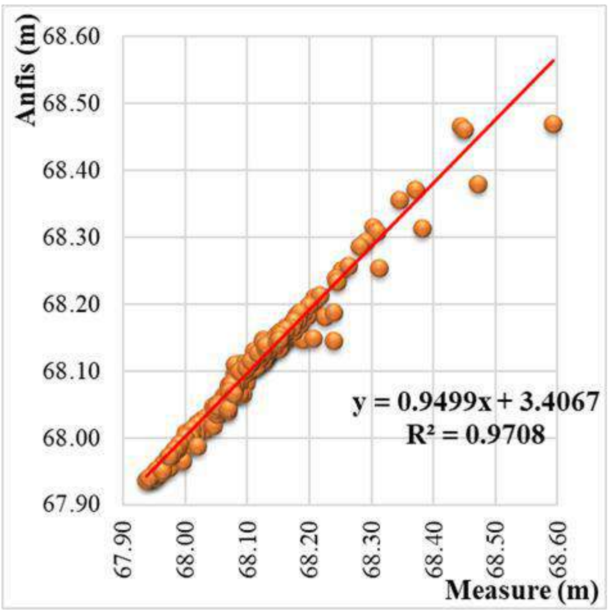

Fig.10: Scatter graph of Anfis model

According to the distribution graph, it was obtained that there was a harmony between the real results and the Anfis estimation results. When Figure 10 and Table 1 were examined, it was seen that the determination coefficient obtained was R^2 = 0.971. It was determined that the Anfis model generally gave estimates closer to the LWL peak values. Therefore, it was seen that there was an increase in the determination values compared to other methods. It was determined that the Anfis results had the best estimation performance for LWL estimations. The results of the Anfis estimation values of the real-time LWL showed better performance than the other model estimates and good estimation results were observed according to the real values. When we look at the MAE, RMSE and R^2 shown in Table 1, the Anfis (0.009; 0.016; 0.971) model showed the best performance compared to the other models.

IV. CONCLUSION

For the purpose of designing and building lakeshore constructions, other industrial operations, and integrated water resources management, it is critical to predict fluctuations in dam reservoir levels. The current study used MLR, M5 Tree, and Anfis models to anticipate dam reservoir Tuscaloosa lake level in the United States. For the performance evaluation of multiple linear regression (MLR), M5 decision tree (M5 Tree) and adaptive network-based fuzzy inference system (ANFIS) models, coefficient of determination (R^2), mean absolute error (MAE), and root mean square error (RMSE) were calculated. From the study, the following conclusions can be made.

As a result of the created models' performance evaluation, all models successfully estimated the reservoir lake level. The results of the MLR method and the M5Tree method showed similar results.

It was seen that the adaptive network-based fuzzy inference system (ANFIS) model was more successful than the other three models due to its lower error values and high coefficient of determination. Compared to the traditional models, the proposed Anfis model yields more accurate estimations of the fluctuations in the reservoir level.

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In Vitro Evaluation of Cholesterol Lowering Properties of Plant Extract, *Trigonella Foenum Graecum* L.

A. Senthilkumar[1]*, M. Padayappa[1], M. Moorthi[2]

[1]PG & Research Department of Zoology, Chikkaiah Naicker College, Erode – 638 004, Tamil Nadu, India.
[2]PG & Research Department of Zoology and Wildlife Biology, AVC College (Autonomous), Mayiladuthurai – 609 305, Tamil Nadu, India
*Corresponding Author

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***Abstract*— *Atherosclerosis is a disorder that causes the inner lining of arterial walls to accumulate lipids, cholesterol, and other chemicals. This restriction of blood flow results in high cholesterol, high blood pressure, high triglycerides, diabetes, obesity, and associated cardiovascular disorders. The current study sought to evaluate the ability of plant extract Trigonella foenum graecum ability to decrease cholesterol in vitro. Plant extracts were used at varying doses to block the activities of enzymes pancreatic lipase, glucose-6-phosphate dehydrogenase, and malic dehydrogenase. The extracts were then sequentially extracted using solvents including methanol, hexane, ethyl acetate, ethanol, and dichloromethane. According to the findings, the ethanol extract had the greatest significant hypolipidemic impact by reducing enzyme activities, and this was followed by the extracts of hexane, dichloromethane, and methanol. The ethyl acetate extracts showed the lowest hypolipidemic activity. These findings imply that the administration of several Trigonella foenum graecum plant extracts may have unique potential cholesterol-lowering qualities for reducing fat absorption via inhibiting pancreatic lipase.*

***Keywords*— Fenugreek, pancreatic lipase, glucose-6-phosphate dehydrogenase, malic dehydrogenase, lipid metabolism.**

I. INTRODUCTION

The hardening of the arteries by an increase in plaque in the inner layer of the artery is known as atherosclerosis. Even though it may not always result in symptoms, high blood cholesterol is one of the primary indicators of risk for heart disease. It has been observed recently that include functional foods in diets might help prevent cardiovascular illnesses (Esposito *et al.*, 2004; Singh *et al.*, 2015; Jan Fedacko *et al.*, 2016). Water soluble fiber diets, including those containing spirulina, oats, and coriander, have been shown to have hypocholesterolemic effects. These diets have also been linked to a significant drop in serum total cholesterol and a decrease in low density lipoprotein without a corresponding reduction in high density lipoprotein (Salas-salvado *et al.*, 2008; Estruch *et al.*, 2013). Cholesterol levels can be influenced by several elements, such as genetics, nutrition and obesity. Maintaining dietary items regarded as nutraceutical functional foods—such as green vegetables, turmeric, peppers, soy products, coriander, bitter gourd, cumin, olive oil, mustard oil, fish, etc. is crucial for decreasing cholesterol. Low density lipoproteins (LDL) and very low density lipoproteins (VLDL) are decreased and high density lipoprotein (HDL) is elevated in the serum when soy, ginger, coriander, and spices are consumed (Lydie and Vilaume, 2001; Pavana *et al.*, 2007; Dhanapakiam *et al.*, 2008).

In many cardiac disorders, it may be advantageous to increase blood levels of high density lipoproteins while reducing levels of low and very low density lipoproteins. Curcumin causes rats that are both normal and hypocholesterolemic to excrete more bile acids in their feces. This suggests that the spice increases the liver's ability to produce bile as well as the process by which cholesterol is converted into bile salts (Dhanapakiam *et al.*, 2008). The effects of *Trigonella foenum graecum* supplementation on several areas of lipid metabolism are poorly studied. The goal of this present work was to use in vitro studies to ascertain the impact of fenugreek on lipid metabolism in light of the significant consequences.

II. MATERIALS AND METHODS

Using distilled water, the gathered plant portion was carefully cleaned to get rid of any dirt or other contaminants. In order to preserve the vibrant green color of the plant components and to stop the breakdown of their active ingredients, they were dried at room temperature. After being dried and ground to a coarse texture, the plant material was sealed in a container that was airtight.

Extraction of *Trigonella foenum graecum* L.

A section of the *Trigonella foenum graecum* L. plants' leaves and stems were gathered from the Chithode neighborhood in the Erode District of Tamil Nadu, India. The stems and leaves of the plant were chopped into small pieces, shadow dried for three days, and then dried for six hours at 60 degrees Celsius in a hot air oven. The plant portions were then ground well into the fine powder using a mill, and the size of the particles ranges from 300 to 400 µm was screened using a sieving machine for future use. Using a Soxhlet device, 50 g of powdered materials were extracted using 95% (v/v) ethanol.

250 ml of solvents, including ethanol, methanol, ethyl acetate, hexane, dichloromethane, and water, were added to the flask's bottom. Using a mantle beneath reflex condensers, all of the solvents were heated for two hours. After the extraction process was finished, the solvents were evaporated using a rotary evaporator at 80°C. In order to prepare the samples for future examination, they were finally gathered, prepared in different concentrations (0.5, 1.0, 1.5, 2.0, and 2.5 mg/ml), and kept at 4ºC (Padayappa *et al.*, 2020).

Inhibition of pancreatic lipase activity

The inhibition activity of pancreatic lipase was used to evaluate the ability of plant extracts to decrease cholesterol (Puneeth *et al.*, 2016). 1 ml of reaction mixtures is comprising one unit of lipase enzyme and 100 ml of phosphate buffer (pH 7.2) containing 0.5% Triton-X-100 was incubated separately with plant extracts. P-nitrophenyle butyrate (5 mM in acetonitrile) was included to initiate the enzyme activity, which was measured at 340 nm. Percentage activity was used to convey the results, and a control was kept in place.

Inhibition of glucose-6-phosphate dehydrogenase activity

By tracking the decrease of NADP at 340 nm, glucose-6-phosphate dehydrogenase activity was determined (Xu *et al.*, 2005). 1 ml of a reaction mixture comprising 0.5 units of enzyme, 50 ml of tris HCl (pH 7.4), and 0.1 ml of glucose-6-phosphate was incubated individually with plant extracts. At 340 nm, the enzyme reactions were monitored after 0.15 mM NADP was added. The control was appropriately kept up to date, and the percentage activity of the findings was reported.

Inhibition of malic dehydrogenase activity

By tracking the decrease of NADP 340 nm, malic dehydrogenase activities were discouraged (Kong *et al.*, 2001). Plant extract was incubated separately in 1 ml of tris HCl (100 mM, pH 7.4) include L-malate (10 mM), $MnCl_2$ (2 mM), and 0.5 unit of malic dehydrogenase enzyme. At 340 nm, the enzyme reactions were monitored after 2.0 mM NADP was added. The control was appropriately kept up to date, and the percentage activity of the findings was reported.

Statistical analysis

Each value was displayed as mean ± SD. Two-way ANOVA was used to evaluate the statistical significance ($p<0.05$), and then a two-tailed Student's t-test was performed.

III. RESULTS AND DISCUSSION

The pancreas secretes the digesting enzyme pancreatic lipase, also referred to as triacylglycerol acylhydrolase. The hydrolyzing enzymes convert dietary fat molecules into triglyceride (Peter Nuhn, 1990). The results of this experiment demonstrated that the activities of pancreatic lipase, glucose-6-phosphate dehydrogenase and malic dehydrogenase were greatest in the ethanol extract meanwhile the lower activities were showed in ethylacetate extract. The pancreatic lipase is more active against short-chain glycerides than long-chain glycerides. According to Yasaman and Sharma (2018), pancreatic lipase plays a crucial part in the mechanism of various medications that are recommended for decreasing cholesterol. One important lipolytic enzyme that catalyzes the breakdown of dietary triglycerides is pancreatic lipase (Lowe, 2002). Pancreatic lipase, which is secreted by pancreatic acinar cells, releases fatty acids that are absorbed in the small intestine and enter the peripheral circulation as chylomicrons. Additionally, lipase inhibition decreases fat absorption by interfering with fat hydrolyses, which decreases the utilization of ingested lipids (Birari and Bhutani, 2007; Seyedan *et al.*, 2015).

The enzyme glucose 6-phosphate dehydrogenase catalyzes the production of fatty acids and cholesterol by converting G6P to 6-phosphogluconolactone and generating NADPH from $NADP^+$. Despite being necessary for lipogenesis, not much has been identified about the possible function of G6PD in adipocytes for energy balance, including glucose and lipid metabolism. The other extracts shown mild and negligible effects on the inhibition of glucose-6-phosphate dehydrogenase, but the ethanol extracts significantly reduced the enzyme's activity at 2.0% concentration (14.00±0.88), resulting in a hypolipidemic impact.

The degree of diabetes generally corresponds with a reduction in the serum activities of malic dehydrogenase (MDH) and glucose 6 phosphate dehydrogenases (G6PDH) (Xu *et al.,* 2005). These enzymes' reduced activity is linked to hyperglycemia. Diminished MDH activity leads to a decreased malate/succinate shuttle mechanism, which modifies the energy metabolism dependent on carbohydrates (Arai et al., 2003). The samples employed in this investigation had varying degrees of impact on the MDH activity in vitro (Table 1). G6PDH activity, however, significantly decreased. It's interesting to note that the remaining samples had no discernible impact on the in vitro activity levels. Since glycolytic enzymes constitute the ultimate energy generation machinery, their activity levels in hepatocytes are hard to change. However, these activity levels are reduced under diabetes circumstances, necessitating the use of alternative glucose-utilizing pathways.

Ono *et al.* (2006) assessed the effect of ethanol and aqueous extracts of *Nelumbo nucifera* leaf on pancreatic lipase inhibition using both in vitro and in animal investigations. The in vivo findings showed that the plasma triacylglycerol levels in the group of rats injected with the plant extract were much lower than those of the control group, and that these levels dramatically increased an hour after the lipid emulsion was orally administered. Kurihara *et al.* (2003) investigated the ability of *Cyclocarya paliurus* water extract (such as leaves) to decrease pancreatic lipase activity. The plant extracts inhibited the activity of pancreatic lipase. Moreover, the extract (250 mg/kg) reduced the plasma triacylglycerol levels in mice that were administered 5 mL/kg of lard and olive oil.

In an in vitro experiment, Kim and Kang (2005) used tributyrin as a substrate and a continuous-monitoring pH-Stat method to assess the lipase inhibitory effect of aqueous and ethanol extracts of different sections of 19 selected medicinal plants. Compared to orlistat, the two plant extracts that had the highest efficacy were *Illicium religiosum* and *Juniperus communis Thuja orientalis*, *Pyrus pyrifolia* and *Euonymus alatus* were shown to have pancreatic lipase activity.

Using a radioactive technique, Sharma *et al.* (2005) examined the antilipase activity of various portions of 75 medicinal plants from various families. Methanolic extracts from the whole portions of three plants such as *Setaria italica*, *Orixa japonica*, and *Eriochloa villosa* exhibited the strongest in vitro antilipase activity of all the extracts that were studied. Kwon *et al.* (2003) examined the inhibitory impact of *Dioscorea nipponica* methanol extract on pancreatic lipase activity. Lipase activity was lowered by the plant extracts in a dose-dependent manner. When compared to orlistat, a popular drug at different levels, the extract effectively inhibited pancreatic lipase at a dose of 10 µg/mL (IC50), resulting in a 50% drop in enzyme activity.

IV. CONCLUSION

Pancreatic lipase, glucose-6-phosphate dehydrogenase and malic dehydrogenase that the administration of several *Trigonella foenum graecum* plant extract were evaluated for their in-vitro hypolipidemic qualities different combinations plant extracts. Research indicates that significant biological impacts of fenugreek and that the effectiveness of enzyme activities.

Table 1: Inhibition activities of pancreatic lipase, glucose-6-phosphate dehydrogenase and malic dehydrogenase at different concentrations of plant extracts

Solvents	Concentrations	Pancreatic lipase	glucose-6-phosphate dehydrogenase	malic dehydrogenase	P value
Methanol	0.5	33.42±1.04	35.11±0.09	32.90±0.67	0.00011*
	1.0	31.55±1.09	32.56±1.04	29.45±0.74	
	1.5	27.74±0.08	29.98±1.22	26.89±0.40	
	2.0	26.89±1.53	25.55±0.93	24.65±0.99	
Hexane	0.5	28.55±0.25	34.04±1.98	32.00±1.93	0.00001*

	1.0	26.98±0.10	31.88±2.87	28.92±1.25	
	1.5	23.49±1.49	29.54±0.41	27.12±1.99	
	2.0	22.23±0.09	26.03±0.66	25.76±1.64	
Ethyl acetate	0.5	40.90±0.98	41.00±0.45	42.78±0.42	0.000115*
	1.0	36.44±0.12	39.81±0.01	40.54±0.20	
	1.5	34.15±0.15	36.91±0.20	38.83±0.31	
	2.0	31.75±0.10	34.23±0.29	35.51±0.92	
Ethanol	0.5	18.68±0.89	20.00±0.30	21.21±0.58	0.000425*
	1.0	16.00±0.22	19.78±0.12	20.12±0.57	
	1.5	13.33±0.98	17.72±0.09	18.33±0.97	
	2.0	11.97±0.19	14.00±0.88	16.12±0.13	
Dichloromethane	0.5	30.23±0.76	35.28±0.43	33.77±0.78	0.000198*
	1.0	28.23±0.11	32.12±0.54	30.22±0.91	
	1.5	27.09±0.67	29.68±0.19	27.64±0.11	
	2.0	24.02±0.35	28.90±0.72	25.23±0.87	
Fenofibrate (Standard)	1.0	26.02±1.10	26.15±1.52	25.10±1.20	0.000488*
	1.5	24.10±1.60	24.01±1.08	23.18±1.45	
	2.0	22.08±1.22	23.12±0.95	21.02±1.16	
	1.0	19.40±1.05	20.15±1.24	20.96±1.10	

Two way ANOVA

* Significance (P< 0.05)

** Insignificance (P>0.05)

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Growth parameters, yield attributing characters and economics of different HYVs of Foxtail millet (*Setaria italica* L.) in the upland of Tripura

Deeptanu Aich, Debashish Sen, Saurav Das, Biman De, Debasree Saha, Niladri Paul, Abhijit Saha

College of Agriculture, Tripura, Lembucherra, Tripura, India
Corresponding author: deeptanu.aich15@gmail.com

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***Abstract*— *A field experiment was conducted in January 2023 at the upland farm of the College of Agriculture, Lembucherra, West Tripura, to evaluate the performance of ten different high-yielding varieties of foxtail millet (Setaria italic L.) under upland conditions. The experiment was laid out in a randomized block design with three replications. The treatments consisted of 10 varieties viz., IIM-FXM-4 (V_1), Prasad (V_2), Garuda (V_3), GPUF-4 (V_4), GPUF-3 (V_5), Fingu (Local) (V_6), Black (Local) (V_7), SiA-4200 (V_8), SiA-3159 (V_9), SiA-3156 (V_{10})with plot size of 4.5m x 3.0m and 100-50-50 NPK kg ha^{-1} recommendation of fertilizer dose.Results of the experiment showed that among the varieties GPUF-3 recorded significantly highest values of plant height (135.33 cm), number of tillers plant^{-1} (8.50), dry matter accumulation (14.76 g) in all the growth stages of foxtail millet during the year of experimentation. GPUF-3 recorded superior yield attributes namely number of ears plant^{-1} (4.47), number of grains ear head^{-1} (1418.62), grain weight ear head-1 (4.97), length of ear head (21.33 cm) and 1000 seed weight (3.63 g) which ultimately produce higher seed yield (2245.81 kg ha^{-1}) stover yield (4215.02 kg ha^{-1}) during the year of experiment.From the economic point of view GPUF-3 fetched higher in terms of gross return, net return and B:C ratio due to higher seed yield.*

Keywords— **Foxtail millet, varieties, growth and yield parameters, high yielding varieties, BCR**

I. INTRODUCTION

Small millets are increasingly important for food security amid climate change, addressing global warming, water scarcity, and health issues. These nutrient-dense crops are resilient to pests, temperature fluctuations, and drought, supporting over 60% of small and marginal farmers in arid regions. Displaced by larger grains over the past forty years, millets like foxtail, proso, barnyard, and tiny millet offer potential as the yield of major cereals stagnates. Millets, from the Poaceae family, produce numerous grains from a single seed and thrive on short, slender, grassy plants.

Small millets like finger, foxtail, little, kodo, barnyard, and proso millet are vital to India's dry farming, known as "nutritious cereals" for their rich nutrients. Essential for the world's poorest in semi-arid tropics, these crops thrive in dry areas with minimal water, quick maturation, and adaptability to various ecological conditions. They excel in challenging environments with little rainfall, poor soil, and uneven terrain(Chandel *et al*., 2014). Rising diabetes rates highlight millets as the healthiest diet for diabetics, spurring interest in health foods and commercialization(Sateesh, 2010). Foxtail millet, the second most cultivated, is notable for its drought resistance and moisture stress tolerance.

Foxtail millet, also known as Italian millet (*Setaria italica* L.), is one of the earliest and second most widely grown small millets. Renowned for its drought tolerance and adaptability to various soils(Cheng and Liu, 2003), it grows quickly and offers affordable nutrition, including protein, vitamins, and minerals. It is a staple for the less fortunate in society(Muniratnam *et al*., 2006).Foxtailmillet is rich in fiber (8g), protein (12g), carbs (60.9g), fat (4.3g), calcium (31mg), iron (2.8mg), phosphorus (290mg), vitamins, amino acids, minerals, and provides 323-350 K Cal per 100g(Vanithasri *et al.,* 2012). Abundant in protein, iron, and β-carotene, it has a low glycemic index, making it ideal for diabetics. Its nutritional benefits have increased its demand in recent years(Hariprasanna, 2006).

India leads in millet production, contributing around 41% of the global output in 2021(Kumar *et al*., 2023), with an annual production of 10.08 million metric tonnes. Foxtail millet is cultivated on 0.87 lakh hectares, producing approximately 0.66 lakh tonnes with an average yield of 762 kg/ha(Hariprasanna, 2023). Andhra Pradesh, Karnataka, and Tamil Nadu account for 90% of foxtail millet cultivation, with Andhra Pradesh alone contributing 79% of the area. Despite low production potential due to traditional farming practices and inadequate management, new high-yielding varieties like SiA 3085 and SiA 3088, yielding 20-25 q/ha, offer potential for expansion.

In Tripura, Foxtail Millet, locally known as Kaon, is the predominant millet grown across all eight districts, primarily consumed by the tribal community. Historically cultivated during the Kharif season, a shift to the Rabi season began in 2020-21 with sustainable water practices. From 2016-17 to 2020-21, the cultivation area grew from 352 to 1,119 hectares, and production increased from 282 to 873 metric tons. Despite annual productivity fluctuations, an overall positive trend is evident, with the highest productivity of 849 kg/ha recorded in the Rabi season of 2020-21.Traditionally cultivated using jhum methods in Tripura, foxtail millet's productivity declined due to low yields. Recently, its nutritional benefits and climate resilience have sparked a resurgence. Studies aim to improve its yield and quality, as foxtail millet remains well-suited to Tripura's climate.

Objectives

To study the growth and yield attributing parameters of foxtail millet cultivars under Tripura condition.To study the performance foxtail millet cultivars under Tripura condition and to work out the economics of foxtail millet cultivation.

II. MATERIALS AND METHODS

During Rabi season of2023, the experiment was carried out at the College of Agriculture Tripura, Lembucherra. The experimental field is located at a South-westerly direction (23°54' N latitude and 91°19' E longitude, 45 M m.s.l.) about 260 metres from the college campus. The field soil is sandy clay loam in texture with pH 5.2 i.e., soil is moderately acidic in nature, bulk density of 1.481 g cc^{-1}. The available soil nitrogen (N) was found 289.23 kg ha^{-1}, phosphorus (P) 6.38 kg ha^{-1} and potassium (K) 110.28 kg ha^{-1} initially.The experimental field was laid out in Randomised Block Design (RBD) by having ten treatments (varieties) which were replicated three time, rows and plants were spaced at 25 x 8 cm. Germplasms were collected from IIMR (Indian Institute of MilletsResearch)Hyderabad, Telangana. Fertiliser dose was recommended 100:50:50 NPK, P and K were applied in full dose and N was applied in two equal splits, one at sowing another at30 DAS.

III. RESULT AND DISCUSSION

Performance of varieties on growth and yield attributes

Plant height (cm)

During harvest, significantly superior plant height was recorded with GPUF-3 over Fingu (Local), Black (Local) and SiA-4200. The variety Fingu recorded the shortest plant height.As the crop growth phase progresses with time the plant height variation was observed among the treated varieties. Garuda excelled in plant height to others at 20 DAS, at 40 ,60 DAS and at harvest GPUF-3 was noted tallest. The advancement in plant height might be due to genetic potential. These results were corroborated with Ravindranadh *et al.* (2019) and Nagaraja *et al.* (2022).

Number of tillers plant^{-1}

The total number of tillers plant^{-1} recorded at harvest was significantly influenced by different varieties. At harvest, higher number of tillers plant^{-1} was found with GPUF-3 which was significantly superior than all other varieties. The lowest number of tillers plant^{-1} was obtained with the variety Prasad.These variations of producing different no of tillers among the varieties might be attributed to the genetic factors and the environment grown. These results were in conformity with Radhakumari *et al.* (2017).

Leaf Area Index (LAI)

At 60 DAS, variety SiA-3159 shown the higher leaf area index and was significantly superior over IIM-FXM-4, Garuda, Fingu (Local), Black (Local) and SiA-3156 and was statistically at par with Prasad, GPUF-3, GPUF-4, SiA-3159 and SiA-4200. Fingu was found to have the lowest index among the varieties.At all the intervals of growth phase variety SiA-3159 exhibited the superior index over the others and Fingu was found to have the least leaf area index throughout the course of crop growth. This might be due to variation on genetic potential for heavy vegetative structure. These results were found similar with Ravindranadh *et al.* (2019).

Dry matter accumulation

At harvest dry matter accumulation was found to be highest in the variety GPUF-3 which was significantly superior over IIM-FXM-4, Prasad, Garuda, Black (Local) and SiA-4200 and statistically at par with rest varieties. The lowest record was found in variety Prasad.Variations in dry matter accumulations might be due to production of more number of tillers and genetic character for higher photosynthetic capacity. Genotypic variations in dry matter accumulation in foxtail millet genotypes were also reported by Vaghdevi *et al.* (2020).

Crop Growth Rate (g m^{-2} day^{-1})

The highest crop growth rate was observed in GPUF-4 at 40-60 DAS which was statistically at par with GPUF-3, Fingu (Local) and SiA-3159 and significantly superior than others. The lowest was found in SiA-4200. Towards the harvest maximum crop growth rate was noted in Prasad which was significantly higher than GPUF-4, Fingu, SiA-3159 and SiA-3156 and rest varieties are at par. The minimum growth rate was discovered in Fingu. Crop growth rate was found to be highest at 40-60 DAS of interval and declined towards the harvest which might be due to the growth has entered the senescence stage since reproductive phase. Greater CGR is resulted from the greater dry matter production which might be due to different genetic makeup of different Varieties. These findings were found to be similar with Ravindranadh *et al.* (2019).

Table 1: Growth parameters of foxtail millet as influenced by different varieties

Varieties	Plant height (cm)	Number of tillers plant^{-1}	Leaf Area Index	Total dry matter accumulation plant^{-2} (g)	Crop Growth Rate (gm^{-2}day^{-1})
IIM-FXM-4	126.57	5.43	3.47	11.77	10.38
Prasad	125.70	4.47	3.84	11.17	11.31
Garuda	120.57	6.00	3.44	12.02	11.80
GPUF-4	124.14	7.53	4.00	13.70	17.95
GPUF-3	135.33	8.50	3.94	14.76	16.76
Fingu (Local)	96.97	4.89	3.34	13.01	15.85
Black (Local)	112.44	4.60	3.53	11.87	11.30
SiA-4200	114.03	5.60	4.04	11.26	8.30
SiA-3159	130.07	7.26	4.10	14.32	17.02
SiA-3156	128.17	6.56	3.53	13.13	14.07
SEm (±)	5.43	0.29	0.14	0.59	0.85
CD at 5%	16.40	0.87	0.42	1.78	2.58
CV (%)	7.75	8.19	6.55	7.96	10.97

Yield and yield attributing characters

Among the investigated varieties, GPUF-3 recorded better number of ears which was significantly superior over IIM-FXM-4, Prasad, Garuda, Fingu (Local) and Black (Local) and rest varieties are at par. These findings were similar with Raviraja *et al.* (2020), Radha kumari and Sahadeva Reddy (2023).

Among the tested varieties, GPUF-3 yielded the highest number of grains per ear head which was significantly superior over Garuda, Fingu (Local), Black (Local), SiA-4200 and rest are statistically at par. Fingu exhibited the lowest grain count possibly due to differences in photosynthate translocation efficiency and genetic potential, consistent with previous studies of Yadav *et al.* (2023).

Among the tested varieties, GPUF-3 exhibited the highest grain weight per ear head which was statistically at par with GPUF-3 and SiA-3159 and significantly superior than rest varieties (Table 2). Conversely, Prasad had the lowest grain weight per ear head.Similar results were reported by Srikanya *et al.* (2019).

GPUF-3 exhibited superior ear head length than other varieties which was statistically at par with varieties Garuda, GPUF-4, GPUF-3, SiA-3159 and significantly superior than rest varieties. However, Prasad had the lowest ear head length. This difference may be attributed to the genetic potential of the variety in determining ear head length and its effectiveness in assimilate partitioning from source to sink. Similar findings were reported by Deva *et al.* (2019) and Srikanya *et al.* (2020).

Among the ten conducted varieties GPUF-3 outperformed the others by having highest weight which was statistically at par with Garuda, GPUF-4, GPUF-3, SiA-3159 and significantly superior than rest varieties. The least weight was found in Prasad. These results are in agreement with the findings of Sahaja *et al.* (2019).

Table 2: Effect of varieties on yield attributes of foxtail millet

Varieties	**No. of ears plant^{-1}**	**Grain no. ear head^{-1}**	**Grain wt. ear head^{-1} (g)**	**Length of ear head (cm)**	**Test weights (g)**
IIM-FXM-4	3.20	1310.42	4.10	16.83	3.13
Prasad	2.77	1293.90	3.79	14.83	2.97
Garuda	3.53	1180.10	4.15	19.63	3.55
GPUF-4	4.10	1389.69	4.51	19.80	3.26
GPUF-3	4.47	1418.62	4.97	21.33	3.63
Fingu (Local)	3.13	1139.70	3.90	18.30	3.45
Black (Local)	3.00	1167.17	4.02	14.93	3.48
SiA-4200	3.10	1142.46	3.92	16.97	3.46
SiA-3159	4.37	1373.96	4.81	20.80	3.41
SiA-3156	3.93	1358.63	4.49	19.23	3.33
$SE_{m\,(\pm)}$	0.22	48.47	0.13	0.69	0.10
CD at 5%	0.65	146.34	0.40	2.07	0.31
CV (%)	10.53	6.57	5.38	6.51	5.20

Seed and stover yield (kg ha^{-1})

Analysis of the data on grain yield reveals that GPUF-3 achieved the highest grain yield, significantly outperforming the other nine varieties of foxtail millet. Secondly followed by SiA-3159 which was statistically at par. Prasad attained the least grain yield and two local varieties viz., Black and Fingu exhibited the similar yield which were slightly higher than Prasad. The genetic makeup of the variety in yield attributing morpho-physiological factors and maximal dry matter content may be the cause of its notable advantage for grain yield. Nagaraja *et al.* (2022), Ravindranadh *et al.* (2019) reported the similar records.

Among the varieties examined, SiA-3159 achieved the highest stover yield which was statistically at par with GPUF-4, GPUF-3 and significantly superior than rest varieties. Lowest stover yield was observed in Prasad. The genetic characteristics of the variety and environmental factors contributed to increased dry matter production, consequently enhancing the stover yield. These findings were in agreement with Sahoo *et al.* (2020) and Ravindranadh *et al.* (2019).

Harvest Index

Highest index was found in GPUF-3 which outperformed the others and was statistically at par with IIM-FXM-4, GPUF-4, SiA-3159 and significantly higher than rest varieties. The minimum index was recorded with Prasad. Variations in harvest indices were the results from dry matter production in terms of no. of tillers, no. of leaves produced in a plant of different varieties. These results were in consonance with the findings of Nandini and Sridhara (2020).

Table 3: Seed, stover yield and harvest indexas influenced by varieties of foxtail millet

Varieties	**Seed yield (kg ha^{-1})**	**Stover Yield (kg ha^{-1})**	**Harvest Index**
IIM-FXM-4	1303.78	2781.37	32.85
Prasad	1099.85	2766.55	28.36
Garuda	1328.31	3275.96	28.92

GPUF-4	1994.17	4255.84	31.90
GPUF-3	2245.81	4215.02	34.76
Fingu (Local)	1257.60	3671.84	25.51
Black (Local)	1164.22	3028.09	27.73
SiA-4200	1179.36	2865.71	29.17
SiA-3159	2101.40	4560.22	31.55
SiA-3156	1542.16	3617.01	29.63
SEm (±)	79.94	181.68	1.29
CD at 5%	241.37	548.53	3.91
CV (%)	9.10	8.98	7.46

Economic studies

The maximum gross return was achieved with the cultivation GPUF-3 which was statistically at par with SiA-3159 and significantly superior than rest varieties. The minimum return was recorded with Prasad due to its poor performance in terms of producing lower yields. These results are supported with the findings of Shashma *et al.* (2023) and Reddy *et al.* (2023).

GPUF-3 outstood in terms of net returns over the others and was at par with SiA-3159 and significantly superior than rest varieties. Prasad was found to have given the lowest net return. The mentioned findings were in agreement with Shashma *et al.* (2023) and Upadhaya *et al.* (2022).

GPUF-3 attained the highest B:C ratio which was at par with SiA-3159 and significantly higher than rest varieties and conversely found lowest in Prasad. Similar results were reported by Upadhaya *et al.* (2022) and Sathisha *et al.* (2022).

Table 4.14 Gross returns, net returns and B:C ratio as influenced by different varieties

Varieties	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C Ratio
IIM-FXM-4	45632.18	23854.18	2.10
Prasad	38494.87	16716.87	1.77
Garuda	46490.73	24712.73	2.13
GPUF-4	69795.83	48017.83	3.20
GPUF-3	78603.47	56825.47	3.61
Fingu (Local)	44016.00	22238.00	2.02
Black (Local)	40747.70	18969.70	1.87
SiA-4200	41277.48	19499.48	1.90
SiA-3159	73549.00	51771.00	3.38
SiA-3156	53975.60	32197.60	2.48
SEm (±)	2798.02	2798.02	0.13
CD at 5%	8447.79	8447.79	0.39
CV (%)	9.10	15.39	9.10

IV. CONCLUSION

Based on the observations, it appears that among the ten varieties of foxtail millet studied, GPUF-3 showed superior performance in terms of growth and yield characteristics, followed closely by SiA-3159. In, under upland conditions, GPUF-3 exhibited higher profitability and production compared to other varieties. Both GPUF-3 and SiA-3159 showed a competitive edge in various aspects of growth and yield.

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Water management for Chilli (*Capsicum annuum* L.) crop in sub-tropical humid region

Ashish Krishna Yadav[1] and P. S. Kashyap[2]

[1]Research Scholar, Department of Soil & Water Conservation Engineering, G. B. Pant University of Agriculture & Technology, Pantnagar-263145, Uttarakhand, India
[2] Professor, Department of Soil & Water Conservation Engineering, G. B. Pant University of Agriculture & Technology, Pantnagar-263145, Uttarakhand, India

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***Abstract*— *Irrigation scheduling is determining the amount of water to be applied and when to achieve desired crop production and quality, to maximize water conservation, and to limit any adverse effects that may be experienced by the environment, such as the leaching of nutrients beneath the root zone of the crop. The study was carried out at the experimental site of Vegetable Research Centre (VRC) of G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India, to investigate the effect of different soil moisture regimes on the yield of chilli crops and growth parameters related to irrigation scheduling. Also, as part of the study, it was determined the minimum irrigation amount that needs to be provided in order to achieve significant returns for the crop, along with recommended guidelines for measuring soil moisture status. Four Treatments of irrigation that of four different Maximum allowable depletion (MAD) levels at 20% (T_1), 40% (T_2) 60% (T_3) and 80% (T_4) were taken for this study. Soil moisture content was estimated using gravimetric method periodically in 0-20, 20-40, and 40-60 cm soil profiles. Field experiments were conducted on chilli (also known as chilli pepper) during 2021-2022. Four irrigation treatments were maintained based on the maximum allowable depletion (MAD) of available soil water. Field experiments showed that irrigation schedule with 40% (T_2) maximum allowable depletion of available soil water gives the maximum water use efficiency while the highest yield was obtained as 7624 kg/ha (T_1) for chilli crop. It was also found that for scheduling of irrigation for chilli crop, 0-20 cm soil profile should be considered as most of the water was found to be extracted from this layer by the plant.*

Keywords*— Available soil moisture, Irrigation scheduling, Chilli, Stress conditions, Water management, Water use efficiency, Yield attributes.

I. INTRODUCTION

A study on irrigation scheduling for chilli (also known as chilli pepper) cultivation would typically focus on determining the most efficient and effective timing and amount of water to apply to the plants. This is crucial for maximizing yield, quality, and resource use efficiency. Water scarcity is a pressing concern in agricultural regions worldwide, prompting the need for sustainable water management strategies to optimize crop production while conserving this precious resource (McLaughlin and Kinzelbach 2015). Also, rainfall is a source that help to reduce water scarcity (Singh et al. 2023a; Singh and Kumar 2021). The various researchers worked on this rainfall parameter to quantify trend, variability, and modelling, etc (Singh et al. 2024; Singh et al. 2023b; Yadav et al. 2022; Singh and Kumara 2021; Yadav et al. 2020). Among crops grown in diverse climates, chilli (Capsicum annuum L.) stands out as a vital commodity globally, valued for its culinary, economic, and nutritional significance. However, the cultivation of chilli demands substantial water inputs, making it susceptible to water stress and exacerbating water scarcity issues (Yadav et al. 2023). The efficient use of water in chilli cultivation is imperative for mitigating environmental impact and ensuring agricultural sustainability (Abdelkhalik et al. 2020). One approach to address this challenge is through the implementation of different water application schedules, which regulate the timing and quantity of water supplied to the crop. By strategically managing irrigation, farmers can optimize water use efficiency, minimize wastage, and enhance crop yields (Kashyap, and Panda, 2001; Panda et al. 2004; Singh et al. 2023c). An investigation has been carried out to determine whether irrigation scheduling can help to increase yields and growth parameters of chilli crops in relation to different soil moisture regimes and the minimum amount of irrigation that should be provided so that significant returns can be obtained from the crop, as well as the identification of simple guidelines for determining the moisture status of the soil, is the objective of this study (Khalkho et al. 2013). Understanding the effect of various water application schedules on water conservation and yield of chilli crops is crucial for informing sustainable agricultural practices. This research aims to investigate the impact of different irrigation regimes on water usage, soil moisture retention, and ultimately, chilli yield. By examining the interactions between water application schedules and crop performance, valuable insights can be gained into optimizing water management strategies for chilli cultivation.

One of the most important vegetables in the world is the chilli pepper (Capsicum spp.) which plays a key role in our daily lives. In almost all parts of the country, it is grown and its growing period of 110 to 150 days and it varies from place to place. Chilli originated from Americas with their cultivars now growth around the world because they are widely used as food, medicine and Indian kitchens for their spicy taste. Pepper (capsicum spp. Capsicum annum and capsicum frutescens) belonging to the family of 'Solanaceae is a crop plant and it is grown in different varieties for the purpose of growing vegetables, spices, condiments, sauces, and pickles. The most important chilli growing states in India are Telangana, Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu, which together constitute nearly 75percent of total cultivated area under chilli production.

II. MATERIALS AND METHODS

The Study was carried out at the experimental field of the G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India. The field is located on Vegetable Research Centre, (VRC) Pantnagar district Udham Singh Nagar India (Fig.1). It is situated at 29.02° N and 79.49° E latitude with an altitude of 244 m above the mean sea level. The climate is typically humid sub-tropical. Summer temperatures can reach up to 44 to 45 degrees Celsius, while winter temperatures can drop to 1.5 degrees Celsius during the winter season. There is usually around 1350 mm of rain per year in this area. It was generally observed that most of the rain takes place in the months of July to September. The physical properties of the soil used in the experimental crop field for chilli production are given in Table1. Field experiments were conducted on chilli crop which belongs to the Solanaceae family, which is a popular 110-150 days vegetable crop of the locality and suits to the prevailing climate of the region. Water deficit during the period of pod initiation have the greatest adverse effect on yield, whereas early vegetative and maturation periods are less sensitive. The field experiment was undertaken during the period from 26 November 2021 to 15 May 2022.

Table 1: Physical properties of various soil profiles of the experimental crop field

Soil depth (cm)	Particle size distribution (%)			Bulk density (g/cm3)	Saturated hydraulic conductivity (cm/h)
	Clay	Silt	Sand		
0-20	12.25	30.56	58.75	1.48	2.15
20-40	13.42	27.80	56.90	1.52	1.95
40-60	11.5	29.50	60.82	1.58	1.68

Field layout and Experimental details:

An area of 100 square meters of surface land was used for growing chilli crop as part of a surface farm. The field was divided into 20 plots of equal dimensions of 2m by 2m. The farm yard manure (FYM) was manually applied to the top 12 cm of the soil layer at a rate of 25 kg/ha 1 week before transplanting on the farm. Second dose of FYM was applied at the time of the fruiting (approximately 45 days after transplanting) at the rate of 12 kg /ha. The transplanting was done at a spacing of 60 cm from row to row as well as 60 cm from plant to plant.

Irrigation treatments and scheduling:

A variety of irrigation treatments were used during the chilli crop growing experiments, including irrigation scheduling based on maximum allowable depletion (MAD) of available soil water (ASW) criteria, which is given as (Kashyap and Panda, 2003), (Kashyap and Anita 2023).

1. T_1 = 20% maximum allowable depletion (MAD) of available soil water (ASW)
2. T_2 = 40% MAD of ASW
3. T_3 = 60% MAD of ASW
4. T_4 = 80% MAD of ASW

The irrigation scheduling was based on a calculation of the percentage of soil water depletion in the root zone of the plant. In this study, soil water availability was determined as the difference between the root zone water storage at field capacity and permanent wilting point of the plants. For estimating water storage, the effective root zone of Chilli crop was considered as 40 cm, irrespective of growth stage. A percentage depletion of available soil water in the effective root zone of the Chilli crop has been estimated using data of soil moisture measured by gravimetric measurements. There was a water meter attached to the hosepipe to measure the exact volume of water applied to each plot, and a hosepipe to irrigate the plots.

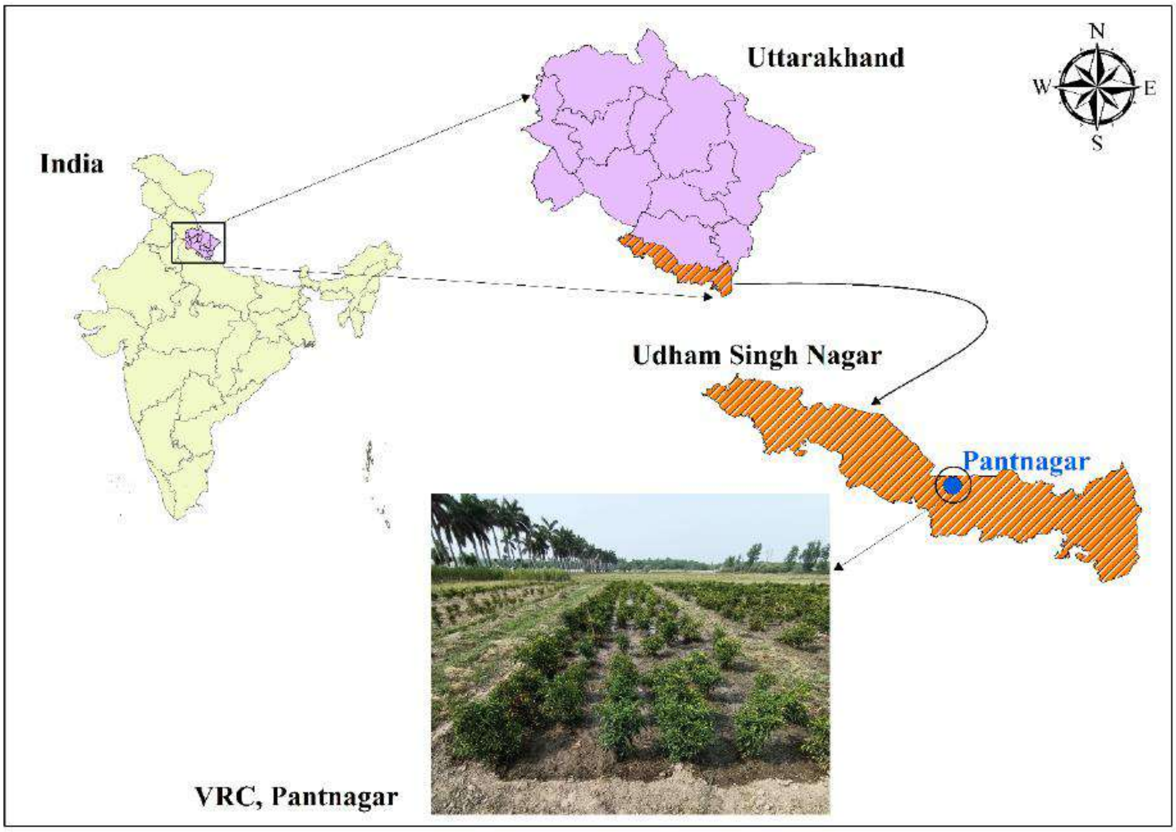

Fig.1. Study Area

Data collection:

This research was carried out in order to investigate the water balance, crop response to deficit irrigation and efficient use of water. To understand the growth attributes of the crop under consideration, data on soil moisture profile content and the characteristics of development of the crop was recorded. The moisture content of soil layers were measured gravimetrically. The moisture levels were measured every 2-3 days throughout the duration of the experiment.

III. RESULTS AND DISCUSSIONS

The study was conducted to assess how soil moisture changes with depth and time under a variety of irrigation scheduling conditions. As a part of experiments, the moisture of the soil was periodically measured at depth intervals of 0-20, 20-40, and 40-60 cm in soil profiles.

Depth and Time variation of soil moisture:

The temporal variation of soil moisture in the root zone and below the root zone of an experimental chilli crop over a period of time is presented in Fig 2 through Fig 5. There was a cyclic variation in soil moisture throughout all depths of soil shown in the Fig 2, indicating cyclic trends.

Regardless of the irrigation level (MAD level) applied to the field, this trend was observed. This figure represents the variation of volumetric soil moisture content (%) at different soil depths over time, specifically in terms of days after sowing. 0-20 cm soil depth. The moisture content at this shallow depth shows significant fluctuations over time, with sharp peaks and valleys. This suggests that the topsoil is highly sensitive to changes in environmental conditions, such as rainfall or irrigation, which quickly affect moisture levels. Towards the end of the observation period (around 160 days), there is a steep decline in moisture content. The moisture content at this intermediate depth is relatively more stable compared to the topsoil but still shows some fluctuations. The variations are less pronounced, indicating that this layer retains moisture better and is less immediately impacted by surface conditions. 40-60 cm soil depth at this deeper depth, the moisture content remains the most stable over time. The black line indicates minimum fluctuation, suggesting that this soil layer is more insulated from surface activities and retains moisture consistently. However, similar to the other depths, there is a notable decrease in moisture towards the end of the period. The overall moisture content across all depths generally decreases over time, especially after around 150 days. This could be due to the depletion of moisture in the soil as the growing season progresses, possibly due to reduced rainfall, increased plant uptake. The top layer (0-20 cm) is most dynamic, showing rapid changes in moisture levels, which indicates that it is more influenced by external factors like weather conditions. The deeper layers (20-40 cm and 40-60 cm) show progressively more stable moisture levels, with the deepest layer being the least variable. The graph highlights how soil moisture content varies significantly with depth and time, with the shallowest layer being the most variable and the deepest layer the most stable. This information can be critical for understanding how water is distributed in the soil profile and for making informed decisions about irrigation and crop management. Since the frequency of irrigation was high under T_1, plants extracted more water from the upper layers. Therefore, 20-40, and 40-60 cm soil profiles did not exhibit much cyclic variation. This trend was observed in the experiments.

A similar temporal variation of soil moisture may be found under the same conditions, soil moisture in 0-20, 20-40, and 4-60 cm soil profiles under 40% MAD (T_2) also exhibited cyclic pattern. The results are presented in Fig. 3. Continuous sharp declines of soil moisture in all soil profiles were observed on 110 DAT. The magnitude of cyclic variation was higher in 20-40 and 40-60 cm soil profiles as compared to similar layers of T_1 during the crop seasons.

The root zone soil profiles under 60% MAD (T3) showed a high level of cyclical variation in amplitude, as was observed in all soil profiles. A 60% MAD irrigation schedule may have caused root penetration deep into the soil layers because the roots had to search for more water as the upper soil layers did not have enough water available. The temporal variation of soil water was observed to be similar during the experiments. The temporal variation under T_3 exhibited cyclic pattern upto 95 DAS in 0-20 and 20-40 cm soil profiles during experiment 1, while 60 cm soil profiles showed a gradual decline on 130 DAT. A similar trend was observed during other experiment also (Fig. 4).

Considerable soil moisture fluctuation was observed under 80% MAD (T_4) schedule. All soil profiles exhibited discernible cyclic variation, with considerably low amplitudes in the lower depths as compared to those observed at upper depths. This was ascribed to the large volume of water applied at a time during irrigation which shown in Fig 5.

The 40-60 cm soil profile tended to remain steady upto the last irrigation applied, after which it decreased only marginally during the remaining growth period. Soil moisture below the root zone (40-60 cm soil profile) of the experimental plots experienced minimum cyclic variation with time. A slight continuous decline was observed when irrigations were discontinued. This trend was observed during experiments.

Crop water use efficiency:

As a measure of crop water use efficiency, the ratio between the fresh fruit yield and the crop evapotranspiration was used. The results pertaining to water use efficiency of the Chilli crop under different scheduling of irrigation during crop experiments are presented in Table 2. It is evident from the table that the highest crop water use efficiency was attained when the irrigation was scheduled at 40% depletion of ASW (T_2). A rising trend of crop water use efficiency was noticed from T_1 to T_2 and after that it decreased for T_3 and T_4 as the irrigations were delayed.

Field water use efficiency:

The field water use efficiency was estimated in terms of fresh fruit yield obtained per unit of land used and per unit of water available to the field. The results shown in Table 2 revealed that the highest field water use efficiency was attained when the irrigation was scheduled at 40% depletion of ASW (T_2). Similar to crop water use efficiency, a rising trend of field water use efficiency was noticed from T_1 to T_2 after that it decreased for T_3 and T_4 as the irrigations were delayed.

Table 2. Water use efficiency (WUE) of Chilli crop under different scheduling of irrigation during experimental year

Experimental Year	Treatments	Fresh fruit yield (kg/ha)	ET (mm)	Irrigation (mm)	Crop-WUE (kg/ha/mm)	Field-WUE (kg/ha/mm)
2021-22	T1	7624	415	490	18.37	15.55
	T2	7240	375	431	19.30	16.79
	T3	6345	354	420	17.92	15.10
	T4	5023	305	351	16.46	14.31

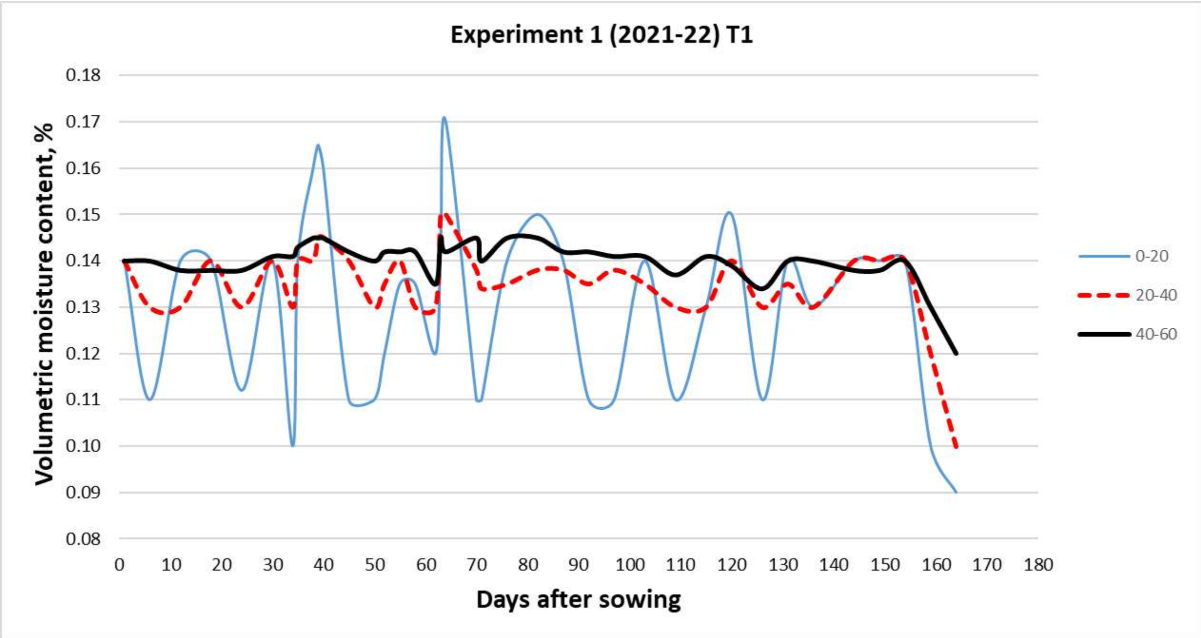

Fig. 2. Temporal variation of soil moisture in chilli crop root zone at 20% MAD (T1) of available soil moisture during experiment

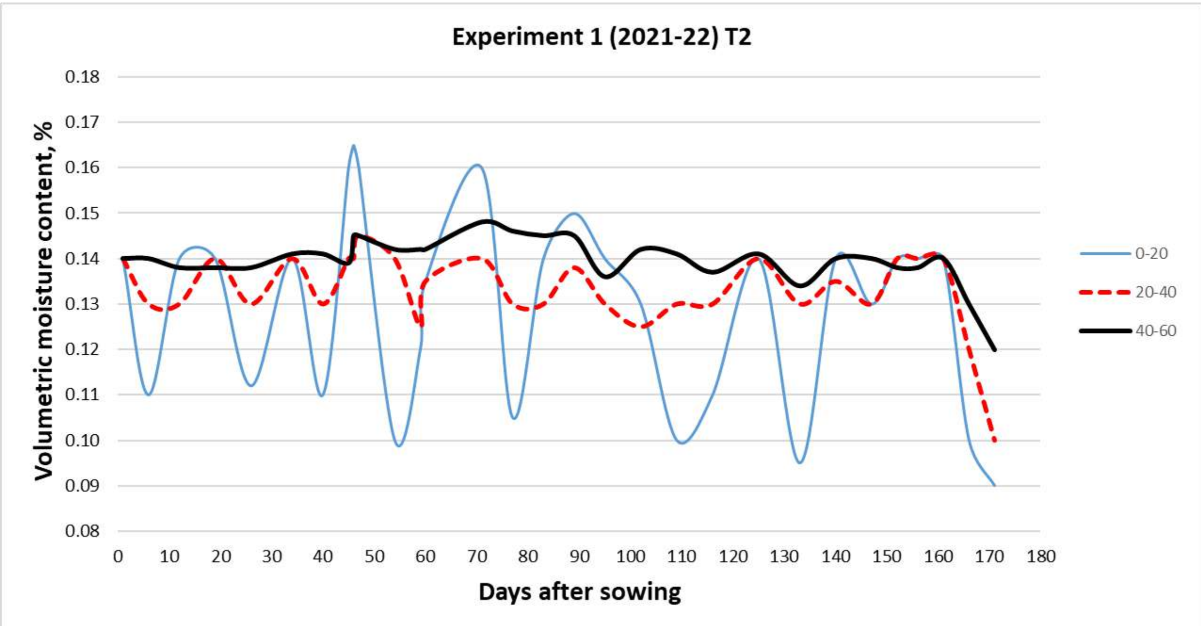

Fig. 3. Temporal variation of soil moisture in chilli crop root zone at 40% MAD (T2) of available soil moisture during experiment

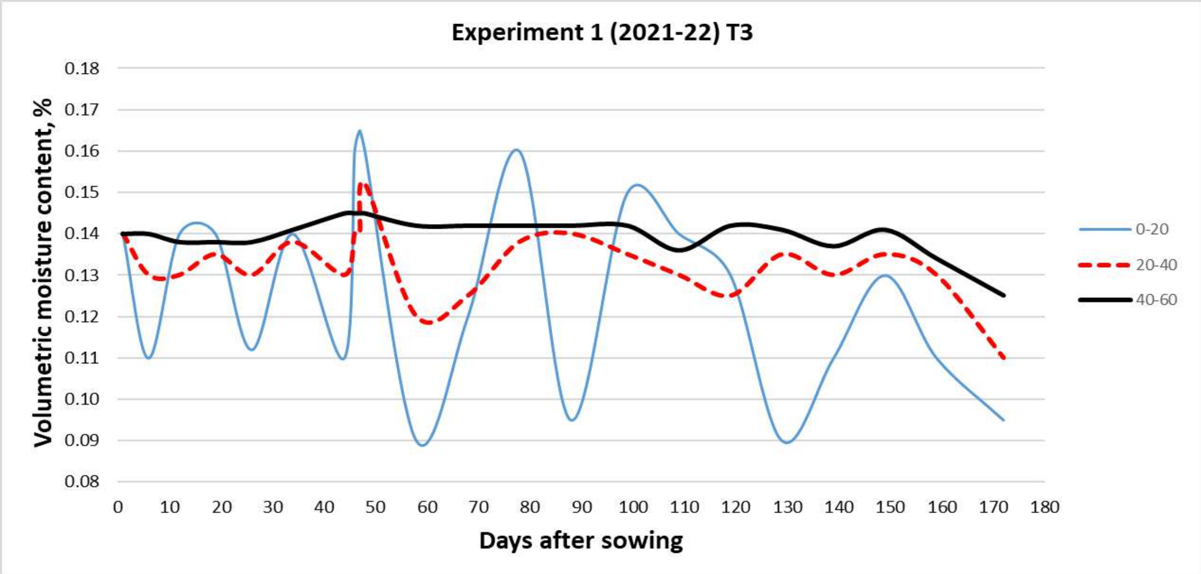

Fig. 4. Temporal variation of soil moisture in chilli crop root zone at 60 % MAD (T3) of available soil moisture during experiment

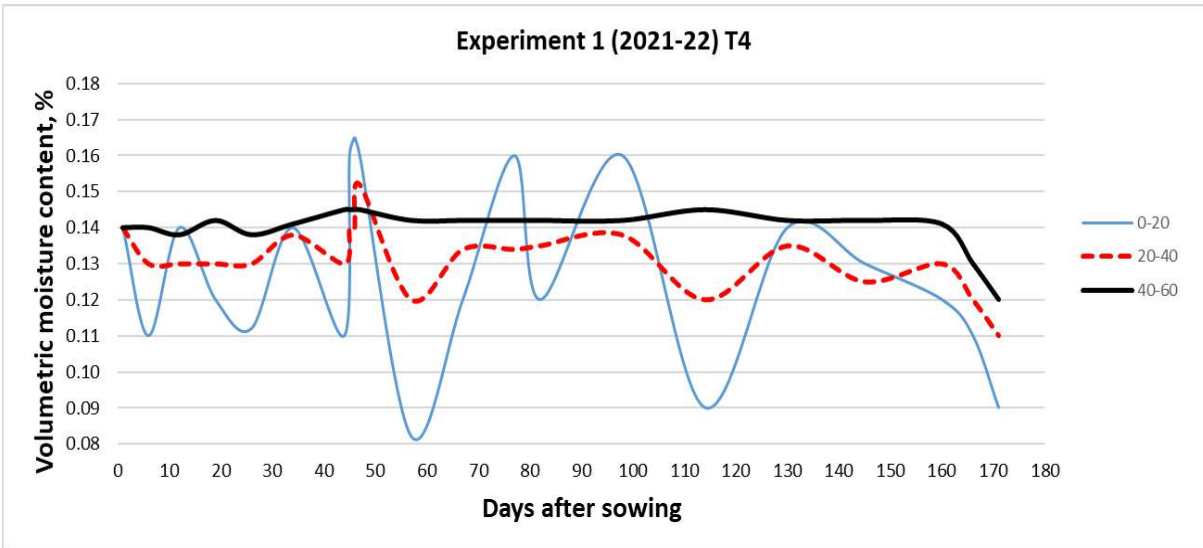

Fig. 5. Temporal variation of soil moisture in chilli crop root zone at 80% MAD (T4) of available soil moisture during experiment

IV. CONCLUSION

As a result of the study, it was found that under conditions, when people impose soil water stress at non-critical stages of growth, the plants tend to exhibit abnormal growing habits. The irrigation is to be scheduled at 40% maximum allowable depletion of available soil water for chilli crop grown in sandy loam soils in a sub-tropical humid region. A soil water stress of 40 % MAD gives the highest crop water use efficiency as well as field water use efficiency. The highest yield of 7624 kg/ha was obtained under least water stress condition (T_1) for chilli crop. It was also noticed that for scheduling of irrigation for chilli crop, the 0-20 cm soil profile should be considered as most of the water was found to be extracted from this layer by the plant.

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The Role of Indoor Plants in Improving Air and Mind-Comprehensive Review

Hemant Dnyaneshwar Chandore

Head and Assistant Professor, Department of Horticulture, Shikshan Maharshi Dnyandeo Mohekar Mahavidyalaya Kalamb, Tal. Kalamb (413507). Dist. Dharashiv, M.S. India.
Email: hemantflori08@gmail.com)

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Abstract*— Rapid urbanization and concrete indoor living environments are posing challenges to human beings and their beloved pets in terms of indoor environmental quality (IEQ). Raising indoor plants has the potential to not only control indoor air quality, but also maintain psychological comfort and health. In the recent COVID-19 pandemic period, indoor plants have highlighted the importance of these plants in their overall maintenance of health and mental well-being. It is highly recommended to plant this tree after reviewing various research benefits. Keeping in mind the above view, we reviewed recent studies on indoor plants and their benefits in improving indoor environments like quality air index, temperature, humidity, etc., as well as providing psychological benefits. This systematic review of the literature demonstrates that various plant species effectively remove volatile organic compounds (VOCs), and other pollutatns, reduce stress, and boost cognitive function. Some important strategies, such as phytoremediation, which uses bi-directional phytofilters and endophytic bacteria, offer the best air purification with well-being and cognitive performance, promoting biophilic design in indoor spaces. Studies are investigating the relationship between indoor plants and various pollutants, taking into account factors such as light intensity and plant species that play key roles in bi-directional phytofilters. In spite of some challenges, integrating plants into healthier indoor environments. Future research should refine plant selection, optimize growth conditions, and explore new technologies for better air quality and well-being.

***Keywords*— Indoor pollution, Indoor air quality (IAQ), Indoor plant,Phytoremediation, Psychological performance**

I. INTRODUCTION

Firstly, human civilization and urbanization which has brought us so far in development on the one hand, but on the other hand we are also a major cause of various global envrionemntal concerns. For instance, there is Indoor air pollution that has reached its zenith since most of the times are spent indoors. People and their companion animals are exposing themselves to a lot of indoor contaminants such as volatile organic compounds (VOCs), formaldehyde, benzene, particulate matter, carbon monoxide (CO), and nitrogen dioxide (NO_2). It's worth mentioning that these substances have serious effects on human health including respiratory problems, heart diseases and brain disorders. As a result environmentalists and scholars are researching for alternative strategies to improving indoor air quality (IAQ) among them being indoor plants. This article will evaluate the role played by indoor plants in combating indoor pollution through phytoremediation which is a process where plants take up or break down harmful substances from air, soil or water. By decreasing internal pollutants levels they enhance healthier internal surroundings.

Different types of houseplants have been shown to be effective at removing different pollutants indoors. For example, peace lilies (*Spathiphyllum)*, spider plants (*Chlorophytum comosum*) and snake plants (*Sansevieria trifasciata*) have long been known for absorbing VOCs such as formaldehyde, benzene and xylene whereas bamboo palms (*Chamaedorea seifrizii*) and Boston ferns (*Nephrolepis exaltata*) are exceptional in removing airborne particulate matter and allergens. Moreover through transpiration by which they emit water vapour among other things. Houseplants help to maintain optimal humidity within the home and prevent problems of drought like dry skin and respiratory irritations caused by low humidity. Indoor plants create a more comfortable indoor environment that promotes the health of occupants.

Although many studies have addressed the positive impacts of indoor plants on individual mental well-being, there is an emerging concern over their effects on the animals' welfare. Indoor plants offer enrichment opportunities for pets through stimulation or companionship as well as natural exploration, foraging and resting behaviours. Furthermore; it implies that having indoor plants might satisfy an innate psychological demand for connection with nature which is fostered by biophilic linkages between humans in general and their companion animals.

Indoor greenery has been linked to a decline in tension, fear, and tiredness that gives rise to relaxed feelings and promotes general sense of well-being. Indoor plants can make you feel better; help you think more clearly by aiding your brain's efficiency thereby making them good partners in rooms designed for healthy occupants. We can tap into the power of plants to create environments that promote tranquility and overall well-being by knowing how indoor plants, air quality and psychological wellness are related.

II. REVIEW OF LITERATURE

1. Reducing indoor air pollution:

After COVID-19 pandemic outbreak there arose global concerns about improved IAQ. This showed the immediate requirement for sustainable green living spaces as well as economically feasible indoor plants. Different plant species either potted or in green walls can act as buffers from the adverse effects of air pollution hence improving IAQ alongside public health outcomes. In this study we delve into the effect of aerial parts of indoor plant, growing medium, roots and associate bacteria on enhancing IAQ with a reference to phytoremediation as a viable low-cost option that is ecologically sound and aesthetically appealing too. Plant-based methods of eliminating indoor pollutants can be better understood with the help of the analysis, yet it underscores the need for more inclusive research on properties of plants such as leaf size, surface area and individual plant parts involved in removal of pollutants. Additionally, deeper understanding regarding phytoremediation physiology and biochemistry as well as functioning of plant microbiome is necessary. To identify useful microorganisms among OMICS methodologies and carry out live tests to ascertain how effective are natural filters based on plants should be examined through forthcoming researches. By focusing on these areas, we will be able to address general problems associated with indoor air pollution elimination and health hazard prevention. In this case the sector is assisted, hence promoting public health through a sustainable eco-friendly environment [16].

According to a study by [32], the increase in light intensity has a profound effect on the capacity of indoor plants for CO_2 absorption with higher lux levels increasing the ability. All plants except Sansevieria trifasciata showed no change in CO_2 uptake at 1000 lux during day time but at 1500 and 2000 lux they could take more carbon dioxide, this was not significant in Sansevieria trifasciata which is categorized as a CAM plant that produced CO_2 throughout the day regardless of light level. In this particular research focused on tropical environments and examined six popular plant species cultivated in Sri Lanka, Spathiphyllum blandum, Aglaonema commutatum, Philodendron hederaceum, Chlorophytum comosum and Dracaena fragrans were identified as being best suited for removal of CO_2 indoors. There was an increase in rates of CO_2 assimilation under high light conditions where Spathiphyllum blandum emerged as most efficient across all lighting levels. The results point to the prospects of using houseplants to improve indoor air quality and thus sustainability particularly in tropical climates. The next steps should consider different types of plants, maintain RH-controlled environments, go for higher light intensities, and measure the other toxicants removed from the air by these plants. In addition, it is proposed to develop botanical biofilter technologies that are sustainable and low-energy for indoor air purification.

Phytofiltration as the most sustainable approach to improving polluted indoor environments' air quality [30] . However, they observe that existing systems of phytofiltration ignore plant biorhythm thus emitting CO_2 at times when plants breathe. They propose a new bi-directional phytofilter that purifies exhaust air from contaminants while cleaning and oxygenating inlet ventilation air. The original device contains spots with different lighting levels and a valve system that directs fresh air into areas where plants emit CO_2 and returns the outlet through another channel. According to literature data, under adverse conditions there is a balance between CO_2 input and output such that there is no net loss of CO_2 emissions out of the atmosphere during daylight hours while during plant growth carbon dioxide gets in the ground thereby mitigating gasses from being release into the environment. In natural light as well as artificial or mixed combination of these two options, which only requires CAM metabolism accompanied by other varieties can be applied to the phytoremediation process, which can also reduce VOCs and microbes to enhance air quality within confined spaces. Existing indoor phytoremediation systems do not consider plant biorhythms and hence results in secondary CO_2 pollution. The suggested ventilation phytofilter has this problem under control by effectively regulating airflow to ensure that it cleans and oxygenates incoming air around the clock while filtering outgoing air to promote environmentally friendly living in crowded areas. Presently, research focuses on gas exchange between plants through the Laboratory of Heat-Mass Exchange in Green Structures using a gas-exchange camera with attempts at developing and testing experimental models of phytofilter mentioned above. Nevertheless, an attempt by some authors has been made to acknowledge that funding challenges have resulted from various external factors such as geopolitical ones specifically the Russian-Ukrainian war which constrains their sponsorship possibilities for carrying out investigations.

The aerial plant *Tillandsia xerographica* behaved when used for air biofiltration by observing CO_2 concentration changes in treated air under different environmental conditions [28]. The botanic filter with *T. xerographica* worked non-stop with ambient air for about three weeks at various light intensities, airflow speeds, temperatures and relative humidities. Regardless of whether there was light or not, the level of carbon dioxide decreased daily provided that the plant had been allowed to follow its normal diurnal rhythm which is made possible through having facultative CAM metabolism allowing nocturnal and diurnal capture of CO_2. Its capability of switching between CAM mode (day/night cycle) and C3 mode (continuous light) has been demonstrated. This means that it can be used as a biofilter in cities not only to remove CO_2 but also other gaseous impurities thus improving air quality index and reducing public health risks associated with pollution fallouts. According to the study, modelling should be further carried out on physiological responses of *T. xerographica* towards varied environments coupled with structural optimization while also looking into morphological changes brought about by biochemical interactions among genes so as to come up with universal systems for purifying different types of airs.

It is important to consider indoor air quality (IAQ) as people spend a lot of time inside where pollution can cause health problems over long periods of exposure [27]. Although they can be used to help purify the air in homes, CO_2 emissions from plants grown under low-light conditions present some difficulties for botanical biofilters. A proposal has been made that combining C3 and Crassulacean Acid Metabolism (CAM) plants might cut down on these emissions while improving efficiency at removing pollutants. In South Korean apartments, research showed that having a mixture of C3 plants and CAM plants together with ventilation reduced levels of indoor pollutants significantly bringing down CO_2, total volatile organic compounds (TVOCs), formaldehyde (HCHO), and particulate matter (PM 2.5 and PM 10) by 76%, 87%, 75%, 52%, and 51% respectively. This work shows that potted plants indoors are a viable option for sustainable cheap fixes towards cleaner breathing spaces which could lead to higher productivity among people as well their general welfare.There is still need however for more studies into selection criteria based on plant traits among other things that would make phytoremediation most effective thus improving overall IAQ even further than what has been achieved so far in this field.The integration of living filtration systems with structures such as ventilators within buildings offers an opportunity through which societies may purify their atmosphere from various indoor contaminants affordably sustainability leading better health outcomes generally.

Indoor plants are often recommended as an easy means to improve air quality, but little research has been done on how they take in ozone. This study measured the rates at which ozone was absorbed by five common types of indoor plants: the Peace Lily, Ficus, Calathea, Dieffenbachia, and Golden Pothos. We calculated transient deposition velocities (vd) using leaf areas for each plant species tested under different lighting conditions (8 h of high O_3 and 16 h of dark). Initial Golden Pothos Vds ranged widely between 5.6 m/h and 0.9 m/h before falling approximately 50% and 66% with subsequent exposures. Investigators also evaluated the effect on vd values of photosynthetically active radiation (PAR) levels; they found that increasing these from 0.6 μmol $m^n \cdot s^2$ up to 41.2 μmol $m^n \cdot s^2$ caused corresponding growth factors ranging from 1.7 times greater for Dieffenbachia than under low light to as much as 4.7 times higher among Peace Lily plants exposed to similarly high light intensities. Based on standard residential dimensions (0.06 m^2 leaf surface area/volume), removal efficiencies varied little between homes: 0.9%–9%. On average, indoor foliage only removes small amounts (0.5–5.5 m/h), although more work is needed to broadly inspect the collective effects of the secondary components, ozone reduction, and volatile organic compounds emissions from indoor plants on indoor air quality [6].

According to one review[37] 28 ornamental plant species commonly used in interior landscaping were evaluated for their ability to remove specific indoor pollutants (namely toluene, a-pinene, octane, benzene and TCE). The removal efficiency varied among species whereby *Hoya carnosa*, *Hedera helix*, *Hemigraphis alternata*, and *Asparagus densiflorus* were the most effective in eliminating all tested contaminants. In addition to this, *Tradescantia pallida* showed excellent elimination capability for four out of five chemicals (i.e., toluene, a-pinene, benzene, TCE). For four types of pollutants (i.e., toluene, octane, benzene, TCE), in particular, H. alternata recorded the highest removal efficiency among the four substances tested. Furthermore, certain contaminants were also removed by *Fittonia argyroneura*, *Ficus benjamina*, and *Polyscias fruticose*. From the findings it can be deduced that different types of volatile organic compounds (VOCs) and their emission rates at various points inside each room necessitate an individual approach with numerous types of indoor plants for improving overall air quality. Therefore, the results demonstrate the potentiality of houseplants in purifying the atmosphere which could be economically significant for the floriculture industry besides having health benefits for people living or working indoors. Moreover, further studies should focus on discovering new plant species capable of removing higher percentages of VOCs than those already known thereby enhancing our knowledge base about the role played by house plants in purifying indoor air.

According to one findings [11], potted plants were researched as a simple and relatively inexpensive approach for reducing indoor air pollution, with a focus on nitrogen dioxide (NO_2) removal. The experiment tested three plant species: *Spathiphyllum wallisii 'Verdi', Dracaena fragrans 'Golden Coast'*, and *Zamioculcas zamiifolia 'Zamioculcas zamiifolia'* across two different growth media under real-time conditions with 100 ppb NO_2 at two standard indoor light intensities (0 and 500 lx) and in both moist and dry substrate environments. It was observed that all plant-media combinations could diminish the NO_2 levels characteristic of polluted urban sites, but to varying degrees. The most effective removal was recorded by *Dracaena fragrans* (i.e., within a 150 L chamber for 1 h under wet conditions at 500 lx), especially when grown on wet substrates under standard indoor illuminance levels. From a conservative point of view, this also amounts to 3 ppb of NO_2 per square meter of leaf area over 1 hour, or 0.62 ppb per potted plant over the same period if modeled for a small office (15 m^3) in a heavily polluted place with due account taken for dilution. Additionally, NO_2 elimination depended on the growth medium type and moisture content. Although they offer a passive means of ameliorating IAQ (indoor air quality), container-grown plants were found inadequate compared to their active counterparts, living walls (or green walls). However, their elementary nature, coupled with their low cost and minimal energy requirements, makes them essential components of strategies aimed at controlling air quality inside buildings, particularly when circulation is poor or there are high levels of pollution. Further research should be carried out so as to optimize these systems and integrate them effectively with other purification techniques.

It was demonstrated that therapeutic horticulture (TH) significantly relieved anxiety and sleep problems among university students with high levels of anxiety [38]. Stress was reduced by various horticultural activities; however, they affected the vitality of the participants differently. Potting plants and handcrafting activities gave more a greater sense of fulfillment than other activities. Decorative plants were found to be more effective in terms of reducing stress, while practical aromatic plants increased satisfaction as well as sleep duration. Consequently, TH should constitute a part of anxiety-relieving interventions within higher education institutions and such settings, where particular activities and plant materials used must be aimed at achieving certain objectives.

The formaldehyde-degrading Ochrobactrum intermedium strain ZH-1R has been shown to enhance the capability of indoor plants to eliminate this gas [17]. According to this research, the best ways of inoculating various kinds of plants were different. The most appropriate method for handling *Epipremnum aureum* was acupuncture injury to the stem, whereas root irrigation in the case of *Chlorophytum comosum* and *Ficus variegata* ZH-1R-inoculated *F. variegate, Chlorophytum comosum* during an 8-day fumigation period recorded 62.88% more formaldehyde removal rates at night than the non-infected ones and 20.17% higher during the day. It means that the endophytic bacteria can not only promote degradation but also prevent harm from happening during the night, especially by the host plants themselves. Henceforth, the combined system stands out as a potential approach that is effective and economically viable for improving IAQ indoors; however, further studies are needed to check its effectiveness on different types of pollutants as well as plants.

One research shows the immediate need for addressing indoor air pollution, especially in developing countries where its impacts on public health and the environment are more and more felt [10] . It provide an extensive review of various studies that show that indoor plants can be a practical and sustainable solution for improving IAQ (indoor air quality) at a low cost. Evidence collected from research around the world points out the astonishing abilities of houseplants to act as self-regenerative bioremediation systems, being able to effectively absorb different indoor air contaminants such as carbon monoxide (CO), ozone (O_3), carbon dioxide (CO_2), and volatile organic compounds (VOCs), among others. This paper not only introduces indoor plant systems as vital parts of biofilters but also foresees their wide application as standard technologies for improving IAQ. With ongoing processes of urbanization and industrialization as well as changes in lifestyle, it is important to notice increasing levels of pollution that necessitate immediate measures for protecting human health and surroundings. Therefore, urgent studies should be carried out mostly in densely populated regions like China, India, or the United States, where this problem has become so acute that public health concerns can no longer be ignored. Furthermore, genetic engineering methods need to be explored in order to increase the capability of plants to get rid of pollutants inside buildings, thus making indoor areas cleaner for future generations. Effective guidelines created aimed at preventing pollution inside buildings, especially critical facilities such as hospitals, schools, or residential houses, are a must if we want to ensure our own safety and comfort while living or working there.

Moreover, Table 1 and Fig. 1 outlines different pollutants, their origins, and their impact on human health and the environment, whereas Table 2 gives a summary of some plants known to help reduce these pollutants.

2. Psychological Performance:

An increase in the importance of nature to human health, stating that it is necessary to study people's interactions with plants from all angles [22] . This area touches such sides as ecology, culture, and psychology, showing how much benefit can be gained through working with greenery for our own good and that of the world we live in. The information above clearly reveals the immense benefits that nature provides for well-being. However, there should be more inquiries to find out why these things happen and many other areas that have not been looked into deeply enough so far; such research may offer some clues into this matter, if only through wide-ranging, large-scale epidemiological studies. It is only after people know the connection between them and plants can they start coming up with ways of ensuring sustainable development while taking care of their health; this will also lead to a conservation-friendly health system as well as environmental management, making sure that we leave behind us an earth better than what we found.

In an exhaustive study [36], investigated the link between mental well-being, cognitive functioning, productivity, and satisfaction in work settings, among other things, and perceived internal environmental characteristics (PIEC). The literature review identifies five main aspects of indoor climate: space, furniture, privacy, and the naturalness of visual quality that have been extensively researched but less so in regards to décor aesthetics and maintenance. It confirms their significant effects on satisfaction levels, productivity rates, and general happiness, while also advocating for more detailed studies, such as configurations for natural elements or privacy arrangements. Furthermore, it points out a lack of experimental research clarifying these factors' impacts on cognitive performance and suggests some practical solutions on how they can be altered through design changes for offices. For mental health, cognitive ability, work productivity and job satisfaction, indoor climate, furniture, privacy are key but we must also pay attention to environmental maintenance and aesthetic aspects. Natural elements should be designed thoroughly with regard to the quantity and arrangement. Further, it is important to allow some flexibility in the arrangement, workstation and furniture to provide sense of privacy. Last but not least, cognitive stimulating office environments should be the focus when creating new offices.

Air pollution is a significant concern especially with the rise of industrial development and urbanization. Indoor air quality problems are exacerbated with rise in exposure to harmful chemicals. The indoor air pollutants or indoor contaminants (IC) such as inorganic gases, biogenic constituents cause Sick Building Syndrome (SBS) which badly affect the health and productivity of building occupants. SBS can be alleviated using NASA-validated air-purifying plants. In the present study, Sansevieria Laurentii were used. The indoor contaminants used for the experiments were adhesives, paint, kerosene, egg crates, cigarette, varnish, wood shavings and coconut husk. The findings showed that using locally available plants for air cleaning is feasible and there is a significant reduction of indoor air pollution with increased number of potted plants. The maximum number of potted plants used in the experiments did not exceed six. It was further identified that potted plants and passive green wall were not effective in reducing air pollutants compared to an active green wall. However, the addition of snake plants resulted in better reduction of pollutants. TVOC decreased by 50% in the case of paint (against 10% without plants) and 75% with varnish (against 10% without plants). HCHO levels were reduced by 63% with kerosene (against 6% without plants) and 57% with adhesive (against 4% without plants). CO_2 levels were decreased by 18% with coconut husk and egg crate (against 3% and 1% without plants, respectively). CO levels were reduced by 77% with cigarettes (against 1.2% without plants) and 27% with wood shavings (against 3% without plants) [18].

The physical features of indoor plants influence psychological outcomes, aesthetic attraction, and perceived plant benefits with respect to subjective well-being (SWB), indoor air quality (IAQ), and relative humidity (RH) [7]. They surveyed 520 participants who rated twelve different interior plant pictures. Descriptors such as "uplifting," "interesting," "relaxing," and "beautiful" had high standardized regression coefficients and were significant predictors of perceived SWB benefits. Plants described as "healthy" and "attractive" were the most frequently selected including palm, ficus sphere, epipremnum, and ficus column. For perceived IAQ and RH benefits, plant health and canopy density were important factors. Unhealthy plants scored negative values, suggesting that such plants should be removed. Results also showed that plant shapes were attractive and rounded contours were preferred, but no single shape was predominantly preferred over others. Finally, demographic factors had weak effects on plant ratings, suggesting that similar plants could be selected for various environments. These results indicate that healthy, dense, and attractive plants should be selected to improve well-being, cognitive performance, and productivity in various indoor environments. These practical results should help designers, architects, building managers, and residents to select and place interior plants in the best locations, most effective species, and optimal numbers. Interior plants can improve psychological well-being and some aspects of indoor environmental quality. Furthermore, this study provides the first step in developing an interior plant selection guide based on psychological and perceived benefits for various indoor spaces.

Biophilic healthcare design is essential for developing healing and restorative settings, which has been discussed for the deficiency of consideration of natural plants inside healthcare facilities as a part of the biophilic healthcare design framework [21]. Nevertheless, there has been evidence that they provide a number of advantages. One key challenge that is well noted and leads to a compromise between emotional healing factors and economic returns influences health care settings to limit indoor plants more often than not as a result of the latter. Interestingly, the connection between the indoor plants and the general increase in microbial counts or infection-causing HAIs is meager. Nonetheless, the regulations forbidding it inherently restrict creativity in care-space designs. Published study samples are often small and scattered, or they lack attention to the abundance of benefits of indoor plants, such as stress reduction and cognitive enhancement. Considering the current increasing demand for people's healthcare, cost-effective solutions like the use of indoor plants can play an important role. Addressing these knowledge gaps through research that cuts across disciplines will support improved health and wellbeing for all building occupants of healthcare facilities around the globe.

III. FIGURES AND TABLES

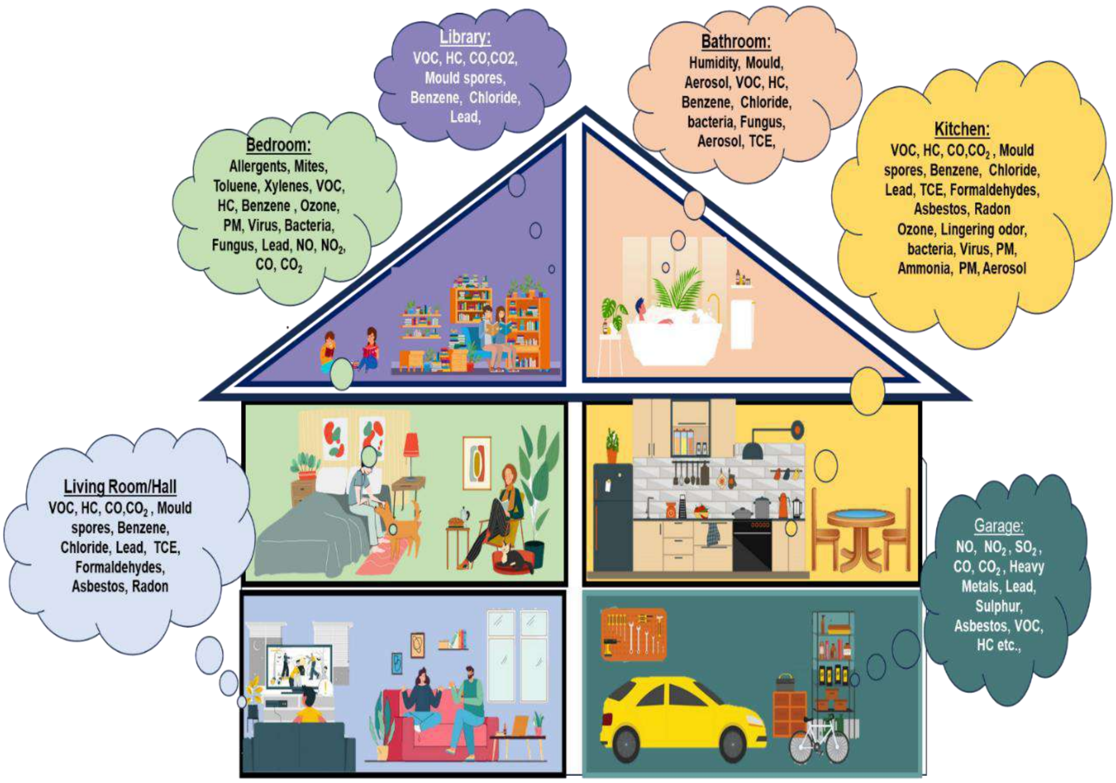

Fig. 1: Common Indoor Pollutant

Table 1: Types of pollutants, their sources and effects on human health

Type of Pollutant	Sources	Effects on Human Health	Mitigation Strategies	Ref.
Hydrocarbons and Volatile Organic Compounds (VOCs)	Paints, varnishes, cleaning agents, pesticides, building materials, furnishings, Fumes from cooking, Fuel/Tobacco combustion and Consume products.	Irritation of eyes, nose, and throat; headaches; dizziness; exacerbation of asthma and allergies; long-term exposure linked to cancer, Failure of nervous system.	Use low-VOC or zero-VOC products; increase ventilation; use air purifiers with activated carbon filters	[13]
Aldehyde, Formaldehyde	Building materials (plywood, particleboard),furniture,adhesives Construction materials, Cooking & Furnishing.	Irritation of eyes, nose, and throat; respiratory issues; headaches; increased cancer risk Breathing problems, cancer, Headache, Decreasing immunity	Proper ventilation; use formaldehyde-free materials; increase indoor plants known to absorb formaldehyde	[13]
Tobacco Smoke	Smoking of cigarettes, cigars, pipes	Respiratory issues (asthma, bronchitis); increased risk of lung cancer, heart disease, and stroke	Implement smoking bans indoors; promote smoking cessation programs; improve ventilation	[23]
Carbon Monoxide (CO)	Incomplete combustion of fuels (gas stoves, furnaces, fireplaces) Tobacco combustion, Wood stove.	Headaches, dizziness, nausea, confusion, fatigue; can be fatal at high levels; long-term exposure linked to cardiovascular issues and cognitive impairment Interferes with oxygen supply, Retarded reflexes due to CO exposure.	Install CO detectors; maintain fuel-burning appliances; ensure proper ventilation	[23]
Nitrogen Dioxide (NO2)	Combustion sources (gas stoves, heaters, tobacco smoke)	Respiratory irritation; exacerbation of asthma symptoms; increased susceptibility to respiratory Infections pulmonary disease, impairment of lung function, and irritation in eye, nose, and throat.	Proper ventilation; use exhaust fans; maintain gas appliances; minimize indoor combustion activities	[14]
Particulate Matter (PM)	Combustion sources (cooking, heating appliances), tobacco smoke, dust, pollen, mold Spores.	Respiratory issues (asthma, bronchitis); cardiovascular diseases; adverse pregnancy outcomes; increased mortality risk, Eye, nose and Throat irritation, Asthma, Various lung, and cardiovascular disorders.	Use HEPA filters in air purifiers; improve ventilation; reduce indoor sources of PM; clean regularly	[31]
Biological Pollutants	Bacteria, viruses, mold, dust mites, pet dander, pollen, Furnishings, Moist area, Ventilation system, Cockroaches	Allergic reactions (sneezing, coughing, congestion); respiratory infections; exacerbation of asthma and allergies, Sneezing, Coughing, Watery eyes, Shortness of breath,Dizziness,Lethargy,Lung diseases	Control moisture levels; clean and disinfect regularly; use air purifiers with HEPA filters; improve ventilation,	[13]
Radon	Soil or rock beneath buildings Burning of Coal and other fossil fuel, Construction materials, Soil gas and Tap water.	Increased risk of lung cancer; long-term exposure is the second leading cause of lung cancer after smoking,	Test for radon levels; seal cracks and gaps in buildings; install radon	[02]

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		Leukemia,	mitigation systems where necessary	
Asbestos	Building materials (insulation, Demolition of construction materials.flooring, ceiling tiles)	Mesothelioma, lung cancer, asbestosis; respiratory issues; increased risk of other cancers, cancer of Kidney , Brain, Urinary bladder, gall bladder, Throat voice box etc.	Identify and safely remove asbestos-containing materials; encapsulate asbestos if removal is not feasible	[19]
Lead	Old paint, dust, soil	Neurological and developmental issues (especially in children); high blood pressure; kidney damage Attack on brain and CNS to cause Coma	Remove lead-based paint and dust safely; test and treat drinking water; cover bare soil with grass or mulch	[13]
Nitrogen oxides	Fuel combustion, Tobacco smoke.	Pulmonary disease, impairment of lung function, and irritation in eye, nose and throat.	Ensure proper ventilation while cooking. Use effective range hoods and consider electric or induction stoves to reduce NOx. Use potted plants bio-filtration and green walls to purify the air.	[14]
Ozone	Printers, Photocopiers, Air purifying devices.	Throat irritation, Cough, Pain, burning or discomfort in the chest ,Chest tightness, Wheezing and shortness of breath.	Keep doors and windows closed on high-ozone days. Use activated carbon filters in HVAC systems. Reduce indoor ozone sources like certain air purifiers and printers. Regularly check indoor ozone levels.	[03]
Pesticides	Dust from outside, consumer products	Blood and nerve disorders, Genetic disorders, Endocrine disruption, and Reproductive problems.	Keep pesticides outside, use non-chemical pest control, improve ventilation, and regularly clean surfaces to reduce indoor pesticide pollutants.	[01]
Sulphur oxides	Fossil fuel combustion	Impairs lung function adversely, Causes Cardiovascular diseases, Irritate skin and mucous membrane of the eyes,nose, throat and lungs.	Use low-sulfur fuels and appliances. Ensure proper ventilation. Install air purifiers with sulfur oxide filters. Regularly maintain HVAC systems.	[14]
Trichloroethelene (TCE)	Varnishes, lubricants,Adhesives, Typewriter correction fluid, Paint removers.	Effects on Liver, Kidney, CNS, Reproductive and Immune system.	Increase ventilation to reduce TCE buildup. Use air purifiers with activated carbon filters. Avoid using	[04]

			products containing TCE. Opt for safer alternatives for cleaning and degreasing. Maintain regular indoor air quality monitoring.	
Benzene	Tobacco smoke,	Causes dizziness, headaches, and drowsiness, Long-term exposure can lead to blood disorders, Carcinogenic, may cause leukemia	Ensure proper ventilation, Use air purifiers with activated carbon filters, Avoid products containing benzene, Regularly monitor indoor air quality	[20]
Ammonia	Cleaning products, Fertilizers, Animal waste, Car emissions, Industrial emissions, Household products (paints, glues)	Irritates eyes, nose, and throat, High levels can cause respiratory issues and burns, - Prolonged exposure can damage lungs	Improve ventilation, especially in areas where ammonia is used, Use natural cleaning products, Store ammonia-based products securely and use them sparingly	[20]
Xylene	- Paints and varnishes, Cleaning agents, Printing and rubber industries	Causes headaches, dizziness, and confusion, Prolonged exposure can affect the liver and kidneys, May cause respiratory problems	Ensure adequate ventilation, Use low-VOC products, Install air purifiers with activated carbon filters, Avoid using products containing xylene indoors	[20]
Toluene	Paints, paint thinners, Adhesives and glues, Nail polish and nail polish remover. Fuels	Causes headaches, dizziness, and nausea Long-term exposure can damage the nervous system May cause liver and kidney damage	Increase ventilation, especially when using products with toluene Use toluene-free or low-toluene products Utilize air purifiers with activated carbon filters Store products containing toluene properly	[20]

Table 2: Table of Indoor Plants and Their Controlled Pollutants

No	**Plant Name**	NH 3	C_6H_6	CO	CH_2O	HC/ VOC	O_3	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	**Ref.**
1.	Aloe Vera *(Aloe vera)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[33]
2.	Areca Palm *(Dypsis lutescens)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[15,25]
3.	Arrowhead Vine *(Syngonium podophyllum)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	-------------	--------------	[29]
4.	Aglonema *(Chinese Evergreen)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
5.	Bamboo Palm *(Chamaedoreaseifrizii)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
6.	Banana (*Musa Oriana*)	-------------	-------------	-------------	CH_2O	--------------	-------------	-------------	-------------	--------------	[25]
7.	Boston Fern *(Nephrolepis exaltata)*	NH 3	C_6H_6	-------------	-------------	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
8.	Chrysanthemum *(Chrysanthemum morifolium)*	NH 3	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
9.	Dumb canes / Dieffenbachia (Dieffenbachia spp.)	-------------	-------------	-------------	-------------	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]

10.	Money plant / Devil's Ivy /Pothos /Goldon Pothos *(Epipremnum aureum)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[24]
11.	Dracaena /(Red edge-draceana) *(Dracaena marginata)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[25, 33]
12.	Dwarf Date Palm *(Phoenix roebelenii)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[25, 33]
13.	Elephant Ear Philodendron (*Philodendron domesticum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[09,12]
14.	Anthurium/ Flamingo Lily (*Anthurium* andreanum*)*	NH 3	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
15.	Gerbera Daisy / Barberton Daisy (*Gerbera jamesoni)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	C_2HCl_3	--------------	[25]
16.	English Ivy *(Hedera helix)*	NH 3	C_6H_6	CO	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33,39]
17.	King of hearts *(Homamena wallisii)*	-------------	-------------	-------------	-------------	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
18.	Heart leaf Philodendron *(Philodendron cordatum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[09, 25]

19.	Janet Craig / Warneckei Dracaena *(Dracaena deremensis)*	--------	C_6H_6	-------------	CH_2O	--------------	-------------	-------------	C_2HCl_3	--------------	[33,34]
20.	Kimberly Queen Fern (Nephrolpis *obliterate*)	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
21.	Lady Palm *(Rapisexcels sp.)*	NH 3	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
22.	Lily turf *(Liriope spicata)*	-------------	-------------	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[33]
23.	Mass Cane/ Corn Stalk Plant *(Dracaena Massangeana)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[26, 33]
24.	Moth Orchid *(Phalaenopsis spp)*	-------------	C_6H_6	-------------	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
25.	Parlor Palm *(Chamaedorea elegans)*	NH 3	C_6H_6	CO	CH_2O	--------------	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]
26.	Peace Lily *(Spathiphyllum wallisii)*	NH 3	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33,35, 39]
27.	Poinsettia *(Euphorbia pulcherrima)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[05]
28.	Rubber Plant *(Ficus* elastica*)*	-------------	C_6H_6	CO	CH_2O	--------------	-------------	-------------	-------------	--------------	[08]

29.	Snake Plant/ Mother-in law's tongue *(Sansevieria trifasciata"Laurentii")*	-------------	C_6H_6	-------------	CH_2O	--------------	O_3	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[24,33]
30.	Spider Plant *(Chlorophytum comosum)*	-------------	C_6H_6	CO	CH_2O	HC/ VOC	O_3	$C_6H_5CH_3$	-------------	$(CH_3)_2C_6$	[08,24, 33]
31.	Split Leaf Philodendron *(Thaumatophyllum bipinnatifidum)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	-------------	-------------	--------------	[26]
32.	Weeping Fig *(Ficus Benjamin)*	-------------	C_6H_6	-------------	CH_2O	HC/ VOC	-------------	$C_6H_5CH_3$	C_2HCl_3	$(CH_3)_2C_6$	[33]

Note: Color Code of Idoor Plants and Their Controlled Pollutants for Table 2

NH 3	**Ammonia**	C_6H_6	**Benzene**
CO	**Carbon Monoxide**	CH_2O	**Formaldehyde**
HC/ VOC	**Hydrocarbon/Volatile Organic Compound**	O_3	**Ozone**
$C_6H_5CH_3$	**Toluene**	C_2HCl_3	**Trichloroethylene**
$(CH_3)_2C_6H_4$	**Xylene**	--------------	**Absent of Pollutant**

IV. CONCLUSION

Indoor plants, therefore, provide a holistic solution to improving the indoor environment in aspects that affect human health. First, through purging the air; second, by moderating the humidity in the room; and third, and lastly, psychologically, plants play a big role in promoting a healthier indoor environment. The subsequent research should aim at establishing the best types of plants that have the most benefits and how to further improve plant management systems. Using indoor plants in building construction and including greenery in interior décor is a potential solution to promote healthier living and working environments. The detailed examination of potential solutions for preventing indoor air pollution further establishes that indoor plants are a key ally in enhancing IAQ and preserving people's well-being. A variety of experimental studies have provided evidence of the effectiveness of numerous plant species in removing pollutants, with overall findings suggesting that light intensity, plant metabolic rates, microbial relationships, etc. play important roles in removing such pollutants. Additional improvements, such as the introduction of bi-directional phytofilters and the use of endophytic bacteria in indoor plant-based air filtration systems, also help to improve their working. Besides, studies also boast of the psychological benefits of having plants within our interiors and corroborate the role of these plants in boosting human performance across various aspects of health. Since an issue with indoor air pollution is an ever-present factor, constant research and development on how to optimize the usage of indoor plants can go a long way to help in realizing the maximization of the effectiveness and general use of indoor plants as an economical way of improving the quality of air indoors. The incorporation of botanical biofilters in building designs and the need for biophilic design bring society closer to a future where people will be assured to breathe clean air within their artificially-made environment.

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Traditional Low-Efficient and Anti-Ecological Agriculture Must Be Replaced with Modern Cellular and Hydroponic Agriculture

Mikhail Krasnyansky

Dr. of Chemistry, Professor, Donetsk National Technical University, Ukraine
Corresponding author's email: drmikhailkrasnyansky@gmail.com

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Abstract*— *The article analyzes traditional agriculture as low-efficient, excessively resource-intensive, and anti-ecological and substantiates the need for its transition to modern cellular and hydroponic agriculture against the backdrop of an unfavorably changing climate.

***Keywords*— climate change, climate resilience, cellular agriculture, hydroponic agriculture**

I. INTRODUCTION

It is evident that completely halting global climate change is unattainable. Alas, traditional agriculture is a low-efficient, excessively resource-intensive, and anti-ecological industry, and it is completely unsuitable under conditions of rapid unfavorable climate change.

So, huge losses of crops and livestock occur during becoming more frequent now extreme weather conditions: droughts, hurricanes, floods, etc. [1]. Agriculture consumes about 70% of freshwater and its consumption is growing every year (Fig. 1) [2, 3]. At the same time, both the area of arable land in the world and global freshwater reserves are rapidly declining (Fig. 2) [4, 5].

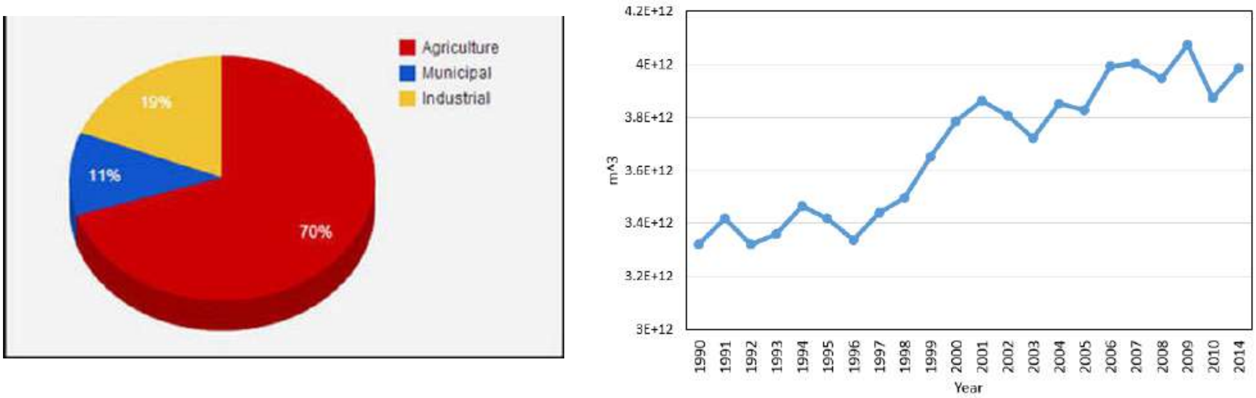


Fig. 1. Global water using (left, [2]) and World water consumption (right, [3])

It's worth noting that approximately 3 million tons of pesticides are produced and sprayed annually worldwide, which poses significant risks to environment and public health but current agriculture cannot do without it [6].

The "Lindeman ten percent rule" underscores that energy transfer from one trophic level to the next in ecosystems typically amounts to just 10% (see Fig. 3, left) [7]. Therefore, around the world, about 40% of arable land (150 million acres or 63 million hectares) is using for growing crops as food for breeding livestock and poultry (it is about 150 million tons) [8].

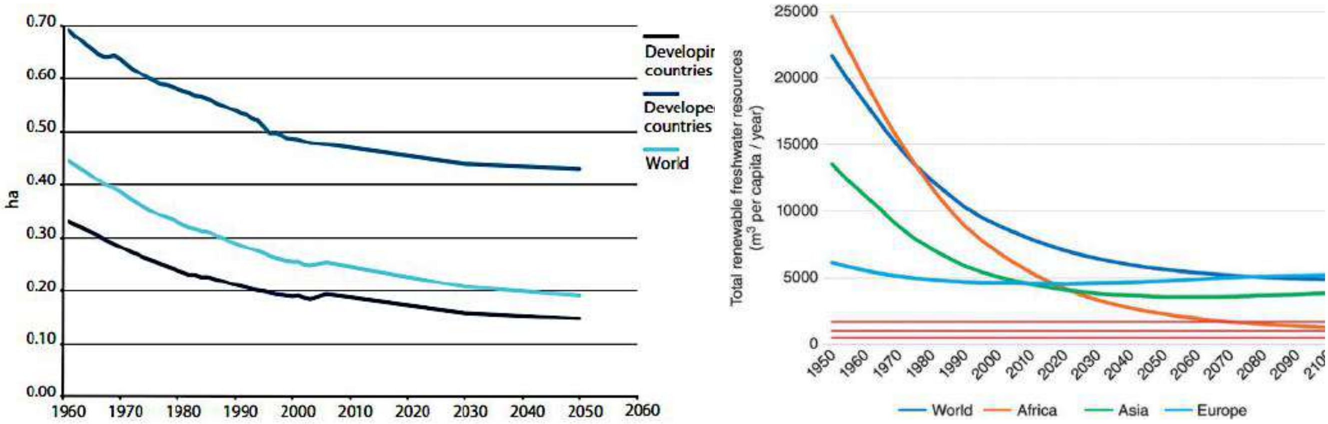
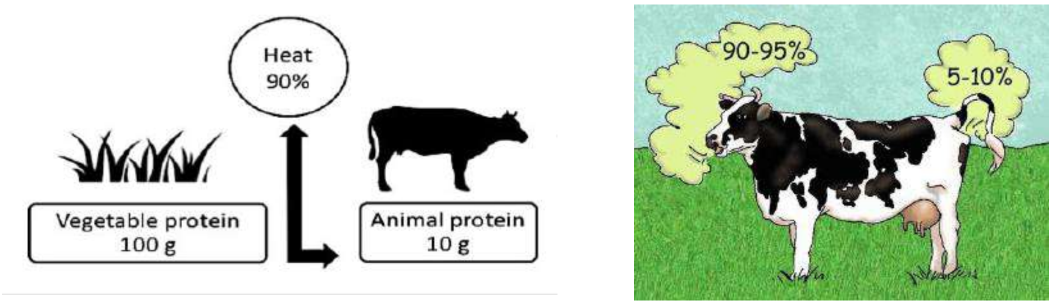


Fig. 2. Decreasing of global arable land area (left, [4]) and global water availability (right, [5])



Progressive loss of efficiency in food chain ("Lindeman rule") - only 10% of the vegetable protein will convert into meat protein, it is the efficiency of a 1900 steam locomotive!

Cow methane emission (burping – 90-95%, flatulence – 5-10%) –

total about 100 million tons of methane annually

Fig. 3. Low-efficiency and anti-ecological cow

Furthermore, the world's bovine population (exceeding one billion) emits roughly 100 million tons of methane annually, equivalent to 3 billion tons of CO_2 (see Fig. 3, right) [9]. With the planet's limited resources and threats of negative climate change, sustaining a billion cows is no longer viable.

Thus, in 20-30 years, under a significantly changed climate, the current agricultural system will become dangerously unworkable. But all of the above problems can (and should!) be eliminated by transitioning traditional agriculture to modern hydroponic and cellular agriculture.

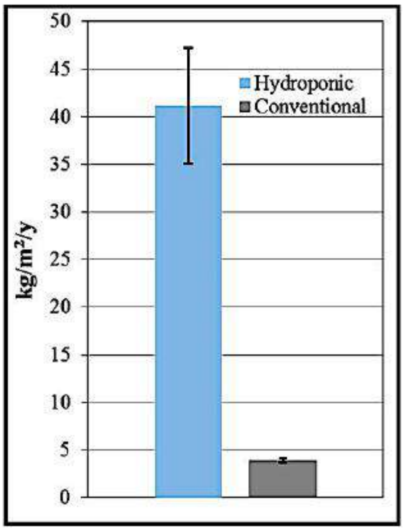
II. DISCUSSION

1. Vertical farms against crop failures, drought, and world hunger. The cultivation of numerous agricultural crops should transition to vertical farms using hydroponic methods within specially designed multi-storey buildings and 10-20-shelf racks on each floor of the farm [10] (see also Fig. 4 [11]). Additionally, numerous suitable unused buildings can be repurposed for vertical farming.

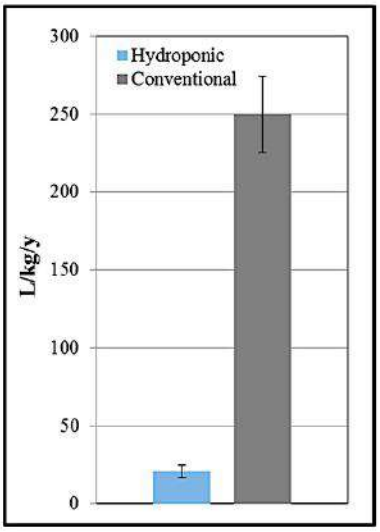
Fig. 4. Europe's biggest vertical farm "Nordic Harvest" in Copenhagen [11]

Vertical farms offer the following advantages:

- complete automation of growth and harvest processes;
- harvesting time is halved, and here you can have several harvests a year;
- crop stability independent of natural conditions including increased resilience to natural disasters, and this is the most effective counteraction to severe droughts;
- implementation of water collection and purification systems, reducing water consumption by up to 90% compared to traditional agriculture;
- potential for location within city limits, leading to a drastic reduction in transportation costs;
- vertical farming conditions negate the occurrence of pests, rendering the use of pesticides unnecessary;
- if a vertical farm is equipped with solar panels, mini-wind generators, and heat pumps, it will provide itself (partially or completely) with electricity and heat.



Modeled annual yield in kilograms per square meter of lettuce grown in southwestern Arizona



Modeled annual water use in liters per kilogram of lettuce grown in southwestern Arizona

Fig. 5. Comparison of water and yield for lettuce grown using hydroponic vs conventional agricultural methods [12]

As shown in Fig. 5 [12], the estimated yield of lettuce in hydroponics is approximately 10 times higher (kg/m^2/year) than in an open field, while water consumption (L/kg/year) is 12 times less.

You must also understand: if there is a 20-story vertical farm building with an "internal" area of 20x50 = 1000 m^2, and on each floor there are 5 racks with hydroponics, then the real area of such a "field" is 1000x20x5 = 100,000 m^2.

Yes, even one vertical farm facility may require millions of dollars in upfront infrastructural costs and equipment but based on the totality of all factors, a vertical farm exhibits approximately 10-15 times the efficiency than of open-field cultivation. In addition, agriculture in Europe and the United States is hopelessly unprofitable. So, the US Department of Agriculture, in 2018, received 140 billion US$ of subsidies [13]. Wouldn't it be better to use this 140 billion to finance vertical farms?

P.S. As for fruits, we need to learn how to grow them using the hydroponic method too. For example, to grow in natural conditions 1 avocado, you need an average of 70 liters of fresh water, which is 14 times the amount of water needed to grow one tomato [14].

2. Cultivated (cell-based) meat against anti-ecological and low efficiency animal breeding. The imperative lies in shifting away from conventional animal husbandry towards cultivated

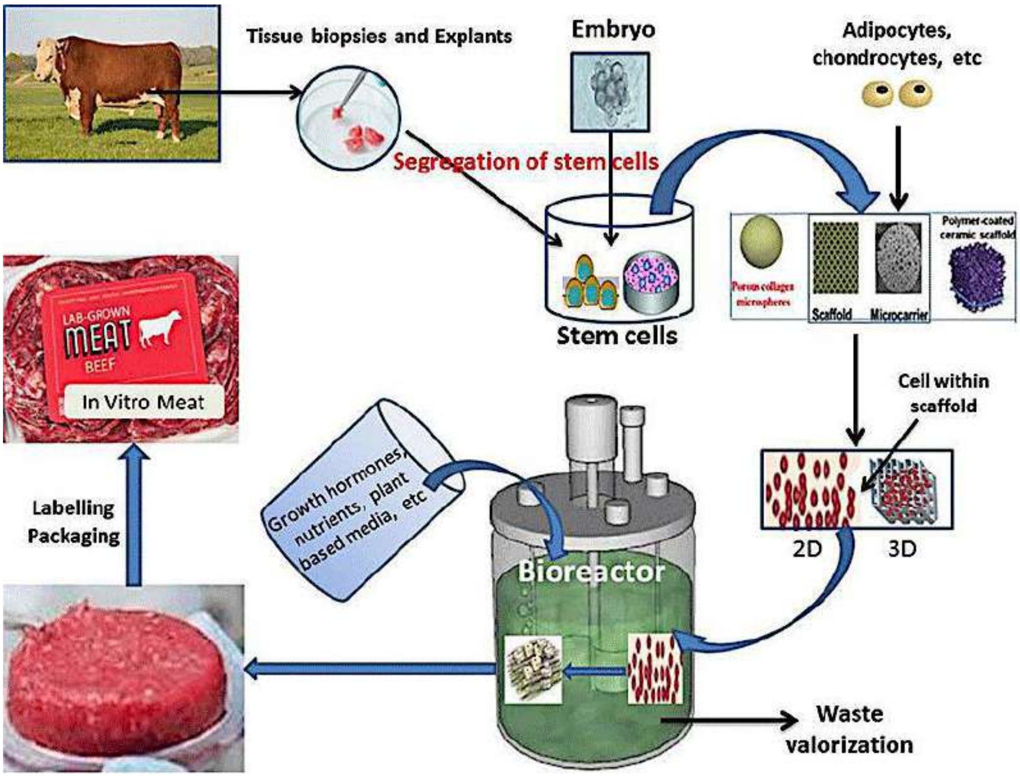


Fig. 6. Scheme of a possible technology for the production of cell-grown meat [15]

(cell-grown) meat produced from cow, pig, or chicken stem cells extracted from their muscles (see Fig. 6 [15]). Production of artificial meat requires five times less energy and 10 times less water than conventional beef production for the same quantity. It also reduces greenhouse gas emissions by 20 times compared to livestock farming. In sterile conditions, artificial meat eliminates the presence of parasitic worms, salmonella, and toxic metals often found in raw meat. The meat-grown technology in vitro should imitate the in-vivo conditions to get cultured tissue similar to natural. Tissue culturing is needed for preparation of high volume of structured meat.

Fig. 7. A future workshop for the production of 150 tons/year cell-grown meat, which will replace a herd of 2000 cows/year, will vacate 5000 hectares for sowing feed for them, and also will save environment from the emission of 200 tons/year "cow methane" (illustration by https://www.voxelmatters.com/meatech-wants-to-establish-and-operate-a-pilot-plant-in-2022/)

Fig. 8. Dr. Mark Post with the first cultivated beef burger, Aug. 5, 2013, Maastricht University

https://www.greenqueen.com.hk/10-years-since-that-burger-10-highlights-the-cultivated-meat-journey/

Moreover, an artificial "meat plant" occupies only 1% of the land compared to a conventional meat farm. In addition, 63 million hectares will be freed up, since there will be no need to sow them for feeding livestock and poultry.

Over 100 startups were dedicated to producing cultivated meat and seafood by the end of 2022. In 2022, the calculated cost of cultivated meat was about $17 per pound (≈$38/kg) [16] but with the transition to its mass production, prices for cultivated meat will eventually become equal to prices for natural meat.

3. Minimizing food wastage – it is fight against world hunger and a huge waste of energy and fresh water at all stages of harvesting and storing crops up to grocery store shelves and home dining tables. Approximately 800 million people out of 8 billion on our planet experienced partial or complete hunger in 2020. Astonishingly, the world produces roughly 4-4.5 billion tons of food annually, sufficient to meet global needs if utilized judiciously. Unfortunately, around 1.3-1.5 billion tons (approximately 30-35% of the 4-4.5 billion tons produced) are lost or wasted each year [17, 18]. It also leads to uselessly spending

20% of global freshwater and 15% of the world's produced oil annually. Given this, the financial impact of global food losses can be estimated at approximately USD 2.5 trillion. This wastage occurs at every stage, from production and processing to storage, transportation, and ultimately reaching grocery store shelves and any dining tables. The United Nations World Food Program (UN WFP) reveals that approximately 14% of food produced is lost between harvest and retail due to transit, storage, or processing issues.

Fig. 9. Where does food wastage and losses occur? [19]

Additionally, about 17% of food is wasted in households. In total, this amounts to a staggering **31%** of global food loss and waste (review authors [19] believe 39% - see Fig. 9). This has significant economic repercussions, as the World Bank values the global food system at roughly $8 trillion, hence, the financial impact of global food losses can be estimated at approximately USD 2.5 trillion. Beyond economic concerns, there are also environmental one: unused food not only perpetuates hunger but also spend uselessly 20% of global freshwater and a corresponding 20% of the world's produced oil annually (i.e. 20 million barrels per day are burned in vain.) Cellular and hydroponic agriculture can reduce food wastage by about 3 times - up to **10%**, hence, losses will be reduced to 0.8 trillion USD, and the savings in lost finances will be (2.5 - 0.8 = 1.7) trillion USD.

So, cellular and hydroponic agriculture can reduce food wastage by about 3-3.5 times - up to 10%, hence, this will bring an additional approximately 0.8-1 billion tons of food and 1.5 billion USD in profit annually.

III. CONCLUSIONS

Our planet no longer has enough resources (arable land, fresh water, etc.) to support the traditional low-efficiency, excessively resource-intensive, and anti-ecological agriculture, also including the use of 3 million tons pesticides.

Approximately 800 million people out of 8 billion on our planet experienced partial or complete hunger in 2020. **Cellular and hydroponic agriculture will end world hunger forever.**

Cellular and hydroponic agriculture can (and should!) become the newest multi-billion dollar industry with millions of jobs for scientists, engineers and workers. *(Another emerging industry with similar potential is "cellular cookery." However, for this sector to gain popularity, regional and global "cellular chef" competitions need to be organized.)*

Besides:

1. It will increase the yield by 8-10 times per 1 m^2 of area, while reducing water consumption by 8-10 times and also making the harvest independent of weather conditions.
2. Will free up millions of hectares of fertile land for other purposes.
3. Meat will become environmentally and biologically clean.

4. The atmosphere will be rid of 100 million tons of methane per year.
5. The production of 3 million tons of pesticides and their spraying above the ground will stop.
6. Food losses will be reduced by 3 times.

Of course, cellular and hydroponic agriculture needs large investments, tax benefits, a loud advertising campaign, etc. But rest assured that cellular and hydroponic agriculture will achieve widespread success in any case, since, in the face of negative climate change and depletion of natural resources, **there is no alternative to it, its triumph is inevitable!**

So, whoever manages to occupy this trillion-dollar super-promising and super-modern market cellular-hydroponic agriculture will become the "king of agriculture" of the 21st century.

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Comparison of Adapted and Improved Feature Extraction Techniques of Different Potatoes Types using Image Processing

D. Ravindra Babu[1*], R.C.Verma[2], Navneet Kumar Agrawal[3], Isha Suwalk[4]

[1,2]Ph.D. Scholar and Professor, Department of Processing and Food Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India
[3&4] Assistant Professor and Ph.D Scholar, Department of Electronics and Communication Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India
*Corresponding Author: drdravindrababu@gmail.com

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***Abstract*— *The characteristics of crack, rotten, sprout, skin peel and good potatoes non destructively with gray level co-occurrence matrix properties (GLCMP), radon, gabor, local binary patterns (LBP) and histogram of oriented gradients (HOG) with default parameters and values i.e. adapted method were compared with improved method. Gabor feature length (16) of improved method was lower compared to adapted method and improved method and it requires less time to plot gabor magnitude and spatial kernels for all potato classes. Radon feature row vector size is same for both adapted and improved methods for all potato classes but differ in column vector size. At theta value of 90° (improved method), the time taken to plot radon transforms is lower compared to adapted method (using theta value 180°). Gray level co-occurrence matrix properties (GLCMP) such as contrast, correlation, energy and homogeneity values were compared to both adapted and improved methods for all potato types. Contrast values found lower in adapted method for all potato classes compared to improved method. But remaining three properties found highest in adapted method for all potato classes compared to improved method. The default values used in adapted method of HOG feature vector length (26140) is higher compared to improved method (1330) for all types of potato images. For crack and rotten potato images, an improved method required higher time to plot visualization than adapted method, while for sprout, good and skin peel images, adapted method has more visualization time. The LBP feature length in improved method was found higher (185) compared to adapted method (59) for all potato classes. The mean time to plot squared errors in adapted and improved methods for crack images were found to be 0.6378 s and 0.6305 s respectively, for rotten images 0.2098 s and 0.2622 s, for sprout images 0.1911 s and 0.2209 s, for skin peel images 0.2197 and 0.2197 s, for good images 0.2672 and 0.2565 s.*

Keywords— ***Local Binary Patterns, Histogram of Oriented gradients, Radon Features, Gabor Features and Grey Level Co-occurrence Matrix Properties***

I. INTRODUCTION

The demand for image processing is increasing day by day by extracting preciuos data from images without touching the objects. An each image contains information and it is extracted either in the form of numerical or in graphical fprm by different feature extraction techniques. Image processing carries excellent verification of agricultural commodities (Unay *et al.*, 2011). One of the most famous cultivations on earth, which is widely consumed as raw or cooked, is potato (*Solanum Tuberosum L.*). Farming of potatoes accounts for almost 80 per cent of countries. Following rice, wheat and maize, it is India's main crop. The need for potatoes for processed products is strong and not for fresh use. This increases the demand on the market for high-quality potatoes (Rani and Prasoon, 2013). In India, 5129.4 million ton potatoes (Anonymous, 2018) are produced for the year 2017-18, and it occupied third position in the world (Anonymous, 2017). In India, potato production has increased substantially over the last six decades. The analysis shows that the potato yield and production increased respectively at the national level at 1.10 and 5.98 million per year during the last decade (Bai *et al.*, 2009). In this paper, gray level co-occurrence matrix (GLCM), local binary patterns (LBP), Histogram of Aloriented gradients (HOG), gabor and radon feature extraction techniques were appiled to crack, rotten, sprout, skin peel and good potato images in adapted and improved techniques, because it is very necessary and important to find best technique interms of feature size and time taken to extract features.

II. REVIEW OF LITERATURE

Local binary patterns and gray level co-occurrence matrix properties are used to estimate the textural features (Matlab, R2018b). Moallem *et al.*, (2013) used three properties of gray level co-occurrence matrix such as contrast; correlation and energy are used for classification using support vector machine and artificial neural network. Alhindi *et al.*, (2018) given that local binary patterns (LBP) for recognizing mammography images, facial recognition and for extracting features of cancerous areas. Ojala *et al.*, (2002) given that LBP features mainly depend on number of neighbors and radius. The general combinations used in LBP are 4, 8, 12, 16 and 24 numbers of neighbors for 1, 1, 1.5, 2.0 and 3.0 radii respectively. Alhindi *et al.*, (2018) stated that output feature has a dimension of 1182 by using radius and number of neighbors as 4 and 14 respectively. In histogram of oriented gradients (HOG), an image is divided into number of cells by using different cell sizes and draw gradients over the image. Features of HOG and LBP are used in facial recognition. An output of 1224 bin dimension HOG vector was formed by using cell size of 18-by-18 and block size of 1-by-1. Gabor features are used for detecting cancerous images from non cancerous images (Alhindi *et al.*, 2018). Radon features uses projections to calculate feature vector (Alhindi *et al.*, 2018).

III. MATERIALS AND METHODS

This section starts with image capturing system development. Five adapted, improved feature extraction techniques used in image analysis were compared and conclusions were drawn.

3.1 Setup for Image Capturing

The image processing units were consisting of acquisition devices, followed by image analysis unit like computer with image storage unit as shown in Figure 1. Image capturing requires an artificial light, image sensor and image storage unit as shown in Figure 1.

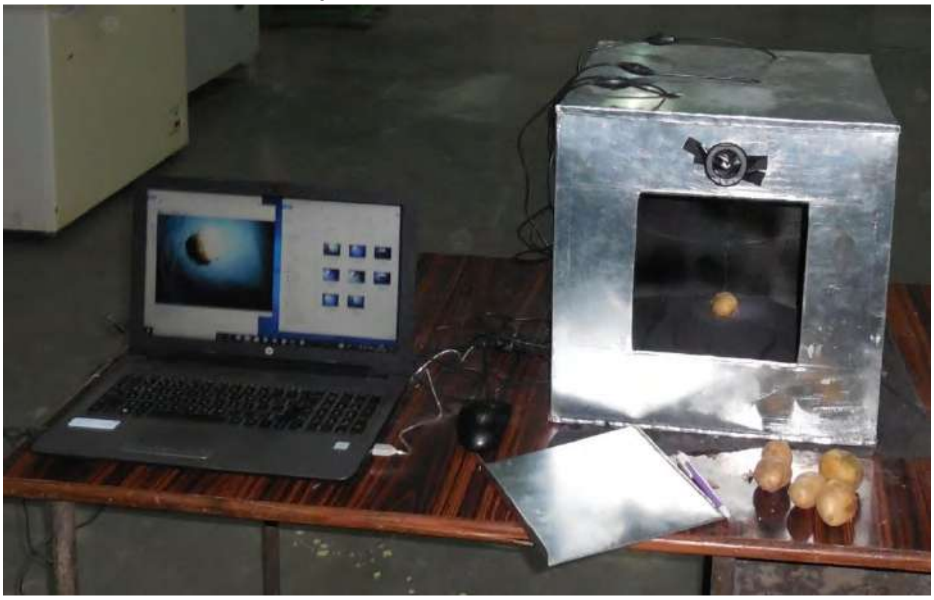

Fig.1 Image processing setup developed for potatoes

A setup was developed with the help of a 40×40×40 cm box using a 20-gauge galvanized iron sheet. Four still web cameras (Model no. QHM495LM) equipped with inbuilt six LED lights and potentiometers were installed on the inner four side walls of the box focussing in the centre of the box (Figure 1). The four ends of cameras were connected to laptop through USB (Zebronics, ZEB-04HB) Hub. While capturing care must be taken by allowing light to settle on potatoes. Potentiometers were used for adjusting the light intensity. Walls of the box were painted with black color to eliminate reflections. A door was provided at the front to place and remove potatoes. After developing setup, next step is image capturing. Crack, rotten, sprout, skin peel and good potato images each of twenty having different image sizes are taken for adapted and improved feature extraction. Feature extraction is the step before classification.

3.2 ADAPTED FEATURE EXTRACTION TECHNIQUES

Feature extraction techniques like gray level co-occurrence matrix properties, local binary patterns, histogram of oriented gradients, gabor and radon transforms were applied to five types of potato images by some default values and adapting changes according to their properties (Matlab, R2018b). Features from images are extracted to maximise the object identification and information available in images. To calculate time taken to plot for all techniques except GLCMP, *tic* function at starting of the algorithm and *toc* function at the end of the algorithm is applied (Matlab, R2018b).

3.2.1 Adapted Gray Level Co-occurrence Matrix Properties (GLCMP)

In adaptive method, an offset of [0 1] is applied to find the contrast, correlation, energy and homogeneity values (Haralick *et al.*, 1973). Following algorithm was developed for extracting the properties of GLCM.

Algorithm 1 : Finding properties of GLCM

Input: Color potato picture

Output: Values of gray level co-occurrence matrix i.e. variance, correlation, uniformity and homogeneity

Step 1: Read color potato image to a variable using imread function.

Step 2: Convert the color potato image to gray image.

Step 3: Specify number of gray levels and offsets to observe GLCM size using *graycomatrix*.

Step 4: Find GLCM properties using *graycoprops* at given number of offsets.

Step 5: Find the mean of above set of values to calculate single value of variance, correlation, uniformity and homogeneity.

3.2.2 Adapted Local Binary Patterns

In adapted method, the default values of 1 and 8 are taken as the radius and number of neighbors respectively (Ojala *et al.*, 2002). For calculating the plot time between squared error and histogram bins, images are rotated to 30°. For calculating feature vector rotation invariant property (Upright) is set to 'true' and incase of calculating plot, time rotation invariant property is set to 'false'. The following algorithm was developed for local binary patterns.

Algorithm 2: Extracting local binary pattern (LBP) features

Input: Color potato image

Output: Local binary feature vector and plot between squared error and LBP histogram bins

Step 1: Read an image to a variable using imread function

Step 2: Convert the color image into gray image using rgb2gray function

Step 3: Rotate gray image to an angle of 30°

Step 4: Calculate local binary feature vector of gray image and rotate gray image using extractLBPFeatures function

Step 5: Square the difference of local binary feature vectors of gray image and rotate gray image

Step 6: Draw bar chart between squared error and LBP histogram bins

3.2.3 Adapted Histogram of Oriented Gradients

In adaptive method all default values are used to calculate HOG feature vector i.e. Cell size 8-by-8, block size 2-by-2, block over lap 1-by-1, number of bins 9 and Used signed orientation is set to false (Dalal and Triggs, 2005). Algorithm for determining of histogram of oriented gradients is given below:

Algorithm 3: Feature vector of histogram of oriented gradients

Input: Gray Image

Output: Visualization of Gradients and feature vector

Step 1: Read an image using *imread* function
Step 2: Selecting the size of cell
Step 3: Extract HOG Feature vector using *extractHOGFeatures* function.
Step 4: Plot distribution of gradients
Step 5: Displaying result.

3.2.4 Adapted Gabor Feature

A wavelength of 2 (Matlab, R2018b) to 10 with equal interval of 2 and orientation of 0 to 180 with an interval of 22.5 degrees was taken for extracting adapted gabor feature vector. Five wavelength values and eight orientation values are suggested by (Bai *et al.*, 2009 and Zhu *et al.*, 2007). Algorithm for extracting gabor feature is given below:

Algorithm 4: Extracting gabor features

Input image: Color image

Output image: Gabor filtered image and visualization of wavelength and orientation

Step1: Read the color image using imread function

Step2: Resize the image by using a fraction of 0.1 using imresize function

Step3: Convert resized color image into gray scale image using rgb2gray function

Step4: Assign the wavelength and orientation values

Step5: Form gabor array

Step6: Apply gabor filter to gray scale image using imgaborfilt function

Step7: Display gabor filtered images

Step 8: Give wavelength and orientation ranges to visualize the wavelength and orientation of spatial kernels.

3.2.5 Adapted Radon Feature

In adaptive radon transform the default values of theta ranges from 0 to 180° are taken (Matlab, R2018b). Algorithm for extracting radon features was given below:

Algorithm 5 : Calculating radon features of a color potato image

Input: Potato color (RGB) image

Output: Radon features of an image

Step 1: Read a color image to a variable using imread function

Step 2: Converting RGB image into gray scale image using rgb2gray function

Step 3: Set projection angle theta (θ) between 0 to 179°.

Step 4: Find the sizes of radon and radial coordinates feature vectors

Step 5: Plotting graph between projection angle (theta) and vector coordinates of radon using plot function

3.3 IMPROVED FEATURE EXTRACTION TECHNIQUES

Adapted feature extraction techniques were limited to their standard type of algorithm but improved feature extraction techniques are will give better and convenient results than adapted techniques. Contrast, correlation, energy and homogeneity values were computed by changing offset in improved GLCMP (Gray Level Co-occurrence Matrix Properties) technique. Cell size and block size are selected to find improved HOG technique. Wavelength and orientation values are selected to find improved gabor features. Half of the projection angle used in adapted technique used to find radon features respectively. Parameters like improved radon are selected based on preliminary studies. Except for GLCMP, time taken to execute plot was applied.

3.3.1 Improved Gray Level Co-occurrence Matrix Properties (GLCMP)

In improved gray level co-occurrence matrix size an offset of [4 0] was applied to find the feature vector containing contrast, correlation, energy and homogeneity values. Offset parameter [4 0] taken because of good coverage of neighboring pixels in calculating contrast, correlation, energy and homogeneity.

3.3.2 Improved Local Binary Patterns (LBP)

In improved method of LBP the radius and number of neighbors taken as 4 and 14 respectively (Alhindi *et al.*, 2018) and the remaining steps are same as shown in Algorithm 2.

3.3.3 Improved Histogram of Oriented Gradients (HOG)

In improved histogram of oriented gradients a cell size of 18-by-18 and block size of 2-by-2 was used (Alhindi *et al.*, 2018) instead of 8 by 8 in adapted HOG, while remaining steps were same.

3.3.4 Improved Gabor Features

In improved gabor feature extraction four wavelength values and four orientation values are taken. Wavelengths of 32, 26, 18 and 16 pixels/cycle and orientation values of 0, 45, 90 and 135 degrees are taken (Fogel and Sage, 1989) and remaining values is similar to Algorithm 4.

3.3.5 Improved Radon Features

In improved radon feature extraction the radon transforms are calculated by using theta value ranging from 0 to 90° and remaining values similar to Algorithm 5.

IV. RESULTS AND DISCUSSION

The developed image capturing setup has a resolution of 0.22 mm/pixel which was in acceptance with strawberry grading system with 0.17 mm/pixel resolution (Xu and Zhao, 2010). The results of five feature extraction methods in terms of adapted and improved techniques were compared and analysed. The size of GLCM in adapted and improved techniques is same i.e. 8-by-8, because all input images were 8-bit images.

4.1 Comparison of adapted and improved gray level co-occurrence matrix properties

Similar patterns are observed for properties of GLCM among all potato classes for adapted and improved feature extraction techniques. Contrast values are lower in adapted method for all potato classes compared to improved method. A difference of contrast values in adapted and improved method was observed in the range of 0.2-0.3. Correlation values are higher in adapted method for all potato classes compared to improved method. A difference of correlation values between adapted and improved method of crack potatoes is 0.04, while for rotten potatoes it is 0.04, for sprout potatoes it is 0.035, skin peel potatoes it is 0.04 and for good potatoes it is 0.025. Energy values are 0.2 times higher in adapted method for all potato classes compared to improved method. Homogeneity values are higher in adapted method for all potato classes compared to improved method (Figure 2).

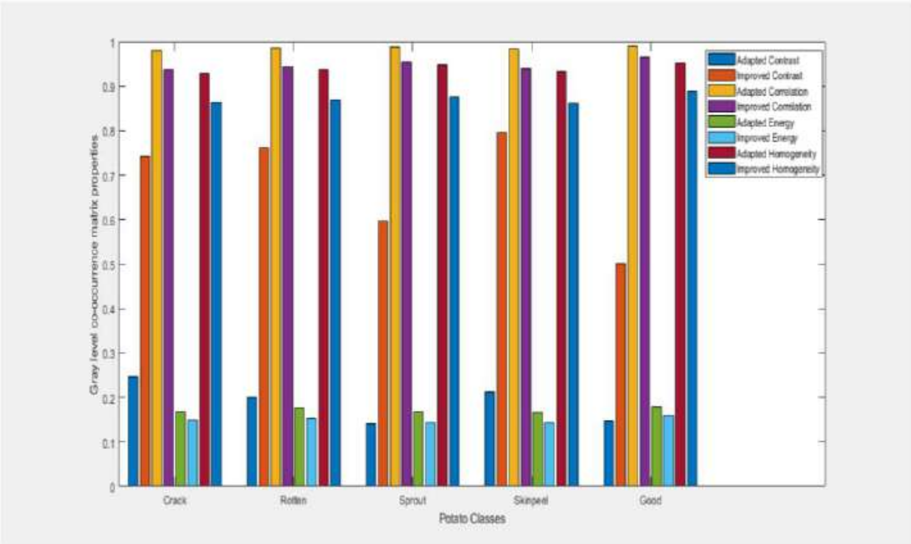

Fig.2 Comparison of adapted and improved GLCMP in relation to potato classes

Homogeneity value of 0.06 was observed for crack potato as difference value of adaptive and improved methods. Similarly, a difference of 0.069 was observed for rotten, 0.07 for sprout, 0.0728 for skin peel and 0.063 for good potatoes were observed.

4.2 Comparison of Adapted and Improved Gabor Features

Adapted gabor feature vector length (40) was same for all types of potato images. The size of gabor feature length depend upon the number of elements in the wavelength and orientation vectors. The size of gabor feature array is the product of number of elements in the wavelength and orientation vectors. Gabor features in adapted and improved techniques were compared using feature vector lengths and time taken to plot magnitude and spatial kernels in seconds. An improved gabor method has lower gabor feature length compared to adapted gabor method (Figure 3).

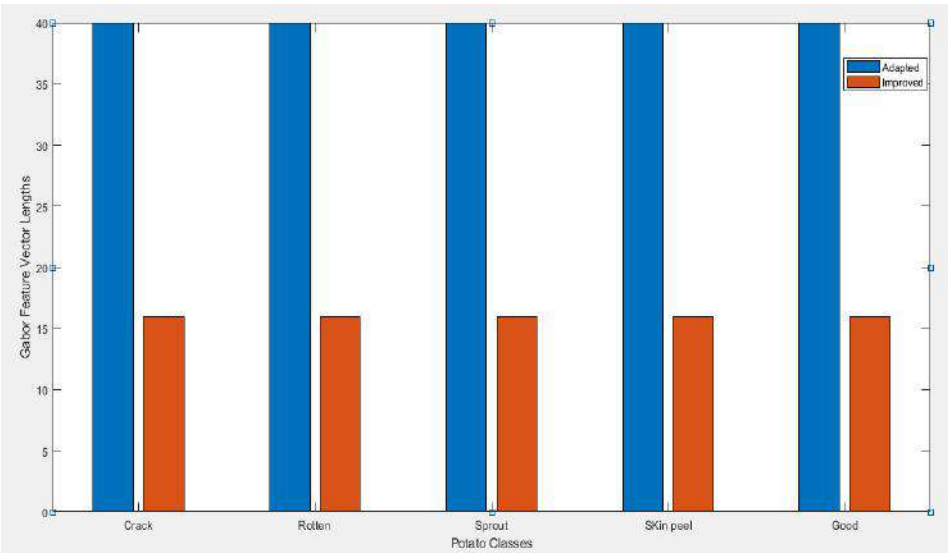

Fig.3 Comparison of adapted and improved gabor feature vector lengths in relation to potato classes

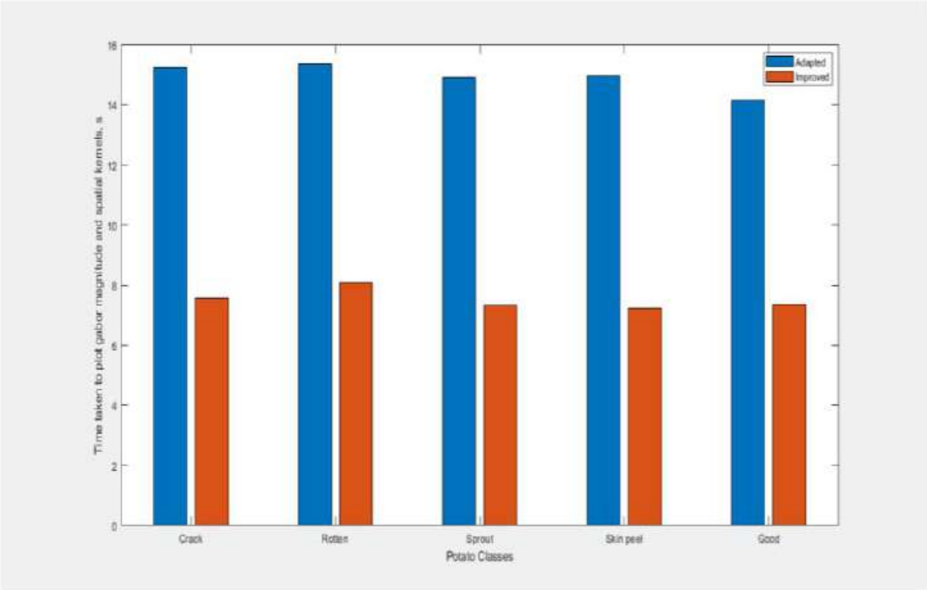

Fig.4 Comparison of adapted and improved plot timings of gabor magnitude and spatial kernels in relation to potato classes

Improved gabor method requires less time to plot gabor magnitude and spatial kernels for all potato classes (Figure 4).

The time taken to plot magnitude and real spatial parts of all types of potato images in adapted radon method is twice to the time taken in improved radon method.

4.3 Comparison of Adapted and Improved HOG Features

The HOG feature vector lengths in adapted HOG method had highest compared to the improved HOG method proposed by (Alhindi *et al.*, 2018) (Figure 5).

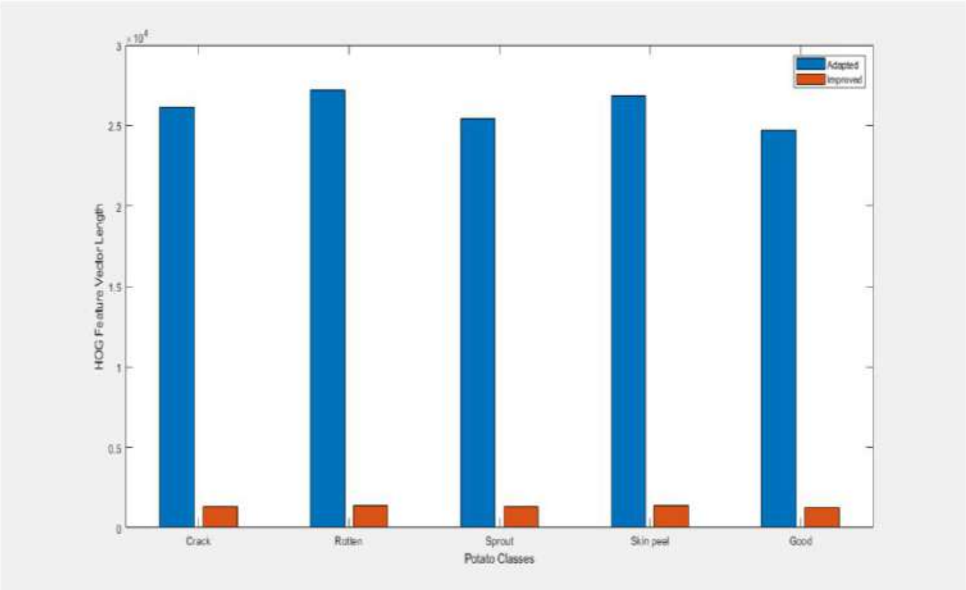

Fig.5 Comparison of HOG feature vector lengths in adapted and improved techniques in relation to potato classes

For crack and rotten images, an improved HOG method proposed by Alhindi *et al.*, (2018) has required higher time to plot visualization than adapted HOG method. While for sprout, good and skin peel images, adapted HOG method has more HOG visualization time because of cell size 8- by-8 compared to improved HOG cell size of 18-by-18 (Figure 6).

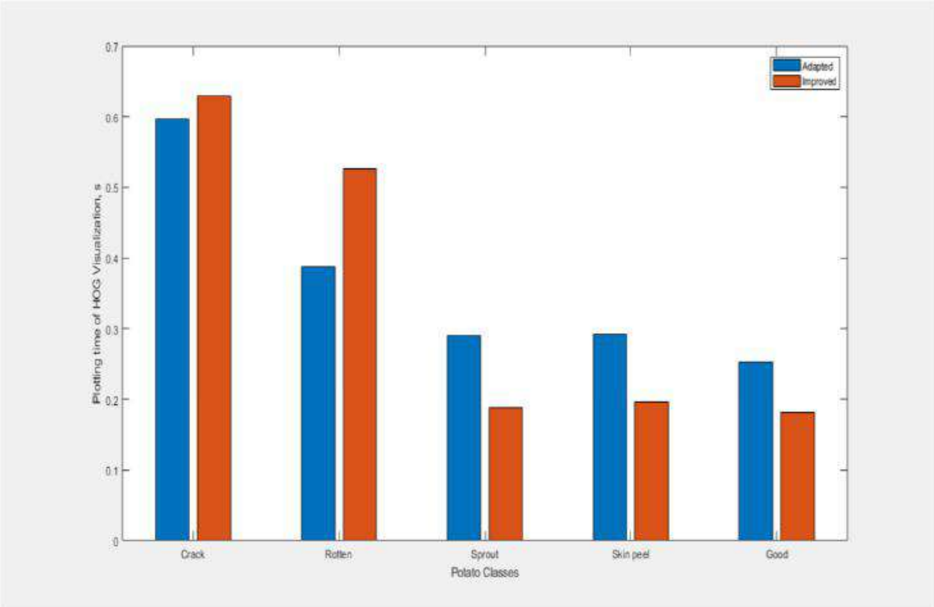

Fig.6 Comparison of adapted and improved HOG visualization times in relation to potato classes

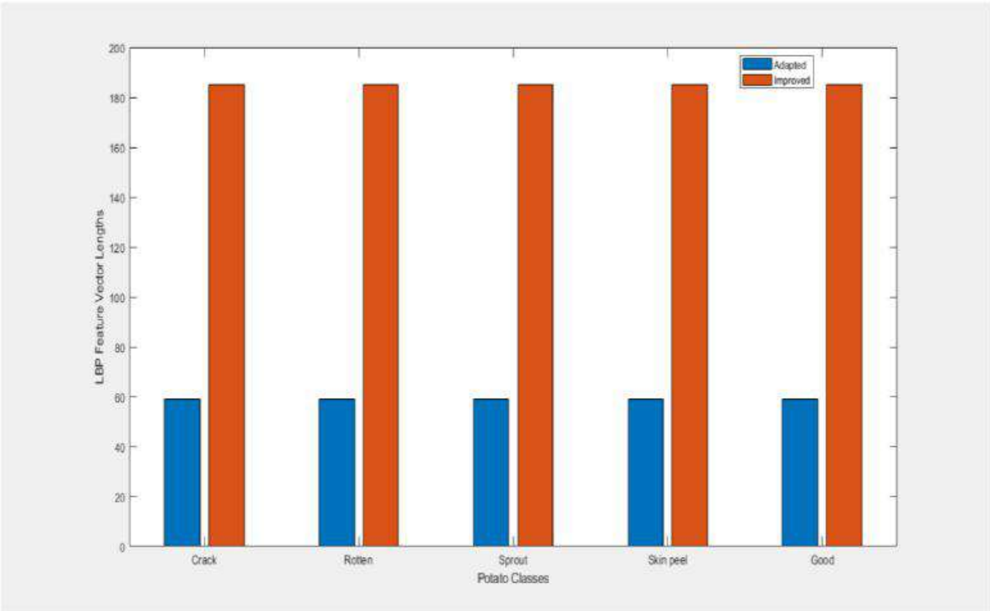

Fig.7 Comparison of adapted and improved techniques in relation to potato classes using LBP feature vector lengths

4.4 Comparison of Adapted and Improved LBP Features

The feature vector lengths of an improved method proposed by Alhindi *et al.*, (2018) were higher (185) compared to adapted method (59) (Figure 7).

The mean time to plot squared errors in adapted and improved methods for crack images were found to be 0.6378 s and 0.6305 s respectively, for rotten images 0.2098 s and 0.2622 s, for sprout images 0.1911 s and 0.2209 s, for skin peel images 0.2197 s in both methods, for good potato images 0.2672 s and 0.2565 s (Figure 8).

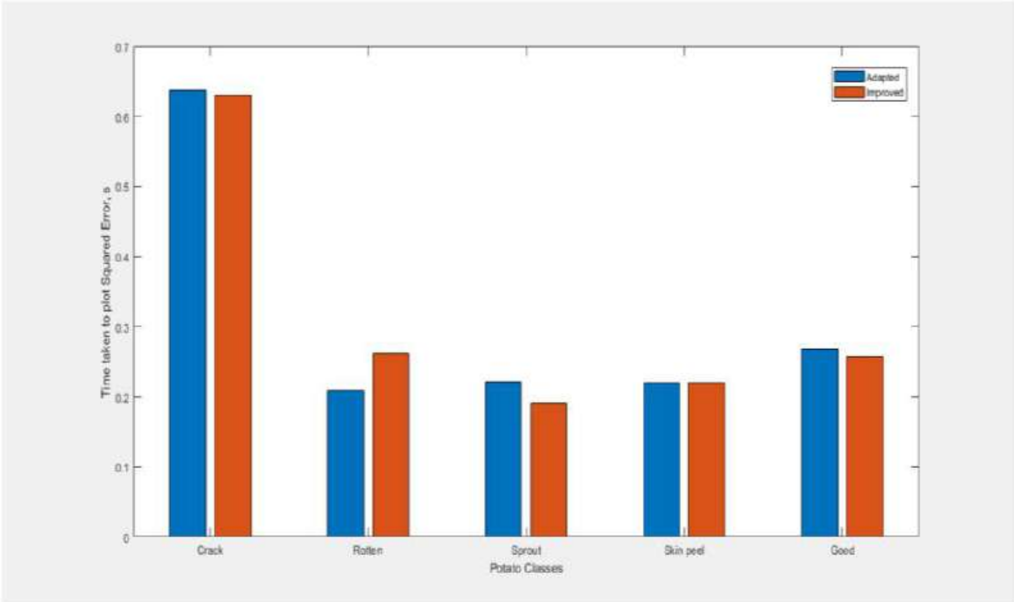

Fig.8 Comparison of adapted and improved techniques in relation to potato classes using squarred errors in LBP

4.5 Comparison of Adapted and Improved Radon Features

Radon feature sizes of adapted (Matlab, R2018b) and improved methods were same but differ in radon transform plotting time. From radon feature sizes of adapted and improved methods, it is inferred that the theta value effect the size of the radon feature (Figure 9).

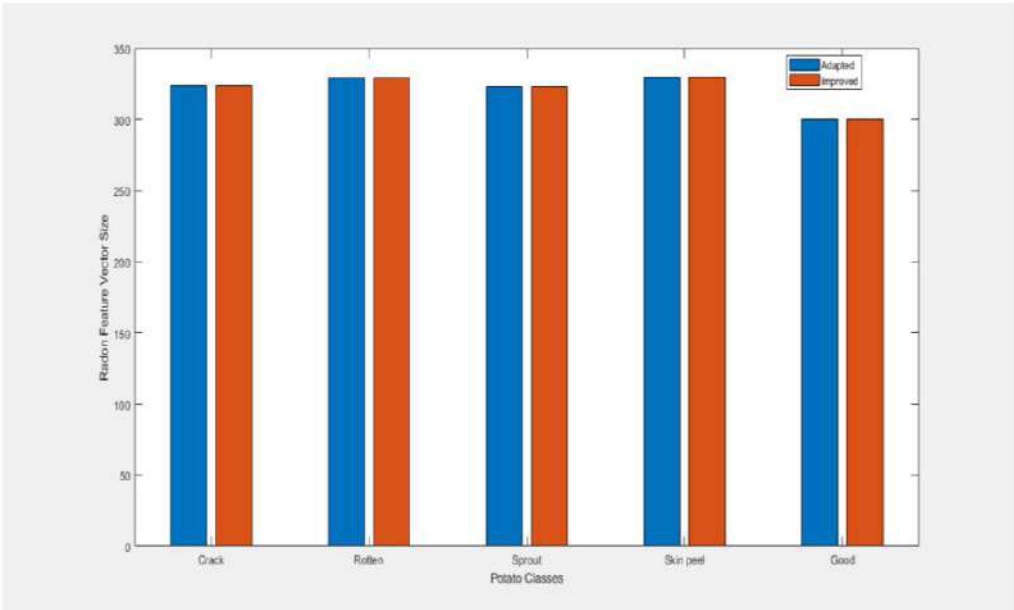

Fig.9 Comparison of radon feature vector lengths of adapted and improved techniques in relation to potato classes

At half of the theta value (90°) in improved method, the time taken to plot radon transforms is lower compared to adapted method (at theta value 180°) (Figure 10).

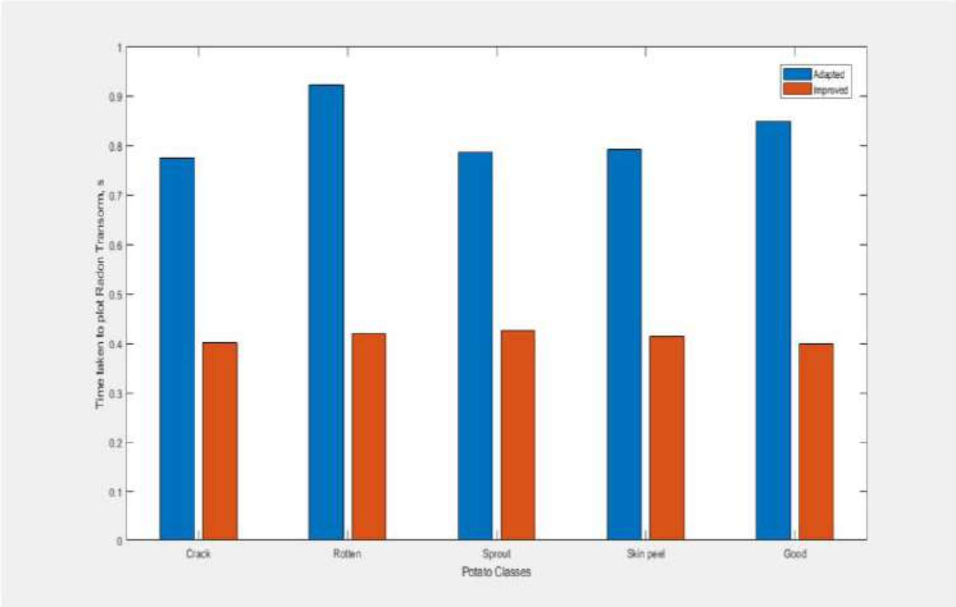

Fig.10 Comparison of time taken to plot radon transforms of adapted and improved techniques in relation to potato classes

V. CONCLUSIONS

The adapted feature vector lengths in HOG were found highest compared to the improved HOG method for all potato classes. For crack and rotten potato images, HOG visualization time in improved method was higher compared to adapted method but for remaining potato image classes adapted method has more HOG visualization time compared to improved method. The LBP feature vector lengths in improved method were higher compared to adapted method for five potato classes. In improved LBP method, the squared error's for all potato classes were same. The gabor feature vector length was highest in adapted method compared to improved method for all potato classes. An Improved Gabor method required less time to plot gabor magnitude and spatial kernels for all potato classes compared to adapted method. For all potato classes radon feature vector sizes were same in both adapted and improved methods but differ in plotting times of radon transformation. Theta value affected the radon feature vector size in all potato classes. In improved radon method, less time had taken for plotting radon transforms for five classes of potato compared to adapted method. In improved GLCMP method, contrast values were highest compared to adapted method for all five potato classes. In adapted GLCMP method, correlation values were greater than adapted method for all potato classes. In adapted GLCMP method, energy values were greater for all potato classes compared to improved method. Also, in adapted GLCMP method, homogeneity values were greater for all five potato classes compared to improved GLCMP method.

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Evaluation of Genotype –Enviroment Interactions of New Peanut Varieties Conditions of Tra Vinh

Nguyen Trong Phuoc, Le Hoang Phuong, Nguyen Thi Lang

High Agricultural Technology Research Institute for Mekong Delta

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Abstract— *The experiment comprised of 10 lines were laid out in a randomized block design replicated three times at 6 different locations at Dong Xuan and HeThu season from Tra Vinh . Analysis of variance indicated the presence of significant genetic variability among the genotypes for peanut under all the 6 location. All analysies of variance for the yield of peanut that were pooled over the six locations . Genotypes x Enviroment (GxE) interactions were also found significant and the mean squares due to environment were highly significant indicating sufficient diversity among the environments. Four lines HATRI 02DP, HATRI 03DP, HATRI 14DP give hight yield both dong xuan and wet season . performed better by in all the locations both satbility at Dong Xuan and HeThu seasones. This varieties is good for multilication in the future .*

Keywords*— *AMMI. Genotypes x Enviroment (GxE) interactions, Peanuts, adaptability, stability

I. INTRODUCTION

Genotype(s) for the test settings in a part of the Southwest region of Nigeria, as well as to investigate the nature and extent of genotype × environment interaction (GEI) effects on Bambara groundnut (BGN) production.The results revealed that BGN accessions performed differently in different test conditions, indicating that the interaction was crossover in nature. To examine and show the pattern of the interaction components, biplots with the genotype main effect and genotype × environment interaction (GEI) were used. (**Oluwaseyi** et la.,2021).Its yield stability and adaptability determine any crop variety's ability to thrive in a given environment. Due to differences in the various environments, these traits are influenced by genotype × environment interactions (GEI). Plant breeders are increasingly interested in GEI to identify long-term solutions to issues controlling plant growth and development. Because of the increasing interest, several statistical methods have been developed for multi-environment trials (MET) to study GEI effects(Eberhart et al.,1966 ; Crossa et al.,1990). The two most common methods used for MET are additive main effects and multiplicative interaction (AMMI), and genotype plus genotype environment interaction (GGE) biplot (Alizadehet al.,2017). The findings derived from the AMMI 2 analysis have yielded support for the significance of including IPCA2 scores in conjunction with IPCA1 scores to enhance our understanding of genotype-environment interactions (GEI) across diverse settings. Moreover, the utilisation of this methodology has facilitated the identification of genotypic adaptations, as depicted(Praveen et al.,2024). Different abiotic stresses often occur together or one after another in the same crop season. Some of the common abiotic stresses that limit rice crop growth and productivity are drought, salinity, nutrient deficiency and high temperature. Of these, drought and phosphorus deficiency have become major concerns which affect rice production. especially in water limited cultivation systems. (Yugandhar et al.. 2018). The environment, the genotype and the GE interaction are also responsible for variations in the quality properties of grains, including the color, the texture, the protein and the fiber content. Among the quality parameters, the protein content of the grains is highly affected by the environment (Nehe et al.,2019). The evaluation of different genotypes on quality traits associating with the improvement of the yield can also contribute to future breeding strategies. In AMMI, the additive portion is analyzed through Analysis of Variance (ANOVA) and interaction effects through the Principal Component Analysis (PCA) model. Biplots helps in displaying genotypic stability statistics and clustering of genotypes based on their performance in different environments

(Thillainathan et al 2001). GGE biplot gives more detailed graphical representation of mean values and stability and displays the which-won-where pattern of genotypes. It also identifies mega environments for selection and discriminating test environments (Sanchez et al 2017). The biplot and the GGE concepts are used in the GGE biplot method to visually analyze the results of site regression analysis in MET data (Yan et al.2003). The concept of GGE biplot involves the use of biplot to show the two important factors, which are also sources of variation (viz., G and GE). GGE biplot fits best for genotype evaluation (mean vs. stability), test environments which provide discriminating power vs. representativeness, and multi-environment analysis (Angelini et la.,2019). GGE biplot is a versatile method with the ability to analyze a range of data types using a two-way structure (Fayeun et al.2018). Since the introduction of the GGE biplot, numerous applications of the method on MET analysis have been reported.This study's main objectives were to characterise peanut genotypes at six locations in terms of yield-related traits, and assess genotype-by-environment interaction and identify stable genotypes yield-related traits in six lines peanut growing regions of Tra Vinh.

II. MATERIALS AND RESEARCH METHODS

2.1 Peanut varieties

Use varieties: Peanuts HATRI 02 DP, HATRI 03 DP, HATRI 14 DP, VD 08. VD 01-1, MD7 (as control varieties)

2.2 Research method

The experiment was arranged in a completely randomized design (CRD) with 6 treatments (treatments = 6), in which each treatment was arranged to plant 1 variety and 3 replications (replications = 3). Thus, there were a total of: 6 x 3 = 18 experimental plots (plots = 18). Each plot (corresponding to 1 replication) had an area of 250m2 planted with 1 peanut variety in 06 varieties: HATRI 02 DP, HATRI 03 DP, HATRI 14 DP, VD08, VD01-1, MD7 (control) and was arranged in 01 district in 03 districts of Cau Ngang, Tra Cu, Duyen Hai to control between treatments. In which:

- Experiment I: Planting peanuts: HATRI 02 DP;
- Experiment II: Planting peanuts of HATRI 03 DP;
- Experiment III: Planting peanuts of HATRI 14 DP;
- Experiment IV: Planting peanuts of VD08;
- Experiment V: Planting peanuts of VD01-1;
- Experiment VI: Planting additional MD7 variety as a control variety.

In each district, all 6 experiments were carried out at 1 household in locations that were relatively homogeneous in terms of terrain, soil, light, etc.

Thus, the total area implemented on 3 experimental sites is: 0.075ha x 6 experimental plots x 3 districts (sites) x 2 crops = 2.7ha

2.3 Monitoring indicators

- Periodically collect agronomic, pest and yield indicators.

+ Agronomic indicators: tree height, number of primary branches, flowering time, harvest time, dry matter accumulation capacity, yield components and yield components. Collect every 15 days.

+ Pest and disease indicators:

Record and evaluate the possibility of pest and disease attack by the 5-point cross-root method, each point monitors and observes 10 plants. Record at 3 periods of plant development:

Period 1: 20-40 days after sowing.

Period 2: 60-70 days after sowing.

Period 3: before harvest.

The disease level is assessed on a 9-level scale.

The rate of diseased plants is assessed in %.

+ Yield index:

Using the 5-point diagonal distribution method to collect the factors that contribute to the yield recorded with: number of fruits/tree, number of firm fruits/tree, weight of 100 fruits, weight of 100 seeds. Data recorded on 20 surveyed trees at each collection point.

Record the number of seeds/fruit, number of firm seeds/fruit, length and width of fruit, and the ratio of 3-seed fruits. Each repetition was 10 trees, 3 repetitions.

+ Statistical method for data processing: data were collected and processed using Excel software and statistical processing software MSTATC or SPSS.

Report on the evaluation of the adaptation, growth and development, yield, output and economic efficiency indicators of the experiments:

- Analyze and compare data on agronomy, pests and yields collected directly to develop a report on the adaptability, growth and development of new peanut varieties in the experiments.

- Directly interview farmers using a prepared questionnaire on production investment costs (labor, fertilizer, chemicals, transportation, others) and peanut production results (number of crops, classification, selling price and profit). The collected data will be compiled, analyzed, compared, and evaluated to assess the economic efficiency of experiments on new peanut varieties including total investment costs, total income, net profit, and return on investment capital..

➢ **Evaluate stability and adaptability using the model according to Eberhart and Russell (1966):**

$Y_{ij} = \quad i + b_iI_j + \quad ij$

Y_{ij}: expression of genotype i (ith) in environment j

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(jth)

i: average of all genotypes across all environments

bi: regression coefficient of genotype ith on environmental index

ij: deviation from regression of genotype ith in environment jth

Ij: environmental index

The yield of varieties can be predicted by the regression equation:

$Y = Xi + biIj + S2di$

Xi: average yield of varieties across environments

bi: regression coefficient is calculated by the formula $bi = (Yij\ Ij)/ I2j$

$Ij = Yij/V - Yij/VL$

where: V – Number of varieties

L – Number of experimental points

$S2di = [\quad 2ij/(L – 2)] - S2e/r$

where: $\quad 2ij = [\ Y2ij - Y2i./L] – [\ Yij\ I2j]2/ I2j$

s2e: average variance of genotype on all environments

r: number of repetitions of a genotype on an environment

According to the above model, genotypes with S2di = 0 are considered stable, adapted to the environment, genotypes with S2di 0 are unstable, not adapted to the environment.

If S2di ≠ 0: the relationship between phenotype and environment (Ij) does not follow a linear regression line (linear), the variety is unstable.

Analyze stability and adaptation according to the model according to Eberhart and Russell (1966) using stability software version 3.0 by Nguyen Dinh Hien (Agricultural University 1).

- Data were analyzed by point, across multiple points using analysis of variance (ANOVA) using MSTAT.C, SAS 9.1 software, ranking treatments by LSD test at = 0.05..

Additive Main Effects and Multiplicative Interaction Model

The classical genotype-environment interaction method has focused on the stability event more than the adaptation event. Therefore, AMMI analysis is synthesized on the basis of the models of Finley and Wilkinson (1963), Eberhart and Russel (1966), Perkins and Jinks (1968), Freeman and Perkin (1971) and many other authors, including many IRRI scientists. Illustration of AMMI diagram of gene-environment interaction using IRRISTAT software.

- Illustration of the diagram of grouping hybrid lines using UPGMA Euclidean coefficient on SAS 9.1

- Samples after harvest will be collected and evaluated for indicators according to ICRISSAT standards.

III. RESEARCH RESULTS AND DISCUSSION

3.1 Evaluation of genotype-environment interactions in the 2023 Winter-Spring crop

The results of peanut yield evaluation at 6 locations: Cau Ngang, Tra Cu, Duyen Hai, Can Tho, Long An, and An Giang of the peanut variety/line are presented in Table 4.14. The results of the yield changes show that: the F test is statistically significant at the 1% level for the linear hypothesis of environment, variety, and variety interaction with environment.

The yield of the 2023 Winter-Spring crop was observed on 10 varieties with 6 different environments, the highest yield was the HATRI 14 DP variety (5.75 tons), followed by the HATRI 16 DP variety (5.70), HATRI 15 DP (5.54) and HATRI 20 DP variety reaching 5.49 tons/ha on average across 6 locations.

This allows us to use the environmental index (Ij) to represent each location, on the interaction diagram between genotype and environment with the order from less favorable to more favorable as follows: Duyen Hai is the highest > Tra Cu > Cau Ngang, Can Tho is on the Ij axis with values in order: 0.103; 0.113; 0.022; 0.017; - 0.38, 0.54 in order. When grouping the environment, Duyen Hai scores the highest.

Environment	Medium	SE	DUNCAN GROUPS	LSD TESTS
Duyen Hai	7.1450	0.12134	.	
Tra Cu	6.9033	0.99073E-01	..	
Cau Ngang	6.7833	0.99073E-01	1..	
An Giang	4.0900	0.99073E-01	333.	
Can Tho	3.9033	0.99073E-01	333..	
Long An	3.3250	0.85799E-01	33333.	

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When grouping by genotype, the most common variety is HATRI 14 DP, followed by HATRI 16 DP, HATRI 15 DP.

varieties Madium SE DUNCAN GROUPS LSD TESTS

HATRI 14 ĐP	5.7456	0.12817	...
HATRI 16 ĐP	5.7067	0.12817	..
HATRI 15 ĐP	5.5400	0.12817	...
HATRI 20 ĐP	5.4956	0.12817	...
HATR I6 ĐP	5.4511	0.12817	....
HATRI 13 ĐP	5.2567	0.12817	21.....
HATRI 03 ĐP	5.2400	0.12817	21.....
HATRI 02 ĐP	5.2233	0.12817	21.....
HATRI 01 ĐP	5.0011	0.12817	33221....
MD7	4.9233	0.12817	33222.....

Table 1: Yield (tons/ha) of peanut varieties/lines tested at 6 locations in the 2023 Winter-Spring crop

Varieties	Can Tho	Tra Cu	Duyen Hai	Cau Ngang	Long An	An Giang	Mean
HATRI 01 ĐP	3.56	6.20	7.15	6.40	3.30	3.40	5.00
HATRI 02 ĐP	3.63	7.13	6.90	6.07	3.52	3.93	5.22
HATRI 03 ĐP	3.63	7.10	6.50	6.53	4.47	3.90	5.24
HATRI 06 ĐP	4.06	6.70	7.60	7.06	3.25	4.20	5.45
HATRI 13 ĐP	3.80	6.76	7.45	6.90	3.37	3.33	5.25
HATRI 14 ĐP	4.23	6.80	7.30	7.30	3.60	5.56	5.74
HATRI 15 ĐP	4.20	7.26	7.15	7.260	3.31	4.13	5.54
HATRI 16 ĐP	4.36	7.53	7.35	6.76	3.31	4.50	5.70
HATRI 20 ĐP	3.53	7.16	7.20	6.83	2.55	4.60	5.50
MD7	3.90	6.90	6.85	6.76	3.33	3.61	4.71
Mean	**3.90**	**6.91**	**7.15**	**6.70**	**3.33**	**4.10**	**5.14**
IJ	**0.103**	**0.113**	**0.022**	**0.017**	**- 0.38**	**0.54**	

Most of the hybrid lines had higher average yield than the control variety MD7 (4.71 tons/ha). The difference in yield between the varieties was significant at the 5% level based on the yield assessment scale through multiple point analysis. The highest yield points were Duyen Hai (7.15 tons/ha), Tra Cu (6.91 tons/ha), followed by Cau Ngang (6.70 tons/ha). ANOVA analysis for the yield of peanut varieties across 6 environments showed that the difference in yield between the varieties was statistically significant at the 1% level, but the stability of yield, as well as the adaptability, was very different, through a very significant GxE (linear) interaction. The results of ANOVA analysis allowed us to consider the interaction between variety and environment here as linear...

3.2 Evaluation of genotype-environment interaction in the 2023 Summer-Autumn crop

The results of yield evaluation across 6 locations (Cau Ngang, Tra Cu, Duyen Hai, Can Tho, An Giang, Long An) of the peanut variety/line recorded yield developments showing: the F test was statistically significant at the 1% level for the linear hypothesis of environment, variety, and variety interaction with environment.

The 2023 Summer-Autumn crop yield was observed on 10 varieties with 6 different environments, the highest average yield was the HATRI 16 DP variety (4.99 tons/ha), followed by the HATRI 15 DP variety (4.88 tons/ha), HATRI 14 DP (4.88 tons/ha) and HATRI 20 DP reached 4.84 tons/ha.

This allows us to use the environmental index (Ij) to represent each location, on the interaction diagram between genotype and environment with the order from less favorable to more favorable as follows: Duyen Hai is highest > Tra Cu > Cau Ngang. Can Tho, Tra Cu, Cau Ngang and Duyen Hai, Long An and An Giang are on the Ij axis with values in order: 0.113; 0.189; 0.015; 0.016; -0.33, -0.45 in order.

When grouping the environment, Duyen Hai has the highest score

Environment	Medium	SE	DUNCAN GROUPS	LSD TESTS
Duyen Hai	6.5800	0.87659E-01	.	
Tra Cu	6.1967	0.71573E-01	2.	
Cau Ngang	6.1933	0.71573E-01	2..	
An Giang	3.3833	0.71573E-01	333.	
Can Thơ	3.2833	0.71573E-01	333..	
Long An	2.8275	0.61984E-01	33333.	

Genotypic grouping

	SE	DUNCAN GROUPS	LSD TESTS
HATRI 16 ĐP	4.9974	0.92593E-01 | .	
HATRI 15 ĐP	4.8863	0.92593E-01 || ..	
HATRI 14 ĐP	4.8807	0.92593E-01 || ...	
HATRI 20 ĐP	4.8474	0.92593E-01 ||	
HATRI 06 ĐP	4.7529	0.92593E-01 |||	
HATRI 02 ĐP	4.7196	0.92593E-01 ||| 1.....	
HATRI 03 ĐP	4.6751	0.92593E-01 || 1......	
HATRI 01 ĐP	4.6363	0.92593E-01 || 2.......	
HATRI 13 ĐP	4.5418	0.92593E-01 | 2111.....	
MD7	4.5029	0.92593E-01 | 3221......	

Table 2: Yield (tons/ha) of peanut varieties/lines tested at 6 locations in the Summer-Autumn crop 2023

varieties	Can Tho	Tra Cu	Duyen Hai	Cau Ngang	Long An	An Giang	mean
HATRI 01 ĐP	3.0	5.63	6.80	5.93	2.80	3.73	4.63
HATRI 02 ĐP	3.10	6.23	6.40	6.28	2.90	3.40	4.71
HATRI 03 ĐP	3.0	6.33	6.75	6.08	2.98	2.93	4.67
HATRI 06 ĐP	3.27	6.23	6.70	6.33	2.80	3.23	4.75
HATRI 13 ĐP	3.10	6.30	6.50	5.83	2.68	2.90	4.54
HATRI 14 ĐP	3.33	6.20	6.70	6.30	2.78	4.03	4.88
HATRI 15 ĐP	3.73	6.30	6.65	6.38	2.83	3.47	4.88
HATRI 16 ĐP	3.50	6.50	6.85	6.16	3.35	3.53	4.99
HATRI 20 ĐP	3.60	6.30	6.40	6.50	2.73	3.53	4.84
MD7	3.30	5.93	6.05	6.18	2.45	3.07	4.50
Medium	**3.28**	**6.23**	**6.58**	**6.20**	**2.83**	**3.38**	**4.54**
IJ	**0.113**	**0.189**	**0.015**	**0.016**	**- 0.33**	**-0.45**	

Regarder peanut varieties, most hybrid lines have higher average yield than the control variety MD7 (4.50 tons/ha). The difference in yield of the varieties is very significant at the 5% level based on the yield assessment scale through multi-point analysis. The highest yield points are Duyen Hai (6.58 tons/ha), Tra Cu (6.23 tons/ha), followed by Cau Ngang (6.20 tons/ha). ANOVA analysis of yield of 10 bean varieties through 6 environments shows that the difference in yield of the varieties is statistically significant at the 1% level, but the stability of yield, as well as the ability to adapt, is very different, through the very significant GxE (linear) interaction. The results of ANOVA analysis allow to consider the interaction between variety and environment here as linear..

3.3 Assessment of stability and adaptation using the model of Eberhart and Russell (1966)

Assessment of stability and adaptability in the 2023 Winter-Spring crop

Through the analysis of the table, we can see the slope corresponding to the yield adaptation index of the varieties in different ecological zones, showing that the variety with a good adaptation slope is the HATRI 20 DP variety with a slope coefficient = 1, followed by the HATRI 20 DP variety. The interactive contribution of the varieties on the stability index shows that the HATRI 20 DP variety has an environmental interaction index of 0, followed by the HATRI 06 DP and HATRI 16 DP varieties, HATRI 15 DP varieties. It proves to be very stable when analyzing the conditions in this crop. If compared with MD7, it also shows high stability suitable for the ecological zone. There are three varieties with very strong environmental impact conditions, the HATRI 16 DP variety followed by the HATRI 15 DP variety.

Table 3: Analysis of stability index and adaptation to different environments in the 2023 Winter-Spring crop

varieties	Productivity	Stability Index	Adaptability index
HATRI 01 ĐP	5.00	0.09	1.0689
HATRI 02 ĐP	5.22	0.13	0.8383
HATRI 03 ĐP	5.24	0.08	1.1024
HATRI 06 ĐP	5.45	0.05	0.9665
HATRI 13 ĐP	5.26	0.12	0.9947
HATRI 14 ĐP	5.75	0.18	0.6352
HATRI 15 ĐP	5.54	0.05	0.9665
HATRI 16 ĐP	5.71	0.05	0.9665
HATRI 20 ĐP	5.50	0.04	1.0462
MD7	4.92	0.07	1.0194

❖ **Assessment of stability and adaptability in the Summer-Fall crop 2023**

To study peanut lines of different origins and compare with varieties in the past 3 years, peanut varieties were tested and improved in yield as well as peanut quality for Tra Vinh province.

The widely selected lines were evaluated on 10 peanut varieties that were widely deployed with an average yield of 6 points.

The test was conducted on 6 points and 10 varieties with high yield, over 6 points in Tra Vinh districts (Cau Ngang, Tra Cu, Duyen Hai). 3 more provinces were added for comparison: Can Tho; An Giang and Long An.

If considering the adaptation index (bi) and stability index (Sdi2), it shows that most of the varieties with the highest bi and stability index are HATRI 06 DP, HATRI 13 DP, HATRI 15 DP, followed by HATRI 16 DP, HATRI 20 DP, MD7. Most of the varieties have high adaptation index.

Table 4: Analysis of stability index and adaptation to different environments in the Summer-Autumn crop 2023

varieties	Productivity	Stability Index	Adaptability index
HATRI 01 ĐP	4.64	0.31	1.041441
HATRI 02 ĐP	4.72	0.02	1.001742
HATRI 03 ĐP	4.68	0.07	1.089535
HATRI 06 ĐP	4.75	0.01	1.000035
HATRI 13 ĐP	4.54	0.02	1.000098
HATRI 14 ĐP	4.88	0.07	1.089535
HATRI 15 ĐP	4.89	0.03	1.000078
HATRI 16 ĐP	5.00	0.04	1.000356
HATRI 20 ĐP	4.85	0.04	1.000356
MD7	4.50	0.04	1.000356

3.4. Additive Main Effects and Multiplicative Interaction Model

The classical genotype-environment interaction method has focused on the stability event more than the adaptation event. Therefore, AMMI analysis is synthesized on the basis of the models of Finley and Wilkinson (1963), Eberhart and Russel (1966), Perkins and Jinks (1968), Freeman and Perkin (1971) and many other authors, including many IRRI scientists. Illustration of AMMI diagram of gene-environment interaction using IRRISTAT software.

- Illustration of the diagram of grouping hybrid lines using UPGMA Euclidean coefficient on SAS 9.1

- Samples after harvest will be collected and evaluated for indicators according to ICRISSAT standards.

❖ **Results recorded in the 2023 Winter-Spring crop**

Correlation shows that the contribution value of multidimensional interaction according to AMMI analysis is very significant. The genotype x phenotype interaction reached 89.7%.

ANOVA analysis of AMMI shows that all three AMMI 1, AMMI 2, AMMI 3 are significant at the 0.01 level, except AMMI 4. This shows that the points are very favorable in the study.

Through the analysis of the AMMI diagram, the interaction level of yield on 6 points reached 77.7%, which is very high. The diagram analysis shows that the HATRI 06 DP variety is very stable, followed by the HATRI 14 DP variety. The variety that is sensitive to the environment is the variety but because it has a negative interaction with the environment, the varieties such as HATRI 03 DP, HATRI 13 DP, HATRI 20 DP have a positive interaction with the environment. Based on the AMMI diagram, the varieties HATRI 02 DP, HATRI 03 DP and HATRI 16 DP are suitable for Tra Cu and the varieties HATRI 15 DP and HATRI 20 DP are suitable for Cau Ngang area, the varieties HATRI 01 DP, HATRI 06 DP, HATRI 15 DP are suitable for Duyen Hai area.

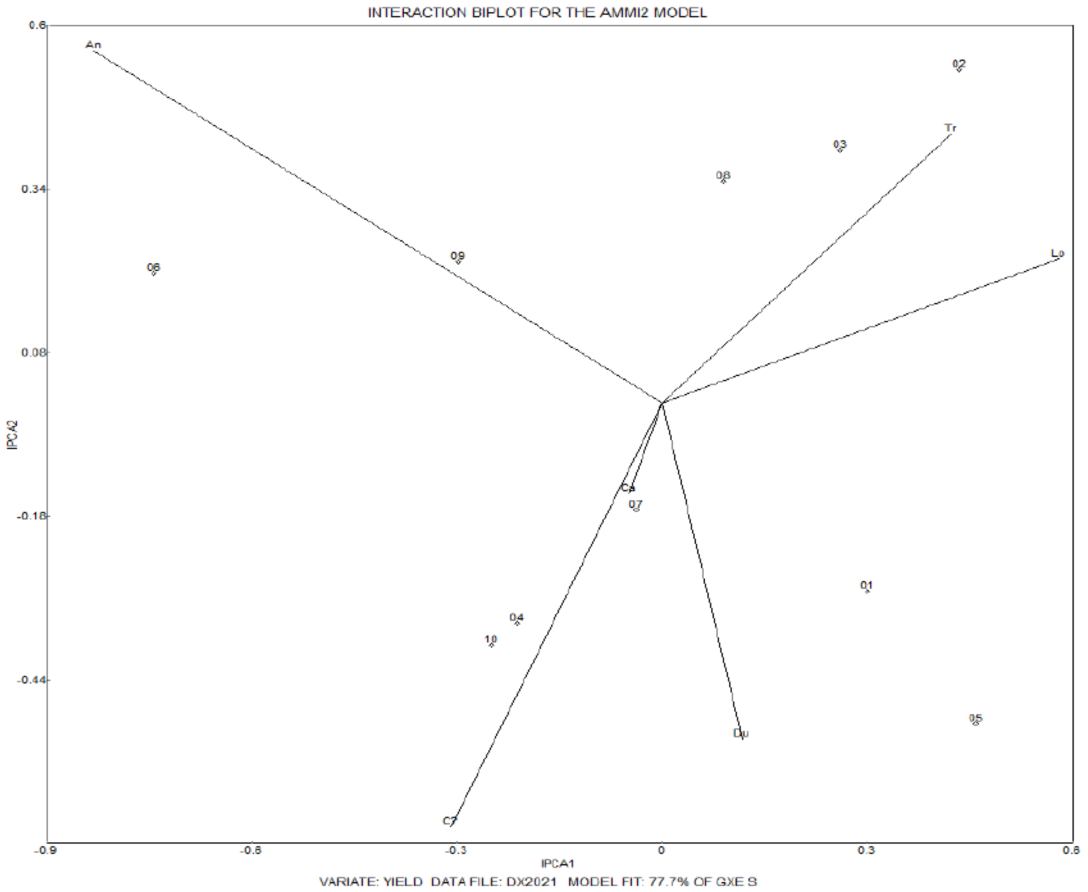

Fig.1: Yield interaction level on 6 location in Winter-Spring crop 2023

The observation in Figure 1 shows that the HATRI 16 DP and HATRI 20 DP varieties tend to lie on the axis with the environment and have a positive interaction, which is also consistent with the analysis in 2023.

Variance analysis of AMMI model in Winter-Spring crop 2023

ANALYSIS OF VARIANCE FOR THE AMMI MODEL

SOURCE	D.F.	S.S.	M.S.	F	FPROB
TREATMENTS	9	4.14669	0.460743		
LOCATIONS	5	155.138	31.0277		
TREATMENT X SITES	45	4.41693	0.981539E-01		
AMMI COMPONENT 1	13	1.72774	0.132903	1.581	0.143
AMMI COMPONENT 2	11	1.70369	0.154881	3.300	0.009
AMMI COMPONENT 3	9	0.705942	0.784381E-01	3.367	0.027
AMMI COMPONENT 4	7	0.240924	0.344177E-01	4.456	0.061
GXE RESIDUAL	5	0.386199E-01			
TOTAL	59	163.702			

The differences in yield between the varieties are significant at the 0.01 level. The stability level is similar, but the adaptability is very different, through a highly significant GxE (linear) interaction. The results of the ANOVA analysis allow us to consider the interaction between variety and environment here as linear. Surprisingly, many analysis points show that the environmental index tends to 0.

Genetic grouping based on the yield of peanut lines as well as the cultivation locations was carried out in this season to classify the genotypes and the environment corresponding to each genotype that brings the best cultivation efficiency. The results of the genetic grouping are expressed in terms of genotype at a difference level of about 30%, the lines/varieties are divided into 4 main groups: Group I includes 3 lines: HATRI 20 DP, HATRI 06 DP, HATRI 14 DP (high yield group); Group II has 2 lines: HATRI 15 DP, HATRI 16 DP; Group III has 1 line: HATRI 03 DP; Group IV includes 3 remaining lines/varieties: HATRI 01 DP, HATRI 02 DP, HATRI 13 DP (low yield group). Regarding the cultivation environment, at a difference of about 50%, there are four different environmental groups. Group I includes 2 locations (Long An, Tra Cu). Group II has 1 location: Duyen Hai. Group III has 1 location: Cau Ngang, Group IV includes 2 locations: Can Tho and An Giang.

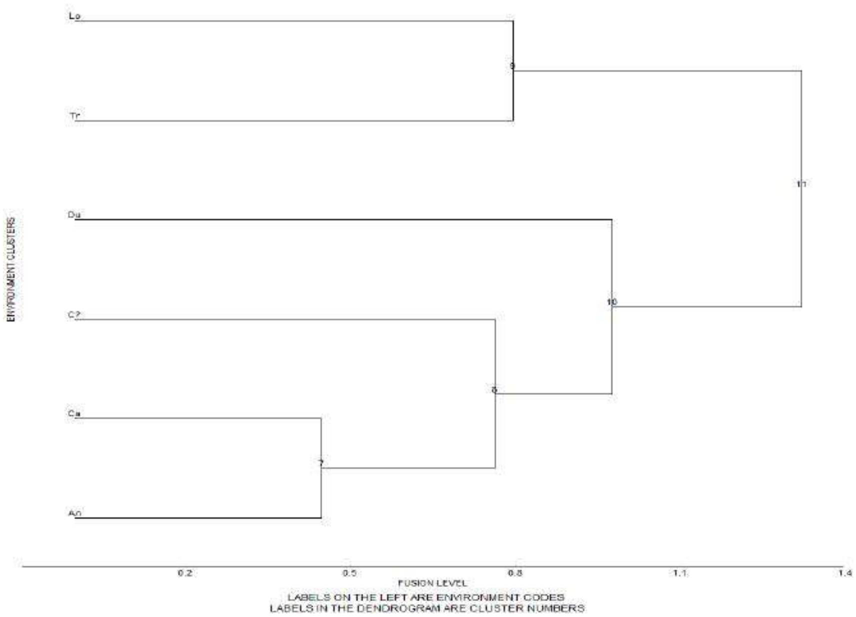

Fig.2: Environmental grouping in the 2023 Winter-Spring crop

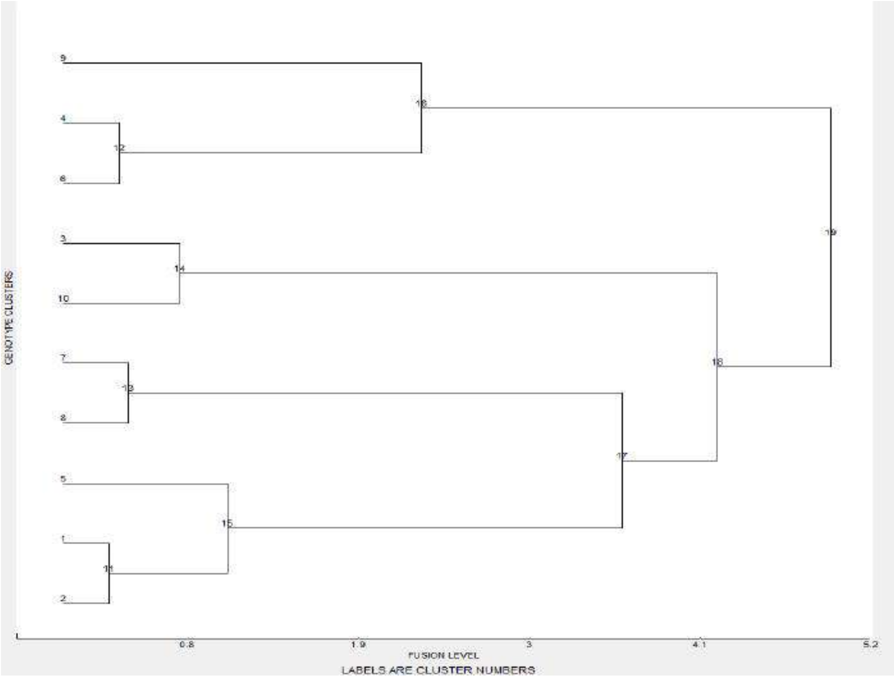

Fig.3: Genotype grouping for Winter-Spring crop 2023

❖ **Results recorded in Summer-Fall crop 2023**

Through the analysis of the AMMI diagram, it shows that the interaction level of yield on 6 points reached 84.2%, which is very high. The analysis of the diagram shows that the peanut variety HATRI 06 DP is a very stable variety, followed by the variety HATRI 14 DP. Varieties such as HATRI 03 DP, HATRI 13 DP, HATRI 20 DP have positive interactions with the environment.

Based on the AMMI diagram, it is noted that the varieties HATRI 06 DP, HATRI 13 DP and HATRI 15 DP are suitable for Tra Cu and the varieties HATRI 15 DP and HATRI 20 DP are suitable for Cau Ngang area, the varieties HATRI 02 DP and HATRI 01 DP are suitable for Duyen Hai area. HATRI 16 DP, HATRI 02 DP are suitable for Long An area.

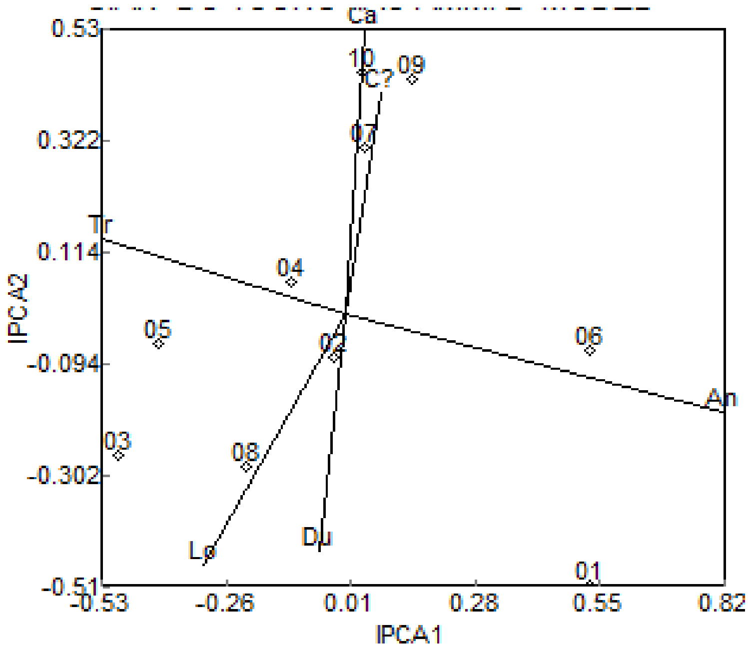

Fig.4: Yield interaction level above 6 points in Summer-Autumn crop 2023 Interaction AMMI 2 MODEL

Note: 1: HATRI 01 ĐP; 2: HATRI 02 ĐP; 3: HATRI 03 ĐP; 4: HATRI 06 ĐP; 5: HATRI 13 ĐP; 6: HATRI 14 ĐP, 7: HATRI 15 ĐP; 8: HATRI 16 ĐP; 9: HATRI 20 ĐP; 10: MD7.

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Variance analysis of AMMI model in Summer-Autumn crop 2023

ANALYSIS OF VARIANCE FOR THE AMMI MODEL

SOURCE	D.F.	S.S.	M.S.	F	FPROB
TREATMENTS	9	1.37896	0.153218		
LOCATIONS	5	150.796	30.1593		
TREATMENT X SITES	45	2.30523	0.512274E-01		
AMMI COMPONENT 1	13	1.10165	0.847419E-01	2.253	0.031
AMMI COMPONENT 2	11	0.840203	0.763821E-01	4.414	0.002
AMMI COMPONENT 3	9	0.164686	0.182985E-01	1.105	0.426
AMMI COMPONENT 4	7	0.108362	0.154803E-01	0.857	0.590
GXE RESIDUAL	5	0.903362E-01			
TOTAL	59	154.481			

Genetic grouping based on the yield of peanut lines as well as the cultivation locations was carried out in this crop to classify the genotypes and environments corresponding to each genotype that gives the best cultivation efficiency. The results of genetic grouping are expressed in terms of genotypes at a difference of about 30%, the lines/varieties are divided into 3 main groups: Group I includes 6 lines: HATRI 16 DP, HATRI 02 DP, HATRI 06 DP, HATRI 14 DP, HATRI 15 DP, HATRI 20 DP (high yield group); Group II has 2 lines with lower yield: HATRI 01 DP and MD7; Group III has 2 lines: HATRI 03 DP and HATRI 13 DP, this is the low yield group. Regarding the cultivation environment, at a difference of about 57.6%, there are five different environmental groups. Group I includes 2 locations (Long An, Duyen Hai). Group II is An Giang and Tra Cu. Group III includes Can Tho and Cau Ngang.

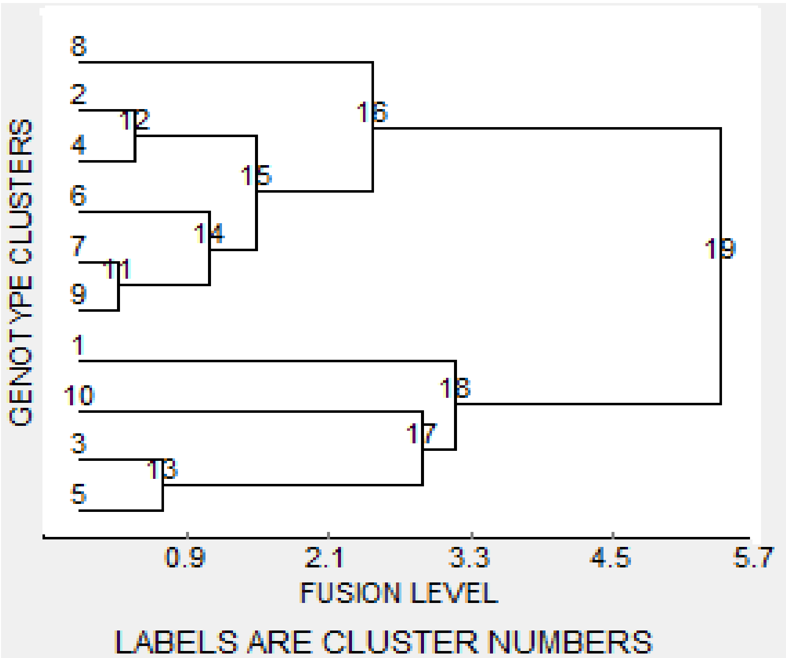

Fig.5: Genotype grouping in Summer-Autumn crop 2023

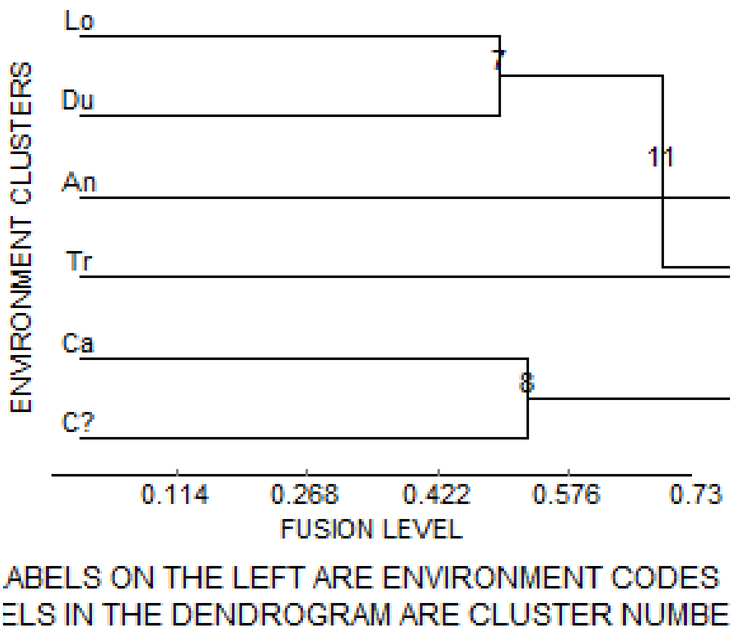

Fig.6: Environmental grouping in Summer-Fall crop 2023

IV. CONCLUSION

Through analysis of the criteria for assessing adaptability and stability. Proposed varieties: HATRI 02DP, HATRI 03DP, HATRI 14DP meet the requirements for seed quality, yield and yield components, and high resistance to pests and diseases.

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Effect of Row Spacing on the Growth and Yield of Peanut (*Arachis hypogaea* L.) Varieties in Cau Ngang, Tra Vinh, Vietnam

Phuoc Trong Nguyen, Khang Minh Le, Loan Hong Thi Nguyen, Lang Thi Nguyen

High Agricultural Technology Research Institute of Mekong Delta, CanTho (HATRI).
*Email: ntlang.prof@gmail.com
Website: Hatri.org

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Abstract*— Field experiments were conducted at the research field of the Cau Ngang, Tra Vinh from May to October to determine the influence of row spacing on growth and yield of peanut under wet and dry season (2023). The experimental design was a 6×5 factorial was a split-split plot experiment laid out in randomized complete block design with three replicates. The factors studied included: Variety [(A1) MD7; (A2) HATRI 03 ĐP; (A3) HATRI 02 ĐP; (A4) HATRI 14 ĐP; (A5)VD08; (A6) VD01-01]; (M) Row spacing [(M1) 20×20 cm, (M2) 15x20 cm, (M3) 15×15 cm, (M4) 10x20 cm, (M5) fellow farmers 10x10 cm] The result showed that Peanut varieties HATRI 03 DP, HATRI 02 DP, HATRI 14 DP, VD08, VD01-01 have weight the seed 100, number of branches/plant, and significantly higher yield than MD7 varieties. The planting spacing of 15 cm x 20 cm for leaf , plant height, number of plant harvested and yield is higher than the spacing of 20 x 20 and 15 x 15 cm in the wet and dry season in 2023. Spacing of 20 x 20 cm and 15 x 15 cm for the highest yield.*

Keywords— ***Peanut, row spacing, yield and yield components.***

I. INTRODUCTION

Cultivated peanut (*Arachis hypogaea* L.; 2n = 4x = 40) is an important oil and cash crop that is grown worldwide, with an annual global yield of about 54 million tons and harvest area of over 32 ha (FAOSTAT, http://www.fao.org/faostat/en/#data/QC, 2021). Because of their unique biological characteristics, peanuts must be shelled before they can be used (e.g., oil extraction, food processing, and seeding). Shelling refers to a process that breaks the peanut shell and separates it from the kernel (Guzman et all.,2019).

The management of planting distances has been a topic of discussion among agronomists for many years of research. In different local natural conditions such as soil, water, climate and rain, there is little information about the optimal row spacing and tree spacing for newly studied varieties. The peanut variety response to planting distance has been published by Konlan et al. (2013). Distances of 30 cm x 15 cm and 50 cm x 15 cm create conditions for taller trees, the highest number of branches, and wider canopy; high yield and quality of peanuts in relation to the respective grain . The highest pod yield (7511.9 kg ha-1) was obtained from 75x10 cm and the lowest (5171 kg ha-1) from 75x25 planting density according to a two-year average. As a result; optimum planting density was found 75x10 cm for Virginia market type varieties in double crop peanut production(Bihter et all.,2017) . Peanut variety L14 is grown in plant densities and row spacing of 35 plants m-2 (25 cm × 25 cm) and 40 plants m-2 (25 cm × 20 cm) are most appropriate; plants grow, develop better and give a higher yield than other densities under the same conditions.(Minh et all.,2021). Most previous studies have focused on food and fruit trees and characteristic forests1(Jayathilaka et all.,2012). Few studies have been conducted on the growth-appropriate zoning of peanuts, a field economic cropand determine peanut quality into zones(Li et al .,2010)such as short duration, small study scope, single selection index, and no distinction between reproductive stages. On the basis of existing research, the temperature, rainfall and sunlight conditions for the growth and development of peanuts in Tra Vinh have been carefully considered. A comprehensive suitability model for the peanut growing season was developed by considering the suitability of the variety, the spacing of the variety and the characteristics of yield variation and composition The yield over time of suitability for the peanut variety in different seasons was analyzed. can provide a scientific basis for the rational use of climate resources and adjustment of planting techniques, which will also increase the income of peanut production, and help economic development(Sicheng et all.,2022). The purpose of this study was to determined, how pod yield and yield components of peanut are affected by row spacing and plant spacing of double crop peanut production in Cau Ngang ,Tra Vinh, VietNam.

II. MATERIAL AND METHODS

The experiment was conducted in Cau Ngang district, Tra Vinh province on sandy soil. With 6 varieties :HATRI 03 DP, HATRI 02 DP, HATRI 14 DP, VD08, VD01-01, MD7.Experimental soil is peanut soil for ten years and in recent years has been managed in the conservation system for the peanut region. Prior to the experiment, topsoil layers from 0 cm to 30 cm were collected in each area to analyze the chemical indicators according to the method of Raij et al., (2001) and the mechanized composition according to Camargo et al., (2009).

- Experiment arrangement: Field experiment consists of 2 elements

Tree Height Tracking Index: determined by a cm ruler at the end of the harvest cycle (90 days) from soil surface to the end of the main trunk of 10 plants in each experiment. Number of leaves and number of branches: calculated at the end of the harvest period, using a sample of 10 plants per experiment. Yield and yield components : The number of pod per plant, the number of seeds per plant is determined by counting the bark and seeds of 10 plants selected from each experiment. Weight of 100 grains: Weigh the mass of 100 grains in each experiment. Seed yield: Weigh the seed weight of the plant, collect over 3m2. The particle size is measured in rulers.

III. RESULTS AND DISCUSSION

Experimental soil properties

Properties of experimental soil The results of soil analysis after harvesting 2 crops Wet and dry in Cau Ngang district show that the total nitrogen parameters in the soil are 0.874%. The content of organic carbon was not high before the test from 0.92 (Tran et al., 2021) to 1.04%. In this experiment, organic carbon increased after the first crop from 0.21%. Some physicochemical properties of untreated soil, treated soil, and peanut husks From the test results, the pH, organic matter, nitrogen, phosphorus, potassium, and magnesium of the samples have been listed in table 1. According to the results, the pH values in the soil sample (6.15), the soil sample after crop (6.05) were found to be consistent with the recommended pH of the soil, i.e. the pH value is from 5.8 to 6.8 (Thermo Fisher Scientific, 2013). The chemical composition of the soil indicates higher soil nitrogen, phosphorus, potassium, and organic carbons after single-crop bean cultivation (table1).

Table 1 : Soil properties before and after harvest at Cau Ngang

Parameter	**Soil physicochemical indicators**	
	Before Testing	**After Testing**
pH_{KCl}	6.15	6.05
Organic carbons (OC - %)	0.97	1.18
N total (%)	0.099	0.971
P_2O_5 total (%)	0.74	0.98
K_2O total (%)	0.58	1.16
Easily digestible phosphorus (mg P_2O_5/100 g soil)	3.14	3.63
Easily digestible Kali (mg K_2O/100 g soild)	19.22	28.9
CEC (lđl/100 g soil	2.01	2.67
Mg (%)	1.09	1.02
Sand (%)	62.1	62.1
Limôn (%)	20.5	20.5
Clay (%)	10.1	10.1

Effects of spacing on growth development and components peanut yield in** wet **season 2023 at Cau Ngang

Effect of distance, fertilizer on growth. development and factors constituting peanut yield in wet season 2023 at Cau Ngang Analysis of the impact of fertilizer on plant growth This analysis is based on three factors: plant height. number of branches on the tree. and number of leaves on the tree in different varieties. The fluctuation of height plant is statistically significant. The average height plant of the MD7 variety is 62.2cm. while the HATRI 03 DP variety has a height plant of 64.3cm. The height at the M5 spacing is the highest 58.3cm. The average height of the plant in the experiments is 56.82cm. Thus. in the M5 experiment, the palnt density is large, so the height plant is higher than that of other experiments. The number of branches on the plant in the experiments is different and has no statistical significance. The number of leaves on the plant of the MD7 variety is higher than that of the HATRI 03 DP variety. In terms of the average spacing of the experiments, the highest number of leaves on the plant in the M5 experiment is M4; the lowest in the M1 experiment.As for the number of seeds on a plant in most experiments there is an interaction between variety and spacing . The highest number of is the spacing in the M1 (20 × 20m) and M2 (15× 20m) experiments. The weight of 100 seeds of HATRI 03 DP. HATRI 02 DP. HATRI 14 DP is higher than that of MD7. Differences between varieties and spacing are not statistically significant. The interaction between variety and spacing was statistically significant in terms of height, number of leaves on the plant , number of pod/plant, and weight of 100 seeds. (Table 2).

Table 2.: Effects of spacing and yield component peanut in wet season 2023 at Cau Ngang

Treatments	**Hight Plant (cm)**	**No branch /plant**	**No Leaf / plant**	pod per plant	**No. seed/ plant**	Weight the seed (100) **(g)**
Varieties						
A1 = MD7	62.2b	10.5e	79.2a	18.4f	31.3e	45.6d
A2= HATRI 03 ĐP	64.3a	11.4d	72.4f	21.6c	35.8b	46.7c
A3= HATRI 02 ĐP	60.36d	14.4b	74.5e	22.4a	36.4a	48.4a
A4= HATRI 14 ĐP	61.41c	15.4a	77.6b	21.3c	35.7b	47.5b
A5=VD 08	66.55a	12.4c	76.4c	20.4d	34.6c	45.6d
A6= VD01-01	62.15b	12.3c	75.5d	19.5e	32.4d	47.1b
Mean	63.25	10.95	75.8	20.0	33.55	46.15
$LSD_{0.05}$	*	*	*	*	*	*
Spacing (cm)						
M1 (20× 20m)	55.1b	10.2b	82.4d	18.6b	35.3a	45.6a
M2 (15x20)	57.5b	11.3a	84.5c	21.4a	35.6a	45.5a
M3 (15X15)	56.9b	10.7b	84.8c	16.9c	30.6c	45.5a
M4 (10X20)	56.7b	8.5b	85.3b	16.8c	30.4c	45.5a
M5: Farmers(10 x 10)	58.3a	9.2b	86.6a	16.3c	32.3b	45.1a
Mean	56.92	9.98	84.72	18.0	32.84	45.44
$LSD_{0.05}$	*	*	*	*	*	ns

*Note: ns: No statistical significance; *. ** Statistically significant in the order of P=0.05 and P=0.01.*

In terms of planting spacing the fluctuation in the number of nodules on the plant shows that there is a difference in statistical significance. The spacing in the M1 and M2 experiments for the number of nodules on tall plant was 40.6 nodules/ plant and 46.8 nodules/plant , respectively. (Table3). For yield (Pod shell). HATRI 13 DP is higher than MD7. The spacing test also has special statistical significance, especially the M3 treatment spacing is the highest followed by M2. Seed (nucleus) yield also recorded statistically significant experiments. Highest seed yields on M2. M1 and M3 (Table 3).

Table 3: Effect of spacing and yield and seed size in wet season 2023 at Cau Ngang

Treatment	**Number of nodules/plant**	**Yield of** Pod shell **(g/ plant)**	**Yield of grain (g/plant)**	pod length **(cm)**	**Seed length (cm)**	**seed** width **(cm)**
Varieties						
A1 = MD7	41.6 a	29.9e	18.7f	3.5	1.6	1.1
A2= HATRI 03 ĐP	46.8b	30.2d	21.9d	3.9	1.8	1.2
A3= HATRI 02 ĐP	48.6b	35.5b	25.4a	3.8	1.9	1.5
A4= HATRI 14 ĐP	50.7a	56.5a	22.8c	3.4	1.8	1.2
A5=VD 08	48.2b	25.6f	19.4e	3.1	1.6	1.1
A6= VD01-01	41.1c	32.7c	23.1b	3.6	1.5	1.2
Mean	42.2	30.05	20.3	3.7	1.5	1.15
$LSD_{0.05}$	*	*	*	*	Ns	ns
Spacing (cm)						
M1 (20× 20m)	43.5c	29.1a	18.5b	3.1	1.4	1.3
M2 (15x20)	44.8b	29.2a	19.4a	3.0	1.6	1.2
M3 (15X15)	46.8a	29.6a	18.8b	3.1	1.8	1.1
M4 (10X20)	43.1c	29.3a	17.2c	3.0	1.8	1.2
M5: Farmers(10 x 10)	40.6 e	28.3b	18.7b	2.8	1.6	1.3
Mean	43.76	29.10	18.52	3.0	1.58	1.22
$LSD_{0.05}$	**	**	**	ns	ns	ns

*Note: ns: No statistical significance; *. ** Statistically significant in the order of P=0.05 and P=0.01.*

Effect of spacing on growth development and compenents peanut yield in dry season 2023 at Cau Ngang

Analysis of the impact of spacing àn 6 varieties on plant growth ,this analysis is based on three factors: plant height, number of branches on the plant, and number of leaves on the plant in different varieties. The plant height is statistically significant. The average height of the MD7 variety is 60.2 cm, while the HATRI 03 DP variety has a height of 61.3 cm. The height at the highest M5 spacing is 59.45 cm. The average height of the plant in the experiments is 55.92 cm. Thus. in the M5 experiment, the tree density is large. so the plant height is higher than that of other experiments. The number of branches on the plant in the experiments is different and has no statistical significance. The number of leaves on the plant of the MD7 variety is higher than that of the HATRI 03 DP variety. In terms of the average distance of the experiments. the highest number of leaves on the tree in the M5 experiment is M4; the lowest in the M1 experiment.

The number of pod on the plant of the HATRI 03 DP variety is higher than that of MD7.Spacing affects the number of pod on the plant . Most recorded the highest number of pod on the plant at M2 (15 × 20m) with 22.4 pod/plant . As for pod / plant , number of seeds on plant , in most experiments there is an interaction between variety and spacing. The highest number of pod is the spacing in the M1 (20 × 20m) and M2 (15× 20m) experiments. The weight of 100 seeds of HATRI 03 DP, HATRI 02 DP. HATRI 14 DP is higher than that of MD7. Differences between varieties and spacing are not statistically significant at Weight of seed (100). The interaction between variety and spacing was statistically significant in terms of hight number of leaves on the plant , number of pod/plant , and number of seeds/ plant. (Table 4.).

Table 4.: Effect of spacing and yield component peanut in the dry season 2023 crop at Cau Ngang

Treatments	**Hight Plant (cm)**	**No. branch /plant**	**No. Leaf / plant**	pod per plant.	**No. seed/ plant**	Weight of seed (100) **(g)**
Varities						
A1 = MD7	60.2b	11.26e	75.2a	20.3f	38.3e	45.3d
A2= HATRI 03 ĐP	61.3a	12.35d	70.4f	25.7c	37.9b	46.2c
A3= HATRI 02 ĐP	58.36d	15.44b	73.5e	23.5a	36.3a	48.6a
A4= HATRI 14 ĐP	60.41c	15.4a	76.6b	24.3c	36.7a	47.5b
A5=VD 08	62.55a	14.4c	76.4c	20.4d	33.6c	45.6d
A6= VD01-01	61.15b	12.5c	75.5d	20.5e	36.4d	47.1b
Mean	61.22	12.95	76.8	21.0	34.55	46.15
$LSD_{0.05}$	*	*	*	*	*	*
Spacing (cm)						
M1 (20× 20m)	54.6b	12.36b	82.4d	18.6c	35.3a	45.6a
M2 (15x20)	56.27b	12.65b	84.5c	22.4a	35.6a	45.5a
M3 (15X15)	55.39b	14.27a	84.8c	18.9c	32.66d	45.5a
M4 (10X20)	56.62b	9.45c	85.3b	18.8c	34.47b	45.5a
M5: Farmers(10 x 10)	59.45a	9.21c	86.7a	20.3b	33.42c	45.8a
Mean	55.92	10.33	85.71	19.0	33.45	45.46
$LSD_{0.05}$	*	*	*	*	*	ns

*Note: ns: No statistical significance; *. ** Statistically significant in the order of P=0.05 and P=0.01.*

Analysis of the impact of spacing on yield and seed size The average number of nodules on the plant of HATRI 14 DP was higher than that of MD7, HATRI 3 DP, HATRI 2 DP . In terms of planting spacing , the fluctuation in the number of nodules on the plant shows that there is a difference in statistical significance. The spacing in the M1 and M2 experiments for the number of nodules on the hight plant was 49.6 nodules/ plant and 49.1 nodules/plant, respectively. (Table 5). For the pod yield (Pod shell). HATRI 14 DP is higher than MD7, HATRI 3 DP, HATRI 2 DP. The spacing treatment also has special statistical significance, especially the M1 treatment spacing is the highest, followed by M2. Seed (nucleus) yield also recorded statistically significant experiments. Highest seed (nucleus) yield on,M1 , M2 (Table 5)

Table 5: Effect of spacing and yield and grain size of the 2023 dry season at Cau Ngang

Treatments	**Number of nodules/plant**	**Yield of** Pod shell **(g/ plant)**	**Yield of grain (g/plant)**	pod length **(cm)**	**Seed length (cm)**	Seed width **(cm)**
Varieties						
A1 = MD7	44.4 d	33.4e	20.4f	3.5	1.7	1.1
A2= HATRI 03 ĐP	49.9b	45.4b	25.3c	3.7	1.8	1.2
A3= HATRI 02 ĐP	47.7c	37.2c	26.2b	3.9	1.9	1.5
A4= HATRI 14 ĐP	56.6a	62.3a	27.6a	3.5	1.9	1.2
A5=VD 08	49.3b	32.5f	21.6e	3.2	1.6	1.1
A6= VD01-01	45.5e	34.9d	24.7d	3.6	1.5	1.2

Mean	48.9	40.95	24.3	3.7	1.5	1.15
$LSD_{0.05}$	*	*	*	*	Ns	ns
Spacing (cm)						
M1 (20× 20m)	49.6a	48.5b	27.7a	3.2	1.6	1.4
M2 (15x20)	49.1a	53.6a	24.6b	3.1	1.7	1.3
M3 (15X15)	48.2b	47.4c	19.6d	3.1	1.6	1.3
M4 (10X20)	47.3c	42.7d	21.7c	3.0	1.7	1.2
M5: Farmers(10 x 10)	42.7 d	41.5e	21.2c	2.8	1.6	1.3
Mean	47.58	46.74	22.96	3.4	1.64	1.32
$LSD_{0.05}$	**	**	**	ns	ns	ns

*Note: ns: No statistical significance; *. ** Statistically significant in the order of P=0.05 and P=0.01.*

IV. DISCUSSION

The HATRI 03 DP variety has significant values in terms of height, number of branches/plant , number of seeds/ plant , Weight of seed (100) number of nodules/plant . Yield of Pod shell (g/ plant) and grain yield (kernels) as well as grain size were higher than those of MD7, except for the number of upper leaves/plant. This is due to the early maturation and high yield potential of the HATRI 03 DP variety. In addition. HATRI 03 DP is a large-seed variety, so it is necessary to use a higher amount of fertilizer than MD7. The traits of the number of Pod shell in this study varied significantly and were similar to the results of Waghmode et al. (2017). For the varieties HATRI 03 DP. HATRI 14 DP. VD08. the distance of 15cm x 20cm. the number of fruits (seeds with shells) on the tree is significantly higher.

This is consistent with the results of Jaiswal et al. (2018) who found that a distance of 30cm x 15cm proved superior in terms of the increasing number of grain on the plant compared to a closer distance of 22.5cm x 10cm. Previous reports have shown that a significant interaction effect exists between planting distance x degree of fractionation on the number of peanut kernels (kernels). Previous reports have shown that a significant interaction effect exists between planting distance× degree of ownership for the number of peanut kernels (kernels). (Gadade et al.. 2018). Fertilizers promote plant growth as well as root growth and increase peanut yield (Jakusko et al.. 2015). Although there was a difference in yield (g/plant), there was no significant difference between varieties, planting distances,and their interactions. Higher yields can be achieved with wide spacing (20cm x 15cm) than with narrower spacing (10cm x 10cm) in the wet season.

The experiment of (Phuong et al.,22) in Tra Cu Tra Vinh with a distance of 15 x 20 cm and 15 x 15 cm for the highest yield . howver ,in this experiment with prolonged rainfall, the yield of the 6 varieties showed a very significant difference in yield indicators and constituent factors. The pod yield (shelled seeds),seed yield (kernels) and number of nodules/plant had statistically significant interactions between variety and spacing . As for the number of seeds on a plant, in most experiments there is an interaction between variety and spacing . The highest number of pod is the spacing in the M1 (20X20) and M2 (15X20) experiments. The gap between the M3 indicators increased the nodule,but the productivity of the experiments increased in significantly.

V. CONCLUSION

Five planting densities were tested with 6 varieties in Randomized Complete Block Design with three replications in 2023 dry and wet crop on the coastal sandy land area in Cau Ngang district, Tra Vinh ,Vietnam. The different density treatments affect the growth. development and yield and yield components of the peanut variety HATRI 03 D, HATRI 02 DP, HATRI 14 DP, VD08, VD01-01. These varieties increasing plant density, the number of pod per plant, whereas plant height,number of branches/plant, leaf and significantly higher yield than MD7 varieties. The planting with treatment M2(15 cm x 20 cm)for spacing , plant height, number of pod and yield is higher than the spacing of M1(20 x 20) and M2(15cm x 15 cm) in the both wet and dry sesaon 2023. Spacing of 20 x 20 cm and 15 x 20 cm for the highest yield. However, the difference in the 100 seeds weight has not been statistically significant in the experiments. For sustainable peanut production, attention should be paid to choosing the appropriate variety.

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Women's Access to Productive Resources: A Case Study of Mid-Hill Sub-Humid Zone of Himachal Pradesh

Deepika Sharma*, Rashmi Chaudhary, Krishan Kumar, Yasmin Janjhua

Department of Business Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni -Solan (HP), India
Corresponding Author: Email- deepikasharma_07@yahoo.co.in

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Abstract— *The aim of this study was to analyse and compare the access of men and women to productive resources, focusing on three aspects: ownership of assets, access to credit, and decision-making regarding lending sources. Data was gathered from the mid-hill sub-humid zone of Himachal Pradesh. The results revealed that a significant portion of the women surveyed did not have ownership rights to land, whether agricultural or non-agricultural. Instead, joint ownership of assets other than land was prevalent in the area. Access to credit, a key factor in women's empowerment, showed that female respondents were more likely to rely on friends, relatives, or informal credit groups. Regarding decision-making on credit, joint decision-making was common in selecting credit sources. The study suggests that strict enforcement of existing laws is necessary to ensure women's property rights, and efforts should be made to promote ownership of assets to enhance women's empowerment and household livelihood security. Additionally, measures should prioritize easy access to formal credit for women, and the formal credit system should be expanded to reach those in need.*

Keywords— ***Women, productive resources, asset ownership, empowerment, decision-making***

I. INTRODUCTION

Gender equality is a global issue, which has been accelerated in recent decades. In general, it is a topical issue with its positioning in the Sustainable Development Goals (SDGs) and Millennium Development Goals. According to the United Nations Sustainable Development Goals (SDG) women's land ownership is essential to ensure their empowerment and welfare with the realization of gender equality. Moreso, the issue has been debated and discussed on various platforms by the policy makers, social reformers, researchers and feminists. Women's issues especially the empowerment of rural women is also focused on by different international organizations like the FAO, World Bank and United Nations. Existing literature provide evidence that women empowerment contributes not only to reducing the gender gap but also have a multiplier effect on development outcomes (Sharma *et al.*, 2020). Although in developing countries women farmers represent more than a quarter of the world's population, yet they have less access than men to agriculture related assets, land ownership and lower level of decision-making power (FAO, 2011). Women's less access to productive resources can refrain them from making economic as well as professional choices and impact negatively on their earnings and limiting their influence in family activities or decisions (Kabeer, 1999; Roy and Tisdell 2002; Alkire et al., 2013; Srivastava and Srivastava, 2017).

Gender mainstreaming into agricultural policies is crucial for achieving gender equality and giving women more rights. Even female farmers' access to productive resources and credit are positively correlated to agricultural output and their ability to make choices (Sharma *et al.*, 2022). Therefore, in the present scenario, in order to address the challenges in gender mainstreaming, it is essential to understand the areas where women lack empowerment so policies and programs can be effective in targeting these areas for strengthening the women empowerment and gender equality. Thus, the present study was conducted with the objective to examine and compare both gender's access to productive resources, based on three sub-dimensions i.e., asset ownership status, access to credit and decisions about lending sources.

II. MATERIAL AND METHODS

The data utilized in this study was gathered through a primary survey, employing a multi-stage random sampling technique. The sampling process involved selecting three districts - Mandi, Sirmour, and Solan, followed by seven development blocks and 28 agriculture-dominated gram panchayats, all from the mid-hill sub-humid zone of Himachal Pradesh (refer to Table 1). A total of 280 households spread across these 28 gram panchayats were surveyed for this study. The study population comprised farm households, categorized into two groups: 'dual adult households' (containing both male and female adults) and 'female adult-only households' (with no adult male present). Interviews were conducted with the 'primary man and primary woman respondents' of each household, identified as the key decision-makers. In total, 548 respondents were selected, comprising 280 primary women and 268 primary men. Data collection was carried out using a structured questionnaire, and descriptive statistics were employed to analyse the data, converting it into insightful information through frequency, percentages, and measures of central tendency.

Table 1: Study Area

Agro-climatic Zone	Selected Districts	Selected Blocks	Gram Panchayat
Sub-Humid Mid Hills	**Mandi**	Balh, Gopalpur, Mandi Sadar	Baggi, Lohara, Nalsar, Salwahan, Bag, Khalardu, Nabhai, Jamni, Bhatwar, Gharan, Nichla Lot, Tihri
	Sirmour	Rajgarh, Sangrah	Bhuira, Karganun, Salana, Tikar, Charna, Jamukoti, Khale Kiyar, Rajana
	Solan	Kunihar, Solan	Bakhalag, Batal, Daseran, Deora, Dangri, Jonaji, Mashiwar, Sanhol

Access to productive resources

To assess access to productive resources, we measured asset ownership status, access to credit, and decisions regarding lending sources. Asset ownership status refers to whether individuals solely or jointly own various productive resources, including agricultural and non-agricultural land, livestock, poultry, fisheries, farm equipment (both mechanized and non-mechanized), non-farm business equipment, residential structures, consumer goods (both small and large), mobile phones, means of transportation, and jewelry. An individual was considered to have inadequate access to productive resources if they neither own any assets solely or jointly nor have the ability to make decisions regarding them or feel capable of doing so.

III. RESULTS AND DISCUSSION

Asset ownership status

Table 2 illustrates the asset ownership status within the study area. Analysis of the data reveals that 72.90 per cent and 68 per cent of male respondents possess sole ownership of agricultural and non-agricultural land, respectively, whereas their female counterparts show lower ownership rates, with 62.10 per cent and 79.30 per cent respectively not owning any agricultural or non-agricultural land (refer to Figure 1). Kieran et al. (2015) similarly found that in India, nearly 90 per cent of agricultural land ownership is held by men.

Regarding assets other than land, more than 50 per cent of female respondents reported joint ownership, except for mobile phones and means of transport. Specifically, 82.80 per cent of female respondents solely own mobile phones in the study area, while 66.30 per cent do not possess any means of transport. Furthermore, all female respondents (100%) own jewelry either solely or jointly. Additionally, significant levels of joint ownership among female respondents were observed for assets such as poultry/fisheries (99%), large consumer durables (96.80%), small consumer durables (96.40%), non-farm business equipment (82.90%), non-mechanized farm equipment (76.80%), residential structures (76.40%), and livestock (74.30%).

Table 2: Asset ownership status

Asset	Ownership status	Male	Female	Total
Agricultural land	Solely	72.90	8.90	40.30
	Jointly	17.10	28.90	23.10
	No Ownership	10.00	62.10	36.60
Non-agricultural land	Solely	68.00	8.60	38.30
	Jointly	13.80	12.10	12.90
	No Ownership	18.20	79.30	48.80
Livestock	Solely	30.10	5.00	17.30
	Jointly	65.40	74.30	69.90
	No Ownership	4.50	20.80	12.70
Farm equipment (Non- mechanized)	Solely	26.80	3.90	15.30
	Jointly	73.20	76.80	75.00
	No Ownership	0	19.30	9.70
Farm equipment (Mechanized)	Solely	27.10	3.80	15.40
	Jointly	72.90	55.40	64.15
	No Ownership	0	40.80	20.50
Nonfarm business equipment	Solely	12.60	5.00	8.70
	Jointly	85.50	82.90	84.20
	No Ownership	1.90	12.10	7.10
House and/or other structures	Solely	32.00	6.10	18.80
	Jointly	63.20	76.40	69.90
	No Ownership	4.80	17.50	11.30
Large consumer durables	Solely	3.00	2.10	2.60
	Jointly	96.60	96.80	96.70
	No Ownership	0.40	1.10	0.70
Small consumer durables	Solely	3.00	2.10	2.60
	Jointly	97.00	96.40	96.70
	No Ownership	0	1.50	0.70
Mobile phone	Solely	99.60	82.80	91.10
	Jointly	0.40	1.80	1.10
	No Ownership	0	15.40	7.80
Means of transportation	Solely	46.80	2.90	24.90
	Jointly	49.00	30.80	39.90
	No Ownership	4.20	66.30	35.20
Jewellery	Solely	14.90	40.00	27.50
	Jointly	85.10	60.00	72.50
	No Ownership	0	0	0

All figures are in percentages

The overall findings of the study highlight the prevalence of joint ownership of assets other than land in the study area, a trend consistent with the research of Akter et al. (2017). This research suggests that while men often hold primary ownership of land, women actively participate in decision-making regarding its use, and joint ownership is common for family resources. Similarly, corroborating findings from Anonymous (2020) for the state of Himachal Pradesh indicate that only 23.40% of rural women possess land ownership, either solely or jointly, while a significant majority, 77.80%, own and utilize mobile phones.

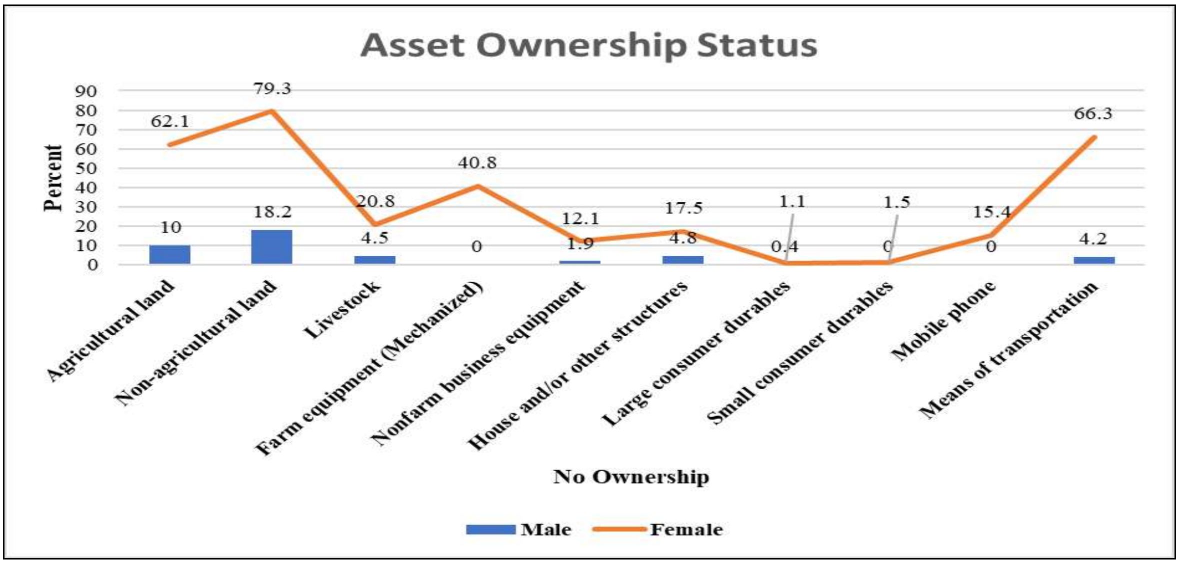

Fig.1: Asset ownership status

Access to credit

Access to and decision-making regarding credit pertain to whether individuals have obtained credit and their involvement in credit-related decisions. Table 3 presents data on access to credit in the study area. The findings reveal that the primary sources of credit utilized by respondents were formal lenders (92%) and friends or relatives (88.30%). Additionally, respondents also access credit from informal credit or savings groups (23.90%) and group-based microfinance lending sources (1.60%). Interestingly, none of the sampled respondents reported obtaining credit from informal lenders such as moneylenders or Sahukars, as households demonstrated access to institutional credit sources and were deemed financially included.

Table 3: Access to credit

Lending Source	Access to Credit	Total
Institutional credit (Bank/Financial Institution)	Yes	92.00
	No	8.00
Informal lender	Yes	0
	No	100.00
Friends or relatives	Yes	88.30
	No	11.70
Group based micro-finance or lending	Yes	1.60
	No	98.40
Informal credit or savings groups	Yes	23.90
	No	76.10

All figures are in percentages

The gender-wise distribution of credit, as depicted in Figure 2, revealed that female respondents were more inclined to acquire credit from friends or relatives (83.60%) and informal credit or saving groups (57.40%). Moreover, analysis indicated that 55 per cent of male respondents and 45 per cent of female respondents accessed credit from formal institutional sources. Conversely, in the case of group-based microfinance, both genders obtained credit equally.

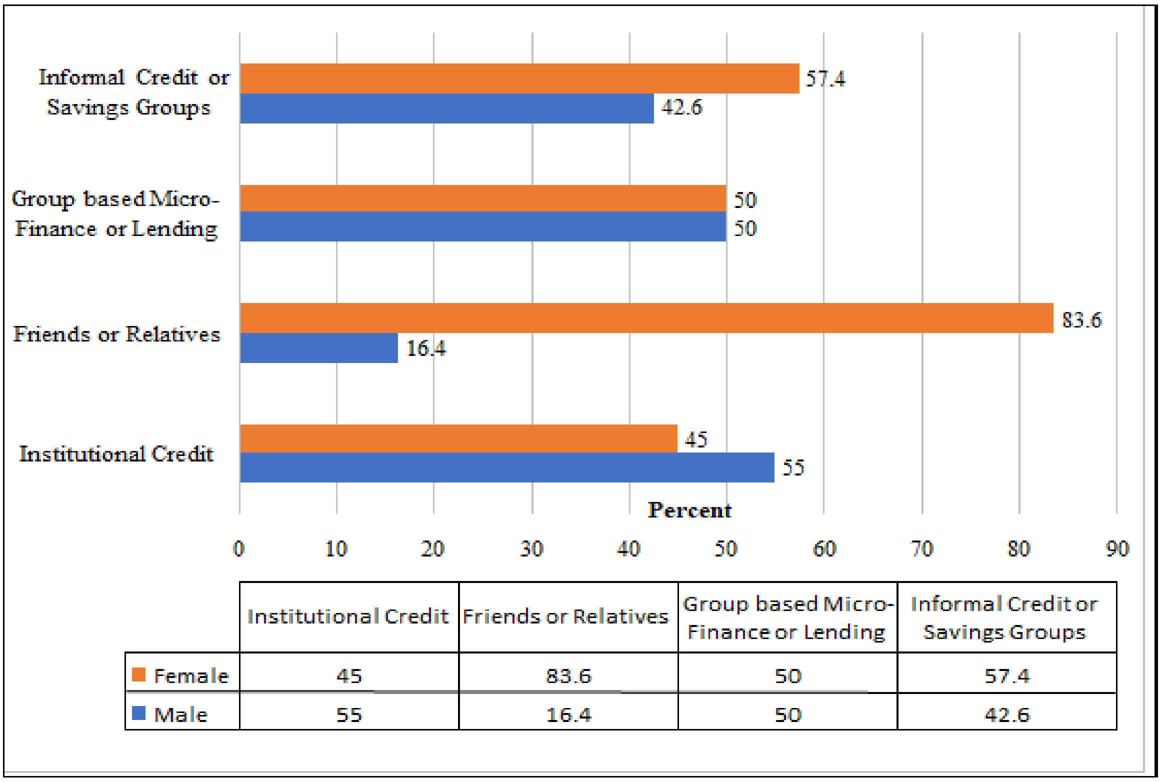

Fig.2: Gender-wise distribution of credit

Decision-making related to credit

Table 4 presents data on decision-making related to the source of lending. Examination of the data suggests that a majority of respondents perceived joint decision-making to be prevalent in the study area, with figures of 98.35 per cent for group-based microfinance, 88.90 per cent for informal savings groups, 88.85 per cent for friends or relatives, and 72.60 per cent for formal lenders. Additionally, respondents indicated that primary males within sampled households had greater access to decisions regarding institutional credit (16.85%) and credit from friends or relatives (9.50%) compared to their counterparts, who reported figures of 4.15 per cent and 1.60 per cent, respectively. Moreover, respondents noted that females had more involvement in decisions about informal credit or savings groups (9.45%) compared to their counterparts (1.65%). Based on the data analysis, it can be concluded that respondents indicated joint decision-making regarding the source of credit.

Table 4: Gender-wise decision-making about credit

Lending Source	**Credit decision maker**	**Male**	**Female**	**Total**
Institutional credit (Bank/Financial Institution)	Primary Male	20.80	12.90	16.85
	Primary Female	2.60	5.70	4.15
	Joint Decision	69.80	75.40	72.60
	Other Household Member	6.70	6.10	6.40
Friends or relatives	Primary Male	2.60	16.40	9.50
	Primary Female	1.10	2.10	1.60
	Joint Decision	96.30	81.40	88.85

	Other Household Member	0	0	0
Group based micro-finance or lending	Primary Male	0.70	0	0.35
	Primary Female	0	0.40	0.20
	Joint Decision	98.50	98.20	98.35
	Other Household Member	1.10	1.10	1.10
Informal credit or savings groups	Primary Male	1.90	1.40	1.65
	Primary Female	7.80	11.10	9.45
	Joint Decision	90.30	87.50	88.90
	Other Household Member	0	0	0

All figures are in percentages

Access to credit was identified as not a significant challenge, with informal women's groups and government banks emerging as dominant sources of credit. Regarding decisions about credit, the findings indicate that mutual decisions were made regarding credit matters.

IV. CONCLUSION

Based on the descriptive findings of the study, it is evident that joint ownership of assets other than land predominates in the study area. The study highlights that a majority of women lack ownership of both agricultural and non-agricultural land, depriving them of any form of land ownership. Despite existing laws granting women equal rights to ancestral property, stricter enforcement and implementation are necessary to ensure women's property rights. Therefore, promoting asset ownership is essential to enhance women's empowerment and improve household livelihood security.

Access to and decisions regarding credit play pivotal roles in women's empowerment in the study area. The study indicates that female respondents are more inclined to acquire credit from friends or relatives and informal credit or saving groups. Thus, prioritizing women with easy and convenient access to formal credit is recommended. Furthermore, expanding the outreach of the formal credit system is imperative to reach women in need.

Regarding decision-making related to credit, the results demonstrate that joint decision-making prevails in the study area concerning the selection of credit sources. This collaborative approach should be acknowledged and further supported to ensure inclusive decision-making processes.

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Morpho-biochemical parameters in blackgram (*Vigna mungo* L. Hepper) genotypes under drought stress condition

G. Kumara Joshi[1], K. Srinivas Naik[2], Bhattu Rajesh Nayak[1] ,Yugandhar.A[1]and G.Vijay Kumar*[1]

[1]Department of Genetics, Osmania University, Hyderabad, India
[2]Center for Plant Molecular Biology, Osmania University, Hyderabad, India
*Corresponding author: vijay.genetics@osmania.ac.in

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***Abstract*— *The present study carried out with ten blackgram accessions collected from NBPGR regional centre and T-9(Check) from ICAR-CRIDA, Hyderabad. The experiment was conducted in experimental farm, Department of Genetics, Osmania University Hyderabad during Rabi,2021. The ANOVA results revealed that for treatments all the yield,physiological and biochemical parameters were showed significant variability except 100 seed weight. All the yield and physiological parameters were significant for genotype x treatment except number of branches per plant and canopy temperature. The character seed yield (g/pl) was observed under irrigated condition highest by IC436524 and lowest by T-9. Whereas highest seed yield (g/pl) was observed under drought condition by IC426766. It was also observed that the genotype IC426766 28.84% over its control and 37.65% over T-9 under drought condition. The genotype IC426766 also showed higher proline content, RWC, lower MDA, higher SPAD reading and lower canopy temperature under drought condition. Among ten blackgram accession IC 426766 was identified as drought tolerant/resistance based on morphological, physiological and biochemical parameters.*

***Keywords*— Blackgram, drought stress, physiological and biochemical parameters.**

I. INTRODUCTION

Blackgram, also known as urdbean (*Vigna mungo* L. Hepper), is one of the major pulses. grain legume having a protein that is quickly absorbed. It is a member of the 2n=22 family Fabacaceace. About 25% of blackgram grain is protein, 56% is carbohydrate, 2% is fat, and 4% four percent vitamins and one percent minerals. Blackgram, or *Vigna mungo* (L.) Hepper, is a common plant that produces 20% of the world's pulses (Saravanakumar *et al.*, 2007). Blackgram is grown on 761.3 thousand hectares of land in India, yielding 678.6 thousand tonnes of output and 891.0 kg ha-1 of productivity.However, a number of environmental stressors, including drought, which lowers yield, have a negative impact on blackgram production (Pandey *et al.*, 2014). Globally, one of the biggest risks to productive agricultural production is soil moisture stress.

Globally, abiotic stressors, particularly drought, significantly reduce crop yields (Vinocur and Atman 2005). It is the main obstacle preventing crops from finishing their life cycle, particularly in light of climate change. The past few decades have seen an increase in the frequency of dry spells during various agricultural growth phases.Plants undergo a variety of morpho-physiological and biochemical reactions in response to drought stress in order to adapt. Stress has varying effects depending on the crop's phenophases, duration, and intensity. The primary criterion in the majority of research evaluating germplasm for drought resistance is seed yield. However, for an effective breeding program identifying characters promoting drought tolerance is as vital. A moderate loss of water is regarded as drought stress,as it causes stomatal closure and restricts gas exchange. It disrupts the ultrastructure of subcellular organelles and the cell membrane, changing the physiological and biochemical processes (Yordanov *et al.,* 2003). It also disturbs the turgor pressure in cells. It hinders the growth of root cells, reduces nutrient intake, and interferes with photosynthesis, all of which have an impact on plant growth and development (Dhole and Reddy, 2010). Poor grain yield is the result of drought stress's effects on morphological, physiological, and biochemical traits (Baroowa and Gogoi 2012, 2013; Baroowa *et al.,* 2016; Maheswari *et al.,* 2016). Increased severity and duration of drought stress result in a greater loss of chlorophyll content (Kiani *et al.,* 2008). Due to a decrease of cell turgidity, drought stress alters turgor pressure and impacts cell expansion, which hinders plant growth (Mondal *et al.,* 2012). Additionally, it affects the photosynthetic apparatus and reduces the rate of photosynthesis (Manivannan *et al.,* 2007).

II. MATERIALS AND METHODS

Ten blackgram accessions collected from NBPGR regional centre and T-9 (Check) from ICAR-CRIDA, Hyderabad were used for the drought stress study. The experiment was conducted in experimental farm, Department of Genetics, Osmania University Hyderabad during Rabi,2021. The seeds of selected ten genotypes were sown in pots in three replication of two sets, one for control (irrigated) and the other for drought stress study. Both sets were irrigated regularly till flowering stage i.e.; up to 24 days. From next day to induce drought stress in genotypes, water supply will be stopped in one set where as other set (control set) will be watered regularly.Observations were recorded on 33rd day i.e.; after 9 days of inducing drought stress and morphological data was recorded in both irrigated and drought plants .

Estimation of Relative Water Content (RWC)

Fresh leaves were taken and data will be recorded for FW-Fresh leaves weight, DW-Dry Leaves weight, TW-Turgid leaves weight.

The RWC was determined by the equation:

$$RWC\ (\%) = \frac{(FW - DW)}{TW-DW} \times 100$$

FW- Fresh leaves weight

DW- Dry Leaves weight

TW- Turgid leaves weight

Estimation of Proline

Proline accumulation levels in leaf samples will be determined based on “Ninhydrin Reagent” method (Bates et al.1973).

Estimation of MDA:

The malondialdehyde (MDA) content was determined by the thiobarbituric acid (TBA). 3g of leaf sample was collected and ground in a mortar and pestle with liquid nitrogen.The optical density was measured at 532 and 600nm and the concentration of MDA-TBA concentration was calculated.The MDA content was calculated based on the following equation: $6.45 \times (OD532 - OD600) - 0.559 \times OD450$.

SPAD meter

The SPAD meter measures the difference between the transmittance of a red (650 nm) and an infrared (940 nm) light through the leaf, generating a three-digit SPAD value(Uddling et al., 2007. The SPAD- 502Plus measures the absorbance of the leaf in the red and near-infrared regions. Using these two absorbance the meter calculates a numerical SPAD value which is proportional to the amount of chlorophyll present in the leaf.

Canopy temperature

Canopy temperature is often used to indicate vegetative water status and is used in models for estimating transpiration rates and sensible heat transport from vegetation.Canopy temperature is measured remotely by the infrared thermometer (IRT) Normal value of temperature is 70-95°C

Results and discussion:

The analysis of variance (ANOVA) results revealed that for treatments all the yield and yield contributing traits were showed significant variability except pods per plant. All the yield and physiological parameters were significant for genotype x treatment (Table 1). Similar significant variability for the traits was observed under drought condition by Gurumurthy *et al.,* 2019 and Anitha *et al.,* 2015 in blackgram.For physiological parameters it was observed that significant variability were found for all the physiological and biochemical parameters due to treatment and treatment vs genotypes except pods per plant due to treatment.Similar significant variability for the traits was observed under drought condition by Gurumurthy *et al.,* 2019 and Anitha *et al.,* 2015 in blackgram.

Table 1: Analysis of variance for quantitative characters in blackgram under irrigated and drought stress conditions

Source of Variation	DF	MSSQ									
		Characters									
		Pl.ht(cm)	Br./pl	No.of L./pl	Cl./pl	Pods/pl	P. wt/pl(g)	No.of S./pl	S.Y.(g/pl)	100 S. wt	H. wt(g)
Replications	2	1.898	1.488	0.197	6.788	0.545	3.519	406.47	0.446	0.09	0.008
Treatments	1	184.034**	63.641**	29.333**	49.227**	0.136NS	127.769**	90058.242**	717.421**	6.231**	39.301**
Genotypes	10	46.574**	3.754**	15.479**	29.212**	181.882**	25.564**	9572.542**	22.195**	0.645**	11.501**
Treatments *vs* Genotypes	10	7.193**	3.442**	42.533**	22.727**	53.603**	8.805**	681.742*	4.921**	0.324*	1.564**
Error		1.6	0.753	1.483	1.677	11.625	1.587	297.660	1.071	0.143	0.209
SD		0.311	0.214	0.300	0.319	0.839	0.31	4.247	0.255	0.093	0.112
CV%		6.5	14.94	9.68	13.29	8.9	8.88	13.06	15.87	10.82	10.2

***Significant at 0.05% and ** at 0.01 % level, respectively**

DF-Degree of Freedom; Pl.ht(cm)- Plant height (cm); Br/pl-Branches per plant; LN/pl-Leaves number per plant; CL/pl-Clusters per plant; PD/pl-Pods per plant; PDW-Pod weight; SDN-Seed number per plant; SDW-Seed yield; 100SDW-100 seed weight; HSW-Husk weight.

Table 2: Analysis of variance for physiological and biochemical parameters in blackgram under irrigated and drought stress conditions

Source of Variation	DF	MSSQ				
		Characters				
		RWC(%)	SPAD	C. Temp	MDA	Proline
Replications	2	3.848	3.3	0.776	0.056	7.378
Treatments	1	567.307**	8.903*	4.41	126.105**	3439.752**
Genotypes	10	103.122**	8.183**	12.963	29.274**	227.949**
Treatments *vs* Genotypes	10	11.141**	2.403	8.569	4.462**	107.153**
Error		2.404	1.857	2.219	0.246	5.5
SD		0.382	0.335	0.367	0.122	0.577
CV%		2.03	3.96	4.25	3.2	7.26

***Significant at 0.05% and ** at 0.01 % level, respectively**

RWC- Relative water content; SPAD-Chlorophyll content; C.Temp-Canopy temperature (°C); MDA-Malondialdehyde(µM/g fresh Wt)

The mean value of plant height recorded highest by IC426766 (30.33cm) under Irrigated condition whereas the variety IC261182 (22.33) recorded highest plant under Drought condition. Whereas under Drought condition the plant height was ranged from IC261182 (22.33cm) to IC436628 (14.22cm). Number of branches per plant ranged from T-9 (9.00) to IC476753 (4.33) under Irrigated condition. Whereas under Drought condition number of branches ranged from IC436524 (5.67) to IC476784 (3.50). In Drought condition highest number of branches per plant was observed by IC436524 (5.67), IC426766 (5.67) and lowest branches per plant was recorded by IC476784 (3.50) drought stress condition. The number of leaves per plant highest was observed in IC426766 (18.00) under Irrigated condition. Whereas highest plant was observed by IC436628 (15.33) under Drought condition. The character number of clusters per plant ranged from IC382811 (12.67) to IC519620 (10.00) under irrigated condition. Where as in drought condition recorded from IC426766 (14.67) to IC519620 (4.00). The mean value of pods per plant highest was observed under irrigated condition by IC261182 (45.00). Whereas under drought condition it was observed in IC426766 (52.00). The character pod weight per plant was observed highest under irrigated condition by IC426766 (17.33g) and lowest by IC546472 (10.00g). Whereas highest was observed under Drought condition IC261182 (16.69g) and lowest by T-9 (11.29g). The mean value of number of seeds per plant highest seeds are observed in plant by IC426766 (243.33) and lowest by IC436628 (136.33) under irrigation condition. Whereas in Drought condition highest seeds by IC426766 (229.00) and lowest by IC436628 (57.67). The character hundred seeds was observed highest by IC261182 (4.23g) lowest was observed by T-9 (3.25g) under irrigated condition. Whereas drought condition heights was observed as IC426766 (3.61g) the lowest was observed T-9 (2.64g).The character of husk weight per plant range from IC382811 (7.24g/pl) to IC519620 (4.16g/pl) under irrigated condition where as in drought condition highest husk weight (g/pl) was observed range from IC426766 (7.62) to IC436524 (2.56) (Table 4). Prior research on legumes also revealed similar results (Bhatt and Srinivasa Rao 2005; Baroowa and Gogoi 2012). Reduced leaf count is the outcome of defoliation and the cessation of new leaf production brought on by drought stress (Mwale et al. 2007). The character seed yield was observed under irrigated condition highest by IC436524 as 14.33g/pl and lowest by T-9 (4.67g/pl). Whereas highest seed yield was observed under drought condition by IC426766 recorded as 7.49g/pl and lowest seed yield was observed in IC436628 (2.27g/pl).It was also observed that the genotype IC426766 28.84% over its control and 37.65% over T-9 under drought condition (Table 5).Gurumurthy *et al.*,2019 reported that similar increased seed yield and yield contributing traits over control under drought stress condition in blackgram.

Table 3. Mean performance of quantitative traits and physiological parameters in blackgram genotypes under irrigated condition.

Genotypes	Pl.ht(cm)	Br./pl	No.of L./pl	Cl./pl	Pods/pl	P. wt/pl(g)	No.of S./pl	S.Y.(g/pl)	100 S. wt	H. wt(g)
IC261182	23.13	7.67	16.67	11.00	45.00	16.67	241.67	10.67	4.23	7.02
IC436524	18.67	7.00	16.00	10.00	39.00	13.67	146.00	14.33	4.22	5.77
IC476753	20.67	4.33	8.67	10.67	32.00	11.33	143.00	4.67	3.41	4.81
IC382811	19.33	7.33	17.00	12.67	35.67	17.00	242.33	5.67	3.36	7.24
IC436628	17.83	4.67	8.33	10.33	36.67	10.67	136.33	4.67	3.72	4.60
IC476784	20.67	7.67	10.00	10.33	35.33	11.33	138.67	5.00	3.62	4.18
IC426766	30.33	7.67	18.00	10.33	39.56	17.33	243.33	5.33	3.50	6.95
IC546452	19.00	6.33	8.33	10.00	31.00	10.67	146.00	5.67	3.42	4.32
IC546472	19.00	7.00	9.00	11.00	35.67	10.00	141.00	5.67	3.26	4.33
IC519620	20.83	6.00	8.67	10.00	33.67	10.67	139.67	4.67	3.78	4.16
T-9	20.52	9.00	10.00	10.33	39.33	11.33	141.00	4.67	3.25	4.37
Mean	***20.91***	***6.79***	***11.88***	***10.61***	***36.63***	***12.79***	***169.00***	***6.45***	***3.61***	***5.25***
Sd	***3.44***	***1.38***	***4.06***	***0.77***	***3.96***	***2.86***	***47.26***	***3.13***	***0.35***	***1.25***

Pl.ht(cm)- Plant height (cm); Br/pl-Branches per plant; LN/pl-Leaves number per plant; CL/pl-Clusters per plant; PD/pl-Pods per plant; PDW-Pod weight; SDN-Seed number per plant; SDW-Seed yield; 100SDW-100 seed weight; HSW-Husk weight.

Table 4. Mean performance of quantitative traits and physiological parameters in blackgram genotypes underdrought stress condition.

Genotypes	Pl.ht(cm)	Br./pl	No.of L./pl	Cl./pl	Pods/pl	P. wt/pl(g)	No.of S./pl	S.Y.(g/pl)	100 S. wt	H. wt(g)
IC261182	22.33	5.40	14.33	14.00	45.00	16.69	129.33	4.44	3.43	5.76
IC436524	18.26	5.67	9.33	13.00	35.33	13.49	95.00	3.08	3.25	2.56
IC476753	14.31	4.50	14.67	4.33	36.67	12.43	65.00	2.39	3.67	2.57
IC382811	21.51	5.00	12.33	13.33	43.67	15.71	123.33	3.08	3.55	4.74
IC436628	14.22	4.50	15.33	8.67	34.33	13.49	57.67	2.27	3.93	2.82

IC476784	14.57	3.50	14.00	6.33	32.33	14.61	70.67	2.56	3.62	2.65
IC426766	22.15	5.67	11.33	14.67	52.00	16.54	229.00	7.49	3.93	7.62
IC546452	16.47	4.00	13.00	7.00	33.00	13.37	75.67	2.89	3.83	2.59
IC546472	17.27	4.50	14.00	5.33	37.67	13.24	66.33	2.59	3.91	2.62
IC519620	15.48	5.00	14.33	4.00	39.33	13.49	79.00	2.36	2.99	3.44
T-9	19.09	4.50	13.00	7.00	32.67	11.29	88.00	2.33	2.64	3.49
Mean	***17.79***	***4.75***	***13.24***	***8.88***	***38.36***	***14.03***	***98.09***	***3.23***	***3.52***	***3.71***
Sd	**3.13**	**0.68**	**1.73**	**4.09**	**6.21**	**1.69**	**49.21**	**1.54**	**0.42**	**1.66**

Pl.ht(cm)- Plant height (cm); Br/pl-Branches per plant; LN/pl-Leaves number per plant; CL/pl-Clusters per plant; PD/pl-Pods per plant; PDW-Pod weight; SDN-Seed number per plant; SDW-Seed yield; 100SDW-100 seed weight; HSW-Husk weight.

Table 5.% increase/decrease of seed yield (g/pl) over respective controls and over T-9 (check) under drought stress condition in blackgram genotypes

	Irrigation	**Drought**	**% increase/decrease**	
Genotypes	**SDW.(g/pl)**	**SDW(g/pl)**	**over control**	**over T-9**
IC261182	10.67	4.44	-140.32	-5.18
IC436524	14.33	3.08	-365.26	-51.62
IC476753	4.67	2.39	-95.40	-95.40
IC382811	5.67	3.08	-84.09	-51.62
IC436628	4.67	2.27	-105.73	-105.73
IC476784	5.00	2.56	-95.31	-82.42
IC426766	5.33	7.49	28.84	37.65
IC546452	5.67	2.89	-96.19	-61.59
IC546472	5.67	2.59	-118.92	-80.31
IC519620	4.67	2.36	-97.88	-97.88
T-9	4.67	2.33	-100.43	-100.43

Biochemical parameters:

Proline:

The proline content observed highest in IC426766 (64.5mg/g weight) fallowed by IC261182(48.3mg/g), IC519620 (41.5mg/g), IC476784 (40.6mg/g), T-9(40.3mg/g), IC436524 (38.2mg/g), IC382811(35.7mg/g), IC546452 (32.4mg/g), IC476753 (31.5mg/g), IC436628 (31.1mg/g) and IC546472 (30.7mg/g) respectively under drought condition. Under irrigated condition the proline content was observed highest in IC476784 (31.2mg/g) Followed by IC426766 (30.1mg/g), IC436524 (28.0mg/g), T-9(27.1mg/g), IC382811 (26.4mg/g), IC546452 (24.7mg/g), IC261182 (23.9mg/g), IC476753 (22.5mg/g), IC436628 (21.7mg/g), IC519620 (21.1mg/g) and IC546472 (20.2mg/g) respectively (Table 6).

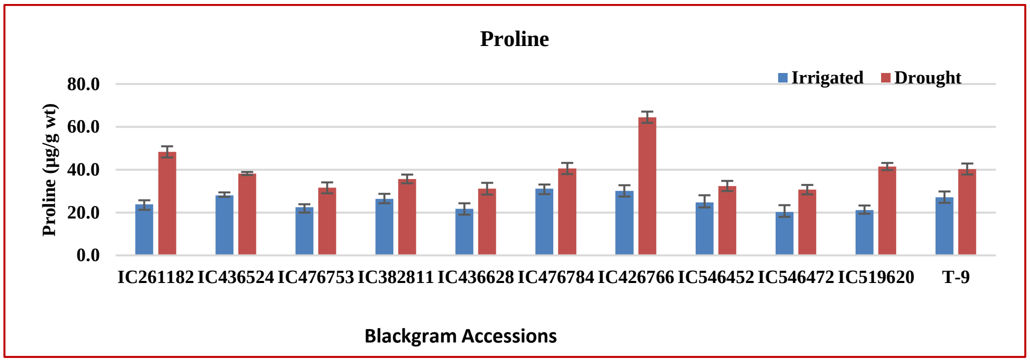

Fig.1 Graphical representation of Proline (%) in selected blackgrm genotypes under irrigated and drought stress condition

Membrane Lipid peroxidation (MDA):

The lipid peroxidation were measured by measuring matoxidaildehyde in our study. It was observed that IC426766 recorded Lowest (12.0µM/g fresh weight) MDA followed by IC261182 (12.9µM/g), IC519620 (15.4µM/g), T-9(16.0µM/g), IC476753 (16.6µM/g), IC436524 (17.0µM/g), IC546452 (18.4µM/g), IC476784 (18.8µM/g), IC546472 (19.3µM/g), IC382811 (19.4µM/g) and IC436628 (20.1µM/g) respectively under Drought condition. The MDA results showed that under irrigated condition the genotype IC426766 registered lowest by 11.6µM/g followed by IC261182(11.7µM/g), IC476753 (11.9µM/g), IC546472 (13.0µM/g), T-9(13.1µM/g), IC519620 (14.1µM/g), IC436524 (14.9µM/g), IC476784 (15.7µM/g), IC43662816.1µM/g), IC546452 (16.4µM/g) and IC382811 (17.1µM/g) respectively (Table 6). Under drought stress, MDA recorded lower in most of the pulse crops(Gurumurthy et al., 2019; Jain et al. 2001; Katsuhara et al. 2005). Free radical production and minimal membrane damage may be the cause of the tolerant plants' low MDA concentration.

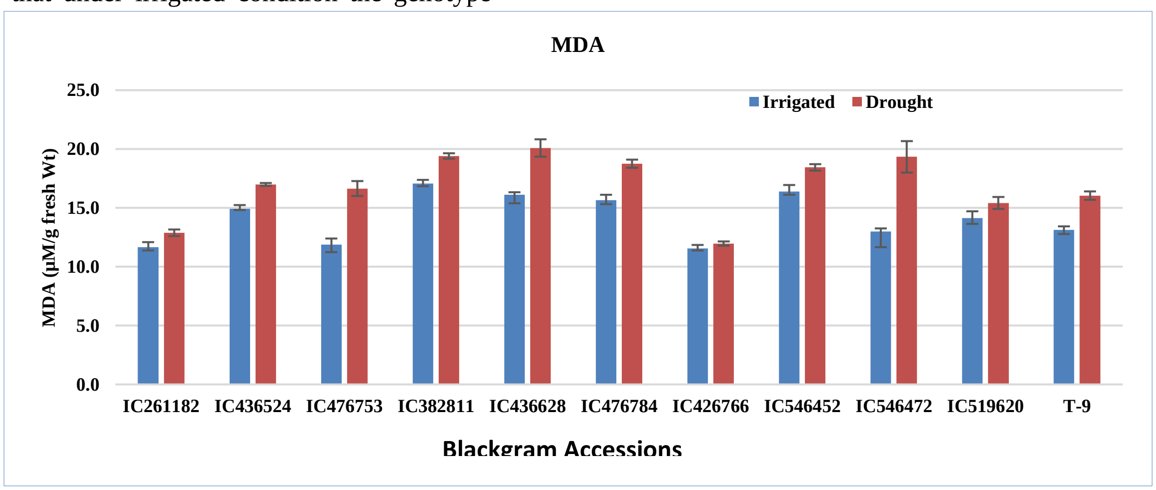

Fig.2 Graphical representation of MDA (%) in selected blackgrm genotypes under irrigated and drought stress condition

Physiological Parameters:

The results showed that relative water content (RWC %) observed highest for the variety IC426766 (87.08%) under irrigated condition whereas the same genotype showed highest (RWC %) (83.42%) under Drought condition .The genotype IC261182 Registered 83.22 followed by IC519620 (81.99%), IC436524 (79.90%), IC436628 (78.82%), IC476753 (77.56%), IC476784 (77.54%), IC546472 (77.42%), T-9(76.78%), IC382811 (76.13%) and IC546452 (75.51%) respectively under irrigated condition. Under drought condition fallowed by IC426766 (83.42%), IC261182 (79.09%), IC519620 (77.82%), IC436524 (75.54%), IC382811 (72.565), T-9 (72.31%), IC476753 (71.23%), IC476784 (70.51%), IC546452 (70.32%), IC546472 (67.79%) and IC436628 (66.82%) respectively (Table 6).

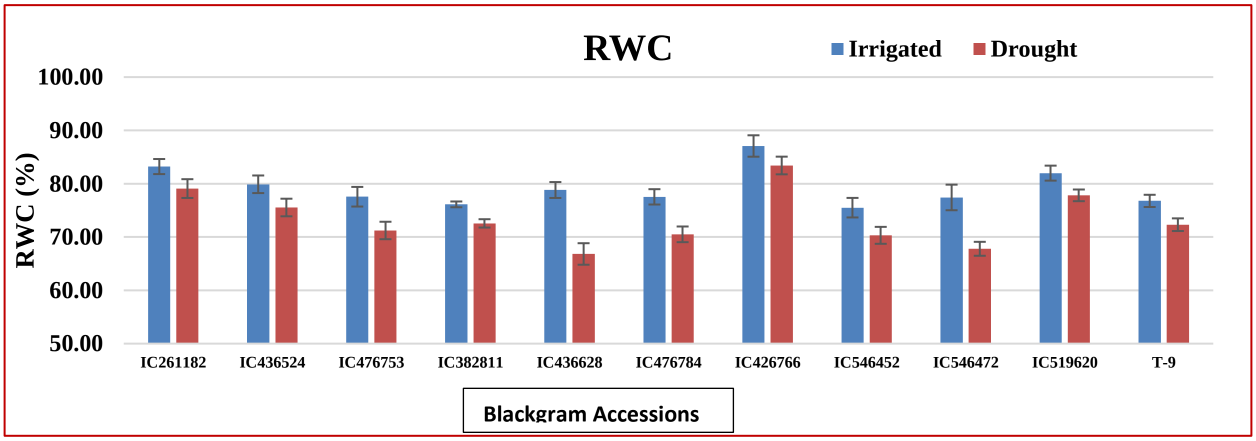

Fig.3 Graphical representation of RWC in selected blackgram genotypes under irrigated and drought stress condition

SPAD readings:

SPAD was observed under irrigation condition range from IC261182 (37.17) to IC476784 (33.15). Whereas under drought condition range from IC261182 (36.12) to IC436628 (32.45).Under irrigation condition varieties were observed followed by IC261182 (37.17), IC436524 (34.75), IC436628 (34.75), IC519620 (34.36), IC546452 (34.34), IC382811 (34.34), T-9 (34.32), IC546472 (33.99), IC426766 (33.78), IC476753 (33.68) and IC476784 (33.15) respectively. Under drought condition varieties were observed followed by IC261182 (36.12), IC426766 (36.00), IC476784 (35.34), IC382811 (35.00), IC546472 (34.40), IC519620 (34.34), IC546452 (33.68), T-9 (33.01), IC436524 (32.45), IC476753 (32.45) and IC436628 (32.45) respectively (Table 6).Similar higher SPAD readings were recorded under drought condition by Anitha *et al.*, 2015 in blackgram.

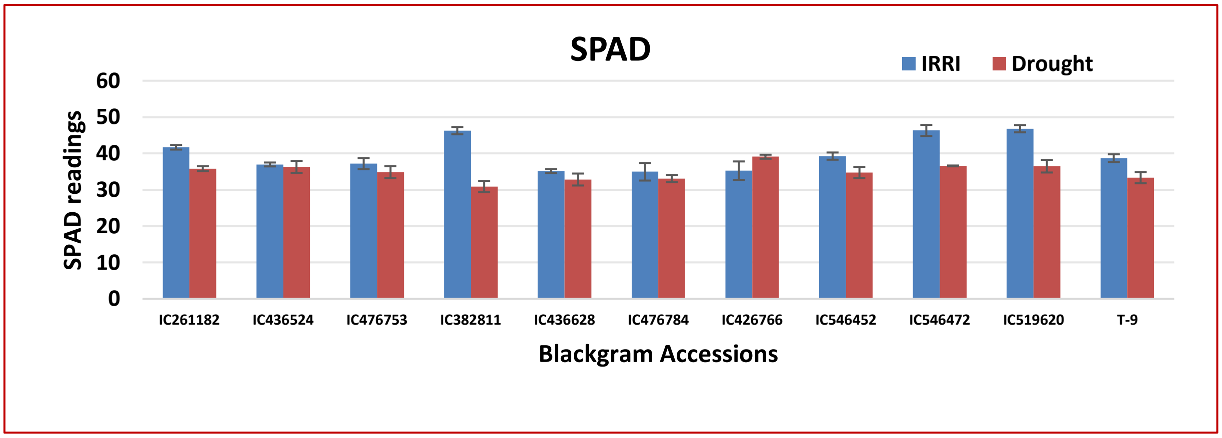

Fig.4 Graphical representation of physiological parameter (SPAD readings) under irrigated and drought stress condition in blackgram accessions

Canopy Temperature:

Canopy temperature was observed highest from lowest followed by IC261182 (37.90), IC546472 (35.34), T-9 (35.09), IC476784 (34.68), IC519620 (34.67), IC476753 (34.42), IC426766 (34.08), IC436628 (34.04), IC382811 (33.42), IC546452 (32.32) and IC436524 (31.81) respectively under irrigation condition.Whereas under drought condition varieties were observed highest range to lowest followed by IC519620 (42.23), IC476753 (41.34), IC436628 (41.33), IC546452 (41.12), T-9(40.33), IC476784 (40.13), IC436524 (40.03), IC546472 (39.98), IC426766 (38.67), IC261182 (37.17) and IC382811 (37.04) respectively (Table 6). Similar lower canopy temperature was recorded under drought condition by Anitha *et al.*, 2015 in blackgram.

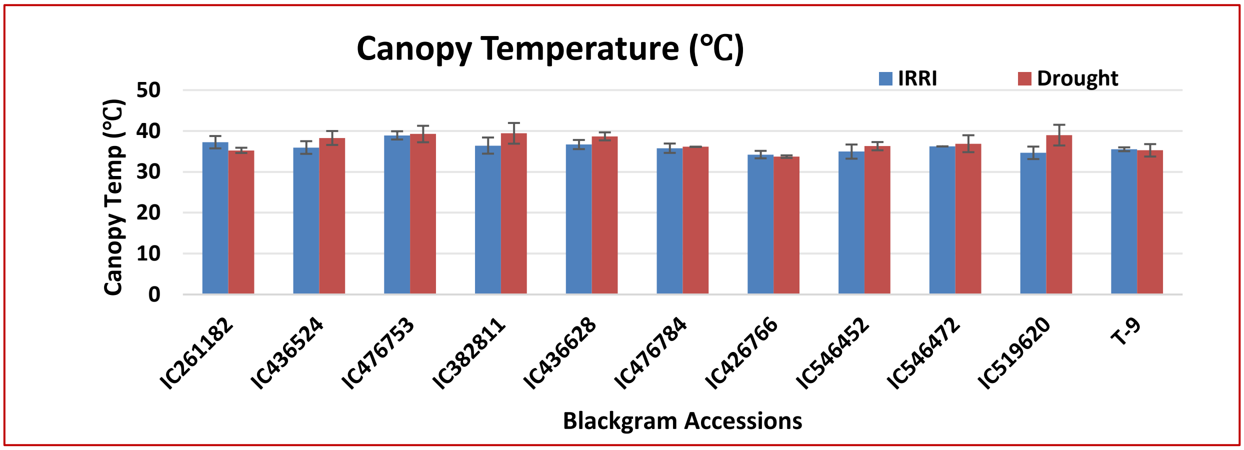

Fig.5 Graphical representation of Physiological parameter (Canopy temp℃.) under irrigated and drought stress condition in blackgram accessions

Table 6. Mean performance of physiological and biochemical parameters in blackgram genotypes under irrigated and drought condition.

	RWC (%)		**SPAD**		**C. Temp(℃)**		**Proline.(µg/g wt)**		**MDA(µM/g fresh Wt)**	
Genotypes	**Irr**	**Drought**	**Irr**	**Drought**	**Irr**	**Drought**	**Irr**	**Drought**	**Irr**	**Drought**
IC261182	83.22	79.09	37.17	36.12	37.90	37.17	23.9	48.3	11.7	12.9
IC436524	79.90	75.54	34.75	32.45	31.81	40.03	28.0	38.2	14.9	17.0
IC476753	77.56	71.23	33.68	32.45	34.42	41.34	22.5	31.5	11.9	16.6
IC382811	76.13	72.56	34.34	35.00	33.42	37.04	26.4	35.7	17.1	19.4
IC436628	78.82	66.82	34.75	32.45	34.04	41.33	21.7	31.1	16.1	20.1
IC476784	77.54	70.51	33.15	35.34	34.68	40.13	31.2	40.6	15.7	18.8
IC426766	87.08	83.42	33.78	36.00	34.08	38.67	30.1	64.5	11.6	12.0
IC546452	75.51	70.32	34.34	33.68	32.32	41.12	24.7	32.4	16.4	18.4
IC546472	77.42	67.79	33.99	34.40	35.34	39.98	20.2	30.7	13.0	19.3
IC519620	81.99	77.82	34.36	34.34	34.67	42.23	21.1	41.5	14.1	15.4
T-9	76.78	72.31	34.32	33.01	35.09	40.33	27.1	40.3	13.1	16.0
Mean	***79.267***	***73.401***	***34.421***	***34.113***	***34.343***	***39.943***	***25.172***	***39.521***	***14.142***	***16.907***
Sd	***3.522***	***5.060***	***1.028***	***1.404***	***1.611***	***1.686***	***3.687***	***9.928***	***2.020***	***2.677***

RWC- Relative water content; SPAD-Chlorophyll content; C.Temp-Canopy temperature (℃); MDA-Malondialdehyde(µM/g fresh Wt)

III. CONCLUSION

It is well known that sufficient water is necessary for crops to thrive and produce as much as possible. Nonetheless, crops are frequently subjected to drought stress at various phenological stages. Productivity of crops under water stress may be decreased as a result of modifications to the physiological and biochemical processes occurring at the molecular and cellular levels of plants because they employ it as a stress-reduction strategy. It was concluded that the genotype IC426766 28.84% over its control and 37.65% over T-9 under drought condition. The genotype IC426766 also showed higher proline content, RWC, lower MDA, higher SPAD reading and lower canopy temperature under drought condition. Among ten blackgram accession IC 426766 was identified as drought tolerant/resistance based on morphological, physiological and biochemical parameters.

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A Retrospect on Special Horticultural Practices in Fruit Crops

R. D. Aghav[1], P. M. Haldankar[2] and A. P. Samant[3]

[1]Ph.D Scholar, Department of Agriculture, Sunrise University Alwar, Rajasthan, India.
E-mail: rushiaghav@gmail.com
[2]The Director of Extension Education, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India.
[3]Ph.D Scholar, Department of fruit Science, College of Horticulture Dapoli, Maharashtra, India.

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Abstract*— *In fruit crops there are many practices and technologies to improve the quality of fruits. The pruning, girdling or ringing, smudging, thinning and bending are practices to affect the carbon nitrogen ratio in fruit crops. C:N ratio control by these practices. C:N ratio may change through these practices and improves the fruit quality and yield. In this review article we tried to discuss all these special horticultural practices which used to improve fruit quality, production, and plant vigour which leads to higher yield of crops.

***Keywords*— Pruning, Girdling, Bagging and Notching**

INTRODUCTION

Special horticultural practices play key role in increasing production and quality of fruits. the major element is carbon and nitrogen which leads to play role in flowering. Girdling is the removal of the bark in circular manner of either branch or trunk of woody plants. Girdling stops the basipetal movement of assimilates through phloem which results in accumulation of carbohydrates above girdle which ultimately helps for induction of early and assured flowering. Urban *et al*. reported that girdling is one of the ways to improve the earliness and intensity of flowering in mango. Thinning helps to getting the good size and shape of fruit tree. Pruning or tip pruning is well known practice which helps to maintain the balance between carbon and nitrogen by removing the top shoots of the plants. In this practice we remove the auxin which helps to early flowering in the plant. (Aghav *et. al,* 2023). Smudging is an ancient method of inducing mango to flower. It is practiced in certain parts of the Philippines to obtain early flowering of 'Carabao' and 'Pico' mango. Ethylene has been identified as the active agent responsible for flowering during smudging (Dutcher, 1972). Bending of shoots improves the carbohydrate level in bended portion which leads to give more flowering and fruiting. The late flowering leads to delayed fruit development and harvesting. The late harvested fruits fetch low market rates. It is often noticed that many of these new shoots do not produce flowers and hence the flowering is sparse which produce poor yield (Soudagar *et al*., 2018). Treatment T_5 (girdling on the first fortnight of November and tip pruning) was best for the highest hermaphrodite flowers, maximum fruit set, and retention and also contributed to the highest yield with greater appreciation with respect to rate in the market (Aghav *et al*., 2023)

Bending:

This is well known practice which is generally followed in guava and flower like rose. It may define as reduction in shoot growth and to enhance flowering and fruiting of plants. Bending frequently increases the polyphenol oxidase, tryptophane, lipid, catalase, proline and levels of peroxidase in bark, fruit and leaves, but decreased phenolics (Eassa *et al*., 2012). Mamun *et al*., 2012 found that significant variation have been seen as bending is used in guava to encourage off-season flowering. Bending encourages more fruiting and flowering, as well as get more returns and helps to regulate flowering by shoot bending (Mitra *et al*., 2008).

Pruning:

In tropical fruit crops like mango, pruning is inescapable necessity to control the canopy size and to produce high quality fruits by facilitating good ventilation, more penetration of sunlight, simple application of plant protection chemicals and early in harvesting (Burondkar *et al*. (1997). The higher percentage of flowering due to pruning treatments was mainly attributed due to the availability of photosynthetic solar radiation to the leaves which enhanced flowering (Lal and Mishra, 2007). Shoot pruning reduces the auxin synthesis at the apex of the branches, directing the transport of assimilates and cytokinin's to the axillary buds of branches, creating favourable condition for flowering (Taiz and Zeiger, 2012). The trial concluded that special horticultural practices *viz*., girdling, removal of new shoots (tip pruning), and smudging in mango cv. Ratna was beneficial for the early induction of flowering and early harvesting. Among all treatments, T_7 (removal of new shoots) was best for early induction of flowering and early harvesting. (Aghav *et al*., 2023).

Girdling:

Girdling is the removal of the bark in the circular manner of either branch or trunk of woody plants. Girdling stops the basipetal movement of assimilates through phloem which results in the accumulation of carbohydrates above the girdle portion which ultimately helps for induction of early and assured flowering. The girdling is one of the ways to improve the earliness and intensity of flowering in mango (Urban *et al*., 2009). Shinde *et al*. (2015) noticed the highest number of fruits per plant in T_1 (ringing during the first fortnight of May) in cv. Alphonso. Ibrahim *et al*. (2016) observed that girdling branches and limbs significantly affected the initial number of fruitlets per branch and fruit set percentage in Washington Navel Orange. Warang *et. al*. (2019) recorded maximum fruit set (8.95 %) and maximum fruit retention (0.83 %) in girdling on first fortnight of the September and first fortnight of October and removal of new shoots in mango cv. Alphonso. Ghadage *et al*. (2017) girdling on 15th July produced significantly maximum yield (94.20 kg/plant) in mango cv. Alphonso.

Bagging:

Bagging prevents insect, pest especially fruit flies, from damaging the fruits. the bags provide physical protection from mechanical injuries (scars and scratches). Stover and Simmonds (1987) reported the use of polythene bags to enhance fruit maturity in banana. Sarker *et al*. (2009) described that the physical quality of bagged fruit was better than un-bagged fruit healthy fruit, which increased their market price. Fruit bagging has helped to reduce bird damage in various fruit (Kitagawa *et al*., 1992).

Earthing Up:

It is important which provides support to the base of the plant and also gives chances for better formation of a better root system. Pineapple is only fruit crop were earthing up is mostly done Farid Hossain (2016) in this review of world pineapple production described that earthing up play better support to pineapple.

Notching:

Notching can be defined as the form of a slanting cut is given a little above the buds, removing a slice of bark. Notching is a simple, ancient trick that stimulates a branch to grow. Notching technique play vital role in enhancing lateral branching.

CONCLUSION

In this overview we concluded that special horticultural practices *viz*., girdling, pruning, smudging, notching, earthing up, bending of shoots and bagging in horticultural crops (especially fruit crops) play important role in quality production and increasing yield of the fruits. This quality fruits fetches more prices in the market and to enhance socio-economic status of farmers.

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Antibiotics in Poultry: Examining Alternatives for Safer Food Production

Ankit Sharma[1*], Anil Kumar[1], Sumit Gangwar[1], Shashikant[2], Gautami Sarma[1], Rishav Kumar[3]

[1]Department of Livestock Production Management, College of Veterinary and Animal Sciences, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India
[2]Department of Animal Genetics & Breeding, College of Veterinary and Animal Sciences, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India
[3] Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya, Mathura, India
*****Corresponding author: ankit29vet@gmail.com

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***Abstract*— *Chicken is the most commonly farmed species with over 90 billion tons of chicken meat produced per year. Many food-producing animals are given antibiotics daily to grow faster and prevent diseases in many parts of the world. When antibiotics are used for the purposes of growth promotion a small amount is often administered as compared to therapeutic use. Therefore, this may cause bacteria to develop antibiotic resistance (World Health Organization, 2017). There are several challeneges related to antibiotic free bird production. Several alternatives to antibiotics, including probiotics, prebiotics, competitive exclusion, enzymes, and organic acids, have shown promise in replacing antibiotics. The use of prebiotics aids in preventing the colonization of the digestive system by harmful pathogens, achieved by creating an unfavorable environment through pH alterations in the intestinal content. Probiotics, which are live strains of strictly selected microorganisms have beneficial effects on health. The incorporation of enzymes in poultry diets offers several advantages, including reduced digesta viscosity, improved digestion and nutrient absorption, increased feed intake, and enhanced weight gain. Maximizing performance and sustaining poultry productivity will rely on employing well-balanced combinations of diverse alternatives alongside effective management practices. This approach remains essential for accomplishing our ultimate goal of reducing antibiotic usage.*

***Keywords*— Chicken farming, antibiotic resistance, alternatives to antibiotics, probiotics and prebiotics, poultry productivity.**

I. INTRODUCTION

Poultry is among the major widespread food industries worldwide. Chicken is the most commonly farmed species with over 90 billion tons of chicken meat produced per year [1]. Antibiotics are mostly used for treatment, prophylaxis and growth promotion in poultry. Many food-producing animals are given antibiotics daily to grow faster and prevent diseases in many parts of the world [2]. This trend is likely to continue to meet the growing demand for the protein of animal origin. When antibiotics are used for the purposes of growth promotion a small amount is often administered as compared to therapeutic use. Therefore, this may cause bacteria to develop antibiotic resistance [3]. The emergence and spread of antibiotic resistance compromise the nutritional and economic potential of poultry and other food-producing animals. This is a global concern that affects both animal and human ecosystems. The European Union (EU) banned antibiotic use in animal production in 2006 [4]. Scientific proof suggests that the extensive use of antibiotics has led to increase of antibiotic resistance [5-7] and presence of antibiotics residues in feed and environment [8-9], compromises human and animal health [10]. Hence, there is an increasing need to find effective alternatives to control infectious diseases and control the spread of resistant bacteria, but more importantly keep antibiotics a useful tool for the future.

II. USE OF ANTIBIOTICS IN BROILER CHICKEN PRODUCTION

Over the past 50 years, the use of antibiotics along with strict biosecurity and hygiene measures has helped the poultry industry to grow by preventing the negative impacts of many avian diseases [11]. Even as biosecurity may be sufficient, vaccination can also be used as an additional measure. A vaccine provides assistance to the immune system by preparing it against certain pathogens such as viruses or bacteria to which it may be exposed in the future. Vaccination protocols and the type of vaccine used vary from country to country and from farm to farm. Many factors can influence the choice of vaccination method such as species, place, number of manpower, type of production, and production cycle. The choice of vaccination method also depends on general health status of poultry, maternal immunity, and vaccine costs. Livestock vaccination against specific diseases is compulsory (e.g., Newcastle disease) in many countries (Belgium, Netherlands, Germany), while in other such as France only long-lived poultry (laying and breeding) are vaccinated [12].

III. ANTIBIOTIC-FREE POULTRY PRODUCTION:

There is little convincing scientific evidence that antibiotic use in food-producing animals contributes to antibiotic resistance challenges in human medicine [13-15]. However, consumer perception in first-world countries implies that this is accurate. Consumer preferences, such as purchasing ABF products, are mostly dependent on perception rather than scientific findings [16]. For example, most people are unaware that all chicken meat is ABF or contains levels below limits considered safe for humans. For decades, regulatory organizations such as the USDA-FSIS have routinely monitored drug residues by sampling and testing tissues to verify that no drug residues (including antibiotics) are discovered to be above the tolerance or maximum residue limit (MRL) specified for each drug**.** The poultry business, in particular, has an excellent track record of adhering to drug withdrawal periods and residual tolerances [17,18]. There are several challenges related to ABF bird production. While several different compounds have distinct physiological, immunological, and/or bacteriostatic actions in the intestine, none (to date) convey the range and extent of the antibiotics' effects [19]. Other researchers have proposed that the unique and highly reproducible effects of in-feed antibiotics may be due to the prevention of immunologic stress [20] or their anti-inflammatory effect [21], rather than their antimicrobial effect, and that this should be taken into account when looking for new compounds to be used as replacements.

IV. IMPORTANT ALTERNATIVES TO ANTIBIOTICS

4.1 Probiotic and Prebiotic

Antibiotics have been known to positively impact poultry performance, but their excessive use as growth promoters poses risks to human health. However, discontinuing antibiotics can negatively affect poultry performance. Some researchers argue that using antibiotics to enhance animal growth and feed efficiency reduces the cost of meat and eggs. Therefore, banning antibiotics could increase the price of animal products. Balancing safety and optimal performance is crucial in addressing this challenging issue. To find viable alternatives, researchers are exploring options such as natural herbs and medicinal plants as substitutes for antibiotics in poultry production [22]. Several alternatives to antibiotics, including probiotics, prebiotics, competitive exclusion, enzymes, and organic acids, have shown promise in replacing antibiotics [23]. Prebiotics, for instance, are potential alternatives for promoting growth in poultry. They are indigestible carbohydrates that selectively stimulate the growth of beneficial bacteria in the colon. The concept of prebiotics was introduced by Gibson and Robertroid (1995) [24], and their effects were noticed in animal feeds as early as the 1980s. Prebiotics can effectively replace antibiotics in the poultry sector due to their ability to support a healthy intestinal microbial population [25]. Moreover, prebiotics offer other advantages such as aiding in the prevention of colon cancer, reducing disease-causing bacteria like Salmonella and E. coli, and positively altering gastrointestinal microbiota [26].

The use of prebiotics aids in preventing the colonization of the digestive system by harmful pathogens, achieved by creating an unfavorable environment through pH alterations in the intestinal content. Within the digestive system, certain beneficial bacteria like *Bifidobacterium* and *Lactobacillus* possess the Manase enzyme. They selectively bind mannan oligosaccharides, which are absent in harmful bacteria lacking this enzyme [27]. Mannan oligosaccharides (MOS) have been observed to increase daily weight gain in broiler chickens by 4–8%

[27, 28]. Studies by Kumprech et al. (1998) [29] have shown that prebiotics offer similar effects to antibiotics without leaving residues or leading to the development of resistance. When chickens are fed MOS, their intestinal villi length increases significantly, though not their width [30]. Probiotics, which are defined as "live strains of strictly selected microorganisms that, when administered in adequate amounts, provide health benefits to the host" [31], are used in poultry feed to promote animal health, stimulate growth, and enhance the host's immunity [32]. Assessing the safety and benefit-to-risk ratio of probiotic strains is a challenging task. These microorganisms are chosen for their beneficial effects on health and must adapt to the specific conditions of the gastrointestinal tract in the targeted animal species [33]. When probiotics are introduced into feeds, they need to adapt to the new environment, including factors like temperature and humidity. In the European Union, the most commonly selected probiotics belong to Gram-positive bacteria, including species like *Bacillus, Enterococcus, Lactobacillus, Pediococcus*, and *Streptococcus.* Probiotics are not limited to bacteria alone; yeast and fungi strains such as *Saccharomyces cerevisiae* and *Kluyveromyces* have also been utilized. Caution is necessary as certain bacteria, like enterococcus, may contribute to the spread of antibiotic resistance, and strains like bacillus cereus have the potential to produce toxins [34].

4.2 Enzyme

Feed additives in the form of enzymes, produced through the fermentation of fungi and bacteria, are utilized to optimize feed conversion in poultry. Commonly employed enzymes like endo-b-1-4-xylanases and b-1-3, 1-4-glucanases are added to wheat and barley diets for broiler chickens, enhancing digestibility [35]. The incorporation of enzymes in poultry diets offers several advantages, including reduced digesta viscosity, improved digestion and nutrient absorption, increased feed intake, and enhanced weight gain [36]. Studies on enzyme supplementation in laying hens conducted by Khan et al. (2011) [37] demonstrated significant improvements in feed conversion ratio, egg production, egg weight, and egg mass. A separate experiment by Mabelebele et al. (2017) [38] which involved xylanase in chicken diets, reported increased crude protein digestibility, feed intake, and weight gain due to the enzyme's addition. Hence, the effects of incorporating enzymes into poultry diets seem to yield mixed results.

4.3 Plant Extracts

Phytobiotics, also known as plant extracts, have emerged as a viable alternative to antibiotics in poultry production due to their antimicrobial, anti-inflammatory, antioxidant, and antiparasitic properties. They have been successfully used in the poultry industry for an extended period [39,40]. One of the main reasons for their success in poultry is attributed to their diverse properties. Plant extracts contain minor metabolites such as terpenoids, phenolics, glycosides, and alkaloids, present in various forms like alcohols, aldehydes, ketones, esters, ethers, and lactones [41]. These metabolites play a crucial role in enhancing the growth performance and health of poultry [40]. However, it is essential to be cautious about the excessive use of these secondary metabolites, as they can potentially negatively affect digestive efficiency [42]. Nevertheless, compared to antibiotics, plant extracts are considered safe and effective in combating certain bacteria [40]. Studies by Rahimi et al. (2011) [43] indicated that poultry diets supplemented with plant extracts led to an increase in feed intake, feed conversion ratio, and body weight gain, along with improved secretion of endogenous digestive enzymes. Conversely, Al-Kassie et al. (2011) [44] reported no adverse effects on productivity and health in broiler chickens when fed plant extracts as a supplement Additionally, herbs like black pepper act as alternative growth promoters without negatively affecting broiler performance [45,46]. Other studies highlighted the ability of cineol and eucalyptol in eucalyptus and garlic extracts to prevent infectious diseases, facilitate proper air circulation, and enhance bird growth by relaxing the air sacs [47,48].

V. CONCLUSION

Foodborne infections pose a significant public health problem in both developed and developing countries. According to WHO, approximately 70% of diarrheal cases are caused due to bacterial contamination in food. Hence, there is need for alternatives to antibiotic use in food animals to manage bacterial infections in both human and veterinary fields. Antibiotics are commonly used in humans and animals for healthier and productive animal production. However, the increased use of antibiotics has led to development of antibiotic-resistant bacteria. The rapid emergence of antimicrobial-resistant bacterial strains is closely linked to the high use of these drugs. Therefore, finding viable alternatives to antibiotics becomes crucial in addressing this concerning issue. Various alternatives such as probiotics, prebiotics, enzymes, plant extracts etc. have the potential to reduce dependence on current antimicrobials. Maximizing performance and sustaining poultry productivity will rely on employing well-balanced combinations of diverse alternatives alongside effective management practices.

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This approach remains essential for accomplishing our ultimate goal of reducing antibiotic usage.

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An Economic Analysis of Organic Farming for Sustainable Agriculture and Facing the Constraints by Organic Farmers of Uttarakhand

Dr. Awadhesh Narayan Shukla[1,*], Dr. Sarju Narain[2] and Dr. Ajay Kumar Tripathi[3]

[1]Assistant Professor, Agricultural Economics, Brahmanand P.G. College Rath, Hamirpur, U.P., India
[2]Associate Professor Agril. Extension, Brahmanand P.G. College, Rath-210431, Hamirpur, U.P., India
[3]Assistant Professor, College of Agriculture, G.B. Pant University of Agriculture & Tech. Pantnagar-263145, Uttarakhand.
*Corresponding author: dr.shuklaan@gmail.com

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***Abstract*— *Introduction: Agriculture is carried out mainly through three types of farming systems namely, natural farming system, inorganic farming system and organic farming system characterized by the different types of inputs and agricultural management practices used for cultivation of land and production of crops. Context: Green revolution brings several changes in agriculture production system via inorganic farming which promotes unsustainable practices for ecosystem and human health. Therefore organic farming practices are more prefer by farmers for obtaining better price. Objectives: In this context it is necessary to find out the economics of major crops grown under Organic Farming System and identify the constraints of production in hilly region of Uttarakhand as compare to Inorganic friendly farmers. Method: A purposive study was conducted in district Tehri - Garhwal and Almora under hill state of Uttarakhand. The result is based on the randomly selected 120 farmers (60 Organic Farming System Farmers and 60 Inorganic Farming System Farmers) interview. The costs of production of different crops have been worked out by using the standard cost concepts with suitable statistics. Results & Discussion: The gross as well as net income or profit of different crops increased significantly by two to three times under organic farming system whereas they remained stagnant and even declined under inorganic farming system over the years. The costs of production of crops per hectare and per quintal under organic farming system are lower than under inorganic farming system. Gross and net incomes or profits are nearly 2 times higher under organic farming systems. Overall organic farming system produces more and sustainable agriculture output with less energy, low cost and fewer resources with many constraints.*

Keywords*— *organic farming, Economic Analysis, Constraints, Sustainable Agriculture.

HIGHLIGHTS

- Organic farming System having less cost of production per hectare and per quintal as compare to Inorganic Farming System. Therefore, gross and net incomes were nearly two times higher under organic farming systems.
- Organic farming system produces safer and sustainable agriculture output with fewer resources utilization.
- Constraints related to scarcity of bio based production inputs and Poor knowledge about Organic certification were the pinpointed by the farmers.

I. INTRODUCTION

Agriculture and food security are the most important concern in 21st century. Agriculture is carried out mainly through three types of farming system namely natural farming system inorganic farming system and organic farming system characterized by the different types of inputs and Agriculture management practices used for cultivation of land and production of crops. The natural farming system is considered as a primitive and extensive farming system giving low production and income. It is found that inorganic farming system over the years burns the soil organic matter and soil microorganisms rendering lifeless and unfertile nature of soil. This had resulted in stagnation and declining in the yield of crops. The chemical inputs used in inorganic farming system are costly and lead to contamination and pollution of natural resources like soil water air and other natural resources of ecosystem and also harm to health of living being including human. As our health is directly connected to the health of the food we eat an ultimately to the health of the soil (Lockie,*et.al*,2006). As such, there is a strong feeling world-over that the solution of this problem and ills of the inorganic farming system now lies in organic farming. According to the FAO, organic agriculture is a system that relies on ecosystem management rather than external agricultural inputs such as synthetic fertilizers and pesticides. India backed by a legacy of organic farming markets and there is an urgent need to promote organic farming in order to increase exports. The increasing demand for organic food products in developed countries and the extensive support for organic farming by the Indian government (Chandrashekhar, 2010) may be seen as the key driver for this development. Attitude is one of the constructs which is very difficult to measure directly. Several psychometric methods of measurement of attitudes have been developed over a period with various advantages and limitations. In the quest to make Ladakh, an organic Union Territory, and several efforts are already in progress. (Huria et al. Indian Res. J. Ext. Edu. 23 (3), July-September, 2023)

According to ministry of Agriculture Government of India the country is divided into three categories in which Uttarakhand State has been placed in first category where the consumption of chemical fertilizers is less than the other states. The state has a large number of certified organic farmers who are supported by the promotion of organic farming as well as with the help of a well developed organization structure for marketing of organic crop products. The total area under organic farming in Uttarakhand is about 16158.86 hectare. The farmers have already made a significant contribution in the field of organic farming and farmer to farmer transfer of technology helps in domestic and export market potential for organic products. Conversion to small organic farms is more profitable and would lead to sizeable increases of food production worldwide. (Satyajeet *et. Al. 2018*). In this regards it is necessary to understand the production economics and constraints of the organic farming system. However, the work done and know edge available on economics of production of organic produce in general and for the produce of hills in particular. In this context it is necessary to find out the following research objectives in the districts Almora and Tehri-Garhwal of Uttarakhand.

1. To study the Comparative economics of major crops grown under Organic Farming System (OFS) *vis-à-vis* Inorganic Farming System (IFS) over the years.
2. To find out the major constraints faced by farmers of the study area.

II. METHODOLOGY

The purposive study was conducted in hill state of Uttarakhand. The data from farmers have been collected from tahsil Chamba of district Tehri - Garhwal and tahsil Almora from district Almora to work out the economics of production of crops and find out the constraints faced by farmers in the study area. Total 120 farmers (60 OFS Farmers and 60 IFS Farmers) for research work were selected from five villages in tehsil Chamba and five villages from tehsil Almora by the random sampling technique with probability proportion to the total households. In the study area maize, wheat, rajmah and pea crops were grown both under organic farming system and inorganic farming system with recommended package of practices.

The data have also been collected, analyzed and presented. The study was carried out for the year during 2018-19, 2019-20 and 2020-21. The costs of production of different crops have been worked out by using the standard cost concepts as follows.

CostA_1: All actual expenses in cash and kind incurred in production by the producer. The items covered in Cost A_1 are:

1. Cost of hired human labor.
2. Cost of hired bullock labor.
3. Cost of owned bullock labor.
4. Cost of hired machine power
5. Cost of home produced /purchased seed
6. Cost of plant protection chemicals
7. Cost of home produced /purchased manure.
8. Cost of fertilizer.
9. Depreciation on farm machinery, equipments and building.
10. Cost of irrigation.

11. Land revenue, land development tax and other taxes.
12. Interest on working capital
13. Miscellaneous expenses

Cost A_2: Cost A_1+ rent paid for leased in land

Cost B_1: Cost A_1+ interest on the value of owned capital assets (excluding land)

Cost B_2: Cost B_1+ imputed rental value of owned land (Net of land revenue) and rent paid for leased in land.

Cost C_1: Cost B_1+Imputed value of family labor.

Cost C_2: Cost B_2+ Imputed value of family labor.

Cost C_2*: Cost C_2 worked out at actual wage rate or statutory minimum wage rate, whichever is higher.

Cost D: Cost C_2*+ 10 per cent of Cost C_2* (on account of managerial functions performed by farmer. The consumption of cost of production was done on the basis of the input and output prices prevailing in the study area during the period of study.

III. RESULTS

A comparative economics of crops grown under organic farming system vis-à-vis inorganic farming system are presented in table-1. Maize in kharif and wheat in rabi season are the most important crops grown by the farmers in the hills. Maize and wheat cultivation was followed by the cultivation of peas and rajmah as well as intercropping of rajmah and peas, respectively. In addition to these crops; vegetable crops were also grown in the study area. It is found that the yield, total production, income and profit of crops increased under organic farming system over the years. The gross as well as net income or profit different crops increased significantly by two to three times under organic farming system whereas they remained stagnant and even declined under inorganic farming system over the years. Furthermore, organic products fetch very high premium prices in the market from the consumers which are often as high as 2 to 3 times more than that of the inorganic produce which makes organic farming a high profitable enterprise.

Table 1: Comparative Economics of crops grown under Organic Farming System (OFS) vis-à-vis Inorganic Farming System (IFS) over the years.

Particulars	**2018-19**		**2019-20**		**2020-21**	
	OFS	**IFS**	**OFS**	**IFS**	**OFS**	**IFS**
Maize						
Cost A_1	8327.85	10284.81	8371.82	10343.09	8657.09	10451
Cost B_1	8827.52	10901.89	8874.12	10963.67	9176.51	11078.06
Cost B_2	11881.52	14069.89	12138.12	14233.67	12546.51	14358.06
Cost C_2	14686.52	16627.89	15045.12	17344.67	15708.51	17622.06
Yield (qt/ha)						
Grains	41.8	39.1	56.4	46.4	58	45.2
Straw	80.3	76.6	109.3	85.5	110	88.7
Price obtained by the farmers Rs./qt.						
Grain	840	480	910	550	950	610
Straw	140	125	150	125	170	135
Gross Income	46354	28343	67719	36207.5	73800	39546.5
Net Income or profit (Rs/ha)	**31667.48**	**11715.11**	**52673.88**	**18862.83**	**58091.49**	**21924.44**
Total Cost/ha	**14686.52**	**16627.89**	**15045.12**	**17344.67**	**15708.51**	**17622.06**
Total Cost/qt	**351.35**	**425.27**	**266.76**	**373.81**	**270.84**	**389.87**
Wheat						
Cost A_1	9995.95	12543.84	11380.08	1776.97	10841.77	12633.62
Cost B_1	10535.7	11176.47	12086.36	12423.6	11432.27	13331.64
Cost B_2	20149.62	21861.33	22540.6	23476.3	25505.79	27596.02

Cost C_2	38495.65	39309.33	40039.33	41120.3	41463.79	42758.02
Yield (qt/ha)						
Grains	44	40	48	45	52	50.00
Straw	85	80	90	81	100	96.00
Price obtained by the farmers Rs/qt.						
Grain	1700	1600	1850	1700	2000	1840.00
Straw	700	700	600	600	750	800.00
Gross Income	134300	120000	142800	125100	179000	168800.00
Net Income or Profit (Rs/ha)	**95804.35**	**80690.67**	**102760.7**	**83979.7**	**137536.2**	**126042.00**
Total Cost/ha	**38495.65**	**39309.33**	**40039.33**	**41120.3**	**41463.79**	**42758.02**
Total Cost/qt	**874.90**	**982.73**	**834.15**	**913.78**	**797.38**	**855.16**
Rajmah						
Cost A_1	9336.44	12226.48	9585.93	12423.37	10243.61	13129.10
Cost B_1	9896.62	12960.06	10161.08	13168.77	10858.22	13916.84
Cost B_2	13061.15	16264.44	13444.52	16736.05	14214.93	17604.04
Cost C_2	15611.15	19120.44	16096.52	19694.05	17121.93	20460.04
Yield (qt/ha)						
Grains	9.2	14.2	23.2	20.8	24.4	26.6
Straw	18.00	30.00	47.4	43.2	45.8	38.5
Price obtained by the farmers Rs./qt						
Grains	3800.00	2800.00	4300.00	3200.00	4600.00	3500.00
Straw	100.00	100.00	100.00	100.00	120.00	120.00
Gross Income	36760.00	42760.00	104500.00	70880.00	116820.00	97720.00
Net Income or Profit (Rs/ha)	**21148.85**	**23639.56**	**88403.48**	**51186.00**	**99698.07**	**77260.00**
Total Cost/ha	**15611.15**	**19120.44**	**16096.52**	**19694.00**	**17121.93**	**20460.00**
Total Cost/qt	**1696.86**	**1346.50**	**693.81**	**946.82**	**701.71**	**769.17**
Peas						
Cost A_1	10810.89	13759.94	11518.49	14477.44	13070.82	16019.71
Cost B_1	11459.54	14585.53	12209.59	15346.08	13855.06	16980.00
Cost B_2	13583.97	17063.87	14695.07	18230.08	17179.49	20823.73
Cost C_2	15215.97	18746.87	16430.07	20066.08	19219.49	22761.73
Yield (at/ha)						
Grains	5.8	5.8	13.2	12.2	15.5	12.0
Straw	9.4	9.4	22.3	20.5	28.3	20.00
Price obtained by the farmers Rs./qt						
Grains	6000.00	4700.00	6300.00	5200.00	6550.00	5500.00
Straw	100.00	100.00	100.00	100.00	120.00	120.00

Gross Income	35740.00	28200.00	85390.00	65490.00	104355.00	68000.00
Net Income or Profit (Rs./ha)	**20524.03**	**9453.13**	**68960.00**	**45424.00**	**85135.51**	**45238.27**
Total Cost/ha	**15215.97**	**18746.87**	**16430.00**	**20066.00**	**19219.49**	**22761.73**
Total Cost/qt	**2623.44**	**3232.21**	**1246.69**	**1644.75**	**1239.96**	**1896.81**

The data of table -1 depicted the results related to net profit (Rs. / ha.), total cost /ha. and total cost/qu. in both conditions, i.e. during Organic Farming System and Inorganic Farming System. Result showed the year wise difference among both type of groups indicating cost / ha. and cost/ql. were found more in case of Inorganic Farming System as compare to Organic Farming System. In India, at present, in addition to food grains output of above 250 million tones, more than 400 million tones of organic matter in the form of biological wastes of cereals and legume plants such as straw and stubbles and another more than one billion tones of annual and perennial crop plants are produced per annum. These biological wastes considered as a bone to increase soil fertility for sustainable agriculture. This plant biomass may be utilized as such or after proper into organic manures. Farmers in India can also use these organic inputs in addition to organic manures for organic farming system and system and sustainable agriculture.

Table 2: Scenario of Net Income (Rs./ha) under Organic Farming System (OFS) vis-à-vis Inorganic Farming System (IFS) of different crops.

Particulars	**Three year average of Organic Farming System (OFS)**				**Three year average of Inorganic Farming System (IFS)**			
	Maize	**Wheat**	**Rajmah**	**Pea**	**Maize**	**Wheat**	**Rajmah**	**Pea**
Net Income (Rs./ha)	47477.61	112033.75	69750.13	58206.51	17500.79	96904.12	50695.18	33371.80

The result depicted from table -2 indicated that net income received from crop grown under organic farming system was found more as compare to inorganic farming system. The variation among wheat is low as compare to maize, rajmah and pea. Organic farming may not lead to higher production and income in the short run as its returns are of a long term nature. Organic farming system ensures in built capacity to maintain and increase soil health and fertility leading to sustained increase in yield and production and low variability of crops; this results in stabilization and high jump in incomes and sustainable agriculture or food security in the long run.

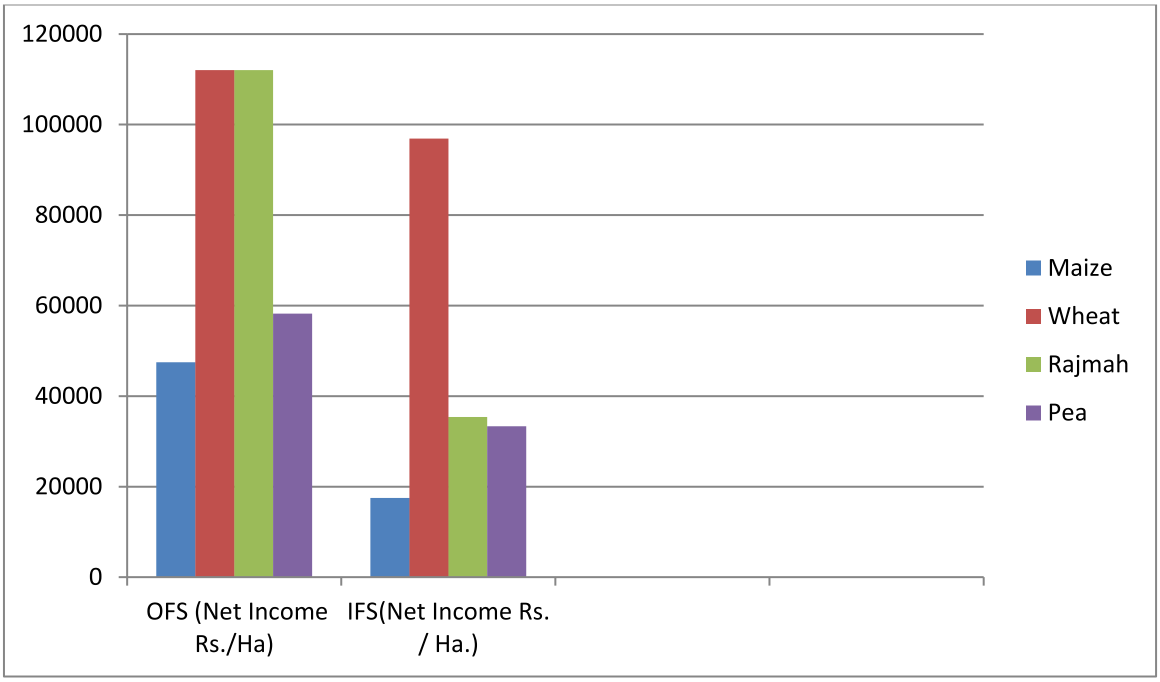

Fig.1. Scenario of Net Income (Rs./ha) under Organic Farming System (OFS) vis-à-vis Inorganic Farming System (IFS) of different crops.

Table 3: Constraints enumerated by the farmers under organic farming system vis-à-vis inorganic farming system:

S. No.	Particulars	Organic Farming System (OFS)			Inorganic Farming System (IFS)		
		f	*%*	*Rank*	*f*	*%*	*Rank*
1.	Unavailability of latest scientific Knowledge about Organic concept	44	73.33	VII	37	61.66	VI
2.	Lack of technical knowledge related to scientific soil management	53	88.33	IV	55	91.66	I
3.	Poor knowledge about Organic certification	57	95.00	II	40	66.66	V
4.	Problems in pests and disease management	40	66.66	VIII	52	86.66	II
5.	Unavailability of high yielding Seeds	55	91.66	III	46	76.66	IV
6.	Scarcity of FYM and other organic manures	60	100.0	I	40	66.66	V
7.	Poor knowledge and availability of bio-fertilizers & bio-pesticides	57	95.00	II	47	78.33	III
8.	Extension service in the form of farmers training	47	78.33	VI	33	55.00	VII
9.	Marketing problems	50	83.33	V	20	33.33	VIII

These constraints make adoption of scientific organic agriculture difficult, which is environment friendly, more profitable and desirable. There is need for dissemination of the OFS to create more awareness among farmers of its success and all round benefits. The non-availability and scarcity of organic inputs as pinpointed by the farmer must be overcome and solved.

The result obtained from table -3 indicated that both types of farmers including OFS and IFS face various constraints. OFS severely faces the Scarcity of FYM and other organic manures. Rank first and poor knowledge of organic certification as well as Poor knowledge and availability of bio-fertilizers & bio-pesticides. In case of IFS concerning farmers Lack of technical knowledge related to scientific soil management has rank first followed by Problems in pests and disease management and other constraints.

IV. DISCUSSION

Comparative Economics of crops grown under Organic Farming System (OFS) vis-à-vis Inorganic Farming System (IFS) over the years

It is found that the yield, total production, income and profit of crops increased under organic farming system over the years. The gross as well as net income or profit from different crops increased significantly by two to three times under organic farming system in case of some crops whereas they remained stagnant and even declined under inorganic farming system over the years. Anurag. Reddy, *et al* (2014) was also reported the impact of the adoption of organic agriculture was positive in terms of profitability and reduction in cost, even though there was a reduction in the yield in all crops.

Constraints enumerated by the farmers under organic farming system vis-à-vis inorganic farming system:

The Scarcity of FYM and other organic manures and Poor knowledge and availability of bio-fertilizers & bio-pesticides as well as Poor knowledge about Organic certification are the pinpointed by the farmers must be overcome and solved. The nature and magnitude of constraints on organic farming system and inorganic farming system related farmers of quite different as revealed by high value. Chou, Y.M.et *.al (2017)* reported that scarcity of organic inputs and labor (particularly family labor) was another constraint, as organic agriculture is relatively more labor-intensive than conventional agriculture. Although lower costs attract farmers to adopt organic farming, they are hesitant to adopt it widely due to low yields, higher labor and supervision time requirements and lack of premium price.

V. CONCLUSION

The inorganic farming system has characterized by input & cost intensive with economically non-viable and ecologically unsustainable as well as risky in nature. On the other hand, the organic farming system has proved to the effective cure for the ills and problems of inorganic farming system. Uttarakhand is a traditionally organic farming hub where several sustainable agricultural practices are done by local community. In this regards to understand the organic production economics of crops and constraints of the organic farming system is the need of the hour. For this purpose a purposive study was planned in districts Almora and Tehri-Garhwal of Uttarakhand. The output of the findings envisages that Organic farming System having less cost of production /ha and per quintal as compare to Inorganic Farming System. Therefore farmers' net profit was found more as compare to inorganic farming. Organic friendly Farmers were also faces several constraints including scarcity of FYM and organic manures, Poor knowledge and availability of bio-fertilizers & bio-pesticides, Unavailability of high yielding Seeds, etc. were the major constraints for OFS. In other hand Inorganic Farming System friendly faces other types of constraints. Thus, availability of organic inputs, technology and other resources must for organic farming. It means that the role of government, private players, farmers, agricultural graduates, other policy makers, etc. are increasing to adopt organic farming system. The role of government policies should be aimed at boosting organic farming on a large scale for export of organic products. The laggards of green revolution will be the pioneer of organic farming.

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Data availability: Data would be available on request.

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Appendix: The supplementary data, table, graph in jpeg format for online visibility to the readers are submitted as an appendix.

Authors' contribution: The corresponding author responsible for identification of problem, conceptualization and development of schedule for survey. The second author participated in contributing to text and the content of the manuscript, including revisions and edits. The third author helps in collection and analysis of data.

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The Study of the Spatiotemporal Evolution of Land Use and Landscape Patterns in Maoming City

Chenlu Wei, Ruei-Yuan Wang*

School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
*Corresponding Author

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***Abstract*— *This study analyzes the changes in land use and the evolution of landscape patterns in Maoming City from 2000 to 2020, revealing the dynamic changes in land use and their ecological effects during urbanization. The results show a significant decrease in cultivated land area, a notable increase in construction land, and a slight decrease in grassland area during this period, indicating that the ecosystem faces certain pressures. The fluctuations in the number of patches (NP) and patch density (PD) reflect a trend of landscape fragmentation in Maoming. The number of patches in cultivated land and woodland has decreased, and the Interspersion and Juxtaposition Index (IJI) and Aggregation Index (AI) indicate that patch distribution tends to be disordered and uneven. At the overall landscape level, diversity has decreased, and the Shannon's Evenness Index (SHEI) has remained relatively stable but is insufficient to offset the negative impacts of reduced diversity. The Landscape Disturbance Index (LDI) shows that landscape interference in Maoming peaked in 2010 and then declined, suggesting that ecological protection and integrated management measures have been effective. The mean disturbance index (MLDI) is higher in the southern Maonan and Dianbai districts, mainly due to higher urbanization, population density, and active economic activities, while the northern Xinyi City, with lower urbanization and fewer human activities, exhibits a lower disturbance index.*

Keywords*— *Land Dynamics Degree; Land Use Transition Matrix; Landscape Pattern Index; Landscape Disturbance Index (LDI); Maoming City.

I. INTRODUCTION

Land resources are a crucial factor influencing human social development. The types of land use and their spatiotemporal changes profoundly impact human production and lifestyle [1]. Landscape patterns are considered the most significant manifestation of land use changes and are a primary focus of landscape ecology. These patterns include the spatial arrangement of patches of different sizes, quantities, and shapes [2], reflecting the ecological environment formed by the synergistic interaction between humans and nature. With the acceleration of urbanization and rapid economic transformation, the efficient and rational use of land resources and the improvement of the ecological environment have become issues of widespread social concern.

Many scholars have conducted extensive research on land use and landscape ecology patterns. Notably, in the study of land use, scholars have employed land use dynamics [3], land use Markov matrices [4], and models such as GeoSOS-FLUS and PLUS for predicting future land use [5-6].In terms of landscape patterns, various indices and models have been used, including the Landscape Disturbance Index (LDI) [7-8], the Landscape Vulnerability Index [9–10], and the Ecological Risk Model [11–12]. However, these studies typically focus on ecologically sensitive watersheds [12–13] or large cities with significant populations, such as Nanning [14] and Beijing [15]. Additionally, some scholars have analyzed landscape patterns and ecological environments from a broader perspective, such as studying the fragmentation of cultivated land in China [16] and the spatiotemporal evolution of landscape ecology in Jiangsu Province [17].

In summary, while there is extensive research on land use and landscape ecology with applications across various scenarios, smaller-scale and less developed cities have not received as much attention. The economic transformation and environmental changes have already impacted provinces, cities, and counties across China. Therefore, this paper focuses on Maoming City as the study area to narrow the research scope. It explores the spatiotemporal changes in land use in Maoming from 2000 to 2020 and how these changes respond through landscape ecological patterns. The aim is to provide some meticulous thinking for land use and ecological environmental protection in Maoming.

II. STUDY AREA

Maoming City is located in the southwestern part of Guangdong Province, bordering Guangxi to the north and facing the South China Sea to the south. Its latitude ranges from 21.67°N to 22.17°N, and its longitude ranges from 110.58°E to 111.38°E (Figure 1). Situated south of the Tropic of Cancer, Maoming experiences a subtropical monsoon climate, characterized by warm and humid weather. Located along the coast of the South China Sea, Maoming boasts abundant mineral and marine resources and serves as an important agricultural base in Guangdong Province. The city's diverse topography includes extensive plains, hills, and mountains, along with numerous rivers and lakes [18].

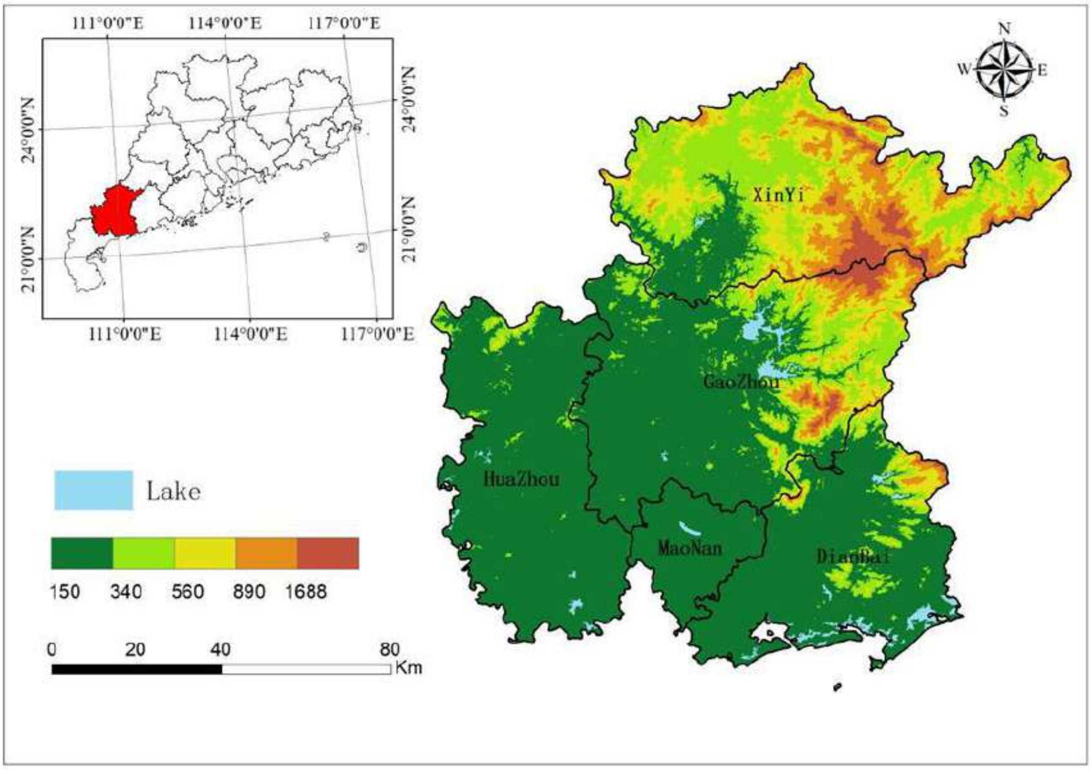

Fig.1 The map of the location and topographic in Maoming

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III. DATA SOURCES AND METHODS

3.1 Data Sources

This study uses land use data with a resolution of 30m × 30m for the years 2000, 2010, and 2020, obtained from the Resource and Environment Science Data Center (RESDC) of the Chinese Academy of Sciences (CAS) (http://www.resdc.cn). After reclassification, the data were categorized into six types: cultivated land, woodland, grassland, water, construction land, and unused land.

3.2 Research Methods

This study analyzes land use data for Maoming from 2000 to 2020, employing land use dynamics and land use transition matrix methods to assess changes in land use types. The transformation processes of land use types are visualized using Sankey diagrams. The study selects several landscape pattern indices at the patch level, including Patch Density (PD), Number of Patches (NP), Aggregation Index (AI), and Interspersion and Juxtaposition Index (IJI). At the landscape level, the selected indices include Area-Weighted Mean Shape Index (AWMSI), Area-Weighted Mean Patch Fractal Dimension (AWMPFD), Shannon's Diversity Index (SHDI), and Shannon's Evenness Index (SHEI), to analyze landscape patterns. Finally, the LDI and the MLDI are calculated to assess the extent of disturbances to the ecosystem caused by human and natural activities (Figure 2).

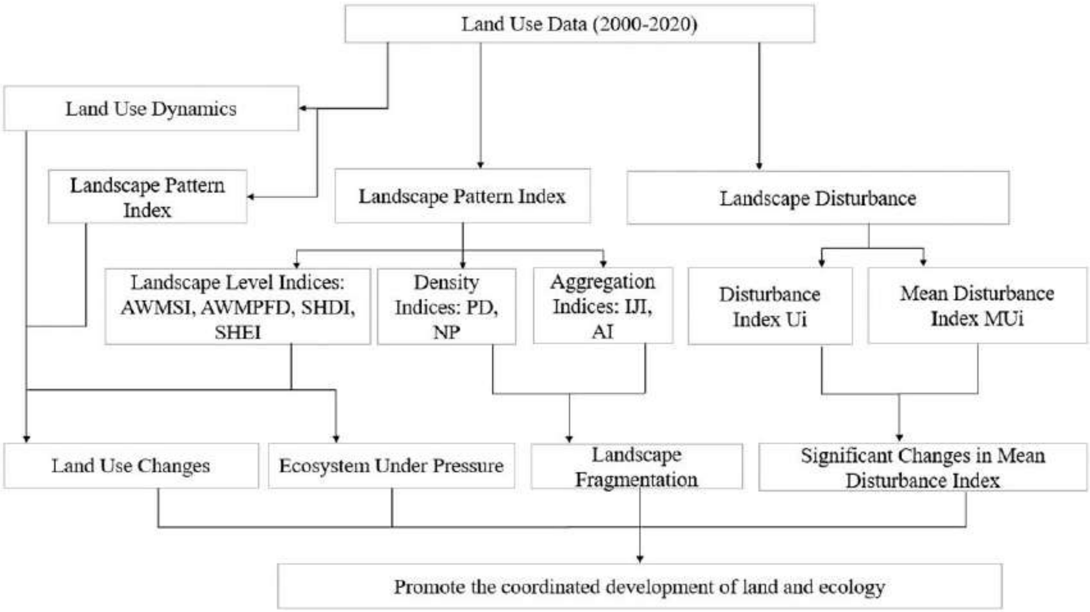

Fig.2 the Map of Technical Route

3.2.1 Land Use Dynamics

Land use dynamics refer to the degree of change in the area of a specific land use type over a particular period. It reflects the degree of dynamic change in land use types, including both comprehensive and single land use dynamics. The larger the value, the stronger the land use change. The calculation method is shown in Equation (1) [19].

$$K_I = \frac{Sit_2 - Sit_1}{Sit_1} \times \frac{1}{t_2 - t_1} \times 100\% \qquad (1)$$

where K_i is the degree of land use change during the period from t_2 to t_1, and S_{it2}, S_{it1} represent the area of a certain land type at times t_2 and t_1, respectively.

3.2.2 Land Use Transition Matrix

The land use transition matrix, also known as the Markov transition matrix model, can visually represent the quantity and direction of mutual conversions between different land use types within a specific period. In this study, the land use transition matrix is used to analyze the conversion relationships of land use in Maoming. It solves the transition matrix based on the changes in the time series, thereby analyzing the change patterns and trends of land use during this time series [20].

If P is the land use transition matrix from time T_0 to T_1, it has the following properties:

1. Normalization: the sum of the probabilities of a

certain land use type converting to other land types is 1.

2. Non-negativity: the transition probability between any two land use types cannot be less than 0, $0 \leq p_{ij} \leq 1$; The expression is:

$$P = \begin{pmatrix} P_{12} & \cdots & P_{1n} \\ \vdots & \ddots & \vdots \\ P_{n1} & \cdots & P_{nn} \end{pmatrix} \qquad (2)$$

In the formula, represents the area of land type i converted to land type j, where i and j denote two different land use types, and n is the total number of land use types.

3.2.3 Sankey Diagram Analysis

The Sankey diagram, also known as the Sankey energy balance diagram, is a special type of flow chart used to describe the flow direction from one set of values to another [21]. It has clear and intuitive utility for data visualization and analysis. To reflect the transformation process of various land use types in Maoming, Origin2024 software was used to visualize the land use changes from 2000 to 2020, constructing a trajectory model of land use changes.

3.2.4 Landscape Pattern Indices and Ecological Significance

Landscape pattern indices can reflect changes in landscape form and distribution and are widely used in landscape analysis and ecological value assessment (Table 1). These indices are categorized into three hierarchical levels: patch level, class level, and landscape level. This study selects four indices at the class level: Patch Density (PD), Number of Patches (NP), Interspersion and Juxtaposition Index (IJI), and Aggregation Index (AI). At the landscape level, four indices were selected: Area-Weighted Mean Shape Index (AWMSI), Area-Weighted Mean Patch Fractal Dimension (AWMPFD), Shannon's Evenness Index (SHEI), and Shannon's Diversity Index (SHDI). These indices were used to analyze the evolution of landscape patterns in Maoming.

The main methodology involved in putting the land use data from 2000 to 2020 in tif format into the Fragstats 4.2 software to calculate the various indices is [22-23]. Finally, the calculated class-level and landscape-level indices were imported into ArcGIS 10.7 software, and natural break classification was used for visualization analysis.

Table 1 Ecological Significance of Landscape Pattern Indices

Level	Landscape Index	Ecological Significance
Class	Number of Patches (NP)	Represents the total number of patches of a type, reflecting landscape heterogeneity and fragmentation.
Class	Patch Density (PD)	Represents the density of a land use type per unit area, directly reflecting the degree of human intervention.
Class	Aggregation Index (AI)	Represents the degree of aggregation of patches.
Class	Interspersion and Juxtaposition Index (IJI)	Reflects the distribution status of patches, indicating the connectivity and distribution of patches.
Landscape	Area-Weighted Mean Shape Index (AWMSI)	Represents the complexity of patch shapes.
Landscape	Area-Weighted Mean Patch Fractal Dimension (AWMPFD)	Reflects the influence of patch shape complexity on human activities.
Landscape	Shannon's Diversity Index (SHDI)	Reflects landscape diversity.
Landscape	Shannon's Evenness Index (SHEI)	Reflects the evenness and dominance of the landscape composition.

3.2.5 Calculation of the LDI

The LDI reflects the degree of disturbance to the landscape structure caused by human activities or natural factors [24], measuring the extent of ecosystem disturbance in the landscape pattern, including both natural and human disturbances. The index is established using the Landscape Fragmentation Index (Pi), Landscape Isolation Index (Di), and Landscape Fractal Dimension Index (Fi). The calculation formula is:

$$LDI_i = W_1 \times P_i + W_2 \times D_i + W_3 \times F_i \qquad (3)$$

where W_1, W_2, and W_3 represent the weights of the Landscape Fragmentation Index, Landscape Isolation Index, and Landscape Fractal Dimension Index, respectively. The value i refers to a specific land use type. Based on relevant studies and the actual situation in Maoming, this study assigns weights of 0.5, 0.3, and 0.2 to the three main landscape indices [25]. Using the moving window calculation method in Fragstats 4.2 software, a window size of 3000 meters was selected for the calculations [26], resulting in the Landscape Fragmentation Index, Landscape Isolation Index, and Landscape Fractal Dimension Index. The calculations were then performed using the ArcGIS raster calculator, and the natural break classification method was used to visualize the LDI.

IV. RESULTS AND ANALYSIS

4.1 Analysis of Land Use Dynamics

4.1.1 Temporal Scale

The analysis of land use dynamics shows that the degree of change in cultivated land was the most intense during the period 2010–2020, consistently showing a downward trend (Table 2). From 2000 to 2010, the change in area was small, about 11.68 km²; however, from 2010 onwards, the cultivated land area decreased by 613.95 km², with a dynamic degree of -1.87%. In contrast, the woodland area showed a growing trend. From 2000 to 2010, the Woodland dynamic degree was 0.04%, indicating a slow increase; from 2010 to 2020, the dynamic degree rose to 0.77%, with the woodland area increasing by 521.15 km². This increase is due to the implementation of the "Returning Farmland to Forest" policy, which facilitated effective ecological restoration in Maoming. Moreover, the dynamic degrees of grassland and water were relatively small, at 0.20% and 0.65%, respectively, from 2010 to 2020. Overall, from 2000 to 2010, the dynamic degree of grassland was -0.32%, and for water, it was 0.25%, indicating a slow but steady increase in the area of water. In contrast, the grassland area decreased at first and then increased, but overall, the increase in grassland area was less than the decrease.

Additionally, the dynamic degree of construction land was relatively high, indicating significant land use changes. As shown in Table 2, construction land accounted for 6.05% of the total land area in 2000, decreased to 5.97% in 2010, and then expanded again to 6.62% in 2020. Unused land experienced the most significant change in land use dynamics from 2000 to 2020. Although the change in area was relatively small, the degree of utilization greatly increased.

Table 2 Dynamics and Change of Land Use in Maoming City from 2000 to 2020

Year	2000		2010		2020		2000-2010		2010-2020	
Type	Area / km²	Ratio / %	Area / km²	Ratio / %	Area / km²	Ratio / %	Change / km²	Dynamics / %	Change / km²	Dynamics / %
Cultivated	3296.80	29.08	3285.12	28.97	2671.17	23.55	-11.68	-0.04	-613.95	-1.87
Woodland	6714.12	59.22	6739.99	59.44	7261.14	64.03	25.86	0.04	521.15	0.77
Grassland	343.81	3.03	337.21	2.93	344.01	2.99	-6.60	-0.32	6.80	0.20
Water	285.22	2.52	292.25	2.58	311.15	2.74	7.03	0.25	18.91	0.65
Construction	685.60	6.05	676.87	5.97	750.27	6.62	-8.73	1.08	73.40	1.08
Unused	12.97	0.11	12.67	0.11	6.95	0.06	-0.30	-0.23	-5.73	-4.52

4.1.2 Spatial Scale

The analysis shows significant changes in the cultivated land area in Maoming from 2000 to 2020. The regions with the most substantial decrease in cultivated land are concentrated in the central part of Maonan District, the northwest of Dianbai District, and the southern part of Gaozhou City (Figure 3). Due to the need for returning farmland to forests and grasslands, as well as urban construction, the sources of construction land in Maonan District and Gaozhou City are primarily from cultivated land. Some cultivated land has been converted to ecologically more significant woodland and water. Thanks to the active ecological protection efforts, the areas of these two land use types have increased, mainly in Maonan District, Dianbai District, and Gaozhou City.

Changes in water are concentrated in Maonan District, while changes in woodland are distributed in the northwest of Dianbai District, the east of Maonan District, and the south of Gaozhou City. Grassland areas showed fluctuations, with some grasslands disappearing in the northwest of Gaozhou and the central part of Huazhou between 2000 and 2010. Afterward, grassland areas slowly increased and were relatively evenly distributed, but overall, the increase was not significant, leading to a decline in grassland area. The increase in construction land is most notable in the central Maonan District and the southern part of Gaozhou.

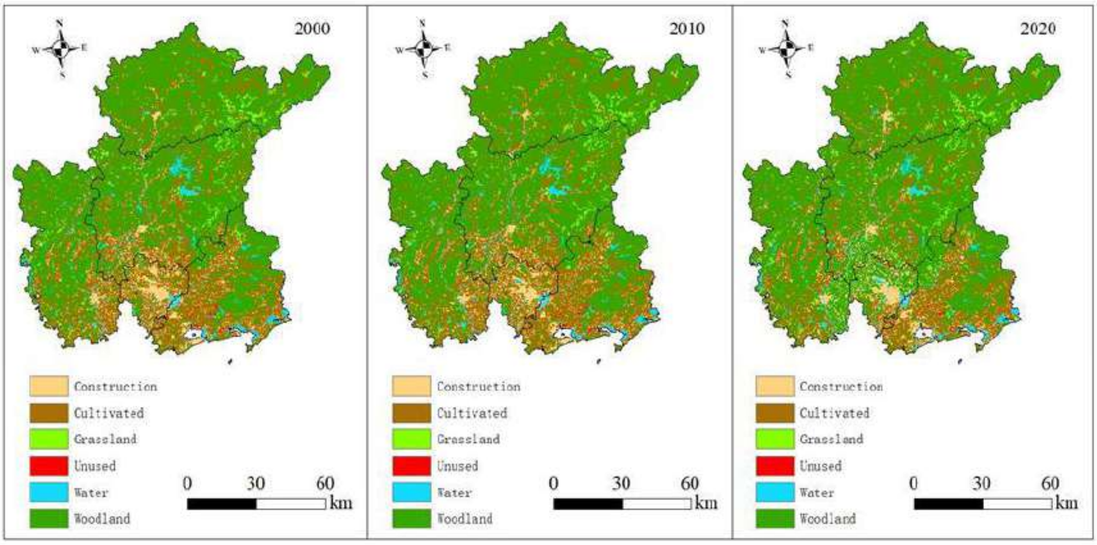

Fig.3 Land Use Changes in Maoming from 2000 to 2020

Since 2010, construction land in Maonan District has expanded significantly, and although the growth area of construction land in Gaozhou is smaller than in Maonan District, its distribution is more extensive. Unused land is distributed in the southeast of Dianbai District. From 2000 to 2010, the change in unused land area was minor, but by 2020, rapid development and construction in Dianbai District increased land use efficiency and developed some of the unused land.

4.2 Analysis of Changes in Land Use Types

From the results of land use type transitions in Maoming from 2000 to 2020 (Table 3), it can be seen that the primary land use changes involve the mutual transformation of cultivated land, woodland, and construction land. From 2000 to 2010, the total transfer of cultivated land reached 3296.61 km², with 19.69 km² converted to construction land and 42.38 km² converted to woodland. Construction land had a total transfer of 685.57 km², primarily converting to woodland (16.50 km²) and cultivated land (21.12 km²). The total transfer of woodland was 6713.43 km², with 30.51 km² and 11.63 km² converted to cultivated land and construction land, respectively. Grassland had a total transfer of 343.73 km², mainly converted to cultivated land and woodland.

This period's land use changes indicate an urbanization trend, with cultivated land being extensively converted to construction land, significantly impacting agricultural land. Some construction land was converted to woodland, possibly due to urban greening and ecological restoration measures. However, the conversion of grassland to cultivated land and woodland reflects a reduction in natural vegetation, which could lead to decreased ecosystem services such as soil and water conservation and biodiversity.

From 2010 to 2020, the total transfer of cultivated land was 3284.38 km², with 84.23 km² converted to construction land and 664.68 km² to woodland. Compared to the previous decade, the pattern of construction land transfer remained similar, still primarily converting to woodland and cultivated land, but with increased conversion areas of 25.56 km² to woodland and 41.10 km² to cultivated land. Woodland transferred to cultivated land and construction land at 106.25 km² and 52.34 km², respectively, showing significant changes. Woodland also converted to grassland at 20.05 km², the largest conversion of grassland area in 20 years. The total transfer of water was 291.62 km², primarily converting to construction land and cultivated land; unused land was mainly converted to grassland and construction land, while grassland was mainly converted to woodland and cultivated land.

These changes indicate a more pronounced trend of urban expansion during this period. Cultivated land continued to be extensively converted to construction land, putting more pressure on agricultural land. The significant increase in woodland converted to construction land could negatively impact the region's carbon storage and climate regulation functions. The large-scale conversion of grassland to woodland, while increasing vegetation cover, could also lead to the degradation of grassland ecosystems. Additionally, the transfer of water to construction land could affect regional water resource management and water quality protection.

Table 3 Land Use Transition Matrix in Maoming City from 2000 to 2020 (Unit: km²)

Year	Land Use Type	Grassland	Cultivated	Construction	Woodland	Water	Unused Land	Total
2000-2010	Grassland	323.48	1.29	0.53	17.66	0.77	0.00	343.73
	Cultivated	1.18	3282.98	19.69	42.38	6.27	0.11	3296.61
	Construction	0.09	21.12	643.94	16.50	3.90	0.01	685.57
	Woodland	7.66	30.51	11.63	6659.70	3.85	0.08	6713.43
	Water	0.21	1.84	0.46	7.44	279.83	0.02	285.10
	Unused	0.00	0.11	0.31	0.08	0.03	12.43	12.96
	Total	332.62	3340.56	676.56	6739.97	291.64	12.65	11337.40
2010-2020	Grassland	308.56	4.06	2.15	16.08	2.12	0.00	332.42
	Cultivated	4.40	2508.44	84.23	664.68	22.34	0.27	3284.38
	Construction	2.15	41.10	701.90	25.56	11.08	0.03	781.82
	Woodland	20.05	106.25	52.34	6532.16	25.85	0.26	6736.91
	Water	2.02	10.12	1.28	19.13	248.88	0.11	291.62
	Unused	2.02	0.36	3.47	0.01	0.19	6.65	12.69
	Total	339.21	2670.46	749.72	7257.91	310.45	6.93	11334.67

The Sankey diagram in Figure 4 intuitively displays the trajectory of land use quantity changes in Maoming from 2000 to 2020, revealing shifts among different land use types over the past 20 years. The diagram shows that cultivated land has been predominantly converted into woodland, followed by construction land.

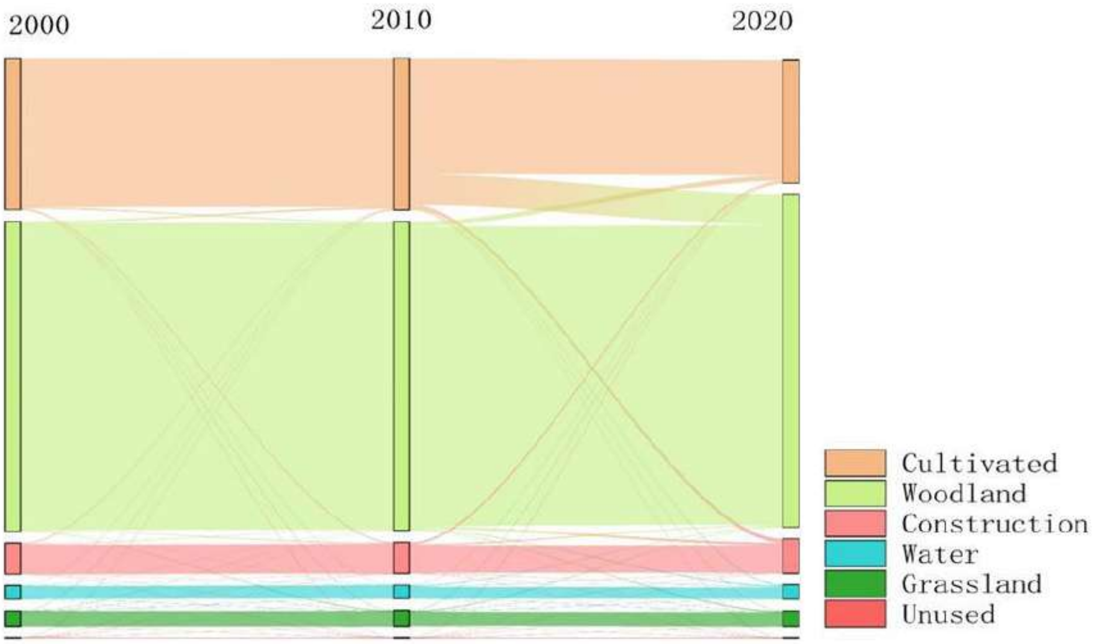

Fig.4 Trajectory of Land Use Changes from 2000 to 2020

The trend of cultivated land being converted to woodland and construction land is particularly evident from 2010 to 2020, indicating that as urbanization progresses, agricultural land is gradually decreasing, with more land likely being used for urban development and greening. While this transformation can help increase urban green coverage and improve ecological environment quality, it may also place pressure on food production and the balance and health of agricultural ecosystems.

The changes in woodland during 2010-2020 are also significant. Woodland has not only received a substantial amount of transferred cultivated land but has also been partially converted into construction land. This conversion can potentially enhance the region's carbon storage capacity, improve air quality, and regulate the local climate in Maoming. Meanwhile, as urbanization and industrialization accelerate, construction land continues to expand from both cultivated land and woodland. This expansion often accompanies the increase of impervious surfaces, which can exacerbate urban heat island effects, increase storm water runoff, and intensify urban flooding.

4.3 Analysis of Class-Level Landscape Pattern Indices

4.3.1 Density Indices

In landscape ecology, the NP and PD are critical indices for describing landscape patterns. NP provides an overall understanding of the number of landscape patches, while PD describes the spatial density and distribution of patches. A comprehensive analysis of these two indices can offer a deeper insight into the ecological characteristics of the landscape and its impact on the ecosystem. These indices are also valuable references for landscape management, biodiversity conservation, and ecological restoration planning.

The analysis shows that the number of cultivated land patches (NP) decreased in 2010 but slightly increased in 2020 (Table 4). The number of woodland patches peaked at 1513 in 2010 before significantly decreasing, likely due to the conversion of woodland into construction land or cultivated land. The number of grassland patches has shown a steady upward trend, indicating that grassland is gradually being fragmented or encroached upon by other land use types. The number of water body patches decreased in 2010 but increased again in 2020. The number of construction land patches has continuously increased, while the number of unused land patches decreased in 2020, indicating that unused land is gradually being converted to other land use types. This trend is likely a result of rapid urbanization and increased infrastructure development in Maoming.

Regarding PD, the density of cultivated land remained consistent in 2000 and 2020 but slightly decreased in 2010, indicating stabilization in cultivated land distribution. The patch density of water remained stable, showing little change in spatial distribution. The density of woodland decreased in 2020, possibly due to the replacement or consolidation of some wood areas. The density of construction land has continuously increased, reflecting the high-intensity of land use during urbanization. The density of unused land was zero in all three periods, indicating its very small proportion.

Table 4 Changes in Density Indices from 2000 to 2020 (Unit: count)

Index	Type	2000	2010	2020
Number of Patches (NP)	Cultivated	2505	2312	2479
	Woodland	1479	1513	1218
	Grassland	828	853	877
	Water	555	518	567
	Construction	3498	3518	3643
	Unused	45	45	38
Patch Density (PD)	Cultivated	0.22	0.20	0.22
	Woodland	0.13	0.13	0.11
	Grassland	0.07	0.08	0.08
	Water	0.05	0.05	0.05
	Construction	0.31	0.31	0.32
	Unused	0	0	0

4.3.2 Spatial Changes in NP and PD from 2000 to 2020

The NP and PD in Maoming experienced significant spatial changes from 2000 to 2020 (Figure 5). From 2000 to 2010, the southern part of Maoming had a higher number of patches compared to the central and northern parts. By 2020, the number of patches in the southern region had decreased rapidly, primarily concentrated in the eastern part of Huazhou City, the central part of Maonan

District, the southern part of Gaozhou City, and the western part of Dianbai District. Similarly, changes in PD can be observed. From 2000 to 2010, the spatial distribution of NP did not change significantly. However, from 2010 to 2020, the patch density in some areas showed a marked downward trend, possibly due to the development and integration of cultivated land, construction land, and woodland in Maoming over the past decade.

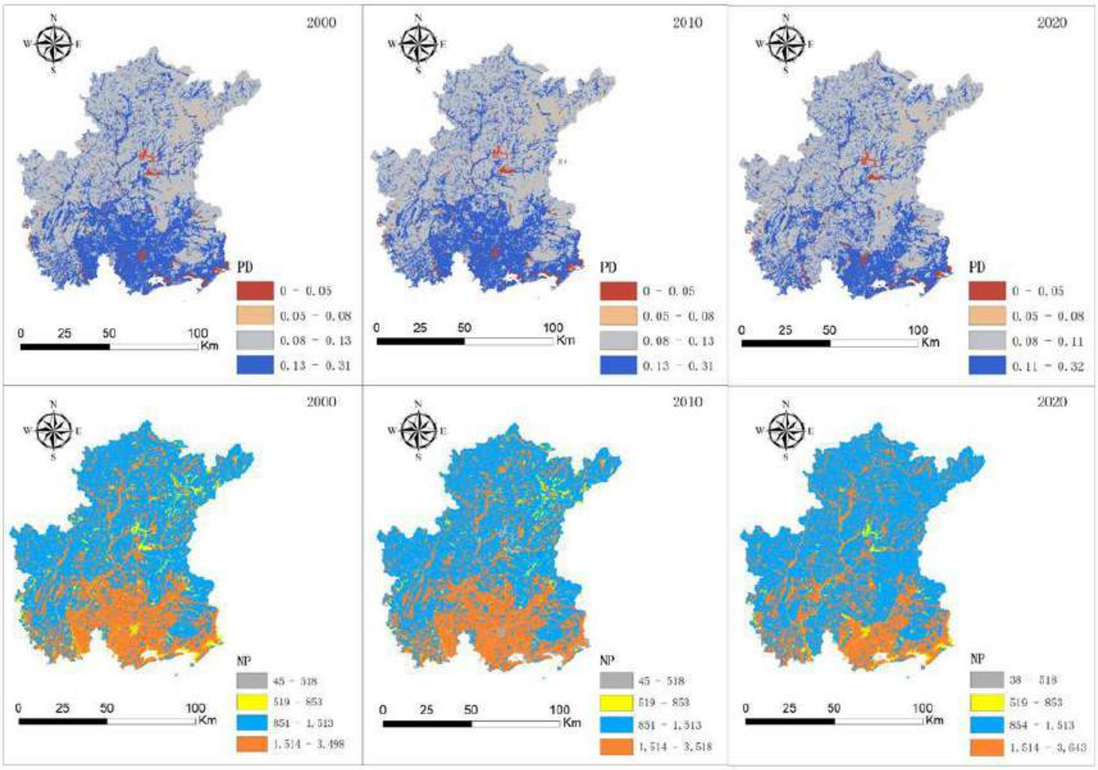

Fig.5 Spatiotemporal Distribution of NP and PD in Maoming from 2000 to 2020

4.3.3 Aggregation Indices

The IJI measures the spatial arrangement and relative position of different patch types in the landscape. Higher values indicate a more uniform spatial arrangement of landscape types. The AI reflects the degree of aggregation of a specific land use type within the landscape. Higher values indicate that the patches of that type are more aggregated.

The data in Table 5 show that from 2000 to 2020, the IJI for cultivated land in Maoming gradually decreased, indicating that the spatial arrangement of cultivated land patches became less uniform. The AI for cultivated land peaked in 2010 and then decreased, suggesting that the concentration of agricultural land and urbanization expansion indeed affected cultivated land. However, the degree of aggregation increased in 2020. The IJI for woodland increased to 59.88 in 2020, indicating that the spatial arrangement of woodland patches became more uniform. The AI value decreased in 2010 but then rebounded, likely due to afforestation and ecological restoration policies and projects in Maoming.

The IJI for construction land increased significantly, indicating that the spatial arrangement of construction land patches became more uniform and urban planning gradually improved. The AI for construction land remained relatively stable, suggesting a stable spatial pattern of urban construction land. The IJI for grassland slightly increased, indicating a trend toward a more uniform spatial arrangement, while the AI remained stable. The IJI for water also slightly increased, indicating a minimal change in spatial arrangement, while the AI slightly decreased. The IJI for unused land peaked at 93.51 in 2010 before declining, and the AI peaked at 93.51 in 2010 before declining as well.

Table 5 Changes in Aggregation Indices from 2000 to 2020

Index	Type	2000	2010	2020
Interspersion and Juxtaposition Index (IJI)	Cultivated	52.01	51.81	48.90
	Woodland	48.55	48.94	59.88
	Grassland	46.03	46.37	47.42
	Water	67.65	67.62	68.21
	Construction	43.07	44.08	57.35
	Unused	64.46	93.51	74.52
Aggregation Index (AI)	Cultivated	93.62	97.04	92.84
	Woodland	97.08	91.27	97.09
	Grassland	91.52	90.98	91.25
	Water	91.00	91.32	89.97
	Construction	91.63	91.35	91.58
	Unused	91.58	93.51	90.14

From Figure 6, the macroscopic spatial changes in IJI and AI values in Maoming between 2000 and 2020 can be observed. In 2000, the IJI values in the southern regions of Maonan District and Dianbai District were relatively high, while the central and northern regions, such as Gaozhou City and Xinyi City, had lower IJI values. This indicates that the land use types in the southern part were more uniformly arranged, whereas the central and northern parts were more irregular.

In 2010, the overall IJI values in Maoming changed significantly, concentrating between 47 and 52 and covering the entire area. Over the ten years, the IJI values decreased rapidly. By 2020, the IJI values had increased quickly, showing notable variability. These significant changes in IJI suggest that the land use types in Maoming shifted from uniform to disorder over these 20 years, possibly due to rapid urban development combined with ecological protection and restoration measures.

Regarding the AI, from 2000 to 2010, the AI values in the southern part were slightly lower than in the northern part, with little change, mostly concentrated in the range of 94-95. This indicates a higher degree of patch aggregation in the southern land use types, while the northern and eastern parts had denser patch distributions. In 2020, Figure 6 shows that AI values in most regions of Maoming decreased after 2010, falling within the range of 91-93, still maintaining a high level. Some areas, such as the northern part of Maonan District, the southern part of Gaozhou City, and the northwest of Dianbai District, showed a noticeable increase in AI values.

The possible reasons are that the rapid urbanization in the southern region led to more diverse land use types, with fragmented patch edges causing AI to rise. Meanwhile, in most regions, the implementation of ecological protection measures enhanced the integrity of patches, leading to a decrease in AI values.

4.4 Landscape-Level Index Analysis

The AWMSI and AWMPFD collectively reflect the complexity of patch shapes. Higher complexity may provide more habitat types and edge effects, thereby supporting higher biodiversity. The SHDI and SHEI reflect species diversity and distribution evenness within the landscape. High diversity and even distribution help maintain the stability and functionality of ecosystems. The combination of complex patch shapes (high AWMSI and AWMPFD) with high species diversity (high SHDI) and even distribution (high SHEI) usually indicates a healthy, stable landscape with high ecological functionality.

The AWMSI increased from 1.75 to 1.79, indicating an increase in the complexity of patch shapes within the landscape. This could be a result of the increased presence of irregularly shaped construction land and infrastructure development during urbanization, leading to decreased landscape connectivity and enhanced edge effects. The AWMPFD remained stable at 1.08, indicating that the spatial complexity of landscape patches did not significantly change, suggesting that urban planning and management measures have controlled changes in patch shapes to some extent.

The SHDI decreased from 1.05 to 1.01, and the SHEI remained relatively stable around 0.58, with only a slight decrease. This indicates that over the past 20 years, urbanization and agricultural intensification may have led to a simplification of land use types in Maoming, reducing the variety and richness of patches within the landscape. Although the distribution of different patch types within the landscape has not changed significantly, this minimal change may not be sufficient to counterbalance the loss of diversity.

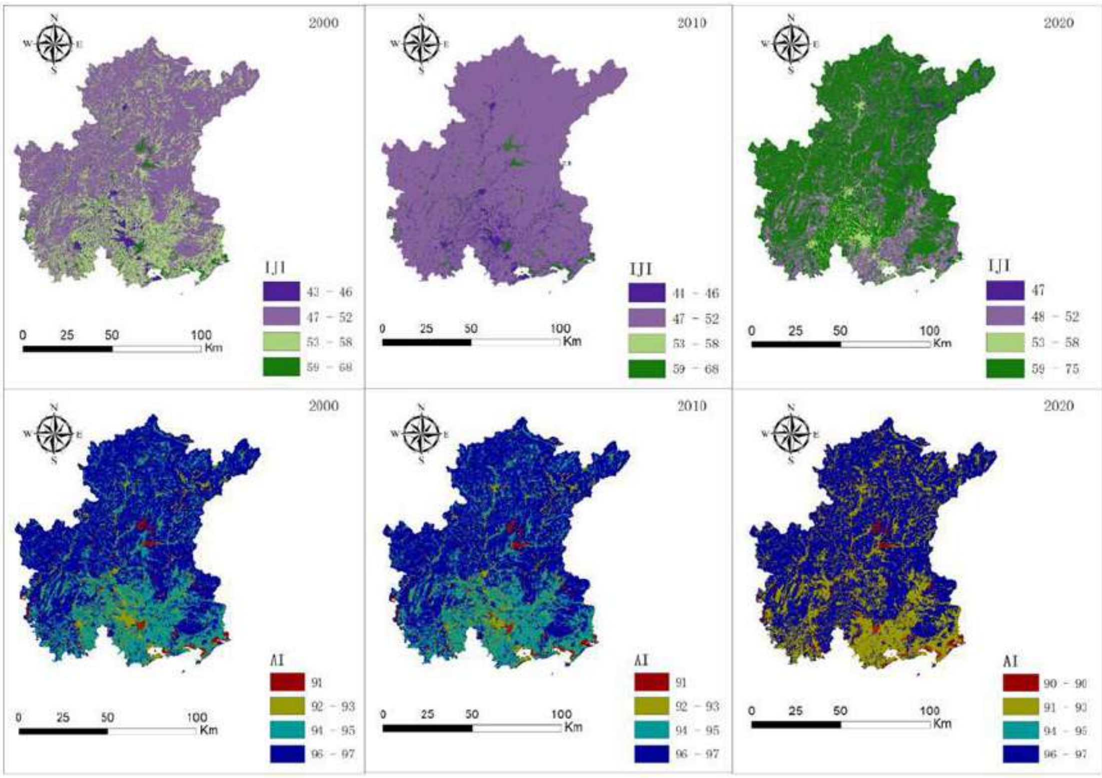

Fig.6 Spatiotemporal Distribution of IJI and AI in Maoming from 2000 to 2020

Table 6 Landscape-Level Pattern Indices from 2000 to 2020

Year	AWMSI	AWMPFD	SHDI	SHEI
2000	1.75	1.08	1.05	0.58
2010	1.78	1.08	1.04	0.58
2020	1.79	1.08	1.01	0.57

4.5 Temporal Differentiation Characteristics of LDI

4.5.1 Spatiotemporal Differentiation of LDI

Based on the analysis of landscape disturbance data from 2000, 2010, and 2020 (Figure 7), the LDI in Maoming has significantly increased over the past 20 years. In 2000, most areas had low landscape disturbance, with LDI values primarily concentrated between 0.2 and 0.5. High disturbance areas (LDI values close to or exceeding 1.69) were distributed in the city center and a few hotspot areas.

By 2010, the landscape disturbance had significantly increased, with a wider range of LDI values, and more areas had LDI values exceeding 1. The disturbance hotspots expanded, particularly around the urban periphery, where disturbances intensified. High-disturbance areas almost covered the entire city and its surroundings. In 2020, the LDI showed a decrease, with overall lower LDI values.

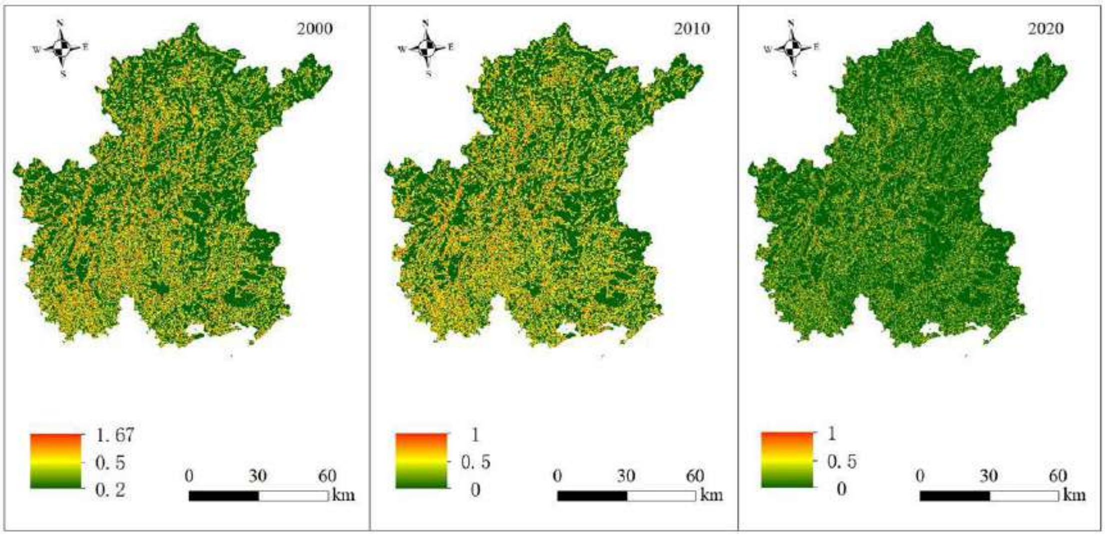

Fig.7 Spatiotemporal Distribution of LDI from 2000 to 2020

The expansion of high disturbance areas in 2010 likely led to habitat destruction, a decline in biodiversity, increased soil erosion, and degraded ecosystem functions in Maoming over the subsequent years. However, by 2020, the LDI had decreased and stabilized. This reduction is likely a result of effective ecological protection and comprehensive management strategies, such as the "Returning Farmland to Forest" policy, which have had a significant positive impact.

4.5.2 Analysis of Mean Landscape Disturbance Index (MLDI)

Based on the LDI calculations, the MLDI for Maoming at three time points (2000, 2010, and 2020) was computed using ArcGIS 10.7 [25]. The spatial distribution of the MLDI for these three time points is shown in Figure 8.

From 2000 to 2020, the MLDI in Maoming exhibited significant spatial changes and highlighted the impact of human activities on the landscape. In 2000, the MLDI values in the southern areas of Maonan District and Dianbai District ranged from 0.34 to 0.51, indicating higher disturbance levels. In contrast, the northern area, such as Xinyi City, had MLDI values between 0.20 and 0.27, dominated by agriculture and Woodland, indicating lower disturbance levels.

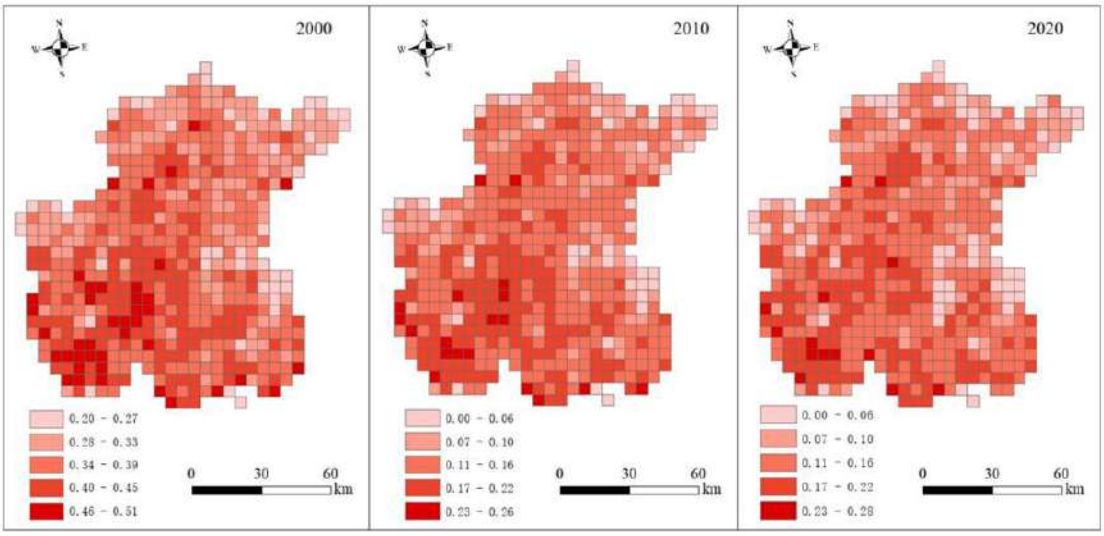

Fig.8 Spatial Distribution of MLDI from 2000 to 2020

By 2010, the MLDI values in the southern region increased to a range of 0.19 to 0.26, and the central regions, such as Gaozhou City, had MLDI values between 0.11 and 0.22. This increase in disturbance was likely influenced by agricultural intensification and infrastructure development. In 2020, the overall disturbance levels decreased, with MLDI values in the southern region concentrated between 0.17 and 0.28. The central and northern regions maintained relatively stable disturbance levels, but some local areas still showed higher disturbances.

To further analyze the changes in landscape disturbance, the average disturbance levels for the three periods were classified using the natural breaks method into five categories: very high, high, medium, low, and very low. The landscape area for each of these disturbance levels in Maoming was obtained (Figure 9). The landscape area with very high disturbance decreased from 1600 km² in 2000 to 675 km² in 2020. The area with high disturbances remained relatively stable. This suggests that urban planning and environmental protection measures have effectively reduced disturbance in some areas, but ongoing human activities continue to have a significant impact on the landscape.

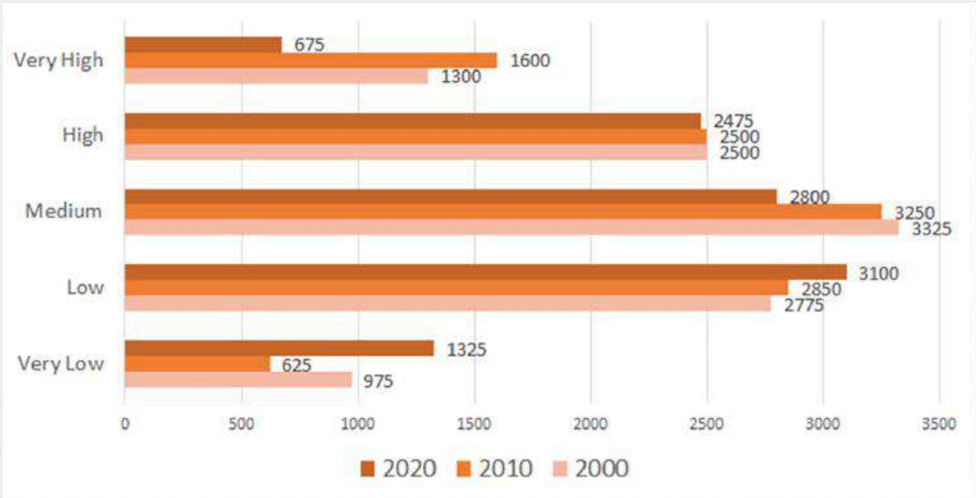

Fig.9 Changes in the Area of MLDI in Maoming from 2000 to 2020

The landscape area with medium disturbances decreased from 3325 km² to 2800 km². Meanwhile, the area with low disturbances also showed a decreasing trend. The landscape area with very low disturbance increased from 975 km² in 2000 to 1325 km² in 2010, but then decreased to 625 km² by 2020, indicating fluctuations over time. Overall, the landscape disturbance in Maoming has decreased, with areas of very high and high disturbance levels reducing. Although there has been a decrease in the area of medium and low disturbance levels, Maoming continues to experience ongoing pressure.

V. CONCLUSIONS

Through a detailed analysis of the spatiotemporal evolution of land use and landscape patterns in Maoming from 2000 to 2020, the following conclusions were drawn:

(1) Significant Land Use Changes

From 2000 to 2020, the cultivated land area in Maoming decreased by approximately 625.63 km², with a reduction of 11.68 km² between 2000 and 2010, and a significant reduction of 613.95 km² between 2010 and 2020.The construction land area increased by 64.67 km² from 2000 to 2020, with urbanization accelerating significantly after 2010, reflecting the notable trend of urban expansion and significant changes in land use in Maoming.

(2) Increasing Fragmentation of Landscape Patterns

The landscape pattern in Maoming is becoming increasingly fragmented, potentially making ecosystem restoration more difficult. The number of cultivated land patches decreased from 2505 to 2479, the IJI dropped from 52.01 to 48.9, and the AI also declined, indicating that the distribution of cultivated land patches became more uneven and less aggregated.

The number of woodland patches decreased by 261, but the IJI increased to 59.88 in 2020, and the AI rebounded to 97.09, indicating that wood protection and restoration measures have had some effect, albeit weaker compared to the rapid urbanization.

Overall, the distribution of IJI and AI indices from 2000 to 2020 showed fluctuations, with IJI significantly decreasing in 2010 and then recovering to a high state, while AI showed a notable decrease in 2020 in most areas. These fluctuations resulted in alternating patterns of uneven and highly dispersed landscape configurations, potentially leading to ecological issues.

(3) Ecosystem under Pressure

Urbanization likely exerts pressure on Maoming City's ecosystem, negatively impacting regional carbon storage and climate regulation. From 2010 to 2020, 84.23 km^2 of cultivated land and 52.34 km^2 of woodland were converted to construction land, while grassland also saw a slight decrease, potentially damaging the grassland ecosystem.

The increase in the AWMSI from 1.75 to 1.79 and the decrease in the SHDI from 1.05 to 1.01 suggest increased patch shape complexity but reduced landscape diversity, making the ecosystem more susceptible to disturbances and weakening its stability and resilience.

Despite the SHEI remaining relatively stable around 0.58, the lack of significant change in patch type distribution uniformity is insufficient to offset the negative impacts of reduced diversity, increasing overall ecosystem pressure.

(4) Significant Changes in Landscape Disturbance

The LDI in Maoming increased significantly from 2000 to 2020 but decreased in 2020. In 2000, most areas had low landscape disturbance, with LDI values mainly between 0.4 and 0.75. From 2000 to 2010, disturbance increased markedly, with more areas exceeding LDI values of 1. By 2020, disturbance levels had generally decreased. The MLDI was higher in the southern Maonan District and Dianbai District in 2000, reflecting high urbanization, population density, and active economic activities, while the northern Xinyi City had lower MLDI values due to lower urbanization and population density.

Based on the key conclusions from the systematic analysis of land use changes and landscape pattern evolution in Maoming from 2000 to 2020, the following recommendations are proposed:

(1) Promote Land Use Planning and Management

The study shows a significant reduction in cultivated land area over the past 20 years, particularly between 2010 and 2020. To protect limited cultivated land resources, it is recommended to reasonably control urban expansion and strictly limit the conversion of cultivated land to construction land, especially in southern areas like Maonan District and Dianbai District. Actively encourage efficient agriculture and intensive farming, and promote ecological agricultural models.

(2) Strengthen Cultivated Land Protection and Wood Restoration

The reduction in the number of cultivated land patches and the uneven changes in their distribution and aggregation indicate that urbanization and land development may lead to the fragmentation of cultivated land. It is recommended to restore and integrate cultivated land patches through land consolidation and efficient utilization measures to enhance the continuity and stability of agricultural production. Further strengthen wood protection and restoration efforts. Despite some success with wood protection measures, the number of woodland patches is still decreasing. Continue promoting reforestation and ecological restoration projects and strictly control the conversion of woodland to construction land. Improve wood connectivity and overall ecological function through scientific management and monitoring.

(3) Balance Urbanization and Ecological Protection

Considering the ecological pressures and changes in disturbance levels over the past 20 years, urban planning should incorporate more ecological construction elements, prioritize the protection of existing green spaces and natural landscapes, and avoid further damage to ecologically sensitive areas. Increase urban green spaces and wetland parks to regulate urban climate and carbon storage issues. In rapidly urbanizing areas like Maonan District and Gaozhou City, further improve the construction of grassland ecosystems and ecological corridors to reduce landscape damage and maintain ecosystem stability and orderliness. Establish long-term ecological monitoring and evaluation mechanisms, utilizing remote sensing technology and GIS to dynamically monitor landscape patterns and ecosystem health, promptly identifying and assessing the ecological impacts of urbanization.

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Ecological Sensitivity Analysis of Kaiping City Based on GIS and AHP Method

Peidan Feng, Ruei-Yuan Wang*, Shaofu Deng

School of Sciences, Guangdong University of Petrochem Technology(GDUPT), Maoming 525000, China
*Corresponding author

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***Abstract*— *Ecological sensitivity analysis is an indicator for studying regional ecological potential problems and environmental measurement, which plays an important role in regional ecological planning and management. In this study, Geographic information system (GIS) and the analytic hierarchy process (AHP) were used to analyze the sensitivity of the ecological environment of Kaiping City. Five evaluation indicators were selected to construct a sensitivity factor level index system, and the evaluation and spatial analysis were carried out. Firstly, the single-factor evaluation was carried out, the AHP method was used to determine the weights of each factor, and then, based on the GIS spatial analysis function, the comprehensive ecological sensitivity was divided into five levels, and the comprehensive ecological environment sensitivity distribution map was obtained. The results showed that: (1) Among the five ecological evaluation factors, land use factors had the greatest impact on the sensitivity of the ecological environment in Kaiping, with a weight value of 0.48. According to the degree of impact on ecological sensitivity, they are ranked as land use, Normalized Difference Vegetation Index（NDVI）, elevation, slope, and water buffer from largest to smallest. (2) The overall sensitivity of the ecological environment was high, with the extremely highly areas and highly sensitive areas accounting for 46.23% of the total area, the medium sensitivity areas accounting for 10.04% of the total area, and the sum of extremely low sensitivity areas and low sensitivity areas accounting for 43.47%. (3) In terms of spatial distribution, the extremely highly sensitive areas and high sensitivity areas of the ecological environment are distributed at the edges of the south and north; the extremely low sensitivity areas and low sensitivity areas are distributed in the central and eastern parts and extend to the north and south sides.*

Keyword*— *Ecological sensitivity; Geographic information system (GIS)；Analytic hierarchy process (AHP); Land use change; Kaiping City

I. INTRODUCTION

With the acceleration of urbanization and the rapid development of regional economies, the degree and scope of human impact on the natural ecological environment are increasing, which has led to a series of regional ecological and environmental problems, such as habitat destruction and acid rain. These ecological and environmental problems seriously threaten the living environment of mankind and the sustainable development of the regional social economy (Ouyang et al., 2000). Ecological sensitivity refers to the possibility of damage to the ecosystem when the ecological environment is disturbed and invaded by the outside world, and it can measure the degree of harm caused by external interference to the ecological environment (Ouyang et al., 2000; Jia et al., 2010; Xu et al., 2015). Therefore, ecological sensitivity analysis and evaluation is one of the important methods for regional ecological environmental protection and construction, and it is also a method to reflect the stability of the ecosystem by combining multiple environmental impact factors (Zhao and Qin, 2007). It is of great significance for national ecological policy formulation to reasonably study the value of regional ecological functions and ecological sensitivity (Qi, 2017). With the development of modern science, ecological sensitivity assessment not only provides a certain scientific basis for monitoring and preventing regional ecological problems but is also an important prerequisite for studying ecosystem function and ecological civilization construction.

Ecological sensitivity analysis and evaluation is a research hotspot in China, and the research scale of ecological sensitivity includes national, river basin, provincial, and city/county scales. Many scholars in China have done relevant research, such as Liu et al. (2015), which evaluated China's ecologically sensitive areas at the national scale. Pan and Dong (2006) on the evaluation of ecological and environmental sensitivity in the Heihe River Basin at the basin scale. Liu et al. (2024) also performed an ecological sensitivity analysis of the Fen River Basin at the basin scale. Yang et al. (2023) explore the spatial and temporal evolution of ecological sensitivity in the Dianchi Lake Basin in the past three decades. Yang et al. (2008) evaluated land ecological sensitivity at the provincial scale in Yunnan Province. Wang et al. (2017) explore the correlation between ecological sensitivity and socio-economic development in Guizhou Province. Su et al. (2019) explored the distribution characteristics of ecological sensitivity in five provinces in northwest China and provided strategies and suggestions for categorical protection. Du and Han (2018) evaluate the ecological sensitivity of Longnan City at the municipal scale. Zhao et al. (2009) analyzed the ecological sensitivity of Wenchuan County at the county scale, and Huang et al. (2019) used analytic hierarchy processes and GIS spatial analysis to evaluate the ecological sensitivity of Longnan County, a forest city in Jiangxi Province, and provided policy suggestions for the sustainable development of the local ecological environment.

In recent years, the research on ecological sensitivity assessment has developed rapidly, the research scope has changed from macro to micro (Li et al., 2007), and the research elements have gradually developed from the study of ecological sensitivity to the ecological sensitivity of comprehensive factors. However, the current ecological sensitivity analysis method is still in the development stage, and there is no unified standard for the selection of evaluation factors and evaluation index system (Cao and Liu, 2010), which is arbitrary and uncertain. Principal component analysis, expert scoring, and the analytic hierarchy process were mostly used in the evaluation methods.

Kaiping City, located in the Greater Bay Area of Guangdong, Hong Kong, and Macao, now has more than 750,000 overseas Chinese, Hong Kong, Macao, and Taiwan compatriots living abroad. Known as the "two Kaipings at home and abroad," it is the location of the only world cultural heritage, "the Kaiping Diaolou and Villages," in Guangdong Province. This article takes Kaiping in Jiangmen City as the research area. Based on RS and GIS technology, the AHP method is used to study the ecological environment sensitivity of the city, analyze the regional differentiation law of ecological environment sensitivity, and provide a relevant decision-making basis for promoting the sustainable development of Kaiping City's social economy and the ecological environment protection and construction planning of relevant departments.

II. STYDY AREA AND DATA

2.1 Study Area

Kaiping City, located in the south-central part of Guangdong Province and the southwest of the Pearl River Delta, spans 21°56 ~ 22°39' north latitude and 112°13'~ 112°48' east longitude and is 139km away from Guangzhou City, the capital of Guangdong Province, with Xinhui District in the northeast, Heshan City in the northeast, Taishan City in the southeast, Enping City in the southwest, and Xinxing County in the northwest. The total area of the city is about 1656.94 km2. There are many small undulating hills in Kaiping, most of which are below 50 meters above sea level, and the Tanjiang River and its tributaries cross Kaiping, forming a dense river network and undulating landscape style (Figure 1). The alluvial formation of a vast and low-lying plain area on both sides of the Tanjiang River makes Kaiping a low-lying and fertile land, but it is mountainous and has little arable land available, so the local people have always had the saying that "six mountains, one water, and three fields" (Huang and Wu, 2013).

Kaiping is bordered by the South China Sea and is located in the subtropical monsoon zone, which is affected by the ocean wind, with heavy rainfall, a relatively mild climate, low latitude, and abundant sunshine. Typhoons bring a lot of precipitation to Kaiping in summer and autumn, and it is located in the middle and lower reaches of the Tanjiang River, resulting in a low-lying delta landform and a dense network of rivers that often cause flooding when encountering typhoons Xiong and Mai, 2016).

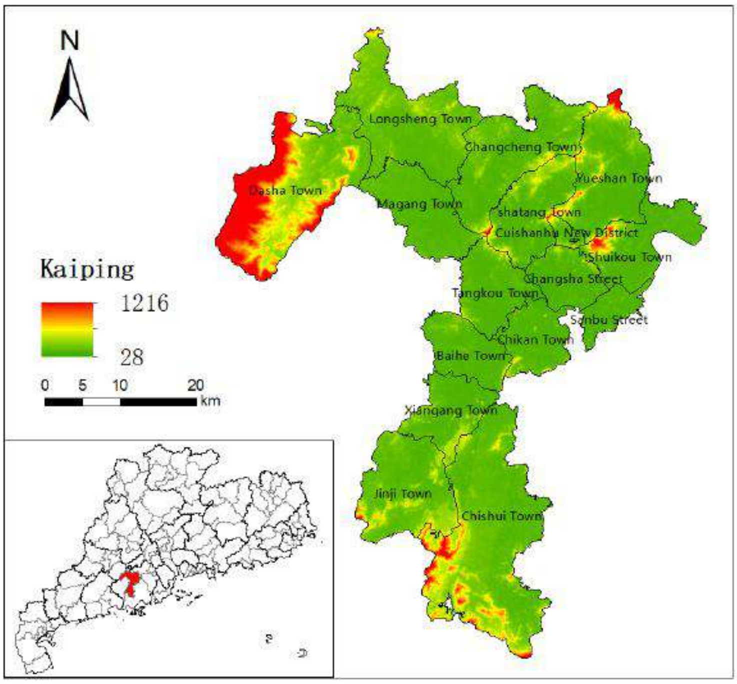

Fig.1 The map of the location and topographic in Kaiping

Kaiping has jurisdiction over Cuishanhu New District, Sanbu Street, and Changsha Street, as well as 13 towns, including Chikan Town and Lily Town. According to the data from the seventh population census, as of 0:00 on November 1, 2020, the permanent population was 748,800. In 2022, the registered population was 682,500. In 2022, the preliminary accounting of regional GDP will be about 45.607 billion yuan, a year-on-year increase of 2.8%. Among them, the added value of the primary industry was 5.650 billion yuan, up by 6.8 percent; the added value of the secondary industry was 21.757 billion yuan, up by 2.6 percent; and the added value of the tertiary industry was 18.199 billion yuan, up by 1.7 percent.

The proportion of the city's tertiary industry structure was 12.4: 47.7: 39.9. The local general public finance budget revenue was 3.077 billion yuan, down 2.8% from the previous year. The budget expenditure of local general public finance was 5.665 billion yuan, an increase of 9.1 percent over the previous year. In addition, the disposable income of urban and rural residents increased over the previous year. In terms of transportation, it is mainly based on highways, with Kaiping South Station for high-speed railways and three ports in the territory for shipping. With the economic development of the Guangdong-Hong Kong-Macao Greater Bay Area, rapid urbanization has also put forward higher requirements for the construction and maintenance of the ecological environment in Kaiping.

2.2 Data Source

The data used in this paper include the administrative boundary vector data of Kaiping City; DEM data with a resolution of 30 m; Landsat 8 OLI remote sensing imagery in 2021 (source: Geospatial Data Cloud, https://www.gscloud.cn/search); and 30 m land cover data for GrobaLand30 in 2021 (source: https://www.webmap.cn/commres.do?method=globeIndex).

Based on the ENVI 5.6 software, the Landsat 8 remote sensing images were processed, the radiometric calibration and atmospheric correction were successively performed, the remote sensing images were mosaic, the vector boundary map was used to crop, and then the NDVI was calculated. The land use factors were divided into forest land, grassland, wetland, agricultural land, water zone, and construction land using the 30 m land cover data of GrobaLand30. ArcGIS 10.8 was used to mask and crop the data, perform slope analysis and hydrological analysis on the DEM, extract slope factors and river factors, establish a multi-loop buffer zone for the river, unify the coordinate system and projection system, and unify the format to 30 m × 30 m through raster data resampling.

III. RESEARCH METHODS

According to the natural and socio-economic conditions of Kaiping and related literature (Yang and Yang, 2022; Gan et al., 2018), five evaluation factors, including elevation, slope, water buffer, land use, and NDVI, were used as the sensitivity indicators of the study area, and the ecological sensitivity level index system was constructed, and the sensitivity evaluation and analysis of the ecological environment of the city were carried out. Then, the weight of each factor was determined by AHP, and the comprehensive evaluation was carried out by GIS. The study area was divided into five levels, namely extremely low sensitivity area, low sensitivity area, medium sensitivity area, highly sensitive area, and extremely highly sensitive area, and the regional comprehensive ecological sensitivity analysis map was obtained. Finally, according to the results of comprehensive ecological sensitivity, appropriate ecological management and protection suggestions are proposed. The relevant technical route is shown in Figure 2.

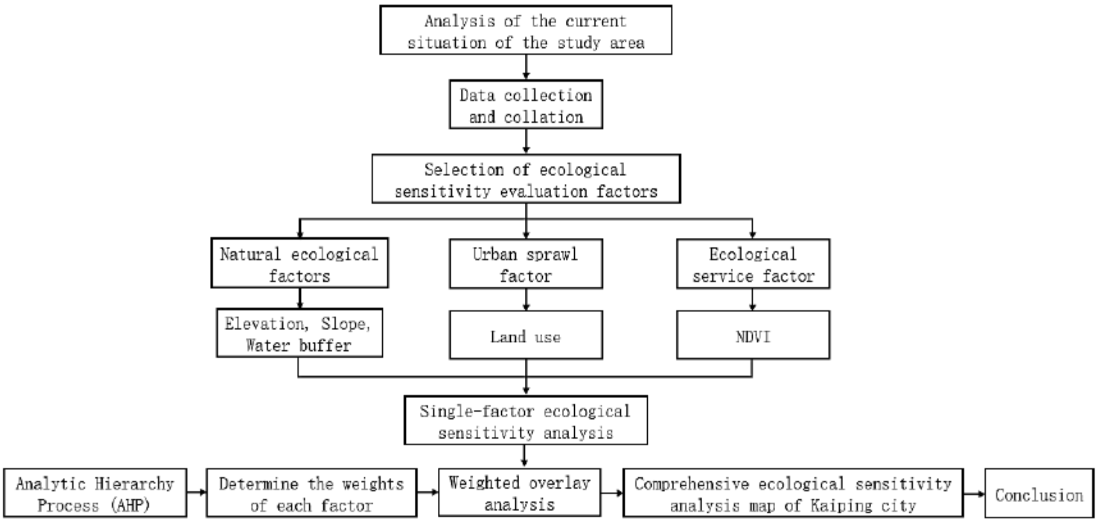

Fig.2 The Map of Technical Route

3.1 Selection of Evaluation Factors and Construction of Grade Indicators

Considering the natural, social, and economic conditions of the study area, the influencing factors of natural ecology were selected, including three factors: elevation, slope, and water buffer. Due to the rapid urban expansion process and development and the renewal of regional land use in Kaiping in the past ten years, the land use type factor is listed as the factor affecting urban expansion. At the same time, there is a large gap between the vegetation and quantity of vegetation in the central city and the suburban and rural areas, and the NDVI factor of the surface vegetation cover is also taken into account. In addition, according to the index classification and scoring criteria of the National Ecological Function Zoning (2015-11-13 revised version), each ecological sensitivity factor was divided into the extremely low sensitivity area, low sensitivity area, medium sensitivity area, highly sensitive area, and extremely highly sensitive area according to the degree of impact, and the values were assigned as 1, 3, 5, 7, and 9, respectively (Table 1). The specific grading criteria for each evaluation factor are as follows:

(1) Elevation. It is an important influencing factor affecting the habitat and spatial distribution of organisms. There are many low mountains and hills in the north, south, and west, and hilly plains in the east and middle, and the plain area below 50 m above sea level accounts for 69% of the city's area, the hilly area accounts for 29%, and the mountain area accounts for 2%, and the highest altitude is 1216 m. Therefore, 50, 100, 300, and 600 m are used as the grading cut-off points.

(2) Slope. Most of the areas are low-altitude plains, and the slopes of mountains and hills at higher altitudes are below 40°. Combined with the general situation of the study area and the grading standard of the General Principles of Comprehensive Planning for Soil and Water Conservation (GB/T 15772-2008), the grading cut-off points are 5°, 15°, 25°, and 30°.

(3) Water buffer. There are many rivers and abundant water resources in the territory, and according to the area closer to the river, different ecological structures are reflected, combined with the scale of the study area. The grading cut-off points are 200, 400, 600, and 800 m.

(4) Land use. By changing the land surface coverage, it will have a certain impact on the atmosphere, water environment, soil, ecosystem, community, and landscape structure. Due to the rapid urbanization process in the study area, land use changes significantly with time and space. It is graded by construction land, agricultural land, grassland, wetland, water area, forest land, etc.

(5) NDVI. It is the best indicator factor for vegetation growth status and vegetation coverage; generally speaking, vegetation coverage in 0 ~ 0.1 is very low coverage; 0.1 ~ 0.3 is low coverage; 0.3 ~ 0.5 is medium coverage; 0.5 ~ 0.7 is medium to high coverage; 0.7 ~ 1 is high coverage. According to the overall vegetation coverage of Kaiping, most areas are medium or above, so the NDVI index is 0.2, 0.4, 0.6, and 0.8 as the grading cut-off points.

Table 1 Grading system of ecological sensitivity indicators in Kaiping City

Indicator layer (values)	Extremely low sensitivity area (1)	Low sensitivity area (3)	Medium sensitivity area (5)	Highly sensitive area (7)	Extremely highly sensitive area (9)
Elevation	<50m	50~100m	100~300m	300~600m	>600m
Slope	<5°	5°~15°	15~25°	25°~30	>30°
Water buffer	>800m	600~800m	400~600m	200~400m	<200m
Land use	Construction land	Agricultural land	Grassland	Water zone、wetland	Forestland
NDVI	0.2	0.4	0.6	0.8	1

3.2 Determination of the Weights of Each Factor

For ecological sensitivity research, the weight can be used to measure the contribution of each factor to ecological sensitivity, and the larger the weight value, the greater the contribution of the factor to the sensitivity and the greater the impact, and vice versa. Therefore, the determination of the weights is the key to the correct analysis of the ecological sensitivity of the study area, and the weights of each factor are calculated by AHP, which is a decision-making method for quantitative and qualitative analysis. The principle is to first construct a hierarchical structure, similar to a tree diagram, construct objects with parent-child levels, construct multi-layer target layers and index layers, and then construct the judgment matrix of each layer, obtain the weight of a certain factor on each layer, and finally determine the weight of the overall goal.

It also needs to test the consistency of the obtained weight results. The weight of each indicator can be used to make more accurate evaluations.

(1) Construct a judgment matrix. The evaluation indicators are compared with each other, given their quantitative values 1, 3, 5, 7, and 9, which represent the same importance, relatively important, relatively important, strong importance, and very important, respectively. The ratings are evaluated according to their importance, and a judgment matrix is formed according to the comparison results, which has the following properties:

$$a_{ij} = \frac{1}{a_{ji}} \qquad (1)$$

where i and j represent evaluation indicators.

(2) Consistency checks. The weight value of each evaluation factor is calculated according to the judgment matrix, and in order to test whether the weight value is scientific, it is necessary to test the consistency of the judgment matrix, and the formula is as follows:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{[\boldsymbol{A}\omega]_i}{n\omega_i} \qquad (2)$$

$$\mathrm{CI} = \frac{\lambda_{max} - 1}{n - 1} \qquad (3)$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \qquad (4)$$

where λmax is the maximum eigenroot; A is the judgment matrix; ω is the eigenvector; n is the order of the matrix; CI is a consistency indicator; CR is the test coefficient. RI is an average random consistency indicator (which can be obtained by looking up a table). In general, if the CR < 0.1, the judgment matrix is considered to have passed the consistency test, and the closer the CR is to 0, the higher the quality of the judgment matrix; otherwise, the matrix has not passed the consistency test, and the judgment matrix needs to be reconstructed until the consistency test is passed.

The judgment matrix constructed in this paper is a fifth-order matrix, and the maximum eigenroot λmax=5.248 and CI=0.062 are calculated, and the CI value of the fifth-order matrix is 1.12 through the table lookup, and the test coefficient CR=0.055<0.1 is finally calculated, indicating that the judgment matrix constructed in this paper has passed the consistency test, so the weight values of each ecological evaluation factor are available, as shown in Table 2.

Table 2 Weights of ecological sensitivity evaluation factors in Kaiping City

Evaluation factor	Elevation	Slope	Water buffer	Land use	NDVI	Weight
Elevation	1	2	3	1/5	1/4	0.12
Slope	1/2	1	2	1/4	1/3	0.09
Water buffer	1/3	1/2	1	1/6	1/4	0.06
Land use	5	4	6	1	3	0.48
NDVI	4	3	4	1/3	1	0.25

3.3 Comprehensive Evaluation

Through the raster calculator of ArcGIS 10.8 spatial analysis, the superposition analysis of each evaluation factor was carried out, and the multi-factor comprehensive ecological sensitivity evaluation operation was carried out (Yang and Yang, 2022; Gan et al., 2018; Qiao and Chong, 2021), which is calculated as follows:

$$\mathrm{S} = \sum_{i=1}^{5} a_i\,\omega_i \qquad (5)$$

Among them, S is the comprehensive ecological sensitivity index; i is the sensitivity classification evaluation value of the ith factor, ai = 1,2,...,5, ωi is the sensitivity weight value of the ith factor.

IV. RESULTS AND ANALYSIS

4.1 Single-factor Ecological Sensitivity Analysis

After the selection of index factors and hierarchical analysis, the results of ecological sensitivity analysis in the study area were obtained, as shown in Figure 3 and Table 3. The relevant circumstances are as follows:

(1) Elevation sensitivity analysis. The regional vertical differentiation is mainly caused by altitude and the elevation sensitivity of the city transitions from the middle to the periphery, gradually changing from low to high. The

extremely highly sensitive area accounts for 1.30% of the city's area and is distributed in the northwest. The extremely low sensitivity area was the largest, accounting for 73.02%. The proportion of low sensitivity areas and medium sensitivity areas was 10.77% and 11.69%, respectively, showing a scattered distribution, with distribution in the northwest, north, and south. The proportion of highly sensitive areas was 3.22%, which was slightly higher than that of extremely highly sensitive areas.

(2) Slope sensitivity analysis. Slope affects surface runoff, soil erosion, and ecosystem stability. The slope-sensitive areas of the city are scattered, but the extremely highly sensitive areas are mostly concentrated in the northwest and southwest of the city, accounting for 1.36% of the total area. The extremely low sensitivity area was the largest, accounting for 60.35%. The low sensitivity area, medium sensitivity area, and highly sensitive area were scattered in the region, accounting for 27.04%, 9.36%, and 1.89%, respectively.

(3) Water buffer sensitivity analysis. Water is an important component of the ecosystem, and it is also a relatively sensitive factor to the ecological environment. The surrounding area of the water area plays a key role in maintaining ecological balance, water purification, and flood regulation. The water resources in the city are abundant and concentrated, and the extremely low sensitivity areas in the region occupy the majority position, covering an area of 757.69 km^2, accounting for 45.73%. The low sensitivity area was 306.64 km^2, accounting for 18.51%. The area of medium sensitivity area, highly and extremely highly sensitive areas accounted for 20.63%, 11.34%, and 3.79%, respectively, indicating that the impact of the water buffer on the ecological sensitivity of the city was low. Therefore, the city needs to establish a water environment buffer zone to strengthen the protection of water resources.

(4) Land use sensitivity analysis. Land use directly reflects the degree to which human activities have transformed the natural environment. The overall reflection of ecological sensitivity analysis based on land use factors was very high. The extremely highly sensitive area (forestland) was the largest, accounting for 47.98% of the total, which was 794.02 km^2, mainly distributed along the southern and northern edges. The low sensitivity area (agricultural land) was the second, with 542.28 km^2, accounting for 32.77%, which was concentrated in the central part and extended to the north and south. The distribution of extremely low sensitivity areas (construction land), medium sensitivity areas (grassland), and the highly sensitive areas (water zone, wetland) was scattered, accounting for 6.17%, 6.27%, and 6.81%, respectively, and the proportion of the three areas was relatively equal.

(5) NDVI sensitivity analysis. It can reflect the vegetation growth and vegetation coverage in the region. The ecological sensitivity of NDVI in the city is generally high, and the area of extremely highly sensitivity is 677.30 km^2, accounting for 40.88%, which is basically distributed in a large number of places in the city. The extremely low sensitivity area, low sensitivity area, medium sensitivity area, and highly sensitive area accounted for 12.95%, 14.64%, 15.82%, and 15.71% of the total area, respectively, and there was little difference between the four areas. Among them, the extremely low sensitivity areas are distributed in the east and northwest of the city, and the low sensitivity areas, medium sensitivity areas, and highly sensitive areas are distributed in the region.

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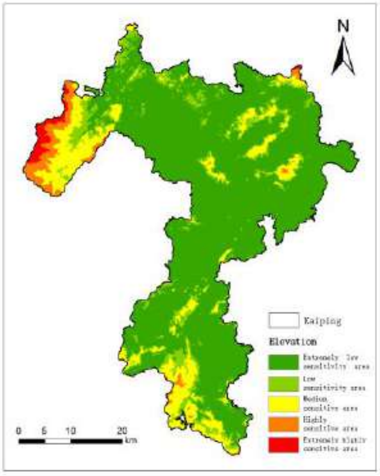
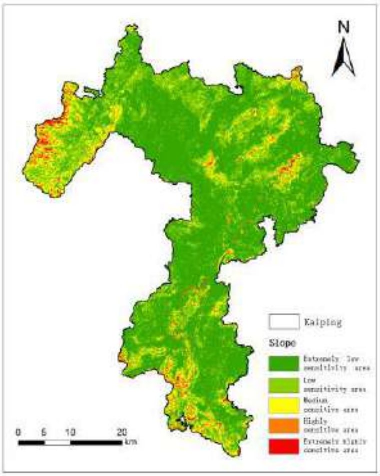
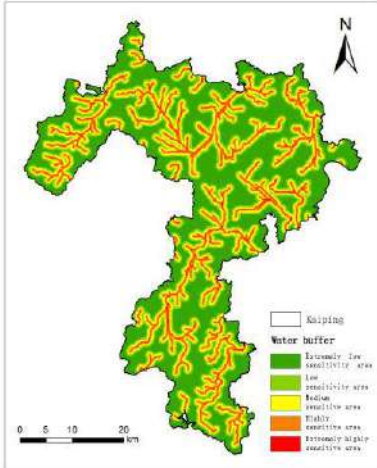


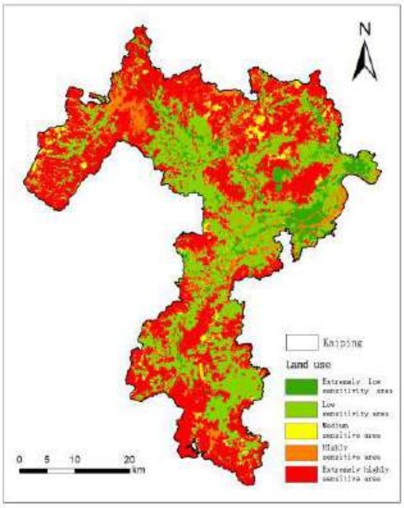
(a) Ecological sensitivity of Elevation



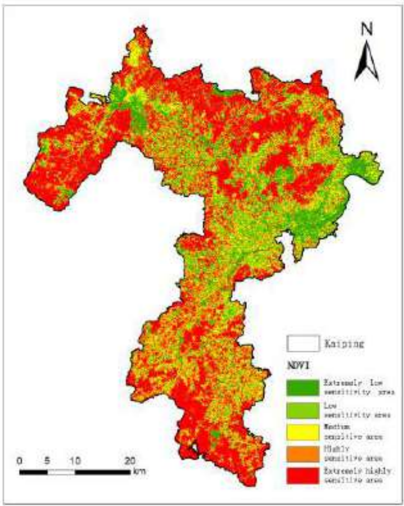
(b) Ecological sensitivity of Slope



(c) Ecological sensitivity of Water Buffer



(d) Ecological sensitivity of Land-use



(e) Ecological sensitivity of NDVI

Fig.3 Single-factor ecological sensitivity analysis in Kaiping City

Table 3 Results of single-factor ecological sensitivity analysis in Kaiping City

Ecological factors (values)	**Extremely low sensitivity area (1)**		**Low sensitivity area (3)**		**Medium sensitivity area (5)**		**Highly sensitive area (7)**		**Extremely highly sensitive area (9)**	
	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)
Elevation	1209.86	73.02	178.45	10.77	193.74	11.69	53.33	3.22	21.54	1.30
Slope	992.61	60.35	444.76	27.04	154.0	9.36	31.04	1.89	22.38	1.36
Water butter	757.69	45.73	306.64	18.51	341.90	20.63	187.91	11.34	62.80	3.79
Land use	102.10	6.17	542.28	32.77	103.68	6.27	112.76	6.81	794.02	47.98
NDVI	214.60	12.95	242.54	14.64	262.10	15.82	260.22	15.71	677.30	40.88

4.2 Comprehensive Ecological Sensitivity Analysis

Combined with the influence of natural environmental conditions and human activities, the five evaluation factors of elevation, slope, water buffer, land use, and NDVI were weighted and superimposed on GIS according to their respective weights, and the comprehensive ecological environment sensitivity distribution was obtained (Figure 4), and the comprehensive ecological evaluation index was between 1 ~ 8.76 (Table 4). Among them, the medium sensitivity area (sensitivity index is 4.38~5.66) and the highly sensitive area (sensitivity index is 5.66~6.8) account for the least, accounting for 10.04% and 12.48%, respectively, which are scattered in the region. The extremely low sensitivity area (sensitivity index is 1~2.98) and the low sensitivity area (sensitivity index is 2.98~4.38) account for 20.23% and 23.50% of the total area, which the land type is mainly construction land. The low sensitivity areas are mostly distributed in the north, extending to the north and south, respectively, and the land use type is mainly agricultural land. The extremely highly sensitive area (sensitivity index is 6.8~8.76) accounts for 33.75% of the total area, mainly distributed in the southern, northern, and northwest edges of Kaiping, and there is also a certain distribution in the central part of Kaiping.

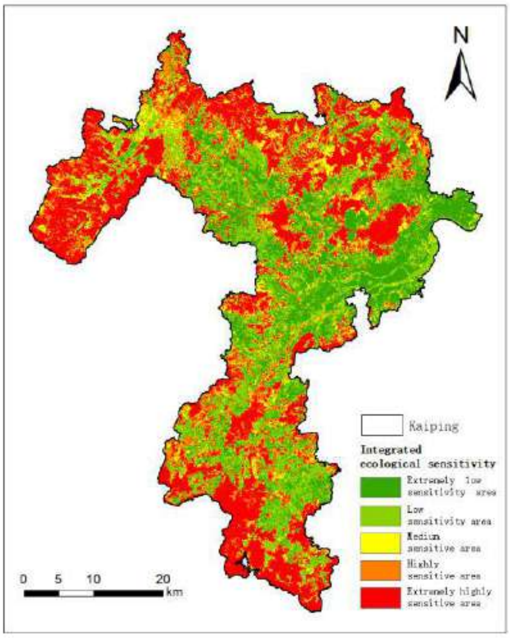


Fig.4 Sensitivity distribution of comprehensive ecological environment in Kaiping City

Table 4 Results of comprehensive ecological sensitivity analysis in Kaiping City

Ecological sensitivity level	Assignment	Comprehensive evaluation index	Area/ km^2	Rate/(%)
Extremely low sensitivity area	1	1~2.98	332.47	20.23
Low sensitivity area	3	2.98~4.38	386.16	23.50
Medium sensitivity area	5	4.38~5.66	164.99	10.04
Highly sensitive area	7	5.66~6.8	205.19	12.48
Extremely highly sensitive area	9	6.8~8.76	554.71	33.75

V. CONCLUSION

Based on GIS software, five ecological sensitivity evaluation factors, including elevation, slope, water buffer, land use, and NDVI, were selected to analyze the single-factor ecological sensitivity, respectively. The AHP method was used to determine the weight of each factor, and then the ArcGIS spatial analysis function was used to obtain the comprehensive ecological sensitivity distribution of Kaiping City. The conclusions are as follows:

(1) Among the five evaluation factors, the land use evaluation factor has the highest impact on the sensitivity of the ecological environment in Kaiping. Because the area of woodland and grassland in this area is large, it shows that the impact of human activities on the environment is the smallest and subsequent development should focus on environmental protection and planning. The evaluation factors of the water buffer had the lowest impact on it, with weights of 0.48 and 0.06, respectively. The NDVI weight value was 0.25, second only to the land use factor, and the results showed that the distribution trend of land use and NDVI ecological sensitivity of the two factors with the highest weight was basically the same, and the distribution trend of comprehensive ecological sensitivity in Kaiping was also roughly consistent.

(2) Through the results of single factor evaluation, it can be seen that the distribution trend of elevation ecological sensitivity and slope ecological sensitivity is highly consistent on the whole, and the extremely highly sensitive areas are concentrated in the northwest. The highly sensitive areas, medium sensitivity areas, and low sensitivity areas are distributed in the region, and the area accounts for the largest proportion of extremely low sensitivity areas due to the low overall altitude of Kaiping; most of them are below 50 m, and the terrain fluctuations are small. The combination of land use and NDVI factors showed that the consistency of the distribution trend of the two was also high, and the extremely highly sensitive area covered the largest area, concentrated in the southern and northern edges. The area of forest land in Kaiping accounts for the largest proportion, followed by the area of agricultural land. The proportion of grassland, water zone and wetland, and construction land is relatively equal, and the area of building land is the least, which is mostly distributed in the eastern region. Therefore, from the perspective of land use evaluation factors, the overall land use degree of Kaiping is low, the ecological environment quality is in a good state, and the local government departments should do a good job in the protection planning related to sustainable development in the future.

(3) The results of comprehensive ecological sensitivity analysis showed that the overall ecological environment sensitivity of the region was high, with the extremely highly and highly sensitive areas accounting for 33.75% and 12.48%, the proportion of medium sensitivity areas being 10.04%, and the extremely low and low sensitivity areas accounting for 20.23% and 23.50% of the total area, respectively. Because the water environment factor is a factor that is more sensitive to the ecological environment, the overall area of the water area of Kaiping is much less than that of forestland and agricultural land, and the weight of the water buffer is low relative to other evaluation factors through the AHP method, so its sensitivity is relatively low in the whole Kaipin.

Kaiping has a good natural geographical environment, but due to the rapid development of urbanization and the lack of reasonable planning and development in recent years, especially in the mountainous and woodland areas, the forest coverage rate in some areas has declined. The degree of land use in the region is low, and the ecosystem has been damaged to a certain extent. According to the results of this study, Kaiping should strengthen ecological environmental protection, formulate strict ecological protection policies, restrict or prohibit development activities, implement ecological restoration projects, protect biodiversity, and maintain the stability of the local ecological environment in extremely highly sensitive and highly sensitive areas. In low and medium sensitivity areas, promote the construction of green infrastructure, such as ecological corridors, guide the transformation of industrial development to low-carbon and environmental protection, and ensure that economic growth and ecological environmental protection are coordinated. In addition, it is necessary to optimize the layout of urban construction, avoid large-scale construction in ecologically sensitive areas, rationally plan land resources, and promote the construction of regional ecological civilization and sustainable social and economic development.

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Dimension of Input Cost and output prices of Paddy in Odisha State of India

N. V. Shende, V. S. Shinde, U. T. Dangore, R. D. Vaidkar and V. K. Khobarkar

Department of Agricultural Economics and Statistics, Dr.Panjabrao Deshmukh Krishi Vidhyapeeth, Akola (Maharashtra), India

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Abstract— *Agricultural growth with stability has been a matter of concern in Odisha. As paddy is the major crop growing in the state, the present study was therefore carried out with the objectives to examine the changes in cost and Prices, growth, trend, parity between cost and Prices, gap between FHP (Farm Harvest Prices) and MSP (Minimum Support Prices), impact of MSP on area, production and productivity of Paddy in Odisha. The data of cost and Prices of Paddy were collected form the period 2000-01 to 2019-20 and analysed the temporal change, growth by using CGR (Compound Growth Rate), instability by using CV (Coefficient of Variation), trends by using linear and non-linear trend model, index number, effectiveness of the Prices policy during the harvest periods was examined by the deviations of FHP from MSP and classified into positive and negative deviations. These deviations calculated by using MAPD, MAND, AMPD and AMND formulas. To study the impact of lagged Minimum Support Prices (MSPs) on the acreage allocation, production and productivity, linear Regression equations have been fitted. The result shows that the temporal change of cost of Paddy crop increased subsequently over the period of time. This increase could due to increase in level of input use for Paddy is increases in Odisha. The growth analysis revealed that the growth in various cost of Paddy are found positively significant at 5 per cent level for overall period. For FHP and MSP of Paddy crop are found positively significant at 5 per cent level for overall period. The Coefficient of variation for various cost and Prices was found to be high in the Period-I and low in the Period-II, on the whole, it was observed that the degree of stability is increasing for over the period. There was an increase in trend in cost and Prices of Paddy during overall period and among the competitive parametric models third degree model are found best fitted based on R^2 significance The gap analysis in which deviations of FHPs from MSPs of Paddy crop results in maximum positive deviations (FHP ruled higher than MSP) in Odisha. The result shows that previous year Prices influences current years' area, production and productivity of Odisha.*

Keywords— ***Agricultural growth, paddy production, price analysis, MSP impact, Odisha agriculture.***

I. INTRODUCTION

Paddy refers to two species, all paddy varieties of Asia, Europe and America belong to Oryza sativa (2n=24), while many cultivated varieties of West Africa belong to Oryza glaberrima. Paddy is a grain belonging to the grass family other grass plants such as wheat, oats and barley which produce grain for a food are known as cereals. Paddy is rich in genetic diversity, with thousands of varieties grown throughout the world.

Paddy is a nutritional staple food which provides instant energy as its most important component is carbohydrate (starch). On the other hand, paddy is poor in nitrogenous substances with average composition of these substances being only 8 per cent and fat content or lipids only negligible, i.e.,1 per cent and due to this reason it is considered as a complete food for eating. Paddy flour is rich in starch and is used for making various food materials.

Paddy is the staple food for about half of the world population and more than two thirds of the Indian population. India ranks first in paddy area and second in paddy production next to China. In India, paddy is grown in about 44 million ha with the production of about 116 million tons of milled paddy. Paddy cultivation engages the most of the workforce in the economy as the source of livelihood for those people.

The Slogan "Paddy is life" is most appropriate for India as this crop plays a vital role in our national food security and is means to livelihood for millions of rural households by providing direct employment in rural areas. Paddy in India's crop and is the staple food of the people of the eastern and southern parts of the country Production of the paddy was 130 million metric tons in the years 2022 - 2023. Orissa Paddy producing state with almost 3.94million hectare land under cultivation producing about 5.87 million tonnes of paddy.

Odisha is the third largest paddy producing state of the country only after Odisha and Odisha. Odisha produces about 12 million tons of paddy in about 3 million ha of area. It produces 11% paddy in 7% area of the country. Agriculture is the lifeline of state's economy as it provides employment to about two third of total workers of the state. Odisha is the pioneer state for various agricultural technologies and techniques but overall state is still lagging behind in various aspects of growth in production. The instability in area and production is quite common as per various institutes and reports in Odisha. Such fluctuations severely affect the production, and indirectly employment and income distribution are affected which there by hamper the economic growth of Odisha.

II. METHODOLOGY

The data was used for study is entire based on secondary source from Agriculture statistics at a glance. The data was collected from various government publications, and websites. Data from the previous 20 years was collected for the study and analysis from 2000-01 to 2019-20. The entire data was split up into two periods and overall i.e. period I: 2000-01 to 2010-11, period II: 2011-12 to 2019-20 and Overall: 2000-01 to 2019-20.

The study was undertaken to study the temporal changes in input use, cost and return of paddy. To estimate growth rates of input utilization and costs of paddy. To examine parity between cost and prices. To work out the impact of prices on area, production and productivity.

1.The growth rates were used to measure the past performance of the economic variable. The growth rates are used to examine cost and prices change over a period of time.

Growth rate was worked from using the following exponential function.

$$\mathbf{Y = a\, b^t}$$

Where, Y= Cost/ Prices**,** T= time in years**,** b = regression coefficient**,** a = intercept

The compound growth rates 'r' was calculated by using the following formula

$$\mathbf{CGR(r) = [Antilog\ (log\ b)\text{-}1] \times 100}$$

Where, r = compound growth rates

2.To measure the instability in cost of cultivation and input utilization, an index of instability was used as measure of variability. The coefficient of variation (CV) will be calculated by the formula.

$$\text{C.V. (\%)} = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

3.The factors affecting the cost of cultivation of paddy crops from the last 20 years was determined the differentials in costs of cultivation and Input use of crops. The significance level of changes in cost will be tested by 't' test.

The effect of cost of cultivation were explained to a certain degree by multiple regression analysis**.**

4.The behaviour of cost and prices of paddy for major states was studied by analysing the trend in the cost and prices of paddy for major states was worked out by fitting linear, quadratic, 3rd degree polynomial equation.

Table: Linear and Non Linear Trend Model.

Model no.	Model	Name of model
1.	$Y_t=b_0+b_1t$	Linear equation
2.	$Y_t=b_0+b_1t+b_2t^2$	Second degree polynomial
3.	$Y_t=b_0+b_1t+b_2t^2+b_3t^3$	Third degree polynomial

5.An index number is a statistical measure design to show the changes in variables or group of related variables or group of related variables with respect to time.

The index number was calculated by choosing the 1^{st} triennium average as a base year.

$$\text{Index Number} = \frac{\text{Current Year Value}}{\text{Base Year Value}} \times 100$$

6.Factors affecting cost of cultivation was analysed by using multiple linear regression analysis. Multiple linear

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regression analysis is a statistical technique used to understand the relationship between multiple independent variables and a dependent variable. In the context of calculating the cost of cultivation, it can be employed to predict the costs based on various factors that influence cultivation expenses. The equation for multiple linear regressions can be represented as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \epsilon$$

Where:

Y = the dependent variable (cost of cultivation).

β_0 = intercept or constant term.

β_1, $\beta_2, \ldots, \beta_5$ = coefficients associated with independent variables

$X_1, X_2 \ldots X_5.$

X_1 = Seed, X_2 = Fertilizer and Manure, X_3 = Human labour, X_4 = Animal labour

X_5 = Machin labour, X_6 = Plant protection, ϵ = error term, representing the unexplained variability in the model.

7.The study was based on the farm harvest Prices and minimum support Prices is of major crops in India. To study the parity between the cost and Prices, the tabular analysis was used. To study the effectiveness of the Prices policy during the harvest period of deviation of farm harvest Prices from the MSP was worked out and classified into the negative and positive deviation to examine whether the market Prices ruled higher or lower over the MSP. Hence the absolute positive deviation (APD) or absolute negative deviation (AND) and mean absolute positive derivation (MAPD) or mean absolute negative deviation MAND) calculated. Also adjusted mean positive deviation (AMPD) and adjusted mean negative deviation (AMND) was worked out.

MAPD or MAND = 1/n ∑ | FHP*i* – MSP*i* |

If, FHP > MSP = Positive deviation (PD)

FHP < MSP Negative deviation (ND)

Where,

MAPD = Mean absolute positive deviation,

MAND= Mean absolute negative deviation,

FHP = Farm harvest prices,

MSP = Minimum support prices, and

n = Frequency of positive or negative deviations.

These deviations were adjusted with MSP in order to examine the degree of their deviation from the MSP. The formulae used for the adjusted mean negative/positive deviation was as follows:

AMPD or AMND= 1/n ∑ (FHP*i*-MSP*i*|/MSP*i*) *100

Where,

AMPD = Adjusted mean positive deviation, and

AMND = Adjusted mean negative deviation

The significance of gap between FHP and MSP of paddy for major states was tested by two sample t-test.

$$t = \frac{(x - y)-(u_x - u_y)}{\sqrt{\frac{1}{n_x} + \frac{1}{n_y}}}$$

Where, x= mean of FHP of size n_x, y= mean of MSP of size n_y, Sp^2 = pooled variance

$$Sp^2 = \frac{(n_x - 1)S_x^2}{(n_x - 1) + (n_y - 1)}$$

To study the impact of lagged minimum support Prices on the area, production and productivity of the paddy. Linear form of equation was used. The previous year MSP generally influence the producer farmer decision on a carrier location for the current year the linear.

1. Linear regression equation:

a. A_t= a + b Pr_{t-1}

b. P_t = a + b Pr_{t-1}

c. Y_t = a + b Pr_{t-1}

2. Logarithmic regression equation:

a. Log. A_t= log a + b Pr_{t-1}

b. Log. P_t = log a + b Pr_{t-1}

c. Log. Y_t = log a + b Pr_{t-1}

Where,

A_t = Area of paddy crop at (t^{th}) period,

P_t = Production of paddy crop at (t^{th}) period,

Y_t = Productivity of paddy crop at (t^{th}) period,

Pr_{t-1} = Minimum Support Prices of major crops taken in per quintal at

$(t - 1^{th})$ period.

III. RESULT AND DISCUSSION

3.1 Temporal changes in input use, cost and returns of paddy.

The Temporal changes in cost and Prices crop have been examined as a whole for Paddy. The temporal changes in cost and Prices were estimated form the period 2000-01 to 2019-20.

The result shown in Table 1.1 shows the changes in the cost cultivation of paddy in Odisha. The total cost of paddy has gone up from Rs. 22822.44 per hectare in 2000-01, Rs. 45239.04 per hectare in 2010-11 to Rs. 101525.6 per hectare in 2019-20 depicting an increase 198.22 per cent and 444.85 per cent during a period of study. The increase has occurred in paddy of cost like hired human labour, family labour, bullock labour, machine labour, seed, fertilizer, farm yard manure, insecticide, rental value of owned land and interest on working capital, costs of interest on fixed capital and depreciation cost.

The cost of human labour, family labour, machine labour, seeds, fertilizer, and insecticide has increased at a faster rate. Among total hired human labour (234.45 per cent) in 2010-11 and (515.59 per cent) in 2019-20 recorded the maximum share followed total family labour (195.71 per cent) in 2010-11 and (543.32 per cent) in 2019-20 followed by machine labour (377.33 per cent) in 2010-11 and (3064.74 per cent) in 2019-20 in the increase in cost of cultivation over time. Out of the total increase of 198.22 per cent and 444.85 per cent in the total cost of cultivation in 2010-11 and 2019-20. The items contributed about 70 per cent and 33 per cent and the remaining 205.87 per cent and 498.70 per cent by fixed cost items in 2010-11 and 2019-20 respectively.

Table 1.1 Temporal changes in cost of Paddy in Odisha

Particulars	**Rs/ha**			**Percent charges over Base period i.e. 2000-01**	
	2000-01	**2010-11**	**2019-20**	**2010-11**	**2019-20**
Hired human labour	5801.91	13602.35	29913.95	234.45	515.59
Total family labour	3065	5998.43	16652.8	195.71	543.32
Bollock labour	1684.05	2980.08	2854.93	176.96	169.53
Machine labour	225.15	849.56	6900.26	377.33	3064.74
Seed	586.1	889.69	1478.27	151.80	252.22
Fertilizer	1001.51	1362.58	4059.39	136.05	405.33
Manures	528.81	950.35	2277.63	179.71	430.71
Irrigation charges	82.57	100.83	827.99	122.11	1002.77
Insecticides	68.98	100.72	166.05	146.01	240.72
Interest on working capital	216.06	463.68	997.03	214.61	461.46
Cost A	13260.14	27298.27	66128.3	205.87	498.70
Fixed costs	4898.43	9018.56	17931.5	184.11	366.07
Rental value	3583.29	7230.77	15526.61	201.79	433.31
Interest on fixed capital	730.54	1192.65	1268.02	163.26	173.57
Depreciation	332.79	478.15	651.59	143.68	195.80
Land revenue	17.25	20.64	19.55	119.65	113.33
Cost B	9562.3	17940.77	35397.27	187.62	370.18
Cost C	22822.44	45239.04	101525.6	198.22	444.85

The increase in insecticide and fertilizer charges has been to the tune of 122.11 per cent, 1002.77 per cent and 136.05 per cent, 405.33 per cent in 2010-11 and 2019-20 respectively, of the total increase in cost of cultivation. The per cent changes over inputs in the cost of cultivation of Paddy at two points of time are also given in Table 1.1 the per cent changeover has remained around per cent in 2010-11, which was lower than that in 2019-20. Within the operational cost, the per cent changeover of machine labour in the total cost increased from 377.33 per cent in 2010-11 to 3064.74 per cent in 2019-20 and the per cent changeover of bullock labour in the total cost decreased from 176.96 per cent in 2010-11 to 159.63 per cent in 2019-20. The decrease in the per cent changeover of bullock labour is on account of substitution by machine labour. The per cent changeover of fertilizer in the total cost increase from 136.05 per cent in 2010-11 to 405.33 per cent in 2019-20, for Paddy.

The extent of change in physical inputs and their prices along with changes in physical output and their prices and gross return for paddy over time is given in Table 1.2. It is remarkable to note that the physical quantity of bullock labour, seed and manure has come down for Paddy due to increase in the wage rate of bullock labour and prices of manure, seed. Only physical quantity of fertilizer is increase and decrease in human labour due to increase in ppaddyof fertilizer and demand for human labour. The gross return for paddy has recorded a 419.92 per cent in 2010-11 and 217.01 per cent in 2019-20 during the period study.

Table 1.2 The extent of changes in physical inputs, input Prices, physical output, output Prices and gross return for paddy in Odisha

S.N.	**Particular**	**2000-01**	**2010-11**	**2019-20**	**Percent charges over Base period i.e. 2000-01**	
					2010-11	**2019-20**
A	**Quantity of input**					
1	Seed (Kg/Ha)	90.47	89.75	58.99	65.20	65.73
2	Fertilizer (Kg/Ha)	81.18	90.82	125.68	154.82	138.38
3	Manure (Qtl/Ha)	23.98	23.76	14.59	60.84	61.41
4	Human labour (hrs/ha)	1089.03	1041.75	837.84	76.93	80.43
5	Bullock labour (hrs/ha)	200.27	188.95	87.07	43.48	46.08
B	**Prices of input**					
1	Seed (Rs/Ha)	6.48	9.91	25.06	386.73	252.88
2	Fertilizer (Rs/Ha)	12.34	15.00	32.30	261.75	215.33
3	Manure (Rs/Ha)	22.05	40.00	156.12	708.03	390.30
4	Human labour (Rs/ha)	5.33	13.06	35.70	669.79	273.35
5	Bullock labour (Rs/ha)	8.41	15.77	32.79	389.89	207.93
C	**Yield (Qtl/Ha)**					
1	Main Product	26.10	28.30	41.87	160.42	147.95
2	By- product	5.54	3.42	2.92	52.66	85.24
D	**Prices of output (Rs/Qtl)**					
1	Main Product	476.46	919.57	1413.48	296.66	153.71
2	By- product	101.16	111.24	98.51	97.38	88.56
E	**Value of output (Rs/Ha)**					
1	Main Product	12435.69	26023.86	59182.37	475.91	227.42
2	By- product	2640.31	3148.09	4124.65	156.22	131.02
3	Gross Return	15076.00	29171.95	63307.02	419.92	217.01
F	**Cost of production (Rs/Qtl)**	477.04	955.59	1505.22	200.32	315.53

3.2 Temporal changes in Farm Harvest Prices of paddy

The results shown in Table 1.3 shows the changes in farm harvest Prices of paddy in Odisha. The increase has occurred form the year 2000-01 to 2019-20. Odisha and MSP shows 409.38 per cent ,190.74 per cent change during 2019-20 over 2000-01 respectively. Odisha shows the positive increase in farm harvest Prices of paddy.

Table 1.3 Changes in Farm Harvest Prices of paddy in Odisha

S.N.	STATES	2000-01	2019-20	% change during 2019-20 over 2000-01
1	Odisha	405	1658	409.38
2	Minimum Support Prices	540	1030	190.74

1.3.2 Growth rates of cost and Prices of paddy in Odisha

The rate of change in terms of various Costs of paddy in Odisha expressed in terms of compound growth rates estimated through exponential function were presented in Table 1.4

Table 1.4 Compound growth rate of cost of paddy in Odisha

S.N.	Particular	Period I	Period II	Overall
		2000-01 to 2010-11	2011-12 to 2019-20	2000-01 to 2019-20
1	Cost -A	6.15*	8.30*	8.91*
2	Cost -B	8.46	8.16*	10.71*
3	Cost -C	6.44*	8.63*	9.44*
4	Cost of production	5.67*	3.95*	8.01*

Note: *= Significance at 5 per cent level

During the first period 2000-01 to 2010-11 (Period-I) the estimated compound growth rates were found to be significant for all the Cost of paddy is found to be satisfactory, except Cost-B it is found to be non-satisfactory. Cost of production shows the positive and significant growth rate at 5 per cent level.

During the 2011-12 to 2019-20 (Period-II) all the Costs of paddy showed positive and significant growth rates at 5 per cent level. Cost of production shows the positive and significant growth rate at 5 per cent level.

In the overall period, all the Costs of paddy showed positive and significant growth rates at 5 per cent level. In general, it can be concluded that there was positive and significant growth rate during the period of study.

3.3 Instability of cost of paddy in Odisha

As seen from Table 1.5, that coefficient of variation of Cost-C for paddy in Odisha was highest during overall period by 50.82 per cent. For period-l the coefficient of variation is highest for Cost-B i.e. 40.09 per cent. And for period-ll it is highest for Cost-C i.e. 23.94 per cent.

Table 1.5 Instability for cost of paddy in Odisha

S.N	Particular	Coefficient of variation (CV)(%)		
		Period-I	Period-II	Overall
1	Cost -A	20.08	23.19	50.08
2	Cost-B	40.09	22.93	50.68
3	Cost-C	21.31	23.94	50.82
4	Cost of production	20.06	12.97	43.26

3.4 Trends in cost and Prices of paddy in India

The trend equations were fitted to assess the cost and Prices of paddy crops in India. Depending upon its better fit, was analysed by the production model viz, linear, second degree and third degree polynomial equation trends results are assessed and presented under cost and Prices of selected crops.

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Table 1.6 Trend in cost of paddy in Odisha

S.N.	Particulars	Model		Coefficients			
			R^2	b_0	b_1	b_2	b_3
1	Cost A	Third Degree Polynomial	0.99	9831.27	-5.19	223.70	-1221.67
2	Cost B	Third Degree Polynomial	0.96	15321.82	-11.37	443.44	-2603.79
3	Cost C	Third Degree Polynomial	0.99	21582.94	-16.45	639.21	-3897.35
4	Cost of production	Third Degree Polynomial	0.97	633.60	-0.66	21.29	-123.23

For trend analysis of Cost-A of paddy (Table 1.6), maximum value of R^2 is 0.99 third degree polynomial trend is best fitted. In trend analysis of Cost-B, maximum value of R^2 i.e. 0.95 is best fitted for third degree polynomial trend. In trend analysis of Cost-C, maximum value of R^2 i.e. 0.98 is best suited for third degree polynomial trend. For trend analysis of cost of production, maximum value of R^2 i.e. 0.97 is for third degree polynomial trend which is best suited.

3.5 Index number

An index number is a statistical measure design to show the changes in variable or group of related variables with respect to time. The index numbers were worked out for the cost and Prices of paddy crop. The basic object of estimating index numbers was to make the trends in cost and Prices of selected crops. For this analysis the data pertaining to the year 2000-01 to 2019-20 i.e. last 20-year data were used. The results are presented in following tables.

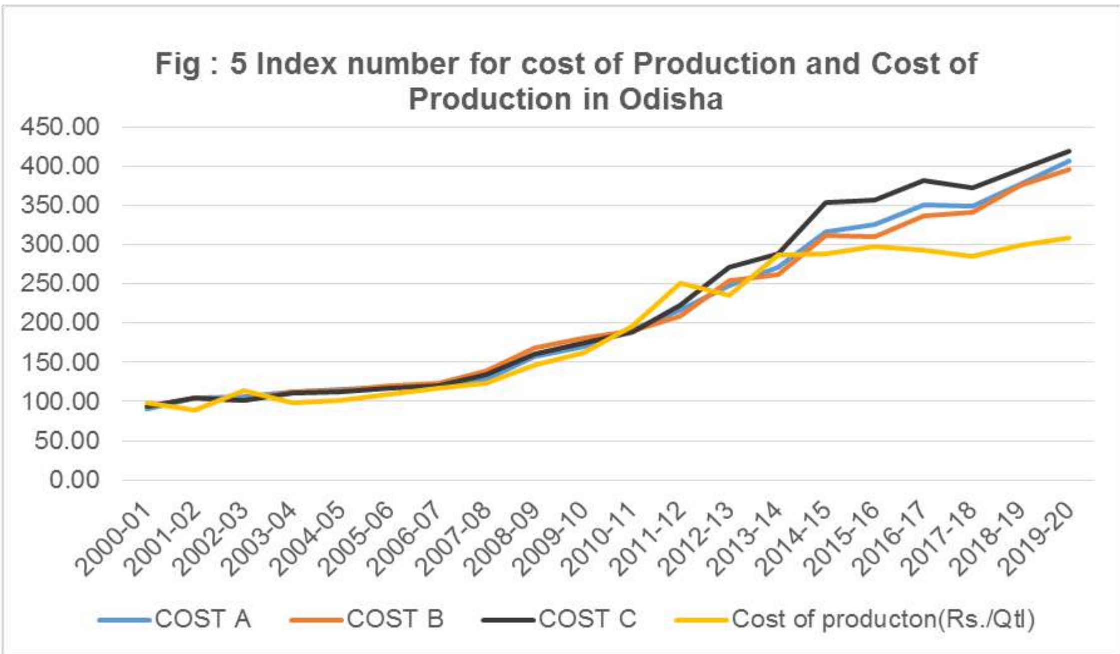
Table 1.7 indicate that the highest increase in index number of Cost-A was (394.13) in the year 2019-20 and with lowest (84.65) in the year 2000-01. Index number for Cost-B was recorded highest (375.87) among all the cost from 2019-20 and with lowest (8711) in year 2000-01. For Cost-C index number was (390.00) the highest value in 2019-20 and with lowest (88.48) in the year 2000-01. Cost of production has the highest index number of in 2019-20 (351.85) and lowest (96.46) in year 2000-01.

Table 1.7 Index number for cost of paddy in Odisha

(First triennium average as a base year)

YEAR	COST A	COST B	COST C	Cost of production
2000-01	90.58	93.74	93.66	97.83
2001-02	104.02	104.64	104.27	88.81
2002-03	105.40	101.62	102.06	113.36
2003-04	112.52	112.17	110.79	98.00
2004-05	114.78	114.44	112.90	101.25
2005-06	118.68	119.97	116.55	108.47
2006-07	121.72	122.78	119.89	116.97
2007-08	127.16	138.71	134.74	122.98
2008-09	158.20	168.35	160.78	146.64
2009-10	170.59	180.56	174.65	162.76
2010-11	191.33	189.53	188.14	195.97
2011-12	216.78	208.99	223.23	250.49

2012-13	248.26	253.99	270.94	235.46
2013-14	271.43	261.61	288.79	286.93
2014-15	316.31	311.90	353.18	288.23
2015-16	325.96	310.23	356.47	297.43
2016-17	349.95	336.07	381.67	292.62
2017-18	348.69	341.10	372.97	285.88
2018-19	377.75	375.04	396.44	299.30
2019-20	406.55	396.15	418.79	308.69



3.6 Factors affecting cost of cultivation of paddy in Odisha

The multiple linear regressions were carried out between the independent variables and dependent variable. The independent variables that represent seeds, fertilizer and manure, human labour and bullock labour, machine labour and plant protection while dependent variable represent cost of cultivation of paddy in Odisha for overall period (2000-01 to 2019-20).

Table 1.8 Factors affecting cost of cultivation of paddy in Odisha

S.r. no	Variables	Coefficients	Standard Error	t Stat
1	Intercept	210.76	1314.86	0.16
2	X_1 (Seed)	16.07**	3.96	4.05
3	X_2 (Fertilizer & Manure)	1.99	0.65	3.07
4	X_3 (Human Labour)	0.92**	0.18	5.06
5	X_4 (Bullock Labour)	-0.61	0.81	-0.76
6	X_5 (Machin Labour)	1.59	0.87	1.83
7	X_6 (Plant protection)	-6.45	6.73	-0.96
8	R^2	1.00		
9	**F**	1799.75		

Note: **Significant at 5% level

Table 1.8 shows that the coefficient of determination (R^2) is used to measure how much the ability of the independent variable in explaining the bound variation. The coefficient of determination (R^2) obtained was 1.00. This means that 100 per cent variation explained by the studied independent variable. Seed and human labour were found to be statistically significant at 5 per cent level.

3.7 Parity between cost and Prices

In this objective the gap between Minimum Support Prices (MSP) and cost of production of major crops and gap between the Farm Harvest Prices (FHP) and Minimum Support Prices (MSP) of paddy crop from 2000-01 to 2019-20 was studied.

3.7.1 Gap between Minimum Support Prices and Cost of cultivation of paddy in Odisha

The gap between Minimum Support Prices and cost of cultivation of paddy in Odisha is presented in the Table 1.9. The gap is calculated for the study period i.e. 2000-01 to 2019-20. The results revealed that the gap between MSP and Cost of cultivation in Orissa recorded which ranged from -111.44 Rs/Qlt to 329.78 Rs/Qlt

Table 1.9 Gap between Minimum Support Prices and cost of production of Paddy in Odisha

YEAR	MSP	Cost of production	Gap
2000-01	540	477.04	62.96
2001-02	560	433.05	126.95
2002-03	560	552.75	7.25
2003-04	580	477.86	102.14
2004-05	590	493.69	96.31
2005-06	590	528.9	61.1
2006-07	610	570.35	39.65
2007-08	675	599.68	75.32
2008-09	880	715.04	164.96
2009-10	1030	793.65	236.35
2010-11	1030	955.59	74.41
2011-12	1110	1221.44	-111.44
2012-13	1280	1148.11	131.89
2013-14	1345	1399.1	-54.1
2014-15	1400	1405.45	-5.45
2015-16	1450	1450.32	-0.32
2016-17	1510	1426.87	83.13
2017-18	1590	1394.01	195.99
2018-19	1770	1459.43	310.57
2019-20	1835	1505.22	329.78

3.7.2 Gap between Farm Harvest Prices and Minimum Support Prices of paddy in India

The gap between Farm Harvest Prices and Minimum Support Prices of paddy in Odisha markets of are presented in the Table 1.10 results revealed that the average gap between FHP and MSP of paddy in Odisha recorded was 130.85 Rs. /Qlt.

Table 1.10 Gap between Farm Harvest Prices and Minimum Support Prices of Paddy in Odisha

S.N.	STATES	FHP	MSP	Gap (MSP-FHP)
1	Odisha	915.90	1046.75	130.85

1.3.7.3 Deviations of FHPs from MSPs of paddy in Odisha

To examine the effectiveness of MSP policy for paddy in Odisha, difference between its FHP and MSP was calculated in different years and is given in Table 1.11 Odisha experienced positive deviations 2, times in 20 years during 2000-01 to 2019-20. This means that the average FHP was ruled higher than MSP in 2 times out of 20 years. The adjusted difference (positive) between MSP and FHP was low as 10 per cent of MSP and the negative difference was 90 per cent.

Table 1.11 Deviations of FHPs from MSPs of paddy in Odisha

		POSITIVE DEVIATION				
S.N.	STATE	Frequency	MAPD	Range	AMPD	Per cent
1	Odisha	2	173	3-173	14.4	10
		NEGATIVE DEVIATION				
		Frequency	MAND	Range	AMND	Per cent
1	Odisha	18	-146.84	(-2)-(-356)	-16.2	90

3.8 Impact of MSP on Area, production and productivity of Paddy on Odisha

The numerical values of the linear lag function for paddy indicates that R^2 is significant at 1 per cent level and supports the results that variation in Area of paddy is explained by the explanatory variable, i.e. previous year's minimum support Prices of the Paddy. Table no 1.12 revealed that 66 per cent variation in area, 43 per cent variation in production, 25 per cent variation in productivity of Odisha is explained by independent variable i.e. lagged MSP.

The elasticity for these variables is significant at 1 per cent level in case of area, production and productivity found as -0.33 per cent, 1.90 per cent, 0.72 per cent respectively indicating thereby that previous year Prices influences current year's area production and productivity of major growing State Odisha.

Table 1.12 Impact of MSP on Area, production and productivity of Paddy on Odisha

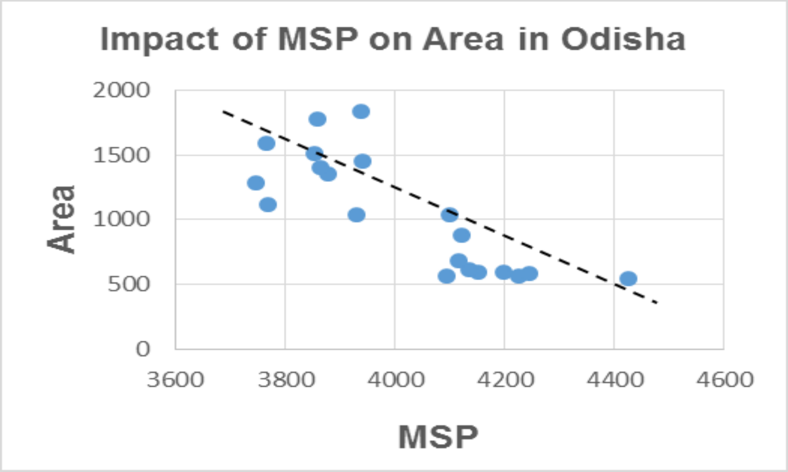
S.N.	Variables	R^2	S.E. of R	Linear regression equation
1	Area	0.66	103.08	A_t= 4332.03+(-0.33)Pr_{t-1}
2	Production	0.43	958.05	P_t=4447.35+(1.90) Pr_{t-1}
3	Productivity	0.25	543.55	Y_t=1198.65+(0.72)Pr_{t-1}

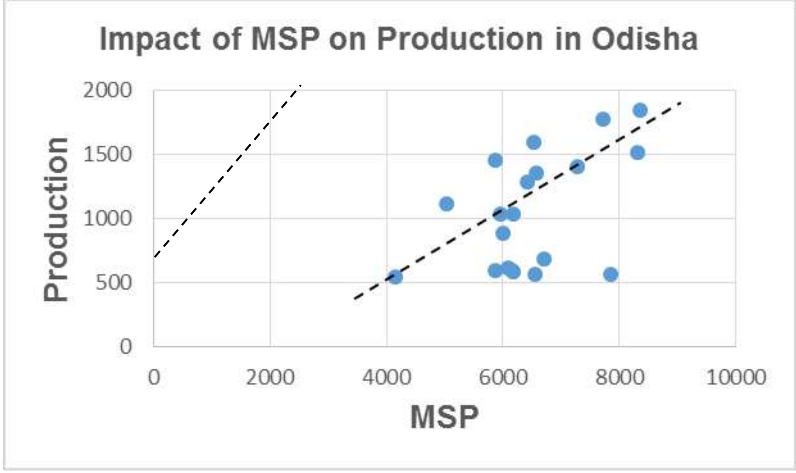
A_t= Area of paddy crop at (t^{th}) period,

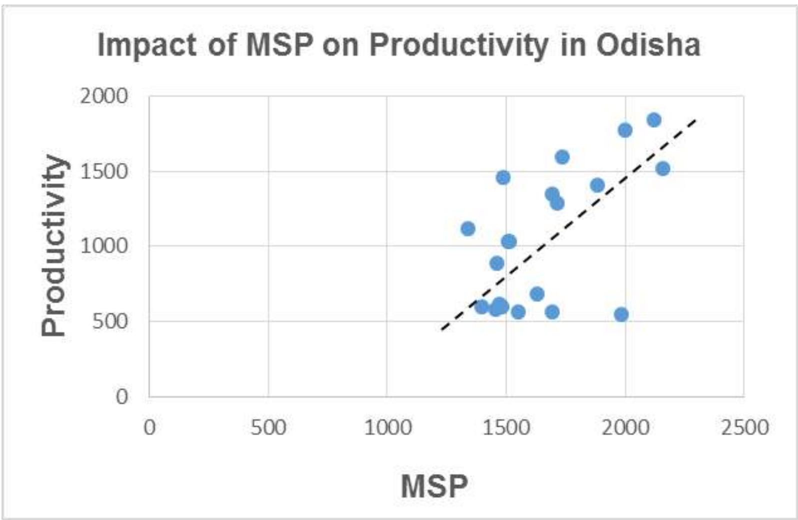
P_t = Production of paddy crop at (t^{th}) period,

Y_t= Area of paddy crop at (t^{th}) period,

Pr_{t-1} = MSP of paddy taken in Per quantal at ($t-1^{th}$) period







IV. CONCLUSIONS

The study of temporal changes, growth rate and trend enable one to indicate the general direction of change in Prices in different markets. To study the effectiveness of the Prices policy during the harvest periods, the deviations of farm harvest Prices (FHP) from the Minimum Support Prices (MSP) were worked out and divided into positive and negative deviations to examine whether market Prices ruled higher or lower than the minimum support Prices. The negative deviations reflected ineffectiveness of MSP policy for producers. These deviations were adjusted with MSP in order to examine the degree of their departure from the minimum support Prices. By using linear and logarithmic regression equations we examined the impact of previous year Minimum Support on farmer decision on acreage allocation, production, productivity for the current year.

The total cost of Paddy in Odisha has gone up from 22822.44 per hectare in 2000-01 to 45239.04 per hectare in 2010-11 and 101525.6 per hectare in 2019-20 depicting an increase during a period of study. The increase has occurred in all major items the cost of machine labour 377.33 per cent and 3064.74 per cent recorded the maximum share during percent change over in 2010-11 to 2019-20 respectively. The gross return for Paddy has recorded 419.92 per cent and 217.01 per cent form 2010-11 to 2019-20 respectively during the period study.

In Odisha the compound growth rates of various cost revealed that, during overall period growth rates of cost were increasing significantly at 5 per cent level of significance. Among the cost the growth rate for Cost-B found highest increased significantly 10.71 per cent during the study period followed by Cost-C, Cost-A and Cost of production has found increased significantly by 9.44 per cent, 8.91 per cent and 8.01 per cent resp. during the study period.

Trend analysis of cost of paddy and Prices i.e. MSP and FHP for the overall period showed that, a wide range of models has been explored, among the competitive models the best fitted models are selected based on the R^2 significance. Among the competitive parametric models, almost all cases Third Degree Polynomial models are found best fitted; thereby indicating that the movement of all the series was uniform throughout the India. The gap between MSP and cost of production of Paddy in Odisha recorded which ranged from -111.44 to 329.78 Rs/Qlt. The highest gap was registered in year 2018-19 (329.78 Rs/Qlt).

Average gap between FHP and MSP of paddy gap was registered in (-136.30 Rs/Qlt). The impact of MSP shown by linear regression equation analysis. The State wise impact of MSP on the areas, production and productivity of paddy is explained by the explanatory variable, i.e., previous year's Minimum Support Prices of the paddy. The result revealed that 86 per cent, 71 per cent and 32 per cent respectively, variation in Odisha state, Value of elasticity has found as 0.38, 2.38 and 0.47 respectively for area, production and productivity. The gap analysis in which deviations of FHPs from MSPs of Paddy crop results in maximum positive deviations (FHP ruled higher than MSP) in Odisha.

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The Study of Ecological Sensitivity Analysis of Qingdao City Using GIS and AHP Method

Tingyin Tan, Ruei-Yuan Wang*

School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
*Corresponding Author

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Abstract— *This study employs the Geographic Information System (GIS), remote sensing (RS), and the Analytical Hierarchy Process (AHP) to create a complete ecological environment sensitivity evaluation system and perform an ecological sensitivity analysis (ESA) of Qingdao City. First, a single-factor ESA was performed by selecting seven indicators of slope, aspect, Normalized Difference Vegetation Index (NDVI), river buffer zone, Land-Use and Land-Cover Change (LUCC), and soil classification, which were then superimposed in GIS based on the weight of each factor, yielding a quantitative ESA of Qingdao. The results indicate that the general ecological sensitivity of Qingdao is largely light and medium. The area proportions of extremely sensitive regions, highly sensitive areas, medium sensitive areas, low sensitive areas, and insensitive areas are 4.09%, 10.4%, 25.58%, 35.1%, respectively.*

Keyword—Geography Information System(GIS), Remote Sensing (RS), Ecological Sensitivity Analysis (ESA), Qingdao City, Analytical Hierarchy Process (AHP)

I. INTRODUCTION`

Ecological sensitivity refers to the extent to which external disturbance and intrusion cause harm to the natural ecosystem. Generally, the higher the ecological sensitivity, the more vulnerable the ecological environment is to external influences [1-3].Ecological environment sensitivity assessment (ESA) is an essential tool for assessing ecosystem stability by integrating numerous environmental influencing elements [4]. In-depth investigation and fair appraisal of ecological sensitivity in a region can serve as a scientific foundation for environmental protection policies and urban development in the area [5].

It is currently widely employed in a variety of industries, including land planning, ecological evaluation, and watershed assessment [6-9]. By precisely evaluating each region's sensitivity, we can scientifically establish adaptation methods and apply varied management based on the level of sensitivity, assuring moderate growth and effective preservation. This is the approach for maintaining ecological balance, resolving environmental issues, and preserving natural heritage.

Since the concept of ecological sensitivity was proposed, numbers of studies have conducted diversified research on it. For example, Chen and Ding (2022) refers to the city as the study scale and conducted ESA on Quanzhou City based on GlS technology[10]; Ding et al. (2022) refers to the county as the research scale, selected sensitive factors from both natural and humanistic aspects, and used The AHP-TOPSlS combination weighting method to evaluate the ecological sensitivity of Minhou County[11]; Zhang et al. (2020) study on the rural areas and used GIS to analyze the difference in ecological sensitivity of Caijiagou Village, Weifang City, Shandong Province[12]; Zeng and Shen (2018) used the regional watershed as the research scale, selected five ecologically sensitive factors such as elevation, slope, water buffer zone, Soil classification and land use status to conduct an ecological sensitivity evaluation of the West Maoli Lake watershed [13]; Yue et al. (2022) study on the scenic spots, conduct ecological sensitivity assessment of Mount Tai Scenic Area, and propose special protection strategies [14]. Overall, from the above research, the key to ecological sensitivity lies in the selection of ecological sensitivity factors, which can generally be selected from factors such as terrain, water buffer zone, and NDVI.

Qingdao is an important city on China's eastern coast. The city's environmental health is inextricably linked to the quality of life for its citizens and its long-term growth. Thus, this paper analyzes Landsat-8 remote sensing images and selects seven regionally representative ecological sensitivity factors, namely elevation, slope, aspect, water buffer zone, NDVI, soil classification, and LUCC, to form Qingdao's ecological sensitivity evaluation index. The Analytical Hierarchy Process (AHP) is utilized to determine the weight of each indicator, and geographical analysis with applicable GIS technology is used to perform single-factor and multi-factor ESA on the seven variables that were analyzed comprehensively for factor ecological sensitivity.

As a result, it can intuitively comprehend the ecological state of the region, laying the groundwork for future targeted ecological environment preservation efforts and strengthening Qingdao's ecological environment protection. Meanwhile, developing a green and sustainable development building route fit for Qingdao is critical for achieving people's and nature's harmonic symbiosis, and it has significant theoretical and practical implications.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

Qingdao City is situated in the southeast of the Shandong Peninsula, at 119°30' ~ 121°00' east longitude and 35°35' ~ 37°09' north latitude. It borders the Yellow Sea to the east and south, adjoins Yantai City to the northeast, and connects to Weifang City to the west. It borders Rizhao City in the southwest (Figure 1) and has an area of 11,000 km^2. The city is a seashore hilly city with high terrain in the east and low terrain in the west, bulges on the north and south sides, and a depression in the center. Mountains make up around 15.5% of the city's total area, hills 2.1%, plains 37.7%, and depressions 21.7%.

There are typically three mountain systems. To the southeast are the Laoshan Mountains, which are extremely steep, with the highest peak reaching an elevation of 1,132.7 meters. There are 224 big and minor rivers in the monsoon area, all of which are rain source kinds, with the majority being mountain streams that run independently into the sea. The soil is divided into five classifications: brown soil, sandy ginger black soil, fluvo-aquic soil, cinnamon soil, and saline soil.

It is situated in the northern temperate monsoon region and has a temperate monsoon climate with mild temperatures. The annual average temperature is 12.7 °C, with the highest temperature in August (average temperature 25.3 °C) and the lowest temperature in January (average temperature -0.5 °C); rainfall is abundant due to the influence of the summer monsoon, with an annual average precipitation of approximately 660 mm, primarily concentrated in July and August. Spring temperatures gradually climb, summer is hot, humid, and rainy, fall has less precipitation and strong evaporation, and winter is windy and cold for an extended period of time.

Qingdao has a diverse range of plant species, influenced by geography and climate. It is a region having a diverse range of plants at the same latitude. There are 1,237 plant resource species and variants throughout 152 families and 654 genera. The city is dominated by North China vegetation, which consists primarily of temperate deciduous broad-leaved forests and temperate coniferous broad-leaved forests, with few shrubs and grasslands. The center plains are dominated by cultivated plants, with a few evergreen broad-leaved trees and bushes scattered across the south. Several subtropical plants, including winter-resistant, nanmu, and lespedeza, may be found along the southeastern coast and islands. Agriculturally grown plants, including winter wheat, corn, and sorghum, are extensively dispersed in plain regions, as are certain planted fruit trees.

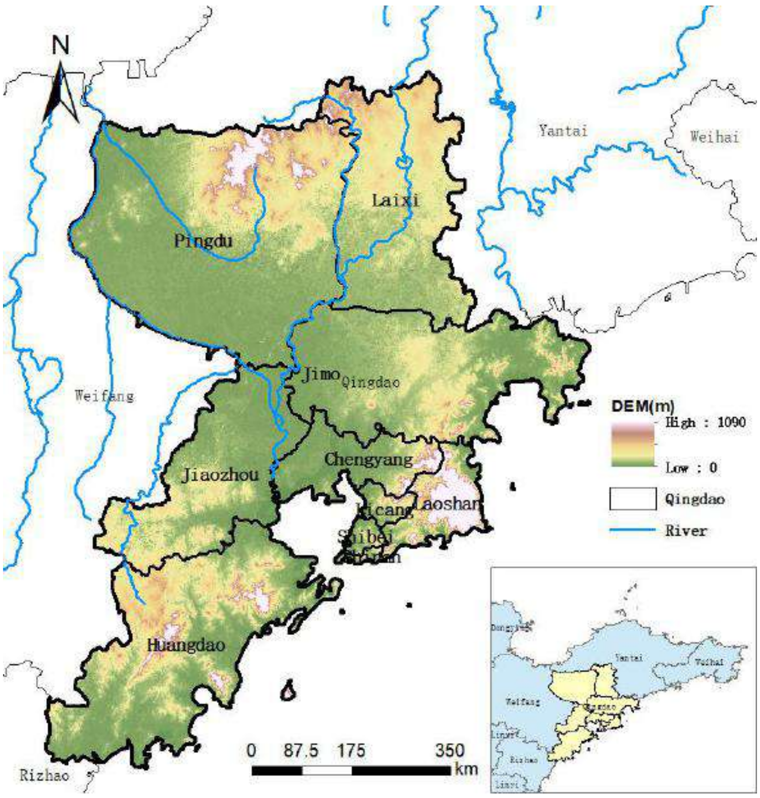


Fig.1 Location of the study area

2.2 Data Source

The study data contains Landsat-8 images and DEM data with a resolution of 30 m x 30 m in June 2016 (from the Geospatial Data Cloud), Qingdao City vector data, Shandong Province land use in 2020 (from GlobeLand30), and a 1:4 million scale soil map of China in 2000 (from SISChina) (see Table 1).

Table 1 Ecological sensitivity analysis data sources

Factors	Data content	Data Sources
Elevation	DEM elevation data (30m×30m)	Geospatial Data Cloud (www.gscloud.cn)
Slope		
Aspect		
NDVI	Landsat-8 images	
River buffer zone	Extracted from land use data of "water "	GlobeLand30 land use data set (www.webmap.cn)
LUCC	LUCC in Shandong in 2020	
Soil classification	1:4 million scale soil map of China (2000)	SISChina (www.issas.ac.cn)

III. METHODOLOGY

3.1 Method

This research is based on Landsat-8 RS images from Qingdao City taken in June 2016, a 30m resolution DEM, land use data, soil classifications, and other data. The major analysis procedure of the study is depicted in Figure 2. The particular stages are as follows.

1. Data Collection and Preprocessing: Collect the DEM, GlobeLand30 data set, and SISChina soil map. Use ArcGIS software to extract elevation, slope, aspect, and other data from Qingdao's 30m DEM; exclude Qingdao City's LUCC and Soil categorization data.

2. Use the "water" part of the LUCC to establish a multi-level buffer zone for Qingdao's river network through software operation analysis of filling, flow direction, flow rate, raster calculator, multi-ring buffer zone, vectorization, and multiple buffer analysis to obtain river buffer zone data; ENVI software obtains NDVI data through radiometric calibration, mosaic, clipping, band calculation, statistical value, and vegetation coverage calculation.

3. Use ArcGIS's reclassification function to reclassify the 7 ecological sensitivity factor data based on the predefined sensitivity levels to produce raster data.

4. Factor overlay analysis: Using ArcGIS's raster calculator tool, execute weighted overlay analysis based on the weight and sensitivity level of each evaluation component to produce the complete ecological sensitivity index for each raster unit.

5. Input the aforementioned parameters into ArcGIS to create an ecological sensitivity distribution map for Qingdao City.

3.2 Vegetation Coverage

Vegetation coverage can to some extent quantify the condition of surface vegetation and characterize the degree of ecological sensitivity. This article uses the pixel binary method to calculate the vegetation coverage in the study area [15]. The specific calculation formula is:

$$FVC = \frac{\mathrm{NDVI} - \mathrm{NDVI}_s}{\mathrm{NDVI}_v - \mathrm{NDVI}_s}$$

(1)

In the formula: FVC is the vegetation coverage, NDVI is the actual NDVI value of the pixel; NDVI*veg* is the NDVI value of pure vegetation area , theoretically close to 1 ; NDVI*soil* is the NDVI value of pure soil or non-vegetation coverage area , theoretically close to 0 .

3.3 Selection and Classification of Ecological Sensitivity Factors

After evaluating the selected 7 factors using previous researchers' grading standards [16] and natural breakpoint classification, combined with the actual situation of the study area, the 7 ecological sensitivities were divided into five levels: sensitive, slight sensitive, medium sensitive, highly sensitive, and extremely sensitive, and assigned 1, 2, 3, 4, and 5 points, respectively. The particular grading results are displayed in Table 1.

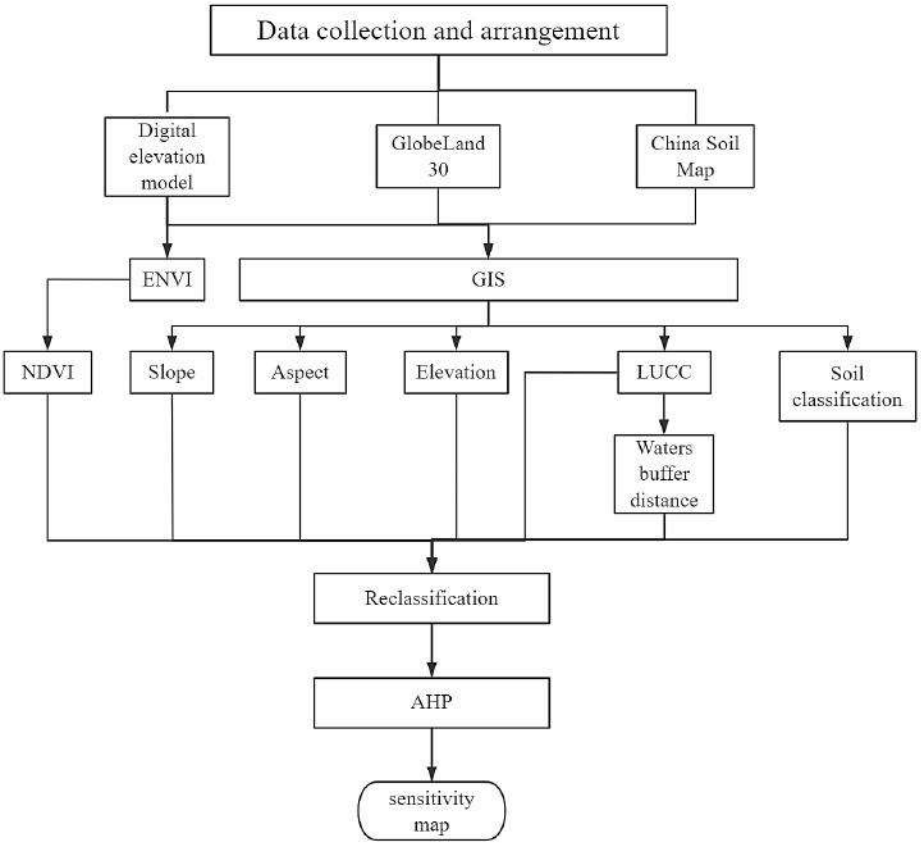


Fig.2 The scheme of the study

Table 2 Ecological sensitivity factor rating system

Index	Elevation	Slope	Aspect	NDVI	River buffer	LUCC	Soil classification	Assigned
Insensitive	≤50	<3°	Flatland, due south	<0.2	>800m	construction land	Muddy clay, brown soil	1
Slight Sensitive	50-100	3°-8°	southeast, southwest	0.2-0.4	800-500m		Yellow soil	2
Medium Sensitive	100-200	8°-15°	Due east, Due west	0.4-0.6	200-500m	Cropland	Grass felt soil (alpine meadow soil)	3
Highly Sensitive	200-300	15°-25°	Northeast, Northwest	0.6-0.8	50-200m		moist soil	4
Extremely Sensitive	≥300	>25°	due north	>0.8	<50m	Woodland, grassland and water bodies	Swamp and Coastal salt soil	5

Qingdao City's ESA is based on the original data for each element, and factor analysis is used to extract the weights of each factor on the evaluation index layer. Formula (2) calculates the sensitivity index for each assessment index based on the sensitivity levels given.

In the formula, N is the sensitivity index; i is the number of influencing factors; The weight of the factor Ci is assigned the sensitivity level of the factor.

$$N = \sum_{i=1}^{n} W_i C_i (i = 1,\ 2,\ 3,\ \ldots,\ n) \quad (2)$$

3.4 Weight Setting and Analysis of Each Evaluation Factor

The weight assigned can objectively represent the value of the assessment index [17]. This study employs AHP to provide weights to each sensitivity evaluation element. This approach creates a judgment matrix, ranks the importance, and ultimately determines if the weight value is near to the objective truth using a consistency test, resulting in the weights of various evaluation factor important levels [18].

(1) Create a judgment matrix. Use Yaahp software to analyze and rate the relevance of each aspect, then create a judgment matrix using the 1-9 score approach. The objective layer of this hierarchical structure is Qingdao's ecological sensitivity, and the indicator layer consists of seven indicators: elevation, slope, aspect, river buffer, NDVI, land use, and soil classification (Figure 3). Quantitative values are ranked in order of significance, and a judgment matrix is created using the results of pairwise comparisons.

(2) Consistency test. In order to test whether the weight value is scientific, the judgment matrix needs to be tested for consistency. This article is using AHP method. When determining the ecological sensitivity judgment matrix, the eigenvector of the matrix is B= [0.3106, 0.1465, 0.2438, 0.0685, 0.0741, 0.09860.0578], and the maximum eigenvalue of the matrix is calculated to be λ max=7.7495>7. After the consistency test, Cl= 0.1249 was obtained. After querying, when n=7, the average random consistency index RI= 1.359. Finally, CR=0.0 919 <0.1 was obtained, indicating that the judgment matrix passed the consistency test. The weight assigned to each evaluation factor is more scientific and reasonable. The assignment of weights to each factor is shown in Table 3.

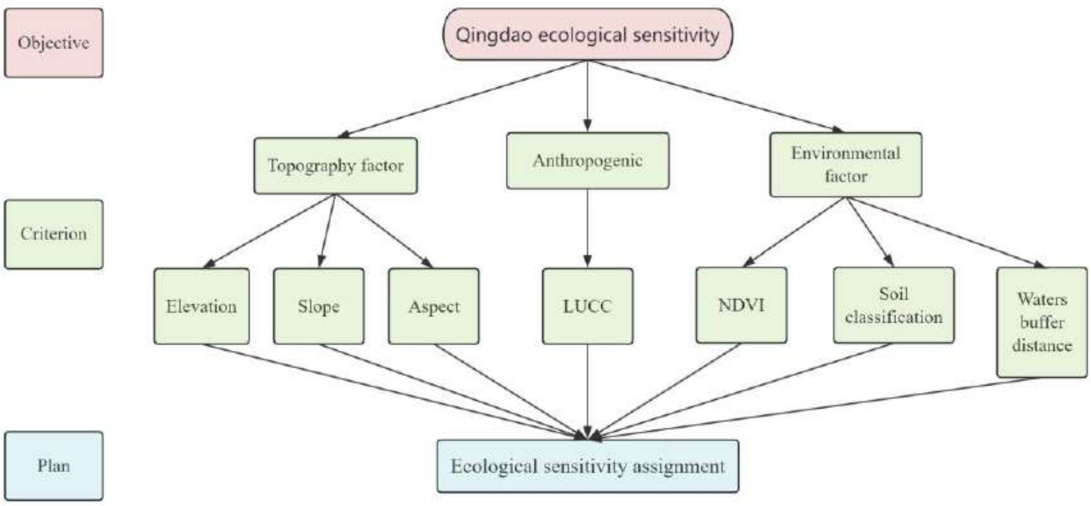


Fig.3 Ecological Sensitivity Hierarchical Model for Qingdao City

Table 3 Ecological sensitivity judgment matrix and weights

Factor	Elevation	Slope	Aspect	River buffer	NDVI	LUCC	Soil	Weights
Elevation	1	3	2	6	5	1	5	0.3106
Slope	1/3	1	1/3	2	4	2	3	0.1465
Aspect	1/2	3	1	5	4	3	2	0.2438
River buffer	1/6	1/2	1/5	1	1	1	2	0.0685
NDVI	1/5	1/4	1/4	1	1	1	3	0.0741
LUCC	1	1/2	1/3	1	1	1	1	0.0986
Soil	1/5	1/3	1/2	1/2	1/3	1	1	0.0578

(3) Weighted superposition analysis. This article uses the raster calculator tool of ArcGlS to perform a weighted overlay analysis based on the weight of each factor. The calculation formula is shown in Equation (3) and then uses the natural breakpoint method to divide it into five ecological sensitivity levels: insensitive, slight sensitive, medium sensitive, highly sensitive, extremely sensitive, and finally the ecological sensitivity distribution map of Qingdao were obtained.

$$S_i = \sum_{k=1}^{n} W_k \times C_i(k)$$

(3)

In formula (3): i is the evaluation unit number; K is the evaluation factor number; n is the total number of evaluation factors; S_i is the comprehensive value of the i-th evaluation unit; W_i is the weight of the k-th evaluation factor; C_i (k) is the sensitivity evaluation value of the k-th evaluation factor of the i-th evaluation unit.

IV. RESULTS AND ANALYSIS

4.1 Single Factor Sensitivity Analysis and Evaluation

The single-factor ESA of Qingdao is shown in Figure 3, and the grading proportions of each evaluation factor in Qingdao are shown in Table 3.

4.1.1 ESA of Land Use

LUCC plays a key role in the quality of the regional ecosystem, and even has a decisive impact on the sustainable ecological development of the region in some aspects. In areas dominated by construction land in the study area, the ecosystem structure is relatively stable and the ecological sensitivity is weak. However, areas dominated by land types that are susceptible to natural or artificial impacts, such as water bodies and woodlands, have fragile ecological structures and high ecological sensitivity.

Judging from the spatial distribution in Figure 4(a), the insensitive areas are mainly distributed in Chengyang District, Licang District, Shibei District, and Shinan District, with a small number of areas distributed in Pingdu City, Laixi City, Jimo District, and Huangdao District; Qingdao City's land use sensitivity is mainly moderate, with medium sensitive areas widely distributed in various regions of Qingdao; extremely sensitive areas are mainly concentrated in Laoshan District, with a small number distributed in Pingdu City and Huangdao District; these places have relatively fragile ecological environments and are extremely sensitive to land use changes. In terms of area proportion, the medium-sensitive area is dominated by the area of 7746.28 km^2, accounting for 73.9% of the total area; the insensitive area is 1934.56 km^2, accounting for 18.46% of the total area; and the extremely sensitive area is 801.49% km^2, accounting for 7.64% of the total area.

4.1.2 ESA of Vegetation Coverage

Vegetation has the functions of soil and water conservation, water conservation, air purification, etc., and can reduce the risk of various ecological and environmental problems. It can be seen from Figure 4 (b) that the insensitive area occupies the smallest area, only 397.49 km^2, and accounting for 3.59% of the total area, and is distributed in the edge areas of Chengyang District and Jimo District; slight sensitive areas and medium sensitive areas. They occupy the largest areas, 2137.78 and 3902.85 km^2, respectively, accounting for 19.33 and 35.29% of the total area, respectively. They are widely distributed in various areas except Laoshan District; the areas of highly sensitive areas and extremely sensitive areas are 2419.11 and 2201.43 km^2 respectively, accounting for 21.88 and 19 of the total area, respectively. 91%, mainly concentrated in Laoshan District, Pingdu City, and Huangdao District.

4.1.3 ESA of Altitude

Regional vertical differentiation is caused by altitude. As altitude increases, biodiversity will gradually decrease, and the environment's ability to resist external interference will also weaken accordingly. Therefore, the higher the altitude, the higher the ecological sensitivity [19]. According to Figure 4(c), it can be seen that the spatial distribution pattern of altitude sensitivity in Qingdao generally shows a gradual increasing trend from low altitude to high altitude. The extremely and highly sensitive areas occupy the smallest areas, which are 200.22 and 174.74 km^2, respectively. Accounting for 1.81 and 1.58% of the total area, respectively, they are concentrated in Laoshan District with a small amount distributed in Pingdu City and Huangdao District; the medium-sensitive area covers an area of 908.23 km^2, accounting for 8.21% of the total area, and is distributed in hilly areas. Marginal zone; the slight sensitive area covers an area of 2201.54 km^2, accounting for 19.91% of the total area, distributed in Laixi City; the insensitive area occupies the largest area, accounting for 2201.54 km^2, accounting for 68.49% of the total area, widely distributed in various areas of Qingdao.

4.1.4 ESA of Aspect

Aspect largely affects how long vegetation is exposed to solar radiation. Since our location is located in the northern hemisphere, the northern slope receives shorter sunlight hours than the southern slope, resulting in poorer biodiversity and higher ecological sensitivity on the northern slope. It can be seen from Figure 4 (d) that the slope aspect sensitivity in Qingdao is spatially dispersed. Among them, the extremely sensitive area is the smallest, 1389.96 km^2, accounting for 12.56% of the total area; the highly sensitive area is 2608.34 km^2, accounting for 23.58% of the total area; the medium sensitive area is 2207.15 km^2, accounting for the total area 19.98%; the area of the slight sensitive area is 2665.56 km^2, accounting for 24.1% of the total area; the area of the insensitive area is 2187.07 km^2, accounting for 19.78% of the total area.

4.1.5 ESA of Slope

Slope is one of the main causes of collapses, landslides, geological disasters, and serious water and soil erosion. It has a greater impact on land use structure and indirectly affects the growth and distribution of plants. It can be seen from Figure 4(e) that the overall slope sensitivity of Qingdao is low. Among them, the extremely sensitive area is the smallest at 141.96 km^2, accounting for 1.28% of the total area. It is mainly distributed in Laoshan District, and a small part is distributed in Huangdao. District, Pingdu City; the highly sensitive area covers the same area of 427.47 km^2, accounting for 3.87 % of the total area, and is distributed around the extremely highly sensitive area; the medium sensitive area covers an area of

1398.66 km^2, accounting for 12.64% of the total area, and is distributed in In Huangdao District, Pingdu City, and Jiaozhou City, the area of slightly sensitive areas is 3772.43 km^2, accounting for 34.12% of the total area, mainly distributed in Laixi City and Jimo District; the area of insensitive areas is 5317.44 km^2, accounting for 48.09% of the area, widely distributed in various areas of Qingdao.

4.1.6 ESA of River Buffer

The water system offers vital living conditions for nearby creatures. The closer the land is near the water system, the more human intervention activity and urbanization there is, and therefore the ecological sensitivity increases. Using ArcGIS's buffer analysis function, buffer the river for 50, 200, 400, 600, and 800 meters, respectively, to generate the ecological sensitivity classification map 4 (f) of the water buffer zone. The ecological sensitivity of Qingdao's river buffer zone is low, and it correlates positively with distance from the river as a whole. The closer the region is to the river, the more sensitive the ecosystem. The extremely region is 220.87 km^2 and accounts for 2.04% of the total area. The highly sensitive zone covers 313.79 km^2, or 2.89% of the total area. The medium sensitive zone has an area of 810.83 km^2, or 7.46% of the total area. The slightly sensitive zone covers 955.26 km^2, which accounts for 8.78% of the total area. The insensitive area is the largest, with 8567.02 km^2, representing for 78.83% of the total area and is spread around the city.

4.1.7 ESA of Soil Classifications

There is a substantial relationship between soil classification and ecological sensitivity. Because of variances in physical, chemical, and biological qualities, various soil types respond and recover differently to changes in the ecological environment.

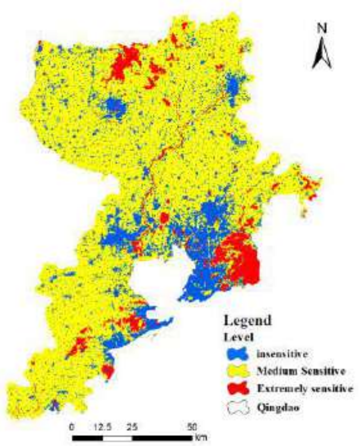
Figure 4 (g) shows that the highly sensitive area of Soil categorization sensitivity in Qingdao is the smallest, measuring 114.59 km^2 and accounting for 1.07% of total area. It is found on the border of Chengyang District and Pingdu City, with marshy coastal salt soil and coastal salt soil. Existing in specific geographical environments, the soil in these areas is extremely sensitive to environmental changes and necessitates special protection and management measures; the highly sensitive area covers an area of 2035.19 km^2, accounting for 19.07% of the total area, and is primarily distributed in Jimo District, Chengyang District, Pingdu City and Laixi City. These areas have plain depressions, poor drainage, and wet fluvoid soil, and are very sensitive to environmental changes; the medium sensitive area covers an area of 2467.12 km^2, accounting for 23.11% of the total area, mainly distributed in Pingdu City, Jiaozhou City, Jimo District, Licang District, Shibei District, Shinan District, with a small number distributed in Laixi City and Huangdao District; the slight sensitive area covers an area of 377.76 km^2, accounting 3.54% is only scattered in the southern half of Huangdao District; the insensitive area is 5679.57 km^2 (53.21% of the total area), which is extensively distributed across Qingdao City.

4.2 Comprehensive Evaluation and Analysis

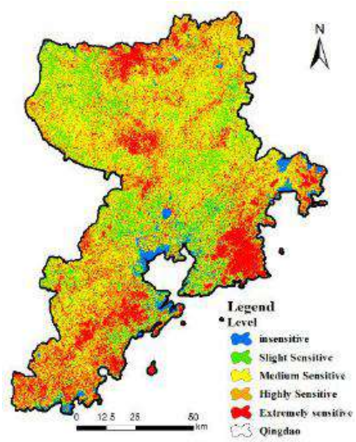
A weighted overlay analysis was performed in ArcGlS software using the weight of each indicator obtained from the analytical hierarchy process, along with the seven indicators of elevation, slope, aspect, river buffer NDVl, LUCC, and soil classification. The natural discontinuity method was used to divide the five levels. The range of Qingdao's total ecological sensitivity evaluation index is 1 to 4.56 (Table 5), with an average value of 2.614. The overall ecological sensitivity is low, and the ecological sensitivity in the center area is relatively low. The adjacent hilly areas exhibit higher sensitivity.

The ESA index of insensitive regions in Qingdao ranges from 1 to 1.71, accounting for roughly 24.83% of the city's territory (Figure 5 and Figure 6). It is mostly spread in the Chengyang, Licang, and Shibei districts of

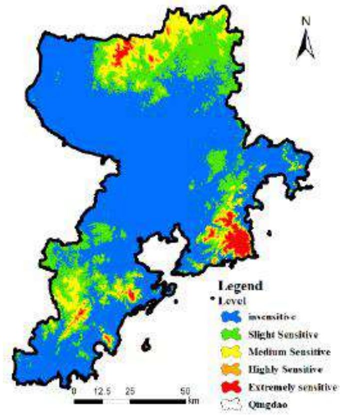
Qingdao City. District and Shinan District are located in plain areas appropriate for human habitation and agricultural activities, with a high degree of land usage, but they also require adequate planning to prevent ecological environment degradation.



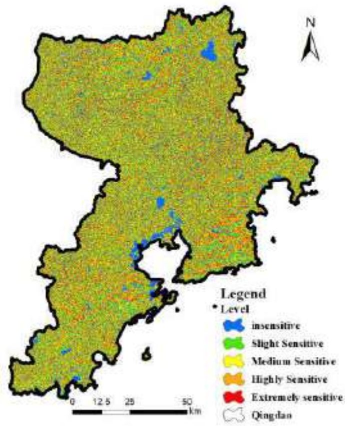
(a)LUCC



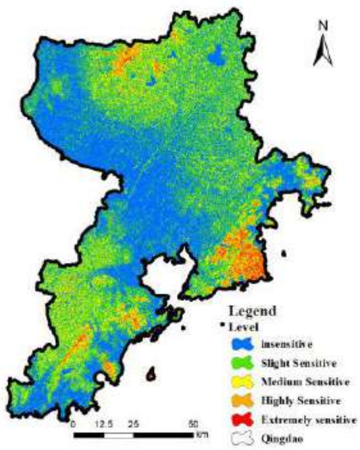
(b)NDVI



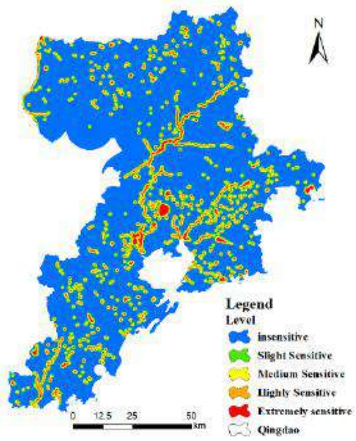
(c) Elevation



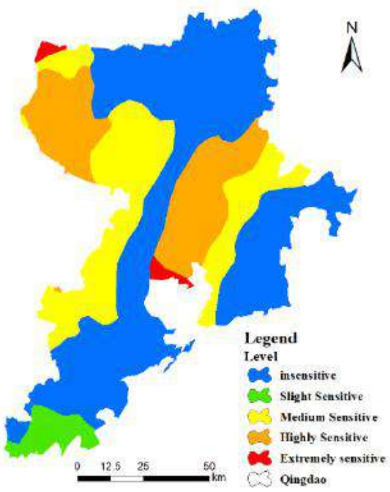
(d)Aspect



(e)Slope



(f)River buffer zone



(g)Soil classification

Fig.4 Single-factor ESA in Qingdao

Table 4 Grading proportions of each evaluation factor in Qingdao

Factors	**Insensitive(1)**		**Slight Sensitive(2)**		**Medium Sensitive（3）**		**Highly Sensitive（4）**		**Extremely sensitive（5）**	
	Area/km²	**ratio/%**	**Area/km²**	**ratio/%**	**Area/km²**	**ratio/%**	**Area/km²**	**ratio/%**	**Area/km²**	**ratio/%**
Elevation	7573.72	68.49	2201.54	19.91	908.23	8.21	174.74	1.58	200.22	1.81
Slope	5317.44	48.09	3772.43	34.12	1398.66	12.64	427.47	3.87	141.96	1.28
Aspect	2187.07	19.78	2665.56	24.1	2207.15	19.98	2608.34	23.58	1389.96	12.56
River buffer	8567.02	78.83	955.26	8.78	810.83	7.46	313.79	2.89	220.87	2.04
NDVI	397.49	3.59	2137.78	19.33	3902.85	35.29	2419.11	21.88	2201.43	19.91
LUCC	1934.56	18.46			7746.28	73.9			801.49	7.64
Soil classification	5679.57	53.21	377.76	3.54	2467.12	23.11	2035.19	19.07	114.59	1.07

The ESA index for slightly sensitive areas ranges between 1.71 and 2.08, it accounted for approximately 35.1% of Qingdao's total area and was widely scattered around the city. Qingdao's ecosystem has a strong anti-interference ability due to frequent human activity. Medium sensitive areas have an ecological sensitivity evaluation index of 2.08 ~2.53 and cover approximately 25.58% of the area, primarily in Huangdao District, Laixi City, Pingdu City, and Jimo District. The ecological environment in these locations is relatively fragile and requires careful preservation and management.

The ecology of highly sensitive zones, the sensitivity evaluation index runs from 2.53 to 3.27, which accounts for approximately 10.4% of Qingdao's area. It is mostly found on the periphery of extremely sensitive areas with complex terrain, heavy forest cover, relatively weak ecological stability, and susceptibility to environmental changes.

The ESA score for extremely sensitive regions spans from 3.27 to 4.56, accounting for approximately 4.09% of the total area of Qingdao. It is primarily spread in Laoshan District, Huangdao District, and Pingdu City, Qingdao. These locations include natural reserves and water supplies. Other key ecological functional zones are particularly valuable for biodiversity conservation and ecosystem services.

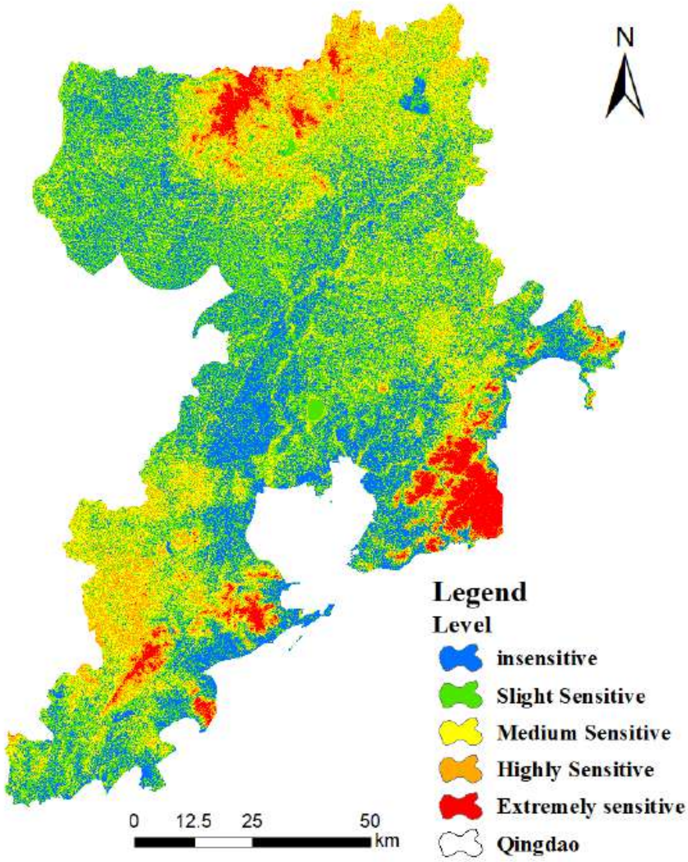


Fig.5 Ecological sensitivity analysis of Qingdao City

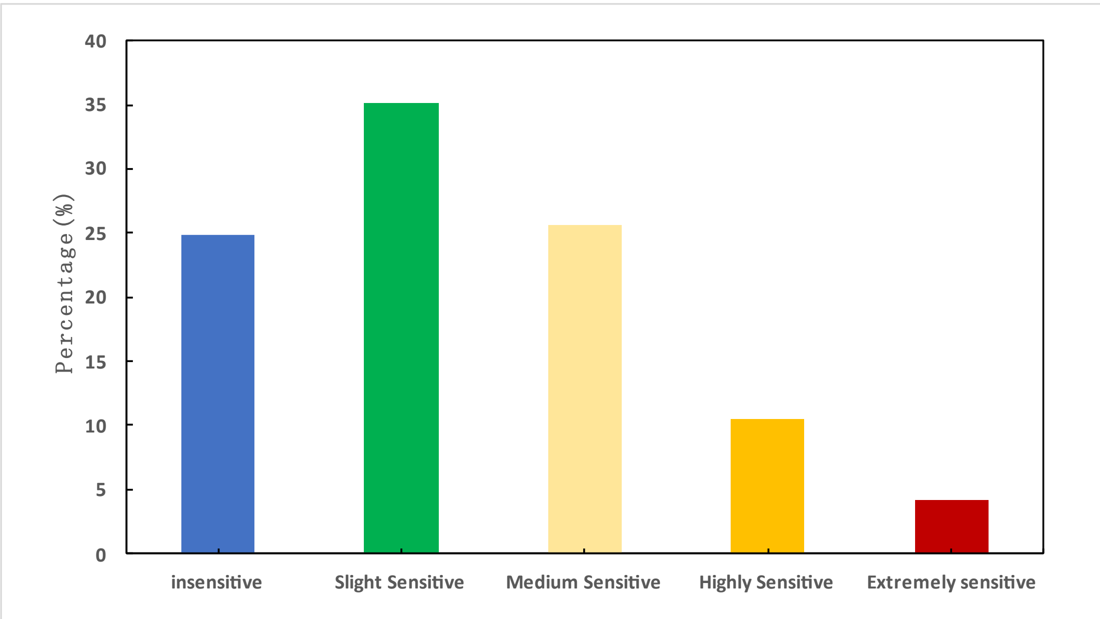


Fig.6 Percentages of various levels of ecological sensitivity in Qingdao

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Table 5 Comprehensive evaluation results of ecological sensitivity in Qingdao

Assigned	Sensitivity level	Ecological sensitivity index classification	Area/km^2	Proportion/%
1	Insensitive	1-1.71	2537.22	24.83
2	Slight Sensitive	1.71-2.08	3585.82	35.1
3	Medium Sensitive	2.08-2.53	2612.71	25.58
4	Highly Sensitive	2.53-3.27	1062.3	10.4
5	Extremely Sensitive	3.27-4.56	417.43	4.09

V. CONCUSIONS AND SUGGESTIONS

5.1 Conclusions

This work uses GlS and AHP to determine the overall sensitivity of the ecological environment in the study region using a single factor and comprehensive ESA.

(1) The use of GlS and AHP methods to evaluate ecological environment sensitivity can effectively identify the spatial distribution characteristics of ecological sensitivity, as well as quantitatively analyze and map them; elevation is one of the seven evaluation factors that has a significant impact on the ecological environment of Qingdao City. Sensitivity has the most influence, with a weight of 0.3106, while soil classification has the least impact on Qingdao's ecological environment sensitivity, with a weight of 0.0578.

(2) Qingdao's ecological sensitivity is classified as mild sensitivity. Overall, the high-altitude mountainous areas to the north and south are more susceptible than the central region. Medium sensitivity accounts for 35.1% and is primarily spread in areas with relatively flat or gentle slopes. Extremely highly sensitive areas account for at least 4.09% and are primarily distributed in mountainous areas with greater elevations in the north and south.

5.2 Suggestions

(1) Extremely sensitive and highly sensitive areas feature high altitudes, steep slopes, little light, thick forest cover, and low levels of development. The ecology has a limited ability to resist external influence, which may readily cause system degeneration. This area is mostly dispersed in mountainous regions with greater elevations in the north and south. It also has a high concentration of natural reserves and forest parks. It is critical for protecting animal and plant habitats and preserving biodiversity. As a result, we must severely safeguard the ecological environment and intensify measures such as closure, afforestation, and management to enhance the stability of the regional ecosystem.

(2)Medium-sensitive zones are primarily found in low-mountain and hilly regions surrounding cities. The ecological environment in these areas is relatively fragile, but the level of development is high. They require modest protection and management to improve ecosystem service functions and minimize environmental pressure.

(3) Insensitive and slightly sensitive regions are primarily found in plain areas with dense populations. This is a region with a high concentration of human activity. It has a high level of development and only one plant type. It can withstand some human influence and tolerate modest pollution, explore, and utilize. However, because of its proximity to a river, pollution of water bodies should be avoided during development and construction, while green development, production, and lifestyle should be encouraged in order to achieve coordinated economic and social development as well as ecological and

environmental protection.

(4) When combined with the full ecological sensitivity study results, Jiaozhou City, Qingdao, is typically in an insensitive area and is suitable for further development and exploitation.

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A Complete Guide: Kitchen Gardening

Ms. Harsha S. Kumbhalkar[1], Mr. Rushikesh D. Aghav[2], Dr. Suraj P. Khedkar[3]

[1]Ph.D. Scholar, Fruit Science Department, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India
[2]Ph.D. Scholar, Department of Agriculture, Sunrise University Alwar, Rajasthan, India
[3]Ph.D. Scholar, Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli, Maharashtra, India

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***Abstract*— *With the help of technology, we can cultivate nutritious vegetables at home using clay pots, empty tins, and discarded utensils. This is known as kitchen gardening. It has been discovered that kitchen/home gardens significantly contribute to the improvement of food security for rural, resource-poor households in developing nations. It is essential for people to keep their health to eat a nutritious diet. Grains, breads, legumes, fruits, vegetables, herbs, and so forth make up a balanced diet. Vegetables are a vital part of a balanced diet since they offer a range of nutrients required for many body functions. About 300 g of vegetables and 100 g of fresh fruits are needed each day (50 g of green leafy vegetables, 200 g of other vegetables, and 50 g of roots and tubers). Growing a variety of crops in your home garden is one of the simplest methods to guarantee that you have access to a balanced diet with enough macro- and micronutrients.*

***Keywords*— kitchen gardening, nutritious vegetables, food security, balanced diet, home cultivation.**

I. INTRODUCTION

India ranks 111th out of 125 countries in global hunger Index and suffers from a serious level of hunger with a score of 28.7 on a 100 scale where 0 (zero) is the best score (no hunger) and 100 is the worst. (GHI, 2023).One of the most crucial areas to concentrate on in developing countries like India is food security and nutritional diversity. Many strategies are required to address the problems of food production and food security. The current social, political, and economic landscape as well as the resources available to plan and carry out the intervention will determine which workable strategies are best. Using home labour in the kitchen garden can increase the household's nutritional diversity and food security. Even in the tiny regions surrounding the house when land resources are limited, a difference in life can be made. Small towns and households make use of vacant land to supply their own food needs as well as the needs of the city in which they live. (Dresche, 2000). A kitchen garden is a garden that is grown in the backyard of a home using the waste water from the kitchen. Also known as a "home garden," "nutrition garden," "kitchen garden," or "vegetable garden," these spaces are used to grow herbs and vegetables for domestic use. A small plot of land next to the house has been used for seasonal vegetable gardening since ancient times. In the kitchen garden, local varieties are grown, including radish, broad leaf mustard, chilli, beans, pumpkins, tomatoes, etc. It is common knowledge that we ought to consume our vegetables. That is the path to health, and we will be happy and healthy if we grow our own greens. You will always be content if you engage in creative endeavours, and gardening is no exception. Cooking in the kitchen brings so much flavour to life. Many of our elders stressed the value of garden produce for a healthy diet long before doctors began prescribing vitamins, minerals, and fiber. Vegetables grown in gardens without the use of pesticides are increasingly becoming popular hobbies. It is inexpensive and requires little space to grow food in the kitchen. You can even grow food in your kitchen by using your window sills or balconies.

Importance of kitchen garden:

A healthy diet is crucial for people to maintain their health. A balanced diet consists of grains, breads, pulses, fruits, vegetables, herbs, and so on. The daily requirement of vegetable is around 300 g vegetables and 100 g fresh fruits/day (green leafy vegetables 50 g, other vegetables 200 g, roots and tubers 50 g) (Singh et al., 2018). As they provide a variety of nutrients necessary for numerous bodily processes, vegetables are an essential component of a healthy diet. Vegetables are vital for development, energy, and illness prevention. Particularly for the young and for women who are pregnant or nursing, vegetables are important. Vegetables are widely acknowledged for their importance in terms of human nutrition, the national economy, and health standards. They are an excellent source of minerals, proteins, and vitamins. Compared to other crops, vegetables yield a significantly higher income per unit area and time. Due to their short growing seasons and year-round availability, they make excellent choices for home gardens. Fruits, vegetables, and other food crops are grown in the nutrient-dense home garden, which is typically close to the house. It is the area of ground in the backyard that family members cultivate a variety of fruits, vegetables, and spices to augment what is immediately needed in the kitchen. This practice not only ensures a healthy diet but also lowers living expenses and increases family income. Home gardens can aid in the recycling of leftover materials, particularly if a compost pit is established.

Benefits of the kitchen garden

- ❖ To reduce the expense of purchasing herbs and vegetables.
- ❖ Grow your own vegetables for health benefits.
- ❖ There are ways to turn household waste into something useful.
- ❖ Supply fresh fruits and vegetables high in nutritive value.
- ❖ Provide a diverse range of fresh produce that is high in nutrients and devoid of harmful chemicals.
- ❖ Vegetables from your home garden have a better flavour than those you buy at the store.
- ❖ Making efficient use of kitchen garbage materials and wastewater.
- ❖ To increase health for both the mind and body.
- ❖ This will only make it easier for us to successfully produce the vegetables we need.
- ❖ Developing a garden yields two benefits: producing food and revenue.
- ❖ Additionally, to providing fuel wood, furniture, crafts, baskets, and other household necessities, gardens also serve as a source of food for domestic animals.

How to make a kitchen garden?

Many people are unable to cultivate the vegetables necessary for a healthy diet because there is frequently no tradition of kitchen gardening. Alternatively, they overspend on vegetables, or the deficiency in vegetables negatively impacts their health. It is possible that you have failed to establish a kitchen garden. There are several reasons why starting a kitchen garden can be challenging, or why starting one will not work out.

For example:

- The crop was damaged by livestock disease s, or pests.
- No good seed or seedlings
- Lack of space
- Lack of water
- Lack of fertility
- No spare time
- Lack of the right skills

In order to create and maintain a kitchen garden with ease and optimal yield, the following elements are critical:

1) **Site selection**: Backyard of house

   The backyard of the home; ideally, this should be an open space with lots of sunlight close to the water source. Vegetable garden dimensions and design are determined by

   - Availability of land
   - The number of family members and
   - Spare time available for its care
   - For a household of five, around five cents of land (200 m2) is enough to produce vegetables all year long.
   - Rather than a square plot or a lengthy stretch of ground, a rectangle garden is preferred.

Table 1: Crops suitable for kitchen garden

Fruits	Vegetables	Spices	Medicinal Plants	Flowers	Trees
Mango Banana Sapota Guava Papaya Acid lime Amla	Tomato Brinjal Chilli Onion Okra Cabbage	Turmeric Coriander Fenugreek Garlic Ginger	Aloe Mint Basil Vetiver Ashwagandha sarpgandha	Rose Jasmine Nerium Marigold Chrysanthemum	Bottle brush Pagoda tree Gulmohor

Pomegranate Anona Date Pam Jamun Fig Dragon fruit Jackfruit Ber Karonda	Bitter gourd Snake gourd Rigde gourd Bottle gourd Pointed gourd Amaranthus Lab lab Pea Beetroot Carrot Radish Curry leaf Moringa Spinach Cluster bean Cowpea Tapioca Agati Pumpkin Taro Cucumber		Adulsa Sadaphulli Gulvel Hirda Behada Shatavari Lemmon grass	Tuberose Sunflower Hibiscus Periwinkle Night Jasmine	

2) Garden design:

When seeds and seedlings are placed too far apart, a large portion of the interstice is wasted and becomes home to weed growth. In addition to taking up valuable water and compost, weeds require more work to keep free. Additionally, you must put in more effort to replenish the water and compost that the weeds steal. For this reason, dense vegetable planting is ideal. However, if a single variety of vegetable is planted in large quantities, it will fight with itself for resources both above and below ground, making it a poor crop. Therefore, it is preferable to grow a variety of small and large varieties to create distinct layers of crops on one bed. Additionally, the soil's root layers for these will change.

3) Edge planting:

Edge planting helps to make maintenance work easy in the kitchen garden. Edge planting means the growing of support crops or companion crops in the edges around the garden and its beds. These plants help support the garden by providing mulch, protection from weeds, wind breaks, repelling pests and producing other useful resources. Plants such as marigold, lemongrass, mulberry, basil, and many others are good for edge planting. Edge planting helps to protect the garden and produces fodder, fuel, nectar for bees, herbs for medicines, soil conservation, habitat for pest predators, etc. Edge plants take nutrients from deep in the soil and cycle them to the surface, where they are used as mulch, and then returned to the soil.

4) Land preparation

1. Stones, stubbles, bushes and perennial weeds should be removed.
2. Soil should be porous that is why through spade digging is made to a depth up to 30-40cm
3. Well decomposed at about 100 Kg farmyard manure or vermicompost is applied and mixed with the soil
4. Flat nursery bed, raised seedbed, ridge seedbed, should formed as per the requirement.

5) Sowing and planting

1. Direct sown crop like okra, cluster beans and cowpeas can be sown on one side of the ridges at a spacing of 30 cm. Amaranthus can be sown after mixing 1 part of seeds with 20 parts of fine sand by broadcasting in the plots.
2. Small onion, mint and coriander can be planted/ sown along the bunds of plots.
3. Seeds of transplanted crops like tomato, brinjal and chilli can be sown in nursery beds or pots one month in advance by drawing lines.
4. Flat bed- Vegetables such as beet leaf, coriander, fenugreek, spinach and root vegetables like carrot, radish, turnip, beetroot are sown by broadcasting or line sowing. Peas beans are sown

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in lines are facilitates ease in intercultural operations and harvesting.

5. Raised seedbed- These beds are prepared for raising cucurbitaceous crops like bitter gourd, bottle gourd, round gourd, smooth gourd, pumpkin, watermelon during rainy season where stagnation of water becomes problematic, beds of required size depending on crop to be grown are raised 15-25 cm high from the ground level with furrows of 30-45 cm width on either side for irrigation. The objective using such raised beds in rainy season is to provide protection to the fruits against rotting.
6. The perennial plants should be located on one side of the garden, usually on the rear end of the garden so that they may not shade other crops, compete for nutrition with the other vegetable crops.

Table 2: Crop calendar: Recommended vegetables, tuber crops and fruits for kitchen gardening.

Recommended Crop	**Season**		**Transplanting (Pot or field)**	**Seedrate (g/Marla)**	**Duration (Days)**	**Availability period**
Vegetables	**Winter**	**Summer**				
Tomato	Oct.-Nov.	---	After 25-30 Days	0.789g	135-150	April- July
Peas	Oct.-Nov	---	---	1875g	90	Nov-Dec.
Okra	---	March	---	62.5g	45-50	April-Sept.
Onion	Oct.-Nov	---	After 40-45 Days	25g	145-150	May
Brinjal	Sept.-Oct.	June- July	After 30-35 Days	1.25g	160-165	April- June
Cucumber	Feb-March	July- Aug	---	6.25g	120	April- May Sept.-Oct.
Chili/peppers	Oct-Nov	May- June	After 40-45Days	3.12g	210-240	May- July
Pumpkin	Oct- Nov	----	---	12.5g	135-180	April-May

6) Seeds and seedlings

A kitchen garden can provide very good food from local, traditional vegetables and its importance not to lose these local varieties. However, sometimes farmers are also interested to try new varieties. So, it is very important to save and protect any good seed- this is the farmer’s responsibility. From good seed, it is important to be able to raise good, healthy seedlings for transplanting into kitchen garden. Good quality seed can recommend that gardeners should emphasis on high yielding and hybrid seeds along with local varieties. Cultivated crops for kitchen gardening are generally- tomato, brinjal, chilli, capsicum, cauliflower, cabbage, broccoli, knol-khol, radish, carrot, peas, bottle gourd, bitter gourd, cucumber, okra, French bean, palak, sweetpotato, ginger, turmeric, dolichos bean and Colocasia.

Table 3: Cropping pattern, which may prove helpful for kitchen under Indian conditions.

Vegetable	Sowing time	Spacing rows (cm)	Plants (cm)
Carrot	August-September	45	7.5
Radish	Mid-September to October	45	7.5
Coriander	October-November	30	Inrows
Spinach	September-October	20	Inrows

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Metha	October-November	22.5	Inrows
Methi	September-October	20	Inrows
Peas	Mid-October to mid-November	30	10
Okra	February-March and June-July	45	15
Bottle gourd	February-March and June-July	250	60
Bitter gourd	February-March and June-July	150	45
Cucumber	February-March	250	60
Cowpea	February-March and June-July	45	15
Pumpkin	February-March	300	60
Sponge gourd	February-March and June-July	300	75
Round gourd	February-March and June-July	150	45

7) Layout of Kitchen Garden

- Fence: a live fence with agati or a fence with barbed wire.
- The kitchen garden's periphery should be planted with perennial crops (mango, sapota, acid lime, amla, and morniga); avoid shading them.
- On one corner, there can be one or two compost pits.
- Use cucurbitaceous vegetables (bottle, bitter, snake, and ridge gourds) to train fences on all sides.
- Certain vegetables, like amaranthus, bottle gourds, bitter gourds, and snake gourds, are sown directly.
- Certain veggies (onion, tomato, brinjal, and chilies) are transplanted from nurseries.
- Create equal-sized plots in the region to be used for growing annual vegetable crops.
- In a kitchen garden, where cropping is done continuously and intensively.
- The soil's texture and fertility can be preserved by regularly adding enough organic manures.
- Every plot has ridges and furrows created in it.
- Planting season: June–July and September–October
- A bee hive can be provided for purposes other than honey production to guarantee sufficient crop pollination.
- On the other hand, chemical fertilizers are also necessary for a decent crop to be harvested.
- Remove and remove any larvae that are on fruits or vegetables, and then apply 4 milliliters of neem oil or 3 percent neem seed kernel extract per liter of water.
- Steer clear of harmful chemical spraying.

Fig. 1. Layout of Kitchen Garden

<table>
<tr><td>Goose Berry</td><td>Drumstick</td><td rowspan="2">Papaya</td><td rowspan="7">ENTRANCE</td><td colspan="2">Manure pit</td><td rowspan="2">Coccinea</td></tr>
<tr><td>Acid lime</td><td>Pomegranate</td><td colspan="2" rowspan="2">Nursery beds</td></tr>
<tr><td rowspan="3">Lab lab</td><td colspan="2">Curry leaf</td><td rowspan="3">Bitter Gourd</td></tr>
<tr><td colspan="2">Checkurrminas</td><td colspan="2" rowspan="2">Herbal plants (Vetivar, Aloe, mint, Lemmon grass, Tulsi)</td></tr>
<tr><td>Mint</td><td>Amaranthus</td></tr>
<tr><td rowspan="2">Snake gourd</td><td>Spinach</td><td>Bhendi</td><td>Green pepper</td><td>Elephant foot yam</td><td rowspan="2">Ridge Gourd</td></tr>
<tr><td>Coriander</td><td>Chillies</td><td>Peas</td><td>Cluster bean</td></tr>
</table>

	Fenugreek	Brinjal		Carrot	Cow pea	
Small Onion	Bellary Onion	Tomato		Tapioca	Radish	Beet root

8) Maintenance of Kitchen Garden

- Place all kitchen trash in the manure pits and keep them moist;
- Train the plants to grow on the fence.
- Take care of your food plants: For direct-sown plants, thinning or stalking the plants is a crucial step towards maintaining a healthy vegetable garden. Vegetables that grew tall and climbed needed to be trellised or stalked in some way. If the plants' suckers are allowed to grow and begin to compete with the original plants for nutrients, remove them.

9) Irrigation:

When and if required. Even with drip irrigation, you cannot always rely on rain. for water to be delivered to the plant roots directly.

10) Manures and Fertilizers:

- **Fertility:**It is common knowledge among farmers that crops cannot flourish in unfertile soil. However, fertility might be as scarce as water. Compost cannot be taken and used for the kitchen garden if there is not enough for the field crops. For this reason, the fertility of our kitchen garden must be self-sufficient. Below are some ideas for fertility sources:
- **Liquid manure**:Produced in a pit or a drum, liquid manure provides nutrients to plants while shielding them from illnesses and pests.
- **Sweepings pit**:You can create enough compost for the kitchen garden by gathering daily sweepings from the house and yard in one location.
- **Legumes**:Adding additional nitrogen to the soil through the planting of legumes, such as peas, beans, sesbania, sun hemp, etc., benefits other crops.
- **Green manure:** Planting green manure seeds improves soil health and increases fertility for greater yield.
- **Other sources**:You can enrich the soil with ash, oilseed cake, and other materials to boost fertility and ward off pests and illnesses.
- **Vegetables are rich in nutrients**. Naturally, different plants have different requirements, so it is critical to pay attention to any fertilization guidelines included with your seedlings or printed on the back of your seed packets. Add the composted kitchen scraps to every crop. fertilizers with complex contents at 5 grams per plant for 30, 60, and 90 days after sowing. All season long, organic plant foods will nourish your plants because they release nutrients gradually.

11) Weeding:

As and when necessary. It is important to remove weeds from surrounding pathways and grass as well; if they are allowed to go to seed, those seeds might end up in your garden.

12) Mulching: It suppresses weeds, cools plant roots and conserve water. Seed free straw. It makes nice cover; it is easy enough to push aside for planting and it can be turned into the soil at the end of the season.

13) Provide shade*:* In the hot season trees can provide shade to the kitchen garden. A few small trees or even fruit trees in the fence or within the garden can be used for this purpose. As well as giving shade, these trees can also provide other benefits, such as firewood, fodder or mulch materials.

14) Wind break: Wind will dry out the soil, so stopping the wind helps to conserve soil moisture.

15) Plant Protection: The kitchen garden requires protection right from the beginning. Livestock should not be allowed to enter the area. The fence needs to be built permanently. Although thorny plants can be chopped and used to create a fence, planting a living fence is the most effective way to keep the garden safe. Furthermore, the crops in the garden will require protection from various pests and diseases. To do this, there are numerous methods. Crop protection techniques include mixed cropping, crop rotations, liquid manure, picking and killing fruit and vegetable larvae before spraying, avoiding the use of toxic chemical sprays, etc.

Organic method of plant protection

- Neem oil
- Neem seed kernel extract
- Panchakavya

16) Implements used in kitchen garden

- Spade
- Pick Axe
- Hoe
- Hand sprayer
- Water can
- Secateur

17) Constraints in adoption of scientific kitchen gardening

1. **General constraints:**
   i. High poultry and monkey menace
   ii. Problem of proper protection of local goat and cattle grazing
   iii. Less priority of kitchen gardening as compared to other farm activities
   iv. Frequent deluge of kitchen garden during rainy season.
2. **Input constraints:**
   i. Unavailability of quality planting materials for fruits and vegetables
   ii. Lack of irrigation facility due to scarcity of water in area
   iii. Unavailability of land for kitchen gardening near residential zone
   iv. Cow dung is utilized as fuel hence organics are less available
   v. Specific eco-friendly insecticides are unavailable in market.
3. **Technical constraints:**
   i. Lack of knowledge regarding sowing time, improved varieties and seed rate
   ii. Lack of knowledge regarding nutritious fruits and vegetables selection
   iii. Lack of knowledge regarding major pests, their identification and management
   iv. Lack of knowledge regarding critical growth stages of crops for irrigation
   v. Lack of knowledge about manures and fertilizers recommendation
   vi. Lack of knowledge about seed multiplication
   vii. Lack of knowledge about seed treatment.
4. **Socio-cultural constraints:**
   i. Fear of farm produce robbery
   ii. Prejudices/orthodoxy
   iii. Adoption of age- old traditional practices
   iv. Migration of rural youth towards urban area
   v. Low involvement of housewives in cultivation practices.

CONCLUSION

Therefore, growing food in one's kitchen is a sustainable and environmentally friendly way to boost economic growth and food security. Considering the current global food crisis and skyrocketing food costs, kitchen gardening appears to be a more effective means of strengthening and constructing local food systems. We placed a lot of emphasis on food grain production during and after the green revolution to meet the growing food needs of our nation's population. Food ingredients include carbohydrates, proteins, fats, fibers, vitamins, and minerals. Food grains are adequate to supply the body with the necessary amounts of fat, protein, and carbohydrates, but not the necessary amounts of vitamins, minerals, or fiber. Our countrymen—especially the impoverished and landless—are victims of malnutrition, which results in child mortality, morbidity, anemia, and other problems—because they do not consume enough vitamins, minerals, or fiber in their meals over an extended period. It is now necessary to figure out how to include vitamins, minerals, and fiber in our diets. It has been noted that fruits and vegetables provide an adequate amount of vitamins, minerals, and fiber to the human diet.

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Simulation Analysis of Spatiotemporal Evolution of Land Use in Yangchun City using Markov-PLUS Model

Jiahong Lai, Ruei-Yuan Wang*

School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
*Corresponding Author

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Abstract— *This article is based on CLCD (China Land Cover Dataset) and employs the Markov-PLUS model to simulate and configure land use structure, predict future trends, deepen the understanding of the causes and mechanisms of land use change, provide a scientific foundation for the formulation of city land policies, and promote scientific planning, efficient utilization, and sustainable development of land resources. The key result is that forests and cropland are the majority of land types in Yangchun City, accounting for over 90%, with cropland distributed northeast to southwest strip. From 2015 to 2020, the dynamic degree of single land use in grassland was -6.39%, with the fastest drop rate. The dynamic degree of comprehensive land use is relatively small, at 0.13%, indicating that the overall changes in land use types are minor, but there are still changes, primarily the conversion of forests to cropland, with 7926.75 hectares of forest converted to cropland and 5669.37 hectares of cropland converted to forest. These variations are impacted by various factors such as building distance, GDP, slope, elevation, and annual average temperature. Prediction shows that urban growth would increase impermeable surfaces and harm the ecological environment; maintaining cropland can increase cropland area while slowing urbanization; and ecological conservation helps to safeguard water bodies and forests while reducing bare land. Therefore, it is suggested that Yangchun City should protect forests and farmland, implement appropriate land use policies, promote ecological agriculture and forestry, optimize land use structure, strengthen grassland and shrub land management, control the expansion of bare land and impermeable surfaces, implement ecological protection measures, establish monitoring systems, and strengthen public participation and publicity education to achieve sustainable use of land resources as well as social sustainable development.*

Keywords— ***Markov-PLUS model, CLCD (China Land Cover Dataset), Land use evolution, Landscape configuration, Yangchun City, Multi scenario simulation***

I. INTRODUCTION

Land use and cover change (LUCC) plays a central role in shaping the appearance of the Earth's land surface. This change not only profoundly affects the local environment but also has a significant impact on climate change and sustainable development strategies on a global scale [1]. As a result, in-depth studies on LUCC and prediction of future trends have become a major concerned issue worldwide [2]. In other words, when changing the way land is utilized and covered, it actually affects the environment and future development path of the earth. This impact cannot be ignored from the local level to the global level. Therefore, research and prediction of LUCC have gained a global focus of attention, and people hope to better understand and manage land resources through this approach to achieve sustainable development.

In the field of land use change simulation research, model selection and implementation are crucial for effectively predicting and planning future land use patterns. As technology advances and models become more perfect, more and more land use change models are being proposed and applied in practice. Among these, PLUS (Patch generating Land Use Simulation) model and Markov model have attracted a lot of attention in the field of land use modeling. The PLUS model is a novel type of land use change simulation model, characterized by the ability to simulate patch level changes of multiple land use types at different time scales and deeply explore the driving mechanisms of land use change. By employing random seed generation and threshold decreasing mechanisms, the PLUS model combines the benefits of transformation analysis strategy (TAS) and pattern analysis strategy (PAS), enabling the model to more accurately reflect the complexity and diversity of land use change during simulation. However, the PLUS model requires input of land use demand as a prerequisite for simulating future spatial distribution of land use. The Markov model, as a traditional method for predicting future land use quantities, has no aftereffect and excellent prediction accuracy. The Markov model predicts the future trend of land use type changes by analyzing the transition probability matrix between land use types.

Therefore, integrating the PLUS model with the Markov model can achieve comprehensive simulation of future spatial and temporal changes in regional land use. Specifically, the Markov model is first used to predict future land use demand, and then the predicted results are used as input parameters for the PLUS model to simulate the spatial distribution of land use. This integration method not only fully utilizes the advantages of the PLUS model in simulating patch level changes, but also ensures the accuracy of predicting the number of simulation results, making the simulation results more comprehensive and accurate [3-4].

As one of the important cities in Guangdong Province, Yangchun City is also facing severe challenges in terms of land use and structural transformation. With the acceleration of urbanization, the demand for urban land is rapidly increasing, while rural land is continuously decreasing, and the land use structure is undergoing significant changes. This change not only affects the ecological environment and food security but also puts forward higher requirements for coordinated urban-rural development. Based on this, this study conducted an in-depth analysis of the spatiotemporal evolution characteristics of land use types in Yangchun City, and simulated the fine configuration of land use landscape structure applying CLCD (China Land Cover Dataset) and Markov PLUS models, providing scientific and reasonable suggestions for the optimization of future land use layout.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

Yangchun City (21°50′36″N—22°41′01″N，111°16′27″E—112°0′22″E) is located in the southwest of Guangdong Province, serving as a transportation hub for the Pearl River Delta (PRD) and western Guangdong regions. The terrain and landforms of Yangchun are primarily mountainous and hilly, extending diagonally from northeast to southwest, approximately rectangular in shape (Figure 1). The city is 104 kilometers long from north to south and 91 kilometers wide from east to west, with a total area of 4054.7 square kilometers.

In recent years, significant progress has been made in the infrastructure construction of Yangchun. In terms of railways, a total length of 178.2 kilometers of ordinary railways has been built, and the construction of the Yangchun section of the Guangzhou Zhanjiang high-speed railway with a speed of 350 kilometers per hour is being promoted. It is expected to greatly shorten the distance to the core area of the Greater Bay Area (GBA) after its opening in 2025, achieving fast access within one hour. The development of highways is particularly rapid, with a significant increase in the length of service to 194 kilometers. The Yangchun section of the Yangchun Xinyi Expressway is expected to open by the end of 2024, further consolidating its leading position in highway density in the eastern and western wings of the province.

In addition, both main and rural roads have been comprehensively improved, with a total length of 487.787 kilometers for main roads and 4127 kilometers for rural roads, all of which have been graded and hardened, significantly improving the level of transportation services in urban and rural areas. With the continuous improvement of infrastructure, urban areas are gradually expanding, which also brings significant changes in land use distribution.

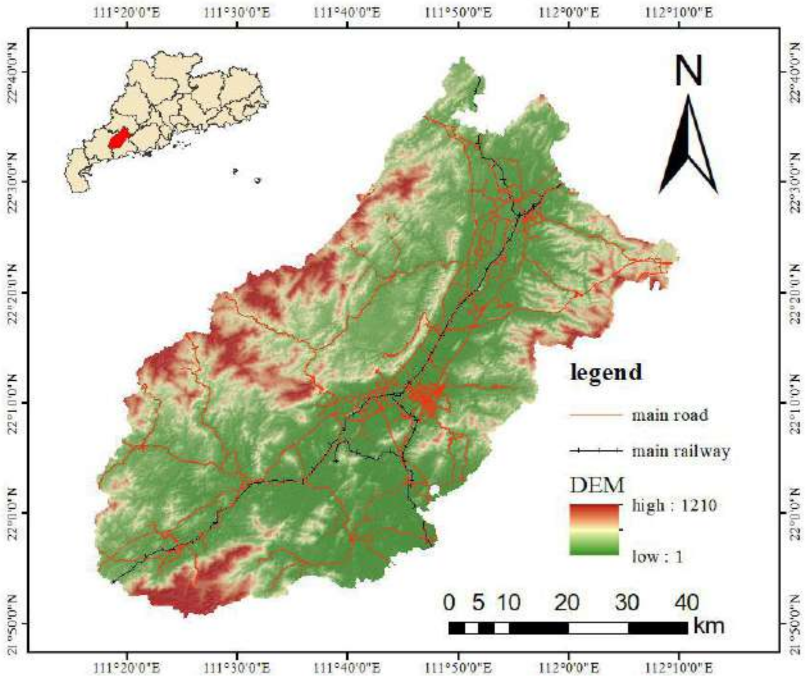

Fig.1 Overview of Yangchun Research Area

2.2 Data Sources

The land use data in this article is CLCD (China Land Cover Dataset). It is a geographic information resource carefully created by Professor Huang Xin from Wuhan University based on Landsat data on the Google Earth Engine (GEE) platform. This dataset covers the annual land cover situation in China from 1985 to 2020 with a total of 335709 scenes. Through the post-processing techniques of random forest classifiers, spatiotemporal filtering, and logical reasoning, accurate classification of land cover is achieved, with an overall accuracy rate of 80%. The CLCD dataset covers land use classification results at a resolution of 30 meters per year for 30 consecutive years, which is superior to other datasets in terms of temporal resolution but may be slightly inferior in spatial resolution and is currently limited to China.

In addition, this study also utilized four natural geographic data, namely elevation, slope, annual average temperature, and annual precipitation, as well as four socio-economic data, namely GDP, highways, railways, and buildings (Table 1).

Table 1 Required Data and Sources

Data requirements	Data sources	Application
CLCD Land Use Data	ZENODO Research Data Repository. https://zenodo.org/records/8176941	Analyzing the spatiotemporal evolution of land use types
Elevation Slope	Geospatial Data Cloud https://www.gscloud.cn/	Create a summary map of the research area; As a driving factor

Annual precipitation Annual mean temperature GDP	Resource and Environmental Science Data Platform, https://www.resdc.cn/	As a driving factor
Distance to highway Distance to railway Distance to buildings	OpenStreetMap https://www.openstreetmap.org/	Create a summary map of the research area; As a driving factor

III. METHODOLOGY

3.1 Study Method

The research route of this article (Figure 2) is as follows:

1. Collect CLCD (China Land Cover Dataset), elevation data, basic data of highways and railways, as well as natural and social data required for the Markov PLUS model for two scenes in Yangchun City in 2015 and 2020.

2. Reclassify the numbering of land use data in ArcGIS to meet the requirements of the input model; Using the Euclidean distance tool in ArcGIS to process road and other data.

3. Calculate the land dynamic degree based on the formula of land dynamic degree in terms of time, and at the same time create and analyze the land use transfer matrix; In terms of space, using ArcGIS to create a land status map and analyze it.

4. Extract the land expansion part through the Extract Land Expansion module in the model and combine it with driving factor data to generate various land development probabilities and contribution values in the LEAS (Land Expansion Analysis Strategy) module for analysis.

5. Use the Markov module in the model to predict land use quantity, simulate land use in 2020 using the CARS (CA based on Multiple Random Seeds) module, and test the accuracy through Confusion Matrix & Fom.

6. Simulate four scenarios of natural development, urban development, farmland protection, and ecological protection in 2030. Finally, draw a conclusion.

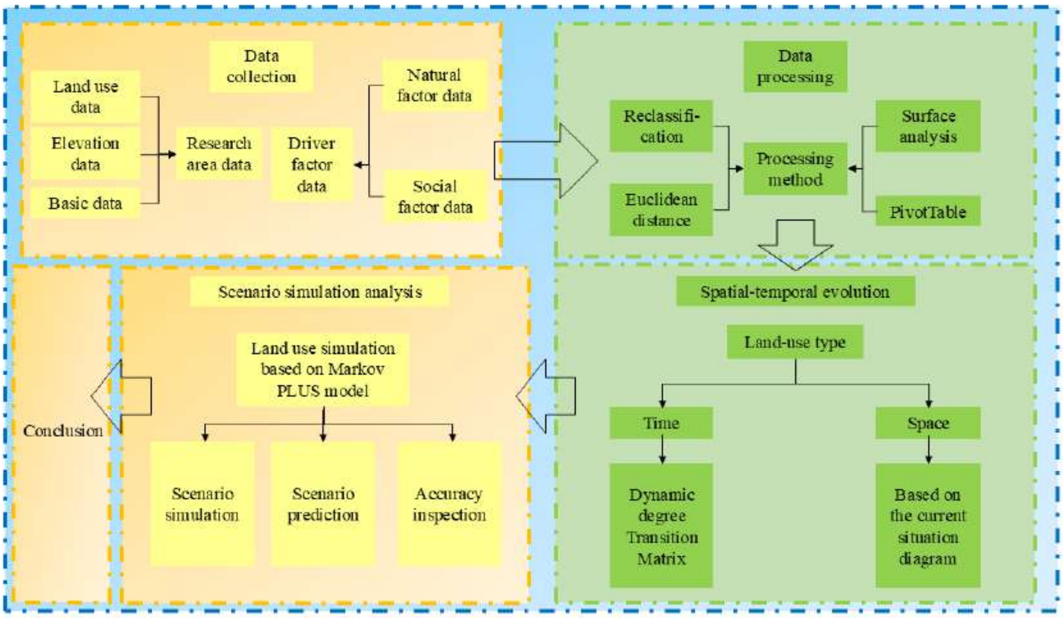

Fig.2 the Schema of the Study

3.2 Dynamic Degree of Land Use

The Land Use Dynamics Index is a quantitative evaluation tool that not only reveals the dynamic changes in land use types, but also accurately captures the degree of local land changes. Its importance lies in simplifying the complex process of land use change, predicting the future evolution trend of regional land use, and comparing the differences in land use change in different regions [5].

The dynamic degree of single land use mainly focuses on the dynamic evolution or change of the quantity of a specific land use type in a research area within a specific time span[6].The calculation formula is:

$K=(U_A-U_B)/U_A\times 1/T\times 100\%$ (1)

Among them, K represents the rate of change in the dynamic degree of a single land use, while UA and UB are the quantity (usually area) of a certain land use type in the early and late stages of the study, respectively; T is the research time scale, usually measured in years. This indicator helps to understand the rate of change in specific land use types, such as the expansion or reduction rate of forests, cropland, or urban land.

The comprehensive land use dynamic degree is a key indicator for evaluating the severity of land use changes in a specific region. The magnitude of its value directly reflects the severity of land use changes in the region, with larger values indicating more significant and drastic changes in land use [7].The calculation formula is:

$B=\left[\sum_{i=1}^{n}(\Delta LU_{i-j})/2\sum_{i=1}^{n}LU_i\right]\times 1/T\times 100\%$ (2)

During the monitoring process, LU_i represents the area size of the *i*-th land use type at the beginning of the monitoring. ΔLU_{i-j} represents the absolute value of the area occupied by the transition from the i-th land use type to a non-i land use type during the monitoring period. And T is the length of the monitoring period.

3.3 Land Use Transfer Matrix

The land use transformation matrix is a two-dimensional matrix constructed based on the transformation relationship of land cover status at different time points in the same region. By analyzing the transition matrix, it is possible to gain a clear insight into how various land types transform into each other between two different time points. This matrix provides a detailed description of the land types that have undergone changes in different land use types in different years, the specific locations of the changes, and the size of the changed areas. In addition to displaying static, specific regional and temporal data on the area of various land types, it can also reveal richer information, including the initial transfer of various land areas and the final transfer of various land areas, providing a comprehensive perspective on land use change analysis **Error! Reference source not found.**.The calculation formula is:

$$S_{ij}=\begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix} \quad (3)$$

Among them, S represents area, which is a universal and core parameter used to measure and calculate the scope or scale of land; I and j respectively, refer to the land use types in two different periods before and after, and these two variables can track and compare the land use status at different time points; N represents the total number of land use types, which gives the range of possible land use categories; S*ij* is the area parameter under specific circumstances, specifically referring to the land use area of type i in the early stage, which transforms into type j after a period of time. This variable reveals in detail the conversion relationship between land use types to provide specific data on land use change **Error! Reference source not found.**.

3.4 Markov Model

Markov models are mainly divided into two types: Markov chains and hidden Markov models. The former has visible states, while the latter has hidden states that can be inferred through observing sequences. The state transition process in the model is based on a predefined probability distribution, which is concise and efficient, capable of processing large amounts of data and quickly providing predictions. However, it also has certain limitations, such as a limited ability to handle long-term dependency relationships. The calculation formula is as follows:

$$P_{ij}=\begin{bmatrix} P_{11} & \cdots & P_{1N} \\ \vdots & \ddots & \vdots \\ P_{N1} & \cdots & P_{NN} \end{bmatrix} \quad (4)$$

$S_{(t+1)}=P_{ij}S_t$ (5)

$P_{ij}\in[0,1),\sum_{N=1}^{N}P_{ij}=1(i,j=1,2,3,\cdots,N)$ (6)

In the formula, $S_{(t+1)}$ and S_t represent the land use status at time t+1 and t, respectively; P_{ij} is the probability matrix for land use type transition; N is the land use type [10,11].

3.5 PLUS Model

In the academic field, the PLUS model demonstrates unique advantages, which are reflected in its two core modules: the rule mining method for integrated land expansion analysis and the cellular automaton model (CARS) with multi-type random seed mechanism. This integration strategy makes the PLUS model more in-depth in explaining the influencing factors of various land use changes and also significantly improves the accuracy of simulation results [12]. The model extracts land change data, uses a random forest algorithm to calculate development probability, and then uses a CA model with multiple types of random patch seeds to simulate and predict future landscape patterns [15].

The random forest algorithm extracts random samples from the original dataset and uses multiple decision tree ensemble learning to calculate the probability P of k types of land use on cell i. This probability is expressed by the following formula:

$$P_{i,k}^{d}(x)=\frac{\sum_{n=1}^{M} I=[h_n(x)=d]}{M} \quad (7)$$

Among them, d is a binary variable, where d=1 indicates that the land use type has changed to the k category, and d=0 indicates that it has changed to the non-k category; X is a vector containing multiple driving force factors; I is the indicator function of the decision tree set; H(x) represents the prediction type of the nth decision tree for vector x; M is the total number of decision trees [11].

The analysis principle of the CARS module is based on a cellular automata model combined with multi-type random patch seeds and a threshold-decreasing mechanism to achieve dynamic simulation of ground-like patches. In the simulation, the land use demand is fed back through a self-regulation mechanism to obtain the adaptive coefficient of land use type competition in order to achieve the future demand target for land use area. The relevant formulas are as follows:

$$OP_{i,k}^{d=1,t}=P_{i,k}^{d=1}\times\Omega_{i,k}^{t}\times D_{k}^{t} \quad (8)$$

$$\Omega_{i,k}^{t}=\frac{con\left(c_i^{t-1}=k\right)}{n\times n-1}\times w_k \quad (9)$$

$$D_k^t=\begin{cases} D_k^{t-1} \text{ if} \left|G_k^{t-1}\right|\le\left|G_k^{t-2}\right| \\ D_k^{t-1}\times\frac{G_k^{t-2}}{G_k^{t-1}} \text{ if} 0>G_k^{t-2}>G_k^{t-1} \\ D_k^{t-1}\times\frac{G_k^{t-1}}{G_k^{t-2}} \text{ if} G_k^{t-1}>G_k^{t-2}>0 \end{cases} \quad (10)$$

In equation (8), $P_{i,k}^{d=1}$ represents the expansion probability of the i-th unit's land use type; $\Omega_{i,k}^{t}$ is the neighborhood effect of land unit i, which refers to the coverage ratio of k types of land use within the neighborhood. Its expression is formula (9); D_k^t is the degree of impact of future land use demand on k types of land use, expressed as formula (10) [14].

3.6 Markov-PLUS Model

The Markov-PLUS model is an innovative land use change simulation model that combines the advantages of Markov and PLUS models, providing a powerful tool for land use change research. It has the following advantages:

(1) High precision prediction: By integrating the advantages of Markov and PLUS models, the Markov PLUS model can more accurately and reliably predict future land use changes.

(2) Powerful spatial allocation capability: The idea of the PLUS model significantly improves the simulation ability of the Markov-PLUS model in spatial allocation, enabling more accurate simulation of the spatial distribution of land use types.

(3) Wide applicability: The Markov-PLUS model is not only applicable to high land cover areas such as agricultural regions and urban agglomerations, but also has good applicability for simulating land use changes in complex environments such as low vegetation cover and arid areas.

3.7 Accuracy Inspection

3.7.1Kappa Coefficient

The Kappa coefficient, as a widely used evaluation tool, is often used to quantify the accuracy of classification and the consistency between different classification results. Provide an objective perspective to evaluate the performance of classification models or manual classification, ensuring that the accuracy and consistency of classification are effectively measured [13].The Kappa coefficient not only considers the overall accuracy, but also integrates the classification accuracy of each category to more comprehensively evaluate classification performance. Its value range is between -1 and 1, with larger values indicating more reliable classification results. The calculation formula is as follows:

$$Kappa=\frac{P_o-P_e}{1-P_e} \quad (11)$$

Among them, P_o refers to the proportion of observed

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precise consistency, that is, the proportion of correct predictions made by the model. This value can be calculated by dividing the sum of diagonal elements in the confusion matrix by the sum of elements in the entire matrix. P_e refers to the proportion of expected exact consistency, that is, the expected accuracy under random classification. This value is calculated by multiplying the actual proportion of each category by the predicted proportion, and then dividing by the square of the total sample size.

3.7.2 Overall Accuracy（OA）

Overall accuracy refers to the proportion of samples correctly classified by the model to the total number of samples. It directly reflects the average accuracy of the model in classifying all samples. The calculation formula is:

$$OA=\frac{TP+TN}{TP+FN+FP+TN} \quad (12)$$

TP (true) refers to the positive samples correctly identified by the model, that is, both the predicted and actual results are positive; FN (false negative) refers to the model incorrectly identifying positive samples as negative, i.e., predicting them as negative but actually positive; FP (false positive) describes the situation where the model incorrectly identifies negative samples as positive, meaning that they are predicted to be positive but actually negative; TN (true negative) represents the negative samples correctly identified by the model, meaning that both the predicted and actual values are negative.

IV. ANALYSIS AND RESULTS

4.1 Temporal and Spatial Evolution of Land Use Types

Analysis shows that the main land types in Yangchun City are forests and cropland, with a combined proportion of over 90% of the total land types from 2015 to 2020. The cropland is roughly distributed in a strip shape from northeast to southwest. The bare land area is the smallest and its proportion is also very small. In 2015, it was 0.00000446%, and in 2020, it was 0.00000669% (Table 2) (Figure 3).

Table 2 Changes in Land Area and Proportion of Various Types in Yangchun City from 2015 to 2020 (hm², %)

		Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
2015	Area	85566.96	309807.45	187.74	120.87	3471.75	1.8	4472.73
	%	21.2	76.76	0.05	0.03	0.86	0.00000446	1.11
2020	Area	87450.3	307491.93	156.78	82.26	3190.59	2.7	5254.74
	%	21.67	76.18	0.04	0.02	0.79	0.00000669	1.3

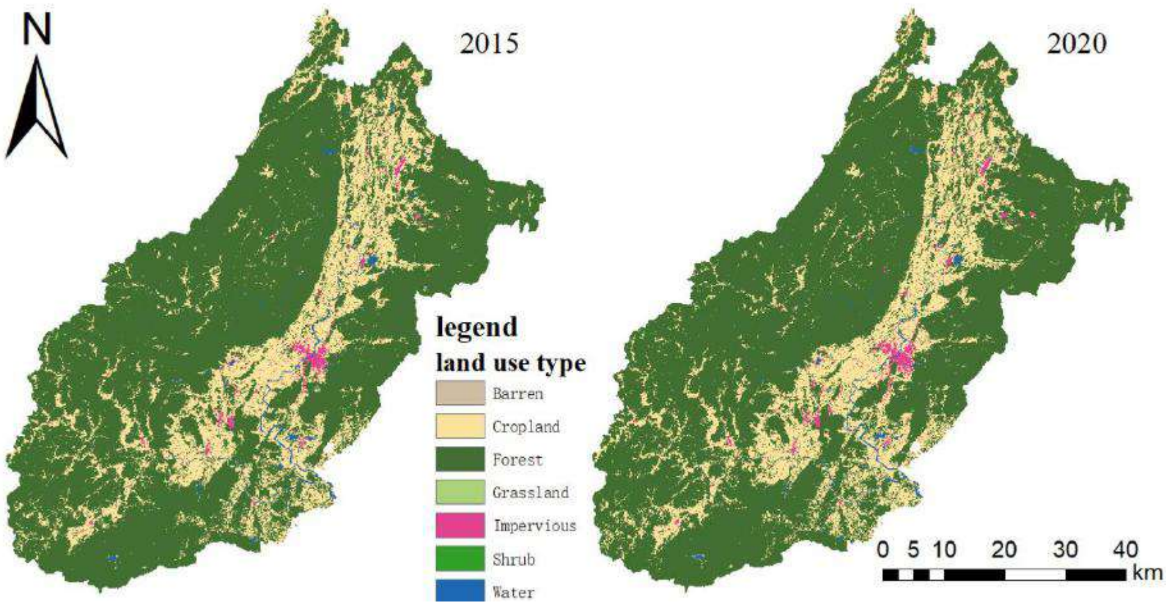

Fig.3 Spatial Evolution of Land Use in Yangchun City from 2015 to 2020

The single land use dynamic degree (K) of cropland, bare land, and construction land between 2015 and 2020 is positive, with bare land having the highest value, indicating the fastest growth rate of bare land. Meanwhile, the dynamics of forests, shrubs, grasslands, and water bodies are all negative, with grassland having the highest value, indicating the fastest rate of grassland decline. The comprehensive land use dynamic degree (B) is relatively small, indicating that the changes in land use types have been relatively gentle in the past 5 years (Table 3).

Table 3 Land Use Dynamics in Yangchun City from 2015 to 2020 (%)

years	Dynamic degree	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
2015-2020	K	0.44	-0.15	-3.3	-6.39	-1.62	10	3.5
	B	0.13						

During the period from 2015 to 2020, the area of forest transfer was the largest, reaching 8047.35hm^2; Following closely behind is cropland, with a transfer area of 6439.14 hectares. In the forest transfer land category, cropland and impermeable surfaces dominate, with transfer areas of 7926.75 hectares and 108.45 hectares, respectively. The types of cropland transferred out are forests and impermeable surfaces, with transfer areas of 5669.37 hectares and 667.35 hectares, respectively. It is worth noting that during this period, except for shrubs and bare land, all other land types were transferred to impermeable surfaces, with a total transfer area of 802.71 hectares (Table 4).

Table 4 Land Use Transfer Matrix of Yangchun City from 2015 to 2020 (hm2)

	2020						
2015	Barren	Cropland	Forest	Grassland	Impervious	Shrub	Water
Barren	0.9	0.09	0	0.81	0	0	0
Cropland	0.18	79127.82	5669.37	25.65	667.35	2.07	74.52
Forest	0	7926.75	301760.1	0.27	108.45	11.79	0.09
Grassland	1.62	41.04	2.61	53.28	5.67	11.43	5.22
Impervious	0	0.54	0	0	4452.03	0	20.16
Shrub	0	21.06	33.3	1.89	0	131.49	0
Water	0	333	26.55	0.36	21.24	0	3090.6

4.2 Selection and Contribution Analysis of Driving Factors for Land Use Change

Table 5 shows the names and numbers of driving factors in Yangchun, and Figure 4 shows the driving factors of land use change in Yangchun. According to Table 5, Figure 4, and Figure 5, it can be seen that GDP has the highest contribution to the expansion of cropland, approaching 0.16, and the lower the GDP, the faster the expansion of cropland. When it grows slowly or is in a declining stage, it may mean that the development speed of non-agricultural industries such as industrial production and service industry slows down. This may lead to a decrease in demand for construction land, as slower economic growth is often accompanied by a decrease in the efficiency of land resource utilization. In this situation, as a relatively stable basic industry, the demand for land in agriculture may increase. Farmers may choose to expand their cropland area to increase agricultural output and income.

The expansion of impermeable surfaces is mainly influenced by the distance between buildings, approaching 0.2, and the closer to the building, the more severe the expansion of impermeable surface area. With the development of cities, especially in urban centers or densely built areas, the increase in their area indicates that land use is moving towards more intensive and compact directions. This may be because more buildings, roads, and other infrastructure are being constructed near existing buildings to improve land utilization. Secondly, the elevation and distance from the railway are both between 0.1-0.15, and the lower the elevation, the closer it is to the railway, and the faster the expansion of the impermeable surface area. Areas with lower elevations are more suitable for the expansion of urban construction land, as these areas often have flat terrain that facilitates infrastructure construction and land development. As an important transportation infrastructure, the construction and operation of railways have a significant impact on the land use and urban development of surrounding areas. The land near railway lines is often more easily developed for urban construction due to convenient transportation, leading to rapid expansion of impermeable surface area.

The annual average temperature is the key driving factor for forest expansion, approaching 0.16, and the higher the annual average temperature, the more intense the expansion. The rise in temperature is a significant feature of climate change, and when temperatures rise, areas that were originally unsuitable for forest growth may become suitable, thus potentially promoting its expansion. Next are the average annual precipitation and distance from buildings, with the former around 0.15 and the latter close to 0.14. And it is the less annual precipitation and the closer to the building, the more intense the expansion. The forest area can still expand even with a decrease in annual precipitation, which may be related to its internal species composition and ecological structure. The increase of some drought-tolerant species may have promoted its expansion. The closer to the building, the more intense the area expansion, which may be related to greening projects and ecological restoration projects around the city or building.

Table 5: Names and Numbers of Driving Factors in Yangchun City

Driver type	Driver Name	Number
Physiographic factor	Elevation	(a)
	Slope	(b)
	Annual average precipitation	(c)
	Annual temperature	(d)
Socio economic factors	GDP	(e)
	Distance to the highway	(f)
	Distance to railway	(g)
	Distance to building	(h)

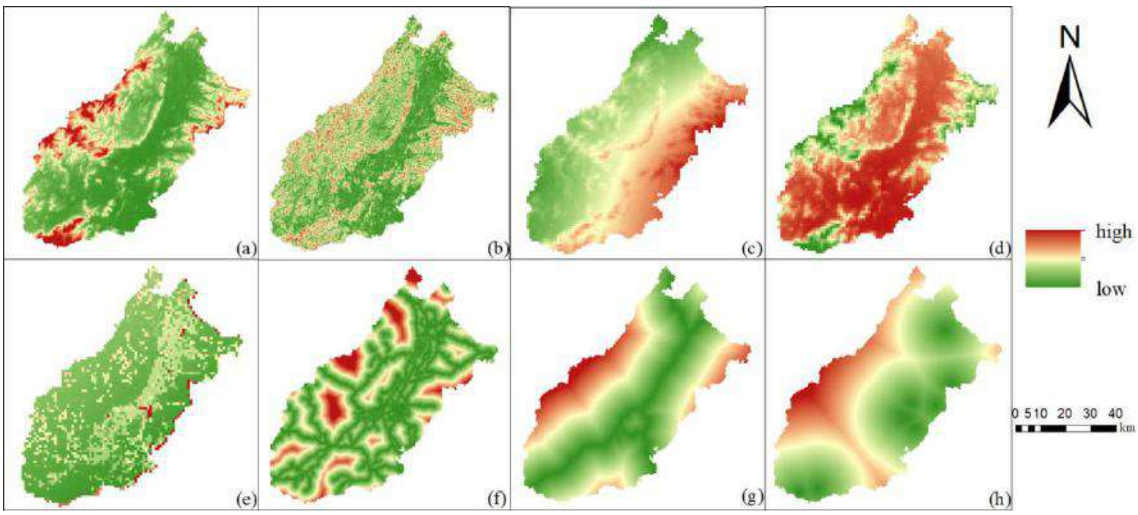

Fig.4 Driving Factors of Land Use Change in Yangchun City

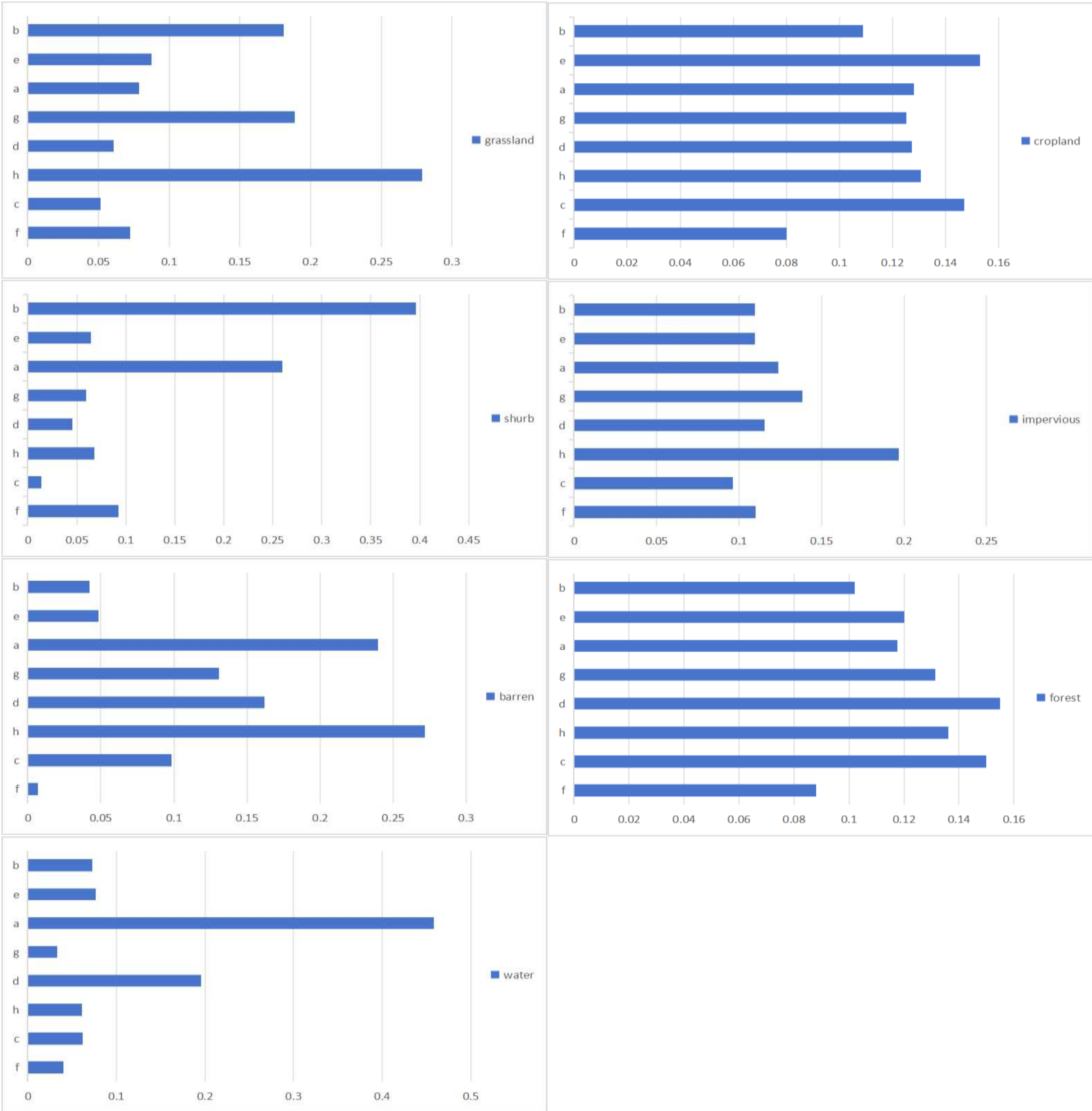

Fig.5 Contribution of Various Driving Factors to Different Land Use Types in Yangchun City

4.3 Simulation of Landscape Configuration of Land Use Structure

4.3.1 Probability of Development of Various Types of Land Use

When conducting in-depth study on the dynamic changes of land use in Yangchun, this study used CLCD land use status data maps from 2015 and 2020 for exploration. To analyze the patterns and trends behind the data graph, use the LEAS module in the PLUS model. Through precise data analysis and algorithm support, this module calculates the development probability map of each land type based on data files from 2015 to 2020 (Figure 6).

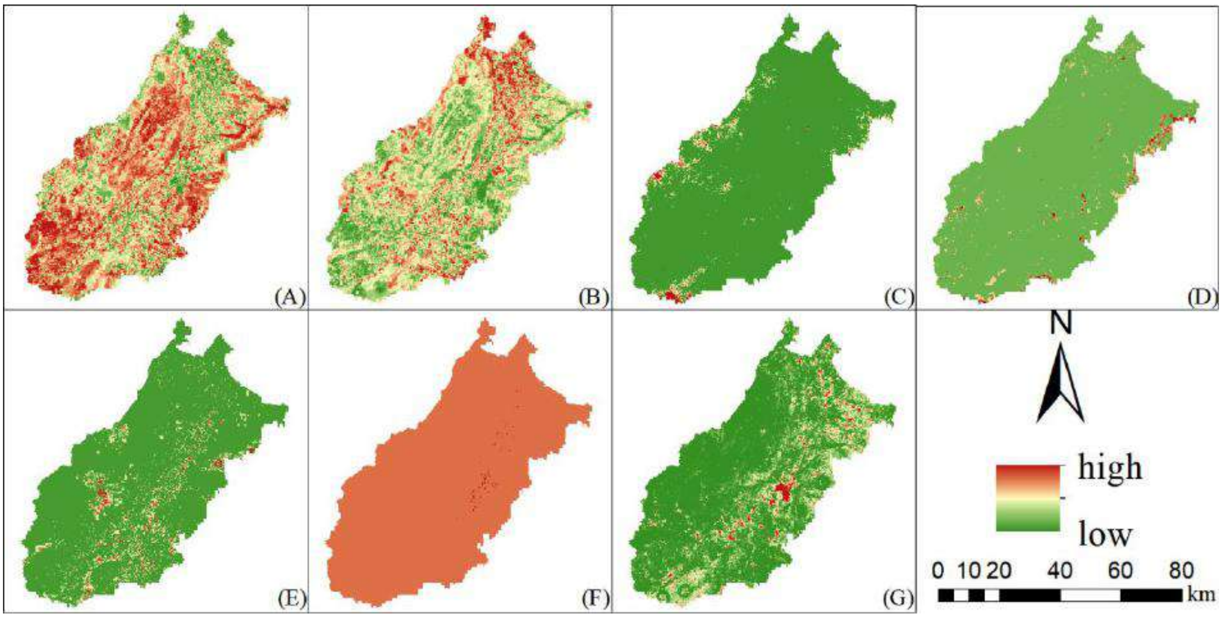

Fig.6 Development Probabilities of Various Types of Land in Yangchun City

(A)Cropland (B) Forest (C) Shrub (D) Grassland (E)Water (F)Barren (G)Impervious

4.3.2 Simulation and Accuracy Testing in 2020

The domain weight references and empirical settings for the CARS module in PLUS are shown in Table 7, and all simulations have the same weight parameters [15]. Applying the confusion matrix and formal module of the PLUS model, the actual land use map and simulation map of Yangchun in 2020 were overlaid and analyzed to obtain the confusion matrix (Table 8) and comparison chart (Figure 7) of the actual land use pattern and simulation pattern. By applying formula (11) for calculation, the Kappa value for simulation accuracy is 0.89. Meanwhile, using formula (12) for calculation, the overall accuracy is 0.96. By combining the accuracy and comparison chart, it can be clearly seen that the PLUS model simulation results have high accuracy and credibility, and can be used for predictive simulation.

Table 7 Land Type Domain Weight Setting Table

	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
Domain weight	0.7	0.4	0.3	0.3	0.2	0.5	0.9

Table 8 Confusion Matrix of Actual and Simulated Data in Yangchun City in 2020 (Pixel Count: 1=0.09 hm^2, %)

	2020 simulation									
	Land use types	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious	Row total	User Accuracy%
Actual in 2020	Cropland	176526	15951	7	47	315	1	1519	194366	90.82
	Forest	17220	666300	75	1	240	0	110	683946	97.42
	Shrub	34	672	270	4	0	0	0	980	27.55
	Grassland	84	14	37	108	6	1	6	256	42.19
	Water	722	79	0	2	6527	0	46	7376	88.49
	Barren	1	0	0	1	0	2	0	4	50.00
	Impervious	39	687	0	4	46	1	10213	10990	92.93
	Column total	194626	683703	389	167	7134	5	11894	897918	

	Producer accuracy%	90.70	97.45	69.41	64.67	91.49	40.00	85.87		

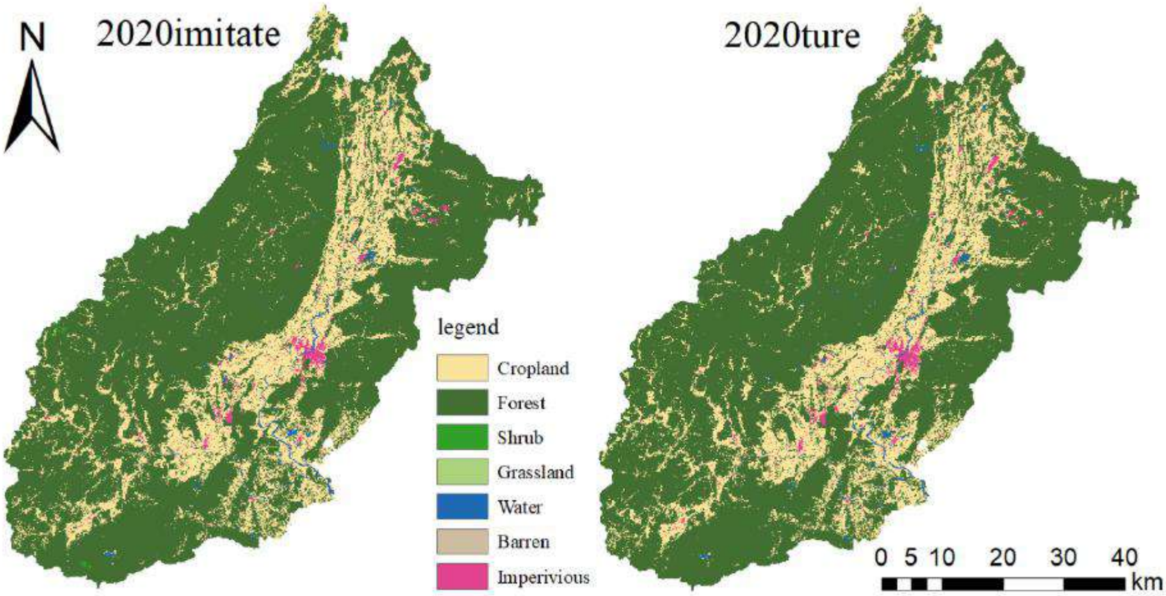

Figure 7 Comparison between Simulated and Real Situations in Yangchun City in 2020

4.3.3 Spatial Distribution of Land Types under Different Scenarios in 2030

This study adopts a combination of spatial and quantitative constraint methods to simulate four scenarios in Yangchun City in 2030: natural development scenario (NDS), urban development scenario (UDS), Cropland protection scenario (CPS), and ecological protection scenario (EPS) (Figure 8). The spatial constraint method adopts a cost matrix for land type conversion, and the quantity constraint method adopts the Markov chain method. The parameters of both methods are set based on literature and continuous testing in this study [15-17].

(1) Natural development scenario (NDS). Based on Figure 8 and Table 9, it can be seen that compared to the land use situation in 2020, the increase in cropland area is the largest under the NDS in 2030, with an increase of 3067.83 hectares, followed by an increase of 701.28 hectares in impermeable surfaces. During this period, the forest area decreased the most, by 4120.74 hectares, followed by water bodies, by 143.91 hectares. The change rate of shrubs is the highest, reaching 113.89%, and the main source is from the forests in the southwest corner. The rate of change in water bodies is the lowest, at -4.37%, and the bare land area has hardly changed.

(2) Urban development scenario (UDS). The main focus is on how urban space expands with population growth, changes in functional positioning, and economic development needs in the context of rapid urbanization, in order to predict the impact of these changes on land use structure, intensity, and ecological environment. Compared to the other three scenarios, the UDS has the largest increase in impervious surface area, at 950.85 hectares, mainly derived from the conversion of forests and cropland. The change rate of impermeable surfaces is the highest at 19.58%, which is 5.14 percentage points higher than the NDS. When only considering urban development without considering the ecological environment, cities will occupy more cropland and forests, causing damage to the ecological environment and not conducive to sustainable development.

(3) Cropland protection scenario (CPS). It is intended to evaluate the protection status of cropland resources and their impact on other land use types under specific policies or measures. Compared to the other three scenarios, the CPS has the largest increase in cropland area, at 3560.58 hectares, and the highest change rate, at 4.07%, which is 0.56% higher than the NDS. It is worth noting that in this scenario, the growth area and change rate of the

impermeable surface are the lowest, at 298.80 hm2 and 6.15%, respectively. Under the scenario of cropland protection, the cropland area will significantly increase, and at the same time, due to the increase in cropland area, the number of farmers may increase, and the urbanization process may slow down.

(4) Ecological protection scenario (EPS). The main focus is on evaluating the changes in land use structure and their impact on the ecological environment under strengthened ecological protection measures. Compared to other scenarios, the water body in this scenario increased instead of decreasing, with an increase of 180.27 hectares. The forest area decreased the least, with a decrease of 4075.29 hectares, which is 45.45 hectares less than the NDS. There is a decrease in bare ground. In this scenario, forests, water bodies, etc. are well protected.

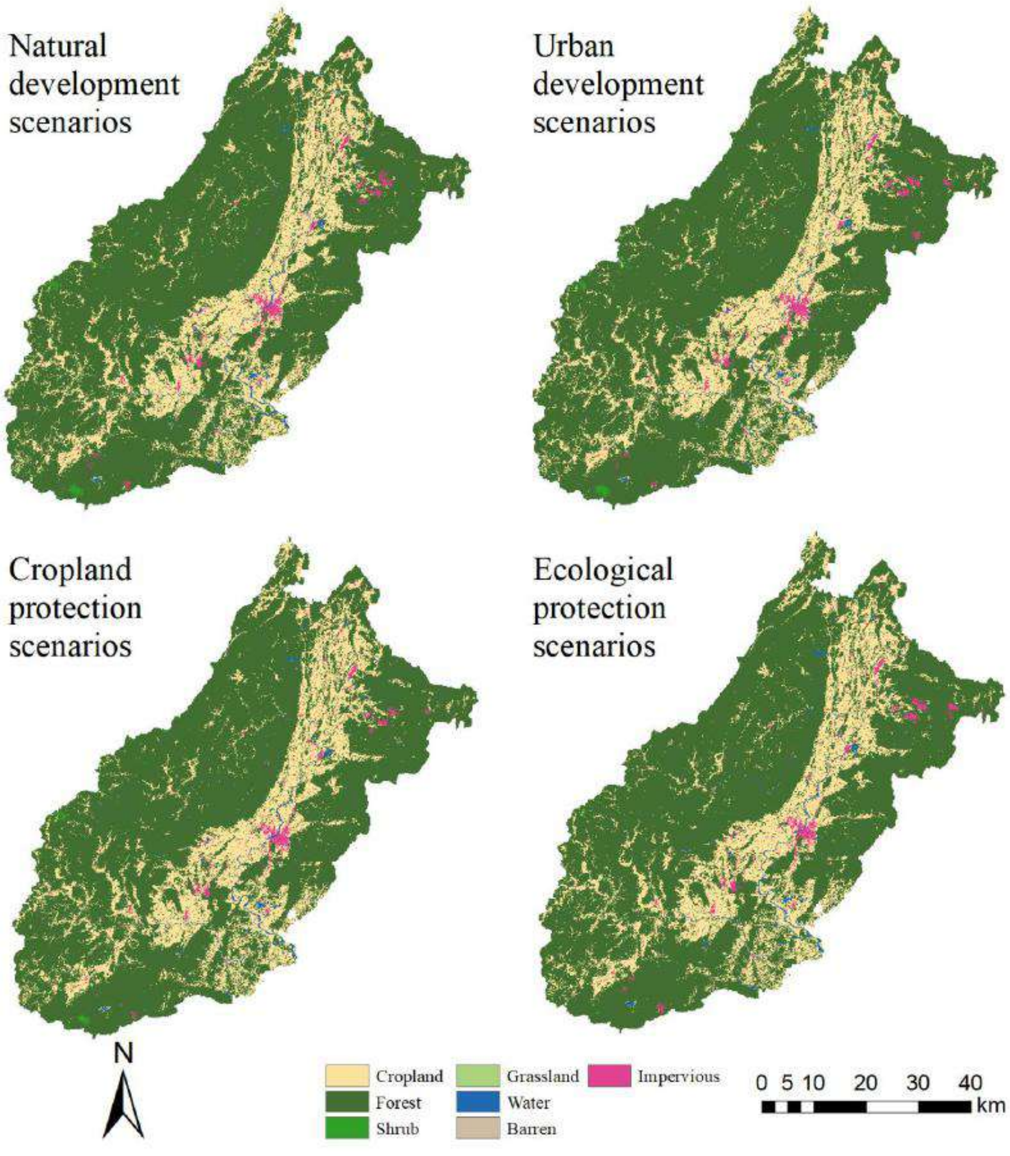

Fig.8: Simulation of Land Use Types in Yangchun City under Various Scenarios

Table 9: Changes in Land Types under Different Scenarios in Yangchun City by 2030 (hm^2,%)

Land use types	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
2020 true	87450.3	307491.93	423.09	115.29	3291.48	1.89	4855.32
NDS	90518.13	303371.19	904.95	128.97	3147.57	1.89	5556.6
Variation	3067.83	-4120.74	481.86	13.68	-143.91	0	701.28
Change rate%	3.51	-1.34	113.89	11.87	-4.37	0	14.44
UDS	90387.9	303341.22	891.18	122.58	3078.36	1.89	5806.17
Variation	2937.6	-4150.71	468.09	7.29	-213.12	0	950.85
Change rate%	3.36	-1.35	110.64	6.32	-6.47	0	19.58
CPS	91010.88	303406.74	786.87	121.59	3147.21	1.89	5154.12
Variation	3560.58	-4085.19	363.78	6.3	-144.27	0	298.8
Change rate%	4.07	-1.33	85.98	5.46	-4.38	0	6.15
EPS	90713.7	303416.64	187.74	120.87	3471.75	1.8	5716.8
Variation	3263.4	-4075.29	-235.35	5.58	180.27	-0.09	861.48
Change rate%	3.73	-1.33	-55.63	4.84	5.48	-4.76	17.74

V. CONCLUSIONS

From 2015 to 2020, the main types of land in Yangchun City were forests and cropland, accounting for over 90% of the total, with cropland distributed in a strip shape from northeast to southwest. During this period, the dynamic degree of single land use in grassland was -6.39%, with the fastest reduction rate. The dynamic degree of comprehensive land use is relatively small, at 0.13%, indicating that land use changes are relatively flat, but there are still some land types that have undergone significant transformation. The land transfer situation shows that forests and cropland are the main types of land transferred out, with forests mainly converted to cropland and a transfer area of 7926.75 hectares. And the cropland is primarily converted into forests, with a transfer area of 5669.37 hectares. Grassland expansion is significantly affected by building distance, farmland expansion is negatively correlated with GDP, shrub expansion is driven by slope and elevation, impermeable surface expansion is closely related to building distance, forest expansion is positively correlated with temperature, and water expansion is greatly affected by elevation. Looking ahead to 2030, land changes vary under different scenarios. UDS may lead to a reduction in forests and cropland, while cropland protection scenarios promote cropland growth. EPS can help protect forests and water bodies.

Based on the above conclusions, Yangchun City should maintain the protection of forests and farmland, implement appropriate land use policies and plans, and promote ecological agriculture and forestry to ensure that these two main land types are not overexploited or illegally occupied, while improving land use efficiency and protecting the ecological environment.

Furthermore, it is also vital to optimize the land use structure, appropriately plan industrial, commercial, and residential property, stimulate intensive land use, and improve land use efficiency and production benefits. Meanwhile, increase grassland and shrub management and maintenance, and make effective use of these resources to develop industries like as ecotourism and leisure agriculture. For the expansion of bare land and impermeable surfaces, it is necessary to strengthen urban planning and construction management and promote green buildings and ecological city concepts to improve the quality of the urban ecological environment. Meanwhile, implement ecological protection measures to protect natural resources such as forests and water bodies and reduce the damage of agricultural production to the environment. Establish a comprehensive land use monitoring system, regularly monitor and evaluate land use changes, adjust land use policies and plans in a timely manner based on the results, and ensure the sustainable use of land resources.

Finally, strengthen public participation and education, raise public awareness of land use change and ecological environment protection, promote democratic and scientific decision-making, and create multi scenario development strategies for different development goals and scenarios to achieve sustainable use of land resources and social sustainable development.

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Land Use Change Monitoring and Carbon Storage Assessment in Qingyuan City Using the InVEST Model

Shuxian Pan, Ruei-Yuan Wang*

School of Sciences, Guangdong University of Petrochem Technology (GDUPT), Maoming 525000, China
*Corresponding Author

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Abstract— *To analyze the spatial and temporal distribution characteristics of land use change and carbon stock in Qingyuan City from 1990 to 2020 and the relationship between them, to provide theoretical decision-making references for balancing economic development and ecological civilization construction and promoting rural revitalization. Based on remote sensing data, ArcGIS was used for land use change visualization, and the Carbon module of the InVEST model was used to estimate carbon stocks to explore the impact of Land Use and Cover Change (LUCC) on carbon stocks. The results show that from 1990 to 2020, the area of cultivated land, forest land, and grassland in Qingyuan City decreased, the area of construction land and water area increased, and the size of the unused land area remained unchanged. The land use type with the largest share of carbon stocks is forest land, and the smallest is unused land. The total carbon stock was 132,300,135 Mg (mega gram) in 1990 and 131,613,007 Mg in 2020, a decrease of 687,128 Mg in total carbon stock. Changes in the area of grasslands leading to changes in the area of carbon stocks are the most obvious, and the conversion of cultivated land, forested land, and grasslands to construction land is the main cause of the loss of carbon stocks..*

Keywords— ***Qingyuan City, Carbon Storage, Integrate Valuation of Ecosystem Services and Tradeoff (InVEST) Model, Land Use and Cover Change (LUCC).***

I. INTRODUCTION

Climate change has become a severe environmental and social issue in this day and age with global impacts on nature and the economy [1]. Carbon stocks in terrestrial ecosystems are at the forefront of global carbon stock composition [2], and their impact on the global carbon cycle and climate change is enormous. Land Use and Cover Change (LUCC) is considered by many researchers as an important factor affecting the carbon cycle process in terrestrial ecosystems [3], and the study of land use change has a crucial effect on carbon storage, which is an important path to mitigate global warming.

In recent years, many scholars at home and abroad have conducted a large number of studies on the impact of LUCC on carbon stocks in terrestrial ecosystems. For example, Li et al [4] used the InVEST model to estimate the carbon stock in Daqing City from 2010 to 2020 and explored the impact of land cover change on it, and found that the conversion of grassland and wetland to cultivated land is the key reason for the loss of carbon stock and that the main contributor to the carbon stock of the ecological conservation scenario is wetland; Wu et al [5] explored the carbon stock changes in terrestrial ecosystems of Guangdong Province and the impact of urban expansion on carbon stocks from 1980 to 2010 based on the InVEST model, and found that the reduction of carbon stocks due to urban expansion in the Pearl River Delta (PRD) is over 80% of the total amount in the province; Zhang et al [6] analyzed the changes in ecosystem services and its spatial distribution characteristics in Hangzhou from 2000 to 2010, and found that the ability of regional climate regulation changes accordingly when land cover changes. Most of the studies on the relationship between land use change and carbon stocks are based on the InVEST model, which was jointly developed by Stanford University, the World Wide Fund for Nature (WWF), and The Nature Conservancy (TNC). The quantitative assessment of ecosystem services is expressed in the form of a graph, which solves the problem of abstract expression in words.

Most of the previous researchers took economically developed cities or larger regions as the research target, while there were fewer studies on small and medium-sized cities, and even fewer of them took Qingyuan City as the research area in the study of the relationship between LUCC and carbon stock.

Given this, this paper, based on summarizing the research results of previous researchers, takes Qingyuan City as the study area, based on the land use cover data from 1990 to 2020, and adopts the InVEST model to analyze the spatiotemporal distribution of the carbon stock from 1990 to 2020, and the influence of the land use changes on it. That is to provide decision-making reference for the ecological civilization construction, urbanization process, and comprehensive rural revitalization in Qingyuan City.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

Qingyuan City (located between latitude 23°26′56″-25°11′40″N and longitude 111°55′17″-113°55′34″E) is situated in the north-central part of Guangdong Province (Figure 1), in the middle and lower reaches of the Beijiang River, south of the southeastern hills, and on the combined belt of the southern side of the Nanling Mountain Range and the Pearl River Delta. It is known as the “Back Garden of Guangdong." By the tip of 2021, the total land area was about 19,000 square kilometers. At the end of 2023, the household population was about 4,533,500 and the resident population was about 3,986,700.

In terms of topography and geomorphology, its terrain displays a high northwest and low southeast, with the eastern part of Lianzhou and the northeastern part of Yangshan being one of the most precipitous mountainous areas in Guangdong Province. Comparatively speaking, the southeastern areas of Qingxin, Qingcheng, and Yingde are located in the valley area of the Beijiang River; therefore, the terrain is relatively low and flat, with an elevation of basically less than 20 meters.

In respect of climate, it belongs to the Subtropical monsoon climate zone, with distinct seasons, sufficient light, and abundant rainfall. The average annual temperature is 20.7 °C, and the average annual precipitation is 1,909 mm. In the development of the economy, efforts to build “ten billion agricultural industries"—Qingyuan chicken, Yingde black tea, Lianzhou cabbage, hemp bamboo shoots, and silk seedling rice—five special agricultural products—to promote the high-quality development of agriculture in Qingyuan City with a unique “Qingyuan way” to help revitalize the countryside.

2.2 Data Sources

The data used in this paper consists of five items, each of which is stated below:

(1) Elevation data (DEM): derived from a geospatial data cloud (GDC) (https://www.gscloud.cn/), with operations such as merge and extraction by mask in ArcGIS;

(2) Meteorological data: average annual precipitation and average annual temperature from the Qingyuan Municipal People's Government Portal (http://www.gdqy.gov.cn/), and the Guangdong Provincial Intelligence Network (https://dfz.gd.gov.cn/), used to calculate carbon pool data;

(3) LUCC data: 1990-2020 remote sensing monitoring raster data of the current land use situation in China, with a spatial resolution of 1km, data from the Resource and Environment Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn);

(4) Carbon pool data: Referring to the study of carbon

density in Guangdong Province by Lin Tong and Yang Muzhuang, etc. [7], the database of carbon density of land use types in Qingyuan City was finally obtained with corrections;

(5) Administrative division data: administrative boundaries of Guangdong Province, Qingyuan City, districts, and counties, data from the website of the National Basic Geographic Information System (http://ngcc.sbsm.gov.cn/).

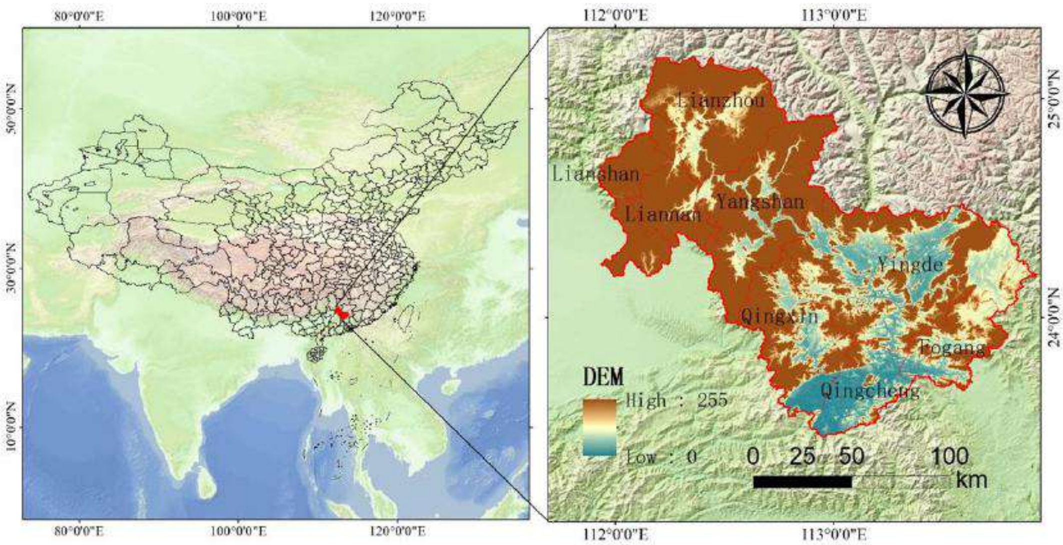

Fig.1 Elevation and Geographic Location of Qingyuan City

III. RESEARCH METHOD

3.1 Research Process

The process of this study is as follows: first, the data are collected and organized, which are DEM remote sensing data, administrative boundaries, LUCC from 1990 to 2020, meteorological data, and carbon density of Guangdong Province in Qingyuan City. Inputting the former three data into ArcGIS for extracting and series operation by mask, we can get the distribution of land use types in Qingyuan City at each time point. Then the LUCC data are reclassified to get the first level of land use classification; the carbon density of Guangdong Province is combined with the average annual temperature and precipitation using the carbon density correction formula to calculate, thus we can get the carbon density data of Qingyuan City; the two data are organized into the required format and inputted into the InVEST model, and then the carbon stock estimation value is achieved. Finally, the results obtained were mapped by using ArcGIS and Origin to visualize the abstract textual data for easier analysis (Figure 2).

3.2.1 Carbon Storage Calculation based on the InVEST Model

In this paper, based on the land cover type first-level classification maps and the carbon density of four carbon pools (above-ground biomass, underground biomass, soil, and dead organic matter), we applied the Carbon module of the InVEST model to estimate carbon stocks at a time point of every ten years, starting from 1990. The detailed carbon stock calculation formula is:

$$C_T=C_a+C_b+C_s+C_d \quad (1)$$

In the formula, C_T is the total carbon stock, C_a is the above-ground carbon stock, C_b is the below-ground carbon stock, C_s is the soil carbon stock, and C_d is the dead organic matter carbon stock.

Carbon density data corresponding to different land classes in Guangdong Province were obtained through the study of Lin Tong et al. [7]. The dead organic matter carbon stock was not considered in this study due to the difficulty of obtaining it and its relatively small share in the carbon pool [8]. The major calculations are aboveground vegetation, belowground vegetation, and soil carbon density values for land use types under various primary classifications.

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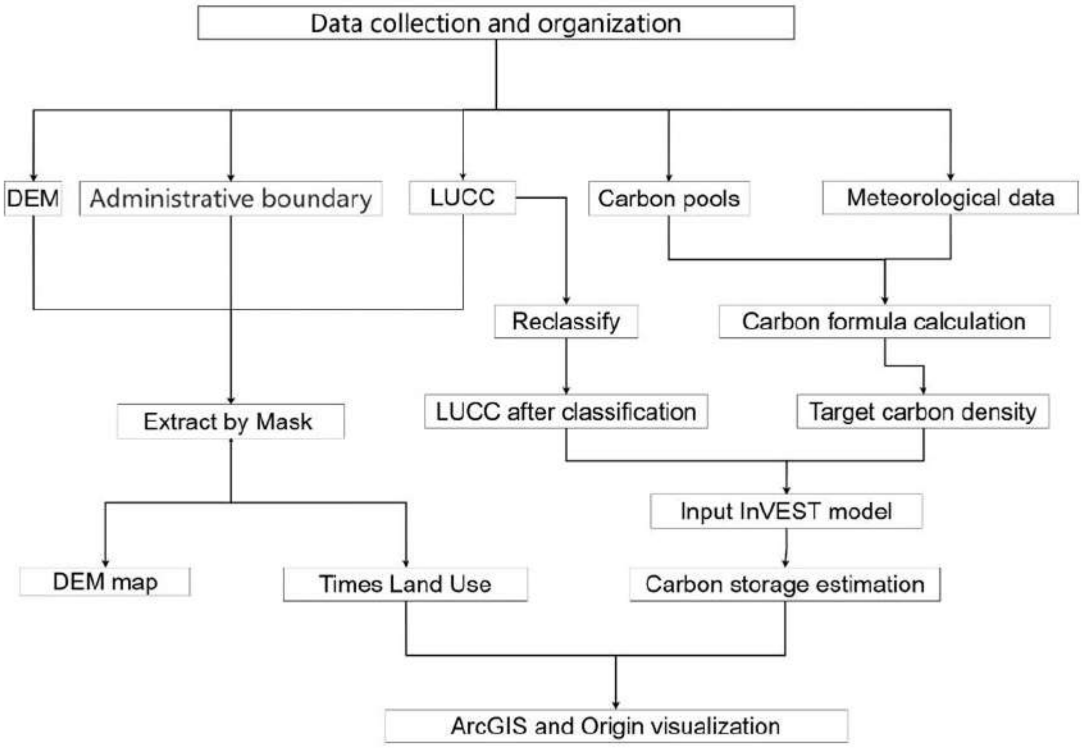

Fig.2 Flow Chart of the Study

3.2.2 Carbon Density Correction

Referring to Guangdong Province Situation Network (https://dfz.gd.gov.cn/) "Guangdong Yearbook 2019" and Qingyuan Municipal People's Government Portal (http://www.gdqy.gov.cn/) "2023 Qingyuan Climate Bulletin," we get the average temperatures of Guangdong Province and Qingyuan City are 21.8°C and 20.7°C, and the average rainfall is 1789.3mm and 1909mm. Based on the principle of a high degree of generalization and more similar climatic conditions, the carbon density correction formula was selected to correct the carbon density of Guangdong Province [7]. The equations for the relationship between annual precipitation and soil carbon density (equation 2, 3) were drawn from Alam's study [9], while the relationship between mean annual temperature and biocarbon density was drawn from Chen Guangshui et al.'s study [10] (Eq. 4). The exact carbon density correction formula is as follows:

$C_{SP}=3.3968\times MAP+3996.1$ （2）

$C_{BP}=6.798\times e^{0.0054\times MAP}$ （3）

$C_{BT}=28\times MAT$ （4）

Where: C_{SP} is the soil carbon density (kg/m^2) based on annual precipitation, C_{BP} and C_{BT} are the biomass carbon densities (kg/m^2) according to the annual average precipitation and annual average temperature, MAP is the annual average precipitation (mm), and MAT is the annual average temperature (°C).

Take the average annual temperature and average annual precipitation values of Guangdong Province and Qingyuan City into the above formula, and the ratio of the two is the carbon density correction factor of Qingyuan City.

$$K_{BP}=\frac{C'_{BP}}{C''_{BP}};K_{BT}=\frac{C'_{BT}}{C''_{BT}}$$

$$K_B=K_{BP}\times K_{BT} = \frac{C'_{BP}}{C''_{BT}}\times\frac{C'_{BT}}{C''_{BT}} \quad (5)$$

$$K_S=\frac{C'_{SP}}{C''_{SP}} \quad (6)$$

In the equation: K_{BP}, K_{BT} are the corrector coefficients of precipitation factor and temperature factor for biomass carbon density; C′ and C″ are the carbon density data of Qingyuan City and Guangdong Province, K_B, K_S are the aboveground and belowground biomass carbon density correction coefficients and the soil carbon density correction coefficient, respectively. Multiply the correction coefficient with the carbon density value of

Guangdong Province to get the carbon density data of Qingyuan City, and finally get the carbon density data of each category in Table 1. This was used to calculate the carbon stock in the study area for different periods and different land use types [11].

Table 1 Corrected Carbon Density of Land Cover Types (Mg/hm²)

Land cover type	Aboveground biomass	Underground biomass	Soil
Cultivated land	29.12	5.82	11.28
Forest	35.6	10.68	20.06
Grass	29.71	154.5	10.39
Waters	0.21	1.01	1.26
Construction	20.87	4.18	18.7
Unused	25.76	5.15	5.55

IV. RESULTS AND ANALYSIS

4.1 Analysis of Land Use Change

The ArcMap raster calculator was used to obtain the land use transfer matrix for each type from 1990 to 2020 (Table 2) and combined with Origin mapping software to produce a Sankey map of the land cover transfer from 1990 to 2020 (Figure 3) to visually analyze the land use cover changes.

The results show an increase in construction land and water area, with the largest increase being in construction land, which increased by 258km², and water area, which increased by 35km². Except for the size of unused land, which did not change, all the other land use types are in a state of decrease, of which the first place is cultivated land, with a decrease of 213km², and the total area of each type of decrease is 293km², with cultivated land accounting for 72.70% of the total decrease. The smallest decrease was in grassland, which decreased by only 10 km², accounting for 3.41%. In the middle of the list of decreases is forest land, with a decrease of 70km², accounting for 23.89%. The largest source of increase in construction land is cultivated land with 241km² converted, followed by forest land with 104km² converted, which is the main source of increase in the area of construction land. The least conversion to construction land was unused land, with only 1km² converted over thirty years. The most conversions to waters were also cultivated land with a total of 110km². Cultivated land converted the most into forest land at 799km², while forest land converted the most into cultivated land, totaling 788km², with conversions between cultivated land and forest land essentially equal. Grassland was mostly converted out to forest land, totaling 296km². Waters and construction land were the most converted to cultivated land, totaling 73km² and 97km², respectively.

Table 2 Land Use Transfer Matrix of Qingyuan City, 1990-2020 (km²)

Year		2020					
Land use type		Cultivated land	Forest	Grass	Waters	Construction	Unused
1990	Cultivated land	2891	799	114	110	241	1
	Forest	788	11634	286	44	104	0
	Grass	94	296	903	2	34	0
	Waters	73	39	9	200	15	0
	Construction	97	18	7	15	168	0
	Unused	0	0	0	0	1	0

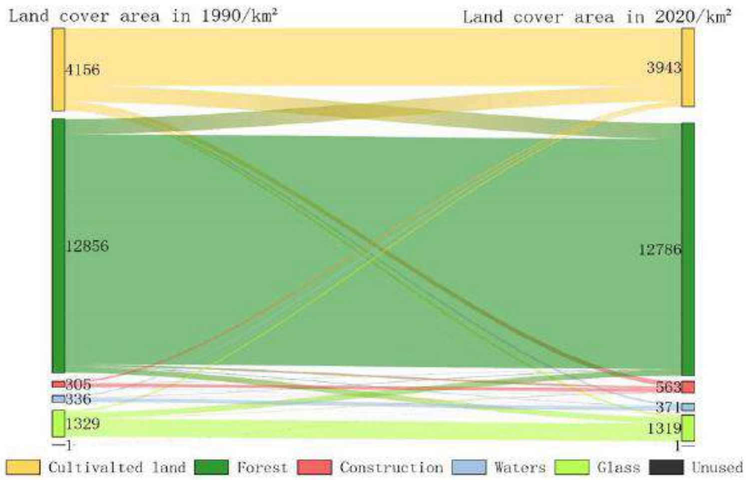

Fig.3 Sankey map of land cover transfer in Qingyuan City, 1990-2020

From the viewpoint of spatial layout (Figure 4), among the four points in time, construction land is clustered in the urban area of Qingyuan City, that is, Qingcheng District, while the rest is basically scattered in the economic centers of counties and county-level cities, without any obvious clustered distribution of construction land even in Qingxin District. During the period, the expansion of construction land in Qingcheng District and Yingde City was obvious, and the construction land in the remaining areas was not significant but also expanded, with construction land expanding area mainly through encroachment on cultivated land. The phenomenon of conversion of grassland to forest land in the eastern part of Yangshan County is evident in the second and third time points, but it recovers in the last time point, and the rest of the land use types do not change significantly.

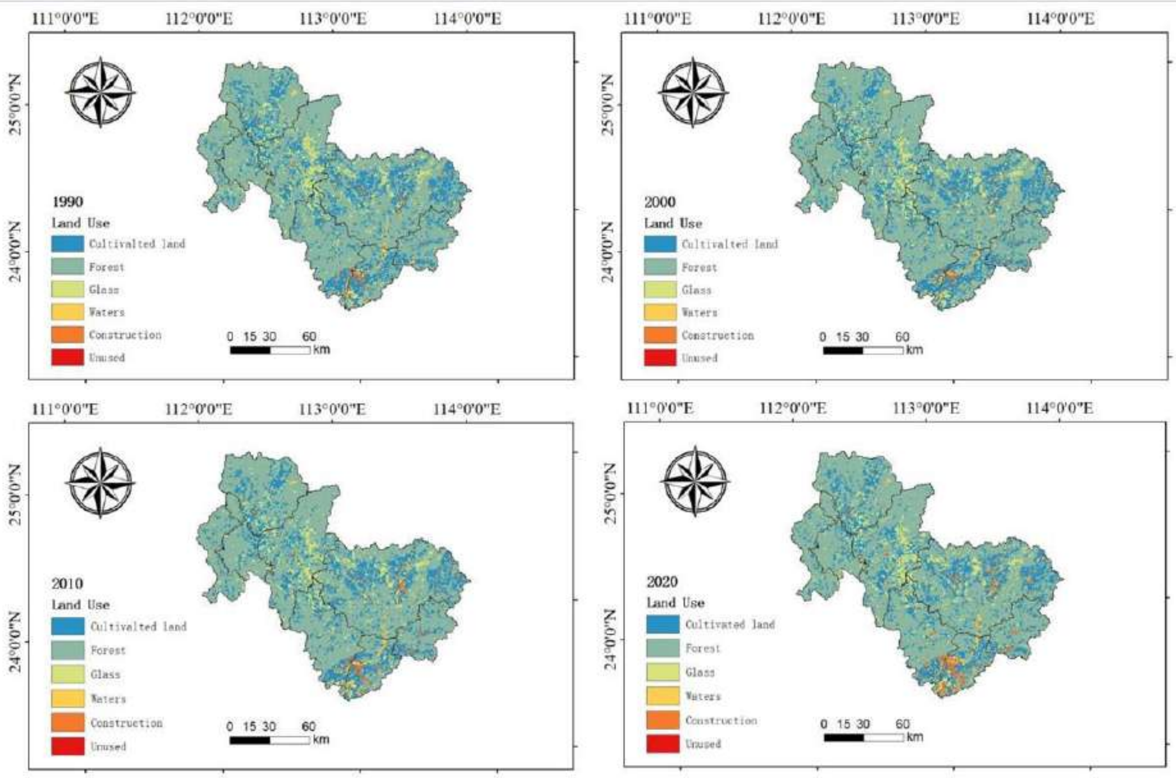

Fig.4 Distribution of land use types in Qingyuan City, 1990-2020

4.2 Distribution and Spatiotemporal Variation of Carbon Storage

By inputting the distribution of land use types and the corrected carbon density data into the InVEST model, the spatial distribution map of carbon stocks at each time point can be obtained (Figure 5). The spatial distribution of carbon stock in Qingyuan City has not changed much in the past three decades, and the low carbon stock area is mainly located in the junction of Qingcheng District and Qingxin District, and the northern part of Yingde and Lianzhou; the high carbon stock area shows a clustered distribution in the eastern part of Yangshan County and the junction of Yangshan County, Qingxin District and Yingde City. Liannan Yao Autonomous County, Lianshan Zhuang Yao Autonomous County, and Fogang County are basically medium. The overall situation is characterized by “high in the middle, low in the south, and medium in the northwest”.

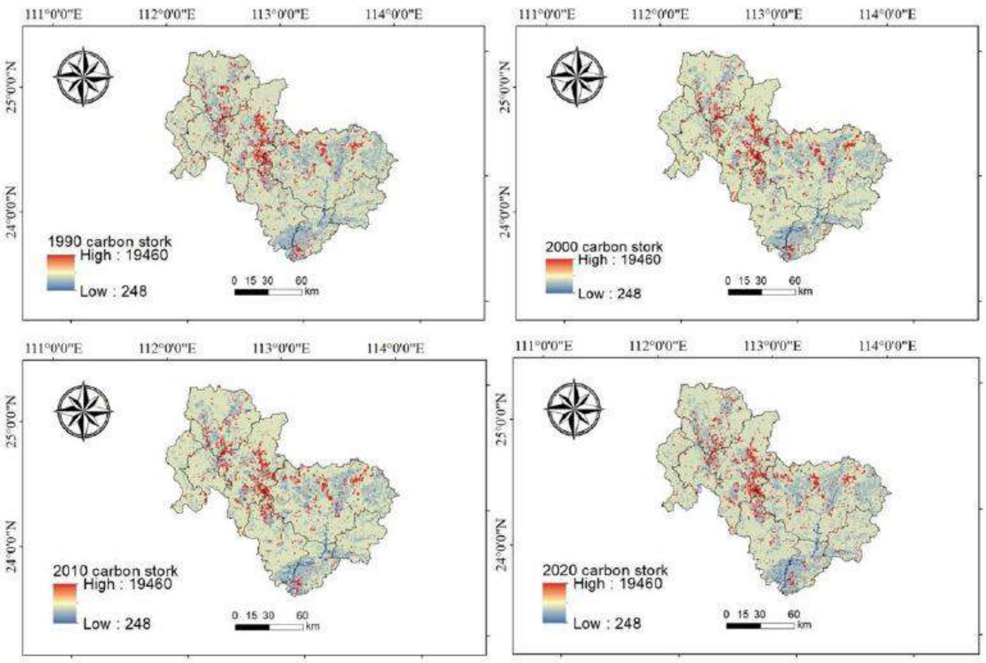

Fig.5 Spatial Distribution of Carbon Stocks in Qingyuan City, 1990~2020

From the analysis of the main land use types (Table 3), the carbon stocks at each time point were, from largest to smallest: forest land > grassland> cultivated land > construction land > waters > unused land, respectively. The land use type with the largest carbon stock in 1990 was forest land, which accounted for 64.77% of the city's total, totaling 85,691,378 Mg. The reason for this was the high carbon density of forest land itself and the fact that forest land was the most extensive among the various land types within Qingyuan. By 2020, forest land was still the largest land use type in terms of carbon stock, accounting for 64.65%, followed by grassland (19.55%) and cultivated land (13.85%).

Analyzing the carbon stock changes of each land use type in the past 30 years (Figure 6), the carbon stock of forest land in Qingyuan City first had a slight decline, then rose in the middle, and finally declined again, with a total reduction of 59.71 × 10^4 Mg; the carbon stock of cultivated land first rose, then declined, with a reduction of 99.37 × 10^4 Mg; and the carbon stock of grassland first declined, then rose, but up to 2020, it still declined by 23.35 × 10^4 Mg. On the other hand, the carbon stock of construction land decreased slightly between 1990 to 2000 but showed a spike after 2000 with the rapid expansion of the area, and finally, the carbon stock of this land category increased by a total of 112.87 × 10^4 Mg. Carbon stocks in waters show slow growth, and unused land carbon stocks show growth due to the change in area and finally also rebound with the area. The area of the most carbon-intensive land use types has decreased significantly over the last 30 years, resulting in a decrease in total regional carbon stocks.

Table 3 Land Use Carbon Stock in Qingyuan City, 1990-2020 (×10^4 Mg)

Land use type	1990 年	2000 年	2010 年	2020 年
Cultivated land	1922.75 （14.53）	1924.14 （14.59）	1871.45 （14.26）	1823.38 （13.85）
Forest	8569.14 （64.77）	8563.17 （64.93）	8586.39 （65.43）	8509.43 （64.65）
Grass	2595.96 （19.62）	2560.94 （19.42）	2483.10 （18.92）	2572.61 （19.55）
Waters	8.36 （0.06）	8.48 （0.06）	9.13 （0.07）	9.20 （0.07）
Construction	133.44 （1.01）	130.38 （0.99）	171.06 （1.30）	246.31 （1.87）
Unused	0.36 （0.00）	1.09 （0.01）	1.09 （0.01）	0.36 （0.00）
Total	13230.01 （100.00）	13188.19 （100.00）	13122.21 （100.00）	13161.30 （100.00）

Note: Percentage in ( ), %.

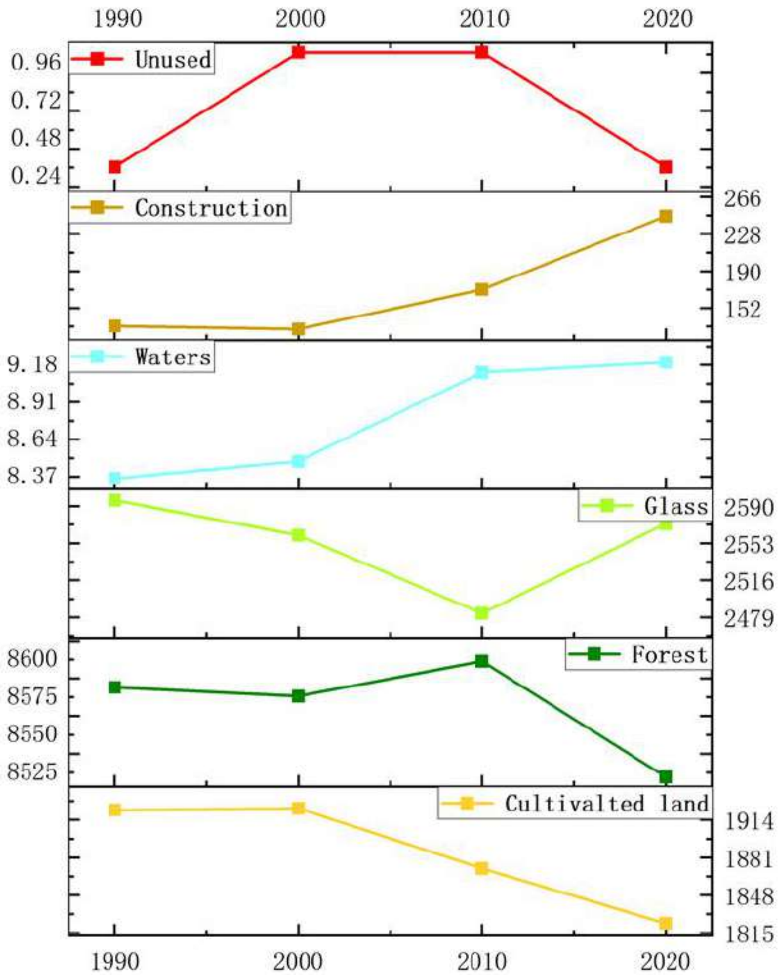

Fig.6 Temporal Change of Carbon Stock by Category in Qingyuan City, 1990-2020

4.3 The Impact of Land Cover Change on Carbon Storage

Based on the comprehensive analysis of land cover and carbon stock change characteristics at each time point in the study area, the area of cultivated land decreased the most during the 30 years (213 km^2), thus resulting in the largest reduction of carbon stock in cultivated land, with a total reduction of 99.37 × 104 Mg. The area of construction land increased the most (258 km^2), so the increase in carbon stock in it was also the most, totaling 112.88 × 104 Mg. The area of construction land increased the most (258 km^2), so the increase in carbon stock in it was also the most, totaling 112.88 × 104 Mg; however, the increase in carbon stock brought about by the increase in construction land was much smaller than the decrease in carbon stock from the degradation of other land use types. The amount of area reduction in grassland is much lower than cultivated land, but compared to other land cover types, grassland area reduction leads to the most significant change in carbon stock, with a loss of carbon stock of about 2.36 × 104 Mg per 1 km^2 of grassland reduction.

On the contrary, the change in carbon stocks due to an increase in water area is the weakest, with an increase of only 0.024 × 104 Mg per 1 km^2 of additional waters. Thus, the dominant factors of carbon stock changes during the studied thirty years were the changes in grassland, forest land, and cultivated land. Taking 1990 as the starting point and 2020 as the endpoint, the carbon stock in Qingyuan City decreased by a total of 68.71 × 104 Mg during the thirty years

V. CONCLUSIONS

Based on the InVEST model, monitoring the changes in land use types and estimating the carbon stock in Qingyuan City in the last thirty years, the following conclusions were drawn:

(1) Changes in land-use types: the areas of cultivated land, forest land, and grassland have all decreased, with the area of cultivated land decreasing by a maximum of 213km^2. The area of construction land and waters increased, with the largest increase in the area of construction land being 258km^2; the area of unused land fluctuated slightly during the study period, but the final area remained the same as at the beginning. By 2020, the percentage of the area of each land use type was: cultivated land (20.77%), forest land (67.36%), grassland (6.95%), waters (1.95%), construction land (2.97%), and unused land (0.01%). Construction land is mainly concentrated in Qingcheng District and southeastern Qingxin District, and the expansion of construction land in Yingde over the past thirty years has been more obvious; cultivated land is mainly clustered in Lianzhou, Yangshan, and Yingde. Grassland is distributed continuously in the eastern part of Yangshan and part of Yingde.

(2) Change in carbon stock: In the past thirty years, the carbon stock in Qingyuan City has decreased by 68.71 × 10^4 Mg, mainly since a large amount of cultivated land, forest land, and grassland have been developed and constructed as construction land and waters. The distribution of carbon stocks is similar to the type of land use, with areas where cultivated land, forest land, and grassland are located having correspondingly higher carbon stocks. Yangshan County, which has the widest distribution of grassland, has the highest corresponding carbon stock, while Qingcheng District, which has the highest degree of urbanization and development, has the largest area of construction land distribution with the lowest corresponding carbon stock in Qingcheng District. Qingyuan City as a whole is characterized by “high in the middle, low in the south and medium in the northwest”.

(3) Carbon stock is one of the important indicators for measuring the function of ecosystem services, which is inextricably linked to the survival and development of human beings and at the same time has an important relationship with the sustainable development of the region. From Figure 5, it can be seen that the carbon stock in the Qingcheng urban area of Qingyuan City has decreased most significantly over the past thirty years, and the rapid economic development may hurt the carbon stock by changing the type of land use, increasing the carbon emission and affecting the ecosystem function. The coordinated development of the economy and ecological protection is a requirement set out in national development plans and an important task for sustainable development.

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Genome-wide identification, Characterization, and Expression analysis of the *Caffeic Acid O-Methyl Transferase* (*COMT*) Gene Family of *Sorghum Bicolor*

Prashanth Bollempally[1], Vinod Kumar Anumandla[1], Anjana Priyadarshani Kanathala[2], Srinivas Naik Kethavath[2] and Prashant Singam[1]*

[1]Department of Genetics, Osmania University, Hyderabad -500 007, India
[2]Centre for Plant Molecular Biology, Osmania University, Hyderabad -500 007, India
*Corresponding author: Dr. Singam Prashant
Email: prashantsingam@gmail.com
Department of Genetics, Osmania University, Hyderabad, India.

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***Abstract*— *Caffeic acid O-methyltransferases (COMTs) are essential enzymes for producing natural products in plants, specifically involved in the phenylalanine metabolic pathway and the monolignol biosynthetic pathway. These enzymes are responsible for the methylation of caffeic acid compounds, which are the building blocks for many plant-derived compounds with various biological activities. The investigation of the evolutionary divergence, expression patterns under diverse abiotic stress conditions, and lignin content-related features of the COMT gene family in Sorghum has not been explored. In this study, forty-eight SbCOMTs were identified in S.bicolor. Based on the examination of evolutionary relationships, 48 SbCOMTs were classified into two distinct categories. The gene characterization and the conserved motif patterns in each group were similar, demonstrating the reliability of the phylogenetic categorization. Chromosomes 5 and 7 have been found as the hotspot of SbCOMTs with 10 and 7 genes respectively. Phylogenetic analysis revealed the conservation of Sorghum COMT genes among Zea mays and Oryza sativa. Investigation of regulatory elements specifies the significant roles that COMT genes play in the monolignol biosynthetic pathway of S. bicolor. Analysis of miRNA, transcription factor binding, and gene expression analysis provides insights to further engineer lignin biosynthetic pathway for better biofuel yield. We found that two SbCOMTs (SbCOMT26& 36) were highly expressed and their relative contents were similar to the variation drift of lignin content under abiotic stress conditions in S. bicolor. These results provide a clue for further study on the roles of SbCOMTs in the development of Sorghum and could favourably be foundations for the cultivation of Sorghum with higher biomass and yield with enhanced abiotic stress tolerance.*

***Keywords*— Caffeic acid O-methyltransferase, Monolignol biosynthesis, Abiotic stress, Biomass, Biofuels.**

Highlights

- Discovery of *COMT* gene family members in Sorghum helps in identification of genes responsible for developmental lignification and their involvement in other metabolic process.
- Cis regulatory analysis, transcription factor prediction and miRNA analysis *SbCOMTs* provide insights into manipulation of these genes for development of crops for better biofuel yield.
- The genomic location and tissue specific expression analysis of *Caffeic acid O-*

methyltransferase (*COMT*) genes under drought and salt stress reveal their critical role in lignification in *Sorghum bicolor.*

I. INTRODUCTION

O-methyltransferases (OMTs) catalyze a wide range of reactions in lignin and flavonoid biosynthesis pathways. COMTs are responsible for lignin biosynthesis and are involved in phenyl-alanine metabolism in plants. According to previous reports on monolignol production, the key methylations of Lignin precursors are primarily facilitated by specific S-adenosyl-L-methionine (SAM)-dependent enzymes, including caffeoyl CoA 3-O-methyltransferase (CCoAOMT; EC 2.1.1.104) and caffeic acid O-methyltransferase (COMT; EC 2.1.1.68) (Louie et al. 2010). The COMTs are grouped in plant type 1 of the SAM-dependent O-methyltransferases family (Noel et al. 2003). These enzymes utilize S-adenosyl-methionine as a methyl group donor and perform methylation of the 5-hydroxyl group of their substrate, 5-hydroxy coniferaldehyde, ultimately leading to the production of S-lignin units.In *Arabidopsis thaliana*, COMT may convert 5-OH coniferaldehyde/5-OH coniferyl alcohol into sinapaldehyde/sinapyl alcohol and caffeic acid into ferulic acid, which results in the synthesis of both G and S units of lignin (Goujon et al., 2003). Previous studies on *Arabidopsis thaliana* by Lee et al. (2015) suggest that COMT is also essential for the conversion of N-acetyl serotonin to melatonin. The COMTs of *sorghum* can methylate flavones such as luteolin and selgin in *sorghum* to aid the synthesis of tricin (Eudes et al. 2017).

Sorghum (*Sorghum bicolor*) is one of the primary staple grains consumed in India, following rice (*Oryza sativa*) and wheat (*Triticum aestivum*), and holds the 5th position in global cereal production. In addition, it is a promising crop for biofuel and a possible source of cellulosic feedstock. The estimated size of its diploid genome is 730 MB, and it has a haploid chromosome number of 10. Plant-based renewable biofuels promise sustainable solutions to food and energy demands. *Sorghum* offers the status of a highly diverse food, feed, and biofuel source globally. *Sorghum* is a useful crop for almost all renewable energy systems that are being developed for green technology and renewable fuels.

Lignin is a polyphenolic polymer enclosed by wood fibres, other tube bundle cells, and thick-walled cell walls. The three major monolignols, p-coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol, yield p-hydroxyphenyl (H), guaiacyl (G), and syringyl (S) subunits, respectively. Upon polymerization, these three subunits will form rigid and complex lignin in plants. The composition of these subunits will regulate the physical properties and digestibility of lignin (Baucher et al., 2003). Bugos et al. (1991) reported the first exploration of the COMT gene family in *Populus tremuloides*. Later, the COMT gene family is uncovered in several species, which include seven COMTs in *Eucalyptus grandis* (Carocha et al., 2015), *Catalpa bungei* comprises 23 COMTs (Lu et al., 2019), 92 COMT members found in *blueberries* (Liu et al., 2021), *Populus trichocarpa* (Chiang et al., 2010), *Brassica rapa* L. (Wei et al., 2016), and *Betula pendula* (Chen et al., 2020) harbours 25 COMT candidates and *Soybean* contains 55 COMTs (Zhang et al., 2021). In plants, COMT regulates responses to a variety of stresses, including drought (Yao et al., 2022), salt (Chang et al.,2021), cold (Zhang et al., 2021), and phytohormone signaling.

In the present study, identification of COMT homologs, gene structure, gene characterizations, chromosomal locations, evolutionary relationships, conserved motifs analysis, cellular localization, promoter analysis, protein modeling, protein-protein interactions, miRNA prediction, transcription factor prediction, and expression patterns was mined in *S. bicolor*. These findings would help in the manipulation of the lignin biosynthetic pathway for better biofuel yield and breeding *Sorghum* cultivars with enhanced abiotic and biotic stress tolerance.

II. MATERIALS AND METHODS

Plant material and induction of stress

Seeds of the *Sorghum bicolor*high biomass variety (IS 4698) were obtained from the Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, and sown in pots filled with 4 kg of black soil at the Departmental Farm, Department of Genetics, Osmania University, Hyderabad (India). Seedlings were raised in a glass house environment at 28–20^{0}C day/night temperatures. Sixty-five-day-old seedlings were treated with 200 mM NaCl solution and 200 mM Mannitol solution for 48 hours each. Under comparable conditions, corresponding controls were kept well-watered and without any treatment. Various plant tissues, such as leaves, stems, and roots, were collected from both the treated and control groups. These tissues were then snap-frozen in liquid nitrogen and preserved at -80°C for future use. Three technical and three biological replicates were employed for the qRT-PCR study.

***In silico* prediction, identification, and characterization of *SbCOMT* genes**

For the identification of the *COMT* gene family in *Sorghum*, the protein sequences of the *Sorghum bicolor* genome were retrieved from the Phytozome (http://www.phytozome.net/) plant database to use as the local protein database. Previously characterized

Arabidopsis COMT genes were used to perform a BLASTP search against the local protein database with a threshold of E-value < 1e-5. The PFAM profile was used as the query to search against the local protein database using HMMER 3.0 with a threshold of E-value < 1e-5. Based on the results of HMMER and BLASTP, the redundant sequences were removed. Then, the putative *Sorghum* COMT genes were retrieved from PFAM databases (http://pfam.xfam.org/search) to predict the conserved protein domain, and those containing a complete COMT domain remained as candidates.

Gene structure prediction, conserved motif analysis, sub-cellular localization, and protein parameters

The prediction of gene structure was carried out using GTF annotation files using TB tools. For the prediction of subcellular localization of the proteins, WoLFPSORT was used. Parameters like isoelectric point (pI), molecular weight (MW), GRAVY (grand average of hydropathy), instability, and aliphatic indexes in ProtParam software were employed. For conserved motifs, MEME with parameters like 10 numbers of motifs, 2–20 motif sites, and 6–20 wide motif widths were used. The genes on the chromosomes were mapped based on their physical location using an online phenogram tool.

Phylogenetic analysis, multiple sequence alignment, generation of Synteny maps, and Ka/Ks analysis

A phylogenetic tree was developed using the MEGAv10 program, employing the Neighbour-Joining algorithm (Kumar et al. 2018) with 1000 bootstrap samples based on the amino acid sequences of *Sorghum bicolor* (Sb), *Oryza sativa*(Os), *Zea mays* (Zm), and *Arabidopsis thaliana* (At). SbCOMT 26 and 36 proteins were aligned with orthologs in the above-mentioned species using MEGAv10.0. All the predicted SbCOMT homologs were mapped on *Z. mays* and *O. sativa* genomes, and synteny maps were generated with TB tools (Chen et al. 2020). The synonymous to non-synonymous ratios and time of evolution (MYA) of the SbCOMT paralog pair were calculated by an online Ka/Ks calculator.

Prediction of cis-elements, protein modelling, and protein-protein interactions

Promoter elements were identified for all the SbCOMT genes from the Phytozome database, and the 1500-bp sequence upstream for all the *Sorghum* COMT homologs was extracted and submitted to the Plant CARE database (http://bioinformatics.psb.ugent.be/webtools/plantcare/html/) to predict cis-elements. The 3D structures of all the SbCOMT proteins were predicted using the SWISS-MODEL server (https://swissmodel.expasy.org/) (Biasini. et al. 2014). The predicted 3D structures of proteins were evaluated for stability using the Protein Structure Verification Server (PSVS) (https://saves.mbi.ucla.edu/) and Ramachandran plots. The predicted protein-protein interaction (PPI) map of *Sorghum* COMT homologs was generated from the STRING database (https://string-db.org/).

miRNA and Transcription factor analysis

We predicted miRNAs that might target SbCOMTs to control their expression using the Plant psRNA Target tool (https://www.zhaolab.org/psRNATarget/) with default parameters, and all of the *Sorghum* miRNAs were used. The regulatory network of the SbCOMT gene and miRNA was visualized using Cytoscape (https://cytoscape.org/). Transcription factor binding sites of all SbCOMT homologs were predicted by the Plant transcription factor database (PTFDB) (http://planttfdb.gao-lab.org/) and a network built using Cytoscape.

***In silico* expression analysis of *SbCOMT* genes**

The transcriptome data (FPKM) of Sorghum was downloaded from the Gramene database (https://www.gramene.org/). The transcriptome data include baseline expression of SbCOMTs in various organs of *Sorghum* (Davidson et al. 2012), vascular and non-vascular tissue (Turco et al. 2017), stem internodes of bioenergy *Sorghum* (Kebrom et al. 2017), and expression patterns in leaf and root tissue under drought conditions (Varoquaux et al. 2019). The expression patterns were visualized by a heat map built with TB tools. Transcriptome (FPKM) data of *S. bicolor* under osmotic stress and ABA stress (Acc: SRP007361) (Dugas et al. 2011) mined from the Morokoshi *Sorghum* transcriptome database (http://sorghum.riken.jp).

Expression analysis of *SbCOMT* genes by qRT PCR

Total RNA was extracted from stress-exposed and control (without stress) plants using the Trizol reagent method. The purity of the RNA was determined using an Eppendorf Bio photometer. One microgram of RNA was used as a template for first-strand cDNA synthesis with the PrimeScriptTM RT Reagent Kit (Takara, Japan) according to the manufacturer's instructions. 2X SYBR Premix Ex Tag (Tli RNaseH Plus, Takara, Japan) Master Mix with gene-specific primers (Table 5) was used to determine the relative gene expression levels of SbCOMTs.

Thermal cycling conditions of 95^{0}C for 2 min, followed by 40 cycles of 95 ^{0}C for 30 s, 58 ^{0}C for 30 s, and 72 ^{0}C for 30 s, were programmed in the ABI 7500 real-time PCR system (Applied Biosystems, Foster City, CA) for qRT-PCR analysis. SbCOMT gene expression in both treated and control samples was normalized using the EIF4a (Eukaryotic Initiation Factor 4A) reference gene. For each sample, qRT-PCR was performed using three biological and three technical replicates. The relative amounts (fold change) of each transcript were calculated using the comparative 2^ΔΔCT method.

III. RESULTS

Identification and Characterization of SbCOMT homologs in *Sorghum bicolor*

A total of 48 potential sequences were obtained from the *Sorghum* genome. Then, all 48 candidate sequences were scanned for a methyltransf_2 domain. Forty-eight sequences with a methyltransf_2 domain (Fig. 1.d) were identified in the Sorghum diploid genome. All of them were mapped on pseudochromosomes and renamed from SbCOMT1 to SbCOMT48 (Table 1). The protein parameters (Table 2) and gene structural characteristics were analyzed (Fig. 1.b). The result showed that SbCOMT43 was the shortest protein (100 amino acids), and the longest one was SbCOMT9.

The molecular weight of 48 SbCOMT proteins ranged from 39 to 47 kDa, and the isoelectric point ranged from 4.65 to 7.13. The investigation of the conserved domain and gene structure indicated that all *COMT* genes possessed a catalytic domain at the C-terminus, which was referred to as the Methyltransf_2 domain, encompassing a binding pocket for SAM/SAH and the AdoMet-MTase superfamily domain. Some of them showed a common structure with an N-terminal domain called dimerization. The binding pocket for SAM/SAH exhibited significant conservation, whereas the binding sites for substrates were distinct for proteins belonging to diverse groups. SbCOMT 32, 34, 37, and 38 contain 3:4 of introns: exons; SbCOMT9, 26; and COMT47 consist of two introns and three exons; and SbCOMT 30, 40, and 41 have only one exon without introns. The patterns of the methyltransf_2 domain in SbCOMTs were similar in the same group.

The structural differences in protein sequences across the *Sorghum* COMTs were assessed using the Multiple Expectation Maximisation for Motif Elicitation (MEME) online tools (Fig. 1.c). A total of 10 motifs were found in the sorghum COMT proteins. Most of the motifs were the same in the two groups, and they were in the same order in COMT proteins within the same group. The consensus motif 1 (Methyl transferase-2) and motif 2 (AdoMet-MTase) are found in all SbCOMTs.

Most of the SbCOMT gene homologs are localized in the cytoplasm, followed by the chloroplast, plasma membrane, and mitochondria. Only SbCOMT39 is present in mitochondria; SbCOMT9, SbCOMT10, SbCOMT15, SbCOMT16, SbCOMT23, SbCOMT40, SbCOMT41, SbCOMT44, and SbCOMT45 are localized on the plasma membrane; SbCOMT5, SbCOMT24, SbCOMT26, SbCOMT27, SbCOMT32, SbCOMT34, SbCOMT35, SbCOMT37, SbCOMT38, SbCOMT43, SbCOMT46, SbCOMT47, and SbCOMT48 are localized in the cytoplasm; and the rest of the SbCOMT homologs are found in the cytoplasm (Table 1).

Phylogenetic analysis, multiple sequence alignment, chromosomal location, synteny, and Ka/Ks analysis of SbCOMTs

The phylogenetic tree analysis revealed the evolutionary connection of SbCOMT homologs in *Sorghum bicolor* with *Oryza sativa*, *Zea mays*, and *Arabidopsis thaliana* (Fig. 2.a). A total of 15 SbCOMT paralogs were identified. A neighbourhood joining (NJ) phylogenetic tree created with *Sorghum* COMT protein sequences showed that the proteins were distributed into two groups.

Sorghum showed 12 ortholog pairs, 11 with *Zea mays* (SbCOMT9 and ZmCOMT18, SbCOMT10 and ZmCOMT12, SbCOMT11, and ZmCOMT20, SbCOMT16 and ZmCOMT29, SbCOMT17 and ZmCOMT5 and SbCOMT20 and ZmCOMT6, SbCONT26, and ZmCOMT22, SbCOMT30 and ZmCOMT31, SbCOMT31 and ZmCOMT4, SbCOMT36 and ZmCOMT28, SbCOMT43 and ZmCOMT17) and 1 with *Oryza* (SbCOMT5 and OsCOMT16). The location of SbCOMT homologs was mapped on the *Sorghum* genome (Fig. 2.b). SbCOMT genes are scattered on all 10 chromosomes of *Sorghum*. Synonymous to non-synonymous substitution rates (Ka/Ks) of 9 *Sorghum* paralogs (SbCOMT1 and SbCOMT2, SbCOMT3 and SbCOMT4, SbCOMT8, and SbCOMT12, SbCOMT14 and SbCOMT20, SbCOMT18 and SbCOMT21, SbCOMT19 and SbCOMT22, SbCOMT23 and SbCOMT24, SbCOMT28 and SbCOMT30, SbCOMT32 and SbCOMT34) were calculated (Table 3).

Multiple sequence alignments of SbCOMT26 and 36 with orthologs in other species displayed highly conserved residues, which indicates these genes are conserved among species. All *Sorghum* paralogs showed substitution rates <1. The lowest Ka/Ks (0.05735056) was observed in gene pairs SbCOMT18 and SbCOMT21, and the highest Ka/Ks were observed in gene pairs SbCOMT32 and SbCOMT34, respectively. The selection pressures on the COMTs in *S. bicolor* were explored based on the Ka/Ks ratios. This investigation revealed that the Ka/Ks ratios of SbCOMT paralogs are <1, which indicates that SbCOMTs experienced purifying selection during evolution.

Collinearity analysis of SbCOMT homologs has been performed on the genomes of *Zea mays* and *Oryza sativa* (Figs. 3a and b). *S. bicolor* chromosomes 1, 5, and 9 display 3, 3, and 2 homologs each with the *Zea mays genome*, respectively. *S. bicolor* chromosome 1 shows 2 homologs with the *Zea mays* 9 chromosome and 1 homolog with the *Zea mays* 10 chromosome; *S. bicolor* chromosome 4 displays 1 homolog on the *Zea mays* 4 chromosome; *S. bicolor* chromosome 5 displays 3 homologs on the *Zea mays genome*, 2 homologs on the 4th, and 1 homolog on the 2nd chromosome; and *S. bicolor* chromosome 9 shows two homologs with *Zea mays* chromosomes 6 and 8, respectively. Pink-coloured links represent homologs between two genomes. The *S. bicolor* genome shows a total of 6 homologs in the *O. sativa* genome. *S. bicolor* chromosome 4 shows one homolog with *O. sativa* chromosome 2, and *S. bicolor* chromosome 3 displays 1 homolog with *O. sativa* chromosomes 1 and 5, and *S. bicolor* chromosome 5 shows 1 homolog with *O. sativa* chromosome 1. Sb chromosome 7 displays 1 homolog with O. sativa chromosome 8 and Sb chromosome 9 shows 1 homolog with *O. sativa* chromosome 5.

Cis-regulatory elements analysis of SbCOMTs

The initiation of transcription is a pivotal phase in gene expression, representing a critical juncture where RNA polymerase interacts with regulatory sequences like the promoter, which ultimately impacts the gene expression level. (Liu et al. 2019). Promoter analysis of SbCOMT homologs revealed the occurrence of lignin biosynthesis, abiotic stress, light-responsive, and phytohormone-responsive putative cis-regulatory elements (Fig. 4). Different elements like defense-responsive, wound-responsive, MYB-drought-responsive, MYB-light-responsive, and MYB-flavonoid genes-related cis-regulatory elements are found in the promoter regions of SbCOMT genes. MYB and NAC represented the highest number of elements in all the SbCOMT homologs, indicating their involvement in lignin biosynthesis and stress tolerance. SbCOMT homologs contain defense-responsive elements, indicating their involvement in biotic stress-related defense. Most COMT homologs have phytohormone-responsive elements like ABRE, MeJARE, GARE, SARE, and AURE. MeJARE and SARE, the defense-responsive elements, have been found to have the highest number of elements among the phytohormone-responsive elements and have been identified in all the SbCOMT homologs, indicating their involvement in defense mechanisms. Light-responsive elements are also found in the promoter regions of SbCOMT homologs. This finding indicates that COMT genes in *S. bicolor* may be regulated by light. Similar cis-regulatory elements within homologs may significantly influence similarities among gene expression patterns and gene roles. A large majority of SbCOMTs had ABRE, related to abscisic acid, and MeJRE, related to methyl jasmonate.

3D structures and PPI analysis of SbCOMTs

3D structures of SbCOMT proteins were predicted with the best PDB templates (Fig. 5.a). The template PDB ID, chain, model of the oligomer, and their structure validations are represented in Table. 3D structures of SbCOMT36 displayed 100% identity with the Caffeic acid-O-Methyltransferase of *S. bicolor* (PDB ID-4pgg.1. A) protein, and SbCOMT38 showed 100% identity with the Stilbene-O-Methyltransferase protein (PDB ID-7vb8.1. A). The rest of the SbCOMT homologs displayed identity, with corresponding templates ranging from 31% to 66%. In the predicted PPI map, one of the putatively expressed and characterized SbCOMT (36) proteins exhibited interactions with several proteins (Fig. 5.b). SbCOMT36 protein shows 11 nodes with 38 edges with other proteins. Each protein showed more than one interactant. The proteins that display interactions with SbCOMT (Sb07g003860.1) are CAD (Sb04g005950.1) terminal gene in Lignin biosynthesis; phenylalanine ammonia-lyase (Sb04g026510.1, Sb04g026520.1, Sb01g014020.1, Sb06g022750.1, Sb06g022740.1) is involved in the L-phenylalanine catabolic process, phenylpropanoid biosynthetic process, and phenylpropanoid metabolic process. Probable 4-coumarate-coA ligase 1 (Sb07g007810.1) is involved in the early stages of lignin biosynthesis; F5H (Sb02g002630.1) is involved in the conversion of coniferaldehyde to sinapaldehyde in lignin biosynthesis; and Folylpolyglutamate synthase (Sb01g049840.1) is involved in purine, pyrimidine, and amino acid synthesis.

miRNA and Transcription factor binding site prediction

Additionally, we predicted the miRNAs that might target SbCOMTs to regulate their expression. In total, 19 SbCOMT genes were found to be targeted by 31 miRNAs, and miRNA-SbCOMT interactions were constructed (Fig. 6.a). Combined with the miRNA-SbCOMT relationship and co-regulation modules of SbCOMTs, which provide some insights into the regulation of SbCOMTs expression to control lignin biosynthesis, in silico analysis of SbCOMTs revealed the presence of numerous cis-elements that may assist as binding sites for transcription factors with vital functions in lignin biosynthesis. To further determine this, Plant TFDB (Jin et al. 2014) was used to attain comparative models of transcription factors binding on regulatory regions of SbCOMTs. The model displays interactions with various transcription factors such as Dof, LFY, BES1, MYB-related, E2F, HSF, TCP, ARF, ERF, MICK-MADS, SBP, NAC, MYB, and LBD (Fig. 6.b). Plants comprise an MYB sub-family protein that is characterized by the R2R3-type MYB domain, which plays the role of master regulatory switch in secondary cell wall biosynthesis (McCarthy et al. 2009; Zhong et al. 2012; Kim et al. 2019). They might also directly activate some lignin genes through the secondary wall MYB-responsive element (SMRE) binding site (consensus motif ACC(A/T) A(A/C) (T/C)) in the promoter region (Zhong et al. 2012). MYB transcription factors function specifically in the regulation of lignin biosynthesis (Stracke et al. 2001).

The NAC family of transcription factors is composed of a vast array of proteins. NAC transcription factors were found to contribute to plant responses to pathogens, viral infections, and environmental stimuli such as drought and salinity conditions (Xie et al., 1999; Ren et al., 2000; Collinge et al., 2001; Kim et al., 2007). Certain NAC transcription factors have been identified as playing a crucial role in controlling cell aging, proliferation, and the development of wood. (Takada et al., 2001; Vroemen et al., 2003; Weir et al., 2004; Zhong et al., 2006; Kim et al., 2007; Yamaguchi et al., 2008).

In silico expression analysis of SbCOMTs

The transcriptome data (FPKM) of SbCOMT genes were analyzed to determine the expression patterns of these genes under natural habitat and in drought, osmotic, and Abscisic acid stress conditions in various tissues and organs of *S. bicolor*. We predicted the expression patterns of SbCOMT homologs in different regions of the stem internodes of bioenergy sorghum (Fig. 7.a). Among all SbCOMTs, SbCOMT36 displayed the highest level of expression patterns in all regions of the stem internodes of bioenergy *sorghum*. SbCOMT11 and 7 showed the highest expression patterns in internode regions 2 and 3. The investigation of expression patterns of SbCOMTs in vascular and non-vascular tissues of s*orghum* (Fig. 7.b) revealed that SbCOMT6, 23, 25, 26, and 27 exhibited the highest expression patterns and the rest of the genes expressed in the medium to very low range. In the baseline expression analysis (Fig. 7.c), at the embryonic stage, SbCOMT26 showed a medium expression level, SbCOMT34 and 30 displayed a low level of expression, and the rest of the genes did not show significant expression patterns. At the flowering stage, SbCOMT36 displayed the highest level of expression, and SbCOMT33 and 17 showed a medium range of expression. In the floral meristem, only SbCOMT26 showed a medium level of expression; none of the SbCOMT homologs displayed significant expression patterns. In meristematic tissue, only SbCOMT26 and 36 showed a medium-range expression pattern. In the shoot, SbCOMT 17 and 36 are highly expressed, and SbCOMT 19, 11, and 26 exhibit an average range of expression. In root tissue, SbCOMT36 and 20 exhibited the highest expression patterns, followed by SbCOMT17 and 3, which displayed the second-highest expression patterns.

In the floral meristem, only SbCOMT26 showed a medium level of expression; none of the SbCOMT homologs displayed significant expression patterns. In meristematic tissue, only SbCOMT26 and 36 showed a medium-range expression pattern. In the shoot, SbCOMT 17 and 36 are highly expressed, and SbCOMT 19, 11, and 26 exhibit an average range of expression. In root tissue, SbCOMT36 and 20 exhibited the highest expression patterns, followed by SbCOMT17 and 3, which displayed the second-highest expression patterns. We analyzed the expression patterns of SbCOMTs in leaf and root tissues under drought conditions at different growth intervals (Fig. 7.d). At 42 days of growth in leaf tissue under drought stress, expression levels of SbCOMT 17, 25, 26, and 30 are highly up-regulated. The expression of SbCOMT 12, 29, and 33 is up-regulated in leaf tissue after 63 days of growth. At 77 days of growth, SbCOMT6, 25, and 26 were up-regulated, and only a few SbCOMT homologs were down-regulated in leaf tissue under drought conditions.

None of the *SbCOMT* genes exhibited significant expression patterns in the rest of the growth stages of *sorghum* in leaf tissue during drought stress responses. When compared with root tissue under drought conditions, SbCOMT1, 2, 20, 21, 37, 38, and 39 displayed a low range of expression and also exhibited constant expression in all stages of growth. The expression of SbCOMT25 is up-regulated in root tissue at 35 days and 77 days under drought, and the expression of SbCOMT6 and 36 displayed the highest level of expression at 77 days of growth under the drought stress response.

Additionally, we explored the expression patterns of SbCOMT homologs in *S. bicolor* shoot and root tissue under osmotic (NaOH), ABA, and PEG stress conditions (Fig. 7.e). SbCOMT-36 was highly up-regulated in root tissue under osmotic stress conditions and displayed moderate expression in root tissue under ABA and PEG stress conditions also, SbCOMT-36 shows moderate expression patterns in shoot tissue, almost in the above-mentioned stress conditions. SbCOMT-20 and SbCOMT-17 displayed medium expression patterns in root tissue under osmotic stress conditions and shoot tissue under PEG treatment, respectively.

qRT PCR analysis of SbCOMT genes

Based on in silico transcriptome analysis, SbCOMT26 and 36 were considered for qRT-PCR analysis in different tissues and organs of *Sorghum bicolor* under control, drought, and salinity stress conditions due to their expression in major lignifying organs of *sorghum*. SbCOMT homologs showed variable gene expression across different tissues (Fig. 8). SbCOMT26 expression was significantly higher during drought stress compared to salt stress. Among the stress treatments, drought-stressed leaves and salt-stressed stem tissues showed a 12.47-fold and 11.75-fold rise in transcript levels of SbCOMT26, respectively. However, there was no significant increase in SbCOMT26 expression under drought and salt stress conditions in other *sorghum* tissues. Whereas, SbCOMT36 expression was found to be higher in salt stress than in drought stress conditions. SbCOMT36 expression was significantly increased in salt-stressed stems. Under salt-stress conditions, there was a 32-fold rise in SbCOMT36 transcript levels in shoots and a 3-fold rise in drought-stressed roots.

IV. DISCUSSION

Caffeic acid O-methyltransferases (COMTs) are essential enzymes that contribute significantly to the synthesis of lignin and the phenylalanine metabolic pathway in plants. Frequently, attempts are made to manipulate the lignin makeup of genetically modified crops to enhance their digestibility as forage, effectiveness in pulping, and the production of biofuels. L-phenylalanine serves as the preliminary material for the synthesis of monolignols. According to the current understanding of monolignol production, the essential O-methylations of hydroxyl groups on the phenolic ring of monolignol precursors are primarily facilitated by specific S-adenosyl-L-methionine (SAM)-dependent enzymes, including caffeoyl CoA 3-O-methyltransferase (CCoAOMT; EC 2.1.1.104) and caffeic acid O-methyltransferase (COMT; EC 2.1.1.68). (Louie et al. 2010). The COMTs are classified in the plant type-1 family of SAM-dependent O-methyltransferases (Noel et al. 2003). *Sorghum caffeic acid O-methyltransferase* uses S-adenosyl-methionine as a donor of methyl groups and performs methylation of the 5-hydroxyl group of its favored substrate, 5-hydroxyconiferaldehyde, ultimately leading to the production of S-lignin units. O-methyltransferases (OMTs) are responsible for a variety of versatile reactions in the biosynthesis pathways of lignin and flavonoids.

Since COMTs may respond to a variety of substrates, including phenylpropanoids, flavonoids, and alkaloids, they are likely to respond to a variety of stimuli. As a result, they are ubiquitous in plants due to their significance in helping plants adapt to their environment and challenging circumstances (Nomura et al., 2010). The publication of diverse plant genomes has allowed analyses of COMT family genes in several species to be carried out (Barakat et al., 2011; Wu et al., 2013; Liu et al., 2016) and is majorly involved in lignin biosynthesis as lignin provides mechanical strength to plants. *Sorghum bicolor* has been extensively studied for its large amounts of flavonoids, primarily in food crops, forage, and biofuel crops. The *Sorghum* v3 genome was released in 2017, and 48 COMTs have been identified, named SbCOMT1-SbCOMT48. Subsequently, many homologs have been detected in plants. We need to understand which of the homologs performs the crucial processes of plant growth, flavonoid metabolism, phenylalanine metabolism, stress tolerance, and lignin biosynthesis. Four plants, including *Sorghum bicolor*, *Zea mays*, *Oryza sativa*, and *Arabidopsis thaliana*, were examined in this study, and each was shown to have a distinct number of COMTs. COMTs in all these plants comprise the conserved methyltransferase-2 and dimerization domains. Furthermore, we found that the number of COMTs in *S. bicolor* is greater than that in *O. sativa*, *Zea mays*, and *Arabidopsis thaliana*. *Oryza sativa* contains the second-highest number of COMTs (39 COMT homologs), followed by *Zea mays* (32 COMT homologs). *Arabidopsis thaliana* comprises the least number of COMTs (17 COMT homologs) of all the studied species. The conserved domains of identified SbCOMT homologs, i.e., methyltransferase-2 and dimerization domains, correlate with those of other plants (Liu et al., 2021).

Lignin is the key component of vascular tissue and provides plants with structural support to stand upright. COMTs are important enzymes involved in lignin biosynthesis that catalyze the methylation of S-lignin monomers. Evolutionary analysis suggests that these 48 SbCOMTs are grouped into two clades denoted as Group Ia, Group Ib, and Group II. SbCOMT homologs were more closely related to *O. sativa* COMTs than *Arabidopsis thaliana*. All the identified SbCOMT proteins comprise the conserved Methyl transferase-2 (PF00891) domain, which has 207 amino acid residues, including a SAM/SAH binding pocket and a substrate-binding site, and the Dimerization domain (PF08100), which contains 52 amino acid residues. All the discovered SbCOMT homologs displayed conserved AdoMet-MTase superfamily domains.

In the present research, all the identified *Sorghum* homologs comprised conserved domains such as methyl transferase-2 and dimerization domains, and they were involved in numerous functions. About 20–30% of SbCOMT homologs belong to the Iso flavone-O-Methyltransferase family. These methyltransferases were involved in secondary metabolite biosynthesis and iso-flavonoid biosynthesis (BRENDA: EC2.1.1.46). Some of them SbCOMTs belong to the ZPR3 and ZPR4 families, which encode O-methyltransferase and might be complicated in suberin biosynthesis (Held et al. 1993). SbCOMT5, belonging to Trans-resveratrol di-O-methyltransferase and Resveratrol O-methyltransferase, plays vital roles in biotic (Sambangi et al. 2016) and abiotic stress responses (Chiron et al. 2000). SbCOMT 34, 37, and 38 functionally belonged to the iso-eugenol O-methyltransferase family and regulated the biosynthesis of secondary metabolites and phenylpropanoid biosynthesis (BRENDA: EC2.1.1.146).

Collinearity analysis of SbCOMTs with other species, including *O. sativa* and *Z. mays*, revealed varied collinearity with each species. One of the SbCOMT genes shows two collinearity blocks on the *Z. mays* genome. This observation suggests that *Z. mays* has undergone two rounds of whole-genome duplication. WGD and TD are the key forces behind gene expansion in *Populus* (Chiang et al., 2010; Barakat et al., 2011). COMTs of *maize*, *rice*, and *foxtail millet* have similar gene copy numbers (Liu et al. 2019). The SbCOMT homolog gene pairs had Ka/Ks ratios of <1, indicating that the SbCOMTs had undergone significant purifying selection. The cis-regulatory elements existing in the promoter regions were the binding sites of the COMTs gene with other proteins, which play an essential role in regulating gene transcription. There were a huge number of light-responsive elements, phytohormone-responsive elements, which involve plant defense mechanisms and growth, drought stress-responsive elements, and regulatory elements that promote lignin synthesis (Sega et al., 2020).

COMT expression was upregulated in plants when stressed or exposed to hormones. (Asif et al., 2014; Zhang et al., 2015; Li et al., 2016; FU et al., 2019). According to in silico expression analysis, SbCOMT26 and SbCOMT36 are highly expressed in all tissues of sorghum under natural conditions and also in leaf and root tissues under drought stress responses at different growth intervals. This study demonstrates the relationship between SbCOMTs, a crucial enzyme in the biosynthesis of monolignol, and the methods by which sorghum adapts to drought stress. Zhang et al. (2021) reported that the COMT gene family plays a significant role in plant defense to abiotic stress and lignification under drought conditions. Under drought conditions, lignin concentration increased considerably in the stems of *Eucalyptus urograndis* and *Eucalyptus globulus* (Moura-Sobczak et al. 2011). SbCOMTs are implicated in salt stress responses. Under salt stress, the contents of S and G units of lignin are raised in Coffea arabica (de Lima et al. 2014).

In many abiotic stress conditions, such as drought stress, the majority of the genes of the monolignol biosynthesis pathway are usually upregulated. This helps plants resist water loss by fortifying their cell walls.We also found that SbCOMT26 and 36 are highly stimulated under drought and salt stress; hence, these are potential targets for manipulation of lignin biosynthesis in sorghum to engineer biomass for better biofuel yield and enhanced abiotic stress tolerance.

CONCLUSION

In the present research, we identified COMT48 genes from *Sorghum bicolor*. Based on a phylogenetic investigation of COMTs, we divided the COMTs into two groups, which specified the existence of two ancestor genes. Gene characterization, conserved domains, motif identification, localization, and phylogenetic analysis revealed a close relationship between *Sorghum bicolor* COMT gene homologs and its relative *Oryza sativa* and *Zea mays*. The Ka/Ks ratios for the COMTs from *Sorghum* were less than one, indicating that the COMTs have undergone strong purifying selection. Identification of cis-acting elements and transcription factor prediction would be helpful to explore further and manipulate SbCOMT genes to design better biofuel crops. The miRNA prediction and elucidation of expression patterns under diverse abiotic stress conditions would help in the regulation of SbCOMT genes to engineer the lignin composition, further improving the biomass and enhancing abiotic stress tolerance in *Sorghum bicolor*.

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AUTHOR CONTRIBUTION STATEMENT

PB and SP have designed the experiments and the structure of the article. PB has prepared the first draft. All others have added lateral text in the manuscript and refined it. APK, and VKA have prepared the figures. SP, SNK, PB, APK, and VKA have revised the manuscript. All authors have read and approved it.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

STATEMENTS AND DECLARATIONS

Competing Interests:

The authors declare that they have no competing interests.

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Table 1: Characterization of SbCOMT homologs.

Gene Name	Transcript ID	Chr	CDS bp	Introns/Exons	A.a	Domain	Mw (kDa)	Localization
>SbCOMT-1	Sobic.010G230800.1	10	1125	01:02	375	Methyl transferase-2	41.366	Cytoplasmic
>SbCOMT-2	Sobic.010G231000.2	10	1287	01:02	429	Methyl transferase-2	47.265	Cytoplasmic
>SbCOMT-3	Sobic.010G234500.1	10	1149	01:02	383	Methyl transferase-2	42.007	Cytoplasmic
>SbCOMT-4	Sobic.010G234400.1	10	1152	01:02	384	Methyl transferase-2	42.131	Cytoplasmic
>SbCOMT-5	Sobic.003G298500.1	3	1152	01:02	384	Methyl transferase-2	41.293	Chloroplast
>SbCOMT-6	Sobic.009G197600.4	9	1089	01:02	363	Methyl transferase-2	39.438	Cytoplasmic
>SbCOMT-7	Sobic.009G197600.5	9	1089	01:02	363	Methyl transferase-2	39.438	Cytoplasmic
>SbCOMT-8	Sobic.009G197800.1	9	711	01:02	237	Methyl transferase-2	25.973	Cytoplasmic
>SbCOMT-9	Sobic.009G043900.1	9	1299	02:03	433	Methyl transferase-2	47.186	Plasma Membrane
>SbCOMT-10	Sobic.009G197400.1	9	1086	01:02	362	Methyl transferase-2	38.919	Plasma Membrane
>SbCOMT-11	Sobic.009G197000.1	9	1068	01:02	356	Methyl transferase-2	38.689	Cytoplasmic
>SbCOMT-12	Sobic.009G198000.1	9	1080	01:02	360	Methyl transferase-2	39.136	Cytoplasmic
>SbCOMT-13	Sobic.005G129100.1	5	1140	01:02	380	Methyl transferase-2	40.75	Cytoplasmic
>SbCOMT-14	Sobic.005G110451.1	5	690	01:02	230	Methyl transferase-2	25.578	Cytoplasmic
>SbCOMT-15	Sobic.005G086600.1	5	1125	01:02	375	Methyl transferase-2	40.754	Plasma Membrane
>SbCOMT-16	Sobic.005G045600.1	5	1116	01:02	372	Methyl transferase-2	39.886	Plasma Membrane
>SbCOMT-17	Sobic.005G101900.1	5	1098	01:02	366	Methyl transferase-2	40.51	Cytoplasmic
>SbCOMT-18	Sobic.005G216100.1	5	1092	01:02	364	Methyl transferase-2	38.627	Cytoplasmic
>SbCOMT-19	Sobic.005G224400.1	5	1119	01:02	373	Methyl transferase-2	40.898	Cytoplasmic
>SbCOMT-20	Sobic.005G107900.1	5	1101	01:02	367	Methyl transferase-2	39.939	Cytoplasmic
>SbCOMT-21	Sobic.005G216200.1	5	1092	01:02	364	Methyl transferase-2	38.641	Cytoplasmic
>SbCOMT-22	Sobic.005G224300.1	5	1119	01:02	373	Methyl transferase-2	41.077	Cytoplasmic
>SbCOMT-23	Sobic.008G014000.1	8	1182	01:02	394	Methyl transferase-2	42.377	Plasma Membrane
>SbCOMT-24	Sobic.008G013900.1	8	807	01:02	269	Methyl transferase-2	29.537	Chloroplast
>SbCOMT-25	Sobic.004G083500.1	4	1098	01:02	366	Methyl transferase-2	39.589	Cytoplasmic
>SbCOMT-26	Sobic.004G351400.1	4	1134	02:03	378	Methyl transferase-2	40.294	Chloroplast
>SbCOMT-27	Sobic.004G083401.1	4	933	02:03	311	Methyl transferase-2	33.646	Chloroplast
>SbCOMT-28	Sobic.004G341600.1	4	1176	01:02	392	Methyl transferase-2	41.801	Cytoplasmic
>SbCOMT-29	Sobic.004G128400.1	4	1089	01:02	363	Methyl transferase-2	39.287	Cytoplasmic
>SbCOMT-30	Sobic.004G341500.1	4	1209	00:01	403	Methyl transferase-2	43.573	Cytoplasmic
>SbCOMT-31	Sobic.007G099400.1	7	1092	01:02	364	Methyl transferase-2	40.032	Cytoplasmic
>SbCOMT-32	Sobic.007G058600.1	7	1110	03:04	370	Methyl transferase-2	40.347	Chloroplast
>SbCOMT-33	Sobic.007G170500.1	7	1107	01:02	369	Methyl transferase-2	39.719	Cytoplasmic
>SbCOMT-34	Sobic.007G058400.1	7	1131	03:04	377	Methyl transferase-2	40.846	Chloroplast
>SbCOMT-35	Sobic.007G074800.1	7	1125	01:02	375	Methyl transferase-2	40.628	Chloroplast
>SbCOMT-36	Sobic.007G047300.1	7	1089	01:02	363	Methyl transferase-2	39.59	Cytoplasmic
>SbCOMT-37	Sobic.007G058800.1	7	1125	03:04	375	Methyl transferase-2	41.064	Chloroplast
>SbCOMT-38	Sobic.007G059100.1	7	1134	03:04	378	Methyl transferase-2	41.492	Chloroplast
>SbCOMT-39	Sobic.001G354400.1	1	1098	01:02	366	Methyl transferase-2	39.583	Mitochondrial
>SbCOMT-40	Sobic.001G246700.1	1	852	00:01	284	Methyl transferase-2	33.125	Plasma Membrane

>SbCOMT-41	Sobic.001G246700.2	1	930	00:01	310	Methyl transferase-2	30.032	Plasma Membrane
>SbCOMT-42	Sobic.001G354200.1	1	1116	01:02	372	Methyl transferase-2	40.284	Cytoplasmic
>SbCOMT-43	Sobic.001G456650.1	1	300	03:04	100	Methyl transferase-2	39.602	Chloroplast
>SbCOMT-44	Sobic.006G008000.1	6	1125	01:02	375	Methyl transferase-2	40.857	Plasma Membrane
>SbCOMT-45	Sobic.006G007900.1	6	1125	01:02	375	Methyl transferase-2	40.884	Plasma Membrane
>SbCOMT-46	Sobic.002G079500.1	2	1140	01:02	380	Methyl transferase-2	40.46	Chloroplast
>SbCOMT-47	Sobic.002G079500.2	2	1032	02:03	344	Methyl transferase-2	36.41	Chloroplast
>SbCOMT-48	Sobic.002G077700.1	2	1188	01:02	396	Methyl transferase-2	42.752	Chloroplast

Table 2: SbCOMT protein parameters.

Gene Name	Protein length (A.A)	Protein Molecular Weight(kDa)	pI	GRAVY
SbCOMT-1	375	41.366	5.46	0.133
SbCOMT-2	429	47.265	5.51	0.036
SbCOMT-3	383	42.007	5.08	0.012
SbCOMT-4	384	42.131	5.21	0.026
SbCOMT-5	384	41.293	5.6	0.22
SbCOMT-6	363	39.438	5.42	0.15
SbCOMT-7	363	39.438	5.42	0.15
SbCOMT-8	237	25.973	4.65	0.248
SbCOMT-9	433	47.186	5.3	0.168
SbCOMT-10	362	38.919	5.45	0.204
SbCOMT-11	356	38.689	5.43	0.175
SbCOMT-12	360	39.136	5.8	0.231
SbCOMT-13	380	40.75	5.56	0.132
SbCOMT-14	230	25.578	5.46	-0.065
SbCOMT-15	375	40.754	5.13	0.2
SbCOMT-16	372	39.886	4.86	0.218
SbCOMT-17	366	40.51	5.61	0.056
SbCOMT-18	364	38.627	4.91	0.184
SbCOMT-19	373	40.898	5.38	0.117
SbCOMT-20	367	39.939	5.75	0.109
SbCOMT-21	364	38.641	4.91	0.185
SbCOMT-22	373	41.077	5.35	0.066
SbCOMT-23	394	42.377	6	0.081
SbCOMT-24	269	29.537	6.5	-0.065
SbCOMT-25	366	39.589	5.45	0.139
SbCOMT-26	378	40.294	5.32	-0.011
SbCOMT-27	311	33.646	5.2	0.106
SbCOMT-28	392	41.801	5	0.195
SbCOMT-29	363	39.287	5.39	0.172
SbCOMT-30	403	43.573	5.23	0.08
SbCOMT-31	364	40.032	5.39	0.086
SbCOMT-32	370	40.347	5.39	0.008
SbCOMT-33	369	39.719	5.84	0.194
SbCOMT-34	377	40.846	4.93	0.117
SbCOMT-35	375	40.628	7.13	0.086

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SbCOMT-36	363	39.59	5.46	-0.015
SbCOMT-37	375	41.064	5.05	0.007
SbCOMT-38	378	41.492	5.15	0.052
SbCOMT-39	366	39.583	5.77	0.166
SbCOMT-40	284	33.125	5.72	0.205
SbCOMT-41	310	30.032	4.97	0.253
SbCOMT-42	372	40.284	5.76	0.174
SbCOMT-43	100	39.602	5.54	0.033
SbCOMT-44	375	40.857	5.13	0.199
SbCOMT-45	375	40.884	5.15	0.199
SbCOMT-46	380	40.46	4.94	0.181
SbCOMT-47	344	36.41	5.29	0.029
SbCOMT-48	396	42.752	5.55	-0.03

pI, isoelectric point, GRAVY, Grand average of hydropathicity index

Table 3: Non-synonymous and synonymous substitution rates of sorghum COMT paralog genes

Gene-1	**Gene-2**	**Ka**	**Ks**	**Ka_Ks**	**T(MYA)**
SbCOMT1	SbCOMT2	0.093790365	0.279215	0.335907	7.148655862
SbCOMT3	SbCOMT4	0.02093362	0.166845	0.125468	1.59555029
SbCOMT28	SbCOMT30	0.099433025	0.390486	0.254639	7.578736631
SbCOMT23	SbCOMT24	0.114992761	0.302893	0.379648	8.764692129
SbCOMT8	SbCOMT12	0.01094577	0.081252	0.134714	0.834281284
SbCOMT19	SbCOMT22	0.065428074	0.459634	0.142348	4.98689589
SbCOMT14	SbCOMT20	0.139548407	0.696896	0.200243	10.63631153
SbCOMT32	SbCOMT34	0.066990967	0.080131	0.836019	5.106018846
SbCOMT18	SbCOMT21	0.001836361	0.03202	0.057351	0.139966528

Ks-synonymous substitution; Ka-non-synonymous substitution; T(MYA)-Evolution time in Million years ago. Time calculated based on T=Ks/2x where x is $6.56x10^{-9}$ formula.

Table 4: COMT genes in the four different genomes sequenced

Species	Total no of protein coding genes	Predicted no of COMT genes	Genome size	Reference
Sorghum bicolor v3	34129	48	730Mb	Phytozome
Arabidopsis thaliana TAIR10	27416	17	135Mb	Ensembl
Oryza sativa v7	42189	39	500Mb	Ensembl
Zea mays v4	39498	32	2.13Gb	Phytozome

Table 5: Primers used for q-RT PCR study

S.no	Name	Sequence	Len	Tm	GC%
1	SbPAL3-FP	5-GGTCTTGTCCGCTCCCTGAAC-3	21	62.96	61.90
	SbPAL3-RP	5-TCGCGCCCTGGATCTTCAC-3	19	62.37	63.16
2	SbPAL8-FP	5- CTCGTCTCCGCCAGGAAGA-3	19	61.05	63.16
	SbPAL8-RP	5-GACGGGTTCATGGTCAGCAC-3	20	61.30	60.00
3	SbC4H2-FP	5- AACCTGATGTCCCTCGCCAA-3	20	61.49	55.00
	SbC4H2-RP	5-GGCCTTTCCCCGTGAAGATG-3	20	61.03	60.00
4	Sb4CL4-FP	5- TGCAGACCTACTGCTTCGGG-3	20	61.89	60.00
	Sb4CL4-RP	5-AGTTGCGGAGCAGGTTCATC-3	20	60.67	55.00
5	SbHCT2-FP	5- GACGACTACGGTGACTTCGC-3	20	60.79	60.00
	SbHCT2-RP	5-CCAGACATGCCATCCGCTAC-3	20	60.88	60.00
6	SbC3H1-FP	5- GGAGCACGCAAAGTCTCTCA-3	20	60.32	55.00
	SbC3H1-RP	5-TCTGCCATTGCCCACTCAAC-3	20	60.90	55.00
7	SbCCoAOMT3-FP	5- CAGTGGGGGTTCATGCAGTC-3	20	60.96	60.00
	SbCCoAOMT3-RP	5-TACTCCCTGCTCACGTCGAA-3	20	60.61	55.00
8	SbCCoAOMT1-FP	5-CGGAGGACGGCACGATCT-3	18	60.26	58.00
	SbCCoAOMT1-RP	5- CGAAGTCGAACGACCCGTG-3	19	59.30	59.69
9	SbCCR1-FP	5- GACCTGGGATTGGAGTTCCG-3	20	60.11	60.00
	SbCCR1-RP	5- CACGCACGGATGGCGATT-3	18	61.20	61.11
10	SbF5H1-FP	5- CATGGACGTGATGTTTGGCG-3	20	60.18	55.00
	SbF5H1-RP	5-TGAGGAAGGGGAGCTTGTCC-3	20	61.20	60.00
11	SbCAD2-FP	5- CGTCCGAGAGGAAGGTGGTC-3	20	61.94	65.00
	SbCAD2-RP	5-GGGTACTTTGAAGCCCCGAG-3	20	60.39	60.00

Tools & Database used in this study:

1. **MEGA v 7.0 (http://www.megasoftware.net)**
2. **TBtools (https://github.com/CJ-Chen/TBtools/releases)**
3. **Wolfpsort (https://wolfpsort.hgc.jp)**
4. **Phytozome (http://www.phytozome.net/)**
5. **MEME (http://meme-suite.org/tools/meme)**
6. **Protparam (https://web.expasy.org/protparam/)**
7. **SMART (http://smart.embl-heidelberg.de/)**
8. **PFAM database (http://pfam.xfam.org/ search)**
9. **Ka/Ks calculator (http://services.cbu.uib.no/tools/kaks)**

10. PlantCARE database (http://bioinformatics.psb.ugent.be/webtools/plantcare/html/)

11. SWISS-MODEL SERVER (https://swissmodel.expasy.org/)

12. Protein structure verification server (SAVES v6.0) (https://saves.mbi.ucla.edu/).

13. STRING database (https://string-db.org/).

14. A Plant Small RNA Target Analysis Server (https://www.zhaolab.org/psRNATarget/)

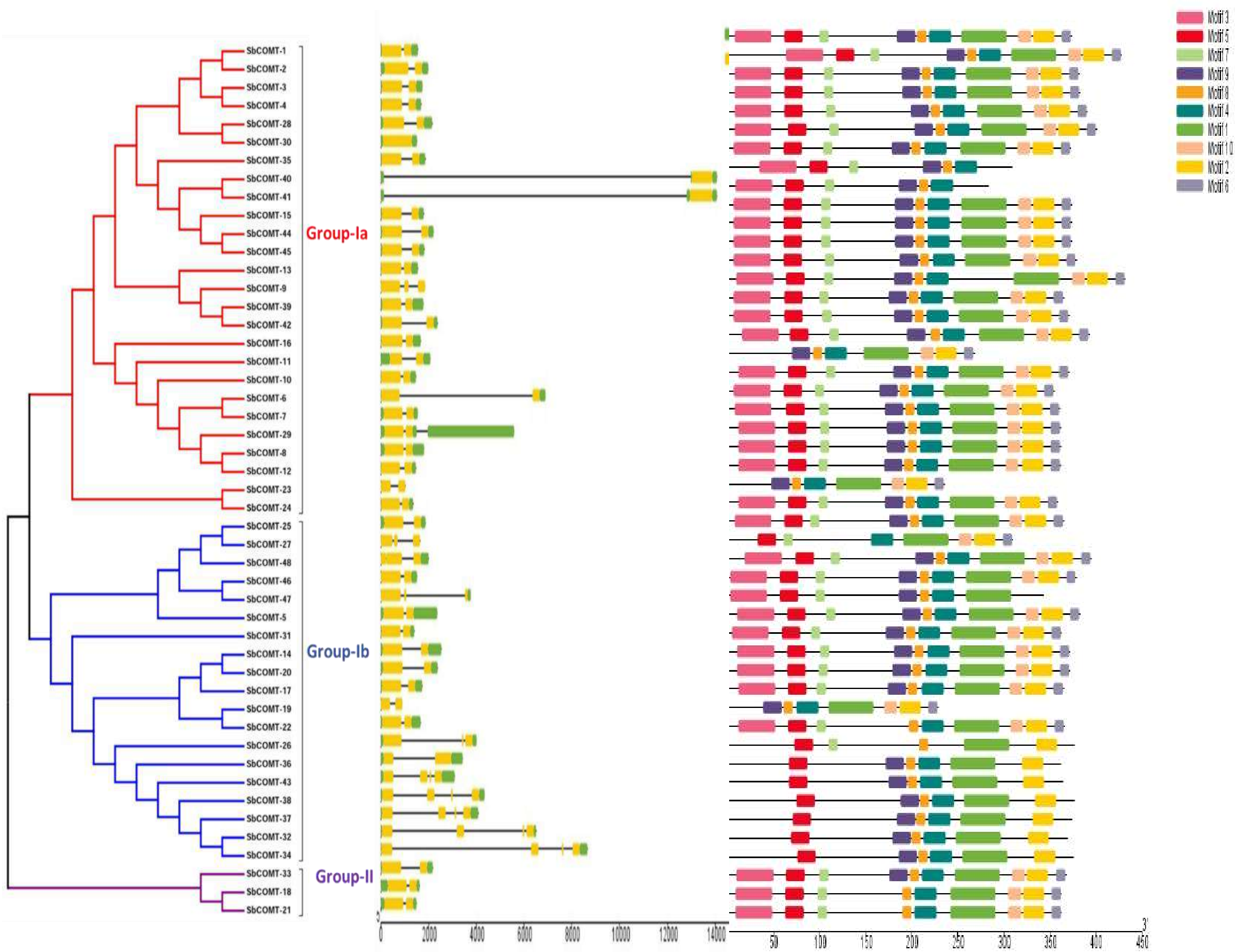
15. Cytoscape (https://cytoscape.org/).

16. Plant transcription factor database (PTFDB) (http://planttfdb.gao-lab.org/)

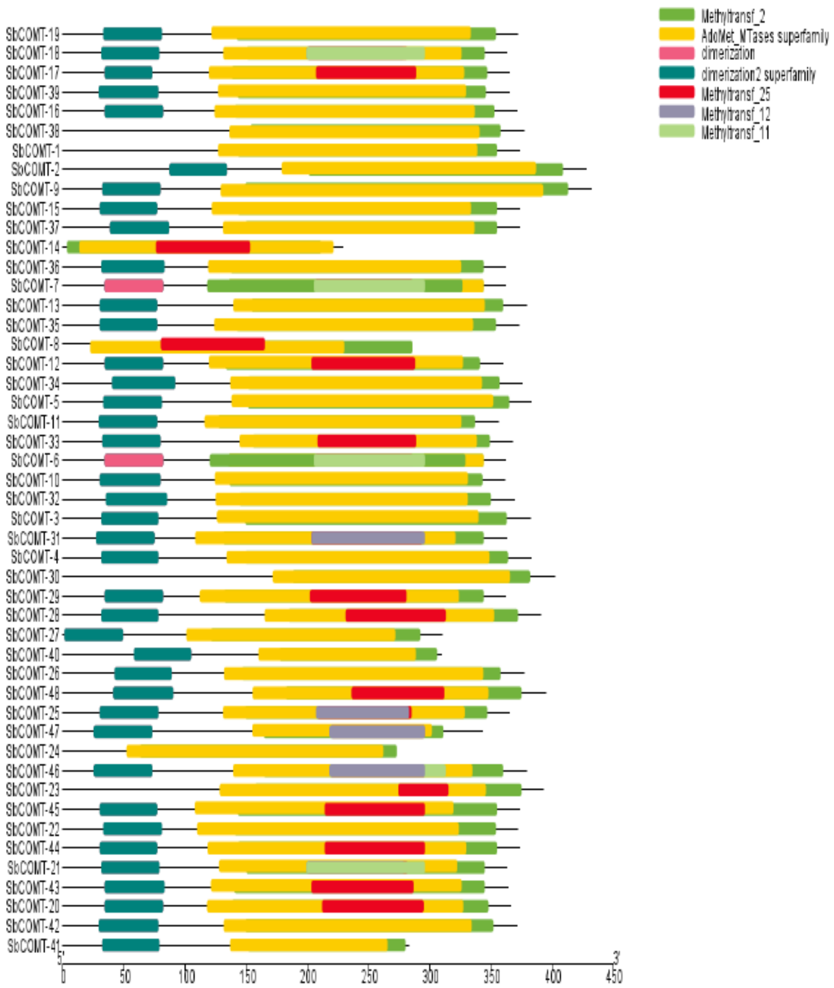
17. Gramene database (https://www.gramene.org/).

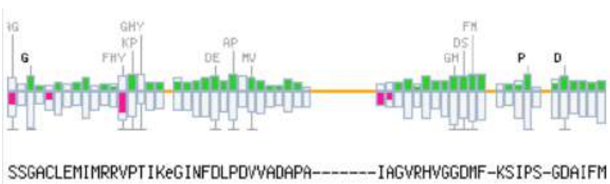
18. **MOROKOSHI Sorghum transcriptome database** (http://sorghum.riken.jp).

a. Evolutionary tree **b. Gene structure** **c. Motif pattern**



d.Conserved domains

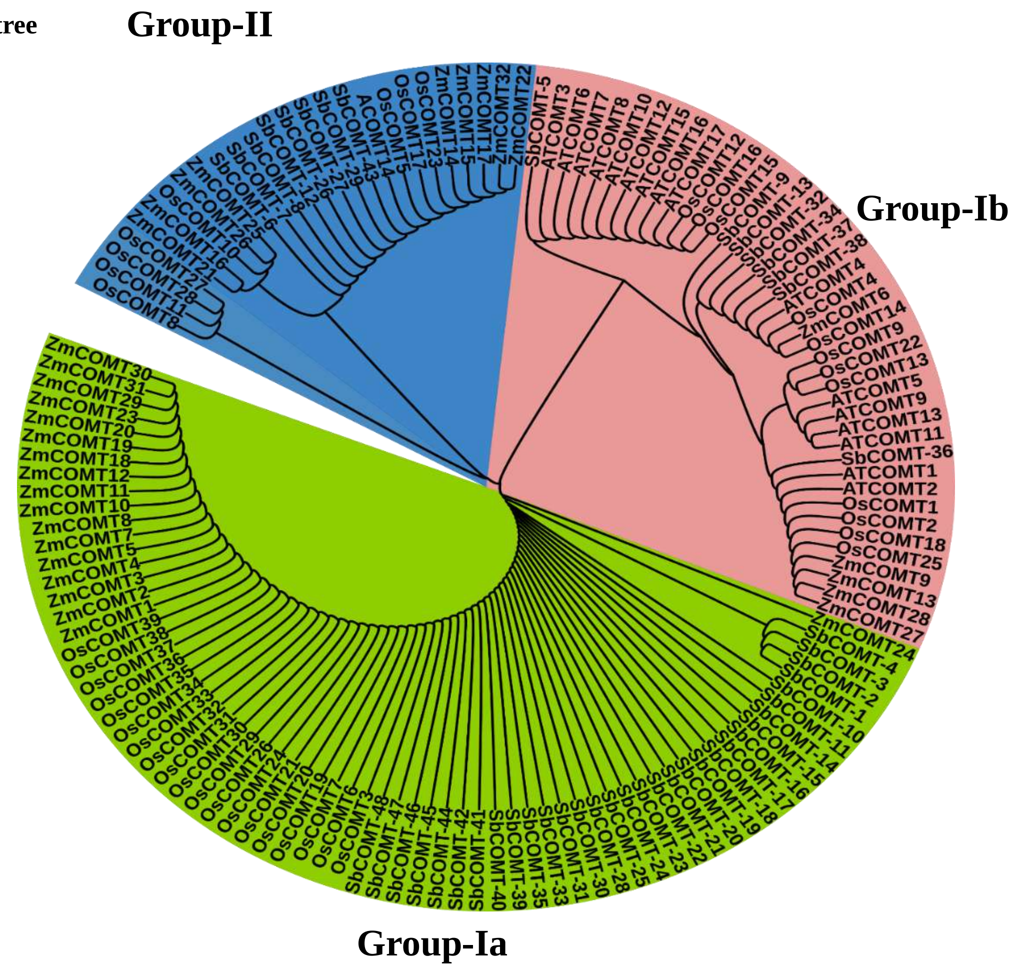




e. Methyl transferase_2 domain
(O-Methyltransferase)

Fig 1: The evolutionary relationship, gene structure, and motif analysis of the 48 SbCOMTs from sorghum bicolor. a. The phylogenetic tree was constructed by MEGA v10.0 with the NJ method. b Structures of the 48 putative SbCOMT genes. c Motif distribution of SbCOMTs proteins, d Conserved domains, and e. Methyl transferase_2 domain. The different motifs are designated by different colours.

a. Phylogenetic tree



b. Physical mapping of sorghum COMT gene homologs.

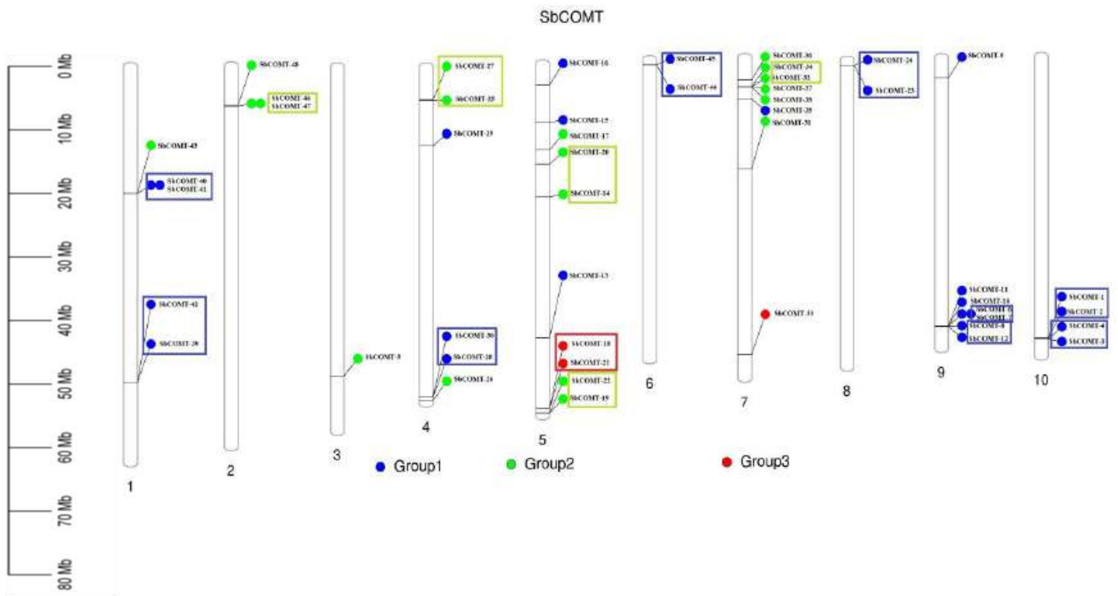
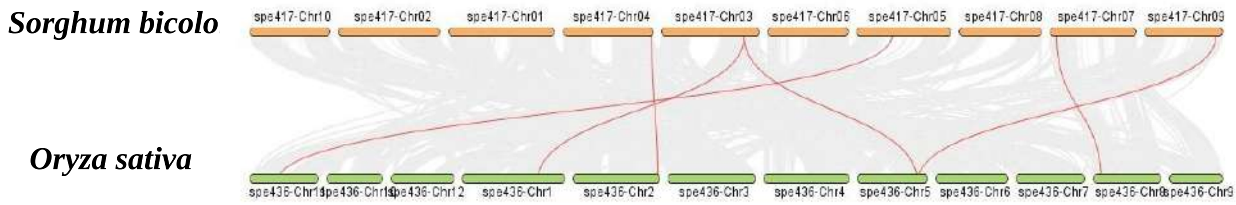
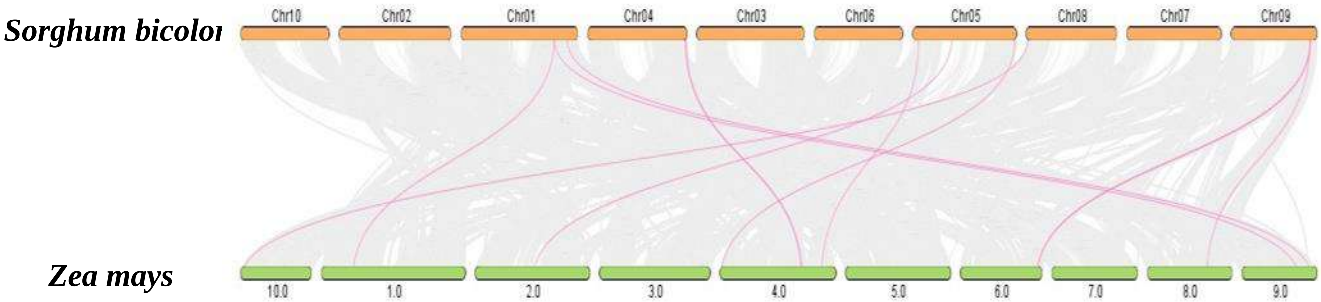


Fig 2:a. Phylogenetic tree representing the evolutionary relationship of COMTs from Sorghum bicolor, Oryza sativa, Zea mays, and Arabidopsis thaliana. and b. Physical mapping of sorghum COMT gene homologs. The 15 Paralog gene pairs are

represented in coloured boxes. The blue, green, and red coloured boxes represent Group Ia, Group Ib, and Group II SbCOMTs respectively



a. Synteny analysis of COMT genes between Sorghum and Oryza



b. Synteny analysis of COMT genes between Sorghum and Maize

Fig 3: a. Synteny analysis of SbCOMT genes between Sorghum and Oryza sativa and b. Sorghum and Zea mays. Gray lines in the background indicate the collinear blocks within sorghum and other plant genomes. The pink colour lines represent COMTs with collinearity in different genomes.

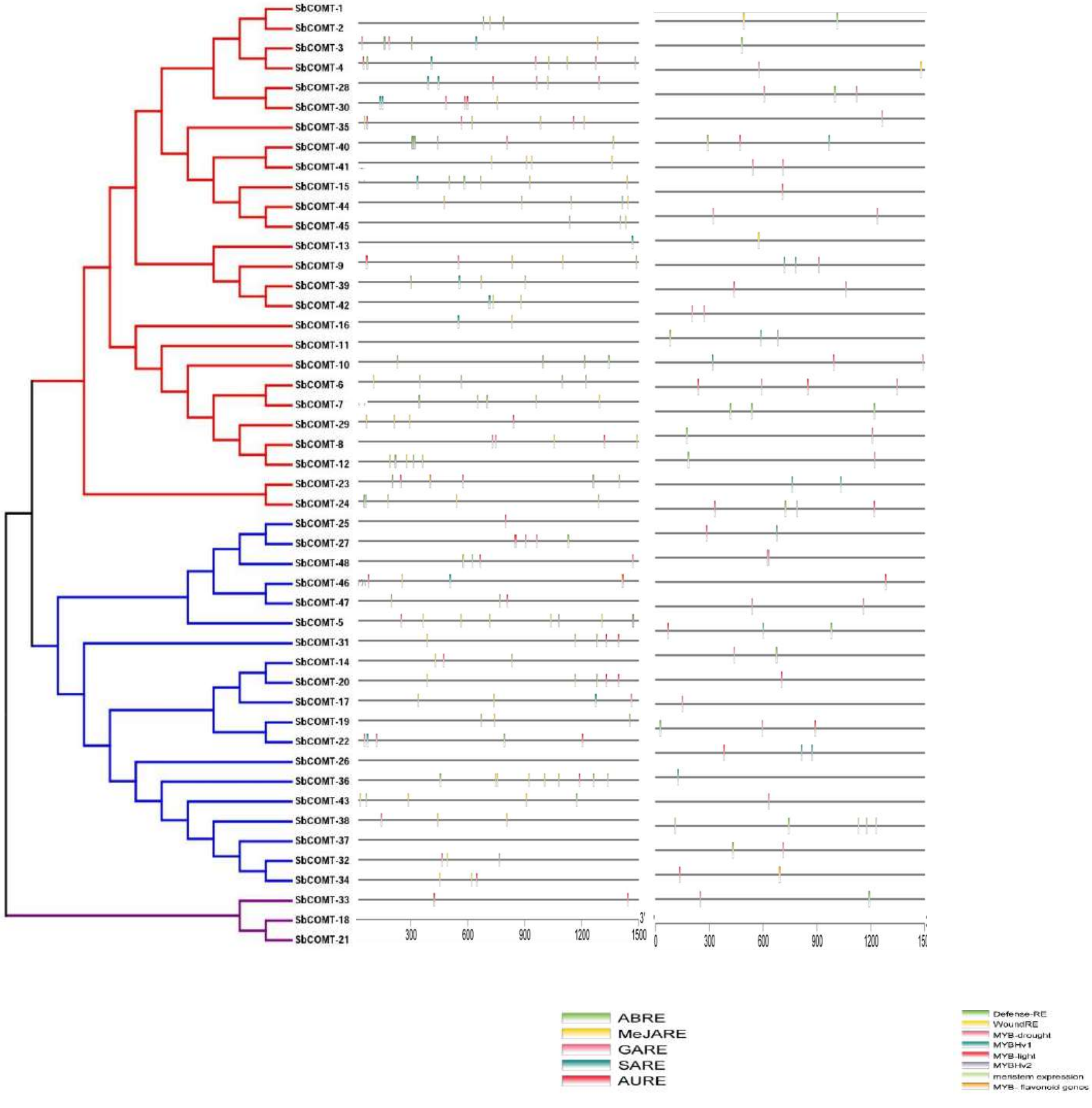
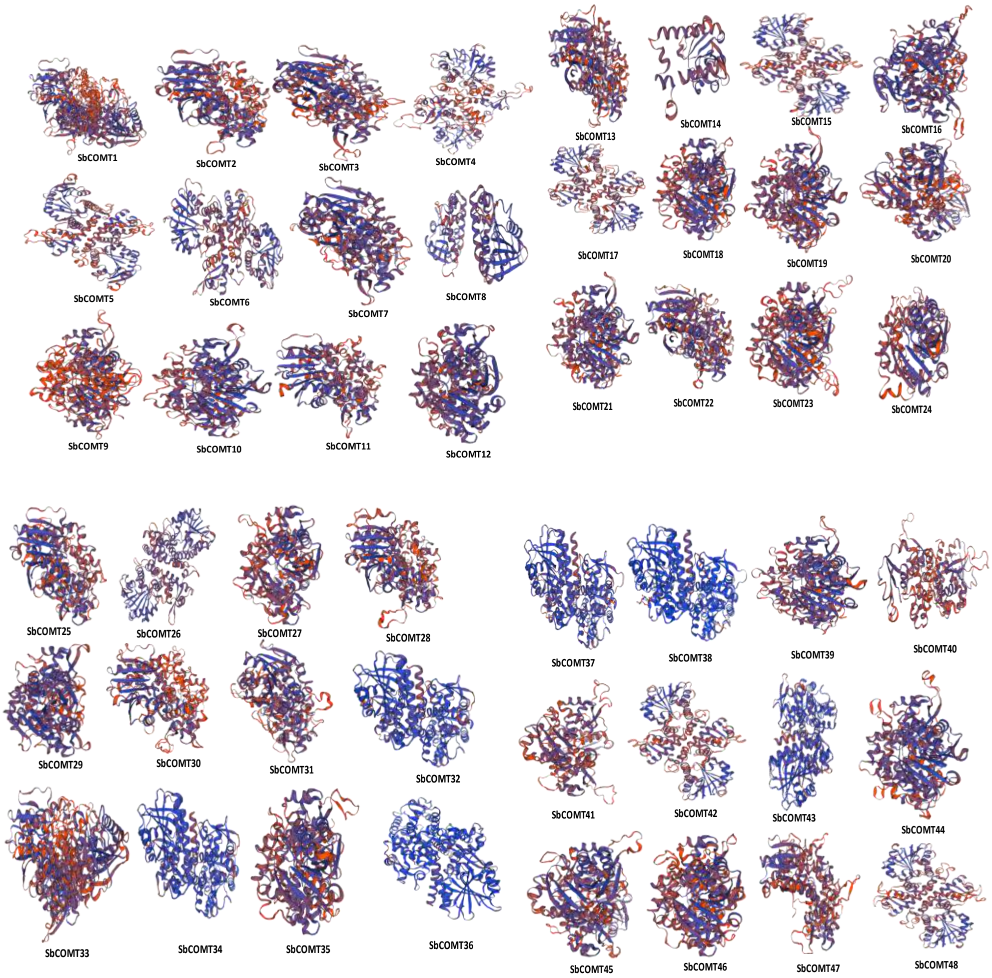
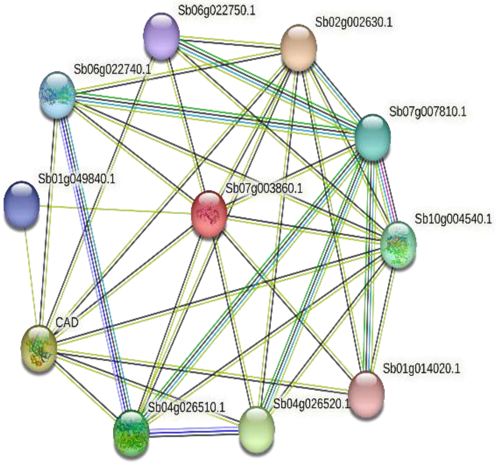


Fig 4: Predicted cis-regulatory elements in the promoter regions of Sb COMT genes



a.

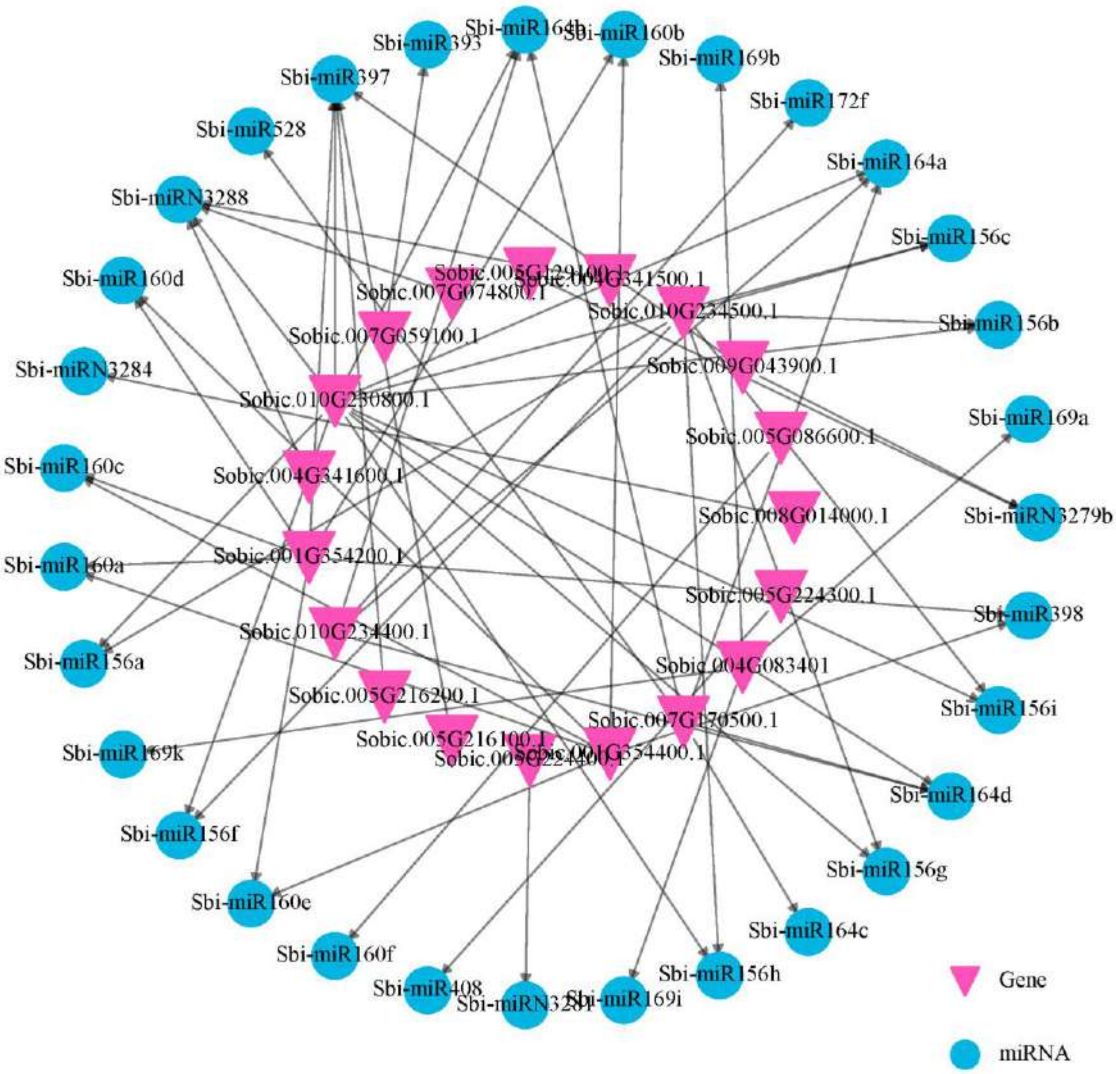
3D structure analysis of SbCOMT homologs



b. String analysis

Fig 5:a. Structural analysis of 48 modelled sorghum bicolor SbCOMT proteins. b. String analysis of sorghum COMT. The SbCOMT protein exhibited interaction with various lignin biosynthetic pathways and secondary metabolite partners.SbCOMT (Sb07g003860.1), CAD (Sb04g005950.1), Phenylalanine ammonia-lyase (Sb04g026510.1, Sb04g026520.1, Sb01g014020.1, *Sb06g022750.1, Sb06g022740.1), Probable 4-coumarate-CoA ligase 1(Sb07g007810.1) F5H(Sb02g002630.1) Folylpolyglutamate synthase (Sb01g049840.1) SbCOMT (Sb07g003860.1)*

a



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b.

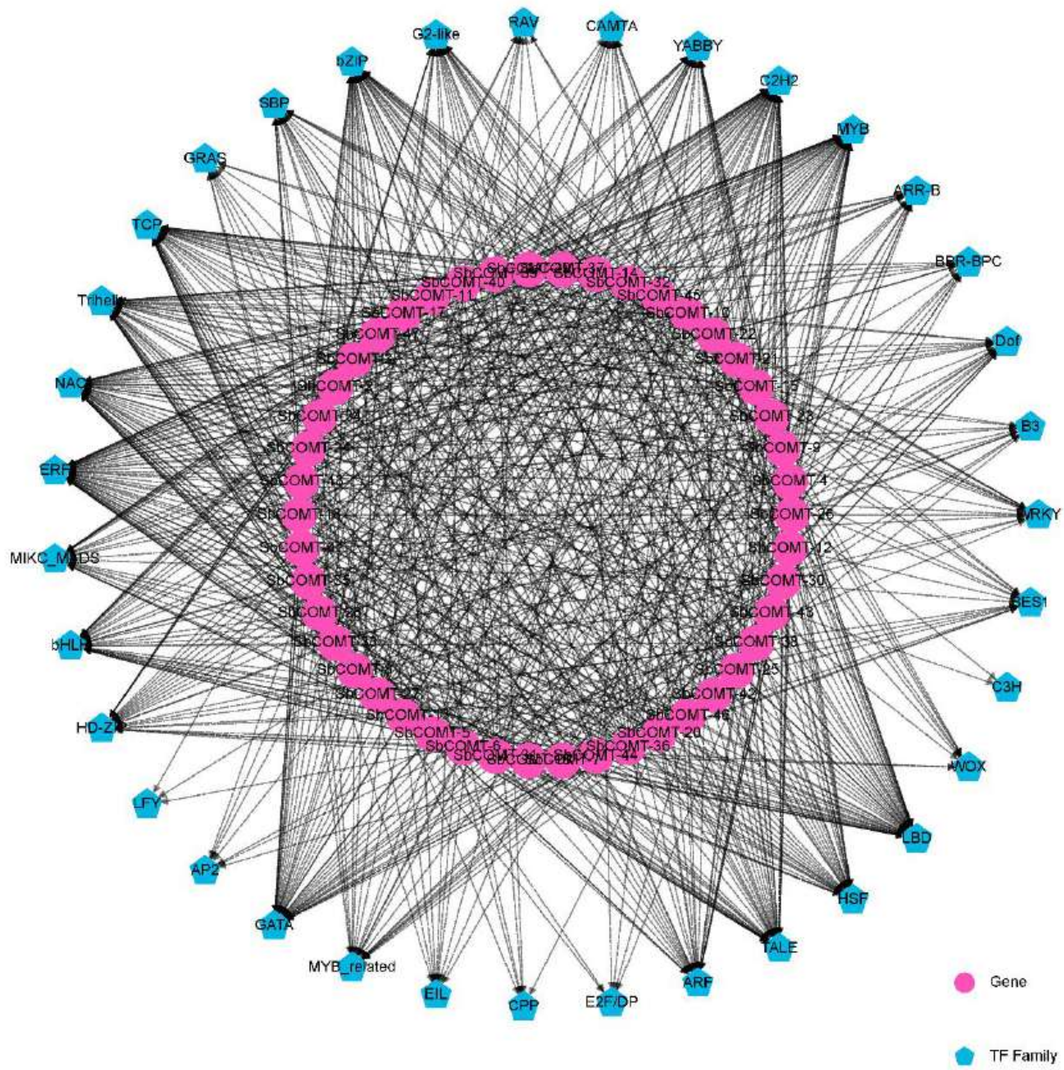

Fig 6: a. miRNA prediction of SbCOMT genes. The blue colour indicates predicted miRNA targets and the yellow colour boxes represent candidate SbCOMT homologs; b. Transcription factor prediction analysis of SbCOMT homologs. NAC, MYB, and MYB-related TFs are indicated in blue colour. The network is built with Cytoscape.

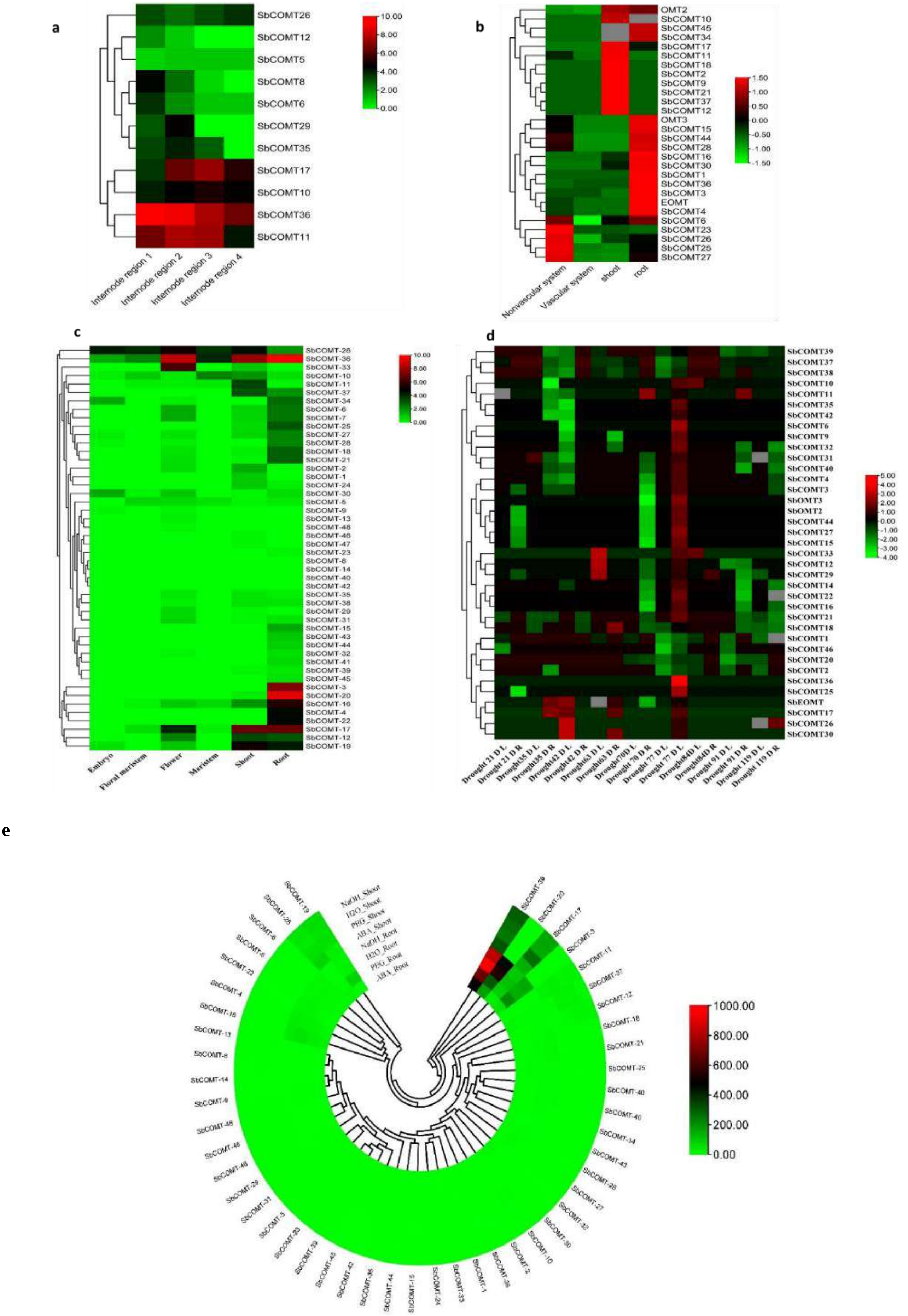
a
SbCOMT26
SbCOMT12
SbCOMT5
SbCOMT8
SbCOMT6
SbCOMT29
SbCOMT35
SbCOMT17
SbCOMT10
SbCOMT36
SbCOMT11
Internode region 1
Internode region 2
Internode region 3
Internode region 4
10.00
8.00
6.00
4.00
2.00
0.00
b
OMT2
SbCOMT10
SbCOMT45
SbCOMT34
SbCOMT17
SbCOMT11
SbCOMT18
SbCOMT2
SbCOMT9
SbCOMT21
SbCOMT37
SbCOMT12
OMT3
SbCOMT15
SbCOMT44
SbCOMT28
SbCOMT16
SbCOMT30
SbCOMT1
SbCOMT36
SbCOMT3
EOMT
SbCOMT4
SbCOMT6
SbCOMT23
SbCOMT26
SbCOMT25
SbCOMT27
Nonvascular system
Vascular system
shoot
root
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
c
SbCOMT-26
SbCOMT-36
SbCOMT-33
SbCOMT-10
SbCOMT-11
SbCOMT-37
SbCOMT-34
SbCOMT-6
SbCOMT-7
SbCOMT-25
SbCOMT-27
SbCOMT-28
SbCOMT-18
SbCOMT-21
SbCOMT-2
SbCOMT-1
SbCOMT-24
SbCOMT-30
SbCOMT-5
SbCOMT-9
SbCOMT-13
SbCOMT-48
SbCOMT-46
SbCOMT-47
SbCOMT-23
SbCOMT-8
SbCOMT-14
SbCOMT-40
SbCOMT-42
SbCOMT-35
SbCOMT-38
SbCOMT-29
SbCOMT-31
SbCOMT-15
SbCOMT-43
SbCOMT-44
SbCOMT-32
SbCOMT-41
SbCOMT-39
SbCOMT-45
SbCOMT-3
SbCOMT-20
SbCOMT-16
SbCOMT-4
SbCOMT-22
SbCOMT-17
SbCOMT-12
SbCOMT-19
Embryo
Floral meristem
Flower
Meristem
Shoot
Root
10.00
8.00
6.00
4.00
2.00
0.00
d
SbCOMT39
SbCOMT37
SbCOMT38
SbCOMT10
SbCOMT11
SbCOMT35
SbCOMT42
SbCOMT6
SbCOMT9
SbCOMT32
SbCOMT31
SbCOMT40
SbCOMT4
SbCOMT3
SbOMT3
SbOMT2
SbCOMT44
SbCOMT27
SbCOMT15
SbCOMT33
SbCOMT12
SbCOMT29
SbCOMT14
SbCOMT22
SbCOMT16
SbCOMT21
SbCOMT18
SbCOMT1
SbCOMT46
SbCOMT20
SbCOMT2
SbCOMT36
SbCOMT25
SbEOMT
SbCOMT17
SbCOMT26
SbCOMT30
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
e
NaOH_Shoot
H2O_Shoot
PEG_Shoot
ABA_Shoot
NaOH_Root
H2O_Root
PEG_Root
ABA_Root
1000.00
800.00
600.00
400.00
200.00
0.00

Fig 7: In silico expression analysis of SbCOMTs; a. different regions of stem internodes, b. vascular and non-vascular system, c. baseline expression patterns in various tissues and organs, d. expression patterns under drought stress conditions and e. expression patterns under ABA, PEG, and NaOH stress conditions.

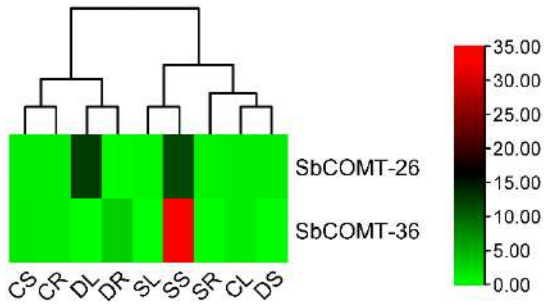

Fig 8: Heat map representing the expression patterns (Fold change) of SbCOMT genes in S. bicolor analyzed by qRT PCR. CL-control leaf, CS-control stem, CR-control root, DL-drought leaf, DS-drought stem, DR-drought root, SL-salt leaf, SS-salt stem, and SR-salt root. (p=0.05)

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In-Vitro Bioavailability of Iron from Green Gram (*Vigna radiata*) Dhal Flour Fortified with Extrinsic Iron and its Absorption Promoter Ascorbic Acid

Rimpa Bose[1], Binata Nayak[2]

[1]Research scholar, Department of Home Science (Food and Nutrition), University of Calcutta, Kolkata, India
[2]Associate Professor, Department of Home Science (Food and Nutrition), University of Calcutta, Kolkata, India

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***Abstract*— *Iron Deficiency Anaemia (IDA) is a global health problem, especially in the developing countries and in India it is also a formidable health challenge. The World Health Organization (WHO) report already identified Iron Deficiency Anaemia as world's most serious health risk factor. The vulnerable groups are pre-school children, school going children, adolescent girls, pregnant women and partially lactating women. Fortification, as generally understood, refer to the process of addition of a nutrient to a food to improve the quality of nutrient to meet the recommended dietary allowance of the population to correctthe existing nutrient deficiency amongst them. Green Gram Dhal (Vigna radiata) was chosen as a vehicle for this study as it is the most acceptable pulse among all Indians irrespective of being vegetarian or non-vegetarian and it contains good quality of protein that helps in iron absorption, moreover pulse, considered to be the second staple food in India, has not yet being considered as a vehicle for iron or any kind of fortification. The in vitro bioavailability of iron in the green gram dhal flour fortified with extrinsic iron and ascorbic acid as iron absorption promoter was studied as compared to non fortified green gram dhal flour. It was found that green gram dhal flour fortified with both extrinsic iron and iron absorption promoter had the highest impact on enhancement of the absorption of both native and added iron, especially in acidic pH, however dhal flour fortified with extrinsic iron only had also the enhancing impact on iron absorption mainly in acidic pH. Thus it can be predicted that fortification of green gram dhal flour with extrinsic iron and iron absorption promoter increases the bioavailability of both native and added iron.*

***Keywords*— green gram dhal flour, fortification, extrinsic iron, ascorbic acid, in vitro bioavailability**

I. INTRODUCTION

Nutritional iron deficiency is a public health problem in developing countries, including India(Sheshadri,1997). Inadequate intake of iron and consumption of foods low in bio-available iron are identified as the causes of iron deficiency.The World Health Organization (WHO) report already identified Iron Deficiency Anaemia as world's most serious health risk factor. The vulnerable groups are pre-school children, school going children, adolescent girls, pregnant women and partially lactating women, even in men,in India. In the initial state of Iron Deficiency Anaemia the haemoglobin level in the blood falls below on age-sex specific standard.

Micronutrient Malnutrition (MNM) is pandemic problem and according to WHO, more than two billion people in the world are suffering from MNM amongst which 0.8 million deaths occur every year due to Iron Deficiency Anaemia.

The approach of enhancing the bioavailability of native food iron seems to be an essential strategy to combat with iron deficiency disorders among the community people, especially in developing countries like India, where poor economic status, ignorance, consumption of nutrient deficient diet, infection, worm infestation etc. directly affect the health of common people.

According to WHO, **"Food fortification is the process whereby nutrients are added to food (in relatively smooth quantities) to maintain or improve the quality of diet of a group, a community or population.''**

Both the term **'Fortification'** and **'Enrichment'** refers to addition of nutrients to the food. The true definition does slightly vary. Enrichment is defined as 'synonymous with fortification and refers to the addition of micronutrients to the food which are lost during processing'.

Our present study is concerned with Iron Fortification in a new vehicle Pulse especially green gram dhal flour and its bioavailability after being fortified with iron and its absorption promoter ascorbic acid. Ascorbic acid is the most potent enhancer of iron absorption, both as natural component present in fruits and vegetables and also when added as the free compound(Hazell & Johnson1987). Thus fortification of green gram dhal flour with extrinsic iron salt and its absorption promoter ascorbic acid to enhance the native and added iron bioavailability appears to be an useful strategy.

OBJECTIVE:

The present study has been undertaken with the objective of evaluating the in-vitro bioavailability of iron and iron absorption promoter, ascorbic acid, when used as fortificant in green gram dhal flour.

II. LITERATURE REVIEW

The minerals present in the human body in less than 0.05%, are defined as **Microminerals or Trace elements**. Iron is one of the important micromineral that determines the good health of every human being. Iron was first recognized as a constituent of body by Lemory in 1713.

Table.1 Percentage Distribution of Iron in Human Body

SL. No.	Types of Iron	SL.no.	Body Parts	Percentage(%)
1	Functional	1.1	Haemoglobin	60-70
		1.2	Myoglobin	3-4
		1.3	Tissue Iron(enzyme)	5-15
2	Storage and Transport	2.1	Storage iron(liver, spleen, bone marrow)	15-30
		2.2	Transport Iron as Transferrin	0.10
		2.3	Serum Ferritin	<1

[Guthrie Helen A., Marry F. Picciano, Human Nutrition, McGraw-Hill,Boston,1999]

CONSEQUENCES OF IRON DEFICIENCY:

The eventual consequences of iron deficiencies are IRON DEFICIENCY ANAEMIA (IDA) where the *body's store of iron has been depleted and the body is unable to maintain levels of haemoglobin in the blood.* Children and pre-menopausal women are the most vulnerable groups, however iron deficiency anaemia is also found in men, in India.

The various symptoms of iron deficiency include, tiredness, lethargy or lack of energy, shortness of breath(dyspnoea), impaired thermoregulation, Immune dysfunction, GI disturbances, neuro-cognitive impairment, chronic kidney disease (if not treated on time),congestive cardiac failure, chronic respiratory distress (in children)

Less common symptoms include- headache, altered sense of taste, sore tongue, Pica- a desire to eat non-food items, such as ice, paper, mud etc, Tinnitus – perception of noise in one or both ears or in the head that comes from inside the body, ringing of ears, feeling itchy. (Srilakshmi B.,2008)

Table 2. Anaemia Prevalence in Children , NFHS-5(2019-2021)

Anaemia in children-

Anaemia Status	***Haemoglobin level in gm/dL***
Anaemic	*<11.0*
Mildly anaemic	*10.0-10.9*
Moderately anaemic	*7.0-9.9*

Severely anaemic	*<7.0*
Non anaemic	*11.0 or higher*

***Haemoglobin levels are adjusted for altitude in enumeration areas that are above 1000 meters.**

Sample: children 6-59 months

Table 3. Anaemia Prevalence among Women and Men, NFHS-5(2019-2021)

Haemoglobin levels below which women and men are considered anaemic-

Respondents	***Haemoglobin level in gm/Dl***
Non-pregnant women age 15-49	*<11.0*
Pregnant women age 15-49	*<12.0table 3.*
Men age 15-49	*<13.0*

**haemoglobin levels are adjusted for smoking, and for altitude in enumeration areas that are above 1000 meters.*

IMPORTANT ROLE OF IRON IN OUR BODY

I. ***Transport and storage of oxygen:*** Iron present within Hemoglobin (pigment of red blood cells) and myoglobin. It binds to the oxygen and facilitates its movement from the lungs through the arteries to the cells throughout the body. Once oxygen is delivered, the iron (as a part of haemoglobin) binds the carbon dioxide which is then transported back to the lungs from where it gets exhaled. Myoglobin is found only in the muscles. There is acts as a reservoir of oxygen which is needed to produce the energy for muscle contractions.
II. ***Cofactor for enzymes:*** The iron containing haem group is a part of several proteins involved in the release of energy during oxidation of nutrients and formation of energy rich compounds (ATP). Also iron can itself act as a co-factor for different enzymes in the body.
III. ***Formation of Red Blood Cells (RBC):*** Bone marrow produces erythroblasts. As it matures iron is required along with vitamin B6 and copper.

Haem iron absorption- it consists primarily of haemoglobin and myoglobin. It represents small fraction of the iron in the diet but with high biological value and absorption. Most of the haem iron seems to enter the intestinal absorptive cell as an intact metalloporphyrin. Subsequently iron is released from the porphyrin in the intestinal mucosa by mucosal haem oxygenase and enters the circulation as metallic iron.

Non-haem iron absorption- It is found typically in cereal pulse based diet and also available from green leafy vegetables. Non-haem iron absorption occurs mostly in the proximal small intestine. (UNICEF report2011, Srilakshmi B.,2008)

In both the cases, ascorbic acid plays a key role in accelerating iron absorption in human body, specially from non-haem iron, converting the ferric form to absorbable ferrous form.

Bioavailability can be defined as the proportion of total mineral in a food, meal or diet that is available for normal body functions. This involves various stages, each of which is affected by different dietary and physiological factors. The amount of mineral that is available for absorption is dependent upon dietary composition, gastrointestinal secretion and luminal interactions. The proportions that is taken by the mucosal cells depends upon a number of host – related factors and the degree of utilizations in the body, depends again upon physiological factors as modified by the chemical form of the mineral.

Bioavailability of trace elements can be broadly classified under three categories i.e. high, medium and low bioavailable elements depending upon how much the human body is able to absorb them from the diet. Much of the research into trace elements bioavalability has been focussed on iron.(Narasingha Rao B.S.,1994)

In vitro methods are relatively simple, rapid, inexpressive methods were developed an alternatives to human absorption studies and usually involve a simultaneous gastric digestion followed by measurement or soluble or dialyzable iron available for absorption. It helps in the measurement of the amount of iron that is soluble and potentially bio-available.(NarsinghaRao, Prabhavathi,1978)

The addition of ascorbic acid causes substantial increase in the amount of iron absorbed from most of the iron compounds, in most of the studies, addition of ascorbic acid as an absorption promoter enhanced the iron absorption. (WHO report on Guidelines on food fortification with micronutrients,2006)

III. METHODOLOGY

Green gram dhal flour, Ferrous sulphate heptahydrate(FeSO4,7H2O), Ascorbic acid were used for the study. The dhal flour wasprocured locally and after ensuring the fact that it was free from contaminant, it was processed for fortification by washing, drying, milling respectively. Ferrous sulphate salt, a cost effective source of iron, L-ascorbic acid were of analytical grade and procured locally.

According to various studies, it was found that Indian adolescents girls are one of the vulnerable group suffering from Iron Deficiency Anaemia (IDA), hence the present study considered the Recommended Dietary Allowance (RDA) of adolescents girls of 16-18 years i.e. 32mg/day (ICMR2020) to derive the level of fortification. Usually, fortification should $1/3^{rd}$ of the RDA, hence it was almost equal to*10 mg/day*. Green gram dhal flour has 4mg intrinsic iron/100gm. Considering the acceptable edible quantity as 50gm/day by any human being, the available intrinsic iron would be 2mg/100gm and rest part can be fortified with extrinsic iron.

With the calculated amount of green gram dhal flour, extrinsic iron as FeSO4,7H2O and ascorbic acid as iron absorption promoters, the following combinations were prepared for the study:

1. *Green Gram dhal flour +no fortificant (control)*
2. *Green Gram dhal flour + $FeSO_{4,}$ $7H_2O$*
3. *Green Gram dhal flour + $FeSO_{4,}$ $7H_2O$ + Ascorbic acid*

A five time concentrated premix of each of the fortificants was prepared in green gram dhal flour base. A two-stage dry mixing (hand procedure)was adopted to obtain a homogenous preparation and then it was diluted by mixing the vehicle in the desired amount.

Iron content of all the preparations were in the mineral solution of the dry digested samples according to Wongs method. About 5-10gm of control and fortified green gram dhal flour were made ash at 600degree Centigrade in a muffle furnace for 12 hours. The residues were treated with concentrated nitric acid and hydrochloric acid and evaporated to dryness. The residue thus obtained was dissolved in 5ml 6N HCL and filtered and process was repeated for 2-3 times with glass distilled water. The combined filtrate was made upto 100ml and further steps were followed as described in Wongs method. (Nayak B., Nair K.M.2003)

In case of in-vitro bioavailability analysis of iron, the method described by Narsigha Rao and Prabhavathi (1978)was used. The method involves incubation of duplication of 8% (g/v) homogenate (25ml) of the fortified green gram dhal flour in pepsin-HCL solution (0.5% pepsin in 0.1 N HCL solution, pH 1.35 adjusted with distilled water at 37 degree centigrade for 90 minutes after which the contents from each set were centrifused at 3000rpm for 45 minutes and the supernatant was filtered and saved for iron estimation. The pH of the other set was adjusted to 7.5 with 5N Sodium hydroxide and incubated and processed as mentioned above to obtain the filtrate. Ionizable iron in the filtrate was estimated by α-α' dipyridylmethod (AOAC,1965).

To working standard iron solution (1-15μg) and blank were added 1ml of hydroxylamine hydrochloride solution, 5ml of acetate buffer solution and 2 ml of αα' – dipyridyl solution in that order. Test tubes were shaken after the addition of each reagent. The solution was made upto 15 ml with water and mixed. Duplicate aliquots (3ml & 5ml) of the acid – pepsin digested extract of pH 1.35 and alkaline extract of pH 7.5 were taken. To the other aliquot, all the reagents described above were added and the intensity of colour measured at 510 nm against reagent blank.

After adjusting the instruments with reagent blank, standard, extract blank and tests were read. From the difference between test and extract blank the ionisable iron present in the green gram dhal flour combinations were calculated, substracting the optical density of extract blank from that of the sample.

IV. RESULTS

The t-test, also known as Student's T test were used for statistical analysis. The Null Hypothesis was considered asthere were no differences between the groups. T-Test provide p-value based on t-distribution and if the p-value is less than the chosen significance level (0.05), the null hypothesis is rejected and the groups are statistically significantly different as per the alternative hypothesis.

The study also represents the data in a Box and Whisker Plots and other diagrams to get a snapshot of the data and analysis at a glance. Box plots are used to show distributions of numeric data values, especially when we want to compare them between multiple groups. They are built to provide high-level information at a glance, offering general information about a group of data's symmetry, skew, variance, and outliers.

The iron content of each of these combinations were estimated and the were as follows:

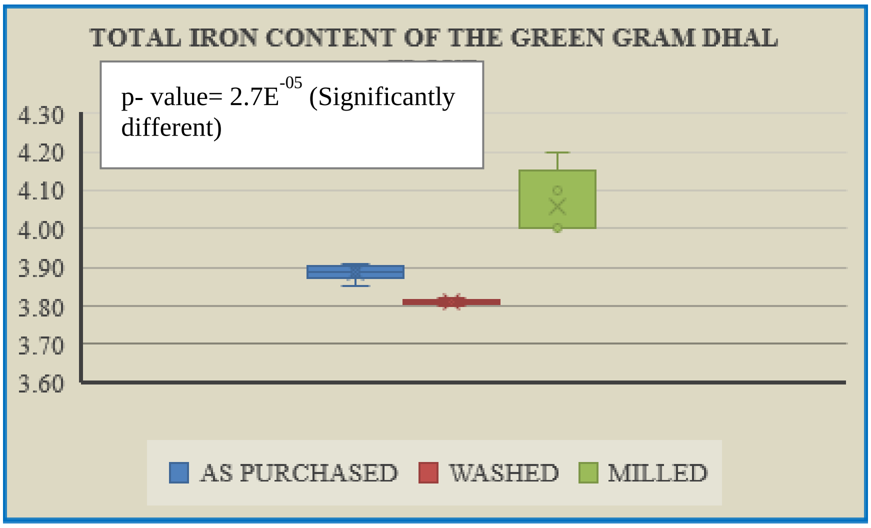

Fig.1. Total Iron Content of the Green Gram Dhal Flour as Purchased, after Washing and after Milling

Table 4. Total Iron content of Premixes, Fortified Green Gram Dhal Flour

Combinations of Research sample	**Iron content of Premix (observed)**	**Iron content of Fortified Dhal flour(observed)**
	Mean±S.D.	Mean±S.D.
Green Gram dhal flour (control) – No fortificant	4.04±0.049	4.01±0.007
Green Gram dhal flour + $FeSO_4$, $7H_2O$	35.06±0.040	9.40±0.005
Green Gram dhal flour + $FeSO_4$, H_2O + Ascorbic acid	33.19±0.024	10.12±0.075

Table 5. In Vitro bioavailability of Iron(Ionizable Iron) from Green Gram Dhal Flour Fortified with Iron and Iron-Absorption Promoter

	Average total iron (mg/100gm)	**Ionizable Iron (mg/100gm)**		**% of Total Iron**	
Combinations of Research		**PH 1.35**	**PH 7.5**	**PH 1.35**	**PH 7.5**
		Mean±S.D.	Mean±S.D.	Mean±S.D.	Mean±S.D.
Green Gram dhal flour (control) – No fortificant	4.0	1.5±0.012	0.6±0.005	38.7±0.170	16.1±0.028
Green Gram dhal flour + $FeSO_4$, $7H_2O$	9.41	4.5±0.005	1.4±0.012	50.3±0.094	15.8±0.082
Green Gram dhal flour + $FeSO_4$, H_2O + Ascorbic acid	9.60	6.4±0.005	2.4±0.012	63.8±0.047	23.6±0.125

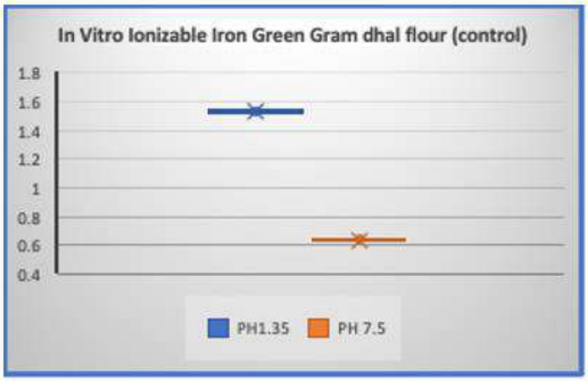

Fig.2

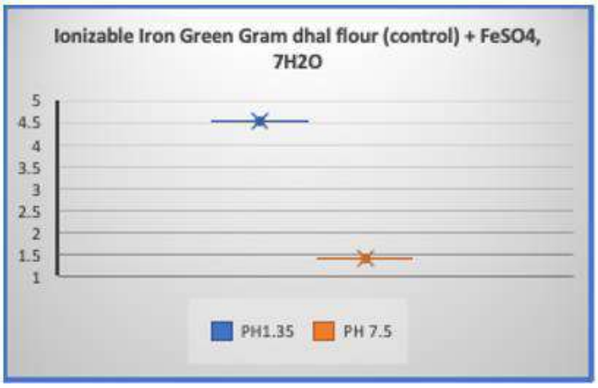

Fig.3

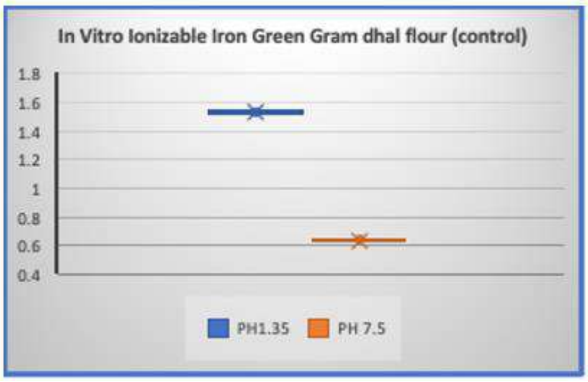

Fig.4

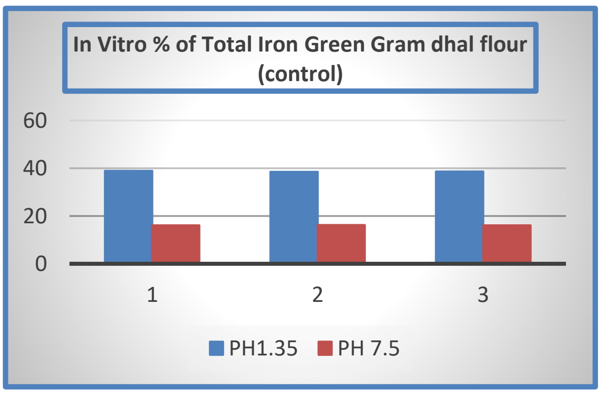

Fig.5

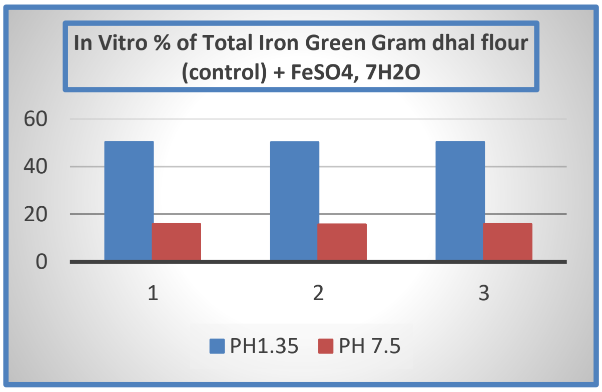

Fig.6

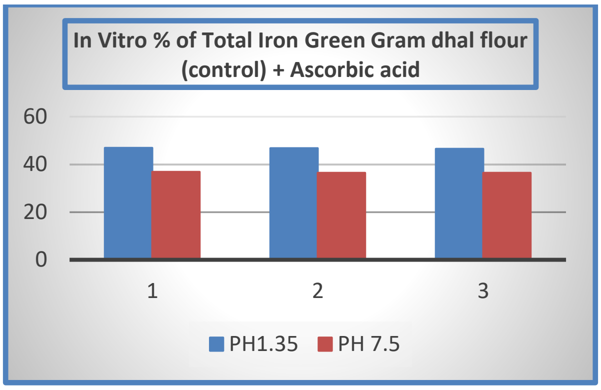

Fig.7

It can be interpreted from the result that the bioavailability of ionisable iron was much higher in presence of extrinsic iron as compared to unfortified green gram dhal flour and gave best result in presence of ascorbic acid as iron absorption promoter. The percentage of availability of total ionizable iron was highest in presence of ascorbic acid in both acidic and alkaline pH. It was also observed that the bioavailability of ionisable iron is much higher in acidic pH as compared to alkaline pH in all combination.

V. DISCUSSION

The statistical analysis showed that there was no change in the intrinsic iron content of green gram dhal flour as purchased and after washing but a significant change was found after milling of the flour, probably because of the use of iron body mortar.

In case of iron content of fortified green gram dhal flour premix and diluted fortified flour, there were no change in the control portion but iron content of premix was desirably high as compared to the diluted fortified dhal flour.

After the statistical analysis it was found that with reference to the average total iron content of non fortified dhal flour, 38.7% of ionisable iron was obtained at the acidic pH and 16.1% of ionisable iron was obtained at the alkaline pH. The ionisable iron obtained from extrinsic iron fortified green gram dhal flour was 50.3% at the acidic pH and that of alkaline pH was 15.8%. When the green gram dhal flour was fortified with both iron salt and iron absorption promoter ascorbic acid, the ionisable iron obtained at the acidic pH was 63.8%, by far the highest among all combinations and ionisable iron obtained at alkaline pH was 23.6% which was also high among all the three combinations. Hence it was indicative that the fortification of green gram dhal flour with extrinsic iron and absorption promoter elevates the in vitro bioavailability of iron as compared to non fortified dhal flour. It was also found from the study that bioavailability of iron in all combinations wassignificantly higher in the acidic pH as compared to the alkaline pH.

Thus it can be predicted from the in vitro bioavailability study that green gram dhal flour fortified with both extrinsic iron and ascorbic acid as absorption promoter has the highest enhancing impact on the absorption of iron where as the dhal flour fortified with extrinsic iron also increases the iron absorption as compared to the non fortified dhal flour having only native iron and with the lowest absorption capacity.

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Yield and quality performance of apples under varied summer pruning intensities in the North-Western Himalayan region

Haseeb Ur Rehman*, Manzoor Ahmad Ganai, Tasneem Mubarak, Ab Shakoor Khanday and Shahid A Shergojry

Krishi Vigyan Kendra, Kulgam
*Corresponding author: haseebpom@gmail.com

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Abstract*— This study aimed to evaluate the influence of varied intensities of summer pruning on five predominant apple cultivars in ultra-high-density planting systems on yield and quality performance at harvest. The experiment was carried out during 2021-22 and 2022-23 growing seasons under the Kulgam district of J&K (UT) in the North-Western Himalayan region of India. Experimental plants were evaluated at harvest for yield and quality performance. The economic value of various treatments was calculated by estimating total costs (Rs/tree), gross income (Rs/tree), and Net income (Rs/tree) by framing questionnaires and collecting requisite information. Results revealed that summer pruning showed varied results in terms of various observations due to different genetic makeup, growing habits, bearing patterns, market price, and fruit quality. Significantly at par highest average yields/tree was obtained in Red Fuji (49.741kg) and Jeromine (49.268 kg) while the lowest value was obtained in Red Chief (27.919kg). However, Redlum Gala excelled over other cultivars in terms of Fancy (4.148kg), A-grade (27.517kg), and B-grade (4.158kg) although its yield was 42.313kg/tree which was lower as compared to Red Fuji and Jeromine. Maximum C-grade apples were obtained in the case of Red Fuji (23.998 kg/tree) and minimum in Red Chief cultivar (2.267 kg/tree). Mild summer pruning resulted in significantly the highest yield (47.076kg/tree) as compared to other summer pruning intensities. Summer pruning significantly affected the quantity of various apple grades. The maximum quantity of Fancy-grade apples (3.451kg/tree) was obtained in medium summer pruning whereas, mild summer pruning resulted in the highest A-grade (25.465kg/tree). Results revealed that the highest average yield was obtained in the mediumly pruned Red Fuji cultivar (57.53kg/tree) which was significantly at par with mildly pruned Jeromine (56.48 kg/tree). Better results in terms of Fancy-grade apples were obtained in mediumly pruned Redlum Gala (5.69 kg/tree) as compared to other treatment combinations. Similarly, mildly pruned Jeromine excelled in other treatment combinations in terms of A-grade apple yield (36.78 kg/tree). Similarly, various treatment combinations varied in terms of B-grade and C-grade apple yield. A negative correlation was observed between the crop yield (t/ha) and pruning severity in almost all cultivars excluding Red Fuji. A strong linear negative correlation (-0.99) between summer pruning and crop yield was observed in the Red Chief variety. A slight positive correlation was observed in the case of Red Fuji. The economic viability of various treatment combinations varied and was found better in terms of BC ratio in mediumly pruned and severely pruned Jeromine cultivar (3.67) followed by mediumly pruned Red Chief cultivar (3.57) and the lowest in unpruned Red Fuji (0.80).

Keywords*— Summer pruning, cultivar, yield, quality.

I. INTRODUCTION

Apple (*Malus* X *domestica* Borkh.) is the most important temperate fruit worldwide with a total production of almost 90 mT (FOA, 2023). India occupies 5th rank globally in terms of production after China, USA, Poland, and Turkey, with Jammu & Kashmir accounting for more than 75% of the country's production (Rehman and Mubarak, 2023). Although Red Delicious strains occupy a major area under apple cultivation, recently Gala strains, Fuji, and other delicious clones/selections have also covered a good percentage of acreage (Rehman *et al*, 2023). These cultivars have gained popularity only after the adoption of some intensive planting systems like ultra-high density, semi-high density, and medium density orcharding. Under these systems, it has been found essential to strike a balance between vegetative and reproductive growth to maximize the production and quality traits and summer pruning is one of the techniques to do so. Summer pruning under intensive systems of planting contains growth, maintains a balance between vegetative and reproductive growth, improves fruit size and fruit production to obtain high yield and quality fruit (Hussein Moatamed, 2012). This technique is also used for breaking apical dominance and increasing twigs and spurs formation of apples (George *et al*, 2002), increasing fruit set (Fathi and Mokhtar, 1998), and increased the percentage of retained fruit to perfect flowers (Ebied, 2005). Summer pruning can also effectively reduce the measured plant growth during the current year (Dejong *et al*, 2004). Time of summer pruning is also an effective factor for improving the quality of the apple and increase in resistance to bruising and storage decay (Ibrahim *et al*, 2007). This technique is required to obtain good fruit colour for tree types such as slender spindle trees whose canopy has gaps that become filled with shoot growth soon after full bloom (Robinson *et al,* 1991).

Similarly, a positive correlation between summer pruning and colour development has been reported by Belter and Thomas (1980); Ogata *et al*1(986); Ystass (1992). Ogata *et al*, 1986 and Platon and Zagrai, 1997 reported that in apple summer pruning significantly improved the yield during the current and succeeding years. Several hypotheses mainly related to endogenous growth control, hormone regulation, and shoot-to-root ratio (Ferree *et al*, 1984; Saure, 1992) have been proposed to partially or fully interpret the effects of summer pruning. Given the above, the present experiment was conducted to not only evaluate the performance of cultivars but also to understand their response to summer pruning under high-density planting system.

II. MATERIAL AND METHODS

Red chief (V1), Redlum Gala (V2), Red Velox (V3), Red Fuji (V4), and Jeromine (V5) on M.9 rootstock in Tall Spindle System after 4th and 5th year of planting were evaluated along with the impact of summer pruning. Plants were trained to the central leader system with uniform cultural practices as per the package of practices of SKUAST-Kashmir. Summer pruning treatments varied in terms of severity as S_1 (no pruning), S_2 (10% removed), S_3 (20% removed), and S_4 (30 % removed). Summer pruning was confined during the 1st week of August in both the years (2022 & 2023) across cultivars without keeping growth habit in consideration. It was a two-year study replicated at 3 different locations on 5 plants of each cultivar. The design of the experiment was two factorial Randomised Block Design (RBD). Data in terms of yield was estimated by taking the yield of all treated plants of individual cultivars, dividing it by the number of plants under the same treatment, and finally converted to yield/ ha. Grades were assigned manually as per the standard procedure keeping size, colour, shape, blemish, scar, and disease or pest symptom on fruit in consideration. After assigning grades as Fancy, A, B, and C-grade, fruits under different grades were weighed using digital balance. The average grade was estimated by adding individual grades under a particular treatment and dividing it by the total number of plants under the same treatment and finally converted to tonnes per hectare. Economics was calculated based on prevailing market rates of the inputs and produce. The data were subjected to statistical analysis of variance using Web Agri Stat Package, an online software developed by Central Coastal Agricultural Research Institute of Indian Council of Agricultural Science (ICAR) and means of treatments were compared based on the critical difference (C.D) test at $p \leq 0.05$.

III. RESULTS AND DISCUSSION

Crop yield:

Table 1 shows a lot of variability in crop yield among different varieties and pruning intensities. Among the varieties, Jeromine and Red Fuji being at par registered significantly higher yields than the rest, with a numerically high value (49.74 t/ ha) recorded in Red Fuji. The performance of varieties is a function of genetic makeup and environment. Since the performance of varieties varies depending on the location, these two varieties under discussion seem to be better suited to the microclimate and other factors of the study location. The results are consistent with the findings of Kumar *et al* (2013) and Kumar (2020). The variation could also be the result of phenotypic characteristics of the varieties, management practices, and the site of the plantation as reported by Bhat *et al*, 2006 and Hampson *et al*, 2009.

Summer pruning also impacted crop yield and it could be observed from the data that severe pruning at 30% removal of growth (S4) reduced yield drastically. A significantly higher yield was recorded in 10% removal (47.07 t/ha) followed by 20% removal of growth. These figures indicate that optimizing pruning has a severity that substantially impacts yield, and severe and no summer pruning causes yield penalty. From the interaction (Table 2 & Fig1) it is clear that severe summer pruning had a negative impact on crop yield in all varieties. A negative correlation was observed between the two (Fig 3-7) in almost all cultivars excluding Red Fuji (Fig 6). A strong linear negative correlation (-0.99) between summer pruning and crop yield was observed in the Red Chief variety (V_1). With the increase in pruning severity, there was a corresponding decrease in yield in this variety. A slight positive correlation was observed in case of Red Fuji (Fig 6). Data in Table 2 shows that the maximum yield (57.53 t ha^{-1}) was obtained in case of Red Fuji (V_4) with 10% summer pruning. From Fig 1, it can be observed that various apple cultivars responded differently to different levels of summer pruning as far as yield is concerned. Yields improved upto moderate pruning but heavy summer pruning had a negative effect on yield across the different cultivars. However, the effect was more prominent in less vigorous cultivars like Red Chief and Jeromine. This varied response of different apple cultivars to different severity levels of summer pruning may be attributed to the different growth habits of studied cultivars (Cooley and Autio, 2011).

Table 1: Average yield and yield of different grades of apple as influenced by variety and summer pruning.

Varieties	Average yield (t/ha)	Fancy	A grade	B Grade	C grade
V_1	27.92	2.24	19.31	4.13	2.27
V_2	42.31	4.15	27.52	4.16	6.51
V_3	39.83	2.60	26.45	4.44	6.11
V_4	49.74	2.02	8.44	15.35	23.99
V_5	49.27	2.55	33.27	5.14	8.45
CD($p\leq0.5$)	2.24	0.31	3.99	1.70	2.07
Pruning Severity					
S_1	41.93	1.77	21.01	7.09	12.30
S_2	47.08	2.87	25.47	7.03	11.57
S_3	43.70	3.45	24.79	6.91	8.41
S_4	34.56	2.76	20.72	5.55	5.58
CD($p\leq0.5$)	2.00	0.28	3.56	NS	1.85

Table 2: Variety x pruning severity interaction effect on yield and different grades of apple.

Treatment combination	Average yield	Fancy	A grade	B grade	C grade
V_1S_1	34.57	1.14	22.11	6.93	4.32
V_1S_2	29.53	2.30	21.92	4.14	1.34
V_1S_3	25.48	3.29	18.17	2.86	1.11
V_1S_4	22.10	2.23	15.02	2.60	2.29
V_2S_1	43.48	2.07	25.77	5.72	10.06
V_2S_2	46.61	3.78	29.14	4.91	8.71
V_2S_3	44.48	5.69	30.07	3.66	4.29
V_2S_4	34.67	5.06	24.53	2.34	2.98

V_3S_1	39.62	2.52	22.78	5.11	9.05
V_3S_2	48.67	3.57	31.66	4.99	7.86
V_3S_3	39.85	2.48	27.94	4.81	4.27
V_3S_4	31.19	1.84	23.42	2.83	3.24
V_4S_1	43.62	1.25	4.77	12.00	26.85
V_4S_2	54.09	1.17	7.82	16.09	29.15
V_4S_3	57.53	2.80	10.38	18.46	25.44
V_4S_4	43.72	2.87	10.84	14.85	14.54
V_5S_1	48.33	1.86	29.66	5.66	11.22
V_5S_2	56.48	3.55	36.78	5.01	10.77
V_5S_3	51.14	3.00	36.75	4.75	6.94
V_5S_4	41.12	1.81	29.87	5.14	4.84
SE	34.57	1.14	22.11	6.93	4.32
CD($p \leq 0.5$)	**4.48**	**0.62**	**NS**	**3.43**	**4.14**

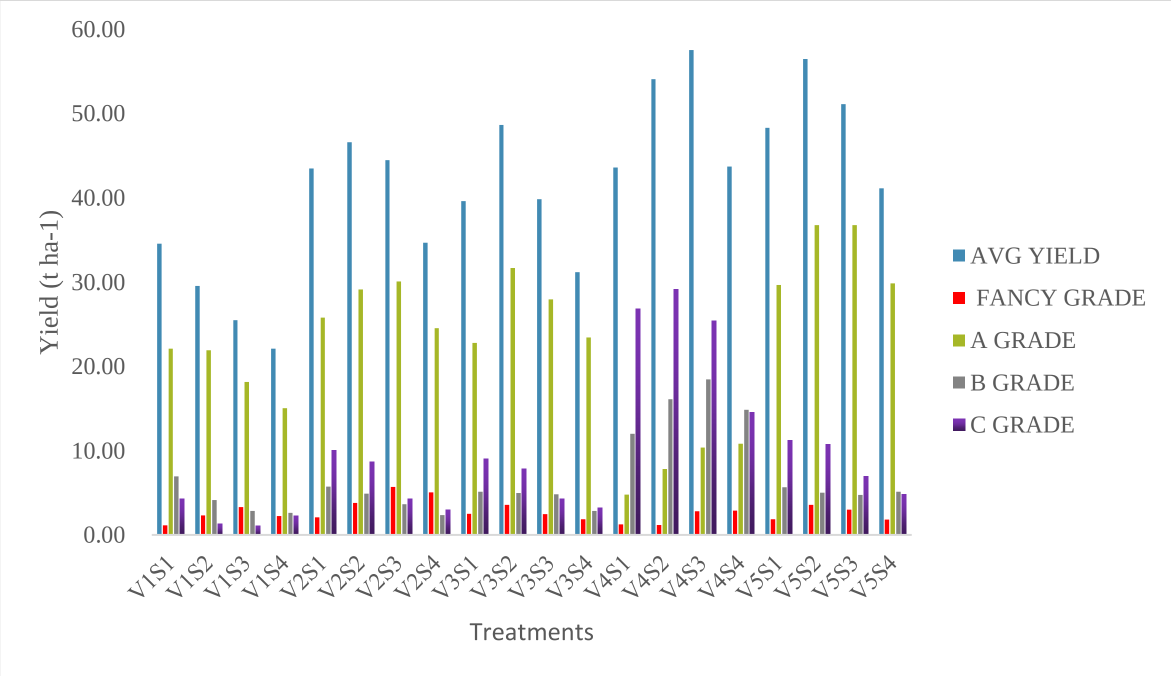


Fig 1: Effect of interaction between variety and summer pruning intensity on crop yield fruit quality.

Apple quality (grades): Apple fruit quality is instrumental in improving the economic value of produce. In Kashmir valley lack of quality apple has been considered a major reason for lower returns. So, any technological intervention impacting fruit quality may prove reasonably beneficial for apple growers. Quality in terms of fruit grading based on standard values was influenced both by the type of cultivar and severity of summer pruning. 'A' grade apple dominated the other grades with higher numerical values irrespective of the cultivar and pruning severity, except for Red Fuji. Since grading is based on size and colour of the fruit, Red Fuji with a lack of round colour under Kulgam conditions was the reason for low fancy and A-grade apple in this variety.

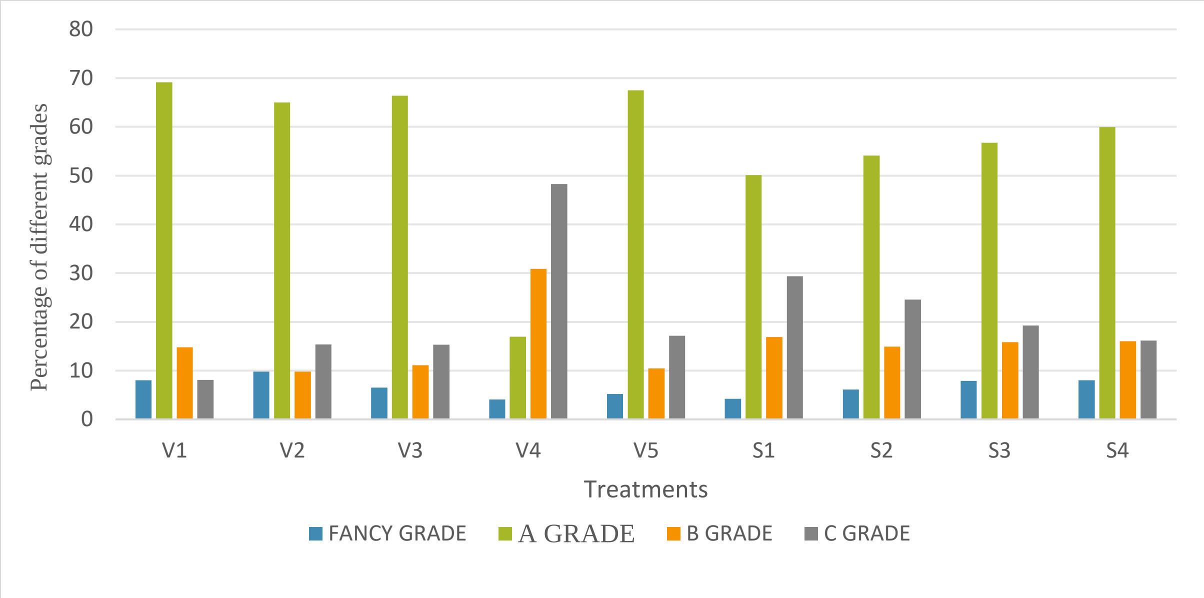


Fig 2: Percentage of different grades of apple as influenced by variety and summer pruning.

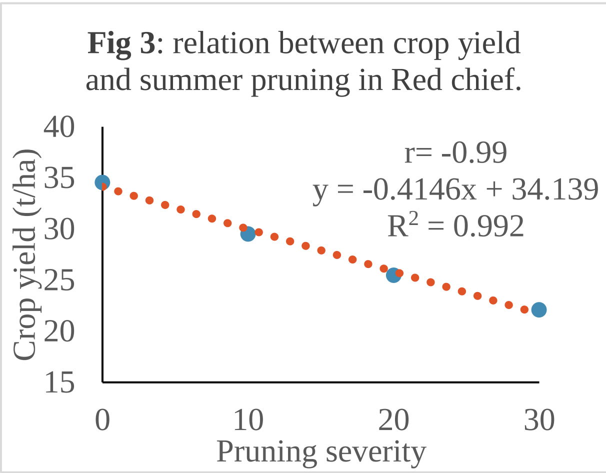


Fig 3: relation between crop yield and summer pruning in Red chief.

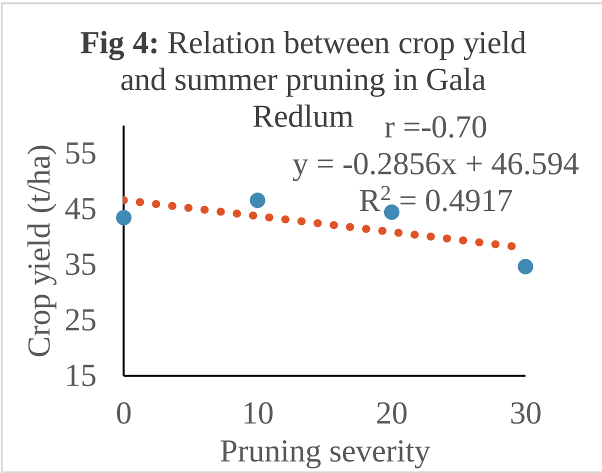


Fig 4: Relation between crop yield and summer pruning in Gala Redlum

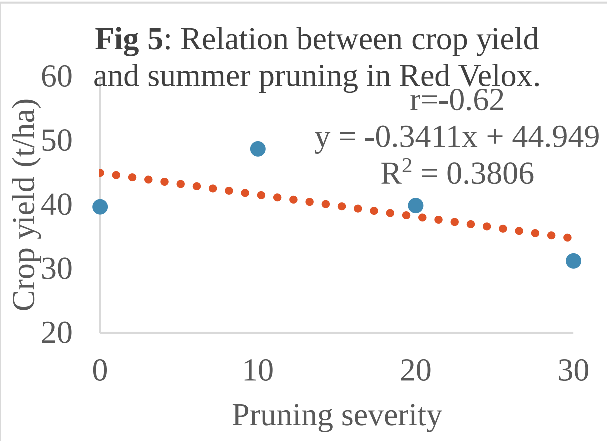


Fig 5: Relation between crop yield and summer pruning in Red Velox.

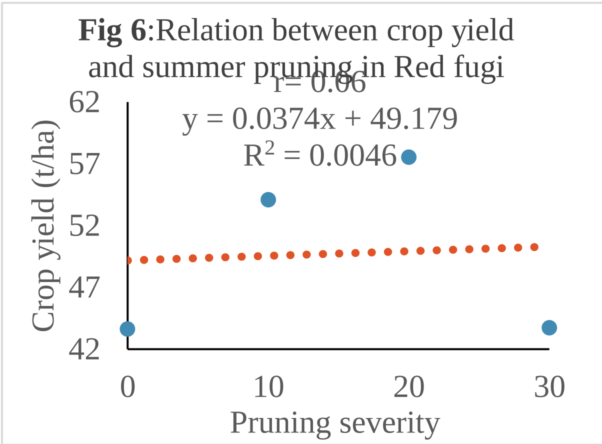
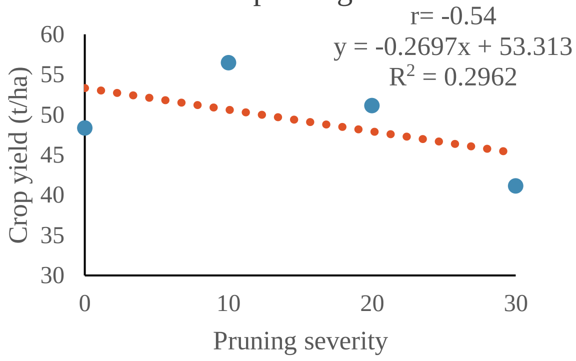


Fig 6:Relation between crop yield and summer pruning in Red fugi

Fig 2 gives an idea about the percentage of different apple grades influenced by variety. It is quite clear that high percentage of 'A' grade was obtained from all varieties excluding Red Fuji where high percentage of apple was of C grade. Fancy grade is considered the top grade of apple and Redlum Gala(V_2) registered significantly higher values for fancy grade apple (4.14 t /ha) in comparison to all other cultivars. Jeromine recorded significantly higher yield of A grade apple (33.27/ ha) in comparison to all varieties, followed by Redlum gala (27.5/ha). Red Fuji registered significantly higher yields of both 'B' and 'C' grade apple. With regard to the pruning severity prominent impact on 'A' grade apple was recorded with 10% and 20% summer pruning, both being statistically at par but significantly superior than rest of the treatments. 20% summer pruning however registered significantly higher yield of fancy-grade apple compared to other treatments. In the interaction it is evident from Table 2 and Fig that the fancy grade apples yield was highest in case of Redlum gala (V_2) with 10% summer pruning. Whereas, the least fancy grade apple was obtained in Red Fuji under no summer pruning treatment (Control). Irrespective of cultivar summer pruning to the extent of 10% and 20% recorded significant improvement in fancy grade apple and both severe pruning and no pruning had negative interaction effect on all varieties.

Fig 7: Relation between crop yield and summer pruning in Jeromine.



Varied responses in terms of fancy grade fruit of various cultivars to different severity of summer pruning may be attributed to various factors like genetic makeup of cultivars (Kumar, 2020), prevailing climatic conditions (Singh and Chauhan, 2002), growth pattern (Cooley and Autio, 2011), fruit drop (Sharma *et al*, 2011) and light interception (Wagenmakers and Callesen, 1989; Barritt *et al*, 1991).

From Table 2 and Figure 2, it can be understood that the highest average A-grade apple (36.78 t /ha) were obtained in mild summer pruned (10% summer pruning) Jeromine cultivar which was at par with moderately pruned (20%) Jeromine cultivar. Red Fuji cultivar yielded more quantity of A-grade apple under severe pruning (30%) as compared to other pruning treatments which was in contrast to results obtained on other studied cultivars at sameseverity of summer pruning. Better results in terms of average A-grade apples were obtained in light summer pruning (10%) across cultivars except Red Fuji. This may be attributed to the vigorous growing habit of Red Fuji as compared to other studied cultivars (Lugaresi *et al*, 2022). Better light penetration during the 1st week of August in highly vigorous cultivars like Red Fuji by summer pruning may contribute to more A-grade apples as reported by Ashraf and Ashraf, 2014; Lugaresi *et al*, 2022; Uselis *et al*, 2020 and Fenili *et al*, 2019.

As evident from table -1, Red Fuji yielded highest quantity of B-grade apples in the current system of planting. Severe summer pruning (S_4) in highly vigorous Red Fuji cultivar decreased average B-grade apple from 18.46 t/ha under-recorded under moderate (20%) summer pruning to 14.8 t/ha (Table-2). However, in other cultivars, severe summer pruning decreased B-grade apples more or less in a similar pattern due to their similar growth pattern. The lower yield of B-grade in Red Fuji apples under severe pruning may be attributed to better light penetration.

In general, a higher percentage of C-grade apples was recorded in Red Fuji among the cultivars and under no summer pruning treatment (S1) among the pruning treatments (Fig 2). C-grade apple was comparatively less in all cultivars, excluding Red Fuji. This may be due to better light penetration under the system of planting these varieties and also due to their genetic ability to develop fruit colour and size under optimum conditions (Uselis *et al*, 2020; Fenili *et al*, 2019; Ashraf and Ashraf, 2014).

Economics

Ultimately it is the economics that defines the feasibility of technology for the farming community. Despite the high yields of certain cultivars, they don't need to fetch good returns under specific situations. Red Fuji for instance attained the highest yield in the present study but failed to compete with other cultivars in terms of returns because of high percentage of low-grade apples in this variety. Data regarding the economic viability of various treatment combinations is shown in Table 3. From the data it can be inferred that various varieties responded differently to the summer pruning. Red Chief (V_1) for instance was economically less feasible when intense pruning was done.

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Highest net returns (Rs.2136858/ha) in Redlum Gala (V_2) resulted in S_3 (20%). However, Red Velox (V_3) responded better (Rs. 2123825/ha) under mild summer pruning(S_2). Summer pruning proved economically important for Red Fuji which generated net returns of Rs. 1016356 /ha under S3 (Medium pruning) as compared to just Rs.524693/ha in case of no summer pruning (S1). Medium summer pruning may have sufficiently open canopy for better penetration of light in Red Fuji, therefore improving the quality and income from this treatment. Mild summer pruning (S2) proved most profitable practice (2937527 /ha) in Jeromine variety and also in comaprison to all other treatment combinations in the experiment. Variation in terms of economic feasibility of varied summer pruning intensities in different apple cultivars may be due to additional costs of cultivation and market price of produce (Nicholas and Anthony, 2003), consumer preference (Guanxin et al, 2015), Demand (Dong and Li, 2008), Supply (Xiang, 2015), yield (Bhat et al, 2006), type of harvested grade (Uselis *et al*, 2020) and storability/shelf life (Naqash *et al*, 2017).

IV. CONCLUSION

This study revealed that summer pruning is highly beneficial for apple grown particularly under intensive systems of planting. Vigorous growing apple cultivars responded very well in terms of yield and quality improvement and overall economic feasibility to more severe levels of summer pruning when compared to less and moderate growing types. To harness the real value of tall spindle system of apple, needs summer pruning to be followed by apple orchardists. Maintaining the right balance between vegetative and reproductive growth in high-density systems is a tedious job, particularly when the scion cultivar is vigorous and the soils are more fertile. Summer pruning curtailed the growth of more vigorous apple cultivars effectively in tall spindle system thereby increasing light interception and ultimately leading to improved yield, quality, and income.

Table 3: Economics of apple crop as influenced by variety and summer pruning.

Treatments	Costs /ha (Rs)	Gross returns Rs/ha	Net returns Rs/ha	BC ratio
V_1S_1	838550	2155784	1317234	1.57
V_1S_2	765950	2032296	1266347	1.65
V_1S_3	388200	1774711	1386511	3.57
V_1S_4	340450	1475185	1134736	3.33
V_2S_1	652200	2406981	1754782	2.69
V_2S_2	702200	2713673	2011473	2.86
V_2S_3	673250	2810107	2136858	3.17
V_2S_4	529100	2243608	1714509	3.24
V_3S_1	594350	2191169	1596820	2.69
V_3S_2	733000	2856825	2123825	2.90
V_3S_3	603800	2412036	1808237	2.99
V_3S_4	476850	1948749	1471900	3.09
V_4S_1	654300	1178993	524693	0.80
V_4S_2	814400	1608061	793661	0.97
V_4S_3	868900	1885255	1016356	1.17
V_4S_4	664850	1587841	922991	1.39
V_5S_1	724950	3115799	2390850	3.30
V_5S_2	850150	3787677	2937527	3.46
V_5S_3	773100	3606917	2833817	3.67
V_5S_4	625850	2919764	2293914	3.67

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Development and Evaluation of Guava Leaf Spiced Herbal Tisane Dips

S. Jayasree[1], M. Kirthy Reddy[2], V M S N S Prasanth[1], K. Rajesh[2], K. Manaswini[1], R. Venkata Srikanth[1] and M. Himasree[1]

[1]Dr. NTR College of Food Science and Technology, Bapatla, Andhra Pradesh, India
[2]Assistant Professor, College of Food Science and Technology, Pulivendula, Andhra Pradesh, India
Email: kirthy88@gmail.com
*Corresponding author: M. Kirthy Reddy, Assistant Professor, College of Food Science and Technology, Pulivendula, Andhra Pradesh, India

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Abstract**—** *Tisane is a generic term for tea made from herbs instead of leaves of tea plant. In recent times, tisanes are gaining increasing popularity among consumers because of new bioactive compounds and their health benefits. The present study aimed to develop and evaluate herbal tisane using guava, mint and tulasi leaves along with some spices. All the leaves were subjected to a series of pre treatments before development of tisane. The unblanched and solar dried leaves showed better color retention when rehydrated. Tisane dips were made weighing 1.7g each, in which control sample is unblanched guava leaves. Spice's mix contains 10% mint, 10% cinnamon, 20% basil and 10% ginger as constant. Sample treatments T1, T2, T3 and T4 respectively formulated using different compositions of guava leaves: spice mix like 40:60, 50:50, 60:40 and 70:30. Sample T4 (70:30) recorded higher amount of carbohydrate content (58.75%), protein content (22.15%), fat content (4.4%), total phenolic (150.1mg GAE/g), total tannin content (1.214mg CE/g) and was highly accepted by sensory panels. Based on the results it concludes that the formulation with 70:30 ratios of guava leaves and spice mix showed better results and can be best alternative to commercial tea with various health benefits.*

Keywords**—** ***Guava leaf, Herbal, Spices, Tisane***

I. INTRODUCTION

Today there is increasing interest in discovering new bioactive compounds derived from ethnomedicine. Tisane, is a generic term for tea which is developed using herbs that can be served as a beverage [1] .These are gaining popularity among health-conscious consumers because of their fragrance, antioxidant properties and therapeutic applications [2]. Tisane can be made from the infusion or decoction of herbs, spices or any other plant material in hot water and they usually do not contain caffeine [3]. Phenolic compounds in guava leaves have been credited with regulating blood-glucose levels [4]. Newer tender leaves are particularly rich in fiber and roughage which is crucial for the prevention and treatment of constipation and hemorrhoids [5]. Guava contains good concentration of quercetin which has been shown to exhibit incredible antibacterial activity against pathogens [6].In recent times, there is renewed interest in functionalbeverage because of growing consumer awareness of health benefits derived from tea consumption. Tea therefore belongs to a rapidly expanding market of wellness beverage. Taking all these points into consideration the following research was taken up with thefollowing objectives- To develop guava leaf-based tisane formulated with other herbs and spices and to evaluate of physicochemical and organoleptic properties of the guava leaf tisane dipextract.

II. MATERIALS AND METHODOLOGY

Medium matured mid rib removed leaves were thoroughly cleaned. All these spices were collected from the nearer markets in the area. i.e, Bapatla, Guntur Dist, Andhra Pradesh. Tea bags that are heat sealable, degradable and made of cellulose were used.

2.1. Methodology: Guava leaves were blanched using water (85±1℃ for 2 mins) and steam (90±1℃for 3mins). They were allowed to cool at the room temperature after draining the water. Basil leaves were steam blanched, dried and pulverized. Mint leaves were dried without any pretreatments. All the leaves were sufficiently flattened in roller flaker in order to rupture and release the leave components from the interstitial cells. This was followed by drying separately in cabinet drier (60±5℃ for 5hrs) and solar drier. The dried leaves were pulverized (Fig 1)

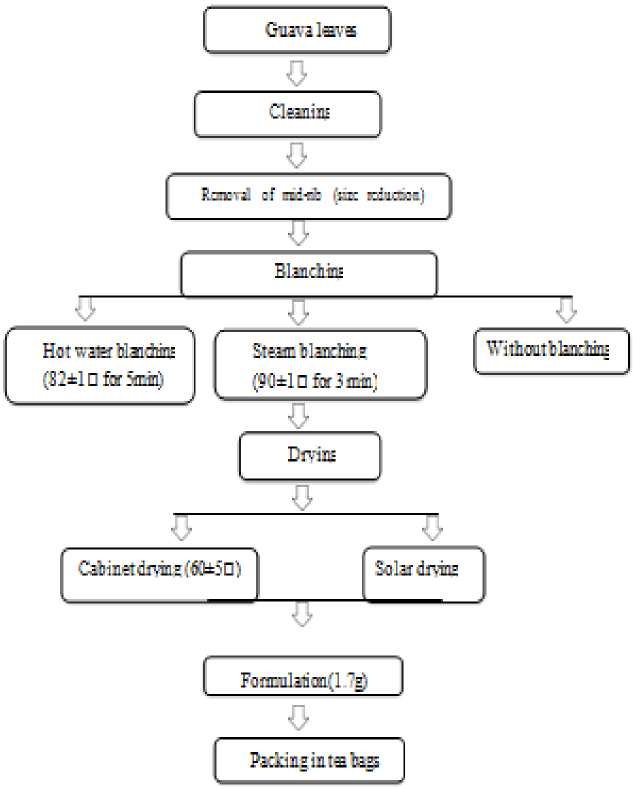

Fig 1: Flowchart of tisane dips preparation

Table 1: Formulation of tisanes

Ingredients	Control 100%	T_1 (40-60%)	T_2 (50-50%)	T_3 (60-40%)	T_4 (70-30%)
Guava leaves	1.7	0.68g	0.85g	1.02g	1.19g
Ginger	-	0.17g	0.17g	0.08g	0.08g
Cinnamon	-	0.17g	0.08g	0.04g	0.049g
Mint	-	0.57g	0.51g	0.51g	0.34g
Tulasi	-	0.17g	0.08g	0.04g	0.04g

Fig 2: Tisane dip

2.2. Formulations: In this study different formulations have been developed by using different combinations of spices and guava leaves (Table 1 and Fig 2). The formulations include 40% guava leaves 60% spices and the second formulation include 50% guava leaves 50% spices, like wise 60% guava leaves 40% spices and the last formulation include 70% guava leaves and 30% spices.

2.3. Analysis: All the formulations were analysed for, Nutritional compositions (The protein content was estimated by using the Kjeldahl apparatus, fat (soxhlet), carbohydrate (anthrone method), ash content (Muffule furnance) and moisture by hot air oven method. The phenolic content was estimated by adopting the method of Mallick and Singh (1980) [7]. Tannin content was analysed by the method of Azeez *et al.*, (2015) [8] using Folin - Ciocalteau reagent and absorbance was read at 725 nm.

2.4. Sensory evaluation 9-point hedonic scale was used to evaluate the sensory attributes (color and appearance, flavor, taste and overall acceptability) of the developed tisane dips as described by Akande *et al.* (2017) [9]. All four formulations along with control were evaluated from 1 to 9 (1 – extremely like to 9 – extremely dislike) by the 25 semi trained panels.

2.5. Rehydration ratios of tea bags: The rehydration ratios for four different formulations i.e., T_1, T_2, T_3 & T_4 at two different temperatures i.e., 70^{O}C and 100^{O}C withinthe time intervals of 2 min, 3min, 4min and 5min was done.

III. RESULTS AND DISCUSSION

3.1. Nutritional composition: The highest protein content in T4 sample is due to increase in guava leaves concentration in the formulation. The lower protein content is observed in T1 sample because spices dominate the formulation which contain low amountof protein. Guava leaves contains high amount of protein i.e., 18.5% which is more than combinationof all the spices in the formulation. The T4 sample showed the lower fat content and the highest ash content (4.38±0.03%) due to guava leaves which contain high amount of micronutrients. The low-fat content is due to increase in concentration of guava leaves which contains low fat content (Table 2).

3.2. Total phenolic content: It is observed the total phenolic content in the T4 showed highest 150.1±1.05mg GAE/g among the samples followed by T3 sample128.14±1.07 mg GAE/g followed by T2 sample having 113.13±0.45 mg GAE/g followed by T1 sample 99.15±1.06 and the control sample recorded least value of 97.15±1.04 mg GAE/g. The highest phenolic content in samples than control sample is dueto presence of spices in the sample.

3.3. Total tannin content: From the data, the total tannin content is observed highest in control sample 2.84±0.12mg CE/g followed by T4 (1.21±0.11mg CE/g) when compared to other samples. T2 sample resulted in least value 1.04±0.16mg CE/g. The highest tannin content is attributed to the amount of guava leaves which contains highest tannin content compared to other ingredients**.**

3.4. Rehydration Ratio: the rehydration ratios at 70^{O}C & 100^{O}C for T_4 sample gave the best results. As the time of dipping increased rehydration ratio increased significantly. Thus, we can conclude that T_4 sample; 70^{O}C & 100^{O}C temperatures and the 5 min time interval are better compared to others respectively (Fig 3).

3.5. Sensory analysis: After development of the tisane dips, their acceptability was done using a panel of 25 members. From the data presented in Table 3 and Fig 4) we can observe that test sample 4 has the highest overall acceptability with a mean value of 7.83 when compared to other samples. As the control sample has only guava leaves, the spices which can mask the bitterness of guava leavesare not present in control sample. This might be reason behind the low overall acceptability.

The score for flavor is highest for T4 and then T3, T1, T2 and control sample respectively. The Scorefor taste is also high for T4 and then T2, T3, control sample and T1 respectively. And coming to appearance and color, the score for this also is high for T4 and then T2, T1, T3 and control sample respectively. So, by this data we can conclude that test sample T4 has the highest overall acceptability with a meanvalue of 7.83 has highest appearance & color with a mean value of 7.65; has a highest score for flavorwith a mean value of 7.67 and has a highest score for taste with a mean value of 8.19 respectively when compared to other samples.

Table 2: Chemical properties of prepared tisanes

Chemical properties	**Control sample**	**T1**	**T2**	**T3**	**T4**
Carbohydrate (%)	60.85±0.01	50.05±0.02	55.23±0.01	54.27±0.12	58.75±0.01
Protein (%)	22.98±0.12	20.56±0.14	21.85±0.10	21.96±0.11	22.15±0.15
Ash (%)	3.80±0.01	3.25±0.03	3.68±0.04	3.58±0.01	4.38±0.03
Fat (%)	1.45±0.04	1.63±0.01	1.66±0.03	1.65±0.02	1.63±0.01
Moisture (%)	8.67±1.02	5.6±0.12	4.6±0.15	4.5±0.14	4.4±0.11
Total phenolic content (mg GAE/g)	97.15±1.04	99.15±1.06	113.13±0.45	128.14±1.07	150.1±1.05
Total tannin content (mg CE/g)	2.84±0.12	1.14±0.14	1.04±0.16	1.15±0.12	1.21±0.11

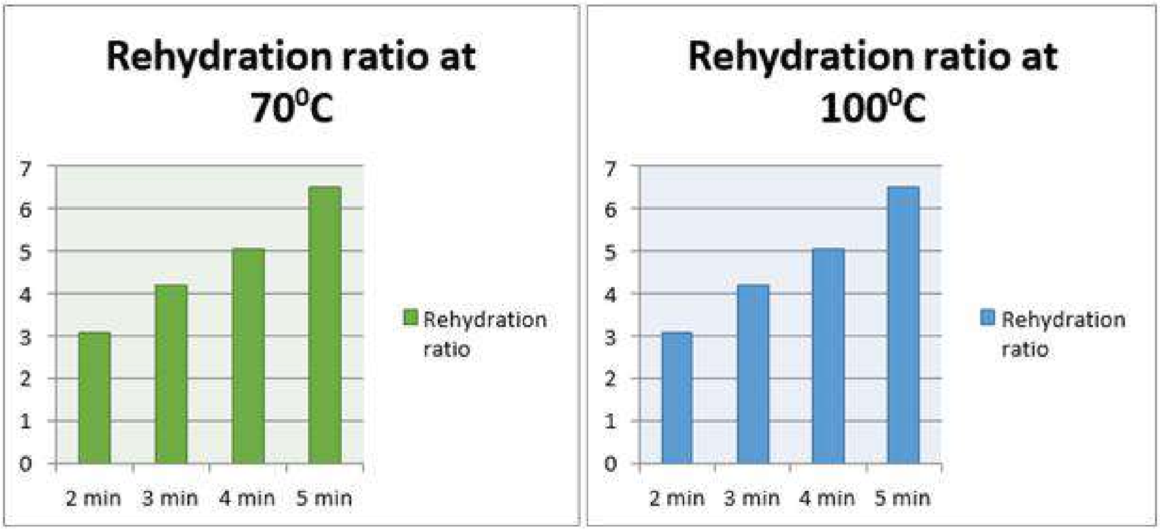

Fig 3: Rehydration ratio at different temperatures and time intervals

Table 3: Sensory analysis of the prepared tisane dips

Sample	**Appearance and color**	**Flavor**	**Taste**	**Overall acceptability**
Control sample	7.13±0.15	7.15±0.14	7.51±0.12	7.26±0.13
T1	7.24±0.01	7.62±0.02	7.21±0.01	7.35±0.01
T2	7.54±0.03	7.52±0.01	8.15±0.05	7.73±0.04
T3	7.15±0.14	7.63±0.12	7.64±0.15	7.47±0.13
T4	7.65±0.01	7.67±0.02	8.19±0.04	7.83±0.03

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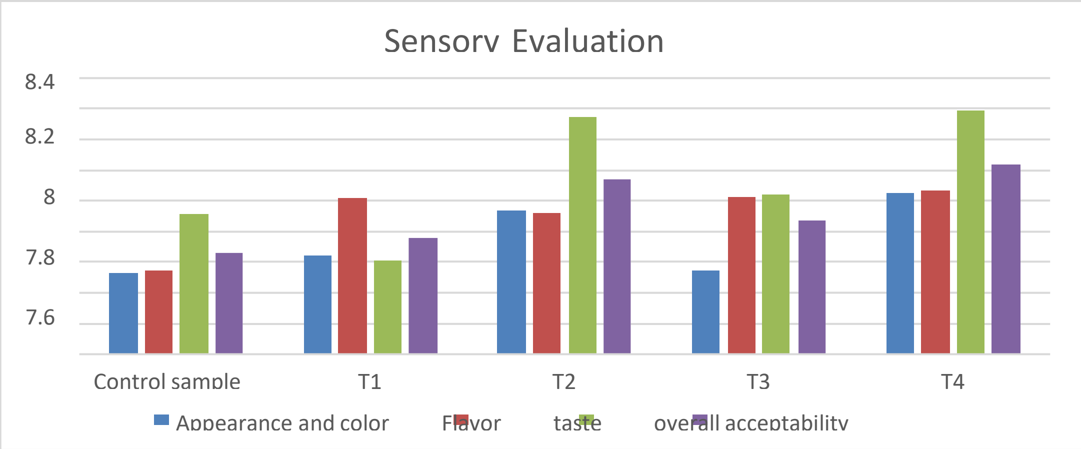

Fig 4: Sensory analysis of the prepared tisane dips

IV. CONCLUSION

It was found that the leaves which were not blanched and dried under solar drying method showed better results and better color retention when rehydrated. The protein content found high in the control sample 22.98±0.12%, among the test samples T_4 (70:30) sample showed highest amount 22.15±0.15%. Total phenolic (150.1mg GAE/g) and total tannin content (1.214mg CE\g) was recorded higher in T_4 sample when compared to other control and other treatments. This study concludes that the formulation with 70:30 ratio of guava leaves and spice mix showed better results and can be best alternative to commercial tea (*Camellia sinensis*) with various health benefits.

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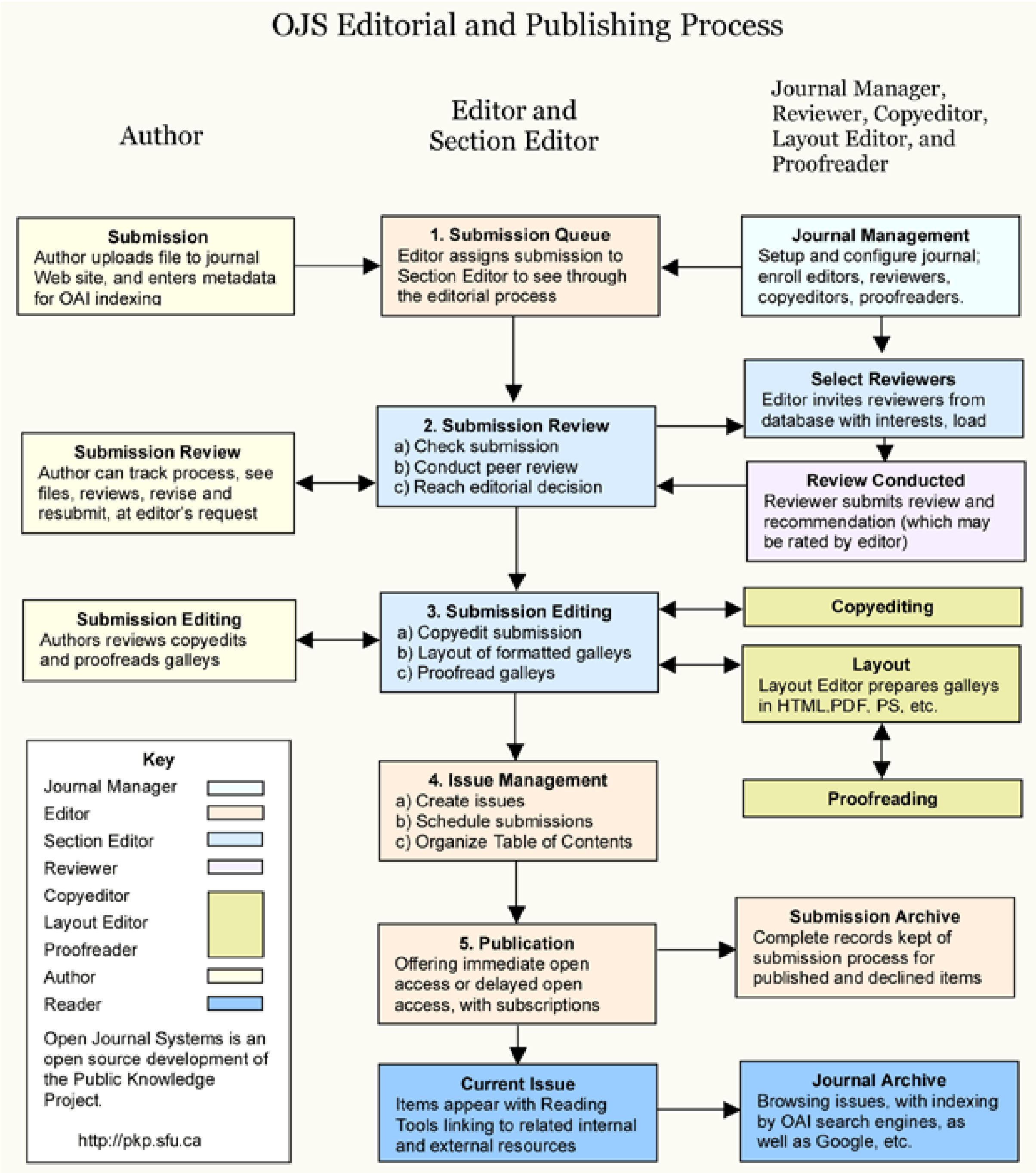

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