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FOREWORD

I am pleased to put into the hands of readers Volume-7; Issue-6: November-December 2022 of **"International Journal of Environment, Agriculture and Biotechnology (IJEAB) (ISSN: 2456-1878)",** an international journal which publishes peer reviewed quality research papers on a wide variety of topics related to **Environment, Agriculture and Biotechnology**. Looking to the keen interest shown by the authors and readers, the editorial board has decided to release issue with DOI (Digital Object Identifier) from CrossRef also, now using DOI paper of the author is available to the many libraries. This will motivate authors for quick publication of their research papers. Even with these changes our objective remains the same, that is, to encourage young researchers and academicians to think innovatively and share their research findings with others for the betterment of mankind.

I thank all the authors of the research papers for contributing their scholarly articles. Despite many challenges, the entire editorial board has worked tirelessly and helped me to bring out this issue of the journal well in time. They all deserve my heartfelt thanks.

Finally, I hope the readers will make good use of this valuable research material and continue to contribute their research finding for publication in this journal. Constructive comments and suggestions from our readers are welcome for further improvement of the quality and usefulness of the journal.

With warm regards.

Editor-in-Chief
Date: January, 2023

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Identification of Bacteria as Health Indicators of Mangrove Crab (Scylla Serrata) at Farm Suppliers in South Kalimantan

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Abstract— *This study aims to identify the types of pathogenic bacteria in mangrove crabs (Scylla serrata) and determine the health condition of mud crabs (Scylla serrata) at farm supply in South Kalimantan Province. The research method used is a case study, with sampling of mangrove crabs by purposive sampling at the farm supplier by considering the form supplier is already a legal entity, is still active in shipping and the frequency of shipments is quite a lot as well as continuous delivery to domestic and export destinations. For locations, sampling of mangrove crabs (Scylla serrata) was carried out at 3 (three) farm suppliers, namely CV. ACS in Banjarbaru City, CV. Three A's in Banjar Regency and UD. SLM in Banjarbaru City. For bacterial examination, it was repeated three times with the number of crab samples adjusted to the delivery population at the time of the study. The results showed that 15 mud crabs were infected with the pathogenic bacteria Plesiomonas sp (42%) followed by Actinobacillus sp. (39%), Vibrio sp. (16%) and Moraxella sp. (3%). The most common type of pathogenic bacteria infecting the farm supplier CV. ACS is a type of Actinobacillus sp. as many as 5 tails, while on the farm supplier CV. Three A are Plesiomonas sp. and Actinobacillus sp each as many as 5 tails and on farm supplier UD. SLM is a type of Plesiomonas sp as many as 6 tails. The condition of the mud crab (Scylla serrata) is declared physically healthy with the characteristics when the swimming legs are pulled away from the carapace and then released, the legs move quickly to their original position, the eye stalks are very responsive, that is, they enter the orbital area when touched, the mouth does not release foam, color The carapace is bright and does not have a bad smell and there are no pathogenic bacteria found in mud crabs that are harmful to the human body or safe for consumption.*

Keywords— ***Mangrove Crab (Scylla serrata). Mangrove Crab Health Indicator***

I. INTRODUCTION

One of the important fishery commodities in Indonesia is the Mangrove Crab (Scylla serrata). According to (Unthari et al, 2018). Mangrove crab (Scylla serrata) is one of the fauna that live in mangrove habitats. Mangrove crab (Scylla serrata) is one of the high economic commodities that is very suitable for breeding. Most of the production of mangrove crabs still comes from the fishing sector in nature.

According to (Risamasu at al, 2014), there are four types of crabs that are generally consumed, namely Scylla serrata, Scylla tranquebarica, Scylla paramamosain, Scylla olilvacea. Scylla serrata is the most popular type of crab as a food ingredient and has a fairly expensive price.

The high traffic of fishery commodities from South Kalimantan Province at this time, especially the Mangrove Crab (Scylla serrata) commodity both for domestic and for export, thus certainly increases the possibility of the entry

and spread of fish diseases from one country to another and from one area to another within the country. territory of the Republic of Indonesia.

Bacterial disease that attacks crabs is one type of infectious disease. This disease occurs from incompatible interactions between three main components, namely the environment, biota, and disease-causing organisms. The cause of this bacterial disease is not always an attack of organisms, but can also be triggered by the environment, such as poor water quality and unqualified food factors.

(Susanti, Prayitno et al, 2016) Bacterial diseases attack all crab stages, both juvenile to adult crabs. This bacterial disease can cause high mortality, so it can cause economic losses. Various studies have been conducted to identify the causes of bacterial disease in mud crabs, including:: *Pseudomonas sp., Aeromonas sp., Vibrio sp.,* dan *Mycobacterium sp.* (Feriandika et al, 2014).

Diseases caused by bacteria can be identified by the symptoms they cause, but laboratory tests can determine the species of bacteria that causes the disease. So that the cause of the disease can only be known if a necropsy is carried out which further examines the cause of the disease. This encourages the identification of bacteria that cause bacterial disease in mud crabs so that appropriate prevention and treatment can be carried out on aquaculture..

Changes in global trade trends and issues are followed by increasingly stringent requirements that must be met, from disease-free, environmental, traceability, biosecurity and certain technical requirements before fishery commodities are trafficked. This shows that the fishery commodities to be traded are not enough to be disease-free when they are exported, but are in good health from the start of production to the time they are shipped.

The market demands for quality products, of good quality, not contaminated with contamination, especially pathogenic bacteria that can disrupt trade both domestically and abroad are very large. Research on the identification and inventory of pathogenic bacteria in mud crab (Scylla serrata) as a health indicator in Indonesia has not been widely carried out, especially the identification and inventory of pathogenic bacteria in mud crab (Scylla serrata) as a health indicator in South Kalimantan Province. Therefore, the authors are interested in conducting research on "Identification and Inventory of Pathogenic Bacteria in Mangrove Crab (Scylla serrata) as Health Indicators in Farm Suppliers in South Kalimantan". Information related to the types of pathogenic bacteria found in mangrove crab commodities that will be sent out of South Kalimantan Province is expected to be used as a reference in efforts to prevent and treat infection with these diseases so that the resulting commodities are of good quality and healthy

II. RESEARCH METHODS

Place and time of research

This research has been carried out at the mangrove crab (Scylla serrata) farm supplier in South Kalimantan Province for three weeks from 6 to 24 June 2022.

Research procedure

The method used in the observation is the case study method. The case study research method is a research that includes an assessment aimed at providing a detailed description of the background, nature and character of a case, in other words that a case study focuses on a case intensively and in detail. A case study is a research strategy to carefully investigate a matter by collecting complete information using various data collection procedures. In addition, case studies are also conducted to gain in-depth understanding and analyze more intensively about an individual, group, or situation (5).

Researchers determine the location of research sampling with purposive sampling technique. According to (Rina et al, 2017) purposive sampling is a data sampling technique based on certain considerations. The purposive sampling method is taken in determining the sampling location at the farm supplier with the consideration that it is already a legal entity, is still active in shipping, has a fairly large and continuous delivery frequency for both domestic and export shipments..

For locations, sampling of mangrove crabs (Scylla serrata) was carried out at 3 (three) farm suppliers, including:

- CV. ACS in Banjarbaru City
- CV. Three A's in Banjar Regency
- UD. SLM in Banjarbaru City.

This study was carried out with three treatments at the farm supplier and three replications for bacterial examination with the number of crab samples adjusted to the delivery population at the time of the study. The minimum number of samples taken according to the Decree of the Head of BKIPM Number 117 of 2017 can be seen in Table 2.1.

Table 2.1 Number of Samples

Farm Name	Mean Delivery Population During Research (Crabs)	Number of Samples (Crabs)	Number of Samples / Replications (Crabs)			Total Sampel (Ekor)
			1	2	3	
CV. ACS	**700 – 1.000**	**4**	**4**	**4**	**4**	**12**
CV. Tiga A	**800 – 1.000**	**4**	**4**	**4**	**4**	**12**
UD. SLM	**500 – 1.000**	**4**	**4**	**4**	**4**	**12**

Source : (7)

Research Tools and Materials

1. Research Tools
   - Stationery
   - Disecting set
   - Microtube
   - Dropper Dropper
   - Laminary flow
   - Ose Needle
   - Bunsen
   - Spray Bottle
   - Autoclave
   - Plastic
   - Digital scales
   - Tray
   - Petri dish
   - Incubator
   - Surgical table
   - Measuring cup
   - Hot plate stirer
   - Refrigerator
   - Magnetic stirrer
   - Cool box
2. Research Materials
   - 70% alcohol.
   - TSA
   - 3% KOH solution
   - TSIA
   - 40% KOH solution
   - Crystal violet solution
   - Urea agar
   - Safranin solution
   - Gelatin hydroxide
   - Paraffin
   - iodine-lugol
   - Naphthol
   - Aquades
   - Aluminum Foil
   - OF
   - MIO
   - Citrate Agar
   - LIA
   - Kovacks reagansia
   - Catalase solution H2O3 3%
   - Potassium
   - Solution
   - Sample Tes

Bacteria Test Flow

he flow of bacterial examination can be seen in Figure 2.1.

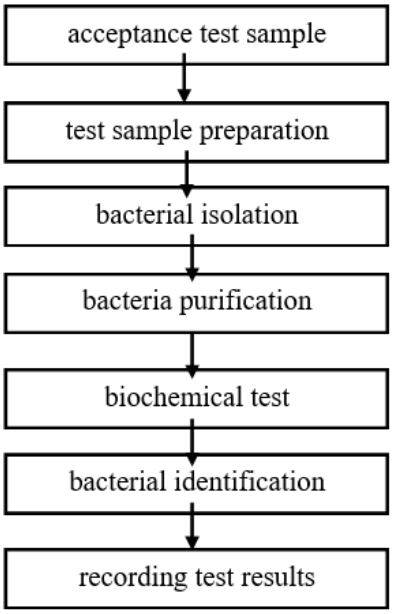

Fig.2.1. Bacteria Test Flow

Preparation of Tools and Materials

Preparation of tools and materials carried out included preparing surgical instruments, trays, scales and other equipment, then preparing test materials, namely materials for bacterial isolation media and biochemical tests used to observe bacteria in mud crabs. Next, prepare samples of mangrove crabs to be observed.

Sampling Method

In accordance with the Decree of the Head of BKIPM Number 117 of 2017 the method of sampling test samples is carried out by random sampling and lethal sampling. Random sampling is a sampling technique in which all individuals in the population are given the same opportunity to be selected as sample members. Lethal sampling is a test sampling technique by turning off the sample fish. The large number of samples taken for research can be seen in Table 2.2.

Table 2.2. Number of samples taken

Total Population (Crabs)	Number of Test Samples (Crabs)
50-100	**2**
101 – 250	**3**
251 – 999	**4**
> 1000	**8**

Source : (7)

The mechanism for taking samples using the random sampling method is a lottery or lottery system where in this method the researcher assigns a number to each basket or container and then the number is chosen randomly. This random selection uses methods such as lottery or social gathering with eyes closed when taking numbers. The randomly selected number represents the selected population member. Farm supplier data that will be used as a sampling location can be seen in Table 2.3.

Table 2.3 Mangrove Crab Sampling Site.

Name	Delivery Destination	Origin of Raw Materials
CV. ACS	**Jakarta and Cina**	**Kotabaru Regency, Tanah Bumbu Regency, Banjar Regency, Barito Kuala Regency**
CV. Tiga A	**Jakarta and Cina**	**Kotabaru Regency, Tanah Bumbu Regency, Banjar Regency, Barito Kuala Regency and Tanah Laut Regency**
UD. SLM	**Jakarta and Batam**	**Kotabaru Regency, Tanah Bumbu Regency, Banjar Regency**

Data analysis

Data from the identification and inventory of bacteria that infect mangrove crabs (Scylla serrata) were analyzed descriptively and presented in the form of figures and tables. Descriptive analysis is an analytical technique that provides information only about the observed data, draws conclusions that are generalized to the population and does not aim to test hypotheses. The purpose of descriptive analysis is only to present and analyze data to be meaningful and communicative (Purwanto et al, 2017)

Analysis of research data is a measuring tool used to measure the parameters that have been observed, namely by examining all types of bacteria that have been found to then carry out an inventory of the types of bacteria that have been found based on literature references which are then compiled in tabulations.

The data analysis technique in this study used descriptive data analysis techniques with percentages. Furthermore, to calculate the percentage in each type of sample population infected with bacteria, the formula from (9) is:

$$P = \frac{f}{n} \times 100\%$$

Information :

P : Percentage Number

f : Number of frequencies found

n :Number of frequency/number of population

III. RESULTS AND DISCUSSION

3.1. Bacteria Identification

The condition of the mud crab (Scylla serrata) samples at each farm supplier at each farm supplier can be seen in table 1

Table 3.1. Condition of mud crab (Scylla serrata) samples

Nama Farm	Gender		Average Crab Weight (grams)	Average Crab Length (cm)
	Male (Crabs)	Female (Crabs)		
CV. ACS	**8**	**4**	**281,2**	**11,3**
CV. Tiga A	**9**	**3**	**318,7**	**11,4**
UD. SLM	**9**	**3**	**258,7**	**10,9**

Based on the results of the examination issued by the Laboratory of KIPM Banjarmasin on bacterial testing on samples of mangrove crabs (Scylla serrata) with a total sample of 36, it was found that 15 were infected with Plesiomonas sp. pathogenic bacteria, 14 were infected with Actinobacillus sp. pathogenic bacteria, 6 tails infected with pathogenic bacteria Vibrio sp. and 1 tail was infected with the pathogenic bacteria Moraxella sp. The results of the identification of pathogenic bacteria in mud crab (Scylla serrata) stated that the type of bacteria Plesiomonas sp. more dominant in infecting mangrove crabs (Scylla serrata) which are trafficked out of South Kalimantan Province compared to other types of bacteria. This is due

to high rainfall conditions when crabs are caught in the coastal waters of South Kalimantan Province which causes the water conditions to become cloudy and mixed with mud and can resulting in contamination that can contaminate the crab. Plesiomonas sp. will grow in muddy water media and tolerant to high pH.

The descriptive percentage of pathogenic bacteria found in the mud crab (Scylla serrata) samples can be seen in Table 3.2.

Table 3.2. Descriptive Data Percentage of Pathogenic Bacteria Found in Mangrove Crab (Scylla serrata) Samples

Types of Pathogenic Bacteria	Number of Crab Test Samples (crabs)	Number of Bacteria Infecting Mangrove Crab (crabs)	Percentage (%)
Plesiomonas sp.	36	15	42
Actinobacillus sp.	36	14	39
Vibrio sp.	36	6	16
Moraxella sp		1	3

It can be seen that the most common type of pathogenic bacteria infecting mud crabs (Scylla serrata) is Plesiomonas sp. (42%), followed by the type of bacteria Actinobacillus sp. (39%), Vibrio sp. (16%) and the bacteria Moraxella sp. (3%).

The number of pathogenic bacteria that infect mud crab (Scylla serrata) in each farm supplier can be seen in Table 3.3.

Table 3.3. Number of Pathogenic Bacteria Infecting Mangrove Crabs (Scylla serrata) in Each Farm Supplier.

Farm Name	Type of Bacteria				Number of Samples
	Plesiomonas sp.	*Actinobacillus sp.*	*Vibrio sp.*	*Moraxella sp.*	
CV. ACS	**4**	**5**	**2**	**1**	**12**
CV. Tiga A	**5**	**5**	**2**	**0**	**12**
UD. SLM	**6**	**4**	**2**	**0**	**12**
Total	**15**	**14**	**6**	**1**	**36**

It is known that the most pathogenic bacteria infecting mud crab samples at farm supplier CV. ACS is a type of Actinobacillus sp. as many as 5 tails, while on the farm supplier CV. Three A are Plesiomonas sp. and Actinobacillus sp each as many as 5 tails and on farm supplier UD. SLM is a type of Plesiomonas sp. as many as 6 tails.

Of the three farm suppliers, UD. SLM is the most infected with the pathogenic bacteria Plesiomonas sp. because the farm supplier does not yet have a CKIB certificate (Good Fish Quarantine Method) issued by the competent authority so that periodic monitoring is not carried out both from the aspect of the feasibility of facilities and infrastructure, product health, handling during distribution as well as sanitation and hygiene.

Mangrove crab (Scylla serrata) shipments that are trafficked out of South Kalimantan Province for both domestic and export shipments through farm suppliers can be stated that the condition of mangrove crabs (Scylla serrata) is healthy and safe from fish diseases even though the results of the examination of test samples indicate infection from pathogenic bacteria . This is because the spread of these pathogenic bacteria can still be controlled both in aquaculture waters and for human consumption as also regulated in the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 17 of 2021 concerning the category of types of bacterial diseases in fish that may be trafficked.

However, the pathogenic bacteria Plesiomonas sp., Actinobacillus sp., Vibrio sp. and Moraxella sp are types of bacteria that can cause disease either through direct invasion or contamination, especially Vibrio sp. is the most dominant type of bacteria causing White spot syndrome virus (WSSV) disease, especially in tiger prawns. Transmission of WSSV disease can be caused by the presence of a carrier organism, which is a disease-carrying organism that can transmit disease to other organisms, but the carrier organism does not show clinical symptoms of the disease. Horizontal disease transmission through carrier organisms, such as crabs (Pranawaty, R.N. et.al, 2012). This is of course a warning to farm suppliers against Vibrio sp bacterial infections so that more careful, faster and hygienic handling is needed in the packing or distribution process at farm suppliers so that bacterial growth can be prevented and the mortality rate can be reduced to a minimum.

3.2 Mangrove Crab Health

Mangrove crab (Scylla serrata) trafficked through farm suppliers in South Kalimantan is declared healthy because it is seen from several aspects, namely:

1. Physical Aspect

Healthy crabs have physical characteristics, namely when the swimming legs are pulled away from the carapace and

then released, the legs move quickly to their original position (close to the carapace), the eye stalks are very responsive, which goes straight into the orbit area when touched, the mouth does not release foam, the color of the carapace bright and does not smell bad (BKIPM, 2016).

2. Aspects of Bacterial Infection

Healthy crabs certainly do not contain any type of pathogenic bacteria that can harm the human body or are safe for consumption, including not containing Edwardsiella ictaluri, Aeromonas salmonicida, Streptococcus iniae, Streptococcus agalactiae, Yersinia ruckeri and Renibacterium salmoninarum bacteria which are required for live food commodities.

The results of the examination did not find pathogenic bacteria so that the mangrove crabs could be declared healthy.

IV. CONCLUSION

1. A total of 15 mud crabs were infected with Plesiomonas sp. pathogenic bacteria, 14 were infected with Actinobacillus sp., 6 were infected with Vibrio sp. and 1 tail was infected with the bacteria Moraxella sp.
2. The most common type of pathogenic bacteria found was Plesiomonas sp (42%) followed by Actinobacillus sp. (39%), Vibrio sp. (16%) and Moraxella sp. (3%).
3. The most common type of pathogenic bacteria infecting the farm supplier CV. ACS is a type of Actinobacillus sp. as many as 5 tails, while on the farm supplier CV. Three A are Plesiomonas sp. and Actinobacillus sp each as many as 5 tails and on farm supplier UD. SLM is a type of Plesiomonas sp as many as 6 tails.
4. The condition of the mud crab (Scylla serrata) is healthy by meeting the criteria for the physical aspect with the characteristics when the swimming legs are pulled away from the carapace and then released, the legs move quickly to their original position, the eye stalks are very responsive, that is, they enter the orbital area when touched, the mouth no foam, bright carapace color and no bad smell. In addition, mangrove crabs did not find pathogenic bacteria that could be harmful to the human body or safe for consumption, namely they did not contain the bacteria Edwardsiella ictaluri, Aeromonas salmonicida, Streptococcus iniae, Streptococcus agalactiae, Yersinia ruckeri and Renibacterium salmoninarum

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An Assessment of a Major Global Full-Service Network Airline's Waste Management: A Case Study of Korean Air

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Abstract— *Using an in-depth longitudinal research approach, this study has examined how Korean Air, a major global full-service network airline, manages its wastes in an environmentally sustainable manner. The study period was from 2007 to 2021. Korean Air has defined and implemented a "Green" Management Policy that underpins its sustainability goals. The airline's waste management is underpinned by the 3Rs Waste Management Framework. Korean Air aims to reduce wastes wherever possible. Where this is not possible then the airline aims to re-use its wastes. Wastes that are unsuitable for re-use are recycled when their characteristics are suitable for such an approach. Wastes that cannot be re-used, recycled, or incinerated are disposed to landfill. The airline's cabin wastes are disinfected and incinerated in accordance with the relevant regulations. Wastes generated by Korean Air can be broadly split into domestic waste generated from transportation services and designated or hazardous waste generated from aircraft maintenance. The case study found that there was an overall upward trend in Korean Air's annual recycled wastes from 2010 to 2019. The airline's incinerated wastes exhibited a general upward trend from 2007 to 2019. Koreans Air's annual wastes disposed to landfill displayed a general downward trend during the study period. Koreans Air's annual wastes were influenced by the reduced passenger traffic and flight operations due to the COVID-19 pandemic in 2020 and 2021. The COVID-19 pandemic has had a profound impact on the global aviation industry and has the global pandemic resulted in a downturn in passenger traffic and flight operations.*

Keywords—***Airline wastes, incinerated wastes, waste recycling, Korean Air, 3Rs Waste Management Framework.***

I. INTRODUCTION

All around the world, the environmental sustainability of air transport has been receiving greater focus in recent times due to its critical impact on climate change and on the environment (Budd, 2017; Chen, 2012; Daley, 2016; Teoh & Khoo, 2016). Environmental issues associated with the global air transport industry have grown in importance in recent years, and in response some airlines located throughout the world have been proactive to demonstrate their 'green' credentials (Mayer et al., 2012). Consequently, many airlines have now defined and implemented environmental related strategies that are designed to "green" their operations (Çabuk et al., 2019; Chan et al., 2021; Migdadi, 2020). Indeed, in recent decades, greening (ensuring the sustainable development of the global air transport system) has been viewed as a highly significant part of the agenda by almost all the industry's involved stakeholders (Janić, 2011). The key objective of the "greening" strategy is for an airline to make its operations more environmentally friendly wherever this is possible (Baxter, 2022).

Solid waste management and waste disposal is regarded as being one of the most significant issues in the environmental management of the global airline industry (Baxter, 2020; Li et al., 2003). Each year the air transport industry generates a substantial amount of comingle waste

(Blanca-Alcubilla et al., 2019). Considering this, airlines are now making a considerable effort to improve their waste management and to reduce waste generation where possible (Blanca-Alcubilla et al., 2019; Moynihan & Moynihan, 2019). Cabin waste is a particular area of concern. The International Air Transport Association (IATA), the world's peak airline association, has reported that around 5.7 million tons of cabin is generated by airlines, of which 80.5% was leftover food and beverages (Nakornkao & Mongkalig, 2022). Consequently, airlines in recent years have been paying increasing attention to the food waste issue, particularly in the cabin service sector of full-service network airlines due to the amount of food wastage and the consequent impact on the environment and economy (Yu et al., 2020). As a result, airlines have also been exploring a number of innovative solutions to reduce their cabin waste (International Air Transport Association, 2020).

In the global air transport industry, airline services are provided by low-cost carriers (LCCs), full-service network carriers (FSNCs), regional airlines, and charter/holiday airlines (Whyte & Lohmann, 2017). Korean Air was selected as the case airline as it an airline that has placed a very high focus and commitment to the sustainability of its operations. Korean Air is also a major global full-service network airline. In addition, Korean Air has adopted and implemented a "green" management policy. A key element of the company's "green" management policy is to minimize the airline's environmental load through proactive measures and improvement in the company's environmental performance (Korean Air, 2021a). The objective of this study is to examine how Korean Airlines sustainably manages its wastes. A secondary objective is to examine the role of recycling in Korean Air waste management. The study also aims to identify the various types of waste generated by Korean Air and how such wastes are handled. A final objective is to examine how the increase in passenger traffic during the study period has influenced the airline's ability to manage its wastes in an environmentally sustainable manner. The study period is from 2007 to 2021.

The remainder of the paper is organized as follows: the literature review presented in Section 2 presents the literature review which sets the context for the study's in-depth case study. The research method that underpinned the study is described in Section 3. The Korean Airlines case study is Section 4. The key findings of the study are presented in Section 5.

II. BACKGROUND

2.1. The Types of Airline Wastes

Airlines produce large volumes of waste which typically includes food and drink containers, newspapers and magazines, food waste (from offices, lounges/cafeterias), light bulbs, printer toner, paper, documents, and computer print outs. In addition to the waste generated from their administration and flight operations, many airlines generate quite large quantities of waste from handling their air cargo services. These wastes include tyres, fluids, lights bulbs, batteries, wood and wooden pallets, plastic wrapping material, green waste from lawn/garden care and landscaping, paper, and computer printouts (Baxter et al., 2018b).

Deplaned aircraft waste is waste that originates on an airline's flights. Cabin waste is comprised of two principal streams: cleaning waste and catering (galley) waste (International Air Transport Association, 2022). Cleaning waste is leftover rubbish from items provided to passengers on the aircraft during their flight. These items include newspapers, paper towels, plastic bottles (United States Federal Aviation Administration, 2013), food dropped on the floor, amenity kits and plastic wrapping from blankets, pillows, and headsets. Cleaning waste also includes the contents of washroom bins and medical waste such as used syringes that have been left by passengers for subsequent disposal. Catering (galley) related waste comes from inflight meals, snacks and beverages served to passengers throughout the flight. This waste can also consist of leftover food, drinks and packaging which is placed back in the service trolleys, in static or compactor bins. Importantly, this waste can contain large volumes of liquid from unconsumed beverages and ice. (International Air Transport Association, 2022).

The type of meals served by an airline on its flights varies according to the duration of flight. As a result, the quantity and content of the generated waste stream is closely related to the length of the flight (Chandrappa & Das, 2012; El-Mobaidh et al., 2006).

Airline wastes can be categorized into in-flight wastes, ground activity-based wastes, industrial wastes, and hazardous wastes (Migdadi, 2020).

2.2. The Waste Management Hierarchy

The Organisation for Economic Development (2003) have noted that "waste refers to materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation, or consumption, and of which he/she wants to dispose". The waste management hierarchy ranks the various types of wastes disposal methods from the most to the least desirable (Davies, 2016; Pitt & Smith, 2003b). The waste management hierarchy therefore establishes the preferable

order in which solid waste should be managed and treated (Pires et al., 2019). The waste management hierarchy is as follows: reduce, re-use, recycle, recovery, and disposal (Figure 1) (Davies, 2016; Okan et al., 2019). For firms using the hierarchy, reducing waste should be their primary concern (Baxter et al, 2018a). In an ideal situation, waste should be avoided wherever possible. This means that in the waste management hierarchy, reducing or preventing waste should be the primary objective of the firm (Baxter & Srisaeng, 2021).

Fig.1: The Waste Management Hierarchy

The waste management hierarchy seeks to minimize the generation of wastes in the first instance. The aim of the hierarchy is for the firm to optimize the opportunities for reuse and recycling of materials, and to minimize the quantities of wastes that need to be disposed to landfill (Thomas & Hooper, 2013). According to the waste management hierarchy, re-use and recycling are the best methods of dealing with unavoidable waste (Pitt & Smith, 2003a). Re-using waste, wherever possible, is regarded as more favorable than recycling because the waste items does not require further processing prior to being used again (Güren, 2015). Reuse of wastes occurs when something that has already achieved its original function is once again used for another purpose. The recycling of wastes involves the reprocessing of used materials that would otherwise be considered as waste (Zhu et al., 2008). Recycling of wastes involves the collection, sorting, processing, and their conversion into raw materials that can be used in the production of new products (Park & Allaby 2013). Recovery relates to the recovery of energy that can be recovered from waste (Zhu et al., 2008). Wastes that are deemed as unsuitable for reuse or recycling can be incinerated to generate heat or electricity (Makarichi et al., 2018; Waters 2020; Zhu et al., 2008). Finally, disposal in landfill sites is regarded as the least desirable option in the waste management hierarchy (Manahan, 2011; Okan et al., 2019; Williams, 2013). Waste that is disposed to landfill and open dumping, is environmentally unsafe due to the emission of greenhouse gases (GHGs) that are produced from the wastes that are disposed in landfill dumps (Ahmed et al., 2020; Trabold & Nair, 2019).

2.3. The Types of Waste Disposal Methods Available to Airlines

2.3.1. Reuse of Wastes

According to the waste management hierarchy, re-use and recycling are the best methods of dealing with unavoidable waste (Baxter et al., 2018b; Pitt & Smith, 2003b). Re-using waste, wherever possible, is preferable to recycling because the waste items do not need to be processed prior to their subsequent re-use (Güren, 2015). Reuse occurs when something that has already achieved its original function is subsequently used again for another purpose (Zhu et al., 2008). Airlines could potentially reuse and repurpose materials. The reuse or repurposing of recovered materials also has the advantage of reducing the demand for new materials (International Civil Aviation Organization, 2022).

2.3.2. Recycling of Wastes.

When recycling waste, the waste fraction is utilized again to produce consumer goods or other products. Recycling produces less pollution and is viewed as being more sustainable than incineration (Morgan, 2009).

Recycling of wastes may also include the conversion of waste into energy through thermal treatment (processing) (Fulekar, 2010; Skrifvars & Åkesson, 2016). Energy recovery reduces the volume of waste that is disposed by landfill and produces useable energy, in terms of heat, electricity or fuel, through a variety of processes. These processes include combustion, gasification, pyrolysis, and anaerobic digestion (Rahman et al., 2017). In conjunction with prevention and recycling measures, waste to energy (WTE) facilities can make a significant contribution to a firm reaching the goals of waste management (Brunner & Rechberger, 2015).

2.3.3. Incineration of Wastes

Firms that utilize incineration as a waste disposal method incinerate their wastes in a dedicated incinerator. Incineration is often a waste disposal method for hazardous wastes (Santoleri et al., 2000). Incineration is the flame-initiated, high temperature, air oxidization of organic matter (David Cooper, 1999). Wastes that are being disposed by incineration need to meet certain basic criteria. This is especially so for the energy content of the

waste, which is termed the lower calorific value (LCV), must be above a minimum level. Also, the specific composition of the waste is important. In addition, to operate the incineration facility on a continuous basis, a firm's waste generation must be stable throughout the year (Rand et al., 2000).

The incineration of solid waste by a firm has two particularly desirable purposes in a waste management system. Principally, it reduces the volume of waste to be that will be needed to be disposed of by sanitary landfill (Rand et al., 2000). Secondly, incineration can also be used by a firm to produce energy (Awasthi et al., 2019; Hettiarachchi & Kshourad, 2019). Notwithstanding, there is often an environmental impact associated with incineration of wastes as during the waste incineration process, there can be substantial emissions of carbon dioxide (CO_2) emissions produced (Reinhardt et al., 2008; Tarczay et al., 2011). Furthermore, there also may be smaller amounts of methane and nitrous oxide (NO_x) emissions produced (Tarczay et al., 2011).

2.3.4. Composting of Wastes

Composting waste is a process whereby the organic portion of solid waste is converted into a humus-like product. The final product, which is inert in nature, can be utilized as a soil conditioner or for landfill cover (Harper, 2004). There are several advantages associated with the composting of rubbish: lower operational costs and composting also lessens environmental pollution. Composting also enables the beneficial use of the end products (Taiwo, 2011).

2.3.5. Wastes Disposed to Landfill

The least desirable waste disposal option is the disposal of wastes to landfill (Manahan, 2011; Muthu, 2020; Pitt & Smith, 2003a).

2.4. The 3Rs Waste Management Framework

One of the most popular approaches to waste management has been the adoption of 3Rs waste management framework, that is, reduce waste, reuse waste, and recycle waste (Manickam & Duraisamy, 2019; Pariatamby & Fauziah, 2014). The 3Rs waste management hierarchy promotes waste minimization through a reduction in the waste generated quantity, reusing post-consumer products and packages as well as recycling wastes as raw material or energy (Boonchit, 2020). In the 3Rs waste management hierarchy, reduction holds the first-place position, and this is followed by reuse, whilst the recycling is viewed as an extremely important component of a sustainable waste management system (Jadhav & Jadhav, 2020). The principal objective of the 3Rs waste management is to reduce the amount of waste that is disposed by landfill (Zhu et al., 2008). The reuse of waste by a firm means any its operations by which products or components that are not waste are used again for the same purpose for which they were first conceived (European Commission, 2019).

2.5. The Airline Waste Management Regulatory Framework

All cabin waste produced on a flight is subject to national waste management controls that limit pollution (International Air Transport Association, 2022). This is because many countries have imposed very stringent health and safety regulations in place for in-flight waste (Moynihan & Moynihan, 2019). Furthermore, many countries have gone further with their regulations, introducing restrictions on catering waste from international flights to protect their agricultural sector (in respect to animal health) (International Air Transport Association, 2022). Airline meals are also prepared using stringent hygiene and quality control standards (Jones, 2004; Sheward, 2006). The regulations often result in the incineration of all cabin waste. These wastes have limited potential for reuse and recycling by the airline (International Air Transport Association, 2022). Thus, as international flights are subject to strict Customs and biosecurity standards; these standards and regulatory requirements add a high degree of complexity as to how an international airline can handle the waste generated on their international services (Air New Zealand, 2019). In addition, governments also typically legislate the requirements for the handling of general and hazardous wastes as well (Baxter, 2020).

III. RESEARCH EMTHODOLOGY

3.1. Research Approach

This study was underpinned by an in-depth qualitative longitudinal research design (Derrington, 2019; Hassett & Paavilainen-Mäntymäki, 2013; Neale, 2018). Qualitative longitudinal research aims to expand and develop theories (Derrington, 2019). A case study enables the researcher(s) to explore complex phenomena (Remenyi et al., 2010; Taber, 2014; Yin, 2018). Case studies also enable the researcher(s) to collect rich, explanatory information that provides in-depth insights into the phenomenon under investigation (Ang, 2014).

3.2. Data Collections

The data used in the study was obtained from a range of documents, company materials available on the internet and records as sources of case evidence. Documents included the Korean Airlines annual ESG reports, and the airline's websites. An extensive search of the leading air

transport journals and magazines was also conducted in the study.

The key words used in the database searches included "Korean Air's Green Management Policy", "Korean Air's waste management framework", "Korean Air's annual wastes", "Korean Air's annual designated wastes", "Korean Air's annual incinerated wastes", "Korean Air's annual landfill disposed wastes", "Korean Air's annual recycled wastes", and "Korean Air's waste sources".

This study used secondary data. The three principles of data collection as suggested by Yin (2018) were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

3.3. Data Analysis

The data collected for the case study was examined using document analysis. Document analysis is quite commonly used in case studies. Document analysis focuses on the information and data from formal documents and a firm's records that are collected by a researcher(s) when conducting their case study (Andrew et al., 2011; Yin, 2018). The documents gathered for the study were examined according to four key criteria: authenticity, credibility, representativeness and meaning (Scott, 2014; Scott & Marshall, 2009).

The document analysis was undertaken in six distinct phases:

- Phase 1: The first phase involved planning the types of the required documentation and ascertain their availability for the study.
- Phase 2: The data collection phase involved sourcing the documents and developing and implementing a scheme for the document management. The documents were stored in a case study database.
- Phase 3: The collected documents were examined to assess their authenticity, credibility and to identify any potential bias.
- Phase 4: The content of the collected documents was carefully examined, and the key themes and issues were identified and recorded in the case study.
- Phase 5: This phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content.
- Phase 6: In this final phase the analysis of the data was completed (O'Leary, 2004, p. 179).

Following the guidance of Yin (2018), the study's documents were downloaded and stored in a case study database. All the documents gathered for the study were all written in English. Each document was carefully read, and key themes were coded and recorded in the case study research framework (Baxter, 2022).

IV. RESULTS

4.1. An Overview of Korean Air

Korean Airlines was formed in June 1962 to succeed the private enterprise Korean National Airlines. The new airline was fully owned by the government. Korean National, established in 1947, operated services on domestic routes and provided services to Hong Kong and Tokyo. Its successor, Korean Airlines, commenced domestic services in 1962. New services were launched to Osaka and Fukuoka in Japan, and the Hong Kong service was restarted in 1966. The airline received its first Boeing B747 on 1 May 1973 (Green & Swanborough, 1975). In March 1969, the government of South Korea sold its controlling interest in Korean Airlines to the Hanjin Transportation Group (Chant, 1997; Oum & Yu, 2019). Korean Air now operates to points in Australia, Canada, Europe, the Far East, the Middle East, and the USA in addition to its domestic network (Chant, 1997). Korean Air is also a major air cargo carrying airline (Hertwig & Rau, 2010).

In June 2000, Korean Air joined Aeromexico, Air France, and Delta Airlines to form the global Skyteam alliance (Kalić et al., 2022; Kiraci, 2019; Wittmer & Hinnen, 2017). In 2008, Korean Air established its low-cost carrier (LCC) subsidiary Jin Air (Holloway, 2016). On 22 February 2022, the Korea Fair Trade Commission (KFTC) announced that it decided to conditionally approve a merger deal by Korean Air Lines ('Korean Air') to purchase fellow South Korea-based Asiana Airlines ('Asiana') (Lee & Chung, 2022). Seoul's Incheon International Airport is Korean Air principal hub airport (Malaval & Bénaroya, 2002).

As previously noted, Korean Air has adopted the full-service network carrier business model. According to Ehmer et al. (2008, p. 5), a "full-service network carrier is an airline that focuses on providing a wide range of pre-flight and onboard services, including different service classes, and connecting flights". As of the end of 2020, Korean Air operated a total of 159 aircraft, which are deployed on 13 cities in Korea and 108 cities in 42 countries, which are located around the world (Korean Air, 2021b). Korean Air aircraft fleet is comprised of Boeing 787-9, Boeing 777-200, Boeing 777-300, Boeing 777-300ER aircraft. The airline's aircraft fleet also includes

Airbus A220-300, Airbus A330-200, and Airbus A330-300 aircraft. Korean Air also has a fleet of the Airbus A380 aircraft (Korean Air, 2022a). The Airbus A380 aircraft is the world's largest passenger aircraft (Dettmer, 2004; Marsh, 2016; Winterton & Turnbow, 2020).

Figure 1 presents Korean Air's annual enplaned passengers and the year-on-year change (%) for the period 2007 to 2021. One passenger enplanement measures the embarkation of a revenue passenger, whether originating, stop-over, connecting or returning (Holloway, 2016). Figure 1 shows the impact of the 2008/2009 global financial crisis on its annual passenger traffic, which decreased on a year-on-year basis in both 2008 and 2009 (Figure 1). The 2008 global financial crisis (GFC) adversely impacted air travel demand (Pearce, 2012; Piccioni et al, 2022; Wong et al., 2019). Air travel demand started to recover in mid-2009 (Yu, 2020), and Korean Air returned to positive growth in 2010, when its annual passenger traffic increased by 9.91% on the 2009 levels (Figure 1). Korean Air's annual passenger traffic decreased slightly in 2013 (-3.62%), 2014 (-0.55%), and 2017 (-0.29%), respectively, reflecting slightly lower levels of demand for its services in these respective years (Figure 1). Figure 1 shows that Korean Air was able to increase its passenger traffic in 2015 (+6.83%), and 2016 (+7.96%). Figure 1 shows, however, that there was a very steep decline in the airlines' enplaned passengers in 2020 (-72.57%). In 2020, Korean Air's annual passenger traffic was adversely impacted by the global COVID-19 pandemic. In 2020, the COVID-19 pandemic caused a decline in economic activity around the world (Dube et al., 2021), and the COVID-19 pandemic severely impacted the global economy (Crotti, et al., 2022). This decline in economic activity caused a severe disruption in the air travel market supply and demand chain (Dube et al., 2021). Air transportation was one of the sectors most adversely impacted by the corona-virus pandemic (Barczak et al., 2022; Karakuş et al., 2021; Remencová & Sedláčková, 2022; Sun et al., 2022). In addition, due to the global coronavirus crisis, most countries placed restrictive measures to confine the pandemia (Maria Iacus et al., 2020). Furthermore, the COVID-19 pandemic outbreaks led to many countries imposing travel restrictions (Akkucuk, 2020; Fabeil et al., 2020; Mat Dawi et al., 2021). The Korean government introduced border controls in 2020 in response to the COVID-19 pandemic (Kang et al., 2020). Figure 1 also shows that Korean Air's annual passenger traffic continued to be impacted by the COVID-19 pandemic and the related pandemic response measures in 2021, at which time the airline's annual passenger traffic decreased by 24.0% on the 2020 levels. The COVID-19 pandemic continued to have an impact on air travel demand in 2021 (Airports Council International, 2022).

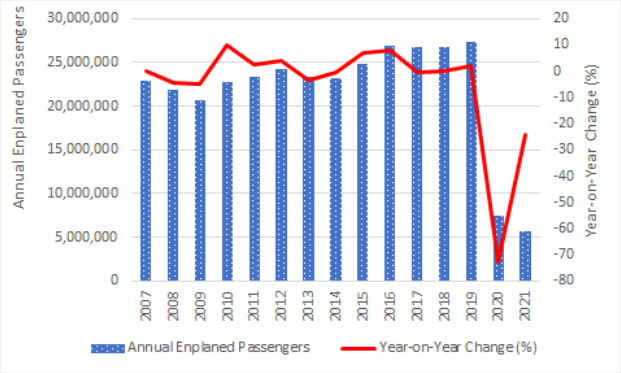

Fig. 2: Korean Airlines annual enplaned passengers and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2017, 2021b)

4.2. Korean Air Green Management Policy

Korean Air is concerned about the sustainable future of the earth and the company respects the universal values as a member of the global community. Korean Air declares that the following "Green" Management Principles will fulfill the company's social responsibilities as a leading global airline. In line with these principles, Korea Air will:

1. Improve flight procedures and introduce new aircraft to reduce noise and greenhouse gases (GHGs).
2. The company will abide by national and international environment laws and all regulations and will apply stricter internal standards.
3. The company will minimize environmental load through proactive measures and improvements in its performance.
4. The company will seek to make constant improvements in its performance to conserve resources and energy and will management them efficiently.
5. Carry out training and provide education so that the company's staff and employees clearly acknowledge environmental goals and actively join the environment protection effort.
6. The company will promote mutual cooperation with partner firms to execute green management through communication on environmental issues.
7. The company will openly share all of its green management efforts and the results to the public.

8. The company will endeavor to protect the natural environment and contribute to the development of local community through international cooperation (Korean Air, 2021a).

Korean Air has also implemented a certified ISO 14001 Environmental Management System (Korean Airlines, 2022b). ISO 14001 is a worldwide meta-standard for the implementation of an Environmental Management Systems (EMS) by an organization or business (Dentch, 2016; Grover & Grover, 2017; Heras-Saizarbitoria et al., 2011).

Korean Air has also adopted the United Nation Development Goals 3, 4, 5, 6, 8, 9,11, 13, 15 and 17 (Korean Air, 2019). In 2015, all United Nations Member States adopted the "2030 Agenda for Sustainable Development" and its seventeen 17 Sustainable Development Goals (SDGs). Each SDG comprises a range of targets to be achieved by 2030 (Katila et al., 2019; Saner et al., 2021; Vij & Singh, 2020).

In 2019, recognizing the environmental pollution caused by single use plastic waste, Korean Air banned the use of single use plastic cups, straws, and plastic muddlers for in-flight services and, as a result, substituted paper cups and straws that are made of environmentally certified paper (Korean Air, 2021b).

4.3. Korean Air 3Rs Waste Management Policy

Korean Air has adopted the use of the 3Rs waste management framework as part of its goal to mitigate the impact that its wastes have upon the environment.

Korean Air has made a variety of efforts to reduce the amount of cabin waste produced on its flights. In light of this goal to reduce wastes, Korean Air has changed the design of plastic cup lids and lids covering in-flight meals to reduce the amount of single-use plastics that will most probably become waste. In addition, the airline has modified the sizing and specification of disposable hand towels placed in restrooms. As a result, Korean Air has achieved the same effect as reducing pulp usage by approximately 104 tons per year. Due to COVID-19 preventive measures, Korean Air still needs to use disposable products, however, the airline plans to gradually replace the items currently used inside its aircraft with more eco-friendly (biodegradable plastics, paper products, and so forth) products in order to reduce the amount of cabin waste from its flights (Korean Air, 2022c).

Korean Air has reduced the use of disposable products and now uses items that can be reused. This measure assists the airline to reduce the amount of waste generated. As part of its waste management policy, Korean Air disinfects and washes the reusable passenger seat covers when cleaning the interior of its aircraft. Furthermore, eco-friendly headrest covers are presently only used on domestic flights and small-sized aircraft, but the airline plans to use them on its international services after diversifying the type of materials used (Korean Air, 2022c).

Korean Air has implemented new methods to increase the recycling rate of its aircraft cabin waste. To help achieve this, Korean Air has held campaigns and training sessions to improve its cabin crew's awareness on recycling. Korean Air aims to recycle and separately collect each type of waste. In addition, the airline has also recently designed recycling bags that will be used for the separate collection of trash. These recycling bags are anticipated to contribute to an increased recycling rate of aircraft cabin waste (Korean Air, 2022c).

It is important to note that various functions are performed during the time that that an aircraft spends on the ground in between flights (Ashford et al., 2013; Kazda & Caves, 2015; Thompson, 2007). As part of its goal to mitigate the impact of its operations on the environment, Korean Air aims to minimize the impact that its aircraft ground handling operations has on the environment. Korean Air has replaced the plastic wraps used to prevent the luggage and air cargo consignments from getting damaged with an eco-friendly renewable vinyl. Up to 50% of the materials used to make the renewable vinyl are reused, including waste vinyl. Koren Air has been able to replace the 350 tons of vinyl used annually for its operations with the more environmentally friendly vinyl (Korean Air, 2022c).

4.4. Korean Air Waste Sources

Korean Air wastes are produced from the airlines passenger services (flights), air cargo services, maintenance of ground service equipment (GSE), in-flight meal production, and from their aircraft maintenance (Korean Air, 2009). Korean Air's onboard aircraft wastes include waste from the aircraft cabin services, for example, newspapers, magazines, and plastic bottles. These wastes are separated and recycled. The airline's catering waste is the leftover waste from its in-flight services (these wastes are incinerated). General waste is comprised wastes from offices and airport operations, these wastes are sorted and recycled. Korean Air also has industrial wastes which include oil and fuel waste from aircraft maintenance works (these wastes are subject to commissioned treatment) (Korean Air, 2007). Wastes generated by Korean Air can be broadly split into domestic waste generated from transportation services and designated waste generated from aircraft maintenance. All food waste originating from the airline's in-flight service is incinerated in accordance with the regulations prescribed by the Animal and Plant

Quarantine Agency (Korean Air, 2021b). The in-flight food waste is disinfected prior to its incineration Designated or hazardous wastes produced by Korean Air, include waste oil, waste paint, and waste organic solvents. These wastes are produced during the aircraft maintenance and manufacturing processes (Korean Air, 2020).

4.5. Korean Air Total Annual Wastes

Korean Air's total annual wastes and the associated year-on-year change for the period 2007 to 2021 is presented in Figure 3. As can be observed in Figure 3, there are three discernible trends with the airline's annual wastes during the study period. There was a general downward trend in this metric in the early years of the study, that is, from 2007 to 2009. Korean Air's annual wastes decreased by 4.46% in 2009, and by 6.01% in 2009. As noted previously, the airline's operations and its passenger traffic were adversely impacted by the global financial crisis (GFC) in both 2008 and 2009, and this had a concomitant impact on the airline's annual wastes in both these years. Figure 3 shows that there was a general upward trend in the airline's annual wastes from 2010 to 2018. This general upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, all the values are above the line. Figure 3 shows that there was a spike in this metric in 2010, when the airline's annual wastes increased by 9.04% on the 2009 levels. This increase in wastes was in line with the airline's passenger growth rate in 2010, at which time it increased its passenger traffic by 9.91%. Figure 3 shows that there was a further spike in the airline's annual wastes in 2016, at which time they increased by 5.60% on the 2015 levels. In 2016, Korean Air's passenger traffic increased by 7.96%, and this increase in passenger traffic could have influenced the amount of additional waste handled by the airline in 2016. Figure 3 shows that there was a small annual decrease in the airline's wastes in 2019, at which time they decreased by 0.23% on the 2018 levels. This was a favorable outcome as Korean Air was able to accommodate additional passenger traffic, whilst at the same time reducing the quantity of its wastes. There was a very significant annual decrease in Korean Air's annual wastes in 2020, at which time they decreased by 58.53% on the 2019 levels (Figure 3). This significant decrease could be attributed to the very significant decrease in passengers and flights because of the COVID-19 pandemic in 2020. Figure 3 shows that there was a further very significant decrease in the airline's wastes in 2021, at which time they decreased by 45.22% on the 2021 levels. As previously noted, Korean Air's annual passenger traffic and its flight operation were still impacted by the COVID-19 pandemic in 2021, and this led to the sharp drop in its annual wastes in 2021.

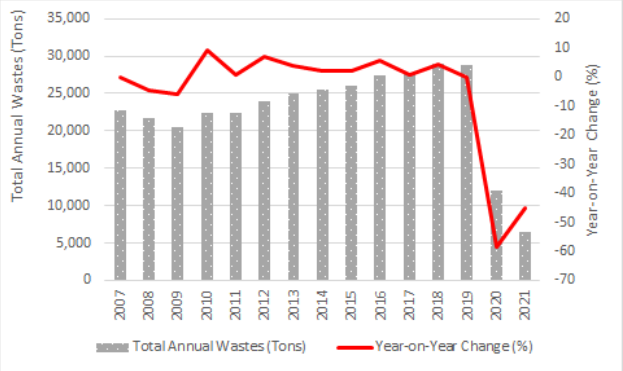

Fig. 3: Korean Airlines total annual wastes (all sources) and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

4.6. Korean Air Annual Designated Wastes

In South Korea, hazardous waste is always defined as designated wastes, and such wastes are controlled under the *Solid Waste Management Act* (Jian, 2012). According to El-Din M. Saleh (2016, p. 4), "hazardous wastes are classified as hazardous if they exhibit one or more of ignitability, corrosivity, reactivity, or toxicity". At an airport, hazardous wastes are produced from aircraft refueling, aircraft operations, aircraft, and ground service equipment (GSE) maintenance and equipment and facilities cleaning. Major aircraft overhauls also use toxic chemicals to remove paint, and these wastes pose an environmental threat (Culberson, 2011). Other contaminants that are produced at an airport's operations or activities include detergent formulations, solids, oils, greases, residues, solvent residues, and heavy metals (Grantham, 1996). As noted earlier, designated wastes produced by Korean Air, include waste oil, waste paint, and waste organic solvents. These wastes are produced during the aircraft maintenance and manufacturing processes (Korean Air, 2020).

Korean Air's annual designated wastes and the year-on-year change (%) for the period 2014 to 2021 is depicted in Figure 4. Figure 4 shows that there were two discernible trends in this metric during the study period. From 2014 to 2018, there was a general upwards trend. This upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, all the values are above the line. During this period, there were two quite significant annual increases in Korean Air's annual designated wastes. These increases were recorded in 2015 (+28.07%), and 2018 (+21.07%), respectively (Figure 4). These increases could be attributed to a higher level of maintenance activities performed by the airline in both 2015 and 2018, respectively. Figure 4

shows that there were two significant annual decreases in this metric during the latter years of the study, that is, 2018 to 2021. These annual decreases were recorded in 2018 (-18.21%), and 2021 (-45.39%), respectively (Figure 4). These decreases are favorable for Korean Air, as they help to mitigate the possible environmental impact associated with the disposal of hazardous materials. In 2020, the airline's annual designated wastes increased by 28.96% on the 2019 levels, reflecting the greater use of hazardous chemicals in its maintenance activities in 2020 (Figure 4). In 2021, the airline's annual designated wastes decreased by 45.39% on the 2020 levels (Figure 4). This decrease could be attributed to a lower requirement for hazardous materials by the airline in 2021.

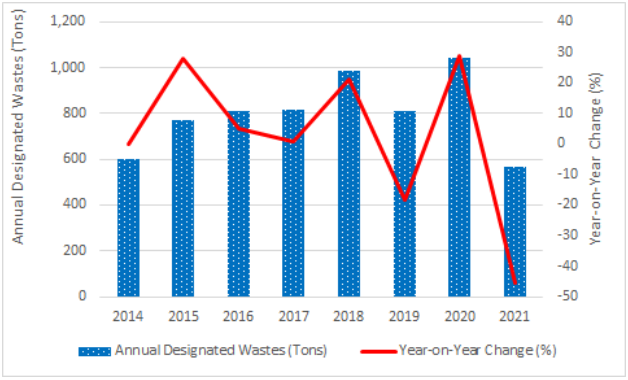

Fig. 4: Korean Airlines total annual designated wastes and year-on-year change (%): 2014-2021

Note: Data prior to 2014 is not available

Source: Data derived from Korean Air (2014, 2017,2021, 2022c)

4.7. Korean Air Annual General Wastes

Korean Air's annual general wastes and the year-on-year change (%) for the period 2014 to 2021 is depicted in Figure 5. Figure 5 shows that Korean Air's annual general wastes displayed a general upward trend from 2014 to 2019, when they increased from 23,825 tons in 2014 to a high of 28,013 tons in 2010. Once again, this general upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, all bar one value is above the line. During this period, the most significant annual increase in the airline's general wastes occurred in 2016 (+6.34%) (Figure 5). In 2016, Korean Air's annual passenger traffic increased by 7.96%, and this had an impact on the airline's general wastes in 2016 (Figure 5). This was because there were higher amounts of wastes generated due to the increase in passenger traffic and flights operated. There was a slightly smaller annual increase in the airline's general wastes in 2018, at which time they increased by 3.91% on the 2017 levels (Figure 5). This increase could be attributed to the slightly higher levels of passenger traffic in 2018, as well as slightly different waste patterns in 2018. During the study period, there were three years where Korean Air's annual general wastes decreased on a year-on-year basis. These annual decreases were recorded in 2017 (-4.09%), 2020 (-61.05%), and 2021 (-45.21%), respectively (Figure 5). In 2017, Korean Air's annual passenger traffic decreased by 0.29%, and this could have led to smaller volumes of general wastes. The decrease of 4.09% was a favorable outcome for the airline as it was able to reduce its annual general wastes at a higher rate than the reduction in passenger traffic. The annual decreases in the airline's general wastes in both 2020 and 2021, reflect the lower levels of passenger traffic and services because of the COVID-19 pandemic. In 2020, the airline's passenger traffic decreased by 72.57%, and this contributed to the lower volumes of general wastes in that year. In 2021, the airline's passenger traffic decreased by 24.0%, and this also led to the lower volumes of general wastes in 2021. In 2021, the airline was able to reduce its annual general wastes at a substantially higher rate than the decrease in passenger traffic, which was a very favorable outcome as it enabled the airline to help mitigate the possible impact that wastes could have upon the environment.

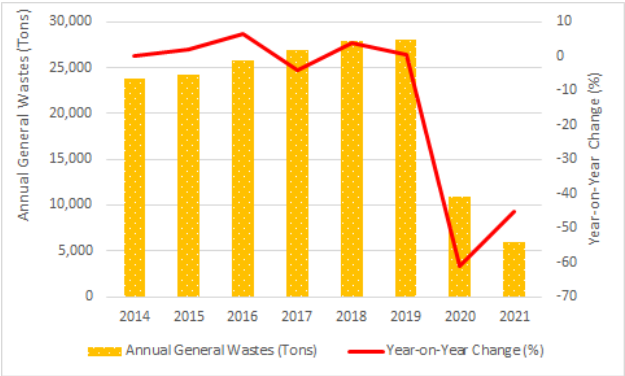

Fig. 5: Korean Airlines total annual general wastes and year-on-year change (%): 2014-2021

Note: Data prior to 2014 is not available

Source: Data derived from Korean Air (2014, 2017,2021, 2022c)

4.8. Korean Air Annual Incinerated Wastes

Korean Air's annual incinerated wastes and the associated year-on-year change (%) for the period 2007 to 2021 is presented in Figure 6. As can be observed in Figure 6, there was a general upward trend in the airline's annual incinerated wastes during the period 2007 to 2018. Figure 6 shows that the airline's annual incinerated wastes increased from 11,060 tons in 2007 to a high of 18,429 tons in 2019. This general upward trend can therefore be

demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, all bar one value is above the line. Figure 6 shows that the three most significant annual increases in this metric, occurred in 2012 (+9.19%), 2016 (+9.73%), and 2018 (+7.93%), respectively. The reason for these annual increases in the incineration of wastes can be attributed to the growth in the airline's annual passenger traffic, as all cabin wastes are required to be incinerated. Also, in 2012, 2016, and 2019, the airline's incinerated wastes increased at a higher rate than its passenger growth, so this suggests that the airline also handled wastes that were deemed appropriate for incineration in these respective years. Figure 6 shows that in the latter years of the study period, that is, from 2019 to 2021, Korean Air's annual incinerated wastes decreased on a year-on-year basis. The two most significant annual decreases in this metric were recorded in 2020 (-71.82%), and 2021 (-61.54%), respectively (Figure 6). The annual decrease in 2020 was almost in-line with the decrease in passenger traffic, which declined by 72.57% on the 2019 levels. In 2021, the airline's passenger traffic decreased by 24.0%, which meant that there were lower volumes of aircraft cabin waste that requited disposal by incineration. Also, in 2021, Korean Air increased its use of incineration as the types of wastes handled were deemed to be appropriate for incineration. The incineration of wastes is an important part of Korean Air's waste management. Importantly, incineration offers many advantages for an organization, such as, an airline, and these include waste volume reduction, detoxification, regulatory compliance, environmental impact mitigation, particularly for organic materials that would leach from landfills and would emit odors, and energy recovery (Santoleri et al., 2000). Other advantages of waste incineration are there is little risk of groundwater contamination, which is a disadvantage of landfill wastes, and the residue ash from incineration takes up less space when it is disposed to landfill, this is because the incineration (burning) process greatly reduces the volumes of many wastes (Travis & Crystal Cook, 1989). Furthermore, bottom ash and Air Pollution Control (APC) residues are new sources of secondary metals (Brunner & Rechberger, 2015).

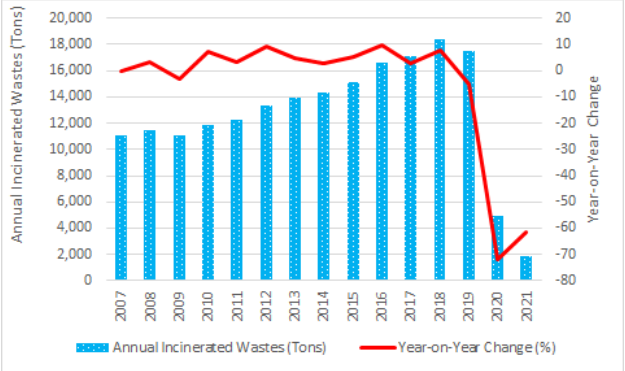

Fig. 6: Korean Airlines annual incinerated wastes and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

An important waste management efficiency measure used in the airport industry is the proportion of wastes that are incinerated (Baxter et al., 2018a). This metric can be very usefully applied in the airline industry. Korean Airlines annual incinerated wastes as a share of total annual wastes and year-on-year change (%) for the period 2007 to 2021 is depicted in Figure 7. Figure 7 shows that Korean Airlines annual incinerated wastes as a share of total annual wastes has oscillated throughout the study period. The most significant increase in this metric was recorded in 2008, at which time it increased by 8.09% on the 2007 levels. In 2008, Korean Air's annual landfill disposed wastes and its recycled wastes decreased on a year-on-year basis, whilst in contrast the airline's incinerated wastes increased by 3.28%. As a result of these factors, Korean Air's annual incinerated wastes increased as a share of its total annual wastes in 2008. The second most significant annual increase in this metric occurred in 2016, when it increased by 3.90% on the 2015 levels. In 2016, incinerated wastes increased at a higher rate than the airline's recycled wastes, whilst landfill disposed wastes decreased on a year-on-year basis in 2016. Consequently, the airline's incinerated wastes accounted for a higher share of total wastes in 2016. Figure 7 also shows that during the study period, there were four years where this metric decreased on an annualized basis. These annual decreases occurred in 2010 (-1.72%), 2019 (-5.09%), 2020 (-32.07%), and 2021 (-29.79%), respectively (Figure 7). In 2010, the airline's annual incinerated and landfill disposed wastes declined, whilst in contrast its recycled wastes increased on a year-on-year basis. Consequently, the airline's annual incinerated wastes declined as a share of its total annual wastes in 2010. A similar situation occurred in 2019 when the airline's recycled wastes increased, yet at the same time both its incinerated and landfill wastes decreased on a year-on-year basis. So, once again, the airline's annual incinerated wastes declined as a

share of its total annual wastes in 2019. In both 2021, and 2021, Korean Air's recycled wastes decreased at a lower rate than that of its incinerated and landfill disposed wastes, and this resulted in incinerated wastes accounting for a lower share of the airline's total annual wastes in both 2020 and 2021.

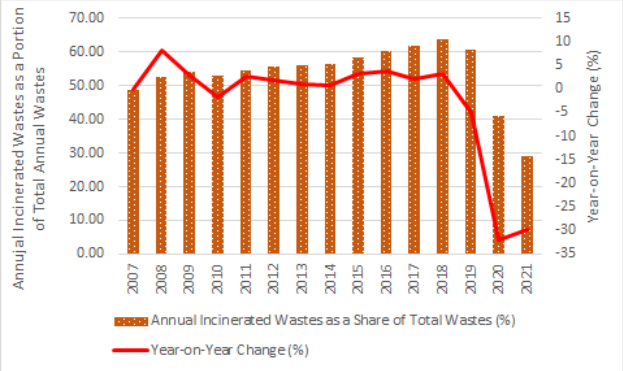

Fig. 7: Korean Airlines annual incinerated wastes as a share of total annual wastes and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

4.9. Korean Air Annual Landfill Disposed Wastes

Korean Airlines annual wastes disposed to landfill and the year-on-year change (%) for the period 2007 to 2021 is depicted in Figure 8. As can be observed in Figure 8, Korean Airlines annual landfill disposed wastes have exhibited an overall downward trend, decreasing from a high of 1,305 tons in 2007 to a low of 11 tons in 2021 (Figure 8). This general downward trend is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. Figure 8 shows that there was a significant annual increase in the airline's landfill disposed wastes in 2017, at which time they increased by 35.58% on the 2016 levels. This increase could be attributed to some of the types of wastes that were produced by Korean Air in 2017 were not suitable for either recycling or incineration, and hence, there was an increased requirement to dispose of such wastes to landfill. Figure 8 also shows that there was a further spike in the airline's landfill disposed wastes in 2012, when they increased by 16.80% on the 2011 levels. Once again, this increase could be attributed to some of the types of wastes produced in 2012 not being suitable for either recycling or incineration. Figure 8 also reveals that there were eight years during the study period where Korean Air was able to significantly reduce its annual landfill disposed wastes. These annual decreases were recorded in 2009 (-26.75%), 2010 (-19.04%), 2013 (-26.23%), 2015 (-23.67%), 2016 (-31.22%), 2019 (-65.56%), 2020 (-70.05%), and 2021 (-78.0%), respectively (Figure 8). The annual decreases in this metric in 2009 and 2010 could be attributed to the declines in the airline's passenger traffic and services due to the global financial crisis (GFC). In 2013, Korean Air was able to increase its recycling and incineration of its wastes whilst also decreasing the requirement to dispose wastes to landfill. In 2015, there were differing patterns in Korean Air's wastes with both landfill and recycled wastes declining, whilst in contrast, the airline was able to incinerate more wastes in 2015. In 2016, Korean Air was once again able to increase the recycling and incineration of its wastes whilst also decreasing the requirement to dispose its wastes to landfill. In 2019, there were once again differing patterns in Korean Air's wastes with both landfill and incinerated wastes declining, whilst in contrast, the airline was able to recycle more wastes in 2019. As previously noted, Korean Air, like other airlines, was severely impacted by the COVID-19 pandemic and the related pandemic response measures, and this had a concomitant impact on its annual landfill disposed wastes in 2020 and 2021. This was because the scale of the airline's operations and its passenger traffic were considerably lower because of the COVID-19 pandemic. Figure 8 also shows that Korean Air's landfill wastes account for the smallest share of its overall wastes. As noted earlier, the disposal of wastes to landfill is regarded as the least preferable method of waste disposal. Wastes that are disposed by landfilling and open dumping is regarded as being environmentally unsafe. This is because of the emission of greenhouse gases (GHGs) produced from the disposed wastes (Ahmed et al., 2020; Trabold & Nair, 2019). Thus, the strategy of Korean Air to minimize its landfill disposed wastes helps the airline to mitigate its environmental footprint.

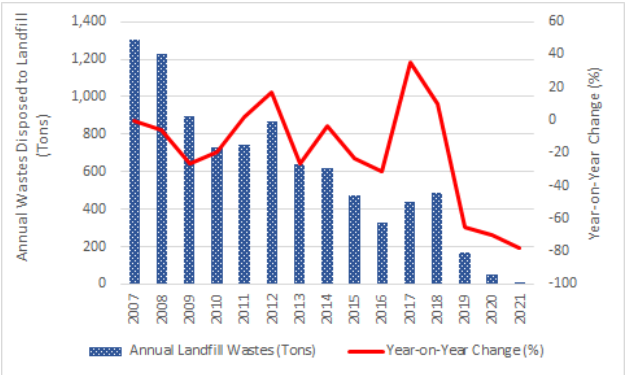

Fig. 8: Korean Airlines annual wastes disposed to landfill and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

Another important waste management efficiency measure used in the airport industry is the proportion of wastes

disposed to landfill (Baxter et al., 2018a; Graham, 2005). Once again, this metric can be very usefully applied in the context of the airline industry. Korean Airlines annual landfill disposed wastes as a share of total annual wastes and year-on-year change (%) from 2007 to 2021 is presented in Figure 9. Figure 9 shows that Korean Airlines annual landfill disposed wastes as a share of total annual wastes has largely displayed an overall downward trend throughout the study period. Figure 9 shows that Korean Airlines annual landfill disposed wastes as a share of total annual wastes declined from a high of 5.73% in 2007 to a low of 0.17% in 2021 This general downward trend can also be demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. Figure 9 shows that there were seven years during the study period, where this metric decreased very significantly on an annualized basis. In 2009, Korean Air's annual landfill disposed wastes as a share of total wastes decreased by 22.02% on the 2008 levels (Figure 9). In 2009, the airline's landfill disposed wastes decreased on a year-on-year basis, whilst its incinerated and recycled increased in the same year. Thus, as a result, Korean Air's landfill wastes accounted for a lower share of its total wastes in 2009. The same situation occurred in 2010, when once again Korean Air's landfill disposed wastes as a share of total wastes declined by 25.74%, whilst its recycled and incinerated wastes both increased as a share of the airline's annual wastes in 2010 (Figure 9). In 2015, Korean Air's annual landfill disposed wastes as a share of total wastes decreased by 25.40% on the 2014 levels (Figure 9). The reason for this decrease in this metric in 2015 was due to the higher incinerated waste volumes, the slightly lower recycled wastes, and the significant decrease in landfill wastes in 2015. Because of the variations in the Korean Air's annual wastes in 2015, its landfill disposed wastes accounted for a smaller share of its total wastes. The most significant annual decrease in Korean Air's annual landfill disposed wastes as a share of total wastes occurred in 2019, when this metric decreased by 65.47% on the 2018 levels (Figure 9). In 2019, Korean Air's annual landfill wastes decreased as did its incinerated wastes. In contrast, the airline's recycled wastes increased in 2019. Consequently, in 2019, Korean Air's landfill disposed wastes accounted for a smaller share of the airline's total annual wastes. This large decrease in this metric in 2019, was followed by a further two annual decreases in this metric in both 2020 and 2021. In 2020, Korean Air's landfill disposed wastes as a share of total wastes declined by 27.58% on the 2019 levels (Figure 9). In 2020, the airline's landfill disposed wastes decreased at a higher rate than its incinerated and recycled wastes, and this led to the annual decrease in this metric in 2020. The same situation applied in 2021, when Korean Air's annual landfill wastes as a share of total wastes decreased by 59.52% (Figure 9). In 2021, the airline's landfill disposed wastes decreased at a higher rate than its incinerated and recycled wastes, and this led to the annual decrease in this metric in 2021.

Figure 9 shows that there was a significant spike in this metric in 2017, at which time it increased by 34.45% on the 2016 levels. As previously noted, Korean Air's annual landfill disposed wastes grew at a higher rate than its incinerated wastes in 2017, whilst its recycled wastes decreased on an annualized basis in the same year. As a result, the airline's landfill disposed wastes accounted for a higher share of its total annual wastes in 2017. Figure 9 also shows that there was another annual spike in this metric in 2012, at which time it increased by 9.36% on the 2011 levels. In 2012, the airline's annual landfill disposed wastes grew at a higher rate than its incinerated and recycled wastes, and, as a result, the airline's landfill wastes accounted for a higher share of its total annual wastes in 2012.

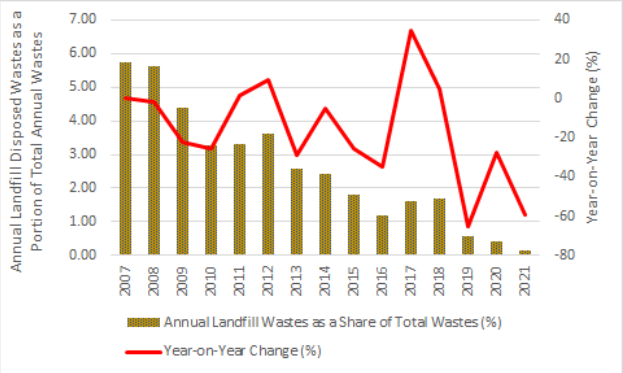

Fig. 9: Korean Airlines annual landfill disposed wastes as a share of total annual wastes and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007- 2014, 2017, 2021, 2022c)

4.10. Korean Air Annual Recycled Wastes

Prior to examining Korean Air's annual recycled wastes, it is important to note that re-use and recycling are two of the key elements in the airline's waste management policy. Paper, wood, cans, and PET bottles are separated and recycled by the airline (Korean Air, 2021b). Korean Air is also recycling plastic waste instead of disposing of it by landfill or incineration. The plastic waste generated in the aircraft cabin service is used as solid fuel through a sorting process, or as a pellet material for construction (Korean Air, 2020). Korean Airlines annual recycled wastes and year-on-year change (%) for the period 2007 to 2021 are depicted in Figure 10. Figure 10 shows that there were

three discernible trends in Korean Air's annual recycled wastes. During the early years of the study, that is, 2007 to 2009, there was a downward trend in Korean Air's annual recycled wastes. In 2008, the airline's annual recycled waste decreased by 12.58% on the 2007 levels (Figure 10). A similar situation occurred in 2009, when the airline's annual recycled wastes declined by 6.56% on the 2008 levels. As noted earlier, Korean Air's annual passenger traffic and its level of operations was adversely impacted by the 2008/2009 global financial crisis, and this led to a reduction in its wastes, including its recycled wastes in both 2008 and 2009. Figure 10 shows that there was an overall upward trend in Korean Air's annual recycled wastes from 2010 to 2019. This overall upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. Figure 10 shows that there was a pronounced spike in the airline's annual recycled wastes in 2010, at which time they increased by 14.43% on the 2009 levels. In 2010, a higher share of Korean Air's wastes was suitable for recycling, and this enabled the airline to manage these wastes through their recycling system. A similar situation occurred in 2019, when the airline's recycled wastes increased by 12.36% (Figure 10). Like in 2010, Korean Air was able to increase its recycling of wastes in 2019, which was a favorable outcome for the airline. During the period 2010 to 2019, the most significant annual decrease in Korean Air's annual recycled wastes, was recorded in 2017, at which time they decreased by 3.81% on the 2016 levels (Figure 10). In 2017, the types of wastes generated by Korean Air were more suitable for incineration (+2.85%) and disposal to landfill (+35.58%) and these waste characteristics led to the slight decrease in recycled wastes in 2017. Figure 10 shows that there were very significant decreases in Korean Air's annual recycled wastes in both 2020 and 2021. In 2020, Korean Air's annual recycled wastes decreased by 37.64% on the 2019 levels. This decrease could be attributed to the impact of the COVID-19 pandemic and the related pandemic response measures had on Korean Air's passenger traffic and operations. Because of the lower levels of passenger demand and flight operations, Korean Air was able to reduce its wastes in 2020. In 2021, Korean Air's annual recycled wastes decreased by 33.51% on the 2020 levels (Figure 10). Korean Air was still affected by the ongoing COVID-19 pandemic in 2021, and once again, this resulted in the airline producing smaller amounts of recycled wastes in 2021.

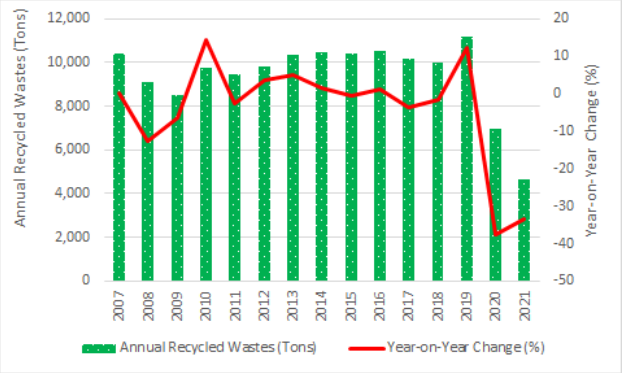

Fig. 10: Korean Airlines annual recycled wastes and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

Another important waste management efficiency measure used in the airport industry is the proportion of wastes that are recycled (Baxter et al., 2018a; Graham, 2005). Once again, this metric can be very usefully applied in assessing the waste management efficiency of an airline. Korean Airlines annual recycled wastes as a share of the airline's total annual wastes and the year-on-year change (%) for the period 2007 to 2021 is presented in Figure 11. Figure 11 shows that there was a slight overall downward in this metric during the period 2007 to 2018. The two most significant annual decreases in this metric were recorded in 2008 (-8.39%), and 2018 (-5.88%) (Figure 11). In 2008, Korean Air's annual recycled wastes decreased on a year-on-year basis, whilst its incinerated wastes increased in the same year. Also, in 2008, landfill wastes also decreased, but at a lower rate than those of the airline's recycled wastes. As a result of these variations in Korean Air's waste mix in 2008, recycled wastes accounted for a smaller share of the airline's total annual wastes. In 2018, Korean Air's annual recycled wastes declined on a year-on-year basis, whilst at the same time, the airline's incinerated and landfill disposed wastes increased, and this resulted in its recycled wastes accounting for a smaller share of its total annual wastes in 2018. Figure 11 shows that there were five years in the study period where Korean Air's annual recycled wastes as a share of its total wastes increased on an annualized basis. These annual increases occurred in 2010 (+4.94%), 2013 (+1.17%), 2019 (+12.59%), 2020 (+50.38%), and 2021 (+21.36%), respectively (Figure 11). In 2010, Korean Air's annual recycled wastes grew at a higher rate than its incinerated wastes whilst its landfill wastes declined by 19.04%. As a result of these factors, the airline was able to increase its recycled wastes as a share of its total annual wastes. The same situation applied in 2013, when the airline's recycled

wastes increased at a slightly higher rate than its incinerated wastes and, in the same year, its landfill wastes declined on a year-on-year basis. Consequently, the airline was able to increase its recycled wastes once again as a share of its total annual wastes. In 2019, Korean Air increased its recycled wastes and at the same time it decreased the quantity of wastes that were to be disposed through either incineration or by landfill. This variation in the waste mix enabled Korean Air to increase its recycled wastes once again as a share of its total annual wastes in 2019. As previously noted, Korean Air's annual wastes declined in both 2020 and 2021 due to the impact of the COVID-19 pandemic. In both 2020 and 2021, the airline's annual recycled wastes decreased at a lower rate than its incinerated and landfill wastes, and this led to recycled wastes accounting for a higher share of its total annual wastes in both 2020 and 2021.

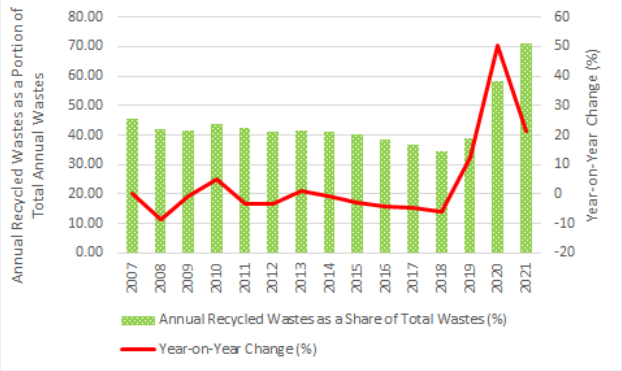

Fig. 11: Korean Airlines annual recycled wastes as a share of total annual wastes and year-on-year change (%): 2007-2021

Source: Data derived from Korean Air (2007-2014, 2017, 2021, 2022c)

V. CONCLUSION

This study has examined how Korean Air, a major global full-service network airline, sustainably manages its wastes. The study was underpinned by an in-depth longitudinal research design. The data collected for the study was examined by document analysis. The study period was from 2007 to 2021.

Korean Air has defined and implemented a comprehensive "green" management policy that underpins it goal of managing its operations and activities in an environmentally sustainable manner. The case study revealed that Korean Air has adopted the use of the 3Rs Waste Management Framework, and, as a result, the airline aims to reduce its wastes in the first instance. A key waste management strategy of the airline is to re-use wastes wherever this practicable. Wastes that are not suitable for re-use are recycled wherever the waste characteristics make this possible. Korean Air's aircraft cabin wastes are disinfected and subsequently incinerated in accordance with the appropriate regulatory framework. The final waste management method is the disposal of wastes that are unsuitable for re-use, recycling, or incineration to landfill.

The case study revealed that Korean Air's wastes are heterogenous in nature. Korean Air wastes are produced from the airlines passenger services (flights), air cargo services, maintenance of ground service equipment (GSE), in-flight meal production, and from their aircraft maintenance. Korean Air's onboard aircraft wastes include waste from the aircraft cabin services, for example, newspapers, magazines, and plastic bottles. General waste is comprised of wastes from offices and airport operations, these wastes are sorted and recycled. Korean Air also has industrial wastes which include oil and fuel waste from aircraft maintenance works. Wastes generated by Korean Air can be broadly split into domestic waste generated from transportation services and designated waste generated from aircraft maintenance. The in-flight food waste is disinfected prior to its incineration Designated or hazardous wastes produced by Korean Air, include waste oil, waste paint, and waste organic solvents. These wastes are produced during the aircraft maintenance and manufacturing processes.

The case study highlighted the importance that Korean Air places on the recycling of wastes. The case study found that there was an overall upward trend in Korean Air's annual recycled wastes from 2010 to 2019. During 2020 and 2021, Korean Air, like other airlines, was adversely impacted by the COVID-19 pandemic and the related pandemic response measures. The reduction in passenger traffic and flight operations resulted in reduced waste volumes. However, in both 2020 and 2021, the airline's recycled wastes decreased on an annualized basis at a lower rate than its incineration and its landfill disposed wastes, reflecting the importance that Korean Air places on recycling wastes.

Korean Air's annual passenger traffic grew from 22,850,000 passengers in 2007 to 27,351,000 passengers in 2019. In 2021, the airline carried 5,700,000 passengers. Like other airlines, Korean Air, was adversely impacted by the COVID-19 pandemic which has had a very adverse impact on airline passenger demand. The case study found that there were three discernible trends with the airline's annual wastes during the study period. There was a general downward trend in the airline's annual wastes in the early years of the study, that is, 2007 to 2009. This downward trend was followed by a general upward trend in the airline's annual wastes from 2010 to 2018. The case study also revealed that there were very significant annual

decreases in Korean Air's annual wastes in both 2020 and 2021. These significant decreases in the airline's wastes in 2020 and 2021 could be attributed to the very significant decrease in passenger traffic and the airline's flight operations because of the COVID-19 pandemic in both 2020 and 2021.

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Wild mushrooms in the hillside of Landour, Mussoorie

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***Abstract*—** *Landour is located at an altitude of about 6,800 to 7,798 ft in the Lower Western Himalaya, in the Mussoorie Range. Along the hillside of Landour one of the oldest residential schools in Asia, Woodstock School is situated. It encompasses a considerable forested area, which is mostly monoculture of Banj Oak (Quercus leucotrichophora) with intermittent Deodars, Pines and Rhododendrons. The climatic condition, forest type and soil in the hillside are congenial for growth and development of different species of mushrooms. A variety of mushrooms belong to edible, poisonous and medicinal species can be seen during rainy season. In the present study, six different mushroom species were collected during rainy season (July to September, 2022). Amongst the six species, five species were mycorrhizal, four species were edible, three species were medicinal and two species were non edible, while one species was poisonous. This study unravelled the abundance of the mushrooms in the campus.*

***Keywords*— mushroom, Landour, Uttarakhand.**

I. INTRODUCTION

Mushrooms are an important part of the ecosystem and over million species have been identified throughout the world till date. Fungi belonging to various taxonomic groups producing conspicuous sporocarps are collectively known as macro fungi which include “gilled fungi,” “jelly fungi,” “coral fungi,” “stink fungi,” “bracket fungi,” “puffballs,” “truffles,” and “birds nest” (Enow, 2013). Large fungi are those that form large fructifications visible without the help of the microscope and include Basidiomycota and Ascomycota with large observable spore bearing structures (Al thani, 2010). Macrofungal diversity is an important component of the global diversity, particularly community diversity, which is an essential part of fungal diversity (Li et al., 2012). According to Sarbhoy et al., (1996) the number of fungi species recorded in India were over 27,000. Bhatt et al., (2018) reported fifteen species of wild medicinal mushrooms belonging to 15 genera and 14 families in the Himalayas. Vishwakarma et al., (2011) reported 6 wild medicinal mushrooms in the Garhwal Himalayas. A survey of wild macro fungi associated with temperate evergreen forest of the Bharsar region of the Pauri Garhwal district, Uttarakhand, India, yielded specimens of 12 different species representing 10 genera (Semwal et al., 2014). Although extensive areas of the Uttarakhand state in the north western Himalaya of India are covered with forests, there have been relatively few taxonomic reports on the diversity of wild macro fungi (Bhatt et al., 1999, Bhatt et al., 2007a, Bhatt et al., 2007b, Chakraborty et al., 2017, Das and Sharma 2003, Das et al., 2016, Semwal et al., 2005, Semwal et al., 2006, Semwal et al., 2007) and many areas remain unexplored for their rich diversity of these organisms.

Landour is located in the Lower Western Himalaya, in the Mussoorie Range. It lies at an altitude of about 984 ft above Mussoorie, which itself is mostly at an altitude of 6,800 to 7,798 ft. Major part of Landour comprises of old forest growth consisting mainly of Deodar, Banj Oak, Chir Pine, Blue Pine, West Himalayan Fir, Himalayan Maple, Rhododendron, Himalayan Manna Ash and other tree species. A considerable area (330 acres appx.) of Landour, lies under the property of Woodstock School, Mussoorie, India. Major forest tree species in the campus comprise of Banj Oak (*Quercus leucotrichophora*, Deodar (*Cedrus deodara*), Rhododendron, Maple, Chir Pine. Due to restricted human interference, these forests are rich in biodiversity supporting various natural cycles. Besides supporting various life forms these forests support diverse varieties of mushrooms also. Mushrooms are used as both medicine and food, and are currently being studied for other uses like cleaning up oil spills and breaking down PCBs

(polychlorinated biphenyl, an organic environmental pollutant). Though a lot is known about how mushrooms can benefit humans, little attention is given to the importance of mushrooms to the forest. Although there are reports of various mushrooms from Mussoorie, meagre information is available on the diversity of mushrooms in the hillside of Landour, Mussoorie. The purpose of the paper is to begin the process of documenting the wild mushrooms in the area and further study their edibility, medicinal, ethnobotanical and cultural values This documentation can be used as a resource to cultivate new wild edible mushrooms to enhance the chances of improving the economy of the local villagers and to maintain the health of forests, since many wild mushroom are involved in the formation of ectomycorrhizal associations with the rootlets of the trees, with both partners in the relationship helping each other in many different ways (Semwal et al., 2014)

II. MATERIALS AND METHODS

Extensive nature walks alongside forest trails were undertaken between July and September 2022 in different localities of the Woodstock School campus in Landour, Mussoorie to collect the samples of macro fungi. During the field surveys, the macro fungi samples were collected with a great care to avoid damage to the base and other parts of the samples. Macroscopic details such as shape, size, colour, colour change on bruising or ageing, taste, odour, spore deposition of the fresh specimens (Largent 1977a, b) and ecological characteristics of the sample were recorded and samples were photographed in their natural habitats. Samples were kept in separate zip lock bags to avoid mixing and were taken to the laboratory. Macro and microscopic investigations were carried out on the samples. Collected specimens were dried, preserved in paper or polythene bags and accession numbers were given (Atri and Saini 2000). Identification of species was based on critical observations of the specimens and perusal of the relevant literature (Moller 1950, 1952, Moser 1978, Miller1981, Phillips 1991). The colour terminology used is that of the Methuen Handbook of Colour (Kornerup & Wanscher 1978). All the identified specimens were deposited in the science laboratory of Woodstock School, Landour.

Standard methods were followed for the collection, preservation, macro- and microscopic studies of the specimens (Singer 1986).

III. RESULT AND DISCUSSION

Some of the wild mushrooms along with their botanical name, family, description, collection place, habitat, collection date and various other details are being discussed as follows

Helvella crispa (Scop.) Fr.

Description

Pileus 15−50 mm broad, saddle-shaped, 2−3 regularly to irregularly lobed, white, creamy to slightly yellowish. Hymenium is the same colour as the pileus surface, hairy. Stipe 30−70 × 5−20 mm, tapering towards the pileus, with deep longitudinal furrows, ribs sharp-edged, irregular. Taste not recorded. Odour is indistinct. Spore deposit is not observed (Figure E).

Ecology - The mushroom was found under *Quercus leucotrichophora*, over moss covered soil, growing solitary or gregarious. It is also reported in both broadleaf and coniferous forests, and also occurs in open grassy or forested areas (Figure D).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie, Uttarakhand, India, 27 September 2022, WS/HC 01

Microscopic features – The asci comprises of 8 spores. Spores are ellipsoidal 16-21 x 10-14 µ; elliptical; smooth; with one large, central oil droplet and, sometimes, several smaller droplets at each end (Figure L).

Discussion – The white to buff cap and deeply ribbed or fluted stipe are characteristics of this beautiful elfin saddle. The fruiting bodies are edible when young but must be tried only after cooking them thoroughly. People recognize this mushroom by its saddle-shaped structure, white color and deep longitudinal furrows on the stipe. Previously reported by Singh et al., (2017) in Pauri, Uttarakhand.

Edibility – Edible, commented upon by Kaul et al. (1978), Purkayastha and Chandra (1985), Phillips (1991), Metzler et al., (1992). Atri & Lakhanpal (2002) and Singh et al., 2017.

Helvella lacunosa (Afzel.)

Description

Pileus: 10–40 mm across and 10–50 mm high; irregularly lobed and convoluted, or occasionally loosely saddle-shaped or cushion-shaped; black to very dark brown; bald but wrinkled; the margin usually attached to the stem in several places; under surface is grey to greyish brown. Stipe 10–40 mm long; 20–50 mm thick; greyish to dark grey; deeply and ornately ribbed and pocketed—the ribs rounded, or sometimes sharp and double-edged. Odour is not distinctive.

Ecology: These mushrooms are considered probably mycorrhizal; growing alone, scattered, or gregariously in woods under *Quercus leucotrichophora*. They are also reported to grow under conifers often in disturbed ground (Figure B).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie, Uttarakhand, India, 27 September 2022, WS/HL 02

Microscopic features: Spores 13–18 x 9–11 µm; broadly ellipsoid; smooth;. Asci is 200–250 x 10–15 µm; 8-spored, filiform, with rounded to clavate apices; smooth; hyaline to brownish, often with granular contents (Figure J and K).

Discussion- *Helvella lacunosa*, known as the slate grey saddle or fluted black elfin saddle in North America, simply as the elfin saddle in Britain, is an ascomycete fungus of the family Helvellaceae. The mushroom is readily identified by its irregularly shaped grey cap, fluted stem, and fuzzy undersurfaces. It is reported from Kashmir in India (Shameem et al., 2016) and in Sikkim (Das, 2010)

Edibility: This species is eaten and regarded highly by some after cooking, though the stems are not eaten. Lightfoot regarded it as edible in 1777, although this genus is now regarded with suspicion due to the presence of toxic compounds in several related species. It has been reported to cause gastrointestinal symptoms when eaten raw (Ammirati et al., 1985) as it may contain small amounts of the toxin monomethylhydrazine. Therefore, cooking is required before consuming (Davis, 2012)

Ganoderma sp.

Description

Pileus 3-23 cm broad, kidney shaped, elongated, more or less fan shaped at maturity, red to reddish brown when mature, when young often with zones of bright yellow and white toward the margin (Figure H). Tubes up to 2 cm deep. Pores 0.1 cm, whitish, usually bruising brown. Stipe 3-12 cm long and 1-2 cm thick, twisted, cylindrical, smooth, dark red to black with a varnished crust.

Ecology: Solitary to scattered sometimes gregarious, on living hardwoods for eg. *Quercus leucotrichophora*, usually near the base of the tree. The mushroom was found growing on the roots of Banj Oak tree (Figure G).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie, Uttarakhand, India, 27 September 2022, WS/GND 03

Microscopic features: Spores 9-12×5.5-8 µ; more or less elliptical.

Discussion: *Ganoderma* sp. is the most popular medicinal mushroom of the world. It has been used for a wide range of health benefits from preventive measures and maintenance of health to the management and treatment of chronic as well as acute human aliments (Rai 1997). *Ganoderma* sp. is previously reported from different parts of Uttarakhand. Species of Ganoderma are known to cause different kinds of rots in both angiosperms and gymnosperms by lignocellulose degradation. *Ganoderma* sp. is a common root pathogen that causes the decay and slow decline of numerous forest tree species (Bakshi,1976; Ko, 2009).

Edibility: It is edible and tastes slightly bitter. Ganoderma tea is relished in different parts of the world. It is also eaten in different parts of Uttarakhand.

Strobilomyces strobilaceus

Description

The cap of the fruiting body is about 6-12 cm in diameter. With age the convex cap becomes flatter and firmer and is covered with dark grey to black pyramid type protrusions. The flesh is white and then slowly dark grey or black. Stipe is up to 10 to 15cm tall. Mostly found between August to October. The odour is slightly earthy.

Ecology: The mushroom was found growing under *Quercus leucotrichophora* and Pine forest in Woodstock School, Mussoorie. It often grows alone and because it is mycorrhizal, hence, it will not be found growing on dead or decaying material (Figure F).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie, Uttarakhand, India, 30 September 2022, WS/SS 04

Microscopic features: The elliptical, dark brown to black spores measure 9-15 × 8-12 microns and are covered with a net-like pattern.

Discussion: Commonly known as Old Man of the Woods, this is one of many mycorrhizal fungus species that help nourish forest trees through symbiosis. The netlike fibres of the fungus cover the surface of a tree's roots, increasing the surface area and the root's ability to absorb water and nutrients. In return, the tree shares nutrients with the fungus. Old Man of the Woods blends in with the background landscape of the woods and forests and can be sometimes challenging to find. As it ages, it becomes darker and resembles a pine cone rather than the mushroom and is quite resistant to decay, unlike other fungi in the Boletaceae family.

Edibility: This distinctive bolete is generally considered edible but of very limited culinary value.

Scleroderma sp.

Description

The fruiting body is 20-120 mm in diameter; roughly spherical in shape; the surface hard and scaly, yellowish to

yellow-brown, often cracked. As the fungus matures, it can turn ochre-brown. Stipe have a few root-like mycelial threads which are attached to the soil. Spores: the spore mass is greyish, becoming purply-black. The individual spores are spherical and spiked. When mature, the outer skin ruptures, creating a large, irregular opening which releases the spores which are then dispersed by wind and rain

Ecology- The species is mycorrhizal with hardwoods and conifers. It is often found in mossy areas beneath *Quercus leucotrichophora*. It grows alone, scattered, or gregariously and widely distributed (Figure C).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie Uttarakhand, India, 27 September 2022, WS/Scl 05

Microscopic features: Spores are 8-13 µm and round in shaped, prominently reticulate (Kuo, 2004)

Discussion: Commonly known as Earth Ball mushroom, *Scleroderma* sp. is a mycorrhizal fungus similar in appearance to a warty potato. It prefers acid soils and mossy or peaty ground on heaths and in woodland, especially on sandy soil. One can observe them on compacted paths in woods and forests.

Edibility- *Scleroderma* sp. has been identified as poisonous and spore inhalation by humans has been reported to cause various symptoms including gastrointestinal distress, rhinitis, tachycardia, unconsciousness, dyspnea, and lacrimation (Uroz et al., 2006).

Humaria hemisphaerica

Description

They are goblet shaped when young, and gradually become cup-shaped and reaching widths of 2-3 cm when mature, fairly smooth; under surface densely hairy with prominent hairs that extend above the margin of the cup, brown; odour none; flesh brownish or pale, brittle. This species typically does not have a stipe although there is small abrupt base sometimes. This mycorrhizal fungus is recognized by its white inner surface and hairy brown outer surface.

Ecology: *Humaria hemisphaerica* grows solitary, scattered, or in groups on the ground or sometimes on rotten wood in wooded areas. It was found growing in clusters in the rhizosphere of Deodar tree (Figure A).

Specimen examined – The sample was collected from Woodstock School, Landour, Mussoorie, Uttarakhand, India, 27 September 2022, WS/HH 06

Microscopic features: Spores 20-24 x 10-12 µ; elliptical, often with somewhat flattened ends; Asci eight-spored (Kuo, 2012)

Discussion: It is commonly known as the hairy fairy cup (Arora, 1986) is a species of fungi in the family Pyronemataceae. This mycorrhizal fungus is recognized by its white inner surface and hairy brown outer surface. Previously it was reported by Thind and Sethi (1957) on dead twigs and soil under Cedrus forest in Mussoorie.

Edibility: Inedible

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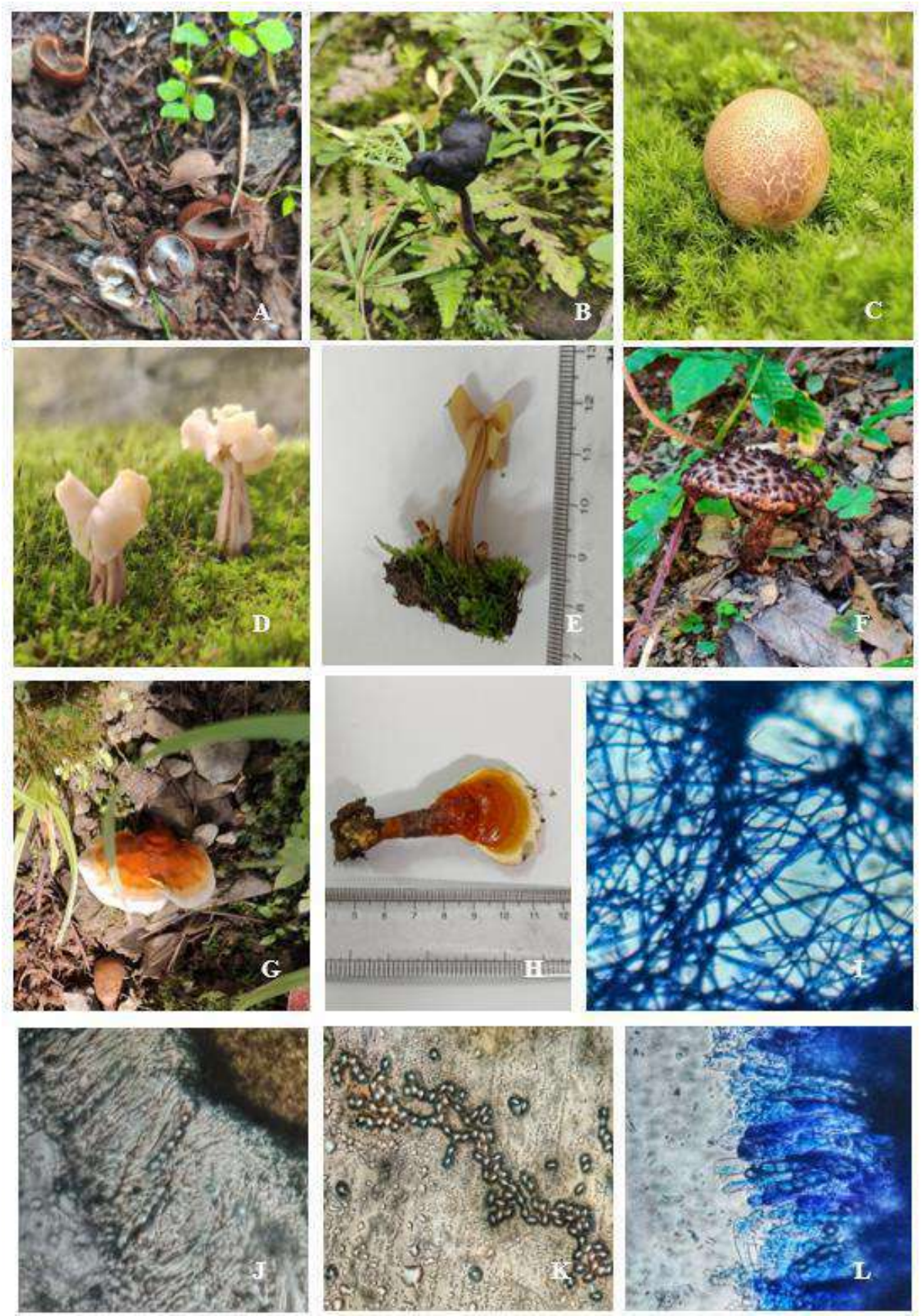

A. *Humaria hemisphaerica* B. *Helvella lacunosa C. Scleroderma* sp. D. *Helvella crispa* E. Morphological study of H. *crispa* F. *Strobilomyces strobilaceus* (Old man of the woods) G. Ganoderma sp. H. Morphological study of *Ganoderma* sp. I. Mycelial network of *Ganoderma* sp. J & K. Asci and spores of *H. lacunosa* under microscope L. Asci and spores of *H. crispa* under microscope

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Selected lines from Tai Nguyen Cho Dao for drought tolerance and good grain quality in rice (*Oryza saltiva.L*) at Long An , VietNam

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Abstract**—** *Selected of Tai Nguyen Cho Dao (TNCD)rice varieties tolerant to drought, high-yielding and good quality is very essential demands has raised to provide poor farmers in coastlines conditions as lowland in Long An ,VietNam. The purpose of this experiment is to selected of 22 lines from TNCD rice varieties tolerant to drought on the basis of a combination of two methods by molecular markers and evaluated phenotype. Evaluating drought tolerance of 22 lines from TNCD on the basis in the field of drought conditions to select promising lines to meet for farmers applying into production.* ***Methods:*** *selection of drought tolerant alleles for landrace rice at Long An by SSR(simple sequence repeated) markers and evaluated phenotype.* ***Results:*** *Some high yielding and good drought tolerant lines as lines: (TNCD 01, TNCD 15 and TNCD 22), however, also many lines failed due to many reasons: expansion of growth day, high rate of unfilled grain, not good for grain quality. Three lines (TNCD01, TNCD15, TNCD22) good for three characters such as high yield, and tolerance with drought. Based on morphological and SSR marker the line TNCD 01, TNCD 22 was identified as good quality which was further confirmed through molecular characterization techniques using RM201, HATRI13D, RM328, RM316, RM 5353, RM3480 primers. Sequence of TNCD01; TNCD22 were submitted to GenBank with accession number MT992254 and MW917241 respectively. Tolerant lines from Tai Nguyen Cho Dao have high-yielding rice varieties. This is a opportunity to improve good landrace rice varieties for condition of selected drought landrace rice varieties in Long An ,Vietnam.*

Keywords**—** ***high-yielding, grain quality, drought tolerance, landrace, SSR molecular marker.***

I. INTRODUCTION

Landraces have been shown to be excellent sources of genes for novel alleles (Loresto et al., 2000). In VietNam, rice is the major agricultural export, especially Tai Nguyen Cho Dao(TNCD) rice is landrace varieties . The cooked kernels of TNCD rice have a highly prized scent and texture. Tai Nguyen Cho Dao rice(TNCD) is normally grown in the Souther of VietNam , based on rain with limited irrigation and acid sufate- soild at Long An. Therefore, it is always affected by drought stress, leading to the reduction in growth and yield. Drought stress affects plant morphology, physiology, and molecular mechanisms. Upon drought stress, cell turgor pressure is decreased due to low water potential in cells. This causes a decrease in the relative water content, leaf water potential, stomatal conductance, and transpiration rate (Siddique et al 2001). Drought-resistant rice plants consume less water indicative of increased root biomass events under conditions of re-irrigation. The HDR gene with AP2/ERF transcoding factor, isolated in the mutant lineage of Arabidopsis (functionally attached), controls root strength trait, branching, epidermal cells, leaf thickness with elevated chloroplast proportions in mesophyll cells, promoting photosynthesis assimilation and photosynthesis performance (Karaba et al. 2007) .Simple sequence repeat is an important tool for genetic variation identification of

germplasm (Ma et al., 2011). SSR marker have some merits such a quickness, simplicity, rich polymorphism and stability, thus being widely applied in genetic diversity analysis, molecular map construction and gene mapping (Ma et al., 2011), construction of fingerprints (Ma et al., 2011), genetic purity test (Ma et al., 2011), analysis of germplasm diversity (Ma et al., 2011, Lang et al 2021) utilization of heterosis, especially in identification of species with closer genetic relationship. A total of 18,828 Class 1 di-, tri- and tetra-nucleotide SSRs, representing 47 distinctive motif families, were identified and annotated on the rice genome. An abundance of microsatellite markers is now available through the published high-density linkage map; there was an average of 51 hyper variable SSRs per Mb, with the highest density of markers occurring on chromosome 3 (55.8 SSRMb-1) and the lowest occurring on chromosome 4 (41.0 SSRMb-1) (IRGSP 2005).In particular, Wang et al. (2007) compared gene expression between water and shallow rice varieties under drought stress, using cDNA microarray. Shallow rice varieties IRAT109, Haogelao, Han 297 and water rice varieties Zhongzuo 93, Yuefu, Nipponbare were used. After reading the DNA sequence, there were 64 unique ESTs expressed at high levels in shallow rice varieties and 79 in water rice varieties. The author predicts that the expression of high levels of target genes in shallow rice may improve drought stress tolerance in rice and other closely related crops (Wang et al. 2007).This study is also need further selection and identification of drought tolerant varieties, good shape and high yield which need attention for TNCD at VietNam**.**

II. MATERIALS AND METHODS

The experiment is carried out parents from 22 different lines from Tai Nguyen Cho Dao. The yield of all the 22 lines were similar to the yield of the standard checks.

Phenotype analysis

A field experiment was transplanted to an irrigated lowland field in a randomized complete block design in three replications in the field of *High Agricultural Technology Research Institute for Mekong delta*.Vietnam (HATRI) at Binh Thuy, Can Tho. One hundred lines TNCD selectd with 22 lines from TNCD with KhaoDawMali 105, Tau Binh (Checked) were used to evaluated agronomic characteristics and drought detection through sensory test and genotypic analysis using SSR markers in lab of HATRI. Data on important agronomic traits like plant height, panicle length, filled grains/panicle, unfiled grain/panicle, 1000-grain weight, harvest index and yield were recorded.

Ten randomly selected plants of each genotype were used for agronomic data analysis. Data on plant height (cm), number of effective tillers/plants, panicle length (cm), number of filled grains/panicle, 1000-grain weight (g), days to maturity and grain yield/plant (g) were recorded and subjected to statistical analyses using SAS software. After harvesting, the seeds of each genotype were dehulled for evaluation of the grain quality. The grains were classified into different types based on their dimension according to (Lang et al, 2018).

Phenotyping: Evaluation of 22 lines for drought tolerance

Screening at seeding stage

Screening of 22 lines for drought tolerance was done under controlled environment condition. Rapid screening method was used. Two pre-germinated seed were planted field . After three days, For drought treatment, the seeds were sown in pots containing vermiculite and nutritional soil, and seedlings were watered with tap water until they reached the three-leaf stage. The seedlings were used as experimental materials. The control seedlings continued to be watered, while water was withdrawn from the drought treatment seedlings for 30 days. Three replicates were performed for each treatment. All experiments were carried out in a greenhouse; the seedlings were harvested prior to measuring the physiological and biochemical indicators. The measured physiological and biochemical traits included leaf dying score and leaf-death score . The drought resistance indices of the physiological and biochemical indicators were calculated as:Modified standard evaluation score (Table 1) was used in rating the symptoms of drought . Scoring was done 30 days. At this period, 22 lines and checked for tolerance (Khoa DawMali 105) scored 1-3 and susceptible (Tau Binh) scored 9.

Table1. Modified standard evaluation score (SES) of visual drought injury at seedling stage(IRRI .1967. Lang et al, 2012).

Score	Observation
1	Normal growth, no leaf symptom
3	Nearly normal growth, but leaf tips or few leaves whitish and rolled
5	Growth severely retarded; most leaves rolled; only a few are elongating
7	Complete cessation of growth; most leaves dry; some plants dying
9	Almost all plants dead or dying

Fig.1. A. growth conditions (drought), (Figure 1,B), under normal

Genotype, Quality Control

DNA extraction

The 22 lines/varieties(TNCD) were grown in pots, maximum protection was employed to ensure healthy and disease-free seedlings. The leaves were collected 2-3 weeks after planting for DNA extraction.Standard molecular grade chemicals and general techniques for preparing stock solutions, buffers, reagents, and equipment were followed according to (Sambrook *et al.*,1989). Molecular work was conducted at the Genetics and Plant Breeding Department of the High Agricultural Technology Research Institute for Mekong delta,Vietnam (HATRI).

DNA suitable for PCR analysis was prepared using a simplified procedure (McCouch *et al.*, 1988). A piece of a young rice leaf (2 cm) was collected and placed in a labeled 1.5 ml centrifuge tube in ice. The leaf was ground using a polished glass rod in a well of a spot test plate (Thomas Scientific) after adding 400 µl of extraction buffer. Grinding was done until the buffer turned green, an indication of cell breakage and release of chloroplasts and cell contents. Another 400 µl of extraction buffer was added into the well by pipetting. Around 400 µl of the lysate was transferred to the original tube of the leaf sample. The lysate was deproteinized using 400 µl of chloroform. The aqueous supernatant was transferred to a new 1.5 ml tube and DNA was precipitated using absolute ethanol. DNA was air-dried and re-suspended in 50 µl of TE buffer (Lang, 2002).

DNA quality checks used 1% agarose by melting 3 g of agarose in 300 ml of TAE buffer. The mixture was heated in a microwave for 5-6 min and then cooled to around 55-60 0C. This was then poured on a previously prepared electrophoresis box with combs. Gels were prepared and the combs removed after about 45 min. Seven microliters of DNA sample plus 3 µl of loading buffer (Tris 1 M pH = 8.0, glycerol, EDTA 0.5 M pH = 8.0, xylene cyanol 0.2%, bromophenol blue 0.2%, and distilled water) was run at 70-80 v, 60 mA for 45 min or until the loading buffer dye moved far away from the wells. The gel was then taken out and stained with ethidium bromide, after which it was observed under UV light.(Lang et al 2015)

Microsatellite analysis

The whole microsatellite analysis included PCR assay, polyacrylamide gel electrophoresis, and band detection and scoring.

PCR assay

Microsatellite primers were used to survey polymorphism on the samples. These were randomly selected from the 6 microsatellite primer pairs currently available for rice such (Table 2). The PCR reaction was as follows:

Table 2. SSR marker on chromosome 9 and 8 used in the present study

SSR markers	Chromosome	Forward primer sequence	Reverse primer sequence
RM201	9	F -5'CTCGTTTATTACCTACAGTACC-3'	R -5'CTACCTCCTTTCTAGACCGATA -3'
RM328	9	F-5'AAGTTTGTACACATCGTATACA-3′	R-5'CGCGACCAGTACTACTACTA-3′
HATRI 13D	9	F- 5' caccacacacccattttcac -3'	R-5' cgcgagtggtgtcttctgt -3'
RM316	9	F-5' CTAGTTGGGCATACGATGGC -3'	R-5' ACGCTTATATGTTACGTCAAC -3′
RM5353	8	F-5' ACCCTCGATCTCCTAGGCTG-3'	R -5'TCTACTCCAAACCCATTGCC-3'
RM3480	8	F-5'GTGCCAAGGAGATTGGATTG -3'	R-5'ATGGTCTGCAACTCTGCAT G-3'

Reactions were overlaid with mineral oil and processed in a programmable thermal controller set for 35 cycles of 1 min at 94 ^{0}C, 1 min at 55 ^{0}C, and 2 min at 72 ^{0}C, with a final extension at 75 ^{0}C for 5 min. After amplification, 10 µl of stop solution was added to the PCR product, which was then denatured at 94 ^{0}C for 2 min. Eight microliters of each reaction were run on polyacrylamide gel.

Data Analysis

Analysis of variance: The agro-morphological data collected were initially analyzed through analysis of variance to verify genetic variation in the traits measured. The few traits with in significant genetic variation, based on the F-test, were not considered for further analyses.

III. RESULTS AND DISCUSSION

Evaluation of physiological responses of 22 lines TNCD under drought-stress conditions. Selected 22 lines and two checked (KDM 105 and Tau Binh) , were evaluated for drought tolerance by growing the seedlings in soil with 100% or in normal growth conditions all of the lines were similar (Figure 1A,B), but they differed under drought field capacity. 22 lines from NTCD displayed the most drought-tolerant phenotype, with the lowest leaf dying score. This was similar to the performance of KDM105(the drought-tolerant line chected). The highest leaf-death score was detected in lines TNCD under drought stress. These data suggest that lines : 1, 3 is the most drought-tolerant line, while some lines are the most susceptible(5-9 score) . The 22 lines are selected through continuous seasons in 2022 and selected under drought to select the stages of 22 lines to evaluate this generation the plant shapes which are relatively uniform were recorded. Through reviews with 22 lines tolernce to drought in the period recorded 1 lines for tolerance to drought such as line TNCD01, TNCD 15, TNCD 22 . Score tolerance numbers 3 such as TNCD 02 , TNCD 03, TNCD 11, TNCD 12, TNCD 13, TNCD 14, TNCD 16 and TNCD 20 the same with KDM 105(cheched). Remain lines are supceptible (Tau Binh Cheked). Continued assessment and analysis of yield and yield components. Response to drought stress in TNCD lines and KDML105, TauBinh , were compared for leaf death and leaf dying score) normal and drought-stress conditions. The mean + 1 standard error (SE) was derived from four replicates. (Table3).

Table 3. Drought tolerance score, of leaf of the extreme tails identified by screening drought (30 days)

STT	Lines	Drought score	leaf dying score **(%)**	leaf-death score **(%)**
1	Tau Binh (Checked)	9	5.533	7.41
2	KDM105(Checked)	3	0.579	0.82
3	TNCD01	1	0.06	0.00
4	TNCD02	3	0.612	0.96
5	TNCD03	3	0.976	0.50
6	TNCD04	9	7.75	6.32
7	TNCD05	5	1.745	3.59
8	TNCD06	5	1.632	2.62

9	TNCD07	5	1.745	2.43
10	TNCD08	5	1.669	2.12
11	TNCD09	7	5.756	5.02
12	TNCD 10	5	2.563	2.16
13	TNCD 11	3	0.75	2.32
14	TNCD 12	3	0.85	0.32
15	TNCD 13	3	0.17	0.32
16	TNCD 14	3	0.532	0.51
17	TNCD 15	1	0.062	0.05
18	TNCD 16	3	0.96	0.32
19	TNCD 17	5	0.612	2.96
20	TNCD 18	7	5.69	4.98
21	TNCD 19	5	1.422	3.89
22	TNCD 20	3	0.745	2.59
23	TNCD 21	7	7.632	4.62
24	TNCD 22	1	0.045	0.01

Line of 22 TNCD there are several applications in which DNA marker data may be useful for breeding, such as cultivar identity, assessment of genetic diversity (Collard and Mackill 2008). Screening drought gene is based on molecular marker (Lang et al 2015). Molecular values are assessed based on polymorphism targets and codominant genome on the varieties. To be based on information of genetic map of (Mackill et al 2006) recorded with the respective molecular marker with marker on chromsome 9. With 5 respective 22 lines have noted (Table 2) the difference between the recorded molecular markers with groups of SSR markers as follow: The line (3:TNCD01, 14:TNCD12, 15:TNCD13, 16:TNCD14, and TNCD22) has polymorphic with molecular markers of HATRI13D , RM201(figure 2A, 2B). The more sensitive method of QTL detection is the simultaneous analysis of the effects of markers binding in the same interval of chromosomes when studying genetic resistance to dry conditions. The effect of different regions on each chromosome on the 3 target traits (selection criteria) associated with drought resistance is shown in the relevant tables. Four drought SSR markers : RM 201 - RM 328 and RM 155- RM 511 have a very significant influence on the two target traits DR, YG and DF. Most target traits showed meaningful influence on defined regions of the genome but DR and DF traits showed influence within a distance of the genetic map (Lang et al, 2012.b) . This article is the first report on SSR based marker using TNCD landrace rice detected for drought tolerance. In the present study, 22 TNCD germplasms tested for genetic diversity were arbitrarily selected, therefore there is a possibility that they have a similar genetic backgrounds, which can result in relatively low genetic polymorphism. However, the fact that most of the primer sets produced normal PCR products is considered, SSR -based molecular markers developed in the present study could provide useful genetic information and materials for future rice drought tolerance breeding programs and genetic diversity study. The PCR product will be amplified with primer RM201, RM 328 , HATRI 13D, RM316 on chromosome 9(Lang et al., 2012.a) and RM5353, RM3480 (on chromosome 8 (Kanjoo et al.,2012) with the genetic code on 22 lines and drought sets to view polymorphisms of these lines (figure 2 and figure 3). TNCD lines evaluated with RM201 markers associated with DC(drought score) traits and for polymorphisms with bands of 210 bp 1:Tau Binh (Suceptible checked) and 225bp it's the same band as 2: KDM 105(drought cheked) . Similary , HATRI 13D to selectd plant homozygous for drought . Only 3: TNCD 01; 14:TNCD 12; 15:TNCD 13;16: TNCD 14 and 24:TNCD 22 give the same banding pattern ás KDM 105(190bp) and Tau Binh (210bp).

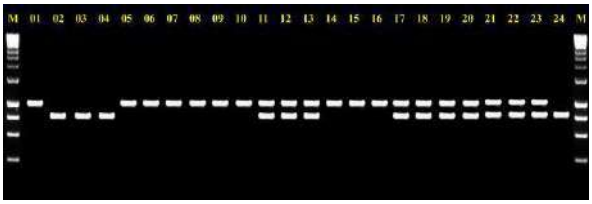

Figure 2A

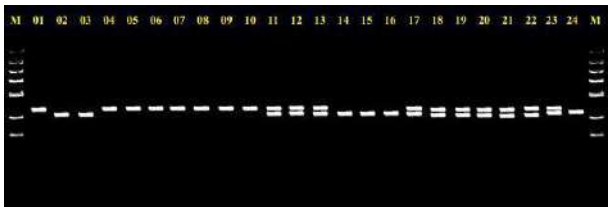

Figure 2B

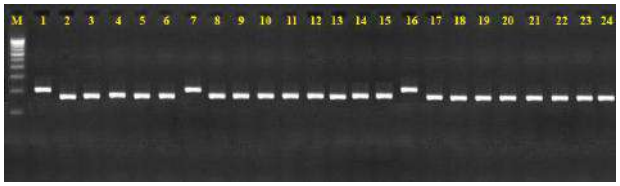

Figure 2C

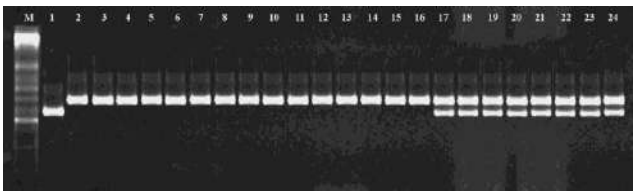

Figure 2D

Fig.2. PCR product of the line at RM 201(A) HATRI 13D (B) RM328 (C) RM316(D), the gene associated with tolerance to drought in chromosome number 9 position on the agarose gel 3%. With reference to the banding patterns of 1:Tau Binh(Susceptible) and 2:KDM 105 (resistance). 3-24 lines of TNCD

The maker RM5353-RM3480 linked with drought on chromosome 8 (Kanjoo et al .,2012) The selectd the plants with two markers in homozygous condition is shown in figure 3. A and figure 3.B.

Figure 3A

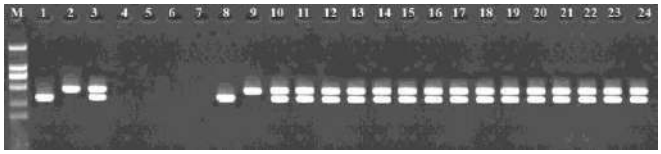

Figure 3B

Fig.3. PCR product of the line at RM5353(A), RM3480 (B) , the gene associated with tolerance to drought in chromosome number 8 position on the agarose gel 3%. With reference to the banding patterns of 1:Tau Binh(Susceptible) and 2:KDM 105 (resistance). 3-24 lines ofTNCD

Yield components

The promising lines of the TNCD variety are planted and assess the yield and yield components. The results showed that these lines had more equal and evener length panicle than the opposition, the lines were quite good panicle , the number of tilling / hill was quite good, and the ratio of panicle was average.Rice yield of grains,and 1000-grain weight . Most lines cultivars had more than 100 grains per panicle, and this character is desirable for breeding program. The 1,000-grain weight ranged from 25.21 to 28.78 g (Table 4). This is very important for farmers choise some size large and bold such as lines TNCD 01, TNCD0 6, TNCD 11 and TNCD 22. In terms of recorded productivity in the present study, yield grain from TNCD 01, TNCD 02, TNCD 11, TNCD 12, TNCD 15, TNCD 16 and TNCD 22 gives the highest yield over compare with KDM 105 and Tau Binh are (59.42 g/plant and 38.17g/ plant respectively), of which lines TNCD 01, TNCD 02, TNCD 11, TNCD 12, TNCD 15, TNCD 16 and TNCD 22 gives the highest yield (67.33;66.23; 66.48 ,63.60, 62.24, 65,73 and 86.03 g/plant) respectively. Through reviews with 22 lines tolerance to drought in the period recorded 6 lines for resistant to drought score 1 such as line TNCD 01, TNCD 15, TNCD 22, the same with KDM 105(cheched) . Through evaluation results of hight plant recorded only 4 lines TNCD 07, TNCD 10, TNCD 16, TNCD 18 had hight plant less than 140 cm. The number of grains per panicle is usually highly proportional to the spikelet number, such as TNCD 07 , TNCD 09 give good for spikelet / panicle (165.22;162.33 grain/panicle) respectively .

Table 4: yield and components yield of 22 lines from TNCD with two rice checked

acession	lines	Hight plant (cm)	Tilling/(Hill)	Weight of 1000 grain(g)	Filling/ panicle)	unfilling (%)	Length panicle (cm)	Biomass (g)	yield (g/ plant)	HI
Tau BInh	Tau Binh	169.33a	19.00d	26.69c	97.23f	17.95c	24.28	86.67c	38.17e	0.226c
KDM	KDM105	161.67a	16.33g	28.51a	127.67e	10.85e	24.22	65.67e	59.42c	0.316b
3	TNCD01	162.67a	19.12d	26.8c	140.44c	23.23b	24.94	86.67c	67.33b	0.401a
5	TNCD02	159.23b	16.67g	26.17c	145.56c	21.41b	27.44b	85.25c	66.23b	0.474a
16	TNCD03	158.67b	13.67h	27.23b	130.11d	27.22a	26.22c	61.67e	46.9d	0.278c
17	TNCD04	136.67d	17.27f	25.43d	100.78f	28.74a	25.46d	50.33f	41.14d	0.291c
18	TNCD05	160.67a	13.62h	25.32d	127.33e	26.79a	28.14a	53.33f	46.58d	0.335b
20	TNCD06	156.68b	17.11f	26.54c	115.23f	18.26c	27.32b	56.23f	32.25e	0.336b
25	TNCD07	162.23a	19.33d	26.25c	165.22a	12.83e	25.89d	57.67f	40.38d	0.350b
31	TNCD08	158.33b	19.67d	26.45c	108.44f	25.5a	26.25c	43.33g	27.5f	0.288c
32	TNCD09	166.33a	19.33d	26.31c	162.33a	16.01c	27.44b	46.67g	34.91e	0.277c
33	TNCD 10	132.33d	17.00f	26.44c	59.05g	20.45b	26.06c	45.67g	28.72	0.253c
34	TNCD 11	147.33c	20.67c	26.63c	137.89	24.97c	26.44c	85.12c	66.48b	0.450a
35	TNCD 12	154.25b	25.22a	25.22d	119.89f	19.01c	26.17c	100.00a	63.6b	0.238c
56	TNCD 13	152.14b	18.01e	25.72d	102.78f	26.92a	26.56c	83.33c	46.16d	0.214c
57	TNCD 14	153.67b	17.33f	26.23c	109.78f	22.91b	25.67c	80.00c	37.08e	0.202c
58	TNCD 15	150.33b	20.33c	26.24c	136.62d	12.71d	26.78c	81.67	62.24b	0.405a
59	TNCD 16	139.67d	21.67b	25.59d	155.44b	14.84d	25.33d	91.67b	65.73b	0.282c
65	TNCD 17	142.25c	19.33d	25.57d	133.44d	14.17d	25.17d	65.00e	39.04e	0.246c
69	TNCD 18	136.33d	19.32d	25.93d	67.67g	26.49a	25.06d	61.67e	19.08	0.147d
75	TNCD 19	148.33c	19.67d	25.32d	136.11d	11.76e	26.78c	76.67d	59.42c	0.279c
76	TNCD 20	154.16b	18.32e	25.41d	136.2d	15.21d	26.22c	62.23e	56.23c	0.254c
77	TNCD 21	152.23b	17.62f	25.21d	110.32f	14.25d	26.52c	62.54e	58.24c	0.321b
79	TNCD 22	155.32b	25.33a	26.06c	154.56b	14.82d	26.61c	90.56b	86.03a	0.421a

Evaluation of 22 lines for quality

Evaluation of rice quality appearance TNCD in physical characteristics, such as the length and width of the rice sample can play an important role in the willingness of consumers to pay for rice. When analyzing the size of rice grains is evaluated according to the IRRI standard scale. Tai Nguyen Cho Dao seed record size has a long rice grain size of 7.24-7.50mm rice grains . This is a very medium group of rice grains. Analysis of the chalkiness ratio of Tai Nguyen Cho Dao lines noted: most lines have chalkiness and chalkiness ratio in order (Table5).

Twenty two advanced lines along after checked with KhaoDawMali 105 and Tau Binh to quality analysis. Grain quality of rice consists of several components: the milling quality such as head rice (Lang et al 2005,Lang et al 2012b). Cooking and eating qualities are mostly determined by amylose content (AC), gelatinization temperature (GT), of the grain starch (Lang et al 2005). Appearance quality is mainly specified by grain shape as defined by grain length, grain width, the length–width ratio, and the translucency or chalkiness of the endosperm (Tang et al 1986). These traits are considered important for the ideal texture of cooked rice, especially for many rice consumers in South and Southeast Asia (Wand et al 2007). Brown rice percentage varied from 77.07-80.52%. The head rice percentage of lines ranged from 41.67-50.23%.Most of the lines were found to give chalkiness. Most consumers prefer rice with intermediate amylose

content ranged between 20-24%, compared to (KDM 105= 18.12%) (Table 5).

Table 5. Quality of 22 lines TNCD from Mua season 2022 at Can Duoc(Long An province)

Acession	lines	% brown rice	%white rice	% head rice	Length (mm)	L/W	gelatinization temperature (GT) (Score)	Chakiness (% score 9)	%Amylose
Tau Binh	Tau Binh	78.34d	75.39-c	41.73g	8.06 a	3.27c	3	6.67-e	24.63b
KDM	KDM105	77.07d	74.62-d	41.90g	8.86a	3.38b	7	0.00f	18.12e
3	TNCD01	79.38d	76.72 b	49.84b	7.19b	3.34b	3	8.33c	24.98b
5	TNCD02	79.32d	74.06-ef	49.47b	6.93c	3.46a	3	7.67d	25.67 a
16	TNCD03	79.38d	77.52a	44.15 f	7.60 b	3.34b	3	12.00b	24.63b
17	TNCD04	80.04a	77.65a	41.67g	7.19 b	3.33b	3	13.00 b	24.98b
18	TNCD05	78.04ab	73.72-f	43.19bc	7.15 b	3.32b	3	7.33 d	22.01d
20	TNCD06	77.63d	75.42c	47.38c	6.99c	3.26c	3	6.33-e	24.28b
25	TNCD07	79.86d	77.69a	44.55g	7.56b	3.20c	3	11.33 bc	24.00b
31	TNCD08	79.51d	74.84d	49.33b	7.32 b	3.44a	3	17.67a	23.35c
32	TNCD09	81.26b	76.32b	46.65d	6.96c	3.38b	3	8.00 c	22.12-f
33	TNCD 10	79.32d	75.62c	45.62e	7.19 a	3.34b	3	8.33c	24.98b
34	TNCD 11	78.23d	76.23b	49.23b	7.93 b	3.47a	3	7.67-d	25.67 a
35	TNCD 12	80.52c	76.25b	46.35d	7.30 b	3.34b	3	10.00 b	24.63b
56	TNCD 13	81.23b	76.77b	46.05d	7.09 b	3.33bb	3	13.00 a	24.98b
57	TNCD 14	79.23ab	75.73c	42.77g	7.05b	3.32b	3	7.33-de	22.01d
58	TNCD 15	80.21c	78.26a	50.23a	6.86 c	3.30b	3	7.00d	22.12d
59	TNCD 16	82.23a	76.25b	46.23d	7.19 b	3.31b	3	8.33c	24.98b
65	TNCD 17	80.15c	76.28b	46.95d	6.93c	3.35b	3	7.67d	25.67 a
69	TNCD 18	79.23d	75.73c	42.77g	7.80 b	3.34b	3	10.00b	24.63b
75	TNCD 19	82.20a	77.30a	42.80	7.09b	3.33bb	3	13.00 a	24.98-b
76	TNCD 20	80.14c	76.23b	45.62	7.05b	3.32b	3	7.33 d	22.01d
77	TNCD 21	80.23c	75.56c	46.23	7.12b	3.11d	3	7.23 d	22.17d
79	TNCD 22	82.15a	76.26b	50.23a	7.79b	3.23c	3	7.62d	23.12c

DNA profiles

The result of the amplification of the TNCD01 lines TNCD22 with RM 223 tershows the read able DNA bands measuring around 900-1250 bp. The success of amplification with PCR is evidenced by the process of sequencing the of *DNA* product with good quality . CLUSTAL 2.1 multiple sequence (https://www.genome.jp › tools-bin › clustalw) alignment compared MW917241(NTCD 22) with MT992254(Lang. 2021) with 84.295% . According to Miller et al. (1990) and Claveri and Notredame (2003), the higher score obtained the higher the homology of the two sequences, while the query coverage is a percentage of the long nucleotide aligned with the database in the BLASTn analysis(https://blast.ncbi.nlm.nih.gov/Blast.cgi). The E-value that gives statistically significant to both sequences.

The E-value indicates the homologous level between the lower sequences, whereas the lower of the E-value indicates that the two sequences are identical(MT992254(TNCD01) and accession number MW917241(TNCD 22). The similarity value of the Lines TNCD 22 cultivars is 92.27% which is similar to sequence, namely Rice in GenBank sequences of TNCD 01 have been registered in GenBank with accession number MT992254.

IV. DISCUSSION

Drought and molecular markers were used to marker on 22 lines at screening phase. An important aim may be to fix alleles in their homozygous state as early as possible. For example, pure lines landrace methods, screening is often performed at the TNCD01, TNCD 22 when most loci are homozygous. Using co-dominant DNA markers, it is possible to fix specific alleles in their homozygous state. However, this may require large population sizes; thus, in practical terms, a small number of loci may be fixed at each generation (Koebner & Summers 2003). An alternative strategy is to 'enrich' rather than fix alleles—by selecting homozygotes and heterozygotes for a target locus—within a population in order to reduce the size of the breeding populations required. For these results throught 4 markers with the homozygote the same with KDM 105 varieties and some allelels give heterozygote for contamination.To find the target breeding tolerant to drought and high yield.The rice varieties are grown and observed growth period of rice varieties. In the rice varieties evaluation recorded the varieties remained 8 lines good for drought . Grain yield in rice is a complex trait multiplicatively determined by its three component traits: number of panicles, number of grains per panicle, and grain weight, all of which are typical quantitative traits Yongzhong et al 2010

Table 3 : Evaluated yield and yield component of the varieties recorded 22 lines. Through evaluation results of yield and yield component recorded only 5 lines had high yield were line number TNCD 07, TNCD 10, TNCD 16, TNCD 18 and had hight plant day less than 140 cm (132.33;136.67,139.67, and 136.33 respectvitive). The number of grains per panicle is usually highly proportional to the spikelet number. To understand the making of the number of grains per panicle, it is essential to understand the basic biological processes of panicle development, as well as the differentiation of meristems into spikelet's at salinity in rice. From an agronomic perspective, the number of spikelet per panicle can be attributed to two components: the duration of panicle differentiation and the rate of spikelet differentiation (Huang Y et al 2006). This result gives 22 lines are selected through continuous seasons in 2022 and selected under drought to select the stages of 22 lines to evaluate this generation the plant shapes which are relatively uniform were recorded. Luo and Zhang 2001 divided drought resistance into 4 types including drought tolerance, drought escape, drought avoidance and drought recovery. Our experiment results indicated that **leaf dying score** and leaf-death score, and traits associated with drought avoidance.Therefore, the inheritance of drought tolerance and drought avoidance is closely correlated and interact with one another; they are not separated(Liguo et al 2016) .Through reviews with 22 lines drought to drought in the period recorded 1 for tolerance to drought such as line TNCD01, TNCD 15, TNCD 22 . Score tolerance numbers 3 such TNCD 02 , TNCD 03, TNCD 11, TNCD 12, TNCD 13, TNCD 14, TNCD 16 and TNCD 20 the same with KDM 105(cheched)(table 3) These lines also give good survival during 30 days with drought tolerance . As discussed above, there are PCR product of the line at RM 201,HATRI 13D, RM328 , RM3252 on chromosoe 9 and RM5353, RM3480 on chromosome 8 , the gene associated with tolerance to drought in chromosome number 9 and 8 for ladrace rice TNCD , Thís ís now over whelming evidence for the existence of extensive regions of conserved colinearity among cereal species at genetic map level. This knowledge can be exploited to advance marker studies on all grass species and to extend our knowledge of key syntenic agronomic genes as they are placed on pure lines in rice landrace .

V. CONCLUSIONS

Evaluating SSR on 22 different lines TNCD recorded different polymorphisms focus on chromosome 9, and 8 but difference group through screening 22 lines recorded a line tolerant to drought conditions during 30-days rate of survival of 95% which is 3 lines good for drought (TNCD 01, TNCD 15 and TNCD 22) . Some promising lines having good grain such as TNCD 01, TNCD 02, TNCD 11, TNCD 12, TNCD 15, TNCD 16 and TNCD 22 gives the highest yield (67.33;66.23; 66.48,63.60,62.24, 65,73 and 86.03 ; g/plant) respectively . Howver give good the high yield and drought tolerance with three lines (TNCD 01, TNCD 15, and TNCD 22) good for three characters such as high yield, and tolerance with drought and showing tolerance and seed multiplication is on going.

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The Role of Animal Traction Technology in enhancing Production for Small Scale Farmers in Sierra Leone

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Abstract— *This paper summarises the results of a base line survey conducted in 2019 and gives an overview of the current status of animal traction in the country. The study assessed the socio-economic characteristics of household heads utilizing the technology, the application of animal power and its associated opportunities and constraints. A total of 130 households were targeted and data were collected through the administration of structured questionnaires, key informant interviews, and focus group discussions. Majority (99.2%) of household heads using this technology were males. The ethnic groups mostly involved in animal traction were Madingos (18.6%), with the least being the Shebro tribe (1.6%). Farming was the main source of income for about (96.1%) of the respondents. The level of awareness of the technology was very high and most (71.3%) of the household heads became aware about traction from other farmers. Cattle was the sole draught animal used and was mainly sourced through purchase (69%). In the selection of oxen for traction, bulls of medium sizes and aged 2 years were the most preferred. Household heads possessed an average of 9.73 years of experience in animal traction and owned at least a farm site with mean sizes of 6.93 acres. Animal power was mostly preferred over traction due to ease of management, cost effectiveness and its potential to give higher crop yields. Traction services was estimated as readily available by (32.6%) of the farmers, with (10.1%) citing the service as not readily available. Animal traction was used solely for agricultural purposes and ploughing was the most common activity. A set of oxen was reported to plough about 1.4 acres within 5.1 hours with weekly and annual work cycles of 5.2 days and 5.3 months respectively. Operators of work oxen were mostly males with few adolescent boys and rarely women. (77.5%) of household heads owned implements with about (22.5%) not owning implements. Majority (80.6%) of the implements were imported with (19.4%) locally fabricated. In conclusion, the awareness and use of animal traction for agricultural purposes was quite high and due to its numerous advantages is highly recommended for small scale farmers.*

Keywords— ***Agriculture, Household heads, Sierra Leone, Socio economic, Work oxen.***

I. INTRODUCTION

Animal traction is the use of draught animals for tillage, seeding and other activities [3]. The most commonly used animals have been horses, mules, oxen, donkeys and buffalos [9]. In Sierra Leone, the use of animal power dates back to a period during the 18th century when horses were imported into Freetown for riding, racing and wheeled transport [4]. However, a devastating outbreak of a disease thought to be trypanosomiasis between 1856 and 1858, spread by tsetse flies, severely restricted the subsequent use of horses [4].

The use of oxen for Agriculture was not introduced in Sierra Leone until the early 1900's. In 1927, the British

authorities banned a traditional form of domestic slavery practiced by the Mandinka people. The Mandinka elders then asked how they could cultivate their rice fields without their traditional labour supply [6]. The Sierra Leone Department of Agriculture, based at Njala, had already experienced problems with the first few tractors introduced, and so suggested the use of animal power. This was a new and innovative technology in the farming systems of Sierra Leone, where human labour was the major power source.

Information concerning the success of the animal traction scheme in Guinea reached Sierra Leone, and in 1928, three agricultural instructors were sent to Kankan in Guinea to learn how to work with N'dama oxen. They returned and were posted to Njala, Batkanu and Karina where they taught farmers how to train animals and plough. In 1930, "all operations in connection with ox ploughing succeeded almost beyond expectations" and animal power training centres were established in four locations [7, 8]). Though animal traction had been firmly established in the country since 1928, its adoption and spread was slow until there was further promotional schemes in the 1950s and again in the 1980s, which led to further adoption, encouraged by support services such as equipment provision, credit and training [7, 1, and 10].

The Sierra Leone Work Oxen Program (SLWOP) was established in the 1970's and was charged with the responsibility of developing animal traction in the country. It had a research and a development phase. The research phase lasted from 1979-1984 and included on-farm and on-station trials, surveys, testing and modification of animal traction equipment, all geared towards tailoring the technology to the agro-socio-economic circumstances of the users (1, 7, and 10]. The development phase commenced in 1985, and during this period the equipment production aspect at the Rolako Work Oxen Technical Centre was strengthened. The initial sets of 30 oxen and equipment in 1980 were increased to 2000 sets located in different parts of the country [2].

However, the outbreak of the civil war which spanned 1991-2002, had a devastating effect on the general economic life of the country, and in particular animal traction development [2]. During this period, work oxen farmers were forced to flee their farms with most of them leaving their oxen behind. Donor-funded projects that promoted traction stopped abruptly and the Work Oxen Programme was temporarily closed at one stage.

Currently, little information exists on the utilization of animal traction in the aftermath of the civil war.

Therefore, this survey aims at providing comprehensive information on the present state of animal traction in the country.

II. METHODOLOGY

The sampling frame of the survey was households utilizing animal traction. In conducting this baseline survey, multi stage sampling was used for the selection of individual households. The first stage was the selection of areas of interest, and this was achieved through purposive selection of two (2) regions based on the farming practices adopted by the farmers; which are the North and North-West regions. In the second stage, districts were also purposively selected from the selected regions based on the availability and rearing of livestock and also from the history of districts known for using animal traction technology. Hence after purposive selection of the districts, these five (5) districts were concluded; Kambia, Bombali, Koinadugu, Port Loko and Falaba districts.

In determining the sampling frame for the animal traction survey, data collection was triangulated in order to capture different dimensions of the animal traction technology. Questionnaires with both demographic and primary questions on animal traction were administered in all the five districts that were selected.

A total of one hundred and thirty (130) respondents were selected and these were equally distributed among the five selected districts, with each district having twenty six (26) respondents. Due to the difficulty of locating households using animal traction, the selection of the respondents to be interviewed in the selected districts was by snowball sampling method. In addition, key informant interviews (at least five per district) and a focus group discussion in each district were done.

Enumerators were trained in administering the questionnaires and on how to enter data directly onto the CSEntry software via tablets. Data collected during the survey was entered into CSEntry and later imported and stored in the Statistical Package for Social Science (SPSS version 21). Descriptive statistics of the explanatory and other variables examined in the study for the animal traction households at the national, regional and district levels were computed using SPSS v.21 and charts developed using the Microsoft excel 2010.

III. RESULTS

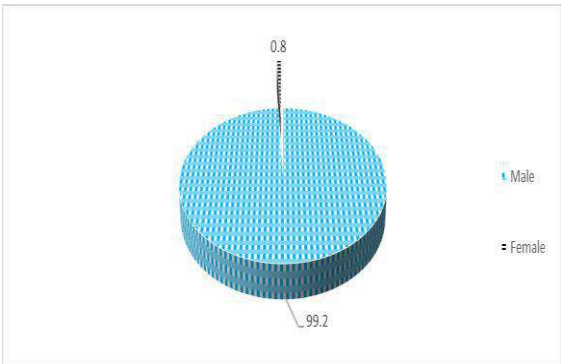

Fig.1. Gender of household heads

Gender of household heads (HH) is shown in (fig. 1). Majority (99.2%) of the HH engaged in animal traction were males with few (0.8%) females.

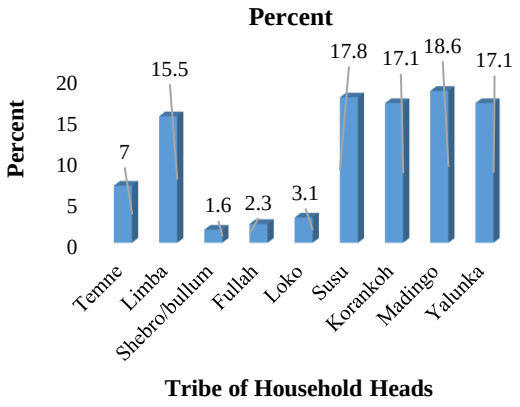

Fig.2. Ethnicity of household heads

The percentage distribution of the various ethnic groups engaged in animal traction is shown in Figure 2. The ranking of the most dominant tribes stood at (18.6%) for Madingo, (17.8%) for Susu, (17.1%) for both Koranko and Yalunka, and (15.5%) for Limba. The least dominant tribes were the Temne (7%) Loko (3.1%), Fullah (2.3%), and Shebro (1.6%).

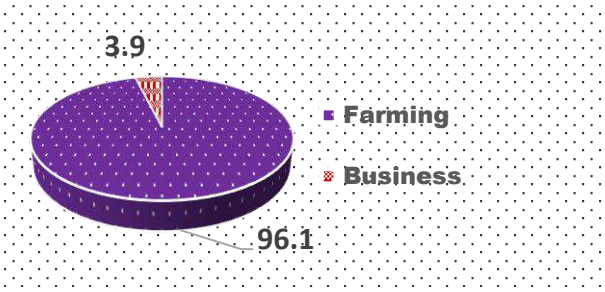

Fig.3. Main source of income for household heads

Figure 3 shows the main source of income for the household heads. Majority (96.1%) of the respondents reported farming as their main source of income with (3.9%) earning from business activities.

Table 1. Information on animal traction

Variables	Category	Frequency	Percent
Have you heard about animal traction?	Yes	129	100
	No	0	0
	Total	**129**	**100**
Source of Information	Other Farmers	92	71.3
	NGOs	13	10.1
	MAF	17	13.2
	Media	7	5.4
	Total	**129**	**100**

Information on animal traction is shown in (table 1). Data indicated that all (n=129) household heads interviewed had awareness about work oxen. Majority (71.3%) of the HH stated that they got information about animal traction from other farmers, while 13.2% cited the Ministry of Agriculture and Forestry (MAF), (10.1%) cited extension workers of Non-Governmental Organizations (NGO's) and (5.4%) stating media as their main source of information.

Table 2. Percentage of utilization, type and sources of work oxen

Variables	Category	Frequency	Percent
Do you use work oxen	Yes	129	100
	No	-	-
	Total	**129**	**100**
Animal used as work oxen	Cattle	129	100
	Buffalo	-	-
	Horse	-	-
	Donkey	-	-
	Total	**129**	**100**
Major source of work oxen	Inheritance	10	7.8
	Gift	13	10.1
	Purchase	89	69
	Hire	17	13.2
	Total	**129**	**100**

Table 2 shows the percentage of utilization, type and sources of work oxen. Data revealed that all the respondents interviewed use work oxen on their farms and solely used cattle as draught animals. Majority (69%) of the HH sourced animals through purchase, with (13.2%) sourcing through hire, (10.1%) deriving them as gifts and 7.8% stating inheritance as their major source.

Table 3. Factors considered in selecting cattle for work oxen purposes

Variables	Category	N	Percent
Sex	Yes	127.0	98.4
	No	2.0	1.6
	Total	129.0	100.0
Type of Sex	Bull	127.0	100.0
	Cow	0.0	0.0
	Total	**127.0**	**100.0**
Size	Small	12.0	9.3
	Medium	78.0	60.5
	Large	39.0	30.2
	Total	**129.0**	**100.0**
Age	Yes	125.0	96.9
	No	4.0	3.1
	Total	**129.0**	**100.0**

N= Number of respondents

Table 3 shows the factors considered in selection of cattle for work oxen purposes. Majority (98.4%) of the respondents cited sex as a major criterion in selecting animals for traction, with only a few (1.6%) who do not consider sex as a factor. However it was interesting to note that, all the respondents (N=127) interviewed prefer bulls rather than cows for the purpose of work oxen. In terms of size as a selection criterion, about (78%) of the respondents prefer oxen with medium body size, (30.2%) prefer large body sizes, with only a few (9.3%) having preference for smaller body sizes. Majority (96.6%) of the farmers considered age as crucial factor in the selection of animals for traction with few (3.4%) neglecting age as a criteria.

Table 4. Farming experience, number of work oxen and farm sites owned and total acreage of land size

Variables	N	Min	Max	Mean	S. D.
Farming experience (years) in using work oxen	129	1	30	9.73	6.173
Number of work oxen owned	127	1	3	1.08	0.61
Number of farm sites	129	1	15	2.52	1.682
Total farm size (acres)	129	1	20	6.93	4.610

N= Number, Min=Minimum, Max= Maximum,

S.D= Standard deviation

Table 4 summarises the level of farm experience in animal traction, number of oxen and farm sites owned and the acreage of farm sites. Most farmers had experience in traction spanning up to three decades with averages of 9.73 years, and a minimum of 12 months. The number of oxen among households were not more than 3 sets with an average of 1 set per household. As regards to the number of farm sites and size of land, all of the respondents had at least a farm site with land sizes not less than an acre or exceeding 20 acres, with a mean of 6.93 acres.

Table 5. Reason for using animal traction

Variable	Category	Frequency	Percent
Why do you prefer animal power over tractor power	Easy to manage	71	55
	Less expensive	40	31
	Higher crop yields	14	10.9
	Affordable & sustainable	4	3.1
	Total	**129**	**100**

Table 5 shows the main reasons why animal traction is preferred over tractor power. Majority (55%) of the household heads stated easy management of work oxen as the main reason why they are preferred over tractors. Most (31%) of the respondents stated that work oxen are less expensive compared to the hiring of tractors which requires the provision of fuel and lubricants. Some (10.9%) of the farmers stated higher crop yields as the major reason for using traction. Few (3.1%) cited affordability and sustainability of the technology as the main reason for using work oxen.

Table 6. Rate the level of availability of animal traction services

Variable	Category	Frequency	Percent
Level of availability of animal traction services	Readily available	42	32.6
	Somewhat available	74	57.4
	Not readily available	13	10.1
	Total	129	100

Table 6 shows the ratings of the level of availability of animal traction services. Majority (57.4%) of the respondents ranked the service as somewhat available. Most (32.6%) of the respondents ranked the service as readily available. Few (10.1%) of the respondents estimated the service as not readily available.

Table 7. Use of animal traction for agricultural activities

Variable	Category	Frequency	Percent
Use animal traction for Ploughing	Yes	129	100
	No	0	0
	Total	**129**	**100**
Use animal traction for Harrow	Yes	64	49.6
	No	65	50.4
	Total	**129**	**100**
Use animal traction for Ridge	Yes	9	7
	No	120	93
	Total	**129**	**100**

Table 7 shows the use of animal traction for agricultural activities. In this study, all respondents (N=129) interviewed stated that they use animal traction solely for agricultural purposes and not for transportation or generation of electricity. Most respondents (49.6%) use animal traction for harrowing with few (7%) of the respondents stated that they used traction to perform ridging.

Table 8. Number of acreage ploughed per day and the time taken

Variables	N	Min	Max	Mean	S.D
Acreage/day animals plough	129	1	8	1.4	0.8
Hours/day animals plough	128	2	8	5.1	1.4
Number of days/week animals plough	128	3	7	5.2	1.0
Number of months/annum animals plough	128	1	5	5.3	9.4

N= Number, Min=Minimum, Max= Maximum,

S.D= Standard deviation

Table 8 shows the time taken for a set of oxen to plough an acreage of farm land. Data revealed that a set of bulls can plough on average an area of 1.4 acres per day and a maximum of 8 acreage per day. According to this study, a set of work oxen ploughs on average 1.4 acres within 5.1 hours. The respondents stated that they use these animals for ploughing an average of 5.2 days per week and 5.3 months within a year.

Table 9. Number of acreage harrowed per day and the time taken

Variables	N	Min	Max	Mean	S. D
No. of acreage harrowed/day	64	1	8	2.2	1.5
No. of hours harrowed/day	64	1	8	4.1	1.8
No. of days/week animals harrow	64	1	6	3.9	1.5
No. of months/year animals harrow	64	1	3	3.7	3.9

N= Number, Min=Minimum, Max= Maximum,

S.D= Standard deviation

Acreage harrowed per day and time taken is illustrated in (Table 9). Results show that work oxen can harrow on

average of 2.2 acres per day within an average period of 4.1 hours a day. Most of the respondents (N=64) stated that their oxen harrow a maximum of 6 days per week with an average of 3.9 days per week. Data also indicated that work oxen operate on farms slightly below four months within the year. It was further observed that out of a total number (N=129) of respondents interviewed (as shown in table 10) only 64 of these farmers use animal traction for harrowing.

Table 10. Number of acreage ridged per day and the time taken

Variables	N	Min	Max	Mean	S.D
Acreage ridged/day by work oxen	9	0.5	2	1.3	0.6
No. of hours/day animals ridge	9	2	9	5.3	2.5
No. of days/week animals ridge	9	3	6	4.4	1.0
No. of months/year animals ridge	9	2	15	5.2	4.9

N= Number, Min=Minimum, Max= Maximum,

S.D= Standard deviation

Table 10 shows the acreage ridged per day and the length of time taken. Few (N=9) of the respondents stated that they utilize animal traction services for ridging.

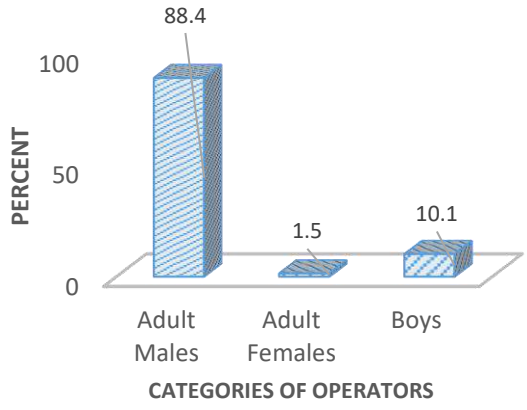

Fig.42. Category of operators

The categories of work oxen operators is depicted in (fig. 4). Majority (88.4%) of the operators comprised of adult males, with (10.1%) being adolescent boys, while only (1.5%) were adult females.

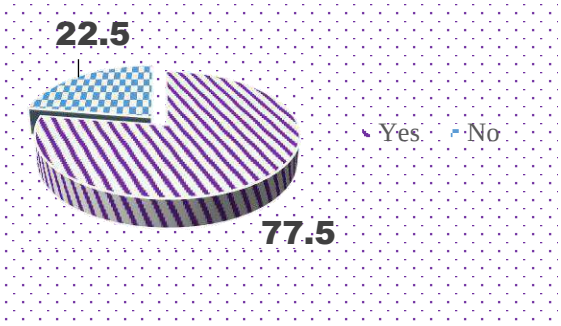

Fig.53. Ownership of implements by household heads

In figure 5, the ownership of implements by household heads is displayed. Majority (77.5%) of the household heads owned implements with those not owning implements accounting for (22.5%) of the respondents.

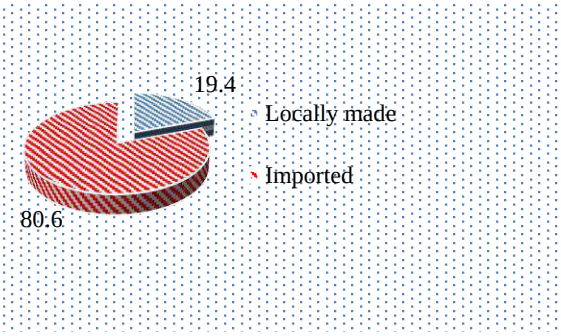

Fig.6. Source of implements

Source of implements is depicted in (fig. 6) Majority (80.6%) of the animal traction implements are imported while only (19.4%) are made locally.

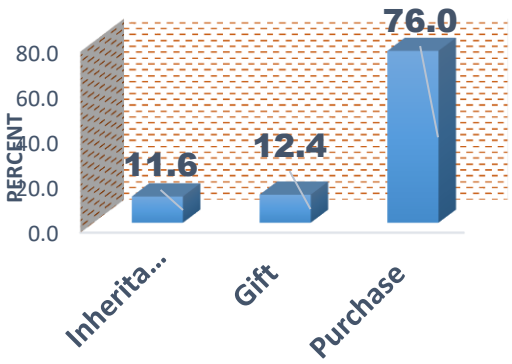

Fig.7. Means of acquisition of implements

The means by which household heads acquire implements is shown in (figure 7). Majority (76.0%) of the respondents stated purchase as a means of acquiring implements, (12.4%) acquiring implements as gifts and (11.6%) through inheritance.

IV. DISCUSSIONS

In this study, majority of the household heads were males. Involvement of women in animal traction will only appear to become comparatively prevalent if there is a higher number of female headed households. Also, barriers to women using work oxen exist and these include; lack of access to assets such as livestock and land which are owned by men and the misconception that animal traction is a male dominated activity.

Ethnicity of respondents engaged in animal traction is mainly dependent on their location, land topography and ecology. It was observed that the most dominant groups using the technology were much closer to Guinea, and this proximity gave them relative advantage through greater access to oxen, implements and operators.

Farming was the main source of income of household heads and this result is in consonance with [12] report which states that, farming is a major economic activity in the rural areas of the country due to the availability of arable land and cheap labour.

The level of awareness of a technology is likely to be higher in areas to which that technology is better suited. In this study, awareness of work oxen was very high among the respondents. The dominant source leading to awareness was farmer-farmer source with marginal contributions from MAF and NGO's. As expected, media was the least source as most household heads in the remote rural areas do not have access to radio, television and internet coverage.

Household heads used work oxen on their farms and cattle was the only draught animal used. This is the case because, during the period when animal power was introduced in the country, cattle was the sole animal used. Infestation of tsetse flies in rural areas hindered the use of other draught animals such as horses and donkeys which were susceptible to trypanosomiasis as opposed to the trypanotolerant N'dama cattle. Oxen was mostly sourced through purchase and this was due to the fact that since the work oxen program at Rolako came to an end, no promotional schemes now exist to provide farmers with sets of oxen.

Sex of cattle was a major criterion in the selection of draught animals, and respondents preferred bulls to cows. The preference of bulls as work oxen is mainly due to the fact that, they can be castrated, which reduces their temperament and eliminates their libido thus improving docility. This is in concurrence with [8] who observed that castrated bulls remain the dominant draft animals in West Africa. Medium sized animals were mostly preferred as farmers opined that they are easier to control. Age of animals was also a crucial factor, and farmers said they preferred animals aged 2 years as young animals can be easily trained and will last longer as work oxen as opposed to older ones.

Household heads had a relatively long experience in using animal power and some of them most likely benefited from the traction schemes of the late 1980s or are descendants of the initial beneficiaries. During that time, implements and oxen were supplied to farmers to encourage them adopt the technology and as expected they might have transferred their knowledge and skills to the younger generation. Work oxen were owned by most household heads with few stating non-ownership. According to the study, majority of the farmers owned at least a set of oxen, however, they complained that at the start of the planting season a set of bulls might not be enough to plough their fields in time.

Household heads cited easy management of work oxen as a main reason why they are preferred over tractors. They further opined that ease of management are manifold; first, oxen can be handled by young boys. Second, animal traction can plough small farms sizes which are scattered and have irregular topography as opposed to tractors which normally operates on medium to large farms. Lastly, animal traction requires less technical operators compared to tractors which require specialized personnel for its operation.

The use of work oxen was considered cheaper than tractor power as the operational and maintenance costs of oxen is lower. Higher crop yield was cited as a reason for using animal traction as it has the potential to increase yields through timeliness of farm operations and deeper ploughing. Also, the use of work oxen improves soil fertility through the deposition of urine and manure on crop fields by the animals.

In terms of availability of animal traction services, most farmers who declared the service to be readily available, were those who own cattle and had easier access to implements and operators. Respondents who gauged animal traction services as somewhat available, attributed this to the fact that, the number of farmers that require the service per production season outweighs the number of traction service available. Farmers who said traction services were not readily available are those who do not own cattle and live far from Guinea thereby making it difficult for them to source the implements.

In this study, animal traction was majorly used for ploughing as it is the main activity in crop cultivation. This is in line with [7] who reported that majority of farmers utilize traction mainly for ploughing. Reasons for this is due to the fact that, the plough can be easily sourced and much cheaper compared to other implements such as the harrow and ridger. Furthermore, most of the operators of work oxen

were trained to operate the plough and not the other implements.

In this study, operators of work oxen were mainly adult males and this is consistent with the report of [5] which stated that operators of work oxen are predominantly male, with few adolescent boys and rarely women. The low occurrence of women as operators can be attributed to the fact that animal traction operations are labour intensive and are better suited to men. Also, due to the numerous roles women play in the household on a daily basis, not much time is left to engage in work oxen operations.

According to the study, most respondents had implements of their own with most sourcing these equipment through purchase and a few through inheritance or as gift token from the work oxen program at Rolako in the 1970's and 80's.

Implements used were mostly imported from guinea and comprised of ploughs, harrows and ox-carts. However, a type of locally made plough referred to as the pecotool was encountered and according to the respondents, these were fabricated at the Rolako centre in the 1980's. Implements such as chains, yokes and ropes, were made from locally available materials such as scrap metal, wood and fibre respectively. Farmers expressed need for a fabrication facility, as particularly, lack of spare parts and repair services were indicated as the main challenges.

V. CONCLUSION

Findings indicates that, the involvement of women in animal traction was very low. The dominant tribes utilizing work oxen were mostly cattle owners found in pastoralist societies close to Guinea. Their location gave them comparative advantage in using work oxen as they had access to draft animals, implements and repair services. The awareness of animal traction was very high and sources leading to awareness were mainly from other informed farmers with Government, NGO's and the media playing less roles in extension. Animal power was used only for agricultural purposes and not for packing or transport. Despite the devastation of the work oxen programme as a result of the decade-long civil war, draught power is still a viable means of assistance to farmers during and after the cropping season. Cattle was the sole animal used for traction as their trypano-tolerance made them ideal for use in tsetse infested areas. Bulls were preferred to cows as work oxen and this implies that they are more dispensable in herd multiplication programmes. Even though farmers had lots of experience in using work oxen on their crop fields, sufficient technical know-how on handling, nutrition and management of oxen was grossly lacking. Most households owned at least a set of work oxen and those that did not own oxen complained that access to credit facility was a major constraint. According to the number and acreage of farm sites cultivated in these study areas it can be inferred that most were small to medium farm holdings. The adoption of traction technology was very high as it was reported to be easy to manage, cost effective, available and sustainable and also produced higher crop yields compared to human or tractor power. Work oxen was used mainly for ploughing and was reported to be more efficient on small acres of land. Implements such as ploughs and harrows were sourced from Guinea as presently no fabrication facility or blacksmiths trained in the manufacture of traction equipment exists.

The use of man and tractor power will continue to have a huge space in the agriculture sector in the country. However, results from this study suggests that animal traction is generally the best option for small-scale farmers as it is affordable, sustainable, and profitable. A major limitation of the study was that no gross margin analysis was conducted to comparatively determine the cost effectiveness and production levels of human, animal and tractor power.

VI. RECOMMENDATIONS

Based on the opportunities and constraints revealed in this study, it is recommended that;

- Women's livelihood be supported by improving their access to ownership and utilization of livestock and technologies for enhanced agricultural production.
- To aid in the level of adoption of animal traction technology, farmers should be supplied with animals and traction implements on a loan basis, possibly at a subsidized rate.
- Work oxen training centers be established and the local manufacture of animal traction equipments be further developed through reopening of the national blacksmith factory.
- Research programs be conducted on all aspects of the use of animal power in farm production.

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Poultry Farmers Willingness to Pay for Agricultural Insurance Policy in Kogi State, Nigeria

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Abstract— *This study looked at the factors that affect poultry farmers' willingness to pay for insurance. Using a standardized questionnaire, 120 farmers was randomly chosen. Binary logistic regression, the t-test, means, frequency distribution, and percentages were utilized to examine the data. One of the main conclusions was that most farmers were men. The bulk of respondents (96.7%) were found to be literate, with the average age of farmers being 44 years old. The majority of responders (72.5%) were married, and poultry farmers had an average of about 12 years of experience. The majority of respondents (62.5%) lived in households with an average of six people and did not belong to any cooperative societies. About 70% of survey participants said they had never used extension services. Before and after owning an insurance policy, a farmer's average yearly income was ₦145,110.83 and ₦252,692.92 respectively. About ₦5466.87 was the average price that poultry farmers were ready to pay. Income, extension access, awareness, cooperative society membership, access to credit, gender, flock size, marital status, and distance, at 5% probability levels, were the characteristics that affected willingness to pay. In order to enhance willingness to pay for poultry insurance, the study recommends measures that would increase poultry farmers' access to agricultural insurance at subsidized rates.*

Keywords— ***Poultry, farmers, WTP, insurance policy***

I. INTRODUCTION

Agriculture is a major contributor to the economies of most developing countries, and Nigeria's economy has profited immensely from it since independence (Jatto 2019). Agriculture, which accounts for close to 40% of the country's GDP, plays a vital role in livestock production (Hirfrfot et al 2014). The agricultural sector, according to Adah et al. (2022), performs a variety of significant functions in enhancing food security, employment creation, foreign exchange earnings, the provision of industrial raw materials, the alleviation of poverty, and environmental sustainability. A crucial element of Nigeria's agricultural economy is poultry farming. It has been well-liked by the populace in virtually all parts of Nigeria as a result of its prolific tendencies and speedy returns in the form of money and other concrete benefits (Akerele et al 2022).

Regardless of the recent finding of crude oil and the fast industrial development that has been seen in Nigeria, agriculture still has a significant impact on the country's economy. Prior to the dominance of crude oil, agriculture was the primary source of foreign exchange. Now that oil production is declining, there is a lot of pressure on Nigeria to diversify its economy. As a result, the government is now concentrating on the agricultural sector in an effort to encourage its expansion as a vehicle for industrial development, food security, and foreign exchange (Akinbamowo 2013).

Despite the fact that the poultry industry has made tremendous technical progress over the past ten years and has continued to support Nigeria's food security and economic expansion, the sector still faces numerous challenges. The success of Nigeria's farming sector is seriously threatened by these risks because they are difficult

to predict**.** The risks involved in farming have been broken down into five categories: production, marketing, financial, institutional, and human risks, according to Anosike et al. (2018). Poultry production is not risk-free. Risk factors that commonly increase production include the weather, predators, theft, droughts, floods, and pest and disease outbreaks (Mapiye et al 2018).

Market risks arise when input and output costs alter as a function of supply and demand fluctuations in the market (Taiwo et al 2019). Financial issues arise when there are uncertainties over the continuation of credit extensions, interest rates, and the proportion of farmers who default on their loans. Human risks are those that affect a farm's profitability because of aspects related to the people who run it, such as bad health, while institutional risks are those that affect a farm's productivity and profitability as a result of changes in governmental rules (De Vries, and Marcondes 2020). Farming communities face a variety of dangers. Even though they have created strategies to stop, reduce, lessen, or manage these risks, there are still problems with residual risks. These are the kinds of tragedies that human activity is powerless to prevent or lessen. The damage they cause to persons and property just cannot be overstated. In such cases, Agricultural insurance might be useful (Assa et al 2021).

Agricultural insurance is defined as the process of stabilizing income, employment, price, and supplies of agricultural products through regular, intentional accumulation of funds in small amounts by many participants during advantageous times to protect some or a small number of participants during adverse times (Jatto 2019). In other words, risk management includes the use of insurance. The basic objective of any farm insurance policy is to serve as a safety net for losses caused by catastrophes. Additionally, it serves as security for bank loans given to farmers for agricultural reasons (Taiwo et al 2019).

Due to problems like high administrative costs, moral hazard, adverse selection, and the protracted delay in indemnity payments in the event of a farm disaster, the majority of Nigerian farmers are not enthusiastic about purchasing agricultural insurance policies. These problems have all discouraged reliance on this insurance option (Cariappa et al 2019). Consequently, just 1% of farmers choose to be covered by agriculture insurance as a whole (Afroz et al 2017). When it comes to rearing chickens, Gbigbi and Ikechukwuka (2020) contends that farmers who have insurance are able to make substantially larger investments and riskier production choices. The insurance program's objective is to safeguard chain participants against the financial ramifications of conceivable agricultural loss scenarios. According to a prior study, the low adoption of agricultural insurance in developing nations may be related to a lack of knowledge of the programs and a poor comprehension of insurance (Kandel and Timilsina 2018). Prior study by Gbigbi and Ikechukwuka (2020) have shown that the demand for micro-insurance products is influenced by a variety of farmers' economic, social, structural, individual, and institutional factors. They reported further that farmers' engagement of crop insurance is apparently influenced by their access to financing, income, and extension services.

Kumari et al (2017) looked into how respondents' socioeconomic characteristics affected their willingness to take crop insurance plans. Discriminant analysis was used by them. According to the research, factors that affected willingness to pay included age, income level, household size, and education level. Other factors included farm size, degree of satisfaction, awareness, and availability to funding. Farmers who earn more money are more inclined to use other risk management techniques, hence it was discovered that farm income has a negative impact. High income farmers are shown to be more ready to pursue other tactics, even if they are more expensive, than purchase insurance.

Idiaye et al. (2020) looked at consumer perceptions and willingness to pay (WTP) for safety and novel aspects of processed chicken meat in Oyo State, Nigeria, while taking into account their risk aversion. The results of the logit regression model demonstrated that sex, household size, major occupation, being a supermarket shopper, income, and age had a substantial impact on customers' willingness to pay a premium for the innovative and safe characteristics of processed chicken meat. The average WTP was calculated to be 1,613.16 Naira. These WTP investigations were all conducted elsewhere than the research location. To the best of my knowledge studies on willingness to pay for poultry insurance by farmers is scanty. This is a serious gap this study has addressed. Therefore current information on poultry farmers' WTP for insurance to guide policy makers for meaningful development becomes vital. The objectives were specifically to

i. describe the socioeconomic traits of poultry producers
ii. ascertain the sources of insurance awareness
iii. estimate the amount farmers are willing to pay
iv. examine the effect of ownership of insurance policy on income
v. determine the factors inducing poultry farmers' WTP insurance

II. MATERIALS AND METHOD

The Study Area

The study was conducted in Kogi State, Nigeria. It is situated between latitude 70 49'N and longitudes 60 45'E. Kogi State consists of 21 local government areas and is broadly divided into three agricultural zones namely A-East, B-West and C-Central (Adah et al 2022). The two main seasons of the climate are dry and wet. March ending marks the beginning of the wet season, which lasts until the end of October. The dry season starts in the month of November and lasts until the end of February. Between December and January, when it is dry, the harmattan wind blows. The annual rainfall ranges from 850 to 2000 millimetres with mean temperature of 280°C during the rainy season and 350°C during the dry season. The main occupation people are agriculture. Also, livestock resources include goats, poultry, pigs, cattle and sheep which are traditionally reared on free range by the farmers. Figure 1 shows the map of Kogi State.

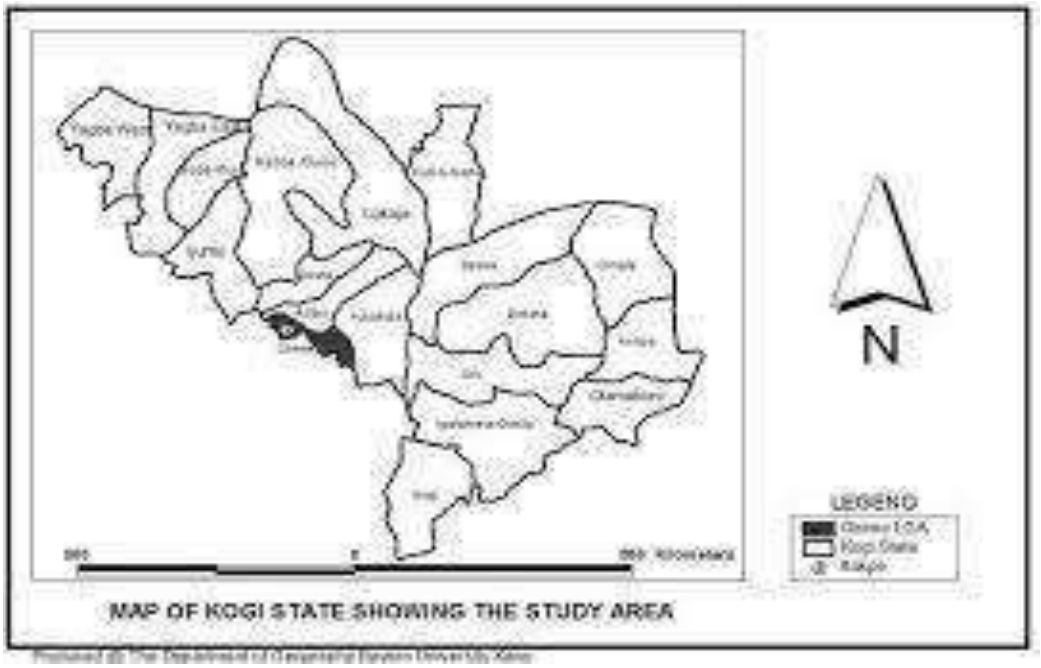

Fig.1: Map of Kogi State

Method of Data Collection/ Sampling Procedure

Data for this study was obtained mainly from primary sources through a well-structured questionnaire. A multistage random sampling procedure was used for this study. The first stage involved a purposive selection of one local government area in each agricultural zone with higher poultry farms and dense population. The second involved the random selection four (4) major communities from the three districts of each selected local governments giving a total of 12 communities. In the third stage entails random selection of 10 respondents each totally 120 farmers.

Method of Data Analysis

Descriptive statistics and inferential statistics such as the logistic regression model was utilized to achieve the objective.

Model Specification

The logit regression model is a multivariate technique which allows for estimating the probability that an event occurs or not by predicting a binary dependent outcome from a set of independent variables. The logit model is based on cumulative logistic probability function and it is computationally tractable.

The Logistic regression is specified as:

$$Pi = \frac{1}{1 + e^{-Y*i}} = \frac{n(n-1)x^2}{1 + e^{-(\beta 1 + \beta 2x + \mu i}}$$

$$1 - Pi = \frac{e^{-(\beta 1 + \beta 2x + \mu i}}{1 + e^{-(\beta 1 + \beta 2x + \mu i}}$$

Let $\beta_1 + \beta_2 x + \mu i = z$

Then it become

$$1 - Pi = \frac{e^{-z1}}{1 + e^{-z}}$$

Rearranging

$$e^{z} = \frac{Pi^{-z1}}{1 - Pi}$$

Taking the log of both sides

$$lne^{z} = ln\left(\frac{Pi}{1-Pi}\right)$$

$$z_1 = ln\left(\frac{Pi}{1-Pi}\right)$$

$$\ln\left(\frac{Pi}{1-Pi}\right) = \beta_1 + \beta_2 x_1 + \mu i$$

The cumulative logistics probability model is econometrically specified as follows:

$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 \ldots\ldots\ldots\ldots \beta_{12}/X_{12} + \mu$

Where Y = WTI (dummy, if the farmer is willing = 1. Otherwise = 0).

β_0 = Intercept

β_1 -β_{13} = Coefficient of independent variables

X_1 = Age of respondents (years)

X_2 = Educational status (years in formal schooling)

X_3 = Income (₦)

X_4 =Access to Extension services (1 access, 0 if no access)

X_5 = Awareness of insurance scheme (1 if aware, 0 if not aware)

X_6 = membership of cooperative (1 if member, 0 if otherwise)

X_7 = access to credit (1 if member, 0 if otherwise)

X_8 = Gender of respondents (1 if male; 0 if female)

X_9 = Farming experience (Number of years in farming operation)

X_{10} = Flock size (number of birds)

X_{11} = Marital status

X_{12} = Distance to insurance institutions (km)

μ_I = Stochastic error term

III. RESULTS AND DISCUSSION

Table 1 showed the socio-economic attributes of the respondents.

Gender of Respondents: The majority of farmers (80.0%) were men, with only 20.0% being women. This might be the case because raising chicken, like raising other livestock, requires a lot of energy, and men can engage in more strenuous activities than women can. The findings suggested that chicken farming is still primarily a male occupation, probably as a result of the high amount of risk involved, labour-intensive nature of the industry, and other husbandry procedures that are not appealing to most women. The research by Gbigbi and Isiorhovoja (2022) is in line with this conclusion.

Age of respondents: The respondents were primarily middle-aged, or between the ages of 30 and 49, with 77 respondents, or 64.2%, of the total. 33.3% of the sample was made up of farmers who were over 49 years old. 2.5% of respondents of farmers were under 30 years (Table 4.1). The average age of individuals who might consider buying insurance was 44. This means that the majority of the respondents were in a period of economic activity, which may have had a beneficial impact on their willingness to pay for insurance.

Educational level: The results showed that 49.2% of the respondents have completed at least secondary school, while 36.7% and 10.8% have tertiary and primary school, respectively, and 3.3% have not completed any formal education. The majority of respondents were literate, as evidenced by this. Because education is thought to have a good impact on decision-making ability and resource utilization in business management, educated respondents were more inclined to buy insurance than uneducated respondents. This study agrees with Kumari et al. (2017), who found that chicken producers had a high level of education.

Farming Experience: The majority of respondents (38.3%), had farming experience ranging from 6 to 10 years. Following closely after were 30.8% of the respondents with 11–15 years of farming experience. About 24.2% of people had been farmers for more than 15 years. The percentage of respondents with less than five years' experience in poultry farming was 6.7%. Twelve years on average were spent farming. The vast amount of farming experience of the respondents may have influenced their aptitude for using technologies and other risk management techniques. This shows that the production of poultry has been a long-running industry in the area under study. This is anticipated to show up in high level poultry management because as a farmer gains more exposure and expertise, they are also predicted to be more effective.

Household Size: The majority of farmers (51.7%) had households with four to six people, while 28.3% had seven to nine people. 12.5% of households had a size greater than 9. Only 7.5% of those surveyed lived in households with one to three people. The average household size of those willing to pay for insurance was 6 persons. This can assist in providing family labour for farming activities.

Cooperative Membership: Only 37.5% of farmers are members of one or more cooperative societies, compared to the majority of respondents (62.5%) who did not belong to

any cooperative societies. Cooperative membership enables farmers to receive credit, knowledge, and inputs through collective bargaining. But it's expected that farmers who aren't part of cooperatives will utilize agricultural insurance schemes less frequently and have less prospects of adoption. This findings is consistent with Gbigbi and Ikechukwuka (2020).

Extension Services: In the research area, only 30% of respondents used extension services to enhance their willingness to pay for insurance, while 70% of respondents did not increase their want to pay for insurance by doing so. Contrary to Ovharhe et al. (2020)'s findings, which indicated that 76.3 percent of respondents had access to extension services during the previous farming season.

Marital Status: Most farmers (72.5%) were married, compared to 27.5% who were single. The findings suggest that being married is a sign of someone choosing to behave properly toward others. It might have a positive effect on agricultural production, particularly in terms of labour availability. The most prevalent form of employment of the majority of Nigeria is subsistence agriculture, with family labour being regarded as the most important component of labour. The findings of this research are consistent with those of Gbigbi and Isiorhovoja (2022), who reported greater percentages of married respondents.

Access to credit: While 56.7 percent of respondents had access to credit from financial institutions, just 43.3% of respondents lacked access to credit to boost productivity. Before credit can be secured, the majority of farmers who get government financial assistance are always required to sign up with insurance companies. As a result, these recipients' farmers indirectly participate in the insurance scheme. Increased production volume due to easier access to financing will affect farmers' level of output.

Table 1: Socioeconomic Attributes of the Producers

Variable	Frequency	Percentages	Mean/Mode
Gender			
Male	96	80.0	Male
Female	24	20.0	
Age (years)			
< 30	3	2.5	
30-39	33	27.5	
40-49	44	36.7	44 years
50-59	30	25.0	
Above 59	10	8.3	
Educational level			
No education	4	3.3	
Primary education	13	10.8	Secondary
Secondary education	59	49.2	
Tertiary	44	36.7	
Marital status			
Married	87	72.5	Married
Single	33	27.5	
Accessibility to credit			
Yes	68	56.7	Yes
No	52	43.3	
Cooperative membership			
Member	45	37.5	
Non-member	75	62.5	Non members
Household size (number)			
1-3	9	7.5	
4-6	62	51.7	6 persons
7-9	34	28.3	

Above 9	15	12.5	
Experience (years)			
1-5	8	6.7	
6-10	46	38.3	
11-15	37	30.8	12 years
Above 15	29	24.2	
Extension services			
Yes	36	30.0	No
No	84	70.0	

Sources of Insurance Awareness

Table 2 demonstrated that farmers obtain information from a variety of sources, such as the farmers cooperative society (96.7), their fellow farmers (95.0%), radio (90.0%), and newspapers (38.1%), which play a significant role in informing farmers about the various insurance services offered by the public sector and private insurance companies. The least often cited source of information in the research area was insurance companies (20.0%). The outcome is similar with studies on information uptake in Nairobi by (Kaee, 2019).

Table 2: Means of Insurance Awareness

Means of awareness	Frequency	Percentage	Rank
Radio	108	90.0	3rd
Television	30	25.0	6th
Fellow farmers	114	95.0	2nd
Farmers' cooperative society	116	96.7	1st
Newspaper	46	38.3	4th
Insurance providers	24	20.0	7th
Extension agents	42	35	5th

Multiple response

Average Amount Willing-to-Pay for insurance

The amount that the respondents were willing to accept as agricultural insurance is shown in Table 3. The findings indicate that 60.0% of the interested respondents were willing to pay an insurance premium of N5000 or less. About 28.3% of the respondents indicated that they would be willing to spend between N5000 and N10000, while 10% said they would spend between N10001 and N15000. Only 1.7% of the interested farmers, however, were prepared to spend more than N15,000 year. The average cost for those eager to purchase insurance was N5466.87. According to Oduniyi et al. (2020), only 10.8% of livestock farmers in South Africa are prepared to pay for Index-Based Cattle Insurance at a maximum cost of R600 (N15,844.50) per unit of livestock, which is far more than the price used in this study.

Table 3: Price Farmers Are Willing to Pay for insurance

Amount (₦)	Respondents	Percentage	Mean (₦)
5000 and below	72	60.0	
5001-10000	34	28.3	5466.87
10001-15000	12	10.0	
Above 15000	2	1.7	

Ownership of insurance policy on income

According to Table 4 findings, most farmers (39.1%) netted between N100,001 and N200,000 per year. About 35.0% of farmers got less than N100,000 per year, 17.5% realized between N200,001 and N300,000 per year, and 6.7% earned between N300,001 and N400,000 per year. A little over 1.7% of farmers had incomes above N400000 prior to purchasing insurance. Prior to owning an insurance coverage, the average annual income was N145,110.83. Similarly, the statistics show that 13.3% of the farmers made N100,000 or less annually. Approximately 19.2% of farmers got between N100,001 and N200,000 in income, 32.5% made between N200,001 and N300,000 in income, and 30.0% made between N300,001 and N400,000 in income. About 5.0% of farmers who owned insurance policies made more money than N400000. After owning an insurance policy, the average income was N252,692.92. The outcome reveals that the income of poultry producers increased by 74% in business. This outcome is explained by the fact that having access to insurance can help businesses flourish.

The findings provide unmistakable proof that after participating, the average income of those who had insurance policies increased dramatically. This was demonstrated by the results, which showed that most farmers made less than N200,000 annually prior to owning an insurance policy but that most of them made more than N200,000 thereafter. This implies that farmers who earned more were more inclined to buy insurance. The conclusion that follows is that insurance greatly boosted the revenue of the scheme's participating farmers. This research supported that of Taiwo et al (2019). In Delta State, Ovharhe et al. (2020) reported a comparable outcome for participants in an extension intervention, who saw their farm income rise from N239,573.46 to N381,753.56.

Table 4: Ownership of insurance policy on income

Income before insurance	Frequency	Income after insurance	Frequency
100000 and below	42(35.0)	100000 and below	16(13.3)
100001-200000	47(39.1)	100001-200000	23(19.2)
200001-300000	21(17.5	200001-300000	39(32.5)
300001-400000	8(6.7)	300001-400000	36(30.0)
Above 400000	2(1.7)	Above 400000	6(5.0)
Mean=₦145,110.83		Mean=₦252,692.92	

Figures in bracket are percentages

Determinants of poultry farmers' willingness to pay for insurance

Table 5 displays the findings of the logit regression estimates of the factors that affect poultry farmers' willingness to pay. In accordance with the statistical diagnostic test, the computed model fit the data well, with chi-square statistics significant at the 1% level of significance. This suggests that the model's indicated variables are pertinent to understanding the respondents' decision to pay. Furthermore, the Log-likelihood statistic ratio (LR) of 47.857 was significant, indicating that the independent variables in the model collectively contributed to the chance that the poultry producers' willingness to pay was explained.

Farm income: With regard to willingness to pay for insurance, the farm income coefficient was positively significant at the 5% level. This suggests that a 1% rise in the farmers' income would result in a 1% increase in their willingness to pay for insurance. This outcome was anticipated since high-income farmers were likely to accept insurance more readily than their low-income counterparts. This could be the result of the fact that people with high farm incomes are more inclined to employ risk management strategies despite the high expense, whilst those with low incomes might not be able to. This may help to explain the favorable correlation between farm revenue and farmers' capacity to purchase livestock insurance. This finding is in line with the findings of a related study by Kumari et al (2017), who found that when crop farmers' income rises, so does their capacity to pay insurance premiums.

Access to Extension: With a 5% willingness to pay for insurance, the access to extension coefficient (5.334) was favorable and statistically significant. Farmers' purchasing decisions are positively impacted by extension services because they provide them with crucial information on modern technologies, management techniques, and husbandry practices. The coefficient of access to extension services is 5.334, which implies that a further rise in access to extension services will lead to an increase in willingness to purchase insurance of 5.334 units. Numerous studies have shown that the likelihood of farmers enrolling in

insurance, which teaches them how to manage risk, increases as the number of farmers who use these services increases. Similar to how Ovharhe et al. (2020) found a positive link between extension services and willingness to participate, this result is consistent with their findings.

Awareness: The likelihood of farmers purchasing livestock insurance was significantly influenced by their knowledge of insurance. Comparatively speaking to their peers who lacked information, farmers who were aware of the insurance plans that were being given were more likely to buy insurance. According to the data, awareness status (4.122) is positively correlated with the likelihood that a person will decide to purchase an insurance, and at a 5% level of confidence, this correlation is statistically significant. According to the analysis, farmers who are aware of insurance find it simple and convenient to pay for insurance services. This is not surprising because awareness implies some understanding of the scheme's workings and economic significance. Therefore, a farmer who is aware of the policy and has a basic understanding of insurance advantages is more likely to accept and pay for insurance than one who doesn't even grasp the fundamentals of the program. This observation demonstrates that knowledge of any topic is essential for making decisions. This was consistent with research by Gbigbi and Ikechukwuka (2020), who found a link between patronage and insurance awareness. This demonstrates that farmers are more likely to adopt an insurance policy as a risk management technique the more information they obtain about livestock insurance.

Cooperative Membership: At the 5% level of significance, there is a negative correlation between cooperative membership and the likelihood that a chicken farmer will get insurance (-5.636). This suggests that compared to their counterparts who do not belong to any cooperatives, poultry producers who are members of cooperative societies are more inclined to not participate in insurance schemes. The adoption of insurance seems to be extremely sensitive to membership in economic associations. This is true because economic organisations, such as farmer groups and cooperatives, give its members access to loans as well as knowledge on new advances

.**Access to credit**: The chance of making a decision on readiness to pay was directly correlated with the coefficient of access to credit (3.111) of the poultry farmers at the 5% level of significance. According to the implication, farmers who have access to credit are more likely to pay for insurance services than farmers who do not. The majority of farmers responded that having an insurance certificate makes it easier for them to acquire bank loans, thus they joined insurance plans to boost their loan eligibility. This supports the argument made by Gbigbi and Ikechukwuka (2020), who claimed that access to credit and participation in the program were positively related.

Gender: The finding that the gender of the poultry farmers was positive and significant at 5% suggests that male poultry farmers are more inclined to pay for insurance policies for their poultry farms than female poultry farmers. Sex was also discovered to have a substantial impact on African farmers of arable crops who purchase insurance in the study by Gbigbi and Ikechukwuka (2020).

Flock size: It is clear from Table 4.11 that the coefficient of flock size (0.002) has a significant role in predicting whether or not chicken producers are prepared to pay for insurance. This variable has a positive correlation with farmers' participation in the program, which suggests that farmers who invested more in their businesses are more likely to insure their farms than their counterparts who made smaller investments. This makes sense because a farmer who has made a significant financial commitment will want to protect his or her investment by getting farm insurance to avoid having to lose everything in the event of a disaster, which is typical in the poultry industry. Similar to this, additional research in Namibia, Nahas et al (2018) and Ethiopia, Amare et al. (2019), found a favorable relationship between household willingness to pay for index-based livestock insurance and herd size (2018).

Marital Status: Marriage status and readiness to pay for insurance exhibited a positive correlation with a statistically significant value of 3.713. Farmers who are married are obligated to enroll in insurance in order to lessen the risks to their home and the negative repercussions that may follow. Married people are more likely to have larger households and more obligations, and they are therefore more ready to pay more for insurance to protect their families and lessen their risk exposure.

Distance to insurance office: The coefficient of distance had inverse relationship with willingness to pay. This suggests that when farmers are further away from their locations, their willingness to pay for insurance will also decline. However, the desire to pay for insurance increases with proximity to the sites of insurance companies. The outcome is in line with Bogale's (2015) findings, which show that distance from the insurance office significantly reduces WTP for implementing insurance. Given that the poultry industry involves regular risks and uncertainties, the researcher chose the variable distance from insurance institutions as a relevant predictor variable.

Table 5: Determinants of poultry farmers' willingness to pay for insurance

Variable	Coefficient	Std. error	Wald	Sig.	Exp(B)
Age	0.037	0.048	0.593	0.441	1.037
Education	0.391	0.685	0.326	0.568	1.478
Income	0.000	0.000	4.011	0.045**	1.000
Extension access	5.334	1.585	11.322	0.001**	207.324
Awareness	4.122	1.418	8.449	0.004**	0.016
Cooperative	5.636	1.683	11.220	0.001**	0.004
Credit access	3.111	1.305	5.685	0.017**	22.438
Gender	5.061	1.563	10.489	0.001**	157.814
Experience	0.069	0.082	0.723	0.395	1.072
Flock size	0.002	0.001	10.641	0.001**	1.002
Marital status	3.713	1.345	7.619	0.006**	40.993
Distance	-0.117	0.031	14.127	0.001**	1.124
Constant	12.493	4.697	7.074	0.008	0.000
–2 Log-likelihood	*47.857*				
Cox & Snell R-square	*0.600*				
Nagelkerke R-square	*0.820*				

Hypothesis

The resulting null hypothesis was tested.

T-test on Income before and after ownership of insurance policy

The average yearly agricultural income of farmers was N145,110.83 prior to owning an insurance policy, but it increased to N252,692.92 afterward (Table 6). This outcome showed that farmers' farm revenue increased significantly as a result of the policy. The average yearly agricultural income of the farmers increased by N107,582.08 as a result. At the 5% confidence level, the results showed that the t-value of 20.485 was significant. This demonstrates that there is sufficient facts to reject the null hypothesis and draw the conclusion that the income of farmers before and after purchase of an insurance policy differs significantly. This improves the outcome of descriptive statistics Table 4. However, the outcome is consistent with research by Taiwo et al (2019). This is a result of farmers' increased confidence following the adoption of an agricultural insurance policy that the insurer will indemnify them in the case of any loss resulting from risks and uncertainties in their business operations.

Table 6: T-test on Income before and after ownership of insurance policy

Variable	Mean	Std. deviation	Mean diff.	t-cal	Sig.
Income before	145,110.83	98,234.34	107,582.08	20.485	0.000
Income after	252,692.92	108,603.14			

IV. CONCLUSION

The research explored the willingness of poultry farmers to pay for insurance. On the average, the farmers were willing to take insurance if the premium is not greater than ₦5466.87. The information of factors affecting farmers decision to pay for insurance policy may assist as a basis for government line agencies to draft inclusive guidelines for poultry farm risk management. The gathered knowledge from this study on farmers influential factors for WTP of livestock insurance may help the government extension workers to expand their awareness program in more vulnerable areas and in a more organized manner. The majority of farmers obtained information on insurance from cooperative organizations, other farmers, and radio. The findings showed that agricultural insurance schemes significantly affect farmers' income and flock size. The results and conclusions drawn from this study will contribute to the body of knowledge available to policy

makers for determining the socially optimal charges for insurance services in Kogi State and other parts of the country.

The following policy recommendations therefore, arise from the study:

i. This study recommends that, in order to encourage more poultry producers to participate in agricultural insurance, the government lower the price at which they can get agricultural insurance coverage.

ii. According to the study, the government should create a policy that will reduce the cost of livestock insurance for poultry breeders in order to encourage them to buy it.

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The Selectivity of Buton Pot's Escape Gap in Kotania Bay, Maluku, Indonesia

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Abstract— *This research was aimed at proving the differences between the catch results of fish trapped inside the bubu buton (fish pot) and those that escaped through the escape gap and to analyze the selectivity of the escape gap for the dominant trapped fish. This research was carried out in Kotania Bay in the period of March-May 2019 through fishing experiment. Five units of bubu buton with a dimension of 70x70x26 cm, containing 4 escape gaps in each unit, were used during the experiments carried out with a total of 11 trips. The results showed that there were 19 fish families caught during the study, dominated by Scaridae family. There was a significant difference between the weight of the trapped fish and those that escaped through the escape gap at the significance level of t_α0,05. Among the 19 families caught, the trapped percentage was different between the fish trapped inside the fish pot and those that escaped through the escape gap. The 50% trapped and escape chance (L50) of the Scaridae family from the escape gap was found in fish with a total length of 22.3 cm, which became the indication of sustainable management.*

Keywords— ***Fish pot's, escape gap, Scaridae, 50% trapped chance.***

I. INTRODUCTION

One of the bay waters with potential biological resources in Maluku is Kotania Bay, located in West Seram Regency. There are 4 (four) important ecosystems in the Kotania bay area, namely estuarine, mangrove, seagrass and coral reef ecosystems which make it rich in marine aquatic resources [1]–[3]. In the seagrass ecosystem, Kotania Bay contains 28 fish families, consisting of 40 fish species, dominated by the Siganidae, Lethrinidae, Lutjanidae and Scaridae families [4]. To take advantage of fish resources in Kotania Bay, fishermen use a variety of fishing gears, namely gill nets, handlines, bottom-trolling line, and fish traps/pots.

The fish pots used by fishermen to catch various species of coral reef fish in Kotania bay are called bubu buton, which are similar to those used by fishermen in the Kepulauan Seribu known as bubu tambun. This is a passive fishing gear that allows fish to enter it easily but will be difficult for them to escape [5]. Fish pot has several desirable characteristics for modern fishing gears (Cole et al., 2003; Dayton et al., 1995). These characteristics are; it needs less labor and uses low energy when compared to the active fishing gears; it only affects the seabed area in accordance with the size of the pot itself; the fish caught alive have minimal physical damage which is a prerequisite for high quality products; the fish caught alive result in unnecessary by-catch to be released back into the sea with low mortality. These characteristics show that it is more environmentally friendly as fishing method than the other gears.

Even though fish pot is considered as an eco-friendly fishing method, it can also affect the environment when it is operated in coral reef waters that have a high diversity of species. The results of research on *bubu tambun* fish pots in the coral reef waters of Seribu islands showed that the percentage of the main catch was 42% while which of the by-catch was 58%, which was dominated by the Chaetodotidae, Phomacentridae and Monachantidae families [9]. The results of research on buton fish pots in Wakal waters on the island of Ambon showed that there

were 22 fish families consisting of 44 species caught with the proportion of main catch of 78% and bycatch of 22% [10].

Both research results indicate that there were more by-catch products than which of the main catch. The great number of bycatch is an indication of the cause of declining fish stocks in various parts of the world [11]. In order to preserve the recruitment in the context of the sustainability of coral reef fish resources, the pressure on bycatch fish must be minimized. Therefore, to increase the sustainability of coral reef fish resources so that recruitment can be preserved, the amount of bycatch products must be minimized by increasing the selectivity of the pots [12]. There are some ways to increase the selectivity of pots, such as, improving the size of the net, funnel, or by using escape gap [13]. Various studies have been conducted on the use of escape gap as evidence to increase the selectivity of the pots [14]–[17].

In general, the buton pots used by fishermen in Kotania Bay have a small size; with a dimension of 70 cm long, 70 cm wide, and 26 cm high. The pots are operated at low tide depths ranging from 0.5 - 1.5 m in order to take advantage when various types of fish looking for food at high tide. The small size and timing of the operation (operated in shallow waters) make it possible to catch the unfit-sized target fish as well as various types of by-catch fish. Therefore, it is necessary to conduct research in order to minimize the impact of Buton pots on both target and by-catch fish through escape gaps. The purpose of this study was to prove the difference between the catch fish trapped inside the pots and those that escaped through the escape gap to the cover net, and to analyze the selectivity of the escape gap towards the dominant trapped fish..

II. RESEARCH METHOD

The research was conducted in the period of March – May 2019 in Kotania bay, West Seram Regency, Maluku. The research location is shown in Figure 1. This research was an experimental catch using 5 units of buton pots. The specifications and dimensions of the buton pots are shown in Figure 2.

The shape of buton pots used in the research resembled a heart. The pots had a dimension of 70 cm long, 70 cm wide and 26 cm high. The funnel had an oval shape, with a height of 26 cm and diameter of 22 cm. The cover net was designed to accommodate fish that can escape through the escape gap. The dimension of the net cover was 65 cm long, 65 cm wide and 26 cm high. The escape gaps were located on both sides of the pots with net cover, in which each side had two escape gaps. The shape of the escape gap was a circle with a diameter of 5 cm.

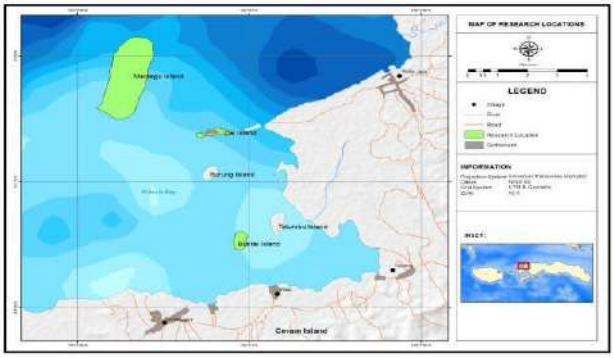


Fig.1: Research location in Koatania Bay, Maluku Indonesia. The location of experimental fishing are Osi and Mursegu island waters

The data collection process was carried out as follows: the pots were operated at a water depth of 0.5 – 1.5 m at low tide; the distance between pots was ranging between 10 - 15 m; the length of soaking time was 2 days; in order to keep the pots remained at the bottom of the water, chunks of dead coral were used to cover the entire top of the pots. The fish caught in the pots were separated from the fish caught in the cover net and then the total length (cm) and weight (gram) of each species caught were measured. Furthermore, each pot that had its catch collected was then reset, and this experiment was carried out for a total of 11 fishing trips.

The t-test was used to prove the difference between the catch fish trapped inside the pots and those that escaped to the cover net. The t-test formula (test of two means):

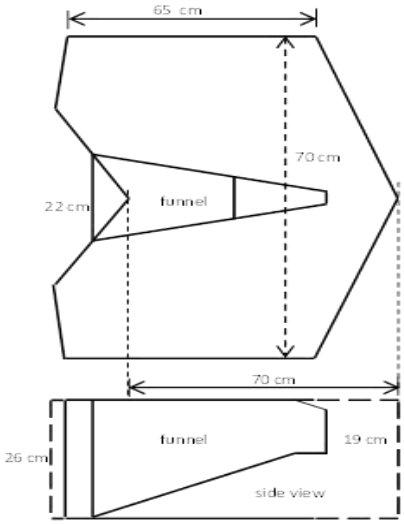
$$t = \frac{Y_1 - Y_2}{S_{\bar{Y}_1 - \bar{Y}_2}}$$

Where Y_1 is the catch fish result, Y_2 is the catch fish escaped to *cover net*, $S_{\bar{Y}_1 - \bar{Y}_2}$ is the variance of two means.

The chance of every total length class of both the trapped and escaped fish from the escape gap for the dominant trapped fish is calculated using the logistic function model:

$$SL = \frac{Exp\,(a + bx)}{1 + Exp(a + bx)}$$

Where SL is the escape chance of fish's total length size class (L), a is the intersection of line equation, b is line coefficient, and x is the total length class.



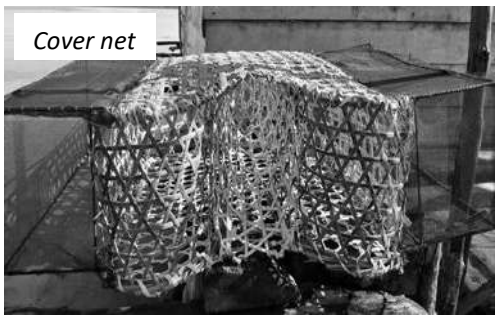


Fig. 2: The specifications and dimension of buton fish pot used during the research. The picture on the above is a sketch of buton pot, on the below is the photograph of buton pot and cover net

III. RESULTS AND DISCUSSION

3.1. Catch Composition

During the research, there were 463 fish caught with a total weight of 91,472 grams. The catch consisted of 19 families, dominated by the Scaridae family by 38.23% and followed by Siganidae 21.0%, Zanclidae 6.0%, Mullidae 5.8%, Serranidae 5.8%, Lethrinidae 5.4%, Acanthuridae 4.8% and other families by 13.0% (Figure 3). By weight, the catch was dominated by Scaridae by 57%, Siganidae 14.7%, Mullidae 7.8%, Serranidae 4.3%, Balistidae 3.8%, Lethrinidae 3.1%, Acanthuridae 2.2%, and other families by 9.3% (Figure 4).

The Scaridae family dominated all catches, both by total individuals and weight, because at the time of the research, the pots were installed in the fishing area where most of the bottom waters were covered by sand and dead coral reefs and only a small part was covered with live coral. According to [18], this family is known as parrotfish, which consumes algae from dead coral substrates and chews algae and rocks to form coral sand, so that it makes this family one of the most important sand producers in coral reef ecosystems.

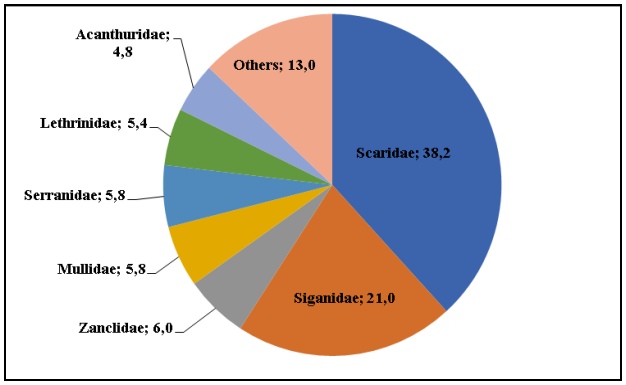


Fig. 3: The percentage of total individual catch

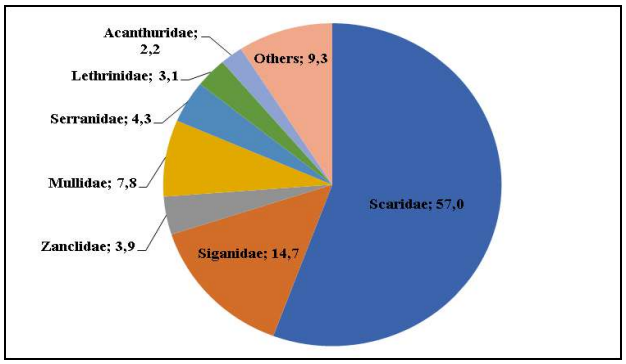


Fig. 4: The percentage of total weight of catch (grams)

Fish around coral reefs can be grouped into three categories, namely the main group, target group and the indicator group[19]. The results of this research indicated that most of the catch was from the main group (51.7%), consisted of Scaridae, Acanthuridae, Pomacentridae, Balistidae, and Holisentridae families. The total catch from the target group was 38.7%, consisted of Serranidae, Siganidae, Mullidae, Lethrinidae, and Haemulidae families, and the total catch from the indicator group was 7.6%, consisted of Zanclidae and Chaetodontidae families.

3.2. The difference between the catch results of *buton* pot and cover net

The t-test showed that there was no difference in the total individual catch between the pot and net cover ($t\alpha$ 0,05 > tcount) but there was a difference in the total weight between them ($t\alpha$ 0,05 < tcount). The average number of individual catch in the pot/trip/pot and cover net/trip/pot is 4 fishes, while the average weight of catch in the pot/trip/pot is 1,275.6 grams, different from the average weight of catch in the cover net/trip/cover net of 381.1 grams.

The number of fish that escaped through the escape gap and was in the cover net was 240, more than those that

trapped in the pot which was 222 (Table 1). From 19 families caught, there were 8 (eight) families that all fish escaped through the escape gap, namely Holisentridae, Pomacentridae, Chaetodontidae, Muraenidae, Diodontidae, Ostracidae, Labridae and Monacanthidae families.

The results of this research indicated that different fish families have different percentages of fish that were trapped or escaped to the cover net. This is because the ability of the fish to escape through the escape gap is influenced by the body morphology of the fish. [20] also obtained data that different body shapes will have different chances of fish being caught. The presence of thorns on the body of the fish also affects the chances of escaping or being caught in a particular fishing gear. Also observed that the morphology of the conger eel had an effect to the ability to escape from the pot [21]. The presence of mucus in the conger eel's body enables the conger eel to escape from the pot even though the mesh size of the pot is smaller than the body girth.

Table 1. The results of total individual catch in pot and cover net

No	Famili	Pot		Cover	
		Individual	%	Individual	%
1	Scaride	105	59,3	72	40,7
2	Siganidae	52	53,6	45	46,4
3	Mullidae	18	66,7	9	33,3
4	Serranidae	19	70,4	8	29,6
5	Haemulidae	3	100,0		
6	Lethrinidae	7	28,0	18	72,0
7	Holisentridae			11	100,0
8	Acanthuridae	4	18,2	18	81,8
9	Zanclidae	2	7,1	26	92,9
10	Pomacentridae			15	100,0
11	Chaetodontidae			7	100,0
12	Balistidae	10	71,4	4	28,6
13	Muraenidae			1	100,0
14	Diodontidae			1	100,0
15	Ostraciidae			3	100,0
16	Dasyitidae	2	100,0		
17	Labridae			1	100,0
18	Monacanthidae			1	100,0
19	Plotosidae	1	100,0		

Table 2. The results of total weight (grams) of catch in *pot and cover net*

No	Famili	Pots		Cover	
		Weight (g)	%	Weight (g)	%
1	Scaride	43.049,0	82,6	9.051,5	17,4
2	Siganidae	10.440,0	77,8	2.970,5	22,2
3	Mullidae	6.130,0	85,5	1.040,0	14,5
4	Serranidae	2.960,0	74,7	1.000,0	25,3
5	Haemulidae	1.030,0	100,0		
6	Lethrinidae	1.270,0	44,9	1.560,0	55,1
7	Holisentridae			910,0	100,0
8	Acanthuridae	1.090,0	53,7	940,0	46,3
9	Zanclidae	210,0	14,2	1.270,0	85,8
10	Pomacentridae			741,0	100,0
11	Chaetodontidae			640,0	100,0
12	Balistidae	2.810,0	79,6	720,0	20,4
13	Muraenidae			100,0	100,0
14	Diodontidae			150,0	100,0
15	Ostraciidae			480,0	100,0
16	Dasyitidae	520,0	100,0		
17	Labridae			90,0	100,0
18	Monacanthidae			70,0	100,0
19	Plotosidae	230,0	100,0		

3.3. The selectivity of escape gap for Parrotfish (Scaridae)

The curve of the selectivity of escape gap for parrotfish of the Scaridae family is presented in Figure 6. The curve uses the selectivity parameters a and b by -14.87 and 0.67. Thus, the logistic function of the curve of the selectivity of the 5 cm circular-shaped escaped gap of *Buton* pot is as follows:

$$r_L = \frac{\exp(-14{,}87 + 0{,}67L)}{1 + \exp(-14{,}87 + 0{,}67L}$$

Based on this logistic function equation, the calculations were made based on the total length of the fish which were then plotted into a selectivity curve (Figure 5). Figure 6 shows that the chance of parrotfish being caught is 50% (L50) using an escape gap in the pot with a total length of 22.2 cm. This value indicates that at the size of 22.2 cm, parrotfish have a chance of being caught and escaping from the escape gap for 50%.

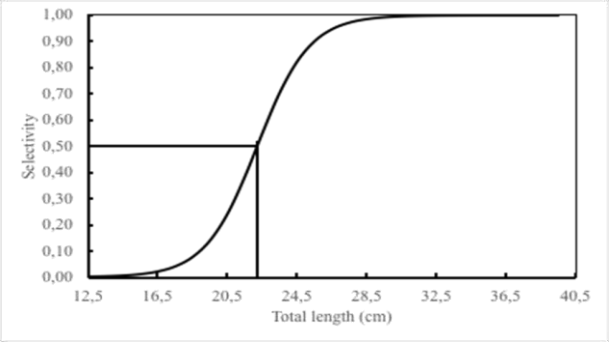


Fig.5:The chance of being caught in the total length class of parrotfish (Scaridae) in buton pot with a 5 cm square-shaped escape gap

Furthermore, Figure 5 shows that, with a total length of 12 - 14 cm, parrotfish from the Scaridae family have no chance of being caught. This means that, with that size, any parrotfish that enter the buton pot have a chance to escape through the circular-shaped escape gap with a diameter of 5 cm. With a total length of 14 – 15 cm, the chance of being caught is 1.0% and the chance of being caught continues to increase exponentially until it is 99.0% at a total length of 29 – 30 cm. Furthermore, the total length > 30 cm has a 100% chance of being caught. Explained that there are several factors that influence the selectivity of the catch in the pot, such as the pot mouth, which includes shape and size, and escape gap, which includes shape, size, and position [12]. Furthermore, explained in more detail the technical factors that affect the selectivity of the pot regarding the shape and size of the mesh, and the escape gap [21]

Parrotfish from Scaridae family consists of many species. Stated that there are 39 species of parrotfish in Indonesian coral reef waters [22]. According to [23], generally, parrotfish found in Indonesian waters consist of Scarus quoyi, Scarus dimidiatus, Scarus ghobban, Chlorurus bleekeri, Cetoscarus bicolor, and Scarus niger. During the research, there were approximately 4 species observed according to the names given by the local fishermen, namely kakatua ijo (green parrotfish), kakatua biru (blue parrotfish), kakatua putih (white parrotfish), and kakatua kuning (yellow parrotfish). There is a lack of information related to the size of the first spawning of the Scaridae family in Indonesia. One of the information related to the size of the first spawning of the Scaridae family, from Scarus rivulatus species, in the waters of South Konawe, Sulawesi, is 24.2 cm for male and 17.5 cm TL for female [24]. The results showed that the Scaridae family with a total length of 22.2 cm has a 50% chance of being caught and escaped through the escape gap with a diameter of 5 cm. Therefore, in order to catch the Scaridae family fish sustainably using a buton pot, it is recommended to use an escape gap in accordance with the design made in this research.

IV. CONCLUSION

There was a difference in the total weight of the catch trapped inside the buton pot and those escaped through the escape gap to the cover net, where the percentage of escaping and being trapped inside the pot varied in accordance with the fish family. The 50% chance to escape the Scaridae family through an escape gap with a diameter of 5 cm was found in fish with a total length of 22.2 cm. The use of a buton pot equipped with a circular-shaped escape gap with a diameter of 5 cm can be an alternative as one of the factors in coral reef fisheries management.

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The Epidemiology of Peste des Petits Ruminants in Sierra Leone

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Abstract— *Peste des petits ruminants (PPR) is a major constraint to the productivity of small ruminants in Sierra Leone. The survey aimed to investigate the prevalence of Peste des Petits Ruminants (PPR) and create awareness among livestock farmers on the dangers of the disease to the livestock sector in the study districts. The sampling frame was small ruminants rearing households in Sierra Leone and 298 households were included in the study. A multi-stage sampling was utilized for the selection of individual livestock households. First purposive selection of the five districts, then random selection of chiefdoms, sections, and small ruminant rearing households in the village/locality respectively. Structured questionnaires were developed and administered to the 298 selected households in each locality/village. Data collected were entered into CSEntry using tablets and later imported and stored in the SPSS (version 21). Males are the dominant household heads and most of them went through a non-formal system of education. Goats, chickens, and sheep, are the predominant livestock reared by the households. Many of the respondents can identify the clinical signs and symptoms of PPR, and reported the incident of the disease in their farms. Free range management system in the dries and uncontrolled movement of animals along borderlines are the main sources of PPR outbreaks. The unavailability of vaccines and drugs are principal problem hindering the disease control programmes in the study localities. Though the livestock owners are aware of the morbidity and mortality effects of PPR disease, they have little knowledge of the preventive and treatment measures of the disease on their farms.*

Keywords— ***Epidemiology, Peste des petits ruminants, Livestock, Sierra Leone.***

I. INTRODUCTION

Sheep and goats are the main small ruminant species of livestock in Sierra Leone [1]. In 2007, about 8.5% and 6.6% of households in the country owned goat and sheep [2]. However, the livestock sub-sector's contribution to the gross domestic product (GDP) was still low (5.7%), compared to that of crop (62%) [3]. In 2010, sheep and goat populations were estimated at 682,000 and 803,000 heads respectively [4]. These numbers have decreased considerably during the outbreak of pest des petits ruminant.

Peste des Petits Ruminants (PPR) also known as goat plaque is a highly contagious viral disease that affects many species of domesticated and wild animals [5], [6] PPR is characterized by nasal and ocular discharges, gastroenteritis, necrotic stomatitis, pyrexia, and erosion of the pulmonary tract mucosa [7], [8]. The virus has a high morbidity and mortality, reaching to 100% and over 90% in naïve herds, respectively [9], [10]. This may reduce both the number and productivity of the flock and herd, which in effect negatively affect food security and the livelihoods of rural women and youth who are the main keepers of sheep and goats in the Country.

Serological studies conducted in 2009 at Central Veterinary Laboratory, Teko, Makeni, Sierra Leone, reveal that PPR is endemic in Sierra Leone [11], [12]. Based on molecular analysis of the fusion protein, PPRV has been divided into four different lineages I, II, III, IV, and the PPR viruses from Sierra Leone are clustered in lineage II [13].

A survey was conduct by the Teko Livestock Research Centre on the prevalence and possible control measures of PPR in five selected districts in Sierra Leone. The overall objective of the survey was to create awareness on the prevalence of PPR disease virus to livestock farmers especially women and youths that are actively engage in rearing sheep and goats the study districts; while the specific objective is to develop control measures that will drastically reduce the incidence of PPR disease virus in the selected areas of study.

II. MATERIALS AND METHODS

The study was conducted in selected communities in Kambia, Port Loko, Tonkolili and Koinadugu Districts in the northern region and Moyamba District in the southern region of Sierra Leone.

The sampling frame of the survey was small ruminants (sheep and goat) rearing households in Sierra Leone. A multi stage sampling was utilized for the selection of individual livestock households. The first stage was the purposive selection of the five districts where the study was done and the sample size was then allocated to these districts based on allocation proportional to size methodology. In the second stage, chiefdoms were randomly selected from the selected districts. The third stage was the random selection of sections in the chiefdom. The fourth stage was the random selection of localities/villages in the selected sections. The fifth and final selection was the random selection of small ruminant rearing households in the village/locality.

A structured questionnaire was developed and administered to the selected households in each locality/village. The interviews focused on collection of information on household demography, flock size, species, sex, health, management practices and common diseases in goats and sheep. Other data collected included movement patterns of livestock in the study areas with the affected neighboring countries, surveillance methods used and knowledge on PPR and vaccination. 298 questionnaires were administered to the sampled small ruminant rearing households in the four districts.

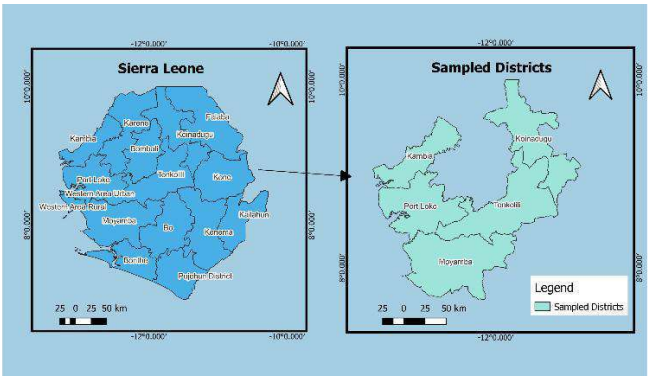

Figure 1. Study Area

Sample Size for the Small Ruminants' Household to Examine

The sample size of small ruminants' household was determined using the formula:

$$n = \frac{z^2 pq}{d^2}$$

Where n = the sample size, z =1.96, p = proportion of agricultural households engaged in animal husbandry, q = a weighting variable computed as 1-p and d = Desired Absolute Precision, ±5%. From the 2015 population and housing census p=0.736 [14].

$$n = \frac{1.96^2 \text{x} 0.736 \text{x} (1 - 0.736)}{0.05^2} = \frac{0.74644}{0.0025} = 298.58 \approx 300$$

The matrix of the number of sample households, localities/villages, chiefdoms and district is shown in Table 1.

The enumerators were trained in administering the questionnaires, and how to enter the data into the CSEntry using Tablets/Smartphones. Enumerators entered data directly into the CSEntry using tablets/smartphones during questionnaire administration, this eliminated errors due to data entry from the filled hard copy questionnaires in to the software.

The baseline data were collected and entered into CSEntry using tablets/smartphones and were later imported and stored in the SPSS (version 21). Descriptive statistics of the explanatory and other variables examined in the study for the small ruminant animal rearing households at the national, regional and district levels were computed using SPSS v.21 software and charts developed using the Microsoft excel 2010.

Table 1. The matrix of the number of sample households, localities/villages, chiefdoms and district

District	Animal Husbandry Household	Sampled Household	Sampled Locality	Sampled Chiefdoms
Kambia	38376	49	5	2
Koinadugu	38968	50	5	2
Port Loko	67071	86	9	3
Tonkolili	48692	63	7	3
Moyamba	40689	50	6	2
Total	**233796**	**298**	**32**	**12**

III. RESULTS AND DISCUSSION

Table 2 shows results for frequency distribution of some demographic attributes of small ruminant farmers in the study area. The results revealed that most of the respondents in all the selected districts are males, representing 73.2% which far exceeds the number of female respondents (26.8). This indicates that males are the dominant household heads with more responsibilities and are therefore left with no option but to take up livestock (especially small ruminants) rearing as a sedentary career to diversify their source of income.

Results for this survey clearly indicate that most (90.9%) of the respondents involved are married. This could be as a result of the age limit captured for this study (18yrs and above). Only 4% of the respondents are single. These are believed to have minimal responsibilities and are mostly school going and are on the search for more lucrative opportunities than rearing animals. 4.4% are Widow/widower who mostly has loss their spouses to sicknesses like the deadly Ebola scourge that devastated the country in 2014 and other conditions.

It could be observed in this study that 94.3% of the respondents are predominately Muslims and are from the northwest and northern regions when compared to Christians representing 5.7% of the sampled population. It indicates that Muslims occupies the chunk of the population in the country. This confirms the 2010 interreligious council estimates of 77% Muslims and 21% Christians for all ethnic groups in Sierra Leone [15]. Despites the vast difference in religious beliefs and practices, the country is perceived as one of the most religious tolerant countries in the world. For the selected study areas, Christians and Muslims accept the consumption of goat meat because of its unique characteristic flavor and low fat; and reared sheep and goats mostly for social, cultural and economic reasons.

Report on educational status of the respondents show that most (54.7%) are non-formal, few attained primary and secondary educational levels (5-7.7%), and 4.4% attained certificates from higher learning institutions. This is because learning institutions (vocational and tertiary institutes) are lacking in these areas with very few primary or secondary school that are miles away. 21.1% of the respondents acquired koranic education. This may be probably owing to the fact that most of the sampled population are coming from Islamic backgrounds, and koranic learning is a mandatory aspect of practicing their beliefs.

Table 2. Frequency distribution of some demographic attributes of small ruminant farmers

Variables		Categories	Gender			Marital Status				Religion			Educational Status						
			Total	Female	Male	Total	Divorced	Widow	Single	Married	Total	Islam	Christianity	Total	Koranic	Tertiary	SSS	JSS	Primary,	Non-formal
North West	North	Freq.	132	26	106	132	1	5	5	121	132	125	7	132	30	8	6	5	4	79
		%	100	19.7	80.3	100	0.8	3.8	3.8	91.7	100	94.7	5.3	100	22.7	6.1	4.5	3.8	3	59.8
	South	Freq.	114	41	73	114	1	6	4	103	114	113	1	114	23	4	9	7	16	55
		%	100	36	64	100	0.9	5.3	3.5	90.4	100	99.1	0.9	100	20.2	3.5	7.9	6.1	14	48.2
	Pooled	Freq.	52	13	39	52	xxx	2	3	47	52	43	9	52	10	1	5	4	3	29
		%	100	25	75	100	xxx	3.8	5.8	90.4	100	82.7	17.3	100	19.2	1.9	9.6	7.7	5.8	55.8
		Freq.	298	80	218	298	2	13	12	271	298	281	17	298	63	13	19	17	23	163
		%	100	26.8	73.2	100	0.7	4.4	4	90.9	100	94.3	5.7	100	21.1	4.4	5.7	6.4	7.7	54.7

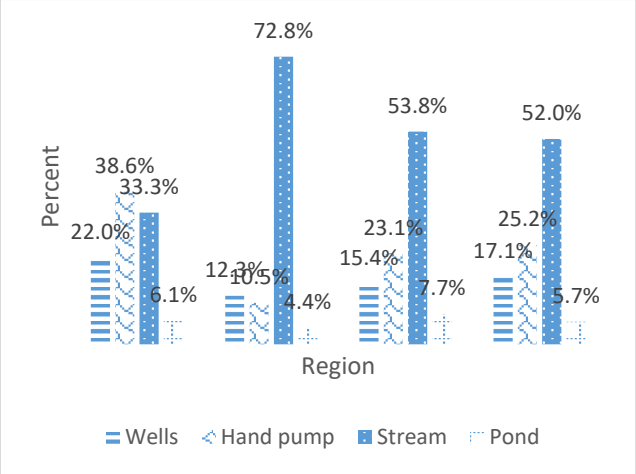

Fig.2. Source of drinking water by region

Source: EU- BAFS survey data 2019

Figure 2 shows the source of drinking water by region for the selected study arrears. 52% of the respondents in all communities used stream as the source of water for their everyday use, while 25% uses well water and 17% uses hand pump with less numbers (5.7%) in these communities used pond water. In almost all rural communities in Sierra Leone small ruminant owners do not provide safe drinking water for their animals. This confirms the results reported by Sierra Leone Demographic and Health Survey (SLDHS) 2013, which clearly stated that higher proportion of rural households uses non-improved sources for drinking water [16]. The animals are free to range in vast communal lands and can thereby make use of the available stream water for drinking. Streams waters are mostly reservoirs for diseases and are highly infested by loads of bacteria, pathogens and other infectious diseases that increase the chances of contracting diseases [17].

Table 3. Animals kept by the respondents

	Percent (N=298)	
Animals Present	**Yes**	**No**
keep chicken	85.2	14.8
keep duck	9.1	90.9
keep Guinea Fowl	1.3	98.7
keep Pig	1.0	99.0
keep goats	89.9	10.1
keep sheep	51.3	48.7
keep cattle	5.0	95.0
Do you keep rabbit	0	100.0
Do you keep Cane rat	0	100.0

Source: EU- BAFS survey data 2019

Table 3 shows livestock kept by the respondents in the study areas. Majority of the small ruminant household heads keep goats, chicken and sheep, (89.9%, 85.2% and 51.3% in that order); very few rear duck and cattle, (9.1% and 5.0% respectively), 1.3% and 1% keep Guinea fowl and pigs respectively and none of the respondents keep cane rat or rabbit.

The number of respondents that keep goats and sheep was high because the study targeted mainly small ruminant rearing households in the study area. In Sierra Leone, it is believed that many households in the rural communities practice small scale poultry or back yard poultry. This was shown in the results by high number of respondents that keep chicken

Table 4. Management system

		Animals (%)							
	Management system	Chicken (n=254)	Duck (n=28)	Guinea fowl (n=2)	Pig (n=1)	Goat (n=261)	Sheep (n=148)	Cattle (n=15)	
Raining season	Intensive	1.97	-	-	100	14.56	12.84	20	
	Semi-intensive	72.44	42.86	50		52.11	53.38	80	
	Extensive	25.59	57.14	50	-	33.33	33.78		
Drying season	Intensive	1.18	-	-	-	4.6	2.03	20	
	Semi-intensive	57.09	42.86	-	-	36.02	37.16	60	
	Extensive	41.73	57.14	100	100	59.39	60.81	20	

Table 4 shows the management systems practiced by ruminant household heads in the two major seasons in Sierra Leone. There are three management systems commonly practiced by livestock farmers in Sierra Leone; these include extensive system, the semi intensive and the intensive management systems. During the rainy season, semi-intensive system of management is said to be predominantly practiced by livestock farmers when compared to the intensive and extensive systems. The raining season is a crop farming season and in the rural area it is compulsory for all livestock farmers to control movement of their grazing animals to prevent them from destroying crop farms. This is believed to be one of the best means of conflict resolutions between crop and livestock farmers. Small ruminants are either tethered on grazing fields or fed on cut and carried grasses by the owners or allowed to browse in paddocks/confined areas.

During the dries however, the extensive management systems for goats and sheep are mostly practiced. After the harvesting periods (a period in anticipation of the dries), the animals are again released to brows freely on the just harvested crop lands. The farmers preferred this system because it is less labour intensive and the animal through their scavenging activities can feed adlib and increased in weight for market values or other purposes.

Table 5. Livestock housing system

	Animals (%)							
Housing system	Chicken (n=254)	Duck (n=28)	Guinea Fowl (n=2)	Pig (n=1)	Goat (n=261)	Sheep (n=148)	Cattle (n=15)
None	7.1	28.6	-	-	5.7	6.8	6.7
Confined in sheds	14.6	14.3	-	-	58.6	64.9	26.7
Confined in paddocks	1.2	-	-	-	8	6.1	46.7
Confined fences	10.6	10.7	-	100	24.5	21.6	20
Cage	35.8	21.4	100	-	-	-	-
Basket covered with net	23.2	21.4	-	-	2.7	0.3	-
Bamboo basket	7.1	3.6	-	-	-	-	-
provides Nest	0.4	-	-	-	0.4	-	-

Table 5 shows animal housing system in the study community. Most respondents rearing goats keep their animals in confined sheds (58.6%) followed by those that confined the animals in fences (24.5%) similarly majority of sheep owners house their sheep in confined sheds (64.9%) and confined fences (21.6%). More cattle owners keep their animals in confined paddocks (46.7%), followed by confined sheds. Since chickens are reared in small scale by many households mainly female members in the family, they either keep them in cages (35.8%) or basket covered with net (23.2%). The cage or basket maybe kept in kitchen stores together with cooking utensils

in order to prevent the animals from theft.

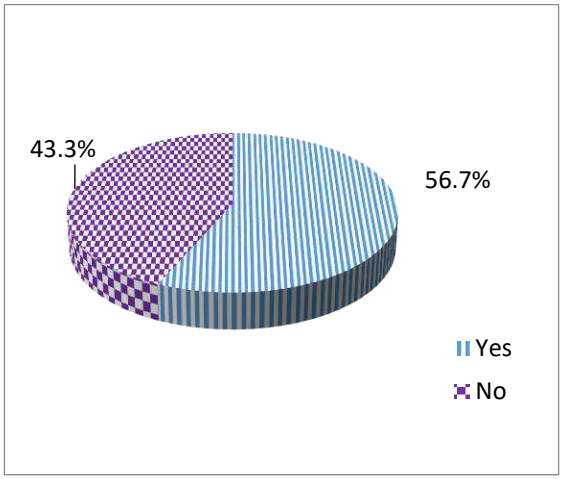

Fig.3. Households that ever heard of the disease Peste des petits ruminants

Figure 3 shows small ruminant household families who are aware of the PPR disease in sampled localities. 56.7% of the interviewed respondents admitted to have heard of the PPR disease possibly from other livestock farmers, Ministry of Agriculture and Forestry, livestock traders Non-governmental Organizations, radio talk shows or even from social media. Despite its endemic stance in the country, 43.3% still complained that they have not heard of the disease probably because most of them are living in rural areas where relevant information on livestock can hardly reach them.

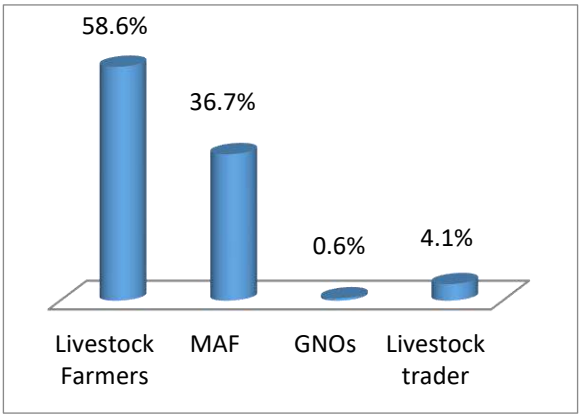

Fig.4. Sources of information for disease Peste des petits ruminants in households

Figure 4 depicts results of sources of information from respondents on the PPR disease virus. Most (58.6%) of the respondents were informed about PPR disease by other livestock farmers that are believed to have concern on the

general welfare of other livestock farmers in their localities. This is commonly done through the town/village heads that can charge the town-crier with the responsibilities of informing the entire community about the outbreak of a disease condition. However, the animal health and extension wings of the Ministry of Agriculture and Forestry (MAF) have played a significantly role (showing 36.7%) in disseminating information about the outbreak and endemic nature of the disease in these sampled communities and beyond. Their involvement in this could be as a result of series of PPR disease outbreak in the year 2018 in the East and Southern parts (Kenema and Moyamba respectively) of the country that left an estimated 127 sheep and goats dead [18], [19]. 4.1% of the respondents learnt about the disease from livestock traders through their trading activities in these communities. The involvement of None Governmental Organization (NGO) in the sensitization is minimal (0.6%). This could be as a result of the very small number of NGOs that are involved in animal health or veterinary activities in the country.

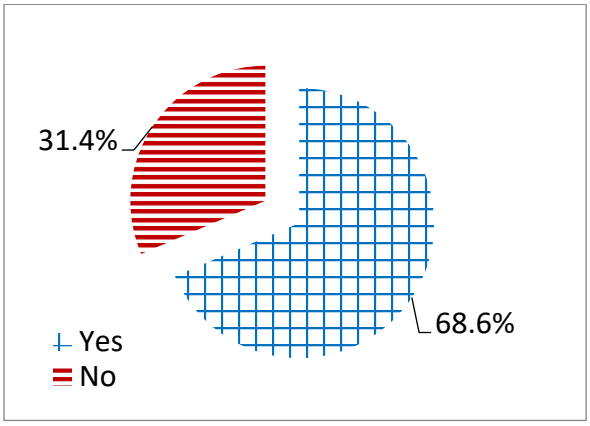

Fig.5. Incidence of PPR in the study area

Figure 5 shows incidence of PPR as reported by the small ruminant households in their flocks. Majority (68.6%) of the respondents reported the incident of PPR in their flocks, only 31.4% of the farmers recorded no cases of PPR in their flocks. The incident of PPR in the study area may be attributed to the various practices, including introducing new animals in the locality without quarantine services, source of drinking water for the animals as many rural farmers leave their animals to roam freely in search of feed and water, and streams provide easy accessibility for drinking water. This water source increases the risk of contracting many animal diseases. Moreover, contaminated water, feed troughs and bedding, could be additional sources of infection for animals [17]. Similarly, free movements of goats and sheep across the porous international borders between Guinea and Sierra Leone along the northern region of the country might have also contributed to the introduction of PPR in the country. In addition, the popular cross border ruminants' market at Gbindi in the Falaba District, northern Sierra Leone bordering Guinea is likely to introduce the disease in the country. introduce the disease in the country.

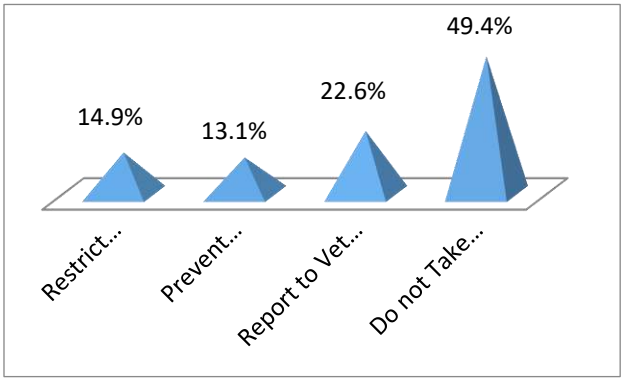

Fig.6. Main protective measures taken during PPR outbreak

Figure 6 expresses results on the main protective measures taken by farmers during PPR outbreak. During PPR outbreak, majority (49.4%) of herds owners do not take protective measures because of the unavailability of vaccines in their localities. 22.6% of the respondents that can access to veterinary services report outbreak of the diseases to veterinary authorities for necessary actions. Other 14.9% and 13.1% of the respondents take proactive measures like adhering to Government instituted laws and reforms that restricted the movement of small ruminant from one place/region of the country to another and preventing contact with other animals respectively. Although the control and preventive measures instituted by the Government to prevent further outbreak of the PPR disease was of immense importance, it is believed to have created an imbalanced socio-economic impact in the lives of livestock farmers.

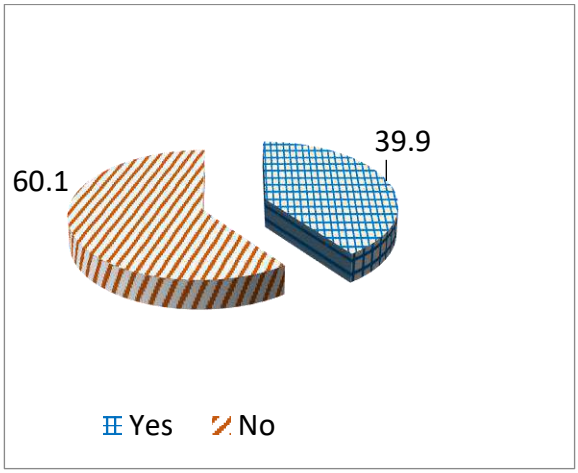

Fig.7. Households that used animal health services in the last 12 months

Figure 7 shows small ruminant households that used animal health services in the last twelve months. The results revealed that majority (60.1%), of the respondents have not used animal health service in the last twelve months. The unavailability of vaccines for the treatment of animals in rural settings, high cost of the relatively available ones and the absence of animal health workers in these localities could be some of the factors responsible for the low use of animal health services by livestock farmers. It was also observed that 39.9% of the respondents admitted to have used animal health service in the last 12 months probably because they can either afford the cost of treating their animals or have access to the services rendered by private veterinarians, or the free services offered by the ministry of Agriculture and Forestry to the very few communities of the sampled areas.

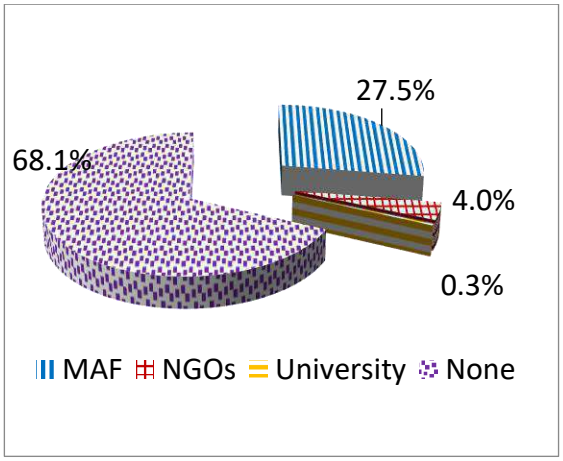

Fig.8. Providers of extension services in the villages/localities

Figure 8 displays results on the institutions that provide extension service to small ruminant farmers in the selected sampled areas. 68.1% of the respondent reported of the unavailability of extension services providers in their localities. This could probably be due to many reasons like the little or no attention given to the livestock sub sector over the years, information on livestock that is not filtering down to farmers in rural settings because of the poor road network, very few or none existing livestock farmer groups that can be contacted by extension officials and limited number of animal extension workers to carry out the task. 27.5% of the respondents measured the Ministry of Agriculture and Forestry as an institution that performed extension services in their localities. These are localities with appreciable road network that extension service providers from MAFs can access. NGOs that are involve in agriculture and universities are playing minimal roles in reaching out these rural communities and spreading out information concerning animal health and diseases.

IV. CONCLUSION

From the study results, it could be concluded that most livestock farmers interviewed are males, Muslims and do not go through formal education and a higher proportion of the population use stream as a source of drinking water.

Majority of the households keep goats, sheep and chicken. Semi-intensive and extensive systems of managements are the main systems of management practiced during rainy and dry seasons, and the small ruminants are mostly kept in confined sheds. Awareness of PPR disease is high among the livestock farmers, and most of them get information on animal diseases from other informed livestock farmers.

The farmers have knowledge on the clinical signs of the PPR disease and therefore majority of them reported the incident of the disease on their farms.

Though the livestock owners are very much aware of the morbidity and mortality effect of PPR disease, they still have little or no knowledge on the preventive and treatment measures of the disease among their herds.

Nevertheless, the survey data indicate that PPR vaccination campaign coverage in the country is low due to a lack of human capacity such as veterinary and extension workers as well as vaccines availability.

V. RECOMMENDATIONS

- Control programmes of PPR should be supported by field data generated by rigorous epidemiological surveillance and risk analysis.
- Veterinary units in the Ministry of Agriculture and Forestry (MAF) across the country should be equipped with more staff, veterinary equipment, and drugs.
- Passive disease surveillance is effective in disease monitoring but should be supplemented with simple laboratory techniques that require low cost equipment—such as light microscopes—to detect parasitic infections in blood and feces. The government should also make available test kits for field diagnosis for PPR and other diseases, as they would be useful to confirm diagnosis and lessen response times.

VI. FUNDING

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Deep thanks are extended to our development partner, the European Union for providing financial and technical support in the implementation of this project. The authors also acknowledge the contribution of the Government of Sierra Leone for the oversight support to the project.

VII. THE CONSENT PROCESSES

Prior to the start of each interview an informed consent was obtained and was done in either English or Krio, which seeks the study participant's willingness to participate in the study.

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Livestock Systems and Forage Resources of Small Ruminant Farms in Some Selected Districts in Sierra Leone

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Abstract— *This survey was conducted to ascertain the demographic attributes of household heads, type of livestock kept, rearing systems, feed resources utilized and also to assess farmer's knowledge on feed production and conservation. A total of 298 household heads were randomly selected within five districts and interviewed. Results indicated that majority of the households (73.2%) were headed by men with only (26.8%) headed by women. In terms of educational status 54.7% of the household heads did not go to school, while 24.1% attained formal education and (21.2%) attained Koranic education. Data for religion showed that 94.3% of the respondents were Muslims with 5.7% being Christians. Among the households, (95.6%) kept poultry, (89.5%) kept goats, (51.3%) kept sheep, 5% reared cattle, with only 1% keeping pigs and none rearing rabbits or grasscutters. In terms of average numbers of livestock per household; chickens were (12), ducks (4), and guinea fowl (3). Goats were (5), sheep (4) and cattle (5). Management system for poultry, small ruminants and cattle was mostly semi-intensive in the wet season and extensive in the dry season except for pigs which were managed intensively during the rains, and extensively during the dries. Housing provided for poultry was mostly in the form of cages and baskets, with small ruminants mostly housed in sheds and within fenced areas. Cattle were majorly sheltered in paddocks and pigs confined in fenced areas during the rains and left to roam during the dries. Few farmers reported that they do not provide housing for their animals. Most household heads (83.6%) practiced grazing/scavenging as the main source of feeding animals with only (16.4%) practicing zero-grazing. The grasses most browsed by the animals were Panicum maximum (21.5%), Andropogon gayanus (17.1%) and Pennisetum purpureum (10.1%). The legumes; Centrosema pubescens, Pueraria phaseoloides, and Mucuna pruriens were hardly grazed by the animals with values < or = 1.0%. Majority (91%) of the household heads fed their animals with forages, with only (3.4%) providing concentrate and (7.4%) utilizing supplements. None of the famers (N=298) fed their animals with hay or silage as they lacked knowledge on animal feed production. Crop residues were utilized by (30.2%) of the household heads, with cassava leaves residues (77%) the most fed and soybean haulms (17.8%) the least fed. Shortage of animal feed was most severe in the peak of the dry season (February-march), with 75.9% of households feeding their animals on forages during this lean period through the cut and carry method. From this survey, findings indicated that the inclusivity of women in livestock rearing is low, with management systems still traditional and mostly characterized by low numbers of conventional and a total absence of non-conventional livestock. Furthermore, un-balanced feed rations, feed scarcity and lack of technical know-how in compounding and conservation of animal feed was mostly existent.*

Keywords— ***Livestock systems, Small Ruminants, Farmers, Feeds, and forages***

I. INTRODUCTION

In Sierra Leone, livestock are economically important for household food security, source of income, and as well as being required for various cultural and ceremonial functions (FAO and ECOWAS, 2016). The livestock sub-sector also contributes about 5.7% of agricultural gross domestic product (GDP) (FAO, 2016). Despite the low contribution of the sector to the agricultural GDP, the country has the right agro-climatic conditions such as abundant rainfall, rich soils, natural forage resources, forest cover, and a low population pressure estimated at 79.2/km^2 on the land (FAO and ECOWAS, 2016). Livestock production in the country, especially small ruminant rearing, is an important agricultural activity though most of it is practiced under traditional system of management (FAO and ECOWAS, 2016). Nutrition is a vital component of livestock rearing systems and the feed requirements of farm animals can be met solely through natural forage and fodder or augmented through direct supplementation of nutrients in concentrated and controlled form (Alemayehu *et al*., 2016). In Sierra Leone, grazing is the predominant form of ruminant feeding practiced in most parts of the extensive and smallholder crop-livestock farming areas. Small ruminants graze on communal, fallow and natural pasturelands during the cropping season and on croplands after harvest. Currently there is paucity of information on the availability of feed resources, rearing systems, and farmer's knowledge on animal feed production in Sierra Leone. Therefore, this study aimed to determine the socio-economic and demographic context of the farming communities, animal rearing practice, availability of feed resources, and to assess farmer's knowledge on preservation and processing of these feed resources for sustainable livestock production.

II. METHODOLOGY

A multi stage sampling was used for the selection of individual livestock households. Purposive selection of the five districts (Kambia, Port Loko, Tonkolili and Koinadugu in the North and Moyamba in the South) was done, followed by random selection of chiefdoms from the districts, and then random selection of sections in the chiefdom. The fourth stage was the random selection of localities/villages in the selected sections and finally the random selection of small ruminant rearing households in the village/locality. A total of 298 questionnaires were administered to the sampled small ruminant rearing households in the five districts. Enumerators were trained in administering the questionnaire and entering data directly into the CSEntry using tablets. The baseline data were collected and entered into CSEntry using tablets and the data later imported and stored in the Statistical Package for Social Sciences SPSS (version 21). Descriptive statistics of the explanatory and other variables examined in the study for the small ruminant animal rearing households at the national, regional and district levels were computed using SPSS v.21 software and charts developed using the Microsoft excel 2010.

III. RESULTS

Table 1: Demographic attributes of the household heads

Variable	Categories	Pooled	
		Frequency	Percentage
Gender	Male	218	73.2
	Female	80	26.8
	Total	298	100
Educational status	Non-formal	163	54.6
	Primary	23	7.7
	JSS	17	5.7
	SSS	19	6.37
	Tertiary	13	4.36
	Koranic	63	21.2
	Total	298	100
Religion	Muslims	281	94.3
	Christians	17	5.7
	Total	298	100

Table 1 shows the demographic attributes of the household heads. Results indicates that (73.2%) of the household heads are males, while 26.8% are females. Data for educational status revealed that 54.6% of the household heads did not go to school, 24.1% attained formal education with 21.2% attaining Koranic education. In terms of religious composition of the targeted household heads, 94.3% were Muslims and 5.7% were Christians.

Table 2: Animals kept by the Households

	Percent (N=298)	
Animals Present	**Yes**	**No**
Do you keep chicken?	85.2	14.8
Do you keep duck?	9.1	90.9
Do you keep Guinea Fowl?	1.3	98.7
Do you keep Pigs?	1.0	99.0
Do you keep goats	89.9	10.1
Do you keep sheep	51.3	48.7
Do you keep cattle	5.0	95.0
Do you keep rabbit	0	100.0
Do you keep Cane rat	0	100.0

Table 2 shows the results for the animals present in the small ruminant households. Data from this study indicates that, among the respondents, (85.2%) rear chicken, (9.1%) keep duck, and (1.3%) keep guinea fowl. Majority (99%) of the households did not keep pigs with most (89.9%) keeping goats and only (51.3%) rearing sheep. Few households (5.0%) stated that they owned cattle, while none kept rabbits and grasscutters.

Table: 3 Animals Present with the 298 Respondents

Animals Present	N	Min	Max	Mean	S.D
No. of chickens	254	1	50	12	8.141
3.2\3 =No. of ducks	27	1	15	4	3.332
No. of Guinea Fowl	4	2	4	3	.957
No. of Pigs	3	2	12	7	5.033
No. of Goats	268	0	39	5	4.477
No. of Sheep	153	0	25	4	2.900
No. of Cattle	15	1	12	5	3.907

N = Number of respondents, Min = Minimum, Max = Maximum, S.D = Standard Deviation

The total chicken population stood at 254 with an average of 50 chickens per household in comparison to duck (N=27) and guinea fowl (N=4). Data from this study showed that the number of chickens present far exceeds the number of the other poultry species (ducks and guinea fowl). Data shows that the total number of goats and sheep stood at 268 and 153. The number of pigs stood at 3 while the total number of cattle present were 15.

Table 4: Management systems of animals during the rainy and dry season

		Animals (%)						
Management system		Chicken	Duck	Guinea fowl	Pig	Goat	Sheep	Cattle
Raining season	Intensive	1.97	-	-	100.00	14.56	12.84	20.00
	Semi-intensive	72.44	42.86	50.00		52.11	53.38	80.00
	Extensive	25.59	57.14	50.00	-	33.33	33.78	
Drying season	Intensive	1.18	-	-	-	4.60	2.03	20.00
	Semi-intensive	57.09	42.86	-	-	36.02	37.16	60.00
	Extensive	41.73	57.14	100.00	100.00	59.39	60.81	20.00

As shown in table 4, chickens (72.44%), ducks (42.86%) and guinea fowl (50.0%) were mostly managed under the semi-intensive system during the rainy season. With regards to goats and sheep, during the rainy season, (52.11%) and (53.38%) were raised semi-intensively, followed by (33.33%) and (33.78%) reared intensively and (14.56%)

and (12.84%) reared extensively for both goats and sheep respectively. However during the dry season (56.7%) goats and (53.4%) sheep were mostly managed under the extensive system.

Respondents (1.0%) who raised pigs did so intensively during the rainy season, while during the dries, pigs were raised in extensive systems. Majority of cattle owners (80%) managed their animals under the semi-intensive system in the rainy season, with about (20%) rearing cattle intensively.

Table 5: Housing system for livestock reared

	Animals (%)						
Housing system	**Chicken**	**Duck**	**Guinea Fowl**	**Pigs**	**Goats**	**Sheep**	**Cattle**
None	7.1	28.6	-	-	5.7	6.8	6.7
Shed	14.6	14.3	-	-	58.6	65.0	26.7
Paddock	1.2	-	-	-	8.0	6.1	46.7
Fences	10.6	10.7	-	100	24.5	21.6	20.0
Cages	35.8	21.4	100	-	-	-	-
Baskets	30.3	25.0	-	-	2.7	0.5	-
Nests	0.4	-	-	-	0.5	-	-

Table 5 shows the housing system for the different livestock species. Data revealed that (35.8%) of the households sheltered chickens in cages, followed by (14.6%) who confined in sheds. Ducks (28.6%) had no form of housing with only (21.4%) housed in cages and baskets covered with net. Respondents stated cages and fences as the only housing system for guinea fowl and pigs respectively. (58.6%) of the respondents housed their goats in sheds, while (65%) stated confinement in sheds for sheep as the major housing type. Confinement in fences for both goats and sheep was (24.5%) and (21.6%) respectively. Most of the cattle owners (46.7%) confined their animals in paddocks, with only (26.7%) confining in sheds and (20%) in fences.

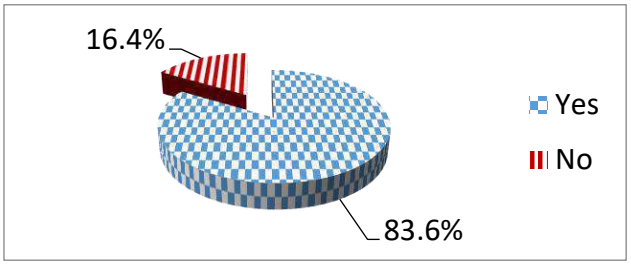

Fig.1: Households that practice Grazing

Majority (83.6%) of the respondents indicated grazing as a feeding practice (fig. 1.) in contrast to (16.4%) who practiced zero grazing.

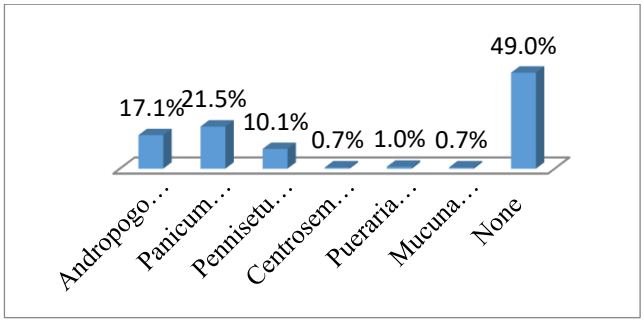

Fig.2: Forages mostly browsed by Small Ruminants

In terms of grazing goats and sheep on herbaceous species of grasses; (21.5%) of the respondents stated that *Panicum maximum* (Guinea grass), as the most preferred, followed by (17.1%) for *Andropogon gayanus* (Gamba grass) and (10.1%) for *Pennisetum purpureum* (Elephant grass). The legumes mostly preferred by the animals were C*entrosema pubescens* (0.7%), *Pueraria phaseoloides* (1.7%), and *Mucuna pruriens* (0.7%). Most of the respondents (49.0%) could not identify or were not aware of the most preferred forages browsed by the animals.

Table 6: Types of feed resources fed to animals

Type of Feed	Percent (n=298)	
	Yes	No
Concentrate feed	3.4	96.6
Forages (grazing)	91.3	8.7
Forages (cut and carry)	68.8	31.2
Hay	0.0	100.0
Feed Supplements (Mineral licks, salt)	7.4	92.6
Produce Silage	0.0	100.0
Other type of feed	19.5	80.5

Table 6 shows the types of feed resources fed to the animals. Few farmers (3.4%) fed concentrate feed, with most (91.3%) grazing their animals directly on forages on pasture lands, with about (68.8%) providing forages for their animals by the cut-and-carry method. None of the respondents (n=298) fed hay or produced silage for their animals while feed supplementation was done by only (7.4%). Few farmers (19.5%) stated that they used other types of feeds.

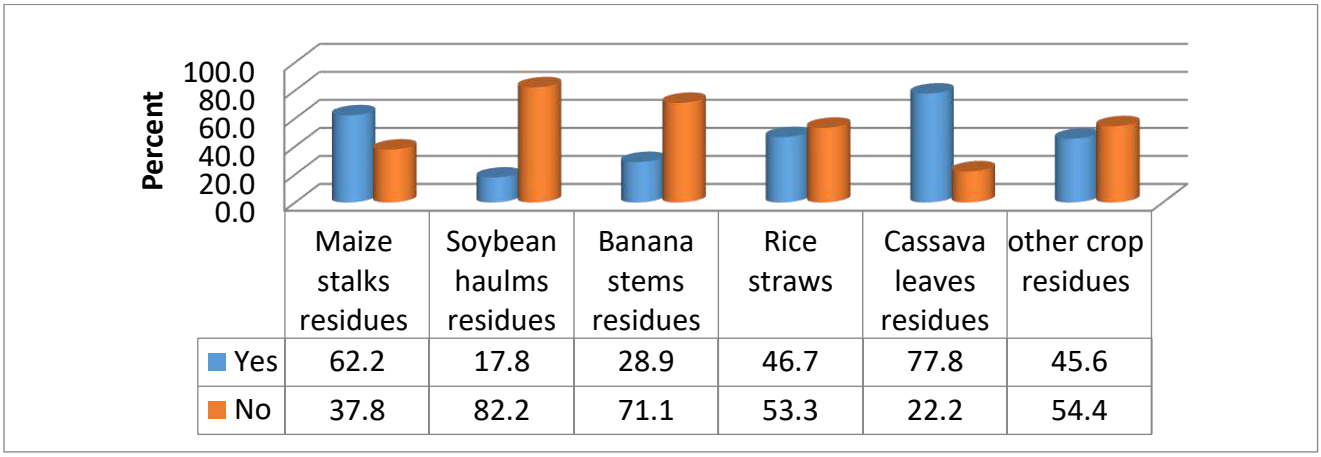

Fig.3: Levels of Utilization of Crop residues by Households

The level of utilization of crop residues is shown in figure 3. The most utilized crop residues were cassava leaves (77.8%), maize stalks (62.2%) and rice straws (46.7%) while the use of soybean haulms and banana stems were (82.2% and 71.1% respectively). For other crop residues (e.g. sorghum and millet), 45.6% of the respondents stated that they offered the residues to their animals while (54.4%) did not feed such residues.

Source of crop residues is presented in (Table 7). Residues sourced from the livestock farmer's own farm accounted for 89.3% (maize stalks), 87.5% (soybean haulms) 88.5% (banana stems,) 71.4% (rice straw) 92.9% (cassava leaves) and 95.1% (other crop residues). Cassava leaves residues (2.9%) was the least sourced as a gift token from farms other than the livestock farmer's while rice straws (28.6%) was the most sourced. Rice straw, soybean haulms and banana stems received as a gift from other farms accounted for about (28.6%, 12.5% and 11.5% respectively) with maize stalks accounting for (7.1%) of crop residues. Purchase of maize stalks, cassava leaves and other type of residues were recorded at (3.6%, 4.3% and 4.9%) respectively.

Table 7: Source of crop residues

Type of crop residues	Source of crop residues (%)		
	Own farm	Gift from other farmers	Purchase
Maize stalks (n=56)	89.3	7.1	3.6
Soybean haulms (n=16)	87.5	12.5	-
Banana stems (n=26)	88.5	11.5	-
Rice straws (n=42)	71.4	28.6	-
Cassava leaves (n=70)	92.9	2.9	4.3
Other crops (n=41)	95.1	-	4.9

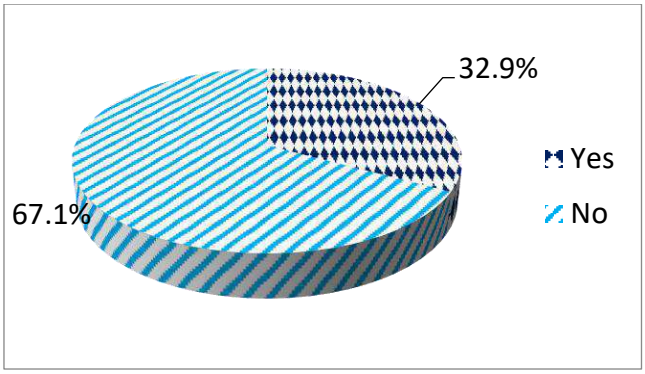

Fig.4: Fodder availability throughout the year

Figure 4 highlights the annual availability of fodder as animal feed. (67.1%) household heads reported that fodder was not available throughout the year while (32.9%) stated relative availability.

IV. DISCUSSION

In this study, the huge disparity in the gender composition of household heads engaged in small ruminant farming is in consonance with (SSL, 2006) report which stated that while women are mostly engaged in crop and poultry farming, men dominate ruminant rearing, hunting and fishing. A major reason for this is due to the fact that in Sierra Leone, women do not have full access or control of property or land, which is a key agricultural resource.

The huge difference in the religious makeup of the household heads in this study, is in line with (ARDA, 2015) which reported that in Sierra Leone, about (71.6%) of the population are Muslims with just (12.9%) being Christians. Formal education is compulsory up to junior secondary school in the country, however majority of the farmers in this study had no formal schooling. In the absence of formal schools, Koranic education was prevalent.

According to (SSL, 2017), the ownership of livestock varies by region and is based on vegetation and cultural habits of the inhabitants of a particular region or district. In this study, the number of households that kept chickens was higher compared to those that keep duck and guinea fowl. This is in consonance with several reports (USAID, 2015; FAO and ECOWAS, 2015) which states that chickens are the most reared poultry species in Sierra Leone. Rearing of pigs was done by few households and this is due to the fact that in this study, majority (94.3%) of the household heads are Muslims and their religion forbids the consumption of pork (*Haram*). Most (89.9%) of the respondents kept goats and about (51.3%) keep sheep. This is consistent with (FAO and ECOWAS, 2016) which reported that in Sierra Leone, goats are more prevalent in livestock farming communities compared to sheep. Few households (5.0%) stated that they owned cattle and this can be attributed to the fact that the target population were mostly small ruminant farmers. None of the households kept rabbits or grasscutters and this was as a result of several factors. Generally for both species, farmers stated that the difficulty in acquiring breeding stock, lack of knowledge in animal husbandry, and feed shortages during the dry season were among the major factors limiting their involvement in small stock production.

Housing for livestock was provided by majority of the respondents with only a few stating that they do not provide housing. The dominant management systems of poultry was mostly semi-intensive and extensive during the rainy and dry season. Ruminants (sheep, goats and cattle) were reared in semi-intensive and extensive systems and was characterized by tethering in natural pastures. This is consistent with (FAO, 2016) which stated that tethering is mostly dominant during the cropping season but the animals are allowed to roam free after the rice harvest in November.

In this study, most of the households grazed their animals on pastures with only a few practicing zero grazing. This is consistent with the result of (FAO and ECOWAS, 2016) which stated that in Sierra Leone, grazing is the most pre-dominant feeding practice in ruminant rearing systems.

According to the farmers, it was observed that the grasses mostly preferred by the ruminants can be attributed to their palatability, abundance and high biomass yield in their localities. Legumes were hardly mentioned as browse plants as farmers stated that their presence was very low. This unavailability may be as a result of the fact that, when legumes are growing with grasses, the grasses are stronger competitors for available nitrogen. This will result to an increased rate of growth, leaf expansion and tillering in the grasses, often leading to suppression of the legume owing to shading (Miles and Manson, 2000). In this study, most (49%) of the farmers could not identify or were not aware of the most preferred forages browsed by the animals. This might be due to the fact that the most of these respondents were not directly involved in the day to day husbandry activities such as moving the animals to grazing sites and therefore could not accurately tell the forages most preferred by the animals.

In this study, the use of concentrate feed was quite low and farmers cited several reasons for this scenario which included; high cost of feed ingredients, availability of feedstuffs and knowledge gap in compounding feeds. Forages (grazing or cut-and-carry) was the major source of feed as it was the most naturally abundant, suitable for their system of small ruminant rearing and which also exacted no financial obligation. Hay and silage was not produced by farmers mainly due to the lack of basic knowledge in

selecting grasses and legumes suitable to be used as standing hay or to produce silage. Supplementation of feed was not common as a result of high cost of supplements, and lack of understanding in adopting the correct levels of supplementation.

According to data from this study, the extent of utilization of the different crop residues mainly depended on traditional feeding practices at village level, where feed resources will vary extensively in both amount and seasonal availability. Furthermore households in rice cropping areas opined that crop residues are used only for shorter periods between the harvest and land preparation for the next cropping season during which rice straws left in the fields are burned.

In this study, cassava leaves residues was mostly sourced from the farmers own farm and this may be due to the fact that the cassava crop, especially the leaves, is highly savored as a major condiment in the diet of rural farmers and therefore this crop was mostly cultivated on farms and backyard gardens.

Natural pastures in the tropics are subject to seasonal variability, with the raining season affecting availability and quality of forage (Fadel Elseed *et al.* 2002). In the wet season, goats have abundant feed in the form of herbaceous species and browse plants. However, animals are not allowed to graze freely in the wet season for fear of straying into cropland and causing crop damage. In the dry season when ruminants are allowed to graze freely, feed availability is low as most forages are lignified and low in nutritive value (Nampanzira *et al*. 2015).

V. CONCLUSION

From this study, it was evident that Livestock production is an important economic activity in the surveyed areas. The inclusiveness of women in animal husbandry was quite low. Islam was the most dominant religion with only a few Christians. Majority of the respondents did not gain formal education and farming was their main source of income.

Livestock kept were poultry, small ruminants, pigs and cattle while none of the farmers reared rabbits or grasscutters. During the wet season, management systems was mostly semi-intensive for all livestock with the exception of pigs. Housing provided for poultry birds was mostly in the form of cages, baskets and sheds. Small ruminants were mostly housed in sheds, cattle were sheltered in paddocks and pigs were mostly confined in fenced areas during the rains and left to roam during the dries.

Majority of the household heads practiced grazing/ scavenging as the main method of feeding animals with only few adopting zero-grazing. Grasses mostly feed upon by the animals were *Panicum maximum*, *Andropogon gayanus* and *Pennisetum purpureum* with the legumes (*Centrosema pubescens*, *Pueraria phaseoloides*, and *Mucuna pruriens*) hardly grazed. Feed resources mostly utilized by these farmers were forages, with few farmers providing concentrate and supplemental feeds. None of the famers fed their animals with hay or silage. Crop residues were utilized by only (30.2%) of the farmers with cassava leaves residues the most fed and soybean haulms the least fed. Shortage of animal feed was most severe in the peak of the dry season (February-march), with majority of households feeding forages during this period by the cut-and carry-method.

RECOMMENDATIONS

Several favorable conditions exists in most rural farming communities for intensifying livestock production. However, these farmers are faced with many challenges which are highlighted in this study. Possible interventions to mitigate these challenges and improve the performance of small scale production are as follows;

1. Advocate for the implementation of gender policies geared towards the inclusion of more women in livestock production. MAFFS have indicated that they have defined policies but lack the resources to implement. Also equal opportunities for women to access credit complimented with subsidies and at reduced rates of interests along with insurance schemes should be provided. Gender issue are significant especially in livestock value chains and they must be addressed in a sustainable way

2. Facilitate access to quality primary and secondary school education in the rural areas especially in communities with high levels of illiteracy

3. Improve access to safe drinking water and sanitation as this may have a positive impact on food and nutritional security

4. Farm field schools for livestock farmers should not only include climate-smart animal husbandry modules but also include animal feed production (especially preservation of hay and silage making) and entrepreneurial/marketing skills

5. GOSL's and its development partners EU, USAID, and World Bank, should promote investments in the livestock value chains especially cane rats and rabbits to diversify livelihoods and reduce vulnerability to shocks. The proliferation of grasscutter farming could also help reduce the risk of a possible re-emergence and transmission of Zoonotic diseases such as the Ebola virus disease (EVD) by providing a readily available and safe source of bush meat.

6. Promote further investment on intensive breeding programs (especially for cattle, goats and sheep) that will

not only increase numbers but also improve performance of the local breeds in terms of meat and milk output through crossing of local breeds with exotic breeds

7. Facilitate the implementation of land ownership policies, and land improvement and conservation strategies. MAF, MLCPE, and EPASL have clearly defined policies that will give women and youths access to land and property and mitigate the effects of climate change through environmental protection. However, they are constrained by lack of funds.

8. Embark on morphological and genotypic characterization of forages existing in the rural livestock farming areas. This will inform decisions on the selection of forages with high economic value for propagation on pasture lands.

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An Assessment of the use of the ISO 50001 Certified Energy Management Systems by Airports

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Abstract—*This study has examined the airports located throughout the world that have implemented an ISO 50001 certified Energy Management System (EMS). The research used an in-depth instrumental case study research design. The study period was from 2011 to 2022. The study found that ISO 50001 certified Energy Management Systems are increasingly being adopted by airports and these systems are playing a key role in their environmental management. Airports located in China, Cyprus, Hong Kong, Europe, India, Turkey, Sweden, United Kingdom, United States of America have implemented ISO 50001 certified Energy Management Systems since the inception of this standard in 2011. ISO 50001 certified Energy Management Systems have been implemented by hub airports, by airports that service both domestic and international airlines services, and by smaller regional airport. The case study found that airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. These airports have implemented a very wide range of energy conservation measures, including the use of light emitting diode (LED) systems, the electrification of ground service equipment and vehicles, the installation of electric vehicle charging stations, the installation of photovoltaic (PV) solar systems, building heating and cooling systems optimization, and the optimization of energy for plant and equipment. The case study also highlighted the importance that the airports using an ISO 50001 certified Energy Management System are placing on the use of more environmentally friendly renewable energy sources.*

Keywords— ***Airports, case study, energy, energy management, ISO 50001 Energy Management Systems.***

I. INTRODUCTION

Airports are an integral component of the world air transport system (Dempsey, 2000) and act as a forum in which discrete elements and activities are brought together to facilitate, for passengers and air cargo, the interchange between air and surface transport modes (Doganis, 2005). The basic infrastructure and facilities provided by airports compromises runways, taxiways, apron space (ramp), passenger terminals, air cargo terminals, and ground transport interchange facilities (Ashford et al., 2011; Seyanont, 2012). Airports provide both aeronautical services (infrastructure, facilities and in some cases ground handling services) and non-aeronautical services (for example, car parks and retail concessions) to two main groups of customers: airlines and air travelers (Marques & Brochado, 2008).

To reduce their long-term operating costs and to ensure that energy demand can be satisfied when the needs arise, airports are placing a higher focus on energy-conservation measures in the design (and operations) of terminal buildings and infrastructure (Thomas & Hooper, 2013). Some airports have also developed and operate new power-generation systems that provide reliable and affordable sustainable energy whilst also lowering their energy costs (Budd & Budd, 2013). Furthermore, airports often work closely with tenants, concessionaires, and service partners to reduce energy consumption through the introduction of low-energy equipment and systems (Thomas & Hooper, 2013).

Airports are extremely energy intensive (Baxter, 2021; Baxter et al., 2018; de Rubeis et al., 2016; Ortega Alba & Manana, 2017). This is due to the large buildings (both

passenger terminals and non-passengers' areas) equipped with heating and air-conditioning systems, and the high-power demand for lighting and electric equipment and the energy requirements from the many facilities located within the airport precinct (Cardona et al., 2006). Airports also consume large amounts of energy due to the comfort requirements of airport terminal buildings (Akyüz et al., 2017). An airport terminal cooling demands can also be energy intensive (Abdallah et al., 2021). Consequently, the maintenance of an ambient temperature and air quality within airport passenger terminals to ensure passenger comfort typically represents the single most significant contribution to energy usage and management at most airports (Thomas & Hooper, 2013).

In addition to the provision of electrical energy required for the aids to air transport operations, for example, lighting and meteorological systems, electrical energy also needs to be provided for airport buildings, aircraft hangers and other airport facilities (Kazda et al., 2015). Thus, energy management, which includes heating, ventilation, air conditioning, and lighting, is extremely important for airports (Graham, 2018).

The implementation of energy management policies over the past thirty years or so has been regarded as being particularly important for firms wishing to save energy resources, to tackle the issue of climate change, whilst also maintaining their competitive edge in an ever-changing business environment (Tachmitzaki et al., 2020. A firm's energy efficiency can be controlled and systematized by using an Energy Management System (Fiedler & Mircea, 2012). In 2011, the International Organization for Standardization (ISO) released its ISO 50001 Energy Management System standard, which has been embraced by organizations all around the world. As a result of its implementation of an ISO 50001 Energy Managements System by an organization, besides the support provided to reduce the energy consumption of the company, the certified ISO 50001 Energy Management System also enables better cost management and greenhouse gas (GHG) emission reduction (Rampasso et al. 2019). In recent times, airports have adopted the use of ISO 50001 certified Energy Management Systems (Baek et al., 2016; Fossi & Esposito, 2015; Strelkova &Agieieva, 2014; Uysal & Sogut, 2017). The key objective of this study is to empirically examine the airports located throughout the world that have implemented an ISO 50001 certified energy management system (EMS) as a system to manage their energy usage in a sustainable manner. A secondary objective is to identify the types of airports, for example, major hub or regional airports, that have implemented ISO 50001 Energy Management Systems. A further objective is to examine how airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. The study period is from 2011, the year in which the ISO 50001 standard came into effect, to 2022.

The remainder of the paper is organized as follows: The literature review is presented in Section 2. The research method that underpinned the study is outlined in Section 3. The case study is presented in Section 4. Section 5 presents the key findings of the study.

II. BACKGROUND

2.1 Core Functions of an Airport

An airport is a complex transportation hub serving aircraft, passengers, air cargo shippers and surface vehicles (Doganis, 2005). An airport is either an intermediate or terminal point of an aircraft operating the air portion of a flight, either on a scheduled or non-scheduled basis. In simple functional terms, the airport must be designed to enable an aircraft to land and take-off. In between these two operations, it may, if required, unload and load passengers, air cargo, mail and crew and service the aircraft (Ashford et al., 2013, p. 8).

The core function of an airport is the operation of premises and facilities for the servicing and handling of aircraft, passengers, and air cargo and mail. This includes the supply and operation of ground handling facilities, aprons, runways, aircraft, and ground service equipment (GSE) maintenance areas, gates, people movers, baggage handling, car parks, passenger and visitor waiting areas, areas for security and social services, and so forth (Meincke & Tkotz, 2010, p. 95).

In addition, airports may also offer/provide non-aviation services. These are primarily the supply of space for shopping and retail operations, convention centres, restaurants, and business centres. The non-aviation revenues are often a major source of revenue and profits, and hence, an essential part of an airport's business model (Graham, 2018). Increasingly more aviation-related businesses are establishing operations near airports (Reiss, 2007). Another important development in the airport industry is that airports are increasing evolving from simple infrastructure providers to complex multiproduct, multiservice enterprises (Appold & Kasarda, 2011). Indeed, airports all around the world have developed into multimodal, multifunctional enterprises, which has driven substantial commercial development both within and beyond their boundaries (Kasarda, 2006). Many airports have diversified their activities and revenue streams and have created so-called "airport cities" (Kasarda, 2013; Orth & Weidmann, 2014). In the case where the airport operator is responsible for the provision of energy, then the

airport's non-aviation facilities will also need to source power, and this will have a concomitant impact on the airport's overall energy requirements and energy consumption.

2.2 Airport Energy Sources

Airports consist of the landside and airside precincts both of which have significant energy requirements (Janić, 2011, 2017). The airside precinct includes the aircraft movement area, and the adjacent terrain and buildings/infrastructure. The landside precinct includes those parts of an airport together with the adjacent terrain and buildings that are not located in the airside precinct (Rossi Dal Pozzo, 2015). The key stakeholders, for example, airlines and ground handling agents, operating within the airport's airside and landside precincts require a reliable and highly efficient supply of energy. Historically, the two primary energy sources have been electricity and fuel, for example, diesel, natural gas, and propane (Ortega Alba & Manana, 2016). Electrical energy is typically supplied directly to the airport through dedicated sub-stations (Janić, 2011). Airports often purchase electricity from the commercial grid and this electricity is supplied by a power company (Ortega Alba & Manana, 2016). In recent years airports have started to adopt the use of renewable energy sources. These technologies include solar photovoltaic (PV), concentrating solar power, wind power, oil and natural gas extraction, steam-generated power production and electricity transmission (Barrett et al., 2014).

2.3 Energy Usage at Airports

The major areas of energy consumption at an airport are heating, cooling, lighting, and the energy required for operating the airport's facilities and systems (Janić, 2011; Radomska et al., 2018). At many airports, crude oil is often used for producing the fuel used to power the ground service equipment (GSE) and vehicles that are used in an airport's airside and landside areas, especially in the aircraft ground handling process (Janić, 2011). Ground service equipment (GSE) refers to vehicles and equipment that are used in the airport precinct to service whilst they are at the gate in between flights (Hazel et al., 2011). Fuel is also used for airport's heating boiler systems and emergency generators (Ortega Alba & Manana, 2016). The airport terminal's heating, ventilation, and air conditioning (HVAC) systems use the largest amount of energy (Akyüz et al., 2017; Yildiz et al., 2022).

Energy consumed by airports can be broadly divided into the energy consumed by the airside activities undertaken at the airport as well as the energy consumed in the provision of the airport's landside area activities. In the airport's airside area, energy requirements include the fuel that is consumed by aircraft during the landing and take-off (LTO) cycles. Also, ground service equipment (GSE) and vehicles serving aircraft at the apron/gate complex consume energy. In the airport landside area, the primary consumers of energy are the airport ground access systems/modes and passenger and air cargo terminals as well as other administrative buildings serving the airport. The primary energy sources are from non-renewable fossil fuels and to a moderate degree from renewable wind, water, and solar sources (Janić, 2011).

2.4 An Overview of the International Organization for Standardization ISO 50001 Energy Management System Standard

Different standards motivate firms to use energy more efficiently (Jovanović & Filipović, 2016). Energy management has been increasingly considered as a way for a firm to improve energy performance and at the same time reduce their greenhouse gas emissions (Hasan & Trianni, 2020; Sola & Mota, 2020). The United Nations Organization for Industrial Development requested the International Organization for Standardization (ISO) to develop an international standard for energy management. This standard development took place within the framework of industries' requirements to have an effective response to global climate change (Castro et al., 2017). Introduced in June 2011, the ISO 50001 International Standard was developed to provide a unified framework for energy management efficiency (Dzene et al., 2015; Gopalakrishnan et al., 2014; Yuriev & Boiral, 2018). According to Brown and Desai (2014), "the adoption of the ISO 50001 Energy Management System standard by the International Organization for Standardization (ISO) served to unite the previously separate national standards and provide a structured, globally accepted approach to the management of energy" The ISO 50000 family of standards developed by the ISO provides guidelines and recommended practices for the utilization, savings, efficiency, and continuous improvement in energy performance. As previously noted, ISO 50001 establishes the requirements for an Energy Management System (EnMS) (Poveda-Orjuela et al., 2018). Since the launch of the ISO 50001 standard in 2011 there has been the growing adoption of Energy Management Systems (EnMSs) by firms around the world (Laskurain et al., 2017). The ISO 50001 Energy Management System standard supports an organizational cost-and-benefits oriented perspective of energy (Kals, 2015). ISO 50001 Energy Management System is a voluntary standard (Lira et al., 2019).

The principal goal of the ISO 50001 standard is for an organization using an Energy Management System to improve the energy performance of the organization

continuously and sustainably so that it can reduce energy consumption and the associated costs. These also include alleviating environmental climate change impacts (Nakthong & Kubaha, 2020). The standard stipulates the measurement of energy performance improvement using energy performance indicators (EnPIs) and the energy baseline (EnB) (Nakthong & Kubaha, 2020; Wulandari et al., 2014).

An ISO 50001 certified Energy Management System is comprised of five key components: Roles and responsibility, energy policy, energy objectives and energy targets, energy efficiency improvement plan, and the monitoring, measurement, and analysis (Energy Efficient Singapore, 2021; International Organization for Standardization, 2021).

The ISO 50001 Energy Management System standard also provides a basis for energy management improvement by a firm (Jovanović & Filipović, 2016). This is because the ISO 50001 Energy Management System standard is based on the management system model of continual improvement. Thus, the ISO 50001 Energy Management System standard makes it easier for a firm to integrate energy management into their overall efforts to improve their quality and environmental management (International Organization for Standardization, 2021).

The ISO 50001 Energy Management System (EnMS) framework is a tool that can be used by organizations to assess their energy management sustainability. The system allows for the determination of an organization's actual strengths and weaknesses in its energy management. The benefits of using this framework (and an energy management system) include the possibility of determining guidelines for correcting and improving the Energy Management System (EnMS) to achieve the sustainability goals of the organization (Nakthong & Kubaha, 2019).

According to the International Organization for Standardization, the ISO 50001 standard provides a framework of requirements for a firm to:

- Develop a policy for more efficient use of energy
- Define targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the energy policy works, and
- Continually improve energy management (International Organization for Standardization, 2021).

As previously noted, ISO 5001 is a voluntary standard. In today's business environment, some firms have decided to implement the standard solely for the benefits it provides. Conversely, other firms decide to get certified, to show external parties they have implemented an Energy Management System. The International Organization for Standardization (ISO) does not perform any certification (International Organization for Standardization, 2021).

The ISO 50001 Energy Management System standard has been designed for implementation by any organization that operates in either the public or private sector, whatever its size, activity, or geographical location. ISO 50001 does not set fix targets for improving energy performance, rather this left up to the user organization or regulatory authorities. As a result, any organization, regardless of its current level of energy performance, can implement the ISO 50001 Energy Management System standard to establish a baseline and improve on it at its own rate (International Organization for Standardization, 2018a).

The ISO 50001 Energy Management System standard has been designed for organizations to improve their energy performance by making better use of its energy-intensive assets. Improvements in energy performance can deliver rapid benefits to the firm using an Energy Management System by maximizing its use of energy sources and energy-related assets, thus, reducing both cost and energy consumption. The ISO 50001 standard is used by both large and small organizations located throughout the world. The benefits of using an ISO 50001 certified Energy Management System include a reduction in the organizations environmental impact, an enhanced reputation, and the ability to drive down costs and improve the firm's competitiveness (International Organization for Standardization, 2018a). The use of an ISO 50001 certified Energy Management System can assist organizations to achieve full compliance in line with the various environmental regulations applicable to their organization (Capital NDT, 2021; Eccleston et al., 2012). In addition, a very important benefit is that the ISO 50001 Energy Management System standard provides an organization with a powerful tool to improve their overall energy performance (Marimon & Casadesús, 2017). The use of an ISO 15001 certified Environmental Management System can also enable an organization to improve the efficient use of existing technologies and practices so they can optimize their energy efficiency. In addition, the use of the system will enable the organization to promote environmental performance whilst also reducing greenhouse gas (GHG) emissions (Eccleston et al., 2012).

As previously noted, the ISO 50001 standard was first published in 2011. However, since its inception, a number of other related standards have been developed by the ISO technical committee ISO/TC 301, Energy management and energy savings. These changes have been made to

complete the energy management and energy savings family (International Organization for Standardization, 2018a).

These include:

- ISO 50002, Energy audits – Requirements with guidance for use
- ISO 50003, Energy management systems – Requirements for bodies providing audit and certification of energy management systems
- ISO 50004, Energy management systems – Guidance for the implementation, maintenance and improvement of an energy management system
- ISO 50006, Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance
- ISO 50007, Energy services – Guidelines for the assessment and improvement of the energy service to users
- ISO 50015, Energy management systems – Measurement and verification of energy performance of organizations – General principles and guidance
- ISO 50047, Energy savings – Determination of energy savings in organizations

Other ISO energy related standards include:

- ISO 17741, General technical rules for measurement, calculation, and verification of energy savings of projects
- ISO 17742, Energy efficiency and savings calculation for countries, regions, and cities
- ISO 17743, Energy savings – Definition of a methodological framework applicable to calculation and reporting on energy savings
- ISO/IEC 13273-1, Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency
- ISO/IEC 13273-2, Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources (International Organization for Standardization, 2018a, pp. 9-10).

The ISO 50001 Energy Management System standard was updated in August 2018 (Kohl, 2020; Naden, 2018). This standard contributes to the following United Nations Sustainable Development Goals 7 (Affordable and clean energy), 11 (Sustainable cities and communities), 12 (Responsible consumption and production), and 13 (Climate action) (International Organization for Standardization, 2018b).

III. RESEARCH METHODOLOGY

3.1. Research Method

To achieve the research objectives, this study utilized an in-depth qualitative instrumental case study research design. An instrumental case study is the study of a case, for example, a business or company, that provides insights into a specific issue, redraws generalizations, or builds theory (Stake, 1995, 2005). The instrumental case study research approach enables researchers to gain an enhanced understanding of a specific phenomenon. An instrumental case study is designed around established theory of the phenomenon that is being empirically examined (Grandy, 2010). The present study was designed around the established theory of ISO 50001 Environmental Management Systems (Eccleston et al., 2012; Kals, 2015; Wulandari et al., 2014; Yuriev & Boiral, 2018).

3.2 Data Collection

The data used in the study was obtained from a range of company materials that were available on the internet and these records formed the source of the case study evidence. An extensive search of the leading air transport and airport-related journals and magazines was also conducted in the study. This study used secondary data. The three principles of data collection as recommended by Yin (2018) were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

3.3 Data Analysis

The data collected for the case study was examined using document analysis. Document analysis is quite commonly used in case studies. Document analysis focuses on the information and data from formal documents and a firm's records that are collected by a researcher(s) when conducting their study (Andrew et al., 2011; Yin, 2018). Following the guidance of Scott (1990, 2014) and Scott and Marshall (2009), the documents gathered in the present study were examined according to four criteria: authenticity, credibility, representativeness and meaning.

The document analysis was undertaken in six distinct stages:

- Phase 1: The first phase involved planning the types and required documentation and their availability for the study.
- Phase 2: The data collection phase involved sourcing the documents and developing and implementing a scheme for the document management.
- Phase 3: The collected documents were examined to assess their authenticity, credibility and to identify any potential bias.
- Phase 4: The content of the collected documents was carefully examined, and the key themes and issues were identified.
- Phase 5: This phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content.
- Phase 6: In this phase the analysis of the data was completed (O'Leary, 2004, p. 179).

Following the guidance of Yin (2018), the study's documents were downloaded and stored in a case study database. All the documents gathered for the study were all written in English. Each document was carefully read, and key themes were coded and recorded in the case study research framework (Baxter, 2021).

IV. RESULTS

Aéroports de Paris was awarded its ISO 50001 Energy Management System certification for its operations and development activities at Ile-de-France airports and its energy management using fossil and renewable sources (biomass, geothermal, solar) by LRQA France, on 25 July 2015. Aéroports de Paris became the first group managing a multi-airports system to have an Energy Management System with an ISO 50001 certification. To achieve the company's strategic objective of reducing carbon dioxide (CO_2) emissions by 25% between 2009 and 2015, beginning in 2008 Aéroports de Paris invested in a major renewable energy development program. As a result, geothermal energy at Paris-Orly airport and a biomass and a solar farm at Paris-Charles de Gaulle airport have resulted in renewable energy sources making up over 15% of internal energy use. To attain its goals of achieving ISO 50001 certification, Aéroports de Paris worked on improving all its internal processes to develop an energy management system (EMS) in line with the international ISO 50001 standard. Importantly, since January 2014, the Energy Management System has complemented the Integrated Management System (IMS) and the Environment Management System (EMS) at Aéroports de Paris. The Aéroports de Paris managed, and operated airports are Paris Charles de Gaulle, Paris-Orly, Paris-Le Bourget, and Issy-les-Moulineaux, all of which have held an ISO 14001 environmental certification for many years (Aéroports de Paris, 2015).

Amsterdam-based Schiphol Airport has implemented an ISO 50001 certified Energy Management System. The airport has implemented energy saving measures including the use of electricity powered buses and cars, electric car charging stations and the use of solar power (Schiphol Group, 2021).

Bali's Ngurah Rai International Airport has introduced an ISO 50001:2018-based Energy Management System for energy conservation and management. The goal of the system is to minimize the environmental footprint of the Island's sole air gateway. The new ISO 50001:2018-based Energy Management System was implemented at Bali's Ngurah Rai International Airport in February 2021, as the result of a Memorandum of Understanding (MOU) signed in October 2020 between Angkasa Pura I, the Director-General of New Energy Sources from the Directorate of Energy Conservation, and the Director-General of Energy Conservation from the Ministry for Energy and Natural Resources. The aim of Ngurah Rai Airport's active participation in the energy management system is to reduce the greenhouse gas (GHG) emissions that contribute to the climate change. The airport's energy conservation measures include the use, whenever possible, of solar energy, lighting powered by solar cells, the use of light emitting diode (LED) lighting, and the deployment of many energy-saving devices in the day-to-day operation of the airport gateway. The energy saving measures implemented at the airport will reduce energy consumption by 3,627.686 MWh and will also reduce the airport's annual carbon dioxide (CO_2) emissions (Daniels, 2021).

Bangalore International Airport Limited (BIAL) in India achieved its ISO 50001:2011 Energy Management System certification on 8 April 2013. The goal of the airport is to create a greener environment. The certification was awarded by DNV (Det Norske Veritas). The implementation of the ISO 50001:2011 Energy Management System has enabled the airport to achieve its policy commitments, and to act as required to improve its energy performance at the airport. This includes energy cost reduction, greenhouse gases (GHGs) mitigation, waste minimization, resource conservation and compliance with all applicable legal requirements (GVK, 2013).

Bologna Airport in Italy uses a certified ISO 5001 Energy Management System. During 2013, the airport began the process of implementing the ISO 50001 Energy Management System into its operations (Bologna Airport, 2014). In 2021, Bologna Airport focused on its active energy efficiency, which are an integral part of the

airport's sustainable development policy. Between cogeneration, photovoltaics, and high-efficiency light emitting diode (LED) lighting, it is estimated that the airport was able achieve energy savings of around 2,600,000 kWh. Bologna Airport has recently completed the energy efficiency upgrade to the workshop lighting and launched an initiative to replace the old lamps in the lighting towers - which will reduce the installed power by over 70% while guaranteeing the same lighting performance. The airport is also renewing the lighting in the Baggage Handling System, which will reduce energy consumption by over 70%. Importantly, Bologna Airport self-produces around 20 MWh of electricity through a photovoltaic system and manages a high-performance trigeneration plant, covering around 58% of its own energy requirements. In addition, the airport has decided to commit to the construction of a new photovoltaic system of around 190 kW, which will be installed on the roof of the passenger terminal, and a photovoltaic system of around 100 kW that will be located on the roof of the BHS building, which will enable the production of over 300,000 kWh of electricity. Furthermore, in 2021, the airport operator only purchased electricity from renewable sources and natural gas with offset-certificated emissions, linked to forest and biodiversity conservation projects certified by third parties (Bologna Airport, 2021).

Brussels Airport Company successfully completed its Environmental Management System audit in 2012 and became the first airport in the world to be awarded the ISO 50001 certificate for its energy management (Brussels Airport, 2021b). A key element of the airport's Environmental Policy Statement is the airport's objective to achieve a continuous improvement in its energy performance and to achieve a structural reduction in carbon dioxide (CO_2) emissions by focusing on energy efficient installations. The airport also aims to increase the share of renewable energy used at the airport (Brussels Airport, 2021a).

Delhi Airport also has introduced an ISO 50001:2018 certified Energy Management System. This system improves the energy performance of the airport by making better use of the energy-intensive assets, and through these concerted efforts, the airport has successfully reduced both fuel and electricity consumption over the years. As part of sustainability goals, the airport has installed 7.84MW solar power plant on the airport site. Delhi Airport has also signed a long-term power purchase agreement with a hydropower plant. The plant, expected to be commissioned by 2022-23, will supply the entire electricity need of the airport, thereby ensuring a clean energy supply to Delhi Airport (Kumar Jaipuriar, 2022).

Dresden Airport in Germany introduced its Energy Management System that was certified to the international standard ISO 5000: 2011 during 2016. Increasing its energy efficiency has the added benefit of reducing emissions of air pollutants from our airport operations. Dresden Airport is also generating renewable energy from the solar panels that were installed on the roof of the car park extension in 2010 (Mittel-Deutsche Flughafen AG, 2021a).

Dublin Airport was granted ISO 50001 Energy Management System certification in 2016. The airport was subsequently recommended for recertification in accordance with the ISO 50001: 2018 standard (DAA International, 2021). In recent times, Dublin Airport has introduced a wide range of energy management measures that enable it to monitor and improve its overall energy use across the campus. The energy savings measures include the use of building management systems, the installation of efficient light emitting diode (LED) lighting, a pilot solar farm project, which will significantly reduce its overall energy consumption. Other energy-related include the transition of all of its light vehicle fleet to low emission vehicles (LEVs) by 2024 and building a second solar farm on campus with a capacity of 7.5MWp. This will contribute 10% of the airport's total annual electricity requirements and will have the potential to generate up to 7.5 megawatts of power (Dublin Airport, 2021).

Geneva Airport achieved AFAQ ISO 55001 energy management system certification on 12 July 2016 (AFNOR Group, 2016). Geneva Airport has installed a photovoltaic (PV) solar system that can produce 7.5 GWh of clean energy per year. Geneva airport's energy strategy is based on lowering the airport's energy requirements, producing, and efficiently using energy and promoting the use of renewables (Petrova, 2017).

GMR Hyderabad International Airport Ltd. (GHIAL) in India obtained its ISO 50001: 2011 Energy Management Systems Standard, 'Design, Construction, Operation and Maintenance of airport facilities' certification in May 2013. The Japan Accreditation Board (JAB) was responsible for the airport's ISO 50001: 2011accreditation (SGS SA, 2013). The airport has maintained a high focus on its energy management and has implemented a range of energy efficiency measures. These measures include power optimization by scheduled operation of AHU and lights, operation of new energy efficient sewage treatment plant, cooling tower efficiency enhanced by upgradation, the installation of a photovoltaic (PV) solar system, and the extensive upgrading of lighting with the latest light emitting diode (LED) lighting (Potdar et al., 2020).

Hartsfield-Jackson Atlanta International Airport received its ISO 50001 Energy Management System certification in

March 2016. The airport was the first United States-based airport to achieve ISO 50001:2011 certification (AECOM, 2016; Weinschenk, 2016). The City of Atlanta Department of Aviation ensures that energy efficiency and conservation is taken into consideration in the planning, design, construction, maintenance, and operational decisions of the airport. The airport also aims to use renewable energy sources wherever feasible (Hartsfield-Jackson Atlanta International Airport, 2016).

Incheon Airport in Korea has also implemented an ISO 50001 certified Energy Management System. The system plays a key role in the airport's goal to be energy efficient. The airport plans to advance the use of its energy management system. A range of energy saving measures have been implemented at the airport in recent times and these include the installation of light emitting diode (LED) lighting, replacement of freezers with more energy efficient models, and the expanded use of photovoltaic solar power generation facilities (Incheon International Airport Corporation, 2021).

Istanbul Airport's (IGA) ISO 50001 Energy Management System was certified by the British Standards Institution (BSI) in October 2020. The airport has placed a high focus on increasing its energy efficiency, decreasing consumption, and protecting resources for future generations and these goals are underpinned by the airport's Energy Management System (International Airport Review, 2020b). To achieve a reduction in carbon dioxide (CO_2) emissions at Istanbul Airport, the airport has achieved system Improvements with energy audits, and has implemented energy saving measures, which include the use of electric vehicles, and the installation of vehicle charging stations (International Air Transport Association, 2021). Istanbul Airport also plans to implement the use of hydrogen fuel for heating and transportation purposes, as well as introducing carbon capture technologies, solar power plant fittings, and the usage of biodiesel (Air International, 2021).

Leipzig/Halle Airport has had a certified Energy Management System in line with the international DIN EN ISO 50001 standard since 2016. A key objective of the airport is to continually improve energy efficiency at the airport. Leipzig/Halle Airport has installed a photovoltaic (PV) solar system, which has annual output of up to approximately 200 MWh (Mittel-Deutsche Flughafen AG, 2021b).

London Heathrow Airport acquired its ISO 50001 Energy Management System certification in 2015 (Virmany & Fitch, 2016). London Heathrow Airport has set a goal to operate zero carbon airport infrastructure (buildings and other fixed assets) by 2050. To achieve this goal, the airport has implemented a range of energy efficiency measures. These measures include embedding leading edge energy efficiency thinking into the design of new airport infrastructure, investing in improvements to the energy efficiency of existing buildings, assets and other infrastructure, the proactive influence of business partners' operations and growth to improve energy efficiency, maximizing the proportion of energy generated from on-airport or local renewable sources, and the purchase of renewable energy from off-site sources (Heathrow Airport Holdings, 2021).

London Stansted Airport received its ISO 50001 Energy Management System certification in 2018 (MAG Airports, 2019). The airports ISO 50001 Energy Management System was recertified on 11 August 2020 (Stansted Airport Holdings, 2020). The airport has defined and implemented an Environment and Energy Policy. In accordance with this policy, Stansted Airport is committed to continually improving its environmental and energy performance. The airport also aims to prevent pollution, protect the environment, reduce carbon emissions, and comply with all environmental legal and other requirements. Furthermore, the airport assesses the impact on the environment and energy consumption of all activities undertaken at the airport and establishes objectives and targets to drive continual improvement performance in these areas (London Stansted Airport, 2020).

Luton Airport in the United Kingdom was awarded its Energy Management Standard ISO 50001 certification in September 2015. The airport has implemented various energy-saving initiatives including light emitting diode (LED) lighting and PIR motion sensors. Other energy efficiency measures include a new coach fleet, more fuel-efficient security vehicles, and a refurbished toilet facility with more efficient lighting and hand dryers (Allen, 2015).

Lyon-Saint Exupéry Airport in France was awarded with its ISO 50001 Energy Management System certification by the French standardization association AFNOR in December 2018. The certification was in recognition of the airport's energy management and the improvement in its energy performance. The energy action plan implemented by Lyon-Saint Exupéry Airport was part of the "Air Pact" environmental strategy defined by VINCI Airports, the airport's owner, for all its facilities. VINCI Airports aims to maintain its energy consumption at a stable level despite its airport's activities increasing significantly. Lyon-Saint Exupéry Airport has implemented various energy saving measures. These include the sensible use of equipment (desktop computer, lights, heating, etc.) by employees, investing in the design and use of buildings (new Terminal 1 constructed to France's HQE high environmental quality

standard), and installing light emitting diode (LED) lighting in the airport's terminals and aircraft parking areas (Burns, 2018; VINCI Airports, 2018). Light-emitting diodes (LEDs) are a feasible option for airports due to their requirement for colored light as well as low light output requirements (Baxter et al., 2018). Consequently, airports are increasingly transitioning to the use of LED systems (Freyssinier, 2014). During 2011, Lyon-Saint Exupéry Airport was the first French airport to purchase 100% green energy (Burns, 2018; VINCI Airports, 2018).

Mumbai International Airport is another Indian airport that has attained ISO 50001 Energy Management System certification. GVK managed Mumbai International Airport (MIAL) received the ISO 50001: 2011 accreditation in July 2015 (Financial Express, 2015). The airport maintains a very high focus on its energy management and has implemented various green energy initiatives across its site. A goal of the airport is to use renewable energy sources. The airport has installed solar panels on the rooftops, contributing to approximately 5% of the airport's total energy consumption (Shergill, 2021). The airport has saved substantial energy of around 38500 MWh due to its sustainable approach towards energy efficiency measures (International Airport Review, 2021). Maharaj International Airport (CSMIA) has entirely switched to green sources for its energy consumption requirements, thereby ensuring it is one of India's 100 percent sustainable airports (Shetty, 2022).

Operated by TAV Airports, Ankara Esenboğa Airport in Turkey is another airport that completed all the work necessary to control energy consumption and is has subsequently received the ISO 50001 Energy Management System certification. The airport has implemented rules in its passenger terminal to minimize our energy losses and achieve more sustainable energy consumption. The airport has also defined energy consumption targets and has provided energy efficiency training to its employees (TAV Airports, 2021).

Salzburg Airport in Austria has attained ISO 50001: 2011 Energy Management System certification (Salzburg Airport, 2018). At Salzburg Airport around 40 per cent of the airport's vehicle fleet is powered by electricity, including an electric high loader. The airport is also changing from conventional to light emitting diode (LED) lighting and is using solar energy (International Airport Review, 2020a).

Shenzhen Airport (Group) Company Ltd has received ISO 5001 certification for its Energy Management System. The company which operates Shenzhen International Airport has implemented a wide range of energy efficiency measures. These measures include the installation of a photovoltaic (PV) solar system, the purchase of new energy vehicles, installation of light emitting diode (LED) lighting, and the installation of a central air conditioning magnetic levitation cold water main engine (Clean Energy Ministerial, 2019).

Stockholm Arlanda Airport received its ISO 50001 Energy Management System certification on 23 December 2016. The airport's Energy Management System was recertified in accordance with ISO 50001: 2018 standard on 24 December 2019 (Swedavia, 2019). At the time of the present study, essentially all heating, electricity and cooling used by the airport are generated from renewable sources. The buildings at Stockholm Arlanda Airport are warmed during the winter period with district heating based on biofuel. Swedavia, the operator of Stockholm Arlanda Airport, also purchases "green electricity certificates". These certificates are equivalent to its entire electricity consumption at the airport. These certificates guarantee electricity production from exclusively renewable sources. The renewable sources include wind, solar, hydropower and/or biofuels. According to Swedavia (2021), "in the summer of 2009, Stockholm Arlanda also inaugurated the world's largest energy storage unit – a so-called aquifer – in the nearby boulder ridge known as Brunkebergsåsen". The airport is both heated and cooled efficiently using the aquifer and there is no adverse environmental impact during the summer or winter. The airport has also installed more efficient and better controlled lighting indoors and outdoors. Other energy saving measures include heat recycling in the airport's terminal buildings, more efficient ventilation, and the use of RPM-regulated electric motors (Swedavia, 2021).

Torino Airport in Italy has implemented an ISO 50001 certified Energy Management System. In October 2020 Sagat S.p.A., the airport operator, along with DNV-GL (the certification body) renewed the airport's Energy Management System certification. The airport's system is certified in accordance with the international standard ISO 50001:2018. The system recertification involved an energy diagnosis update in line with the manner provided for by Italian Legislative Decree n. 102/2014. The airport is focusing on limiting energy consumption both through investments in plants and systems with significant potential for improvement and through the enhancement of management and control systems. In 2020, 75% of the electricity came from certified renewable sources (Sagat S.p.A, 2021).

The Airport Authority of Hong Kong (AA) achieved the ISO 50001:2011 Energy Management System (EnMS) Certification for its Terminal 1 in February 2017. The use of the system will enable the airport authority to continuously improve energy efficiency and to identify

energy reduction opportunities. At the time of the certification, the airport authority envisaged that it would expand the scope to other terminal areas, office buildings and the airport's apron area. The company's goal is to become the most energy efficient international airport (Airport Authority of Hong Long, 2017). The airport's ISO 50001 Energy Management System (EnMS) certification covers Terminal 1 and the Midfield Concourse, and it was envisaged that it would be expanded to cover all terminal buildings at the airport by January 2020 (Airport Authority of Hong Long, 2019). The airport in recent times has implemented energy efficiency initiatives, such as, the replacement of light emitting diode (LED) lights in Terminal Building 1, the modification of gantry lighting control in Terminal Building 1, the replacement of apron high mast lighting with light emitting diode (LED) lighting, the replacement of three energy efficient chillers in the airport's Ground Transportation Centre, and the replacement of energy efficient pump sets and motors at Seawater Pump House No.5. The airport has also acquired electric cars and buses and electric ground services equipment (e-GSE) are being introduced (Airport Authority of Hong Long, 2018). In 2018, Hong Kong International Airport introduced the ground service equipment (GSE Pooling Scheme) which centralizes the deployment of GSE used at the airport in the aircraft turnaround process (Airport Authority of Hong Kong, 2021). The new scheme optimizes and expedites the allocation and maintenance arrangements for the equipment. During the first phase of the scheme, which comprised over 250 units of critical GSE operating in the Midfield Apron precinct, led to an improvement in air quality and reduction of GHG emissions at the airport as 95% of the GSE are powered by electricity (Airport Authority of Hong Kong, 2021). In the 2018/19 financial year, Hong Kong International Airport continued with the replacement of end-of-service-life light emitting diode (LED) lights in terminals with higher efficient model. Also, in the 2018/2019 financial year the modification of gantry lighting control from 3 stages to 9 stages in Terminal Building T1 was completed (Airport Authority of Hong Kong, 2019). Hong Kong International Airport has also installed an "Air-conditioning Control System" (Weather FACTS) and "Battery Energy Storage System" (BESS), which enhances HKIA's energy efficiency. The airport's "Weather FACTS" system automatically collects hourly weather data, for example, temperature, humidity, cloud amount, wind direction, wind speed and solar radiation, from the Hong Kong Observatory, and the airport's own flight index, passenger flow and seawater temperature information. The system subsequently employs big data and machine learning to forecast the cooling demand of the airport's Terminal T1 building for the coming 24 hours. Based on the forecast, the chiller system is set to deliver the appropriate amount of cooling volume required. The optimization of the cooling levels eliminates unnecessary energy consumption. Together with the replacement of two new 5,000-refrigerant tonne chillers in 2021, an estimated 5.1-gigawatt hours of electricity is saved annually. The airport plans to introduce the same system in other passenger facilities to further optimize the airport's energy efficiency. The airport has also developed the BESS system to cope with the airport's continued traffic growth and requirement for a backup power supply. Importantly, the airport's BESS system, which operates without fuel, is more environmentally friendly than other existing backup generators and can efficiently store up electricity generated from routine testing of backup generators for future use (Airport Authority of Hong Kong, 2021). It is important to note that many airports in recent times are utilizing clean energy technologies and have also implemented practices that reduce local emissions. This environmental-related strategy includes replacing fossil fuel-based with electricity-based operations at the airport (Sajed Sadati et al., 2018). Hong Kong International Airport has introduced electric powered vehilces. Electric-powered vehicles are considered more environmentally friendly because they reduce vehicle emissions when deployed at an airport (Gellings, 2011).

The Delhi International Airport Limited (DIAL) attained its ISO 50001:2011 Energy Management System accreditation on 8 September 2011. Delhi International Airport Limited (DIAL) became the first airport operator in India to receive this certification. The certification was granted by the British Standards Institution (BSI) India (Josh, 2011). The airport has implemented various energy efficiency programs which include the use of renewable energy, development of green airport infrastructures, energy conservation and efficiency improvements. The airport's energy-related infrastructure includes electric vehicle charging facility, state-of-the-art Sewage Treatment Plant (STP) and Water Treatment Plant (WTP), and energy efficient lighting systems. The airport has also adopted the use electric vehicles and "taxibots" (Garg, 2021).

The Energy Management System of Biju Patnaik International Airport (BPIA) in Odisha, India, was certified as ISO 50001:2018 standard in October 2020. The airport places a very high focus on energy efficiency (Sambad English Bureau, 2020).

TÜV Austria Cyprus certified the Energy Management Systems of Hermes Airports Ltd, which is responsible for the management and operation of international Larnaca

and Paphos airports in Cyprus in accordance with the requirements of EN ISO 50001 in January 2017 (TÜV Austria Cyprus, 2017). Hermes Airports places a high focus on its energy management, and energy-related issues are addressed within the framework of the Energy Management System (EnMS) (Hermes Airports, 2021).

V. CONCLUSION

Airports are extremely energy intensive, and thus, there has been a growing trend by airports around the world to optimize their energy efficiency. In addition, airports are also focusing on mitigating their environmental impact and are also seeking ways to reduce their carbon footprint. This study has examined the airports located throughout the world that have implemented an ISO 50001 certified Energy Management System (EMS). The study found that ISO 50001 certified Energy Management Systems are increasingly being adopted by airports and these systems are playing a key role in their environmental management. Airports located in China, Cyprus, Hong Kong, Europe, India, Turkey, Sweden, United Kingdom, and the United States of America have adopted the use of the ISO 50001 certified Energy Management Systems since the inception of this standard in 2011.

The case study revealed that the ISO 50001 certified Energy Management Systems have been implemented by hub airports, for example, Hartsfield-Jackson Atlanta International Airport and Hong Kong Airports, by airports that service both domestic and international airlines services, and by smaller regional airport, such as, Lyon-Saint Exupéry Airport in France.

The case study further revealed that airports are using their ISO 50001 certified Energy Management System to optimize their energy efficiency. These airports have implemented a very wide range of energy conservation measures, including the use of light emitting diode (LED) systems, the electrification of ground service equipment (GSE) and vehicles, the installation of electric vehicle charging stations, the installation of photovoltaic (PV) solar systems, building heating and cooling systems optimization, and the optimization of energy for plant and equipment. The case study also highlighted the importance that the airports using an ISO 50001 certified Energy Management System are placing on the use of more environmentally friendly renewable energy.

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Soil carbon stock and physico-chemical properties in important plantations of Tamil Nadu, India

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Abstract— *Soil organic carbon (SOC) plays an important role in soil fertility and is of paramount importance for its contributions to mitigation and adaptation to climate change. The present study was undertaken to estimate the SOC stock and soil properties in important plantations of the Southern zone in Tamil Nadu. Four different species were selected for the study viz, Eucalyptus, Casuarina, Melia and Teak. In all the plantations selected for estimation of biomass, composite soil samples were collected at three different depths; i.e., 0-15, 15- 30 and 30-45 cm. The soil samples were analysed for the carbon stock and various properties such as pH, Electrical conductivity, Organic carbon, Available N, Available P, Available K. Among Eucalyptus plantations, clonal plantation of >6 years sequestered the highest amount of soil carbon (19.8 Mg ha^{-1}) at 30 cm depth. SOC stock was maximum in Casuarina plantation of > 5 years (23.3 Mg ha^{-1}). Among the different Melia plantations, maximum SOC stock was observed in Melia plantation of 5 to7 years old (15.6 Mg ha^{-1}), and in Teak plantations, SOC stock was highest in plantations of > 15 years old (22.1 Mg ha^{-1}). The soil pH and Electrical conductivity significantly differed among the plantations and decreased with an increase in the age of plantation. Nitrogen availability was highest (303.98 kg ha^{-1}) in >5 years of Casuarina clonal plantation at 0-15 cm depth. Among the plantations the available potassium was high in surface soils (0-15 cm) of >5 years Casuarina clonal plantation (329.50 kg ha^{-1}). The data generated in the present study would provide valuable information on the scope of afforestation and reforestation projects for sustaining the livelihoods of the farming community and also will encourage them to contribute to mitigating global carbon emissions and expanding forest and tree cover.*

Keywords— ***Soil carbon stock, soil properties, plantations, climate change.***

I. INTRODUCTION

Global climatic conditions due to human activities have directed towards utilizing soils as a resource to both mitigate and adapt to climate change. The importance of soils and SOC in climate change adaptation and mitigation has been widely accepted and demonstrated in various studies (Scharlemann et al. 2014). At global level, Soil Organic Carbon (SOC) stocks are estimated at an average of 1,500 ±230 Pg C in the 100 cm of soil, and this is nearly twice as that of atmospheric carbon (828 Pg C) and thrice as that of terrestrial vegetation (500 Pg C) (Quere et al. 2016). The Intergovernmental Panel on Climate Change identified creation and strengthening of carbon sinks in the soil as a clear option for increasing removal of CO_2 from the atmosphere and has recognized soil organic carbon pool as one of the five major carbon pools for the Land Use, Land Use Change in Forestry (LULUCF) sector (IPCC, 2003). As an important indicator of soil health, SOC is important for its contributions to food production, mitigation and adaptation to climate change, and the achievement of the Sustainable Development Goals (SDGs). Judicious soil management needs to be implemented to ensure that soil is rendered a sink rather than a source of atmospheric CO_2 by

considering the role of soils in climate change mitigation and adaptation (Paustian *et al*., 2016). Therefore, it is ideal to study and determine, for any given ecosystem, the current SOC stocks to determine a soil's carbon sequestration potential. The role of soils and SOC in climate change adaptation and mitigation has been widely recognized and validated in various studies, both experimentally and through modelling (Scharlemann *et al*., 2014)**.** Studies on soil organic carbon stock and properties under important plantations *viz*, Eucalyptus, Casuarina, Melia and Teak in the Southern zone of Tamil Nadu, India using IPCC guidelines are lacking. Therefore, the present study aims to assess the carbon stock and soil properties in important plantations in the Southern zone of Tamil Nadu.

II. MATERIALS AND METHODS

The study was conducted in the Southern agro-climatic zone of Tamil Nadu. The Southern zone is situated between 8° and 10° 55' North latitude and 77° and 79° 50' East longitude. The Southern zone consists of Tirunelveli, Virudhunagar, Ramanathapuram, Thoothukudi, Sivagangai, Madurai (Tirumangalam, Madurai South, Madurai North and Melur taluks) and Dindigul (Natham and Dindigul taluks). The zone receives a mean annual rainfall is 876.4 mm. The maximum temperature ranges between 30.0° C and 37.5° C, while the range of minimum temperature is 20.0° C to 27.0° C. Predominant soil types occurring in this zone are black soil, red soil, deep red loam soil, red sandy soil, lateritic soil, river alluvium and saline coastal alluvium.

Soil sampling

The existing stands of three different ages of tree plantations viz, Eucalyptus, Casuarina, Melia and Teak were selected from within the available plantations on farmlands. In all the selected plantations composite soil samples were collected at three different depths; i.e., 0-15, 15- 30 and 30-45 cm. Soil samples were collected in four cardinal directions around the tree and mixed in equal proportions to form a composite sample for each layer. At each sampling point, an area of 0.5m x 0.5m was removed and a pit of 50cm wide, 50 cm in length and 45cm deep was dug. The soil was scrapped from three sides of the pit with the help of a kurpee at each depth. The soil was mixed thoroughly and transferred to a polythene bag with proper labeling. Latitude, longitude and altitude of each sampling point were recorded by GPS.

Soil preparation

The collected soil samples were air dried in shade and powdered to fine soil particles using wooden mallet. The soil thus prepared was sieved through 2.0 mm sieve and stored in cloth bags. A small portion of each sample was again sieved through 0.2 mm sieve for analysis of organic carbon.

Soil carbon stock estimation

Soil organic carbon was estimated by standard Chromic acid wet oxidation method of Walkley and Black (1934). Organic matter in the soil was oxidized with the mixture of potassium dichromate and concentrated sulphuric acid, utilizing the heat of dilution of sulphuric acid. Unused potassium dichromate was back titrated with ferrous ammonium sulphate. Two to three clods of 2mm size were collected from each pit for estimating bulk density. Bulk density was estimated by the wax coating (clod) method. The clods were wrapped in cotton and placed in plastic containers to avoid breakage during transportation of the clods to the laboratory. In the laboratory, the clods were tied with a thread and dipped in molten wax to coat the clod surface. The wax coated clod was dipped in water and the bulk density was determined from the volume of water displaced. The per cent of coarse fragments was quantified by visual observation of the area occupied by coarse fragments. Soil organic carbon pool was estimated up to the depth of 45 cm in this study. Soil organic carbon pool was calculated by using the following equation as suggested by IPCC Good Practice Guidelines for LULUCF (2003).

$$SOC = \sum_{Horizon=1}^{Horizon=n} SOC = \sum_{Horizon=1}^{Horizon=n} ([SOC] * \text{Bulk density} * \text{Depth} * (1\text{-C frag}) * 100)$$

Where,

SOC = Representative soil organic carbon content for the forest type and soil of interest, tonnes C ha^{-1}.

SOC = Soil organic carbon content for a constituent soil horizon, tonnes C ha^{-1}

Horizon

[SOC] = Concentration of SOC in a given soil mass obtained from analysis, g C $(kg\ soil)^{-1}$

Bulk density = Soil mass per sample volume, tonnes soil m^{-3}(equivalent to Mg m^{-3})

Depth = Horizon depth or thickness of soil layer, m

C frag = % volume of coarse fragments/100, dimensionless.

Estimation of soil properties

The soil samples were analysed for the various properties such as pH, Electrical conductivity, Available N, Available P, Available K. The detailed methods are described below. The pH of soil was determined using an aqueous suspension of soil (soil and water in 1:2.5 ratio)

using a pH meter (Jackson, 1973). The electrical conductivity of soil was determined using an aqueous suspension of soil (soil and water in 1:2.5 ratio) using a conductivity meter (Jackson, 1973). The available nitrogen in the soil was estimated by the alkaline permanganate method. The amount of soil nitrogen released due to the oxidation of part of soil organic matter by $KMnO_4$ was estimated by distillation with NaOH (Subbiah and Asija, 1956). Available phosphorus was determined by the Olsen method. Blue colour was developed using ascorbic acid and the intensity of colour was measured using a spectrophotometer at 660 nm (Olsen *et al.*, 1954). In the Bray method, available P was commonly extracted using Bray No. 1 which consisted of 0.03 NH_4F and 0.025 HCl. The extracted phosphorus was measured colorimetrically based on the reaction with ammonium molybdate and development of the 'Molybdenum Blue' colour. The absorbance of the compound was measured at 882 nm in a spectrophotometer and is directly proportional to the amount of phosphorus extracted from the soil and Bray and Kurtz, 1945). Exchangeable potassium in the soil samples were extracted using 1N ammonium acetate and estimated using flame photometer (Stanford and English, 1949).

All statistical tests were performed with SPSS ® 19.0 version statistical software. One-way analysis of variance (ANOVA) was used to assess the biomass carbon and soil carbon sequestration. Duncan's test was performed to separate means if differences were significant (P=0.05).

III. RESULTS AND DISCUSSION

Soil represents the major reservoir of terrestrial carbon pool and the amount of carbon stored in soil organic matter is one of the largest and most dynamic reservoirs of carbon in the global carbon cycle. The organic carbon content in plantations of the Southern zone ranged from 0.29 ± 0.00 to 0.68 ± 0.00 (Table 1) and was found between low to medium in range. The lowest soil OC (0.29 %) was recorded under >7 years of Melia at 30-45cm. The maximum OC (0.68 %) was recorded in Casuarina clonal plantation of > 5 years at 0-15 cm depth, followed by >5 years of Casuarina plantation of seedling origin (0.67%), >6 years of Eucalyptus clonal plantation (0.62), >15 years of Teak (0.60 %), >6 years of Eucalyptus plantation of seedling origin, (0.58%) and > 7 years of Melia (0.52%) at 0-15 cm plantations. Among the plantations, the maximum OC was recorded in older plantations. The trend of changing SOC content in the different plantations along the age was significantly different ($p \leq 0.05$) and increased with an increase in the age of the plantation. However, SOC decreased with an increase in soil depth. The increase in SOC content at the surface soil layer is attributed to higher amount of carbon input from litterfall, dead roots, and root exudates (Chauhan et al., 2010 and Kaushal et al., 2012).

The bulk density of plantations of the Southern zone ranged from 1.25 ± 0.02 to 1.40 ± 0.01 (Table 1). The minimum soil bulk density (1.25 g/cc) was observed under 0-15 cm of >5 years of Casuarina clonal plantation. The highest bulk density (1.40 g/cc) was observed in 2 to 4 years of Melia at 30-45 cm followed by 1 to 2 years of seedling origin Casuarina plantation (1.40 g/cc) followed by Casuarina clonal plantation of 1 to 2 years of (1.39 g/cc), 5 to 10 years of Teak (1.39 g/cc), 1 to 2 years of Eucalyptus clonal plantation (1.37 g/cc) and 4 to 5 years of Eucalyptus plantation of seedling origin (1.36 g/cc) plantations at 30-45 cm depth. The measured bulk density was significantly varied ($P \leq 0.05$) and decreased with the increasing age of plantations. However, in 4 to 5 years of seedling origin Eucalyptus plantation, the bulk density increased at 30-45 cm. Among the different depths, the BD was low in surface (0-15 cm) compared to lower depths and increased with depth increment for all the plantations. The increase in bulk density is largely due to decreasing organic matter content and reduced aggregation with depth (Chauhan et al. 2018).

Soil organic carbon stock of different plantations is given in Tables 2 and Fig.1. In Eucalyptus plantation, clonal plantation of >6 years sequestered the highest amount of soil carbon (19.8 Mg ha^{-1}) at 30 cm depth, SOC stock was maximum in Casuarina plantation of > 5 years (23.3 Mg ha^{-1}), among the different Melia plantations, maximum SOC stock was observed in Melia plantation of 5 to7 years old (15.6 Mg ha^{-1}), and in Teak plantations, SOC stock was highest in plantations of > 15 years old (22.1 Mg ha^{-1}). The increase in SOC content at the surface soil layer is attributed to higher amount of carbon input from litterfall, dead roots, and root exudates (Chauhan et al., 2010 and Kaushal et al., 2012). Gupta et al. (2009) also reported that SOC increased significantly with age of plantation in the 0–15 cm soil layer and was 18% higher under 3-year plantations than in the soils under 1-year plantations.

Table 1. Soil organic carbon (%) and soil properties in the Southern zone

Plantation type	Soil Depth	pH	EC (dS m^{-1})	OC (%)	BD (g/cc)	pH	EC (dS m^{-1})	OC (%)	BD (g/cc)	pH	EC (dS m^{-1})	OC (%)	BD (g/cc)
Eucalyptus		1 to 2 Years				4 to 5 Years				>6 Years			
	0-15	6.28±0.24^{abc}	0.08±0.00	0.40±0.00^{c}	1.29±0.01^{ab}	6.08±0.07^{ab}	0.08±0.00	0.52±0.00^{g}	1.27±0.01^{a}	5.99±0.05^{a}	0.07±0.00	0.58±0.00^{h}	1.26±0.00^{a}
	15-30	6.35±0.05^{bc}	0.08±0.00	0.36±0.00^{b}	1.32±0.01^{bc}	6.14±0.06^{ab}	0.06±0.00	0.48±0.00^{f}	1.31±0.02^{bc}	6.12±0.05^{ab}	0.06±0.00	0.44±0.00^{e}	1.28±0.01^{ab}
	30-45	6.58±0.05^{c}	0.11±0.00	0.34±0.00^{a}	1.34±0.01^{cd}	6.18±0.05^{ab}	0.05±0.00	0.42±0.00^{d}	1.36±0.00^{d}	6.36±0.05^{bc}	0.04±0.00	0.41±0.00^{cd}	1.31±0.00^{bc}
Eucalyptus Clone		1 to 2 Years				4 to 5 Years				>6 Years			
	0-15	6.30±0.05^{ab}	0.08±0.00	0.49±0.00^{c}	1.30±0.01^{abc}	6.10±0.05^{ab}	0.08±0.00	0.59±0.00^{e}	1.29±0.02^{ab}	6.00±0.05^{a}	0.11±0.00	0.62±0.00^{f}	1.26±0.01^{a}
	15-30	6.65±0.24^{cd}	0.10±0.00	0.44±0.00^{b}	1.32±0.02^{bc}	6.22±0.05^{ab}	0.06±0.00	0.51±0.00^{cd}	1.31±0.01^{abc}	6.16±0.05^{ab}	0.08±0.00	0.53±0.00^{d}	1.28±0.01^{ab}
	30-45	6.78±0.09^{b}	0.13±0.00	0.39±0.00^{a}	1.37±0.01^{d}	6.38±0.07^{bc}	0.05±0.00	0.45±0.00^{b}	1.35±0.01^{cd}	6.27±0.07^{ab}	0.06±0.00	0.49±0.01^{c}	1.30±0.01^{abc}
Casuarina		1 to 2 Years				3 to 5 Years				>5 Years			
	0-15	6.29±0.05^{b}	0.15±0.00	0.54±0.00^{d}	1.36±0.00^{bcd}	6.28±0.09^{b}	0.18±0.00	0.62±0.00^{g}	1.34±0.01^{abc}	5.96±0.23^{a}	0.16±0.00	0.68±0.00^{g}	1.31±0.01^{a}
	15-30	6.56±0.05^{b}	0.17±0.00	0.48±0.00^{c}	1.38±0.01^{cd}	6.35±0.05^{b}	0.20±0.00	0.56±0.00^{e}	1.37±0.01^{bcd}	6.28±0.05^{b}	0.12±0.00	0.59±0.00^{f}	1.33±0.01^{ab}
	30-45	6.58±0.05^{b}	0.20±0.00	0.38±0.00^{a}	1.40±0.01^{d}	6.46±0.05^{b}	0.14±0.00	0.44±0.00^{b}	1.39±0.01^{d}	6.45±0.05^{b}	0.09±0.00	0.49±0.00^{c}	1.35±0.00^{bcd}
Casuarina Clone		1 to 2 Years				3 to 5 Years				>5 Years			
	0-15	7.16±0.06^{ab}	0.11±0.00	0.55±0.00^{b}	1.30±0.01^{abc}	7.00±0.06^{a}	0.11±0.00	0.60±0.00^{e}	1.28±0.03^{ab}	6.98±0.06^{a}	0.08±0.00	0.68±0.00^{f}	1.25±0.02^{a}
	15-30	7.21±0.08^{ab}	0.14±0.00	0.48±0.00^{b}	1.35±0.04^{cd}	7.13±0.08^{ab}	0.09±0.00	0.52±0.00^{c}	1.33±0.02^{bcd}	7.06±0.10^{a}	0.06±0.00	0.57±0.00^{d}	1.27±0.02^{ab}
	30-45	7.36±0.08^{b}	0.17±0.00	0.40±0.00^{a}	1.39±0.01^{d}	7.24±0.08^{ab}	0.07±0.00	0.42±0.00^{a}	1.35±0.02^{cd}	7.17±0.10^{ab}	0.04±0.00	0.50±0.01^{c}	1.30±0.02^{abc}
Melia		2 to 4 Years				5 to 7 Years				>7 Years			
	0-15	6.98±0.08^{ab}	0.17±0.00	0.46±0.00^{f}	1.30±0.01^{abc}	6.95±0.08^{ab}	0.16±0.00	0.50±0.00^{a}	1.26±0.01^{ab}	6.86±0.06^{a}	0.08±0.00	0.52±0.00^{h}	1.26±0.02^{a}
	15-30	7.16±0.06^{ab}	0.19±0.00	0.38±0.00^{c}	1.37±0.00^{de}	6.99±0.06^{ab}	0.13±0.00	0.40±0.00^{d}	1.31±0.01^{bc}	6.90±0.08^{a}	0.06±0.00	0.42±0.00^{e}	1.29±0.00^{abc}
	30-45	7.23±0.16^{b}	0.21±0.00	0.30±0.00^{ab}	1.40±0.01^{e}	7.11±0.10^{ab}	0.12±0.00	0.31±0.00^{b}	1.33±0.01^{cd}	7.11±0.03^{ab}	0.05±0.00	0.29±0.00^{a}	1.33±0.02^{cd}
Teak		5 to 10 Years				11 to 15 Years				>15 Years			
	0-15	5.74±0.06^{a}	0.17±0.00	0.48±0.00^{d}	1.33±0.01^{abcd}	5.62±0.08^{a}	0.14±0.00	0.55±0.00^{e}	1.31±0.01^{ab}	5.62±0.05b^{c}	0.07±0.00	0.60±0.00^{f}	1.29±0.01^{a}
	15-30	6.16±0.22^{b}	0.19±0.00	0.38±0.00^{c}	1.39±0.05^{cd}	5.78±0.05^{a}	0.12±0.00	0.46±0.00^{d}	1.33±0.00^{abcd}	5.78±0.05^{cd}	0.06±0.00	0.55±0.01^{e}	1.32±0.00^{abc}
	30-45	6.21±0.07^{b}	0.23±0.00	0.30±0.00^{a}	1.39±0.01^{d}	6.08±0.05^{b}	0.09±0.00	0.34±0.00^{b}	1.36±0.01^{bcd}	6.08±0.06^{d}	0.04±0.00	0.46±0.00^{d}	1.35±0.00^{abcd}

Mean values with lower case superscript letters indicate significant difference between different aged plantations across different depths at (P ≤ 0.05). ± indicates standard error

Table 2: SOC stock in (Mg C ha^{-1}) plantations of the Southern zone

Plantation type	**Soil Depth**	**SOC stock (Mg ha^{-1})**		
		1 to 2 Years	**4 to 5 Years**	**>6 Years**
Eucalyptus	0-15	7.4±0.06^{a}	9.7±0.11^{c}	10.6±0..09^{d}
	15-30	13.3±0.0.11^{f}	18.1±0.20 ^{h}	16.1±0.14^{g}
	30-45	17.8±0.16^{h}	21.7±0.24^{l}	20.7±0.18^{k}
		1 to 2 Years	**4 to 5 Years**	**>6 Years**
Eucalyptus Clone	0-15	8.9±0.07^{b}	11.1±0.12^{e}	11.5±0.10^{e}
	15-30	16.2±0.14^{g}	18.9±0.21^{i}	19.9±0.17^{j}
	30-45	19.5±0.17^{j}	23.2±0.26^{m}	25.9±0.22^{n}
		1 to 2 Years	**3 to 5 Years**	**>5 Years**
Casuarina	0-15	8.7±0.07^{a}	11.3±0.09^{c}	12.4±0.10^{d}
	15-30	18.5±0.16 ^{f}	22.0±0.19^{h}	23.4±0.21^{i}
	30-45	19.8±0.17^{g}	23.6±0.21^{i}	26.4±0.23^{j}
		1 to 2 Years	**3 to 5 Years**	**>5 Years**
Casuarina Clone	0-15	9.9±0.08^{b}	11.2±0.13^{c}	12.5±0.11^{d}
	15-30	17.5±0.15^{e}	19.9±0.22^{g}	22.1±0.19^{h}
	30-45	20.0±0.17^{g}	21.8±0.25^{h}	26.8±0.23^{j}
		2 to 4 Years	**5 to 7 Years**	**>7 Years**
Melia	0-15	8.3±0.07^{a}	9.4±0.08^{b}	9.4±0.08^{b}
	15-30	14.3±0.12^{c}	15.7±0.13^{f}	15.6±0.13^{ef}
	30-45	15.3±0.13^{e}	16.6±0.15^{g}	14.8±0.13^{d}
		5 to 10 Years	**11 to 15 Years**	**>15 Years**
Teak	0-15	9.0±0.07^{a}	10.5±0.38^{b}	11.5±0.42^{b}
	15-30	14.5±0.12 ^{c}	17.4±0.64 ^{d}	21.5±0.79 ^{e}
	30-45	15.6±0.14^{c}	17.8±0.66^{d}	24.5±0.91^{f}

Mean values with lower case superscript letters indicate significant difference between different aged plantations across different depths at (P ≤ 0.05). ± indicates standard error

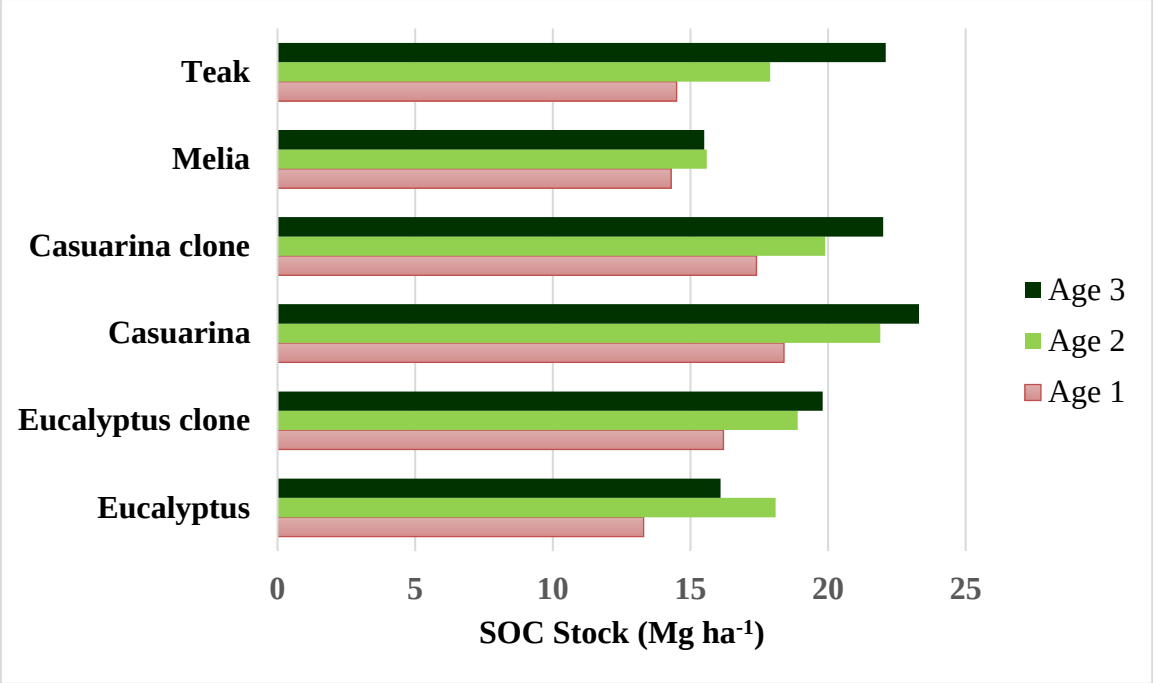

Fig. 1. Soil Organic Carbon stock (Mg ha^{-1}) of different plantations in the Southern zone

The mean soil reaction (pH) in plantations of the Southern zone is given in Table 21. The overall soil pH varied from 5.62 ± 0.05 to 7.36 ± 0.08 and the samples were slightly acidic to neutral in range. Among the different plantations the minimum soil pH of 5.62 was recorded in >15 years of Teak plantation at 0-15 cm depth and the maximum of 7.36 was recorded in 1 to 2 years of Casuarina clonal plantation at 30-45 cm depth. The soil pH was significantly different and decreased with an increase in the age of plantation except >6 years of Eucalyptus plantation of seedling origin at 30-45 cm depth, where it was slightly increased. The surface soils (0-15 cm) of older aged Eucalyptus seedling origin plantation, Eucalyptus clonal plantation, Casuarina seedling origin plantation, and Teak plantations revealed that the pH was acidic in range while in Melia and Casuarina clonal plantation the pH was neutral. However, the soil pH increased with depth increment. The increased pH at lower soil depth might be due to leaching and accumulation of basic cations in deep soil profiles (Kumar et al. 2018).

The mean soil electrical conductivity in plantations of the Southern zone ranged from 0.04 ± 0.00 to 0.23 ± 0.00 (Table 1) and was non-saline. Among the plantations the minimum soil EC (0.04 dS m^{-1}) was observed under >15 years of Teak plantation at 0-15 cm depth and the highest EC (0.23 dS m^{-1}) was observed in 5 to 10 years of Teak plantation at 30-45 cm depth. The electrical conductivity (EC) significantly ($P \leq 0.05$) decreased with the increasing age of the plantation and increased with depth increment.

The available nitrogen content in plantations of the Southern zone ranged between 165.84 ± 1.47 to 303.98 ± 2.69 (Table 3) and was found between the low to medium range. The lowest available nitrogen 165.84 kg ha^{-1} was recorded under 1 to 2 years of seedling origin Eucalyptus plantation at 30-45 cm depth and the maximum available nitrogen 303.98 kg ha^{-1} was recorded in >5 years of Casuarina clonal plantation at 0-15 cm depth. Among the plantations, the available nitrogen was medium in the surface layer (0-15 cm) of > 5 years Casuarina clonal plantation (303.98 kg ha^{-1}), >5 years of Casuarina plantation of seedling origin (299.40 kg ha^{-1}), and > 15 years of Teak (298.10 kg ha^{-1}), while it was low in Eucalyptus plantation of seedling origin, Eucalyptus clonal plantation and Melia plantations. The available phosphorus content in plantations of the Southern zone ranged from 13.95 ± 0.35 to 24.62 ± 0.22 (Table 3) and was found between medium to high in range. The minimum available phosphorus of 13.95 kg ha^{-1} was recorded under >7 years of Melia at 30-45 cm depth and the maximum 24.62 kg ha^{-1} was recorded in >5 years of seedling origin Casuarina plantation at 0-15 cm depth. The maximum available phosphorus content was recorded in the surface soils (0-15 cm) of >5 years of seedling origin Casuarina plantation (24.62 kg ha^{-1}) followed by >5 years of Casuarina clonal plantation (23.82 kg ha^{-1}), >6 years of Eucalyptus plantation of seedling origin (23.52 kg ha^{-1}) and >6 years of Eucalyptus clonal plantation (22.73 kg ha^{-1}) while, it was medium in >7 years of Melia (21.70 kg ha^{-1}) and >15 years of Teak (20.66 kg ha^{-1}) plantation. However, the available phosphorus concentration found in the soil

under different plantation forests significantly varied ($p \leq 0.05$) and it increased with an increase in the age of plantation except for >7 years of Melia plantation, where it decreased at 30-45 cm depth. However, the phosphorus concentration decreased with an increase in soil depth. Higher availability of nutrients on surface layers under different plantations might be due to accumulation and decomposition of litterfall on the soil surface as well as its incorporation in the soil surface layers. It assists in the mineralization of organic N and P from the litter and its release into the soil (Singh and Sharma, 2007).

Table 3. Available macronutrients status in different plantations of the Southern zone

Plantation type	**Soil Depth**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**
Eucalyptus		**1 to 2 Years**			**4 to 5 Years**			**>6 Years**		
	0-15	197.94±1.75^{d}	19.14±0.17^{f}	249.56±2.21^{f}	219.66±1.94^{f}	21.33±0.19^{ij}	265.91±2.35^{h}	233.82±2.07^{h}	23.52±0.21^{l}	289.43±2.56^{j}
	15-30	173.17±1.52^{b}	16.46±0.14^{cd}	226.35±1.99^{cd}	200.60±2.32^{d}	19.20±0.22^{f}	230.70±2.66^{d}	213.89±1.89^{f}	20.43±0.18^{gh}	270.00±2.39^{hi}
	30-45	165.84±1.47^{a}	14.25±0.13^{a}	199.63±1.77^{a}	180.00±1.59^{c}	16.34±0.14^{c}	215.68±1.91^{b}	197.74±1.75^{d}	17.84±0.16^{e}	245.98±2.18^{ef}
Eucalyptus Clone		**1 to 2 Years**			**4 to 5 Years**			**>6 Years**		
	0-15	207.31±1.83^{e}	19.97±0.24^{g}	251.16±2.22^{fg}	223.85±1.98^{g}	21.60±0.25^{j}	269.40±2.38^{hi}	247.57±2.19^{i}	22.73±0.33^{k}	290.45±3.51^{j}
	15-30	184.16±2.23^{c}	16.89±0.20^{cd}	229.73±2.03^{d}	201.80±2.33^{de}	19.30±0.23^{f}	241.59±2.14^{e}	220.07±3.21^{f}	20.83±0.31^{hi}	275.38±2.44^{i}
	30-45	169.06±2.05^{ab}	14.95±0.13^{b}	204.02±1.80^{a}	182.60±2.11^{c}	17.04±0.15^{d}	219.87±1.95^{bc}	197.74±2.88^{d}	18.14±0.16^{e}	257.54±2.28^{g}
Casuarina		**1 to 2 Years**			**3 to 5 Years**			**>5 Years**		
	0-15	289.43±2.56^{e}	21.33±0.19^{gh}	299.70±2.65^{d}	295.81±2.62^{ef}	23.72±0.21^{k}	316.94±2.80^{e}	299.40±2.65^{fg}	24.62±0.22^{l}	329.50±2.92^{f}
	15-30	273.69±2.42^{cd}	18.54±0.16^{bc}	274.68±2.43^{bc}	267.81±2.37^{c}	20.33±0.18^{f}	296.11±2.62^{d}	279.46±2.47^{d}	21.63±0.19^{ghi}	318.64±2.82^{e}
	30-45	249.37±2.20^{b}	16.34±0.14^{a}	249.87±2.21^{a}	239.80±2.12^{a}	18.14±0.16^{b}	275.48±2.44^{bc}	254.05±2.25^{b}	19.64±0.17^{de}	297.40±2.63^{d}
Casuarina Clone		**1 to 2 Years**			**3 to 5 Years**			**>5 Years**		
	0-15	292.02±2.58^{ef}	22.05±0.27^{i}	299.70±2.65^{d}	298.00±2.64^{fg}	22.80±0.27^{j}	316.94±2.80^{e}	303.98±2.69^{g}	23.82±0.35^{k}	329.50±2.92^{f}
	15-30	273.69±2.42^{cd}	18.87±0.23^{c}	277.07±2.45^{bc}	267.81±2.37^{c}	21.00±0.24^{g}	295.41±2.61^{d}	289.03±2.56^{e}	21.73±0.32^{hi}	300.20±2.65^{d}
	30-45	252.84±2.22^{b}	16.65±0.15^{a}	254.15±2.25^{a}	254.70±2.94^{b}	19.04±0.17^{cd}	269.10±2.38^{b}	274.48±2.43^{cd}	19.87±0.24^{ef}	278.53±3.37^{c}
Melia		**2 to 4 Years**			**5 to 7 Years**			**>7 Years**		
	0-15	209.00±4.38	20.26±0.42^{e}	199.46±4.18^{c}	226.80±4.54^{e}	21.70±0.43^{f}	220.90±2.55^{d}	270.50±6.83^{g}	20.63±0.52^{e}	246.98±3.60^{e}
	15-30	199.73±3.06^{c}	16.34±0.25^{b}	194.75±1.72^{c}	197.94±3.03^{c}	19.33±0.30^{d}	184.09±1.63^{b}	249.56±3.82^{f}	15.75±0.24^{b}	220.06±1.95^{d}
	30-45	185.16±3.88^{b}	14.10±0.30^{a}	173.44±2.10^{a}	172.40±3.45^{a}	17.30±0.35^{c}	166.40±1.92^{a}	224.65±5.67^{e}	13.95±0.35^{a}	198.04±2.89^{c}
Teak		**5 to 10 Years**			**11 to 15 Years**			**>15 Years**		

	0-15	285.34±4.37^{e}	17.54±0.27^{d}	269.90±4.14^{c}	289.43±4.44^{e}	19.23±0.30^{e}	287.44±4.40^{d}	298.10±6.25^{e}	20.26±0.42^{f}	298.10±6.25^{d}
	15-30	263.32±4.03^{cd}	15.15±0.23^{a}	249.77±3.83^{b}	269.60±4.13^{d}	16.94±0.26^{cd}	253.75±3.89^{b}	286.85±17.96^{e}	18.79±1.18^{e}	271.86±17.03^{c}
	30-45	239.50±3.67^{a}	14.95±0.23^{a}	225.64±3.46^{a}	249.87±3.83^{ab}	15.65±0.24^{ab}	234.02±3.59^{a}	252.90±5.30^{bc}	16.19±0.34^{bc}	268.80±5.64^{c}

Mean values with lower case superscript letters indicate significant difference between different aged plantations across different depths at ($P \leq 0.05$). ± indicates standard error

The available potassium content in plantations of the Southern zone ranged from 166.40 ± 1.92 to 329.50 ± 2.92 and was found between medium to high in range. The minimum available potassium 166.40 kg ha^{-1} was recorded under 5 to 7 years of Melia plantation at 30-45 cm and the maximum 329.50 kg ha^{-1} was recorded in >5 years of Casuarina clonal plantation at 0-15 cm depth (Table 3). Among the plantations the available potassium was high in surface soils (0-15 cm) of >5 years Casuarina clonal plantation (329.50 kg ha^{-1}), >5 years of seedling origin Casuarina plantation (329.45 kg ha^{-1}), >15 years of Teak (298.10 kg ha^{-1}), >6 years of seedling origin Eucalyptus (290.45 kg ha^{-1}) and >6 years of Eucalyptus clonal plantation (289.43 kg ha^{-1}), while it was medium in Melia (246.98 kg ha^{-1}) plantation. The available potassium in the different plantations significantly varied ($p \leq 0.05$) and it increased with an increase in the age of the plantation except for 5 to 7 years of Melia plantation at 15-30 and 30-45 cm, where it was slightly reduced in all depths. However, with increase in the soil depth, the potassium content decreased. Chauhan et al. (2018) also reported higher availability of soil nitrogen, phosphorus and potassium (kg ha^{-1}) under different plantations at various soil depths. Nutrient availability was higher in the top 0-15 cm of the soil profile which might be due to the surface layer enrichment through nutrient cycling and decreased with the increased soil depth,

IV. CONCLUSION

Soil organic carbon is an indicator of both soil quality and environmental stability. The study has generated baseline data on soil organic carbon stock and soil properties in important plantations of the Southern zone of Tamil Nadu, India. The present study identified suitable plantation species of clonal and seedling origin for enhanced storage of soil organic carbon. The data generated in the present study would provide valuable information on the scope of afforestation and reforestation projects for sustaining the livelihoods of the farming community and also will encourage them to contribute to mitigating global carbon emissions and expanding forest and tree cover.

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Effect of Corn Waste Fermentation as Livestock Feed on Fiber Fraction Content

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Abstract— *Corn straw and cob are wastes from corn farming which are not utilized. These corn wastes have potential as an alternative feed for livestock, but have low nutritional quality. Therefore, these corn wastes are fermented to improve its nutritional quality. The purpose of this study was to analyze the effect of corn straw and cob fermentation on the fiber fraction content. This experiment used a completely randomized design with 6 treatments, namely control (elephant grass and grinting grass), corn straw, fermented corn straw, corn cob, and fermented corn cob. Each treatment was repeated 5 times. The variables measured were Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), hemicellulose, cellulose, and lignin. The results showed that the treatment had a very significant effect on the content of NDF, ADF, hemicellulose, cellulose, and lignin. Based on the results of this experiment, it can be concluded that corn cob fermentation can reduce lignin content thus corn cob lignin content can match elephant grass but on the contrary corn straw fermentation cannot be able to reduce lignin content.*

Keywords— ***Fermentation, fiber fraction, straw and corn cob, lignin***

I. INTRODUCTION

Indonesia has a tropical climate with two seasons, namely rainy and dry season. East Nusa Tenggara (NTT) is one of the provinces in Indonesia which is located in the eastern part of Indonesia. The difference between this province and other provinces is that the dry season in NTT is longer than the rainy season. From June to September, the wind flows from Australia not containing much moisture thus causes dry season. On the other hand, from December to March, wind flows originating from Asia and the Pacific Ocean contain a lot of water vapor, resulting in the rainy season. This causes an eight-month dry season and a four-month rainy season in NTT. Based on rainfall and the number of rainy days, NTT region has low rainfall and short rainy days (BPS, 2022a). This condition affects the NTT existing agricultural system, including Belu Regency. This causes limited forage availability for animal feed because it is available in abundance during the rainy season while the dry season causes the dry land thus forage is also limited.

The limited feed availability in the dry season makes it difficult for stock farmers to provide animal feed. In addition, livestock that are grazed or shepherded can only eat dry grass which has low nutritional quality. Therefore, livestock lack feed quantity and quality during the dry season. Livestock condition during long dry season shows that feed consumed by livestock is only used for survival, not for increasing livestock production.

Corn is an NTT leading agricultural commodity. In 2021, corn agricultural land area in NTT reached 290.664 ha with 750,166 tons corn production (BPS, 2022b). Corn farming produces waste such as corn straw and cob, where

these by-products are not utilized by the community. Therefore, after corn main product is obtained, these by-products are then burned, however corn straw and cob can be used as livestock alternative or additional feed. Corn straw and cob still contain enough nutrition to meet livestock needs. However, these corn straw and corncob have a low palatability or preference level for livestock because corn straw and cob taste and color are not liked by livestock.

Moreover, corn straw and cob contain high lignin level. According to Sun and Cheng (2002), corn cob contains 45% cellulose, 35% hemicellulose and 15% lignin, and have low nutritional value and degradation. Lignin can inhibit the cellulose and hemicellulose material degradation in the rumen (Carrillo et al. 2004; van Kuijk et al. 2015). To improve corn straw and cob quality and reduce their environmental impact, microbial fermentation is the most effective way in dealing with these problems (Villas-Boas et al. 2002; Basu et al. 2002; Shrivastava et al. 2011).

Corn straw and cob nutritional value quality can be improved through fermentation using EM4 (Effective Microorganism). EM4 contains fermented and synthetic microorganisms consisting of lactic acid bacteria *(Lactobacillus* sp.), photosynthetic bacteria (*Rhodopseudomonas* sp.), *Actinomycetes* sp., *Streptomyces* sp., yeast and cellulose-degrading fungi (EM Indonesia.com, 2022). EM4 can degrade crude fiber content because it produces cellulase and ligninase enzymes. These enzymes are produced by the microbes contained in it, primarily Lactobacillus and Actinimycetes bacteria (Santoso and Aryani, 2007), the use of EM4 as feed fermentation inoculum can improve feed nutritional quality and palatability for livestock. Moreover, EM4 can preserve fermented feed and the feed can then be stored as dry season backup feed for a long time. Therefore, this study was conducted to analyze corn straw and cob fermentation effect on the fiber fraction content.

II. MATERIALS AND METHODS

Fermented Corn Straw and Cob Sample Preparation

Elephant grass (*Pennisetum purpureum*), grinting grass (*Cynodon dactylon*), corn straw and cob were obtained from the area around Belu Regency, East Nusa Tenggara. Sample collection of the experiment used Simple Random Sampling method, namely random sampling, the samples were then composited into one. All parts of elephant grass and grinting grass were used except the roots. This corn straw was an old corn plant where the corn fruit has been taken. Corn cob are part of the corn fruit where corn husk and seed have been taken. After the corn straw, corn cob, elephant grass, and grinting grass have been collected, then these were placed in a sack and brought to the Animal Husbandry Unit of the Haliken Nenuk SVD Mission, Atambua, Belu Regency, East Nusa Tenggara.

Corn Straw and Cob Fermentation

The fermentation process conducted in this study is solid fermentation. The fermentation method used is feed ingredient fermentation method conducted by the Animal Husbandry Unit of SVD Haliklen Nenuk Mission, Atambua, Belu Regency, East Nusa Tenggara. The inoculum was prepared prior to fermentation, by mixing 20 ml of EM4, 40 ml of molasses, and 30 ml of water. Next, 1 kg of corn straw and cob was prepared. Then, the prepared inoculum was sprayed using a sprayer onto the corn straw and cob evenly. After that, rice bran was sprinkled as much as 100 g evenly. When finished, the processed corn straw or cob were placed in a plastic bag and tightly sealed. This fermentation process occurred for 3 weeks.

Sample Preparation and Analysis

After corn straw and cob were processed by fermentation methods then each of these was dried and ground into powder. These powders were ready to be analyzed for NDF (Neutral Detergent Fifer), ADF (Acid Detergent Fiber), Cellulose, and Hemicellulose content.

Parameters

NDF (Neutral Detergent Fifer), ADF (Acid Detergent Fiber), Cellulose, and Hemicellulose were analyzed using the method of Van Soest (1982).

Data analysis

This experiment was conducted using a completely randomized block design with six treatments containing two control groups (elephant grass and grinting grass), and four treatment groups (unfermented corn straw, fermented corn straw, unfermented corn cob, and fermented corn cob). Each treatment group has five replicates. Data were analyzed using analysis of variance utilizing the WPS Excel-Statistics 2022 software (version 11.2.0.11254) for a completely randomized design. Before analysis, all percentages were logarithmically transformed log10 x + 1 to normalize data distribution. Mean values for each treatment were further tested by Duncan Multiple Range Test (DMRT), and the significance was declared when $p < 0.05$.

III. RESULTS AND DISCUSSIONS

Fiber Fraction Content

The average fiber fraction content consisting of NDF, ADF, hemicellulose, cellulose, and lignin from elephant

grass, grinting grass, corn straw, fermented corn straw, corn cob, and fermented corn cob is shown in Table 1.

Table 1. Average Fiber Fraction Content (%)

Forage	NDF	ADF	Hemicellulose	Cellulosa	Lignin
Elephant grass	81,36^{c}	48,41^{b}	32,95^{c}	33,17^{c}	12,23^{c}
Grinting grass	82,33^{c}	48,38^{b}	33,95^{c}	31,06^{d}	13,23^{bc}
Corn straw	82,73^{c}	57,93^{a}	24,80^{d}	40,53^{a}	13,35^{bc}
Fermented corn straw	83,15^{c}	59,98^{a}	23,17^{d}	36,16^{b}	20,24^{a}
Corn cob	91,29^{a}	46,98^{b}	44,31^{a}	32,31^{cd}	14,07^{b}
Fermented corn cob	85,26^{b}	48,73^{b}	36,54^{b}	32,14^{cd}	12,65^{c}

Note: Different superscripts in the same column show significant difference (P<0.05)

The analysis of variance results showed that different forage had a significant effect ($p < 0.01$) on the content of NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), hemicellulose, cellulose, and lignin. Based on the further DMRT test results, the NDF content of elephant grass, grinting grass, corn straw, and fermented corn straw was not significantly different ($p > 0.05$), but significantly different ($p < 0.05$) with corn cob and fermented corn cob, and the NDF content of corn cob was significantly different ($p < 0.05$) with fermented corn cob. The ADF content of elephant grass, grinting grass, corn cob, and fermented corn cob were not significantly different ($p > 0.05$), but significantly different ($p < 0.05$) with corn straw and fermented corn straw. The ADF content of corn straw was not significantly different ($p > 0.05$) with that of fermented corn straw. The elephant grass and grinting grass hemicellulose content were not significantly different ($p > 0.05$), but significantly different ($p < 0.05$) with corn straw, fermented corn straw, corn cob, and fermented corn cob. The corn straw and fermented corn straw hemicellulose content was not significantly different ($p > 0.05$), but significantly different ($p < 0.05$) with corn cob and fermented corn cob. Corn cob hemicellulose was significantly different ($p < 0.05$) with fermented corn cob. Cellulose content elephant grass; corn cob, and fermented corn cob, as well as grinting grass; corn cob; and fermented corn cob was not significantly different ($p > 0.05$), but significantly different ($p < 0.05$) with fermented corn straw and corn straw. Corn straw cellulose was significantly different ($p < 0.05$) with fermented corn straw. Lignin content of elephant grass; grinding grass; corn straw; and fermented corn cob and grinting grass; corn straw; and corn cob was not significantly different ($p > 0.05$). The fermented corn straw lignin was significantly different ($p < 0.05$) with other forages.

The fermented corn straw NDF and ADF content showed no change or did not differ from that of unfermented corn straw. This is thought to be influenced by microorganisms that had not worked optimally to break down corn straw lignocellulose due to the lack of EM4 dose used. According to Dewi et al (2019), the appropriate inoculum concentration is one of the success factors in the fermentation process. Lack of inoculum causes slow substrate degradation process. Moreover, it can also be affected by the lack of water in the substrate because the water content in this substrate will affect the microorganism growth and the dynamics that occur during the fermentation process. According to Gervais and Molin (2003), water is very important for microorganism metabolism in the solid fermentation process. It was further explained that if the need for water is not fulfilled it will cause the solute and gas diffusion interference and cell metabolism inhibition (Gervais and Molin, 2003), enzyme work disruption (Todd, 1972), plasma cell membrane damage, permeability property and cell membrane transport disruption (De Loecker et al., 1978; Wolfe and Steponkus, 1983).

The fermented corn cob NDF content showed a decrease of 7.26%. This is thought to be caused by microorganisms capable of breaking down lignocellulosic corn cob into simpler components. According to Santoso and Aryani (2007), EM4 contains Lactobacillus and Actinimycetes bacteria that produce cellulase and ligninase enzymes. Furthermore, it can be seen from corn cob hemicellulose and lignin content which decreased after fermentation. Therefore, fermented corn cob NDF content decreased. The unfermented and fermented corn cob NDF content was higher than that of corn straw, fermented corn straw, elephant grass, and grinting grass. This is influenced by the different fiber composition. According to Renge et al. (2012), one of the factors that affect the fermentation is

substrate composition. The fermentation results can vary greatly, depending on the substrate nature and characteristics (Subramaniyam and Vimala, 2012).

Corn straw and fermented corn straw have higher ADF content. This is thought to be influenced by the higher cellulose and lignin content compared to the other forage. Furthermore, fermented corn cob ADF content did not decrease compared to unfermented corn cob. This is thought to be caused by fermented corn cob cellulose content which also did not decrease. According to Amalia et al. (2000) ADF components consist of cellulose and lignin. Therefore, the fiber components have a connection.

Fermented corn straw hemicellulose content did not decrease. This is thought to be influenced by microorganisms that did not work optimally to break down lignocellulosic. The corn straw and fermented corn straw hemicellulose content is lower than other materials because fiber fraction composition of each material is different. This is in accordance with Rhamdani (2014), each feed ingredient contains different fibers. Furthermore, fermented corn cob hemicellulose content decreased. This is caused by microorganisms capable of breaking down hemicellulose into simple sugars.

Corn straw cellulose content decreased compared to that of unfermented. The decrease was 3.78%. Cellulose decrease was influenced by added EM4 inoculum microorganisms. EM4 contains cellulolytic microorganisms that can break down cellulose into simple sugars. This is in accordance with EM Indonesia.com (2022), EM4 contains fermented and synthetic microorganisms consisting of lactic acid bacteria (*Lactobacillus* sp.), photosynthetic bacteria (*Rhodopseudomonas* sp.), *Actinomycetes* sp., *Streptomyces* sp., yeast and cellulose-degrading fungi. Further explained by Santoso and Aryani (2007), EM4 can degrade crude fiber content because of cellulase and ligninase enzymes which are produced by the microbes contained in it, especially Lactobacillus and Actinimycetes bacteria. However, fermented corn cob cellulose content did not change. Although corn straw and corn cob are fermented by the same method, these two materials have different fiber components (cellulose, hemicellulose, and lignin). Therefore, fiber component composition results will differ. This is supported by Subramaniyam and Vimala (2012), the fermentation results can vary greatly, depending on the substrate nature and characteristics.

Fermented corn straw lignin content showed an increase compared to unfermented corn straw. This increase is thought to be influenced by the cellulose breakdown by microorganisms which is not followed by lignin breakdown so that the decrease in cellulose percentage causes an increase in lignin percentage. Unlike corn cob lignin content which decreased after fermentation. This decrease can be influenced by lignocellulolytic microorganisms that degrade corn straw lignin. The different microorganism ability to degrade corn straw and corn cob lignin is thought to be influenced by differences in these two materials' lignin constituent components. According to Rhamdani (2014), each feed ingredient contains different fibers. The fermentation results can vary greatly, depending on substrate nature and characteristics (Subramaniyam and Vimala, 2012).

Based on Table 6, it can be seen that the NDF, ADF, hemicellulose, cellulose, and lignin content of elephant grass and grinting grass are almost the same. Fermented corn straw and corn straw NDF content can match elephant grass and grinting grass. Fermented corn cob ADF content can match the ADF content of elephant grass and grinting grass. However, corn straw and fermented corn cob hemicellulose content could not match the hemicellulose content of elephant grass and grinting grass. The fermented corn cob and corn cob cellulose content in can match elephant grass and grinting grass. Furthermore, fermented and unfermented corn straw and corn cob lignin content can match that of elephant grass and grinting grass.

IV. CONCLUSION

Fermented corn cob was able to reduce lignin content thus corn cob lignin content could match elephant grass but on the contrary fermented corn straw was not able to reduce lignin content.

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Impact of Occupational Hazards on the Technical Efficiencies of Oil Palm Processors in Edo State, Nigeria

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Abstract— *This study examined the effect of occupational hazards on the technical efficiencies of oil palm processors in Edo State. A multistage sampling procedure was used in selecting 210 oil palm processors in the study area. Data were analyzed using percentages, frequencies, Occupational Hazard Indices and Stochastic Frontier Production Analysis (SFPA). Results revealed that 79%, 90.5% and 80.5% of the processors were male, married and educated respectively. Also, the mean age, processing experience and household size were 42 years, 15 years and 7 persons respectively. The most prevalent occupational hazards experienced were smoke irritation (100%), presser injury (94.3%) and spikelet injury (83.8%). The occupational hazards indices computed were, lost time rate, incidence rate and severity rate with values of 15.85, 23.77 and 2.4 respectively. SFPA revealed that the mean technical efficiency of the oil palm processors was 0.75. Furthermore, palm fruits ($\beta = 0.662$, $p<0.01$), the volume of water used ($\beta = 0.180$, $p<0.05$) and labor in man-day ($\beta = 0.415$, $p<0.01$) increased the production of palm oil. Also, processing experience ($\beta = -0.110$, $p<0.05$),), loss time rate ($\beta = 0.087$, $p<0.05$), incidence rate ($\beta = 0.03$, $p<0.1$), and severity rate ($\beta = -0.098$, $p<0.01$), decreased technical efficiency. The study concluded that occupational hazards had a negative influence on the technical efficiency of oil palm processors. The study recommended that stakeholders in oil palm processing should create health awareness and consistently research occupational hazards peculiar to oil palm processing as well as safety practices to enhance technical efficiency.*

Keywords— ***Maximum Likelihood, Occupational hazards, Palm Oil Processing. Technical Efficiency, Stochastic Frontier Production Analysis.***

I. INTRODUCTION

I.1. Background of the Study

The demand for palm oil is rising globally, and people are discovering more and more uses for it in their daily lives. The greatest source of edible oil in the world, palm oil makes up around 25% of the world's production of edible oils and fats, according to the Malaysia Palm Oil Council (MPOC, 2007). Exporting this commodity has benefited nations like Indonesia and due to increased demand for the commodity and Indonesia's palm oil export competitiveness, the country's palm oil exports increased dramatically between 1991 and 2001 and 2005 to 2007

(Amzul, 2010). Margarine, soap candles, lipstick bases, waxes and polish bases in condensed form, and confectionary products can all be made with palm oil (Embrandiri *et al*., 2011). Based on these diverse uses, oil palm was referred to as a crop of multiple values by Akangbe *et al*., (2011). According to Omoti (2004), before 1965 Nigeria was the world's top producer and exporter of palm oil, but since 1975, this has declined due to an imbalance between local demand/consumption and production. This economic turn caused Nigeria to become a net importer of palm oil (Olagunju, 2008). Nigeria produced 3% of the world's palm oil, placing it as the fourth-largest producer overall. The upstream production of palm oil was estimated at 0.98 million tons by the Nigerian Institute for Oil Palm Research (NIFOR) (Proshare, 2018). Ironically, despite the availability of modern tools and equipment for planting, harvesting, and processing agricultural products as well as ongoing research on agricultural mechanization, the majority of Nigerian rural farmers—including those who grow oil palm—remain dependent on outdated agricultural production techniques. This puts workers in danger from a variety of physical, biological, chemical, mechanical, and emotional risks that are common to many professions, including the production of palm oil. Workplace risks specific to oil palm processing include: falling from palm trees during harvesting, which can result in broken legs or even paralysis; injuries from particles getting into the eyes; being pierced by a spikelet from a palm fruit bunch; smoke from the fire made during processing the crude palm oil, which can affect the eyes and respiratory system; and burns that can happen during boiling the fruits or during threshing if leg chopping is involved (James, 2015). The ability of a farm to use inputs in the best proportions given their separate pricing is reflected in a farm's allocative efficiency, which may be quantified, as well as technical efficiency (TE). However, this study looks at how the technical efficiency of the processors is impacted by workplace dangers related to processing palm oil. There is little doubt that a dangerous encounter has an impact on a person's physical agility. This study concentrated on the metrics that influence how labor uses resources and the injuries that occur among palm oil processors. Additionally, it lists the different workplace dangers and illnesses that are common among processors in the research area.

Researchers have conducted numerous investigations on each idea of technical efficiency (Ekunwe and Orewa, 2007) and occupational dangers (Rawlance *et al*., 2015). The risks of a given profession seriously impact the practitioners' health and have a detrimental impact on their ability to do their jobs (Oluoch, 2015). Hazard analysis and critical control points (HACCP), a preventive program focused on recognizing, accessing, and controlling hazards, is now acknowledged internationally for managing the food safety aspect of palm oil production, processing, distribution, and preparation, according to Christe and Sathianathan (2006). However, because the government failed to establish connections with traditional farmers so that they could be taken into account when formulating legislation, it is unclear to what extent traditional palm oil processors were taken into account in this type of hazard control study. The majority of processors are somewhat aware of the risks involved in processing activities, especially those who are inclined to use traditional techniques of processing, but they must continue manufacturing to satisfy their financial responsibilities. The main issue, though, continues to be a failure to consider the detrimental effects this may have on their technical efficiency.

As a result, this study added to the body of evidence by:

- identifying and assessing the predominant occupational hazards faced by oil palm processors
- investigating the effect of occupational hazards on technical efficiency.

I.2. Literature Review

Any source that could cause harm, injury, or detrimental health effects to something or a person under specific circumstances is a hazard (World Health Organization (WHO), 2001). However, an occupational danger is one that typically results from the workplace. As a result, it is an injury received while performing a job or duty. A malfunctioning component may cause disease or even death. A serious risk to a worker's bodily or mental health that arises from their employment in a particular task, job, profession, or occupation is known as an occupational hazard. Workplace risks are caused by being exposed to a dangerous environment. Occupational hazards typically originate from many sources, some of which may be harmful equipment or employee behavior. Dangerous working conditions and unsafe behavior are the main causes of workplace dangers (Kalejaiye, 2013). However, other factors contribute to occupational dangers, many of which are frequently intimately linked to jobs. Numerous research studies have supplied data on illnesses and occupational dangers in the agriculture industry (Joseph and Minj, 2010). In agricultural settings, machinery has the highest incidence and fatality rates of injuries (Yiha and Kumie, 2010). Numerous pesticide exposures cause toxicity and, in rare instances, work-related cancer and death (Fieten *et al*., 2009). Allergies, lung ailments, zoonotic infections, and parasitic diseases are possible side effects of frequent contact with toxic and wild animals, plants, and biological agents (Kesavachandran, *et al*., 2008). Stress, musculoskeletal disorders (repetitive motion disorders, back disorders), psychiatric disorders, and noise-induced

hearing loss are also common (Bernard *et al*., 2011; Rocha *et al*., 2010; Wesseling *et al*., 2010). Production is the process by which some products and services are changed into new products. There are three different categories of production: primary (which encompasses all branches of production that may not be readily consumed at first but are used for subsequent production), secondary, and tertiary (comprises of all kinds of manufacturing and constructing works i.e. turning the new materials produced in primary production into finished goods.) and tertiary production, which entails the delivery of direct services like the distribution of goods and services at each stage of production to the ultimate consumers (Nweze, 2002). Land, labor, capital, and management are examples of production factors.

Stochastic Frontier Analysis (SFA) has been used in many efficiency studies. For instance, it was discovered that most farmers were technically inefficient, with 70% of them operating with less than a 0.60 efficiency score while measuring technical efficiency in Kenya's maize production using SFA (Kibaara, 2005). According to this study, the usage of hybrid and tractors, the presence of male-headed families, the age of the farmer, access to credit, and the length of formal education all have a beneficial impact on technological efficiency. According to the findings of this study, the Ministry of Agriculture should direct its extension service program toward the women who perform 80% of the work but receive only 5% of the funding. Using SFA, the technical efficiency of sorghum production in Adamawa State, Nigeria, was also calculated. It was found that the mean technical efficiency of sorghum was around 73%. (Wakili, 2012). The research indicated that the farmers' educational backgrounds, household size, interactions with extension agents, and sorghum farming experience were the main factors that were relevant in explaining efficiency. To discover and analyze factors impacting efficiency, the technical efficiency of Arabica coffee farmers in Cameroon was studied using a maximum likelihood method and a translog stochastic production frontier. The range of technical effectiveness was 0.24 to 0.98, with an average of 0.90. (Nchare, 2007). A study that used the SFA one-stage simultaneous estimate approach to estimate the technical efficiency of maize smallholder farmers in Southern Malawi and identify the variables that account for variances in technical efficiency was carried out (Chirwa, 2007). With an average technical efficiency of 46.23% and a low of 8.12%, it was shown that many families were technically inefficient. Utilizing hybrid maize and joining a club improved effectiveness. The study's findings suggest that to increase social capital and encourage the use of hybrid seeds by smallholder maize farmers, farmer organizations need to be revived or new agricultural cooperatives need to be established.

II. MATERIALS AND METHODS

This study was carried out in Edo State. Edo State Agricultural Development Programme (EDADP) zone, which divided the state into 3 zones was adopted. A multistage sampling procedure was used. In the first stage, three blocks were selected from each zone giving a total of nine blocks. In the second stage, four cells were randomly selected from each block. Finally, six respondents were randomly selected from each cell. This gave a total of 216 respondents. However, 210 sets of questionnaires were used for the analysis as they provided sufficient information. Frequency, mean and percentages were used to capture the socioeconomic characteristics of the respondents, the various occupational hazards encountered by the respondents and the various illnesses experienced. Occupational hazards that were considered include piercings from fruit spikes, burns from oil splashes/spills, hot objects, fire burns, injuries from tools and equipment (cutlass, presser) as well as snake and insect bites. Several indices were used to assess the occurrence of occupational hazards. Occupational Safety and Health Administration (OSHA) stressed that several rates could be computed for the occurrence of occupational hazards (OSHA, 2015). Some of these are lost time case rate, incidence rate, severity rate and proportional rate.

i. Proportional Rate: expresses the occurrence of various occupational hazards as a fraction of the total number of hazards under consideration. It is therefore a value between 0 and 1.

$$PR = \frac{n}{N} \quad (1)$$

Where:

n = number of observed occupational hazards experienced by the ith processor; and

N = total number of expected occupational hazards

ii. Total Incident Rate: a mathematical calculation that describes the number of recordable incidents per 100 full-time employees in any given time frame.

$$\text{TIR} = {}^{r}/_{W} * 200000 \quad (2)$$

Where:

TIR = total incidence rate

r = number of recordable cases; and

w = number of employee labor hours worked

iii. Lost Time Case Rate: a mathematical calculation that describes the number of lost time cases per 100 full-time employees in any given time frame.

$$LTR = {}^{n}/_{W} * 200000 \quad (3)$$

Where:

LTR = lost time rate

n = number of lost time cases; and

w = number of employee labor hours worked

iv. Severity Rate: a mathematical calculation that describes the number of lost days experienced as compared to the number of incidents experienced.

$$SvR = {}^{t}/_{i} \quad (4)$$

Where:

S_vR = severity rate

t = total number of lost workdays; and

i = total number of recordable incidences

The standard base rate for the calculations is based on a rate of 200,000 labor hours. This number (200,000) equates to 100 employees who work 40 hours per week and who work 50 weeks per year. Using this standardized base rate, any company can calculate its rate(s) and get a percentage per 100 employees (OSHA, 2015).

The cobb-Douglas functional form of the stochastic production function was used to estimate the production function and predict the technical efficiencies of the processors in the study area. The choice of this model is because it allows for the presence of technical inefficiency while accepting that random shocks beyond the control of the processor can affect output.

The empirical model of the stochastic production frontier function is specified as follows:

$$\ln Ti = \beta 0 + \beta 1 \ln R1 + \beta 2 \ln R2 + \beta 3 \ln R3 + \beta 4 \ln R4 + \beta 5 \ln R5 + Vi - Ui \quad (5)$$

Where:

T = quantity of palm oil (liters)

R_1 = fruit (bunches)

R_2 = fuel (liters)

R_3 = labor (labor days)

R_4 = water (liters)

R_5 = transport (hours)

$\beta_0, \beta_1, \beta_2, \ldots, \beta_5$ = Parameter estimates

The technical efficiency of the individual respondent was computed as an index and the average technical efficiency for the system was determined. Using several socio-economic factors and indicators for illness burden as explanatory variables and the efficiency index as the dependent variable, the inefficiency model was estimated. The model assumes that the inefficiency effect U_i is independently distributed with mean u_i and variance $\sigma^{2.}$ The model is specified as:

$$\mu i = do + d1z1 + d2z2 + d3z3 + d4z4 + d5z5 + d6z6 + d7z7 + d8z8 + d9z9 + e \quad (6)$$

where:

μ = inefficiency (number)

Z_1 =age of respondents (years)

Z_2 = household size (number of persons)

Z_3 = education level of farmer (1 = formal education; 0, otherwise)

Z_4 = processing experience (years)

Z_5 = sex of the farmer (1 = male; 0, otherwise)

Z_6 = lost time rate

Z_7 = incidence rate

Z_8 = severity rate

$d_o, d_1, d_2, d_3, \ldots, d_9$ = regression estimates

III. RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of the Oil Palm Processor

The socioeconomic traits of oil palm processors in the research region were listed in Table 1. The responders were 42 years old (±8.9) on average. Anzanku *et al*., (2006) reported that oil palm processors in Nassarawa State were within the age range of 30 and 50 years, and this opinion was shared by the outcome of this study as the majority (78.1%) of the respondents were between the ages of 31 and 50, otherwise known as their "active years." This suggests that the respondents will likely enjoy higher output because they have not yet experienced some constraints like weakness, which hinders production and comes with aging. Male workers made up the majority of those who processed oil palm (79.0%). It is implied that oil palm processing is a laborious job, which explains why fewer women were involved in it. This result supports James (2015) results that, oil palm processing was predominately male with a male-to-female ratio of roughly 4 to 1. James (2015) investigated

the effects of occupational hazards on the socioeconomic characteristics of oil palm processors in Delta State. The majority of respondents (90.5%) were married. This data confirms Emokaro and Ugbekile's (2014) assertion that married people primarily operate the oil palm processing industry in Edo State. The assumption is that a sense of duty would be ingrained as marital status encourages devotion due to the requirements of the family that must be satisfied, and this would subsequently improve productivity.

In addition, 19.5% of the processors had no formal education, 16.2% had only completed their primary education, 51.0% had completed only their secondary school, and 13.3% had completed their university education. According to this finding, 80.5% of the respondents were literate and had some kind of formal education. The high level of reading among the respondents is anticipated to have a good impact on their consciousness and awareness of safety practices, as well as their productivity. Their standard of living would eventually be affected by this. This supports Erhabor and Emokaro's (2007) assertion that an educated producer in Edo State produces 13% more than an uneducated producer. The average amount of processing experience among the respondents was 15 years (±4.7), with the maximum amount of experience among 1.4% being 10 years. The majority (96.2%) of those with oil palm processing expertise had between 11 and 20 years of experience, and 0.9% had more than 30 years. According to the theories put out by Karki (2004) and Onyenweaku, and Nwosu (2005), experience and technical efficiency are positively correlated. Therefore, respondents with more experience are likely to be technically more adept than respondents with less experience. The mean household size was seven people (±2), with 19.0% of respondents having no less than five members, 79.5% having six to ten members, and 1.4% having more than ten members. This suggests that the firm must be profitable enough for the processors to be able to adequately provide for their families. Large household sizes also reduce the negative effects that a worker's absence from work due to illness would have on the performance of the business This is because there would be sufficient hands to replace any weak hands. Due to the ready availability of family labor, big family sizes also have the propensity to lower production costs. This outcome confirms the report by Agwu (2006) that the average household size among oil palm processors was six people.

3.2 Occupational Hazards of Processors

Regarding the occurrence of hazards, every respondent said that they had dealt with instances of the dangers that are typical of the oil palm processing industry. In this study, the local palm oil processors primarily suffered from smoke irritation (100%) presser injury (94.3%), spikelet injury (83.8%), burns from fire and oil splashes (55.7%), cutlass injury (42.9%), bee stings (22.4%), and snake bites (19.1%) in addition to other ailments. The respondents' frequent exposure to these risks as a result of their lengthy tenure in the industry demonstrates a direct correlation between their risky events and their years of processing experience. According to James (2015), workers who stay at their jobs for less time (less than five years) are less likely to have a work-related injury, and because processors typically have 15 years of industry experience, they are more likely to be exposed to occupational dangers.

Table 1: Socioeconomic Characteristics of the Respondents.

Variables	Frequency	Percentage	Standard Deviation	Mean
Age				
≤30	19	9.0	8.895	42
31 – 40	78	37.1		
41 – 50	86	41.0		
51 – 60	20	9.5		
61 – 70	6	2.9		
>71	1	0.5		
Total	**210**	**100.0**		
Sex				
Male	166	79.0		
Female	44	21.0		
Total	**210**	**100.0**		
Marital Status				
Single	9	4.3		
Married	190	90.5		

Widowed	11	5.2		
Total	**210**	**100.0**		
Educational Level				
Non-Formal	41	19.5		
Primary	34	16.2		
Secondary	107	51.0		
Tertiary	28	13.3		
Total	**210**	**100.0**		
Processing Experience				
≤10	3	1.4.0	4.692	15
11 – 20	202	96.3		
21 – 30	3	1.4		
>30	2	0.9		
Total	**210**	**100.0**		
Household Size				
1– 4	20	9.5	2.085	7
5 – 8	155	73.8		
>8	35	16.7		
Total	**210**	**100.0**		

Table 2: Illness Experiences and Occupational Hazards.

Variables	Frequency	Percentage
Hazard Experience		
Yes	210	100.0
Occupational Hazards (n= 210)*		
Spikelet Injury	176	83.8
Burns (Fire, oil splash)	117	55.7
Cutlass injury	90	42.9
Smoke irritation	210	100.0
Bee sting	47	22.4
Presser Injury	198	94.3
Snakebite	40	19.1

*Multiple responses

3.3 Occupational Hazard Indices

The indices from the International Labour Organization (ILO) that were used to measure the impact of occupational risks are shown in Table 3. The indices include the proportionate rate, severity rate, incidence rate, and lost time rate (ILO, 1998). According to the findings, approximately 14 processors out of every 100 processors have missed time at work due to an illness or injury. The number of instances where processors lost actual production hours is taken into account when calculating the lost time rate, which also calculates the typical number of processors who have missed time at work because of illnesses or accidents connected to their jobs. As a result, a high lost time rate has a negative effect on the processing industry, and managers of oil palm processing enterprises should make sure that precautions are made to protect their employees in order to lower the lost time rate's value. According to the incidence rate data, there have been around 15 recordable injuries or illnesses among every 100 processors. Smaller businesses with recordable events (injuries or illnesses) are more likely to have high incident rates or incident rates that vary dramatically from year to

year, according to OSHA (2015). They went on to say that in smaller enterprises as opposed to larger ones, the impact of a single injury or sickness on incidence rates is substantially greater. They said that when an employer compares his company's accident and illness experience to that of other companies with similar work and workforce sizes, the incidence rates become more meaningful. The severity rate, a metric that determines the average number of days lost per incident that can be recorded, also reveals that the processors had a severity rate of 2.4. Accordingly, an average of 2.4 days will be lost as a result of work-related illnesses and injuries for each event that can be recorded. According to the proportional rate of occupational hazards experienced, 60% of the risks that oil palm processors are exposed to were experienced by those in Edo State. This finding suggests that the business's potentially dangerous situations are not being given the required attention, and this neglect may increase the frequency of work-related injuries.

Table 3: Occupational Hazard Indices.

Index	Number
Lost Time Rates	
Number of lost time cases	368
Number of employee labor hours worked	5300050
LTR	13.89
Incidence Rate	
Number of recordable hazardous cases	392
Number of processor labor hours worked	5300050
IR	14.79
Severity Rate	
Total number of lost workdays	944
Total number of recordable hazardous cases	392
SR	2.4
Proportional Rate	0.6

3.4 Analysis of Factors Influencing Efficiency of Oil Palm Processors in the Study Area

Table 4 displays the findings from the Maximum Likelihood Estimates (MLE) of the Cobb Douglas Stochastic Frontier Production Function (SFPF) and the inefficiency model. Sigma squared was statistically significant in the results (2 = 1.33, p 0.01), supporting the given assumption about the distribution of the composite error term as well as the goodness of fit. The percentage of the total divergence from the frontier that can be attributed to the processors' inefficiency is shown by the gamma (γ). It demonstrates that the technical inefficiency of the processors was responsible for around 71.0% of the drop in output below the frontier. The findings also showed that even though the processors used a variety of inputs, palm fruits (β= 0.66, p < 0.01), water (β=0.18, p <0.05), and labor (β= 0.42, p<0.01) were the main inputs that had the greatest impact on the output of each oil palm processing enterprise in the study areas. The outcome demonstrates a considerable increase in palm oil production of 0.66 liters per unit increase in oil palm fruit. Processors should consequently pay close attention to the number and quality of fresh fruit bunches processed each time. The condition of these fresh fruit bunches is crucial since the quality of the fruit (in terms of oil content, appearance, and rancidification) is also significant. Additionally, an essential input that emphasizes how vital it is for processing palm fruits is that a unit increase in the amount of water utilized during processing greatly increased production by 0.18 liters. The amount of water needed increases with how much the fresh fruit bunches are processed. It is crucial to know how much water should be used for each output.

The output of palm oil was also greatly boosted by 0.42 liters per additional man-day of labor. The amount and quality of labor used by any producing business have a significant impact on the production of that business. To guarantee that labor is used effectively, the proper precautions must be taken. Specialization in the workforce should not be disregarded because it will increase labor productivity. Production involves all types of labor, both skilled and unskilled, and processors should make sure that this aspect of production (labor) is used effectively. The conclusions of Muhammad-Lawal *et al*., (2009), Amaza and Maurice (2005), and Oniah *et al*., (2008) that the coefficient

of labor was positive and significant and that an increase in labor consumption would lead to an increase in output levels are supported by this result. The inefficiency model as revealed in Table 4 examined how the technical efficiency of oil palm processors was affected by variables such as sex, age, education level, processing experience, household size, lost time rate, severity rate, and incidence rate. Processors' inefficiency was considerably influenced by their processing experience (d = -0.11, p<0.05). This implies that the technical inefficiency diminishes as the processors gain expertise in the processing industry, hence improving their technical efficiency. This result defies Usman's (2012) findings, which suggested that the technical efficiency of rice farmers in Niger State was not greatly impacted by experience. Processor efficiency was strongly impacted by the lost time rate (d = 0.09, p<0.05), severity rate (d = 0.10, p<0.01), and incidence rate (d = 0.03, p0.1). This suggests that the technical efficiency of the oil palm processors would decrease if the values of these inputs increased by a unit.

Table 4: Determinants of Oil Palm Processing Output and Efficiency.

Variables	Coefficient	t-value	P- value
Constant	0.798	1.47	0.850
Fruits	0.662***	6.86	0.002
Water	0.180**	2.04	0.022
Fuel	0.056	0.65	0.754
Transport	-0.061	-0.88	0.262
Labour	0.415***	3.65	0.003
Inefficiency Model			
Sex	0.344	0.29	0.676
Age	-0.041	-0.56	0.201
Educational level	1.489	1.04	0.300
Processing experience	-0.110**	-2.97	0.049
Household size	0.120	0.48	0.879
Loss time rate	0.087**	2.68	0.026
Incidence rate	0.030*	1.99	0.078
Severity rate	0.098***	3.57	0.001
Variance Parameters			
Sigma squared	1.328***	11.22	0.000
Gamma	0.711***	5.67	0.000
Log-likelihood	-156.353		

***Significant at 1%; **Significant at 5%; *Significant at 10%

IV. CONCLUSION AND RECOMMENDATIONS

It is impossible to overstate the connection between the nature of a job and its impact on technical efficiency. This study has shown how important it is to take precautions when performing hazardous occupations because doing so will help to increase productivity. According to this study, there are several occupational hazards associated with processing oil palm, and these risks have an immediate impact on the technical efficiency of the processors. The study's primary risks were presser injury, smoke irritation and spikelet damage. This study also demonstrated that, although most processors were technically efficient in terms of how they used the majority of their inputs, there was still space for advancement. According to the study's findings, the following recommendations were suggested:

- Processors of oil palm should make sure that only high-quality fruits are used. This is due to fruits' substantial contribution to the output of the processors.
- Adoption of safety procedures and thorough, reliable research on occupational dangers are both necessary. This would help oil palm processors become more aware of the risks associated with

their line of work and help them take the necessary precautions to guarantee that they are not exposed to these risks.

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Impact of Fecal Waste Management on the Profitability of Poultry Farmers in Nigeria

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Abstract**—** *The observation that there is far more quantity of poultry waste than can be managed by land disposal being produced yearly suggests the obvious problem of poultry waste management. This scenario offers great opportunities for organic farming and bio-energy generation in Nigeria. Hence, this study examined the economic contribution of fecal waste to the profitability of poultry farmers in Delta State, Nigeria. A multi-stage sampling process was used to select the 123 poultry farmers for this study. The data collected were analyzed using descriptive statistics, profitability ratios and the Stochastic Frontier Profit Function model. The Gross Margin analysis gave a value of ₦5,771,437.10 and a Net Farm Income of ₦1,960.18 per bird. The profitability ratios showed a Profitability Index of 0.86, a Rate of Return on Investment of about 19.25%, and a Return per Naira Invested (RNI) of ₦0.23. From the Stochastic Frontier Profit Function analysis, veterinary cost and cost of labor for fecal waste management had a significant positive effect on profit efficiency. The cost of birds and depreciation on fixed input had a significant negative effect on profit efficiency. Age and cooperative membership of layer farmers were significant socioeconomic factors positively influencing profit inefficiency. While education and household size were shown to negatively influence profit inefficiency. It was therefore concluded that farmers should focus on improved quality feed either self-compounded or purchased and better emolument for their workers as these positively influenced their profit. They should also be enlightened on the huge benefit of fecal wastes-to-biogas-electricity technology.*

Keywords**— Delta State, Gross Margin, Profit Efficiency, Profitability Index, Stochastic Frontier Analysis.**

I. INTRODUCTION

1.1 Background of the Study

Poultry production is one of the most developed aspects of the Nigerian livestock industry (Miebi, 2020), and with the increase in population, there is pressure on local poultry farmers and the potential to expand the sector (The Commonwealth Scientific and Industrial Research Organisation, CSIRO, 2021). This expansion is not unrelated to the fact that they have a high level of energy and protein as they are good converters of feed into usable protein (Farrell, 2013; Qaid and Al-Garadi, 2021) and some researchers have associated this expansion potential with various factors including relatively low production cost per unit, short incubation period, high returns on investment and the absence of geographical, cultural, and religious restrictions (Achoja, 2013; Akanni and Benson 2014; Heise *et al*., 2015). This implies that fecal waste generated from the industry contributes significantly to the total waste generated in agriculture.

While there is difficulty in getting the true figures of waste produced from the Nigerian livestock industry, there are obvious indications that the volume is massive, and the environmental consequences are enormous. In the wake of the 20th Century, Itodo *et al*., (2001) estimated 1.4 million, 6.40 million and 5.2 million kilograms of cattle, poultry, and piggery manure per day respectively. Another estimate shows that about 932.5 tonnes of manure are produced annually from the well-established poultry industries alone, which keeps expanding at 8% every year (Adewumi et al., 2011). Delta State livestock industry is known to have poultry production as the predominant enterprise with layer production taking the central stage as it is a double-barreled approach serving both the egg and meat production purposes of poultry production. Generally, there is a tendency for farmers to focus on the main production output than the waste of any production system. However, since poultry fecal wastes generate a lot of environmental concerns and possess some economic value, there is a need to reconsider such waste viz-a-viz the economic impact on layer production.

1.2 Problem Statement

Nigerian poultry farmers faced with the need to intensify production have the problems of waste management and inflated input prices to grapple with. This is particularly true in terms of the long-term growth and sustainability of poultry production in larger bird facilities located near urban and peri-urban areas, as well as for smaller commercial systems associated with live bird markets, and for village and backyard flocks located in rural areas (Williams, 2013). It has been estimated that a layer bird produces about 63–70 kg of waste in a year and 1,000 layers can produce 1 tonne of manure weekly while in deep litters (Oluyemi and Roberts, 2000). There is far more quantity of waste than can be managed by land disposal being produced yearly (Gerber *et al*., 2008). While on the one hand, this shows the obvious problem of poultry waste management, on the other hand, it offers great opportunities for organic farming and bio-energy generation in Nigeria.

The sales of fecal waste from poultry farms increase revenue and ensure environmental stewardship at the same time as these wastes are recycled as organic manure for crop cultivation. Generating bioenergy from these wastes or developing other eco-innovative strategies to manage these wastes of environmental concern, is expected to reduce the cost of waste management and money spent on fossil fuel and electricity bills in the long run. Both approaches to managing waste ensure a cleaner environment and the generation of more revenue through the reduction of cost which is consistent with the objective function of profit maximization. In recent times, arable crop farmers from the northern part of Nigeria have besieged the South (Delta State inclusive) with a request for poultry droppings. This is obviously in recognition of its long-term benefit of helping to improve the soil's physical properties. However, since there is a dearth of information on the profitability of fecal waste or its contribution to the profitability or otherwise of layers enterprises in Delta State, this work is designed to answer the following research questions:

- What is the contribution of revenue from fecal waste to the profitability of layer farms in the study area?
- What is the profit efficiency of layer farms generating income from fecal wastes?

The broad objective of the study was to investigate the impact of fecal waste management on the profitability of poultry farmers in Nigeria and the specific objectives of this study were to:

- estimate the contribution of revenue from fecal waste to the profitability of layer farms in the study area.
- determine the profit efficiency of layer farms generating income from fecal wastes in the study area.

The above objectives were used to explain the hypothesis below:

- H_0: There is no significant contribution of fecal waste to the profitability of poultry farmers in the study area

1.3 Justification and Novelty

Numerous research efforts bordering on the economics and the profitability of poultry production in different parts of Nigeria exist. Adewunmi (2008) researched the economics of poultry production in Egba Division of Ogun State. Hassan *et al.,* (2016) did work on the economic analysis of poultry egg enterprise in Kaduna State, while Nmadu *et al.,* (2014) looked at the profitability and resource use efficiency of poultry egg production in Abuja. Emokaro and Erhabor (2014) did a comparative analysis of the profitability of layers production in Esan North East and Ovia North-East local government areas of Edo State. Joining this array of research, Achoja (2013) researched the allocative efficiency of feeds among poultry farmers in Delta State. Also, there have been several studies on the environmental effects of poultry production and the potential of poultry waste (Gerber *et al*, 2008; Williams, 2013; Alabi *et al*., 2014). It is also worth noting that outside Nigeria, there have been studies on the use and profitability of poultry manure in electricity generation. Works of Murphy *et al*., 2004; Gebrezgabher *et al.*, 2010 and Lassner, 2011 looked at various aspects of this eco-innovative way

of waste management. More specifically, bothered that the use of wastes for biogas production has been restricted to a few feedstocks like cattle manure and food waste, Ajieh *et al*., (2021), reasoned that increasing the feedstock base for biogas production can increase the sustainability of feedstock availability. Thus, the sociocultural and acceptability issues associated with the use of fecal waste as a source of energy in Benin City, Edo State, Nigeria were assessed. Ihoeghian *et al*., (2022), also looked at anaerobic co-digestion of cattle rumen content and food waste for biogas production as an alternative energy source. This was against the backdrop that Nigeria generates approximately 42 million tonnes of solid waste, with attendant poor waste management practices that have made it impossible to properly collect and harness these waste materials. However, while the plethora of research around profitability gives great insight to all stakeholders in the solid waste management and poultry subsector of the livestock industry, there is hardly any work on the economics of the fecal waste generated from poultry production in terms of their contribution to the profitability of the poultry enterprise and meeting the objective of environmental stewardship in line with the trend of eco-innovation. This identified gap is what this current research effort is designed to fill.

1.4 Review of Previous Studies

A major challenge in Nigeria in terms of poultry waste management is the fact that reliable data on the volume of waste generated from poultry farms annually are not readily available. In Nigeria, about 932.5 metric tonnes (MT) of manure are produced annually from the well-established poultry/livestock industries which keep expanding at 8% every year (Adewumi *et al*., 2011). It is obvious that with the increased intensification of poultry production over the past 15 years, the figures have soared. In Minna, North-Central Nigeria, Adeoye *et al*., (2014) reported an estimate of 100.97 tonnes of dead birds over a brooding cycle and about 159,430 metric tonnes of poultry manure being generated annually from the 117 poultry farms in that State. The case in the other States of the country may not be different. To better overcome the monumental task of poultry waste management, different waste management practices like sanitary landfills rendering faculties, extrusion machinery, compost plants, lagoons, or holding tanks and land application have been used (Pope, 1991).

Apart from being a by-product of poultry production, fecal waste has economic value and potential thus the potential for income in the farm. This is because they could be applied as manure for soil nutrient augmentation, thus saving or reducing the money that would have been spent on inorganic fertilizers for the case of poultry farms integrated with crop production. The value of the money saved through this process and from selling manure to crop farmers become an additional source of income from the poultry enterprise. Making money from fecal waste is also a way of waste management, thus this double-barreled model is what any farm can adopt. Researchers (Akanni and Benson, 2014; Alabi *et al*., 2014; Onu *et al*., 2014) have shown that one of the ways of managing poultry waste, especially fecal waste is through selling these wastes, especially for those involved in urban agriculture. In fact, in the research on poultry litter/manure management practices in intensively managed poultry farms in Port Harcourt (South-South Nigeria), it was shown that 53.3% of the respondents sell their bags of fecal waste immediately, 43.3% store and sell later, and 3.3% apply manure directly to their farmlands (Kalu, 2015). This shows that there is an available market, not just for poultry products but also for the by-products, specifically, fecal waste.

Beyond the sales of fecal waste for soil fertility supplementation, poultry and other types of animal wastes could be used as energy feedstock to generate biogas. The production of methane from biomass e.g., human excreta, animal manure, sewage sludge, and vegetable crop residues can be used in families, farms and industrial units for cooking, heating, and lighting, and in larger institutions for power generation (Simeon, 2009). Although this option has been adequately explored in many developed countries (Mehta, 2002; Murphy *et al*., 2004; Singh *et al.*, 2008; Gebrezgabher *et al*, 2010; Jensen *et al*., 2010; Lassner, 2011), there are only a few farms or institutions currently employing this technology of environmentally-friendly waste management in Nigeria. This may be due to ignorance, unavailability of technical know-how, unavailability of adequate poultry wastes to feed biogas digester to produce desired energy demand, lack of policy attention and government support, and lack of research on the feasibility and profitability amongst others.

However, whenever poultry farmers are ready to look toward methods to decrease farm energy costs, use energy for their operations in a sustainable manner, and sustainably dispose of litter, their interest would always increase in using poultry litter as a potential energy feedstock (Jensen *et al.*, 2010). The use of poultry wastes as energy feedstock for biogas generation is not only an efficient and environmentally friendly way of managing waste but also helps to save money or a part of the cost that would have been spent on electricity.

II. METHODS

2.1. Sampling and Sampling Procedure

The study was conducted in Delta State, Nigeria. The State lies approximately between Latitudes 5°00' and 6°30' North and Longitudes 5°00' and 6°45' East. It is bounded in the North by Edo State, the East by Anambra State, South-East by Bayelsa State, and on the Southern flank is the Bight of Benin (Delta State Ministry of Agriculture and Natural Resources, 2010). It is situated in the tropics and therefore experiences a fluctuating climate, ranging from the humid tropical in the South, and the sub-humid in the Northeast.

A three-stage sampling procedure was employed in drawing the sample. In the first stage, the stratification of the State into three zones following the ADP-Agricultural zones delineation namely, Delta North Agricultural Zone (DNAZ), Delta Central Agricultural Zone (DCAZ) and Delta South Agricultural Zone (DSAZ) was maintained. The second stage involved the simple random sampling of five blocks (LGAs) from DNAZ, five blocks from DCAZ and three blocks from the DSAZ. Since, poultry farms were randomly distributed in communities (cells) within these blocks, with some towns having several farms and others having no poultry farm at all, the third stage involved the use of a simple random sampling to select 12 poultry farms from each of the earlier selected blocks in DNAZ and DCAZ while eight poultry farms each were selected from the blocks of DSAZ. The ratio of farmers selected from the three zones was done in proportion to the total number of farms in the sampling frame. This selection was drawn from the sampling frame containing the lists of active layer farmers across the State as provided by the Delta State Ministry of Agriculture, Asaba and the Delta State Agricultural Development Programme, Ibusa. The sampling frame contained 224 active layer farmers and the sampling goal was to sample 130 layer farmers (58% of the sampling frame) satisfying the Central Limit Theorem and inclusion of a 10% buffer (i.e. 13 extra respondents) to give allowance for non-response and invalid responses. Thus 60 respondents each were obtained from DNAZ and DCAZ while 24 respondents came from DSAZ giving a total of 144 respondents in all. A total number of 144 copies of the research questionnaire were administered. However, upon collation, only 123 copies were found useful for further analysis, thus giving a response rate of 85.41%.

2.2. Analytical Techniques

Gross Margin Analysis: This was used to determine the profitability or otherwise of the poultry farmers. Gross Margin is the difference between gross income (revenue) and total variable cost (TVC) of production (Olukosi and Erhabor, 2005). This was one of the indices used in determining the costs, returns as well as the profitability of the poultry farmers in the study area. It was determined as follows:

$$GM = TR - TVC \quad (1)$$

Where;

GM = Gross Margin (₦),

TR = Total Revenue (₦),

TVC = Total Variable Cost (₦).

Net Farm Income**:** This was another index for profitability determination, and it represents the total profit and was determined using the:

$$NFI = TR - TC \quad (2)$$

Where;

NR = Net Farm Income; TR = Total Revenue and TC= Total Cost.

$$TR = P_V V + P_W W + P_X X + P_Y Y + P_Z Z \quad (3)$$

But:

$$TC = TVC + TFC = TVC + Depreciation\ on\ Fixed\ Input \quad (4)$$

P_v = Price of eggs; v = quantity of eggs (in crates); P_w = Price of cracked eggs; w = quantity of cracked eggs (in crates); P_x = Price of spent bird x = quantity of spent birds (in kg); P_y = Price of fecal waste; y = quantity of fecal waste (in bags of kg); P_z = Price of feed bags/sack; z = quantity of feed bags/sack (in dozens).

Profitability Index (PI) = $\frac{NFI}{GM}$ (5)

Rate of Return to Investment (RRI) = $\frac{NFI}{TC} * 100$ (6)

Return Per Naira Invested on Variable Cost = $\frac{GM}{TVC}$ (7)

The depreciation of all fixed assets (cost) was calculated using the Straight-Line Method as shown below:

$$D = C - \frac{S}{N} \quad (8)$$

Where;

D = Depreciated amount; C = Initial cost of the assets; S = Scrap value (which in this case is assumed to be zero); and N = Expected number of useful life spans.

Furthermore, the Student's t-test was used to find out if there is a significant contribution of fecal waste to the profitability measures of poultry farmers. The formula for the T-test is given below:

$$t = (X_1 - X_2)/S_d \quad (9)$$

Where;

$$S_d = \frac{\sqrt{S_1^2}}{n_1} + \frac{\sqrt{S_2^2}}{n_2} \quad (10)$$

Where;

X_1 = Mean of the first set of values (those who make money from fecal waste), X_2 = Mean of the second set of values (those who do not make money from fecal waste), s_1 = Standard deviation of the first set of values, s_2 = Standard deviation of the second set of values, n_1 = Total number of values in the first set, n_2 = Total number of values in the second set.

While the formula for standard deviation is given:

$$S = \sqrt{\sum (x - \mu)^2 / (n - 1)} \quad (11)$$

Where;

x = profit of a given layer farmer, μ = Mean profit of layer farmers, n = Total number of layer farmers.

The profit function was used to determine the profit efficiencies of farms generating income from fecal wastes in the study area by employing the stochastic profit frontier model. This followed Battese and Coelli (1995) who extended the stochastic production frontier model by suggesting that inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of the model is that it makes it possible to estimate the specific efficiency scores and the factors explaining the efficiency differentials among farmers in a single-stage estimation procedure.

The profit function which is assumed to behave in a manner consistent with the stochastic frontier concept is defined as:

$$\pi_i = f(P_{ij}, Z_{ik}).\exp(\varepsilon_i) \quad (12)$$

Where;

π_i is the normalized profit of the i^{th} farm defined as gross revenue less variable cost, divided by farm-specific output price P; P_{ij} is a vector of j^{th} variable input prices faced by the i^{th} farm divided by output price (in this case, the price of fecal waste); Z_{ik} is the level of the *kth* of fixed factors on the i^{th} farm; ε_i is an error term; here i =1,., n, is the number of poultry farms in the sample. The assumption here is that the error term ε_i behave in a manner consistent with the frontier concept, that is;

$$\varepsilon_i = v_i - \mu_i \quad (13)$$

The symmetric two-sided error term (v) accounts for random variation in profit attributed to factors outside the farmer's control (white noise). The one-sided component (μ) is a non-negative error term accounting for the inefficiency of the farm. Therefore, it represents the profit shortfall from its maximum possible value on the stochastic profit frontier.

A multiple regression model based on the stochastic frontier profit function which assumes a translog functional form was employed to determine the profit efficiency of farmers generating revenue from wastes in the study area. This is in line with Ifeanyi and Onyenweaku (2007). It was chosen due to its inherent advantage as well as suitability in estimating sole enterprises and analyzing interactions among input variables and the output. This is specified below:

$$\ln\pi^*_i = a_0 + a_1\ln X_1 + a_2\ln X_2 + a_3\ln X_3 + a_4\ln X_4 + a_5\ln X_5 + a_6\ln X_6 + a_7\ln X_7 + 0.5a_{11}\ln(X_1)^2 + 0.5a_{22}\ln(X_2)^2 + 0.5a_{33}\ln(X_3)^2 + 0.5a_{44}\ln(X_4)^2 + 0.5a_{55}\ln(X_5)^2 + 0.5a_{66}\ln(X_6)^2 + 0.5a_{77}\ln(X_7)^2 + a_{12}\ln X_1{*}\ln X_2 + a_{13}\ln X_1{*}\ln X_3 + a_{14}\ln X_1{*}\ln X_4 + a_{15}\ln X_1{*}\ln X_5 + a_{16}\ln X_1{*}\ln X_6 + a_{17}\ln X_1{*}\ln X_7 + a_{23}\ln X_2{*}\ln X_3 + a_{24}\ln X_2{*}\ln X_4 + a_{25}\ln X_2{*}\ln X_5 + a_{26}\ln X_2{*}\ln X_6 + a_{27}\ln X_2{*}\ln X_7 + a_{34}\ln X_3{*}\ln X_4 + a_{35}\ln X_3{*}\ln X_5 + a_{36}\ln X_3{*}\ln X_6 + a_{37}\ln X_3{*}\ln X_7 + a_{45}\ln X_4{*}\ln X_5 + a_{46}\ln X_4{*}\ln X_6 + a_{47}\ln X_4{*}\ln X_7 + a_{56}\ln X_5{*}\ln X_6 + a_{57}\ln X_5{*}\ln X_7 + a_{67}\ln X_6{*}\ln X_7\, v_i - \mu_i \quad (14)$$

Where:

π^*_i = restricted profit (total revenue less total cost of variable inputs) profit normalized by the price of the output computed for the i^{th} farmer; ln = natural log; X_1 = normalized cost of layer feed (in Naira); X_2 = normalized cost of labor (in Naira); X_3 = cost of stock/birds (in Naira); X_4 = normalized veterinary cost (in naira); X_5 = normalized cost of labor for fecal waste management (in Naira); X_6 = normalized cost of bags for waste; X_7 = depreciation on fixed assets; a_0 and a_{1-7} are parameters to be estimated, v_i represents statistical disturbance term and μ_i = represents profit inefficiency effects of i^{th} poultry farmer generating income from fecal waste.

The determinants of profit inefficiency of layer/egg production in line with Bamiro *et al.* (2013) were modeled following specific characteristics of farmers in the study area. From equation (13) component is specified as follows:

$$\mu_i = l_0 + \sum_{d=1}^{5} l_d W_d + k \quad (15)$$

Where:

μ_i = Profit inefficiency of i^{th} farmer; l_0 and l_d are parameters to be estimated; W_d = variables representing socioeconomic variables (d =1,2,3...., n,); W_1 = ages (in years); W_2 = education (yearsj); W_3 = years farming experience; W_4 = Household size (head count); W_5 = Cooperative membership (Member = 0, Nonmember =1); k is truncated random variable.

III. RESULTS AND DISCUSSION

3.1. Socioeconomics Characteristics of Poultry Farmers in the Study area

Results presented in Table 1 show that the majority (66.67%, 73.47%, 65% and 69.11%) of the poultry farmers in Delta North Agricultural Zone (DNAZ), Delta Central Agricultural Zone (DCAZ), Delta South Agricultural Zone (DSAZ) and pooled sample respectively were males, indicating that only a few females were actively involved. Thus, the industry is male-dominated. Age distribution among the majority (85.19%, 83.67%, 90% and 85.17%) of the poultry farmers in DNAZ, DCAZ, DSAZ and pooled sample were within 25-54 years, 55-64 years, 25-54 years, and 25-54 years of age, respectively. The mean ages were 46 years, 45 years, 45 years, and 46 years, respectively. This implies that the majority of the farmers were young, agile and within their active age, this may positively influence their productivity. This finding resonates with the findings of Yusuf and Malomo (2007) who reported an average age of 44 years.

The greater proportion (57.41%, 69.39%, 65% and 63.41%) of the farmers in DNAZ, DCAZ, DSAZ and pooled sample had tertiary education. This implies that the majority of them were well-educated. Generally, educated farmers are more receptive and apt to adopt new technologies that would enhance productivity, better manage waste, and increase profit, and profit efficiency (Paltasingh and Goyari, 2018). The greater proportion (46.3%, 46.94%, 55% and 47.97%) of the respondents in DNAZ, DCAZ, DSAZ and pooled sample respectively had 6 -10 years of poultry farming experience. The mean farming experience for DNAZ, DCAZ, DSAZ and the pooled sample was seven years, six years, eight years, and seven years, respectively. Since the continuous practice of an occupation for a long time has the potential of making a person more experienced and productive in the practice, it could imply that they have good experience in poultry production, a development that can influence their efficiency and productivity positively. Concerning household size, a greater proportion (61.11%, 61.22%, 55% and 60.16%) of the farmers in DNAZ, DCAZ, DSAZ and pooled sample had a household size of 4 - 6 persons. The mean household size was five persons. This implies that the majority of the farmers had a fairly large size of household members, thus increasing their employment of family labor.

Table 1: Frequency and Percentage Distribution of Farmers according to their Socio-economic Characteristics

Variable	Description	DNAZ		DCAZ		DSAZ		Pooled	
		Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Sex	Male	36	66.67	36	73.47	13	65.00	85	69.11
	Female	18	33.33	13	26.53	7	35.00	38	30.89
Age (years)	≤30			1	2.04			1	0.81
	31-40	16	29.63	18	36.74	5	25.00	37	30.08
	41-50	22	40.74	14	28.57	11	55.00	49	39.84
	51-60	12	22.22	13	26.53	4	20.00	29	23.58
	Above 60	4	7.41	3	6.12			7	5.69
	Mean	46		45		45		46	
	Standard deviation	8.48		9.06		6.32		8.36	

Level of education	Primary	3	5.56	2	4.08			5	4.07
	Secondary	20	37.04	13	26.53	7	35.00	40	32.52
	Tertiary	31	57.41	34	69.39	13	65.00	78	63.41
Farming experience (years)	1-5	20	37.04	26	53.06	4	20.00	50	40.65
	6-10	25	46.30	23	46.94	11	55.00	59	47.97
	11-15	8	14.81			5	25.00	13	10.57
	16-20	1	1.85					1	0.81
	Mean	7		6		8		7	
	Standard deviation	3.33		2.10		3.15		2.97	
Household size (persons)	1-3	10	18.52	12	24.49	3	15.00	25	20.33
	4-6	33	61.11	30	61.22	11	55.00	74	60.16
	7-9	11	20.37	7	14.29	6	30.00	24	19.51
	Mean	5		5		5		5	
	Standard deviation	1.64		1.95		1.56		1.78	

3.2. Profitability of Poultry Production

The mean result of the profitability accruable from poultry farming is presented in Table 2. The result showed that the average revenue realized by the farmers in the study area was ₦30,773,161.91. Revenue from egg production was ₦27,489,426.19, the revenue realized from cracked eggs was ₦287,336.37, and revenue realized from culled layers was ₦2,923,621.89 while revenue realized from fecal waste was ₦72,777.45. The total cost of production incurred by the farmers was ₦25,806,399.9, and the variable cost incurred was ₦25,001,724.81 which represented most (96.88%) of the total production cost. The cost of feed contributed 88.51% to the total production cost. The fixed cost of production was ₦804,675.15 and this contributed 3.12% to the total cost of production. The gross margin and net farm income were ₦5,771,437.10 and ₦4,966,761.94, respectively. The positive gross margin and net farm income imply that this is a profitable enterprise in the area. The profitability measures (Profitability Index, Rate of Return on investment and Return on Variable Cost) showed that poultry production in the area is profitable. The Profitability Index showed that for every naira earned as revenue, ₦0.86 returned to the producers as net income. In other words, 86% of the total revenue earned constituted the net income. This implies that an appreciable profit level can be made from the enterprise. The rate of return on investment (RRI) in this study was estimated to be 19.25%, implying that for every one naira spent or invested in layer production by farmers in the study area, the farmers earned on average 19.25% profit.

Table 2: Mean Cost and Return Structure of Layer Production

Variable	**Quantity**	**Cost/unit**	**Value (₦)**	**% Total Cost**
Revenue				
Eggs produced/season	30,216.26	909.76	27,489,426.19	
Cracked eggs sold/season	803.24	357.72	287,336.37	
Layers disposed	2,336.62	1,251.22	2,923,621.89	
Fecal waste per season	209.93	346.67	72,777.45	

Total Revenue			**30,773,161.91**	
Variable Cost				
Labor cost	82	10,645.19	873,944.21	3.39
Cost of feed	7,922.26	2,883.05	22,840,257.25	88.51
Electricity cost	38.02	3,769.51	143,327.09	0.56
Fuel	37.11	9,397.45	348,781.73	1.35
Stock/DOC	2,533.83	178.83	453,115.52	1.76
Veterinary cost	2,533.83	130.70	331,159.16	1.28
Labor for waste management			11,139.85	0.04
Total variable cost			**25,001,724.81**	**96.88**
Fixed cost				
Depreciation on Fixed inputs			636,770.51	2.47
Feeding bag	660.63	247.24	163,332.16	0.63
Cost of waste sacks			4,572.48	0.02
Total fixed cost			804,675.15	3.12
Total cost			**25,806,399.96**	**100.00**
GM			5,771,437.10	
NFI			4,966,761.94	
PI			0.86	
RRI			19.25	
Return on Variable Cost			0.23	

3.3. Contribution of Fecal Waste to Profitability

The result for testing the hypothesis of whether fecal waste contributes significantly to profitability or not is shown in Table 3. The null hypothesis was tested using a paired student t-test. The result of the hypothesis test showed that the probability of the test statistics of the profitability measures (0.314, 0.157 and 0.843) was higher than the critical probability value of 0.05, leading to a non-rejection of the null hypothesis. This result implies that fecal waste generation has no significant contribution to the profitability index and rate of return on investment of the farmers. This might be because the amount of revenue generated from layer waste is small compared to that generated from eggs, cracked eggs, and culled layers.

Table 3: Result of Test of Hypothesis

Null hypothesis	Profitability measures	Fecal	Non-fecal	Mean difference	p-value	decision
There is no significant contribution of fecal waste to profitability	PI	0.86	0.86	0.00	0.314	Fail to reject null
	RRI	19.25	18.96	0.29	0.157	Fail to reject null

3.4. Profit Efficiency of Layer Farmers

The result of the Maximum Likelihood Estimates (MLE) of the parameters of the Translog profit efficiency and inefficiency model of the layer farmers is presented in Tables 4 and 5, respectively. The variance parameters, sigma-square and gamma were estimated at 0.142 ($p< 0.01$) and 0.928 ($p<0.01$), respectively. The sigma-square attests to the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma indicates the systematic influences that are unexplained by the profit function and the dominant sources of random errors. This implies that about 92.8% of the variation in profit is due to the differences in their inefficiency. The parameter estimates of the translog functional form of the stochastic frontier suggest that cost of feed ($p<0.01$), cost of bird/stock ($p<0.05$) and depreciation on fixed assets ($p<0.01$) negatively influenced the profit of the farmers while veterinary cost ($p<0.01$) and labor cost for fecal waste management ($p<0.01$) had a positive influence on profit of layer farmers.

The coefficient of feed showed that a 1% increase in the cost of feed would reduce the profit by 18.25%. This is so because feed is a vital input in poultry production and about 70-80% of the production cost was expended on feed, any attempt to raise the cost of feed will result in to decrease in the profit of the farmers. The coefficient of stock showed that a 1% increase in the cost of birds would reduce the profit by 9.44%. Increasing the cost of layer birds will reduce the profit of the farmers. The coefficient of veterinary cost showed that a 1% increase in the cost of veterinary services would increase the profit by 8%. This is so because as veterinary cost increases so do the layer birds become healthier thereby resulting in higher output which will invariably increase the profit level of the farmers. The coefficient of cost of labor for fecal waste management showed that a 1% increase in the cost of fecal waste management would increase the profit of the farmers by 1.17%. The coefficient of depreciation on fixed assets showed that a 1% increase in the cost of depreciation of fixed assets would reduce the profit by 9.36%. This is so because fixed assets like cages, pens, and buildings are vital in poultry production and any attempt to increase their cost will have a negative impact on the profit level of the farmers.

Table 4: Maximum Likelihood Estimates of Profit Efficiency Model

Variable	**Coefficient**	**Standard Error**	**z-value**	**P-value**
Feed	-18.251***	4.516	-4.040	0.000
Stock	-9.435**	4.402	-2.140	0.032
Labor	3.307	3.295	1.000	0.316
Veterinary	8.002***	2.582	3.100	0.002
Labor*Waste	1.174***	0.372	3.150	0.002
Bag*Waste	-0.571	1.791	-0.320	0.750
Depreciation on Fixed Assets	-9.362***	1.456	-6.430	0.000
Feed*Feed	-1.953***	0.128	-15.280	0.000
Stock*Stock	-1.800	5.563	-0.320	0.746
Labor*Labor	-0.210	0.614	-0.340	0.732
Veterinary*Veterinary	0.987	0.700	1.410	0.159
$(Labor*Waste)^2$	-0.202	0.168	-1.200	0.231
$(Bag*Waste)^2$	0.058	0.198	0.290	0.771
$(Depreciation\ on\ Fixed\ Assets)^2$	-1.802*	0.992	-1.820	0.069
Feed*Stock	6.892***	1.731	3.980	0.000
Feed*Labor	-1.316	1.339	-0.980	0.326
Feed*Veterinary	5.545	.	.	.
Feed*Labor*Waste	0.072	0.767	0.090	0.925
Feed*Bag*Waste	0.483	1.067	0.450	0.651
Feed*Depreciation on Fixed Assets	13.536***	1.069	12.660	0.000

Stock*Labor	-0.116	1.009	-0.110	0.909
Stock*Veterinary	-13.123***	1.954	-6.720	0.000
Stock*Labor*Waste	-1.076	1.318	-0.820	0.414
Stock*Bag*Waste	0.001	0.001	0.790	0.428
Stock*Depreciation on Fixed Assets	-13.491	.	.	.
Labor*Veterinary	2.144	1.749	1.230	0.220
$Labor^2$*waste	0.433**	0.218	1.990	0.046
Labor*Bag*Waste	-0.482	0.501	-0.960	0.335
Labor*Depreciation on Fixed Assets	-0.836	0.522	-1.600	0.109
Veterinary*Labor*Waste	0.055	0.574	0.100	0.923
Veterinary*Bag*Waste	-0.095	1.159	-0.080	0.934
Veterinary* Dep. on Fixed Assets	2.155***	0.803	2.680	0.007
Labor*Waste*Bag*Waste	0.011	0.101	0.110	0.910
Labor*Waste*Dep. On Fixed Asset	0.434	0.306	1.420	0.156
$Sigma^2$	0.142	0.018		
Gamma	0.928	0.024		
Log likelihood	30.816			

****, ** and * means significant at 1%, 5% and 10% respectively.*

3.5. Determinants of Profit Inefficiency of Poultry Farmers

The result of the determinants of profit inefficiency is presented in Table 5. The result showed that age ($p<0.1$) and cooperative membership ($p<0.01$) positively influence profit inefficiency while education ($p<0.01$) and household size ($p<0.05$) negatively influence profit inefficiency. The coefficient of age revealed that an increase in age increases profit inefficiency. This implies that older farmers are more profit inefficient compared to their younger counterparts. This may be because as age increases so does the ability to be more productive reduces thereby making farmers less profit efficient. The coefficient of education showed that as the number of years spent in school increases the profit inefficiency of the farmers reduces. This is so because education exposes the farmers to innovative ways of raising their birds at reduced cost thereby reducing their profit inefficiency. The coefficient of household size showed that an increase in the size of the household reduces the profit inefficiency of the farmers. This might be because most of the layer farmers engaged their household members on their farms to save costs expended on labor, this will invariably increase their profit level. The coefficient of cooperative membership suggests that the profit inefficiency of the farmers that are members of cooperative society increases than their counterparts that are non-members of cooperative society. This might be because those that belonged to cooperative societies did not receive adequate training and financial support from their association.

Table 5: Estimates of Determinants of Profit Inefficiency

Variable	**Coefficient**	**Standard Error**	**z-value**	**P-value**
Constant	0.377***	0.104	3.630	0.000
Age	0.003*	0.002	1.680	0.096
Education	-0.088***	0.022	-3.910	0.000
Farming experience	-0.005	0.005	-1.050	0.294
Household size	-0.019**	0.008	-2.450	0.016
Cooperative membership	0.149***	0.035	4.210	0.000

IV. CONCLUSION AND RECOMMENDATION

From the analysis, poultry production is profitable with a high potential for farmers to make more profit than the current average farmers if inputs are more efficiently used. The following recommendations are suggested:

- Farmers are advised to invest in their education as this is shown to have a significant negative effect on their profit inefficiency.
- Poultry farmers are advised to creatively manage the factors of production that significantly affect their profitability such as veterinary costs, cost of birds, cost of labor for fecal waste management and depreciation to improve the performance of their farm.

If these recommendations are adequately followed, there will be a boost to poultry production in the study area as well as an increase in the income of layer farmers. In addition, a sub-enterprise will be created from fecal waste which has great untapped potential, while production goes on in an environmentally sustainable manner.

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Effectiveness of some biological control agents and agricultural practices in controlling pea leaf blight caused by *Ascochyta* spp. under field conditions

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Abstract**—** *Ascochyta blight is one of the most common diseases that threaten pea and cause severe crop losses. The research is concerned with the integrated control of this disease by studying the effect of biological control agents with inorganic salts, planting dates and planting distances, especially in light of climate change and the impact of these factors on the spread of the disease. In this study, two bacterial strains Bacillus megaterium and Pseudomonas fluorescens as biocontrol agents; potassium carbonate and sodium carbonate were evaluated with the effect of planting dates, where the first date was at the beginning of October, and the second date was at the beginning of November. Also the distance between the irrigation lines (0.75 and 1.5 meter) in two successive seasons 2020/2021 and 2021/2022 under the conditions of the Dakhla Oasis, the New Valley Governorate. The best results were with the first date of planting and a planting distance of 1.5 meters, which led to a significant reduction of disease severity, with a significant increase in traits associated with vegetative growth. Also, treatment with Pseudomonas fluorescens led to an increase in vegetative growth and plant height compared to treatment with Bacillus megaterium. By studying the interaction between planting dates with biocontrol agents, it led to a significant decrease in disease incidence and severity, with a significant increase in vegetative growth. Also, there was no significant effect with interaction between planting dates and planting distances, while it had a significant effect on the incidence and severity of infection. Bacterial isolates used in this study with mineral salts contributed to increasing plant growth rates and reducing ascochyta blight infection rates. Further studies can be conducted to include these treatments within the integrated control programs for Ascochyta blight on pea.*

Keywords**— field pea; biological control; Bacillus megaterium; Pseudomonas fluorescens; potassium carbonate; sodium carbonate**

I. INTRODUCTION

Field pea (*Pisum sativum* L.) is an annual, cool-season legume native to northwest to southwest Asia. It was among the first crops cultivated. Pea is a winter season vegetable crop. Master B. is an old cultivar has been cultivated for more than 23 years ago in Egypt because of its superior features. Otherwise, this cv. has decline in its certain good attributes, many reasons are behind this decline some this reasons is wrong agricultural practices) Elsadek, *et al.*, 2017). Pea are affected by many fungal diseases, the most important group of these diseases are leaf spots. Ascochyta blight disease is one of the most important diseases affecting field pea. The disease occurs in almost all pea-growing regions of the world and can cause significant crop losses when conditions are favorable for an epidemic (Bretag, *et al.*, 2006). The extent and severity of disease depend on the cropping system and weather conditions. The most favorable conditions for the

pathogen are frequent rainfall, high relative humidity, and leaf wetness duration (Roger *et al.*, 1999, Tivoli and Banniza, 2007). Ascochyta blight is a destructive disease in many field peas (*Pisum sativum* L.) growing regions and it causes significant losses in grain yield. It caused by a complex of fungal pathogens, it is commonly referred to the Ascochyta complex, including *Ascochyta pinodes* L.K. Jones (teleomorph: *Mycosphaerella pinodes*; Berk and Blox, Vestergr.), *Phoma medicaginis* var. *pinodella* (Jones) Morgan-Jones and K. B. Burch, *Ascochyta pisi* Lib.(teleomorph: *Didymellapisi* sp.nov.) and *Phoma koolunga* (Davidson *et al.*, 2009; Liu *et al.*, 2013; Liu *et al.*, 2016). This blight complex causes range of different symptoms, including, Ascochyta blight, foot rot, black stem, leaf and pod spot. Seed quality may also be reduced through seed discoloration or retardation of seed development. *A. pinodes* can infect seedlings and all aerial parts of pea plants, causing necrotic leaf spots, stem lesions, shrink age and dark-brown discoloration of seeds, blackening the base of the stem, and foot rot in seedlings. The mycelia of *A. pinodes* can penetrate pea leaves across the stomas, and formed specific penetration structures (Liu *et al.*, 2016). The disease symptoms caused by *P. pinodella* are similar to those observed with *A. pinodes*. However, *P. pinodella* infection can result in more severe foot rot symptoms that can extend below ground, while causing less damage to the leaves, stems and pods. *A. pisi* causes slightly sunken, circular, tan-colored lesions with dark brown margins that occur on the leaves, pods, and stems (Chilvers *et al.*, 2009). Ascochyta blight accelerates the maturity of affected pea crops, the plants lose water in stems, leaves, accelerate seed desiccation, reduce seed weight, disturbs nutrient metabolism and reduces photosynthetic potential of plants (Garry *et al.*, 1998). The severity of disease can differ due to the temperature and duration of leaf wetness. Even a low level of infection can cause significant losses in both production and quality (Kraft and Pfleger, 2001). Usually fungicides are used to control Ascochyta blight, seedling blight, and root rots. Treating seeds with fungicides is one time application, it's activity is too short-lived to protect the plants throughout the growing season. Multiple fungicide applications are often required to manage foliar diseases. However, each application results need additional expenses, carries risks to the environment, and repeated applications may lead to reduced fungicide efficacy due to pathogen evolution, i.e. the development of genetic resistance to frequently applied fungicides (Jones and Ehret, 1976; Cook and Zhang, 1985). This requires the evaluation of safe alternatives in disease control, such as biological control to avoid environmental pollution and avoid adverse effects on public health. The key to achieving successful, reproducible biological control is gradual appreciation that knowledge of the ecological interactions in soil and root environments is required to predict the conditions under which biocontrol can be achieved (Deacon, 1994; Whipps, 1997a). Bennett *et al.*, 2019 showed that time of sowing had a greater impact on yield, emphasize the need for adopting biological methods for the control of plant diseases. Bacterial antagonists offer a promising alternative to existing chemical control practices and have great market potential for disease management. The use of bacterial antagonists as biofungicides for the control of various plant diseases has attracted considerable interest (Baker and Cook, 1982; Cook and Baker, 1983). Many bacteria, including *Bacillus subtilis* (Ehrenberg) Cohn, *B. megaterium* de Bary, and *Pseudomonas fluorescens* Migula, have been studied as biocontrol agents for plant pathogens of food legumes. Many researchers using inorganic salts carbonate and bicarbonate as alternative disease control strategies it is proved to be cost effective and eco-friendly for the management of many plant diseases due to the development of resistant fungal strains. Türkkan *et al.* (2017) reported that using carbonate and bicarbonate salts completely inhibited the mycelial growth of *Botrytis cinerea* under *in vitro* conditions. Carbonate and bicarbonate salts had the highest efficacy on powdery mildew of Tomato plants, (Bakeer, *et al.*, 2012). Sodium carbonate (SC), potassium carbonate, sodium bicarbonate (SBC), and potassium bicarbonate inhibit spores germination of *Penicillium digitatum* (causal agent of citrus green mold), and SC and SBC were equal and superior for control green mold on lemons and oranges (Smilanick *et al.*, 1999). In same trend (Ahmad *et al.*, 2019) revealed that inorganic salts sodium bicarbonate followed by potassium carbonate have shown significant inhibition to mycelial growth of *Alternaria solani* and proved to be cost effective and eco-friendly for the management *A. solani* in comparable with fungicides. Ascochyta ascospores are released into the air from infested residue at certain times of the year, depending on environmental conditions, sowing date, and row spacing of crops can be manipulated to avoid the maximum risk period when airborne ascospores are at their highest numbers (Bretag, 1991; Jacobson and Backman, 1993). Wide row spacing and low seeding rate reduced Ascochyta blight severity and increased seed yield per plant, also reduced plant population density could be effective factor in a program to manage Ascochyta blight of chickpea (Chang *et al.*, 2007). In addition, these methods were useful in combating several other diseases, for example, delaying in sowing date increasing the disease incidence of rust and powdery mildew on pea varieties, and early or late planting dates causing losses in seed yield (Sangar and

Singh, 1994; Singh and Singh, 2011). Early sown in the season caused minimum disease incidence while maximum disease severity was observed when the crop was sown late in the season (Kumar *et al.*, 2022). Plant density is an important agronomic factor that affects crop growth, development, and yield. The optimum plant density to attain the highest yield can vary with genotype, production and, environmental factors, also plant density is one of the most effective agronomic factors for determining optimum plant nutrient uptake (Asik *et al.*, 2020).

The objectives of this current study were to investigate the use of two strains of *Bacillus megaterium*, *Pseudomonas fluorescens* antagonistic bacterial agents for disease control, and effects of Potassium carbonate, Sodium carbonate as inorganic salts for disease management, as well as investigate effect of different practices such as the difference in sowing dates and row spacing on *Ascochyta* blight diseases control of pea as one of the new crops that were recently introduced in New Valley Governorate, and some diseases have appeared under these conditions, such as *Ascochyta* blight.

II. MATERIALS AND METHODS

Isolation, purification and identification of Ascochyta Blight-Associated Fungal Isolate

Infected pea plant tissues with typical ascochyta blight symptoms were collected from fields in Dakhla Oasis, The new valley governorate and from extension fields implemented by the agricultural clinic project for desert and reclaimed lands. Infected plant parts were cut into small pieces and surface sterilized in 70% ethanol with a 30s treatment followed by sodium hypochlorite with a 10 min, then washed for three times with sterile water. Sterilized samples were placed onto potato dextrose agar (PDA) plates (200g potato, 20g glucose, 15g agar, and 1L water) supplemented then incubated at 25°C for 4 days. After incubation, the culture were purified with single conidium and saved at 4°C for further Experiments.

Source of seeds, salts and bioagents

The source of pea cv. Master B was obtained from Horticulture Research Institute, Agricultural Research center, Egypt. The source of tested mineral was Al-Gomhoria Company for medicines and medical supplies, and bio agents were obtained from microbiology and soil fertilizing unit, Desert Research Center.

Agricultural Practices

Sowing Date (SD): Pea seeds were sown in two dates, First date on the first of October (SD1); Second date on the first of November (SD2). The planting was carried out at two Row spacing (RS), using GR irrigation lines; as 1.5 m between the two lines (RS1); 75 cm between the two lines (RS2).

Pea Foliage Sprayed with (FS): *Bacillus megaterium*, (B1); *Pseudomonas fluorescens* (B2); *Potassium carbonate* (Pc); *Sodium carbonate* (Sc) were used to evaluate their effects on ascochyta leaf blight. Bacterial culture grown on nutrient broth medium then incubated on 28°C±2 for 4 days and resuspended at a concentration. Bacterial isolate *P. fluorescens* was grown on King's medium B (KMB) broth (per liter, Proteose peptone 20g, Glycerol10 mL, K_2HPO_4 1.5g and $MgSO_4$ 1.5g). The flasks were placed on a rotary shaker to grow at 120 rpm for 60 hrs at 24±1°C. Plants were inoculated with 48h bacterial suspension diluted to give approximately 10^8 cfu/ml.

Experimental layout and growth of plants

The experiment was conducted at Dakhla Oasis, the New Valley Governorate during two successive seasons 2020-2021 and 2021-2022 to evaluate the efficacy of two biological control strains (*Bacillus megaterium* and *Pseudomonas fluorescens*), two mineral salts (potassium carbonate and sodium carbonate). Role of planting dates and spacing between irrigation lines in reducing disease incidence and severity of natural infection of Ascochyta blight, and improving pea productivity. Experiment was conducted in 3 replications, each replicate is 6 m long, (each meter has 3 drippers, and each replicate has 18 drippers. The treatments were on the first two true leave stage, and repeated every 10 days until the beginning of flowering stage. All other agriculture practices were used as recommended.

Data recorded:

Disease incidence and severity; Ten plants per plot were randomly taken for evaluation of the following traits:

Disease severity, was assessed visually on a 0–9 scale, where: 0 = no infection, 1 = 1–9% of foliage area affected per plot, 2 =10–19%, 3 = 20–29%, 4 = 30–39%, 5 = 40–49%, 6 =50–59%, 7 = 60–69%, 8 =70–79% and 9 ≥ 80% of the foliage area affected per plot according to (Chang *et al.*, 2007). First assessment was done 10 days after treatment and the next at two weeks intervals. The severity of infection was estimated on 10 plants in each replicate, and the percentage of infection severity was calculated based on the formula:

Total (the number of plants in each degree of the scale × the degree of the scale) ÷ (the number of plants in which the estimate was taken×5). Diseases incidence recorded on the basis of number of infected plants in each treatment relative to the number of plants sown in each treatment.

Growth parameters

Total Fresh weight of plant, plant length, No. of branches per plant, No. of flowers per plant, No. of pods per plant, were recorded at the end of the season and the average results of the two seasons were analyzed.

Data analysis

Data were statistically analyzed by ANOVA, differences between treatment means were considered significant at P< 0.05. All values presented are the averages of each season.

III. RESULTS AND DISCUSSION

One of the reasons responsible for the low productivity of peas is fungal diseases that cause large annual losses in the grain yield; from the main disease that affected peas is Ascochyta blight which more commonly known as black spot disease, and it is distributed worldwide (Bretay *et al.,* 2006). The control of Ascochyta blight on pea is a complex process that is affected by many factors which related to environment, other are related to the host plant, and the pathogen. This study aims to reduce the disease incidence and severity under natural infection conditions by using treatments that do not have a polluting effect on the environment or plants.

Identification of fungal pathogen

The infection of ascochyta blight in field peas is a complex of different fungi including *Ascochyta pinodes*, *A. pisi* and *Phoma glomerata*. Sometimes these pathogens can occur together in one field and on one the same host plant (Liu *et al.,* 2016). While the *Ascochyta pisi* was the main pathogen infecting peas in the cultivation sites from which the fungi were isolated in this study, where symptoms of infection were included lightly sunken, circular, tan-coloured lesions with a dark brown margin on the leaves, pods, and stems (Chilvers *et al.* 2009). This fungus usually does not attack the base of pea plants or cause foot rot. Single spore fungal isolates were grown on pea agar medium (2% pea powder, 1.5% agar, w/w) for 15 days with a 16-h photoperiod under fluorescent light at 20±2 °C. Colony characteristics were assessed with a stereo microscope, and the shape and size of conidia were determined with a compound microscope *A. pisi*. The color of the spore masses was observed with a stereo microscope since the production of carrot-red spore masses is the principal characteristic according to (Jones *et al.,* 1927 and Dokken *et al.,* 2007).

Effect of bioagents and tested salts on Ascochyta blight and growth of peas

The results in Table (1) showed that effects of spraying treatments, planting dates and row spacing were significant, whether between treatments or treatments compared with control. Spraying with bacteria *B. megaterium* was the most efficient in reducing the incidence and severity of infection (20.83 %,12.92 %) in first season (46.67 %,30.08 %) in second season, whether from other treatments or control(50.50 %,45.67) for S1 and (72.00 %,66.5 %) for S2 then followed by *Pseudomonas fluorescens* and spraying with potassium carbonate. Spraying with sodium carbonate was the least efficient than other treatments (36.42 %, 31.50 %) for S1 and (59.58 %, 56.17 %) for S2 in reducing incidence and severity of infection, but it was still more efficient than control. The difference was significant between the treatments and treatments compared with control in terms of the effect on growth parameters, as the spraying with bacteria *P. fluorescens* had the highest effect on fresh weight (69.6g), plant length (74.5cm), on other hand *B. megaterium* had the highest effect on other growth parameters, whether number of leaves (22.8), number of pods (35) and number of branches (3.1) per plant, followed by bacteria and potassium carbonate. Hence, the use of sodium carbonate was the least effective among the treatments. The results also showed that the planting date and row spacing had significant effects on the incidence and severity of infection, as well as on the growth parameters of (fresh weight, plant length, and number of leaves, pods and branches). Where the incidence and severity were lower in the case of the first planting date first of October and RS1 with long row space 1.5 m than the second planting date (first of November) and RS2 the (short row space 75cm) in each season. So the fresh weight, plant height, number of leaves, number of pods, and number of plant branches were significantly affected by the sowing dates and row spacing. These results in the same line with Bretag *et al.* (1995) where reported that, infection level with ascochyta differed from year to year and region to region depending on local climatic conditions. El-Mohamedy *et al.* (2013) indicated that, using biological control agents is an active and non-toxic approach to decrease crop loss initiated by plant pathogens. *Bacillus megaterium* was reduced severity of *septoria tritici* blotch (STB) of wheat caused by the fungal pathogen *Mycosphaerella graminicola* by combination of different mechanisms (Kildea, *et al.,* 2008). Ganeshan and Manoj (2005) reported that *Pseudomonas fluorescens* are known to enhance plant growth promotion and reduce severity of various diseases, and induced systemic resistance. Chang *et al. (*2007) found that wide row spacing reduced ascochyta blight severity and increased seed yield per plant. Bennett *et al.* (2019) revealed that

sowing date had a greater impact on growth parameters than repeated application of fungicide.

Table (1): Effect of foliar spraying with bio-agents, mineral salts, sowing dates and Row spacing on Ascochyta blight and growth parameters of peas (average of combined data over 2020/2021 and 2021/2022 seasons) of pea

Traits / Treatments	DI		DS		Fresh weigh t (g)	Plant lengt h (cm)	Leaf No.	Pod No.	Branch es No.
	S1	S2	S1	S2					
B1	20.8	46. 7	12.9	30.8	69.6	74.5	22.8	35	3.1
B2	24.6	52	18.4	37.8	64	68.7	18.8	28.3	2.7
PC	31.1	54	26. 7	50	63.3	65	17.8	24.9	2.1
SC	36.4	59.6	31.5	56.2	63. 7	53.3	15.8	20.8	1.7
C	50.5	72	45. 7	66.5	44.8	38.2	14.2	13.5	1.6
LSD at 0.05	1.9	2.8	2.4	1.6	0.98	1.3	1.5	0.7	0.4
SD1	24.1	51.6	18.5	46.3	62.9	61.9	18.9	26.2	2.4
SD2	41.3	62. 7	35.6	49.9	59.2	57.9	16.8	22.8	2.3
LSD at 0.05	1.2	0.8	1.8	0. 8	0.7	0.7	0.5	0.5	0.2
RS1	28.4	51.9	22.9	44.8	62.6	61.3	18.8	25.8	2.4
RS2	36.9	61.7	31.2	51.4	59.5	58.5	16.7	23.2	2.7
LSD 0.05	1.2	0.9	1.8	0.9	0.6	0.4	0.4	0.5	0.3

- DI, disease incidence ; DS, disease severity; S1, season 2020/2021; S2, season 2021/2022.
- B1, *B. megaterium;* B2, *Pseudomonas ;* PC, potassium carbonate; SC, sodium carbonate; C, control.
- SD1, first of October; SD2, first Of November; RS1, row space 1.5m; RS2, row space 75 cm.

Effect of interaction between foliar spraying and sowing dates on Ascochyta blight and growth of peas

The results in Table (2) revealed that, the effect of interaction between foliar spraying (FS) and sowing date (SD) on the total vegetative growth, diseases incidence and diseases severity were reduced significantly, in comparing with control. The first sowing date in the (first of October) showed the lowest in the percentage of incidence and severity of infection during the two seasons. Plant lengths, fresh weight, number of leaves, number of pods and branches per plant, at the same time are higher in SD1 than SD2 (first of November). FS with B1in SD1 recorded lowest percent of DI (11%) and DS (5.17%) in S1 and gave superior number from leaf (24.5), No. of pod (37.0) and No. of branches (3.3). These obtained data in the same trend with Singh and Singh (2011) they revealed that early sowing dates resulted in poor seed yield and delayed sowing dates resulted in poor seed yield and quality.

Effect of interaction between foliar spraying and row spacing on Ascochyta blight and growth of peas

Data in table (3) showed significant effect in interaction between foliar spraying (FS) and row spacing (RS) on DI, DS, plant length, and leaf number while data recorded for fresh weight, pod numbers, and branches numbers were not significant. Percentage of DI and DS were lower in RS1 in the two seasons with all FS treatments, otherwise percentage of DI and DS were higher in RS2. FS with B1 gave the highest effect in suppressing DI (16.7%), DS (8.8%) in case of RS1 followed by B2, PC, and SC gave the lowest effect DI (32.8%), DS (26%) in comparison with control DI (48%), DS (40%) in season 1. Also in RS1 Foliar spraying with B2 gave good effect on fresh weight (70.5g) and plant length (75.3cm) comparing with control which gave fresh weight (46g) and plant length (40cm). Lowest growth parameters date were recorded in control treatment in RS2 which average was (43.5g, 36.4cm, 12.8, 12.5and 1.33) for fresh weight, plant length, No. of leaves, No. of pods, and No. of branches respectively. Decreasing in disease incidence and severity in large row spacing may be due to dispersal of Ascochyta conidia which may be more effective via narrow row spacing than wide rows, also when plants are grouped more tightly together in a row than if they are widely spaced. Second, air movement within a dense canopy is reduced, thus maintaining a more humid microclimate that

supports blight development (Burdon and Chilvers 1982; Boudreau and Mundt 1997). Jaccoud-Filho *et al.* (2016) reported that, reduced row spacing increase severity of *Sclerotinia sclerotiorum* in soybean, while increase row spacing decreased disease severity.

Table (2): Interaction between foliar spraying and sowing dates on Ascochyta blight incidence, severity and some growth parameters of pea (average of combined data over 2020/2021 and 2021/2022 seasons)

Treatments		DI		DS		Fresh weight (g)	Plant length (cm)	Leaf NO.	Pod No.	Branches No.
		S1	S2	S1	S2					
B1	SD1	11	41.3	5.7	28	66.5	70.8	24.5	37	3.3
	SD2	30.7	52	20.7	32.2	61.5	66.6	21	33	3
B2	SD1	16	48.3	10.3	36.8	72.2	75.8	20.2	31.2	3.2
	SD2	33.2	55.7	26.5	38.7	67.1	73.2	17.4	25.5	2.2
PC	SD1	19.7	48.5	16.7	49	65	67.5	17.7	25.3	2.2
	SD2	42.5	59.5	37.7	51	61.5	62.5	16.5	24.5	22
SC	SD1	27.7	52	20.3	54.8	64.2	565	16.7	22.5	1.7
	SD2	45.2	67.7	42.7	57.5	63.2	50.6	15	19.2	1.7
C	SD1	46.2	68	40.3	63	47	39.6	15.8	15	1.8
	SD2	54.8	76	51	70	42.5	36.9	12.5	12	1.3
LSD 0.05		2.7	1.8	3.9	1.8	1.6	1.6	1.2	1.1	0.5

- DI, disease incidence ; DS, disease severity; S1, season 2020/2021; S2, season 2021/2022; FS, foliar spray; SD, sowing date.
- B1 *B. megaterium* , B2 *Pseudomonas* , PC potassium carbonate, SC sodium carbonate, C control.
- SD1, first of October; SD2, first of November.

Table (3): Effect of interaction between foliar spraying and row spacing on Ascochyta blight incidence, severity and growth of pea (average of combined data over 2020/2021and2021/2022 seasons).

Treatments		DI		DS		Fresh weight (g)	Plant length (cm)	Leaf No.	Pod No.	Branches No.
		S1	S2	S1	S2					
B1	RS1	16.7	40.8	8.8	25	66	69.7	24.2	36	3.3
	RS2	25	52.5	17	35.2	62	67.8	21.3	34	2.8
B2	RS1	18.5	46	16.8	33.3	70.5	75.5	19.7	29.5	2.8
	RS2	30.7	58	20	42.2	68.8	73.8	17.9	27.2	2.5
PC	RS1	26	48	22.8	47.2	65	66.5	17.6	26.8	2.2
	RS2	36.2	60	30.5	52.8	61.5	63.5	16.6	23	2
SC	RS1	32.8	56	26	55	65.5	55.3	17	22.2	1.7
	RS2	40	63.2	37	57.4	61.8	51.3	14.7	19.5	1.7
C	RS1	48	69	40	63.5	46	40	15.5	14.5	1.8
	RS2	53	75	51.3	69.5	43.5	36.4	12.8	12.5	1.3
LSD 0.05		2.6	1.9	3.9	2.1	NS	0.8	0.9	NS	Ns

- DI, disease incidence ; DS, disease severity ; S1, season 2020/2021; S2, season 2021/2022.
- B1, *B. megaterium ;* B2, *Pseudomonas ;* PC, potassium carbonate; SC, sodium carbonate; C control.
- RS1, row space 1.5m; RS2, row space 75 cm.

Effect of interaction between Row spacing and sowing dates on Ascochyta blight and growth of peas

Data in table (4) revealed that (RS)×(SD) significantly effected on DI, DS, and fresh weight while there were no significant differences between data recorded for plant length, leaf, pod, and branches numbers. The good suppressing for percentage of DI and DS were recorded in SD1 with both RS1 (18.8% DI, 15.87 DS) and RS2 (29.4%DI, 21.1%DS) for S1. On the other hand good fresh weight were obtained in SD1 with both RS1 and RS2 (64.8g and 61.1g) respectively. These data in line with Migawer and Bakeer (2003), they reported that interaction between sowing date × plant spacing significantly effected on disease severity.

Table (4): Effect of interaction between row spacing and sowing dates on Ascochyta blight and growth of peas (average of combined data over 2020/2021and2021/2022 seasons)

Characters / Treatments		DI		DS		Fresh weight (g)	Plant length (cm)	Leaf No.	Pod No.	Branches No.
		S1	S2	S1	S2					
RS1	SD1	18.8	47.2	15.8	43.7	64.8	63.4	20	27.5	2.5
	SD2	38	56.7	29.9	45.9	60.4	59.3	17.9	24.1	2.2
RS2	SD1	29.4	56.7	21.7	49	61.1	60.5	17.5	24.9	2.3
	SD2	44.5	67.4	41.3	53.8	57.9	56.6	15.4	21.6	1.9
LSD 0.05		1.6	1.2	2.5	1.3	0.8	NS	NS	NS	Ns

- DI, Disease incidence; DS, disease severity; S1, season 2020/2021; S2, season 2021/2022.
- B1, *B. megaterium;* B2, *Pseudomonas;* PC, potassium carbonate; SC, sodium carbonate; C, control.
- SD1, first of October; SD2, first Of November; RS1, row space 1.5m; RS2, row space 75 cm.

Effect of interaction between foliar spraying, sowing date and row spacing on Ascochyta blight and growth of peas

Data in table (5) clarified that the interaction between (FS)×(SD)×(RS) gave significant effect in suppressing both DI, DS and increased the average of fresh weight in the two seasons, otherwise the interaction increased plant length, leaf number, pod number, and branches number than control treatment but without significant deference. The good result in suppressing percentage of DI, DS comes out when spraying pea plants with B1 in SD1 on RS1 (6% DI& 2.7%DS for S1) followed by spraying with B2 (8.7% DI& 8.3%DS for S1) also B2 increased average of fresh weight (73g, 68g) (71.3g, 66.2g) and plant length (76.7cm, 73,8cm) (75cm, 72.5cm) in both (SD1, SD2) RS1, and (SD1, SD2) RS2, respectively. Data recorded in SD1 were superior for all FS whether RS1and RS2.The lowest data were recorded with control treatment in SD2 in both seasons and RS1 and RS2.

Table (5): Interaction between foliar spraying, sowing date and row spacing on Ascochyta blight incidence and growth of peas (growth parameters of pea (average of combined data over 2020/2021 and 2021/2022 seasons)

Treatments		DI				DS				Fresh weight (g)		Plant length(cm)		Leaf No.		Pod No.		Branches No.	
		S1		S2		S1		S2											
		RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2	RS1	RS2
B1	SD1	6	16	36	46.7	2.7	7.7	24	32	69	64	72.17	69.5	26	23	38	36	3.3	3
	SD2	27.3	34	45.7	58.3	15	26.3	26	38.3	63	60	67.2	66	22.3	19.7	34	32	3.3	2.7
B	SD1	8.7	23.3	44	52.7	8.3	12.3	32.7	41	73	71.3	76.7	75	21	19.3	32	30.3	3.3	3

2	SD2	28.3	38	48	63.3	25.3	27.7	34	43.3	68	66.7	73.8	72.5	18.3	16.5	27	24	2.3	2
PC	SD1	12	27.3	44	53	15.7	16.7	46	52	68	62	69	66	18.2	17.2	27.7	23	2.3	2
	SD2	40	45	52	67	30	44.3	48.3	53.7	62	61	64	61	170	16	26	23	2	2
SC	SD1	23.3	32	48	56	18	22.7	53.7	56	66	62.3	58	54	18	15.3	24	21	1.7	1.7
	SD2	42.3	48	64	70.3	34	51.3	56.3	58.7	65	61.3	52.5	48.5	16	14	20.3	18	1.7	1.7
C	SD1	44	48.3	64	72	34.7	46	62	64	48	46	41	38	17	14.7	16	14	2	1.7
	SD2	52	57.7	74	78	45.3	56.7	65	75	44	41	39	34.8	14	11	13	11	1.7	1
LSD 0.05		3.7		2.7		5.6		2.9		1.8		NS		NS		NS		NS	

- DI, disease incidence; DS, disease severity ; S1, season 2020/2021; S2, season 2021/2022; FS, foliar spray; SD, sowing date.
- B1, B. megaterium ; B2, Pseudomonas; PC, potassium carbonate; SC, sodium carbonate; C, control.
- SD1, first of October; SD2, first Of November; RS1, row space 1.5m; RS2, row space 75 cm.
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IV. CONCLUSION

Data obtained from this research indicated that, the use of biological control strains and mineral salts as a foliar spray had a significant effect in reduction of incidence and severity of Ascochyta blight natural infection and improving vegetative growth, with significant differences between treatments also between treatments and control. The effect of *Bacillus* strain was most effective isolate in reducing incidence and severity of infection followed by *Pseudomonas* strain, then potassium carbonate, and sodium carbonate had the least effect on infection. Bacterial isolates used in the study with mineral salts also contributed to increasing plant growth rates and reducing ascochyta blight infection rates. Further studies can be conducted to include these treatments within the integrated control programs for ascochyta blight on pea.

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Evaluation of heat stress tolerance in wheat (*Triticum aestivum* L.) genotypes using stress tolerance indices in the western region of Nepal

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***Abstract*— *Heat stress is the major constraint for wheat production causing significant drops in the yield and potential productivity making it difficult to achieve the target yield by 2030, increasing food insecurity in Nepal. The main aim of the study is to help plant breeders to select appropriate heat stress-tolerant indices for increasing wheat yield by coping with the major problem of heat stress. The experiment holds the study for three years at the Institute of Agriculture and Animal Science (IAAS), Paklihawa campus. The experimental trial was of alpha-lattice design with 5 blocks and 4 plots. There were in total of 2 replications each of 20 genotypes. MP (Mean Productivity) had the highest strong correlation with the stress tolerance indices followed by STI (Stress Tolerance Index) for all three years, whereas YSI (Yield Stability Index) had the lowest tolerance index with a negative correlation for the years 2019 and 2021. The selection of MP and STI is encouraged for the production of heat-stress-tolerant varieties for high-yielding with tolerance.*

Keywords*— *Genotype, heat stress, tolerant, wheat.

I. INTRODUCTION

Wheat is the most important food crop in the world and Nepal in terms of both area coverage and productivity. As of 2021, wheat is grown on 708,000 hectares which produced 218,500 metric tons in Nepal which represents an almost six-fold increase in yield from the same amount of land since 1960. Asia is the largest import region, followed by Africa, South America, Central America, and Europe (M. R. Poudel et al., 2020). But wheat in Nepal still faces consequences of climate change, in the form of extreme weather events like increasing temperatures, and erratic rainfall patterns, which threatens to reduce wheat yield by 30% by 2030.

Heat stress is a key abiotic stress affecting crop and cereal production in all regions of Nepal. The ability of wheat to adapt to a wide range of ecological conditions has made it one of the most important crops worldwide, but heat stress has severe negative effects on yield, especially when associated with other stress factors.

Crop output around the world will be severely hampered by global climate change (Bishwas et al., 2021). An increase in the Earth's near-surface temperatures is one of the most critical aspects of global climate change (P. B. Poudel et al., 2021a). This rise in temperature is frequently linked to rising levels of carbon dioxide (CO_2) and other heat-trapping greenhouse gases including methane, nitrous oxide, ozone, and water vapor in the atmosphere. At the current rate of greenhouse gas emissions, atmospheric CO2 levels are expected to double by the end of the century, raising surface temperatures by 1.8–5.8°C (Farooq et al., 2011). Cereals are the primary source of our diet. Heat and drought stress have a substantial impact on their output (Wasaya et al., 2021). Climate change will have a huge impact on the yield of essential food crops like wheat in different parts of the world (Hossain, A. et al., 2012).

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops, belonging to the Poaceae family (M. R. Poudel et al., 2020). It is a strategic crop that plays an important role in the economies of developing countries (Yassin et al., 2019). Wheat (*Triticum aestivum* L.) cultivation dates back to 10000 years ago, when the hunter-gatherer society transitioned to agriculture. Wheat is a major human food crop that ranks among the world's top three cereal bowls due to its versatility, nutritional content, and high yield potential (Reynolds et al., 2007). 35 developed cultivars, 540 landraces, and 10 wild cousins exist in Nepal (Bishwas et al., 2021). It feeds about 35 percent of the world's population in more than 40 nations, including Nepal, and supplies over 20% of calories and protein for human nutrition (Al-Naggar et al., 2020). Wheat is planted on 754243 hectares in Nepal, accounting for 20.13 percent of total cereal production and yielding 2.29 tons per hectare (P. B. Poudel et al., 2020). Arid and semiarid regions are home to the majority of wheat-growing areas (Rahman & Riad, 2020). Due to its importance as a staple crop in many nations, durum wheat accounts for more than half of the total wheat-growing area in the Mediterranean region (El-Rawy & Hassan, 2014). The durum grain is used to make a variety of foods, including bread, couscous, freekeh, bulgur, and, most notably, pasta (Mehmood et al., 2020). Pasta is widely acknowledged as a healthy addition to a well-balanced diet, and consumer demand is reflected in rising pasta production (Guzmán et al., 2016). In 2014, the global wheat trade recorded 153.0 million tons, while wheat use was 711.7 million tonnes. Asia is the biggest import region, followed by Africa, South America, Central America and Europe (M. R. Poudel et al., 2020).

Wheat's growth and development are governed by specific abiotic and biotic needs. Temperature is a crucial abiotic element that influences crop growth and development (Li et al., 2011). Heat stress, however, is a severe threat to agricultural output around the world due to high ambient temperatures (El-Esawi et al., 2019). The worldwide mean ambient temperature is expected to rise by 6 degrees Celsius by the end of the twenty-first century. Wheat is extremely susceptible to heat stress. It was estimated that a 1°C increase in temperature would result in a 6% decrease in global wheat yield (P. B. Poudel et al., 2021b). Drought (water stress) and heat stress (increases in above-optimal air temperatures) sometimes occur together, but their impact on wheat's physiological, biological, and biochemical processes can be vastly different. Grain filling time, photosynthetic ability, and pace of assimilating translocation are all affected by high temperatures (Hossain et al., 2017). Drought is the most common abiotic stress that impacts wheat production, lowering grain yields by roughly 30%. (H.R. Balouchi, 2010). Furthermore, both genetic and environmental factors have a direct impact on wheat quality (El Gataa et al., 2021). Drought stress influences the quantity of seeds per spike and kernel weight, two critical components of grain yield, during flowering and grain filling (H.R. Balouchi, 2010). Such heat occurrences can diminish both grain number and individual size, lowering yield (Farooq et al., 2011). For example, yield losses of 15% were related to every day above 30°C during or around flowering in a correlation study based on data from over 600 field experiments in southern Australia (Shirdelmoghanloo et al., 2016).

High temperatures and drought stress at the same time shorten the grain-filling period, especially in dry land and rain-fed farming areas (Prasad & Staggenborg, 2008). Wheat breeders' key difficulty in these places is selecting genotypes that can endure heat stress and water scarcity conditions at the same time (Tahmasebi et al., n.d). Breeders frequently utilize indirect selection and use well-correlated qualities with grain yield to improve grain output in dry conditions since grain yield is a complicated trait influenced by many genes (Bashyal et al., 2021). Plant height, days to heading, days to maturity, spike length, number of spikelets per spike, number of grains per spike, thousand kernel weight, grain yield per spike, grain yield, biological yield, and harvest index are some of the yield traits that breeders have used to assess drought stress on wheat plants (Hossain, A. et al., 2012). Due to changes in various edaphic and climatic conditions, several high-yielding cultivars that were previously recommended are now losing their yield capacity (P. B. Poudel et al., 2020). Despite the fact that drought and heat stress have been widely researched separately, little is known about how they interact to effect agricultural output (Telfer et al., 2018). The few studies that looked at the combined impacts of drought and heat stress found that the combination of drought and heat stress had a much more negative impact on crop growth and productivity than when each stress was applied separately (Mkhabela et al., 2019). Furthermore, it was discovered that the combination of drought and heat stress alters physiological processes like as photosynthesis, lipid accumulation, and transcript expression (Prasad & Staggenborg, 2008). The negative effects of temperature could be reduced by altering planting time to an optimal date and employing various genetic techniques to generate crop plants with enhanced thermo-tolerance (Taheri et al., 2011). However, a detailed understanding of plant physiological reactions to high

temperatures, heat tolerance mechanisms, and potential solutions for enhancing crop thermo- resistance is required for this. This study was carried out to discover heat-tolerant and susceptible wheat types for future breeding initiatives in this environment (Ahmed & Fayyaz-Ul-Hassan, 2015).

II. MATERIALS AND METHODS

2.1 Experimental material, design, site, and entries of genotypes

20 entries of wheat genotypes as given in Table 1 were grown at the agronomy field of IAAS, Paklihawa (27.4809414 °N, 83.4468789 ° E) in Bhairahawa of Rupandehi district. Rupandehi is a major wheat production district of Nepal with suitable weather conditions, favorable monsoons, and enough irrigation availability. National Wheat Research Program (NWRP) is also located in Bhairahawa, Rupandehi, promoting research on wheat. The experimental site area is depicted in Figure 1, which is prepared via ArcGIS software.

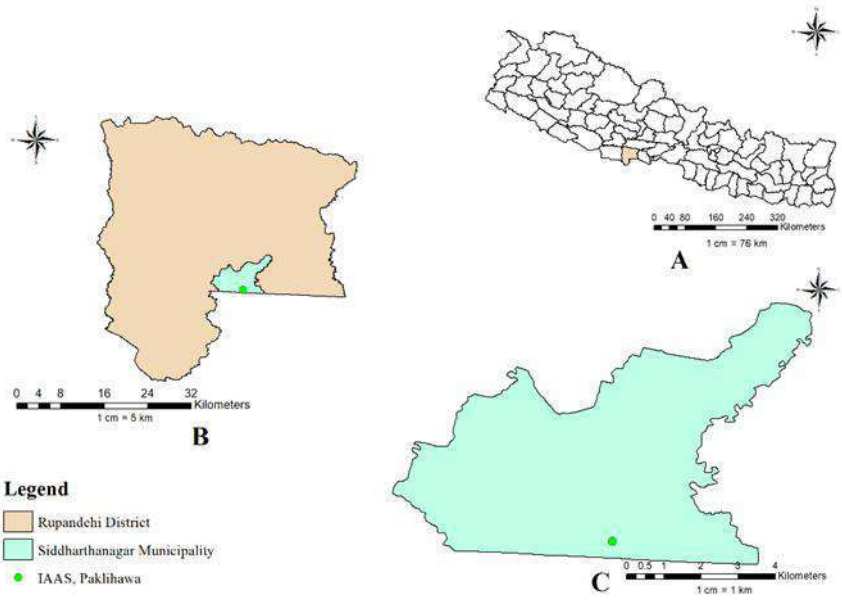

Fig.1. A. Map of Nepal showing Rupandehi district in pink color B. Map of Rupandehi district showing Siddharthanagar municipality in blue color C. Map of Siddharthanagar municipality with a green dot representing IAAS, Paklihawa

Table 1: List of wheat genotypes grown in the experimental plots along with their origin.

S.N.	Name of wheat genotypes	Origin
1.	Gautam	Nepal
2.	BL 4669	Nepal
3.	NL 1412	CIMMYT, Mexico
4.	BL 4407	Nepal
5.	NL 1368	CIMMYT, Mexico
6.	NL 1417	CIMMYT, Mexico
7.	Bhirkuti	CIMMYT, Mexico
8.	BL 4919	Nepal
9.	NL 1376	CIMMYT, Mexico
10.	NL 1179	CIMMYT, Mexico
11.	NL 1350	CIMMYT, Mexico
12.	NL 1387	CIMMYT, Mexico
13.	NL 1350	CIMMYT, Mexico
14.	NL 1420	CIMMYT, Mexico
15.	NL 1384	CIMMYT, Mexico
16.	NL 1346	CIMMYT, Mexico

17.	NL 1404	CIMMYT, Mexico
18.	NL 1413	CIMMYT, Mexico
19.	NL 1386	CIMMYT, Mexico
20.	NL 1381	CIMMYT, Mexico

Each entry was sown in 26th December, 2021 on a plot surface of 10 m2 per genotype. A single plot consisted of 10 rows at a spacing of 25 cm where the seeds were sown following continuous sowing method. Recommended dose of 50:50:20 kg NPK/ ha fertilizer was applied as basal application. Weeds were controlled manually. This same arrangement was followed in adjacent field to implement the irrigated condition. Irrigation was provided via pipes.

The experiment was conducted on alpha lattice design with two replications as shown in Figure 2. The replications were separated at a distance of 1m. 4 plots were arranged in a single block, resulting in 5 blocks per replication.

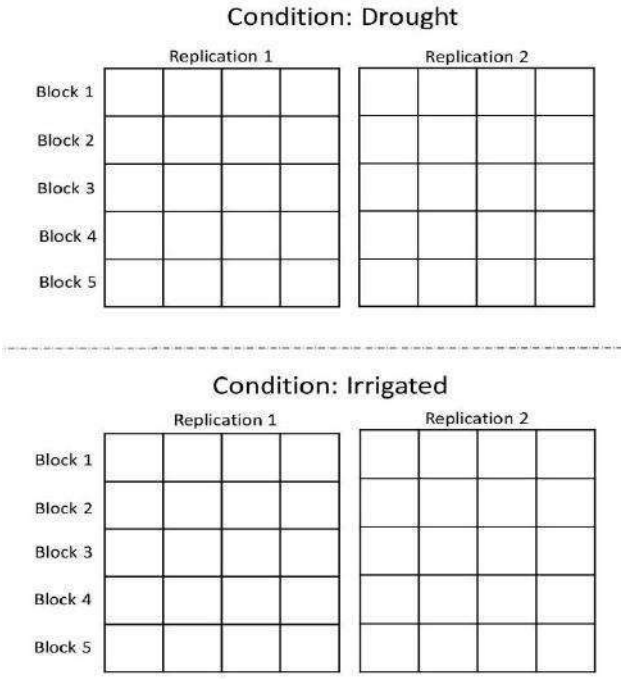

Fig.2: Experimental layout of the plots under drought and irrigated conditions

2.2 Traits analyzed

Ten sample plants were selected randomly from each plot to collect data. Grain yield and Yield attributing traits like Plant height (PH), Spike length (SL), Spike weight (SW), Spike per m² area (S/m²), Number of grains per spike (NGPS), Number of spikelets per spike (NSPS), and 1000 kernels weight or Test weight were noted.

2.3. Statistical analysis

Data entry and processing was conducted through Microsoft Office Excel 2016. The entered data were analyzed via IBM SPSS Statistics 25 Version 25 to compute Pearson's correlation among variables at 5 and 1% levels of significance. Path coefficient analysis was performed using Microsoft Office Excel 2016.

The stress tolerance indices were calculated by the following relationships:

1. Tolerance Index (TOL)TOL = Yp – Ys (Ramirez-Vallejo et. al., 1998)
2. Stress Susceptibility Index (SSI) = $\frac{1-(Y_S/Y_P)}{1-(\bar{Y}S/\bar{Y}P)}$ (Hossain et.al., 1990)
3. Yield Stability Index (YSI)YSI = Ys/Yp (Fischer et.al., 1978)
4. Mean Productivity (MP)= $\frac{(Yp+Ys)}{2}$ (Bouslama et.al., 1984)
5. Geometric Mean Productivity (GMP) = $\sqrt{Yp+Ys}$ (Khan et.al., 2014)
6. Stress Tolerance Index (STI) = $\frac{Yp \times Ys}{Yp2}$ (Khan et.al., 2014)

Where, Yp and Ys are the grain yield of genotypes under normal and heat stress conditions respectively. Whereas, *Yp* and *Ys* are mean yield of all genotypes under normal and heat stress conditions respectively. The grain yield was measured in term of kilogram per hectare.

The experimental data were processed using Microsoft Excel 2010 and analysis of variance was conducted using ADEL-R (Analysis and design of experiments with R for Windows) developed by CIMMYT, Mexico. Stat Graphics software was used to perform correlation, principal component and biplot analysis**.**

III. RESULT AND DISCUSSION

3.1. Correlation among Yp, Ys, and stress tolerance indices:

Correlation analysis showed low, positive, and insignificant relations between grain yields under normal and stress conditions i.e. 0.331 and 0.199 in 2018 and 2021 respectively.(Khan and Kabir 2015), (Puri et al., 2020) and (Nouri et al. 2011) also reported the same result. Thus, it is not accurate to select heat-tolerant genotypes on the basis of

their performance in normal conditions. In 2021, Yp and Ys showed positive and highly significant relationships with each other (1.000). It implies that the selection of heat-tolerant genotypes on basis of their performance under normal conditions is applicable. TOL positively associated with Yp in 2018 while it has a positive and highly significant association with Yp in 2019 and 2021. While TOL has a negative association with Ys in the years 2018 and 2021. Similar results were reported by (Tahir et al., 2022).It was in accordance with results reported by (Puri and Gautam 2015). (Nouri et al. 2011) suggested that a lower value of TOL is favorable for the selection of high-yielding genotypes under stress conditions.

YSI has a positive and highly significant relation with grain yield under stress conditions in 2018. Furthermore, YSI has a negative and highly significant association with Yp in 2019. In 2018 and 2021, SSI shows a negative association with grain yield under stress conditions in accordance with the result of (Puri et al. 2020). MP, GMP, and STI have possessed a positive correlation with grain yield at normal and stress conditions during all three years. These results are in conformity with those obtained by (Kamrani, Hoseini, and Ebadollahi 2018), (Sareen, Tyagi, and Sharma 2012) and (Puri and Gautam 2015).Hence, MP,GMP and STI should be considered while selecting the high yield potential genotypes under both normal and stress condition.

Table 1: Correlation coefficient between grain yield of wheat genotypes and heat stress indices under normal and heat stress conditions in 2018

Correlations-2018

	Yp	Ys	TOL	YSI	SSI	MP	GMP	STI
Yp	1	0.331	0.295	0.008	-0.008	.711**	.552*	.584**
Ys	0.331	1	-.804**	.945**	-.945**	.899**	.965**	.958**
TOL	0.295	-.804**	1	-.952**	.952**	-.463*	-.629**	-.602**
YSI	0.008	.945**	-.952**	1	-1.000**	.708**	.831**	.810**
SSI	-0.008	-.945**	.952**	-1.000**	1	-.708**	-.831**	-.810**
MP	.711**	.899**	-.463*	.708**	-.708**	1	.975**	.985**
GMP	.552*	.965**	-.629**	.831**	-.831**	.975**	1	.994**
STI	.584**	.958**	-.602**	.810**	-.810**	.985**	.994**	1

Table 2: Correlation coefficient between grain yield of wheat genotypes and heat stress indices under normal and heat stress conditions in 2019

Correlations- 2019

	Yp	Ys	TOL	YSI	SSI	MP	GMP	STI
Yp	1	1.000**	1.000**	-.987**	.987**	1.000**	1.000**	.998**
Ys	1.000**	1	1.000**	-.987**	.987**	1.000**	1.000**	.998**
TOL	1.000**	1.000**	1	-.987**	.987**	1.000**	1.000**	.998**
YSI	-.987**	-.987**	-.987**	1	-1.000**	-.987**	-.988**	-.976**
SSI	.987**	.987**	.987**	-1.000**	1	.987**	.988**	.976**
MP	1.000**	1.000**	1.000**	-.987**	.987**	1	1.000**	.998**
GMP	1.000**	1.000**	1.000**	-.988**	.988**	1.000**	1	.998**
STI	.998**	.998**	.998**	-.976**	.976**	.998**	.998**	1

Table 3. Correlation coefficient between grain yield of wheat genotypes and heat stress indices under normal and heat stress conditions in 2021

Correlation 2021

	Yp	Ys	TOL	YSI	SSI	MP	GMP	STI
Yp	1	0.199	.847**	-.723**	.723**	.894**	.836**	.854**
Ys	0.199	1	-0.352	.522*	-.522*	.616**	.703**	.678**
TOL	.847**	-0.352	1	-.974**	.974**	.520*	0.417	.448*
YSI	-.723**	.522*	-.974**	1	-1.000**	-0.343	-0.234	-0.266
SSI	.723**	-.522*	.974**	-1.000**	1	0.343	0.234	0.266
MP	.894**	.616**	.520*	-0.343	0.343	1	.993**	.996**
GMP	.836**	.703**	0.417	-0.234	0.234	.993**	1	.998**
STI	.854**	.678**	.448*	-0.266	0.266	.996**	.998**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

IV. CONCLUSION

Under the observation of three years data of stress tolerance, MP seems to have the highest strong correlation with the Yp and Ys followed by STI in all those years accordingly. Therefore, these indices are found suitable for selection of high yielding genotypes under both conditions. It can be recommended that for future research, these results could contribute to the development of varieties with better heat tolerance. It is clear that wider genetic diversity should be explored if greater heat stress resilience is to be achieved in wheat breeding programmes to cultivate in the heat prone areas of Nepal.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Correlation analysis of maize (Zea mays L.) genotypes: A review

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Abstract— *In many regions of world, maize is one of the most significant crops grown for staple foods. To increase the effectiveness of breeding programs using the right selection indices, it is very important to be aware of the correlations between grain yield and its numerous causal (contributory) components. This article presents the results of many studies that were carried out to ascertain the nature of relationships between grain yield and its contributing factors and to pinpoint those factors with significant effects on yield with the goal of using them as selection criteria by using path coefficient analysis (PCA). The direct and indirect impacts of cause factors on effect variables are displayed through path analysis. This approach divides the components of the correlation coefficient between two traits into those that assess the direct and indirect effects. Plant height, number of kernels per row, ear per pant, ear height, leaf width, days to 50% silking, tasseling, ear diameter, ear length, thousand kernel weight, days to physiological maturity, tassel length, and ear weight may have significant (or non-significant) influence on grain yield, either positively or negatively. The present review of different studies might be useful to the breeders to select the potential parental materials for maize improvement program in Nepal as well as region with similar geographical topography.*

Keywords— ***Breeding, correlation coefficient, maize, yield***

I. INTRODUCTION

Maize is a popular grain crop farmed all over the world (Food, 2020). It has a very high yield potential than any other cereals and thus is popularly known as the 'queen of cereals' (Magar et al., 2018). After wheat and rice, it is the third most important cereal (Vinay Kumar, 2011). It is a key staple food crop that provides a significant amount of raw materials for livestock and a variety of agro-allied industries around the world (Kandel et al., 2018). In terms of acreage and production, maize ranked second next to rice in Nepal (Abziew, 2016). However, because of its high production potential and supportive environment for cultivation in the country, it demands special attention. For decades, improved cultivars from the International Institute of Tropical Agriculture (IITA) and the International Maize and Wheat Improvement Center (CIMMYT) have been widely used in the country. However, producers and consumers do not appreciate or cultivate them, and they need be modified for critical agronomic qualities (Karki, 2013). A few features, particularly grain yield, need to be improved in promising populations established from some of the types (Yuan et al., 2019). The most efficient selection technique is determined by the correlations between attributes (Inamullah et al., 2011). Several researchers have undertaken correlation studies on maize (Karki, 2013). However, the outcome varies depending on the features, population, and location(Pariyar et al., 2018).

Maize is one of the most important staple food crops for mountain people in Nepal, and it may be used for both feed and fodder (Kandel and Shrestha, 2020). Knowledge

of the link between yield and yield component is essential for developing yield improvement programs (Khodarahmpour, 2012). Studies on the correlation coefficients of various characters are a valuable criterion for identifying desirable qualities that boost grain production in breeding programs (Dewey & Lu, 1959). As a result, correlations between yield and various yield components are an important consideration when developing a yield improvement program (Dewey & Lu, 1959). Correlations, in combination with path coefficient analysis, are a useful technique for determining the relationship between yield contributing features and grain yield, as well as quantifying the direct and indirect effects of these characters on grain yield (ElLakany & Russell, 1971). As a result, an attempt was made to establish the correlation coefficient along with path value for the association between grain yield and yield component of early maize genotype, demonstrating the magnitude of direct and indirect effect of various yield components on grain yield of early maize (Verhulst et al., 2012). Despite its high yield potential, maize production in Nepal is modest (Rijal et al., 2016). With rising industrial demand, maize production must increase at a considerably higher rate than it is now(Genotypes & Baitadi, 2016). Grain yield per unit area is heavily influenced by cultivars with favorable features(Ndhlela et al., 2014). It is critical to understand the relationships between different features, particularly grain yield, which is the most important end goal in any breeding program, in order to generate successful genotypes(Health & Pool-, 2018).

OBJECTIVES OF THE STUDY

i. To develop promising genotypes, for starters (Pariyar et al., 2018).

ii. To investigate the relationship between grain yield and yield attributing qualities, as well as to estimate the genetic components of grain yield and yield attributing traits(Open et al., 2019). The goal of this review was to see if there was a link between distinct quantitative features in maize and grain yield.

II. MATERIAL AND METHODOLOGY

The materials and methods for this review paper were gathered from a variety of sources, including research papers, journals, websites, articles, and books. All of the information presented in this review was previously discovered by other scholars. We also gathered information from their publications and journals to use in our maize genotype correlation research in Nepal.

III. DISCUSSIONS

Analysis of Variance and Mean performance

For all of the features tested, the analysis of variance revealed extremely significant differences between genotypes, showing that the experimental materials were genetically distinct. This demonstrates that there is enough room among the available genotypes to pick promising lines for improving maize genetic yield potential (Mustafa, H.SB. Ahsan, M . Aslam, M. Ali, Q. Hasan, E. Bibi, T. Mehmood, 2013). Significant results were observed among the tested genotypes for the traits grain yield ton ha-1, ear weight, number of kernel row-1, number of row kernel per ear, ear length, ear girth, plant height, ear height, days to 50% silking, days to 50% tasseling, and days to physiological maturity, indicating the presence of genotypic differences and the importance of their genetic value in order to identify the best genetic makeup for a particular condition (Bello et al., 2010).

Correlation

The correlation value indicates the type and extent of the relationship that exists between two characters. Correlation is also a metric that identifies features that should be considered in order to boost yield. The genetic link between the features could be the cause of trait correlation. The sort of relationship between grain yield and its component qualities is critical from the standpoint of the breeder (B. T. Magar et al., 2021). Higher genotypic correlations than phenotypic correlations revealed a higher genetic relationship between traits and yield, as well as lesser disparities between GCV and PCV for most traits, owing to a lower modifying effect of environment on character association (Vaezi et al., 2000). In most cases, the genotypic correlation was larger than the phenotypic correlation in all of the trials, showing a stronger degree of linkage among the features. As a result, phenotypic trait selection would be effective in producing genetic gain (Beulah et al., 2018).

Grain yield ton ha-1, plant height, ear height, 1000-kernel weight, days to physiological maturity, days to 50% silking, and days to 50% tasselling all had high estimates of genotypic and phenotypic variance, indicating the presence of sufficient inherent genetic variance over which selection can be effective. The phenotypic correlation coefficients between yield and yield components revealed that grain yield and related factors varied significantly across genotypes (Of et al., 2010).

Plant height, leaf breadth, and ear height

For all genotypes, the PH, EH, and leaf width indicated a highly significant difference (P0.05) (standard check). Plant height, ear height, and leaf breadth had no significant

link with grain yield ton ha-1, according to the phenotypic correlation of all genotypes (Ghimire et al., 2017).

Number of kernel row per ear, number of kernels per row and ear per plant

The number of kernel rows per ear, the quantity of kernels per row, and the ear per plant are all factors to consider. The number of kernel rows per plant, the number of kernels per row, and the ear per plant all showed that genotypes were highly significant (Amgai, 2021). The number of kernel rows per ear, number of kernels per row, and ear per plant all exhibited a non-significant link with grain yield ton per hectare, according to the phenotypic correlation of all genotypes. The number of kernel rows per ear and grain yield have a non-significant negative relationship, according to phenotypic correlation (Ghimire et al., 2015). The number of ears per plant was also shown to be positively and non-significantly associated to grain yield ton ha-1, confirming our findings (Raut et al., 2017).

Days to 50% silking, and Days to 50% tasseling

For days to 50% tasselling and days to 50% silking, the results demonstrated that genotypes were significantly significant. Days to 50% silking and days to 50% tasselling had no significant link with grain yield ton ha-1, according to the phenotypic correlation of all genotypes (Agbaje et al., 2000).

Tassel length, ear diameter, and ear length

For all genotypes, ear diameter, ear length, and tassel length are highly significant (P0.05). Grain yield ton ha-1 has previously been associated in a positive and highly significant way to ear diameter, ear length, ear weight, and tassel length (Barros et al., 2010).

Ear weight and thousand kernel weight

The results showed that there was no significant difference in TKW between genotypes (P0.05).

Ear diameter, ear length, thousand kernel weight, days to physiological maturity, tassel length, and ear weight had a substantial positive association with grain yield ton ha-1, according to phenotypic correlation of all genotypes (Pariyar et al., 2018). The strongest link to grain yield was ear diameter and thousand kernel weight, followed by number of kernels per row, ear length, days to physiological maturity, and ear height (Raut et al., 2017).

Days to physiological maturity

The days to physiological maturity were found to be statistically significant (P0.05). The grain production per hectare is positively influenced by thousand kernel weight and days to physiological maturity (Barros et al., 2010).

Several maize researchers have previously published similar conclusions on a range of subjects, including the relationship between grain yield and ear length, diameter, husk weight, 1000 grain weight, and days to physiological maturity (Dewey & Lu, 1959). Other studies have revealed no significant relationship between grain yield and ear height, number of kernels per row, or number of ears per plant, implying that selecting for higher levels of these traits may not result in a significant increase in grain yield (Abziew, 2016). Days to 50% silking and tasseling had a non-significant positive relationship with grain yield (Rajesh Singh & Kumar, 2017). High densities were often used to obtain correlations between yield components and yield components with yield that would be most valuable to maize breeders for prediction purposes (Figliuolo et al., 2007). Because the number of ears per plant was discovered to be the most important factor, the findings suggest that each plant should be stressed to the point of barrenness in order to establish the best relationship between yield components and yield (ElLakany & Russell, 1971). As the value of the ear aspect grew (i.e. the cob was more damaged), grain yields decreased (Tripathi et al., 2016). When looking at genetic correlations between different quantitative variables, it's critical to look at the material's genetic base as well as environmental impacts (Neupane et al., 2020).

IV. CONCLUSION

In conclusion, different studies about correlation analyses revealed that grain yield is mostly positively correlated with all variables, with the exception of the inverse relationships between the number of kernel rows per ear and the ear aspect. The results of the correlation analysis show that some characteristics can be picked while also being improved. For instance, a higher thousand seed weight could result in a higher grain output. An increase in the number of leaves per plant may result in an increase in ear height. Similar to how days to silking and tasseling can be selected and improved simultaneously when breeding for early maturity, ear height and plant height can be selected concurrently when breeding for small stature. The genotypes' total mean performance implies that there is a lot of variances in the germplasm that might be utilized in quality protein maize breeding to create acceptable hybrids and varieties. Because of its positive relationship with production, the large genetic increase seen for thousand seed weight indicated that there is potential for improving this trait and, and consequently, the yield.

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Bilimbi Fruit (*Averrhoa bilimbi*) Juice: Nutritional Analysis and Microbial Analysis

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Abstract— *Food's nutritional analysis guarantees that it contains the correct number of vitamins and minerals while also allowing for a better understanding of the food's fat, carbohydrate dilution, protein, fiber, sugar, etc. Identifying pathogens and food spoilage microorganisms is essential tofood microbiology because it ensures consumer safety, prevents brand desecration, and reducesthe cost of remediation after failed inspections or food poisoning outbreaks. This study's primary objective was to determine the nutritional content and identify the hazardous microbes in the Bilimbi Fruit (Averrhoa bilimbi) Juice. The study used an experimental methodology and underwent careful analysis to get detailed results regarding the product. To ascertain the product'snutritional value, samples of the three treatments—plain, grapes, and apple—were sent to theF.A.S.T. Laboratory. Analysis revealed that Bilimbi Fruit (Averrhoa bilimbi) Juice contains Vitamins and minerals that benefit consumers; it includes Crude Fiber, Calcium, Vitamin C, and phosphorus. The result is that each of the three treatments' nutritional contents of "Bilimbi Fruit Juice" is within the recommended dietary requirement for Filipinos. Microbial Analysis reveals nohazardous microbes and bacteria found in the products. Therefore, Bilimbi Fruit Juice is an organic and nutritional juice safe for consumption and an excellent alternative to existing fruit juiceon the market.*

Keywords— ***Natural resources, Nutritional Content, Microbial Analysis, malnutrition, and Food Security.***

I. INTRODUCTION

Everyone should have access to nutritious food that is both affordable and of high quality. People with mild food insecuritymust make trade-offs between the quantity and quality of food consumed because they are uncertain about their ability to obtainfood. According to Egal (2019), theprevalence of overweight and obesity is rising across the board, especially among school-age children and adults. This issue was widespread in the Philippines, which is backed by the claim made by Talukder et al.in 2010 that micronutrient malnutrition among mothers and children is a severepublic health issue in Bangladesh,Cambodia, Nepal, and the Philippines. The economic consequences of contaminated food are felt at different levels in society. At the individual and family level, illness caused by the consumption of unsafe food results inexpenditure on care, be it institutionalized health care or self-care. Income is lost because of illness—the consequence of foodborne illness--death is severe and results in significant socioeconomic and psychological trauma. It is mandatory in thePhilippines to label food products, whether locally manufactured or imported. Bilimbi Fruit Juice is an organic juice created with natural fruit and natural flavoring. In line with this Bilimbi Fruit Juice was subjected to nutritional analysis to distinguish the nutritional value of a product that conforms to the Recommended Dietary Allowance in the Philippines, and it is undergone to microbial

analysis to ensure that there are no hazardousmicrobes and bacteria present for safe consumption. This can be one of thesolutions to the existing problem, which is obesity and micronutrient deficiency in the Philippines and the global order.

Food According to a survey on organic food consumption conducted by Rakuten Insight on September 2021, 32 percent of respondents in the Philippinesstated that they sometimes bought organic food products. The same survey revealed that consumers tend to buy these products

because they are perceived to be healthier and more nutritious. Increased consumption of nutrient-dense beverages (100% fruit juice, milk) and water as part of a varied dietshould be encouraged.

Department of Health Administrative Order no. 2014-0030 known as Revised Rules and Regulations Governing the Labeling of Prepackaged Food Products Further Amending Certain Provisions of Administrative Order No. 88-B s. 1984 or The Rules and Regulations Governing the Labeling of Pre-packaged Food Products Distributed in the Philippines," and For Other Purposed stated: All nutrient quantities shallbe declared in relation to the average or usual serving in terms of slices, pieces or a specified weight or volume. The declaration of the nutrients can also be expressed eitherin units per serving or % RENI or both. Locallymanufactured food products intended for local consumption shall also indicate the corresponding Recommended Energy andNutrient Intake (RENI).

Department of Trade and Industry Bureau of Philippine Standards Republic ActNo. 7394 known as The Consumer Act of thePhilippines Article 2, states that It is the policy of the State to protect the interests of the consumer, promote his general welfare, and establish standards of conduct for business and industry. Towards this end, the state shall implement measures to achieve one objective mentioned is to protect against hazards to health and safety.

The ancient theory of nutrition datesback to the time of Aristotle and Galen. Theyconsidered nutrition as a vital part of health, disease, performance, and healing. The power in each part of the body is believed tobe dependent on the blood flowing to that part. The blood is formed by the nutrients absorbed from the consumed foods.

Objectives of the study

The primary purpose of this studywas to determine the nutritional content of Bilimbi fruit (*Averrhoa bilimbi*) juice in terms of crude fiber, calcium, Vitamin C, and phosphorous and identify hazardousmicrobe present in the product for safer consumption.

II. METHODOLOGY

The primary purpose of this studywas to ascertain the nutritive value and identify the microbes present in the product to assure that the Bilimbi Fruit (*Averrhoabilimbi*) Juice in three different treatments (i.e., plain, grapes, apple) was safe for consumption through microbial analysis.

The researcher sent a sample of 100ml of Bilimbi fruit Juice to F.A.S.T. Laboratoryfor analysis. The method used for nutritional analysis was Ankom Fiber Analysis, Flame AAS, Titrimetry, and Colorimetry. For microbial analysis E.coli, S. aureus Count (CFU/g), Yeast and Mold Count, (CFU/g), andSalmonella, in 25 grams. Those were the threats bacteria for processed food and beverages. The nutritional and microbial analysis were obtained by subjecting the samples to First Analytical Services and Technical Laboratory in Cebu City.

Nutritional Content

Serving size: 1L/230ml

Nutrients	T1 (Plain BilimbiFruit Juice)	T2(BilimbiFruit Juice Grapes Flavor)	T3 (BilimbiFruit Juice Apple Flavor)
Crude Fiber	4.51%	3.68%	4.70%
Calcium	50.5 mg/kg	25.6 mg/kg	35.6 mg/kg
Vitamin C	29.5 mg/L	30.6 mg/L	38.0 mg/L
Phosphorus	37.6 ppm	54.2 ppm	46.9 ppm

Results identified the following nutritive content of Bilimbi Fruit *(Averrhoa bilimbi)* Juice. The crude Fiber content of T1 is 4.51%, T2 is 3.68%, and T3 is 4.70 %.

T1 has the highest Crude Fiber content whileT2 has the lowest. Crude fiber is one type of dietary fiber, and an obsolete nutritional term for fiber, as mentioned by Recommended Dietary allowances, 10th edition, 2002. The recommended dietary fiber intake per day forages 16 to 49 is 20-25 grams, as Food and Nutrition Res recommends. Institute DOST,2015.

The Calcium content in T1 is 50.5 mg,T2 is 25.6 mg, and T3 is 35.6 mg. T1 had thehighest content of calcium, while T2 had theleast. Tanaka et al. The Philippine Journal ofScience provides information that a higher calcium intake is significantly associated with

a lower prevalence of the periodontal disease. Aside from its major role in skeletal function,calcium plays a regulatory role in a number of specialized functions in muscle contraction, neurotransmitter secretion,digestion, and blood coagulation. The Philippine Dietary Reference Intakes' (PDRI 2015) recommended daily nutrient intake (RNI) of calcium for 6 to less than 12-month infants is 400 mg, among 1-2-year-oldchildren 500 mg, among 3-5-year-old children 550 mg, among 6-9-year-old children 700 mg and 10-12-year-oldchildren 1000 mg (FNRI-DOST 2015).

The Vitamin C content of T1 is 29.5 mg, T2 is 30.6 mg, and T3 is 38 mg. T3 had the highest content of Vitamin C, while T1 had the least. The current recommendeddietary allowance (RDA) for vitamin C, as proposed by the Food and Nutrition Board/National Research Council in 1980and reconfirmed in 1989, is 60 mg daily. The 1989 recommendation for Filipinos was retained for the 2002 RENI based on a localstudy that determined intake levels that maintained "acceptable" serum vitamin C levels among Filipino men and women.

The Phosphorous content in T1 is

37.6 ppm, T2 is 54.2 ppm, and T3 is 46.9 ppm. T2 had the highest content of phosphorus, while T1 had the lowest. Phosphorus works with calcium to help buildbones. You need the right amount of both calcium and phosphorus for bone health.Phosphorus also plays an important structural role in nucleic acids and cell membranes. And it's involved in the body's energy production (Rogers, G.,2016). The Recommended Nutrient Intake per day of phosphorus for adults and children is 1250 mg (Food and Nutrition Res. Ins. DOST,2015.)

The data above signify that all the nutritional contents of "Bilimbi Fruit Juice Flavored Drinks" in the three treatments are within the recommended dietary allowance for Filipinos. Hence it is an excellent organicfruit juice substitute for an existing product inthe market.

Microbial Analysis

Analysis	***Result***	***TolerableLimit***
S.aureusCount	< 1 *Est* CFU/g	<20CFU/g
Yeast and Mold Count(CFU/g)	41 CFU/g	40-49 CFU/ml
Salmonella, in2g	Negative	Not Detected in25g
E. coli	< 1 *Est* /Negative	Not Detected in25g

Based on the analysis of First Analytical Service and Technical Cooperative Laboratories, Bilimbi Fruit Juicehad microbial loads on S. aureus Count of <1 *Est* CFU/g and Yeast and Mold Count of 41CFU/g and its tested negative for Salmonellaand E.coli bacteria.

S. Aureus test results indicated good microbiological quality because the < 1

*Est*CFU/g is lower than the permissible limit of <20CFU/g. S. aureus toxin does not normally reach levels that will cause food poisoning until the numbers of the pathogen reach 500,000 to 1,000,000 per gram.

Yeast and mold tests showcontamination with a count of 41 CFU/g.Robinson and Tamime (2002) explicitly reported that yeasts as spoilage organisms generally enter food products as contaminants from the air. FDA Guidelines state that the acceptable level of Yeast and molds in concentrated Juice is 40- 49 CFU/ml. The result of the microbial analysis is within the acceptable or in the borderline limit of microbiological quality of microorganisms determined by a specified method; the values are generally based on levels that are achievable under Good Manufacturing Practice (FDA Revised Guidelines for the Assessment of

Microbiological Quality of Processed foods,2013). Meanwhile, according to Hariyadi,2013 The control of Yeast and molds has to be placed along the productionline, starting from receiving fruit as the primary raw materials. Only appropriately mature and sound fruits produced with GoodAgricultural Practices can be used. Sorting must be done to remove damaged 35 and spoiled parts of fruits. Trimming out a rotten apple for making apple juice, for example, has reduced 90 percent of patulin.

E. coli and Salmonella yield negative results. According to de Louvois et al. 2000, it is the opinion of the ACFDP that ready-to-eat foods should be free from Salmonella spp, Campylobacter spp, and E. coli O157 and other Verocytotoxin-producing E. coli. The ACFDP believes that there is nojustification for processed ready-to-eat foodsbeing contaminated with these organismsand that their presence, even in small numbers, results in such foods being of unacceptable quality/potentially hazardous.

According to the specification of Gulfstandards, the higher counts, however, may not necessarily pose a hazard to consumers'health, provided that there are probably no potential pathogenic strains such as E. coli and Salmonella species within the fruit juicesto be consumed (Babiye, 2017). Hence, the microbial analysis result denotes that theBilimbi Fruit Juice laboratory results is withinthe permissible limit for human consumptionthat fulfilled the criteria safe for human consumption

III. FINDINGS

After a thorough and careful analysis and interpretation of the laboratory results, it can be deduced that Bilimbi Fruit Juice is packed with different nutrients, whichis beneficial for the consumer's health. It is rich in Vitamin C, which can help boost the immune system. The data above signify that all the nutritional contents of "Bilimbi Fruit Juice Flavored Drinks" in the threetreatments are within the recommended dietary allowance for Filipinos. Hence it is an excellent organic fruit juice substitute for an existing product in the market.

Results revealed no hazardous or harmful bacteria in Bilimbi Fruit Juice. The microbial analysis result denotes that the Bilimbi Fruit Juice laboratory results are within the permissible limit for human consumption thatfulfilled the criteria safe for human consumption

Hence, are no hazardous microbes andbacteria present in the product. Hence Bilimbi Fruit Juice is safe for human consumption.

IV. CONCLUSION

The result signifies that bilimbi fruit juice can be an alternative to organic fruit juice in the market. Moreover**,** no detected level of hazardous or harmful bacteria inBilimbi Fruit (Averrhoa bilimbi) Juice. It contains nutrients within the recommended dietary value, which are healthy and valuablefor human consumption. Hence, Bilimbi FruitJuice is a feasible nutritious juice to be produced for consumption.

RECOMMENDATIONS

1. The product must be subject to nutritional facts for future use.
2. The product will be introduced to the market as an alternativenutritious organic juice.
3. The researcher may pasteurizethe bilimbi fruit juice to eliminate the yeast and molds present for safe consumption and to improveits keeping quality.
4. The researcher may secure the intellectual property protection of the product by patenting its process and composition.

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Perception of Farmers on Climate Change and Adaptation Strategies Employed to Enhance Rice Production in Taraba State, Nigeria

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Abstract— *This study examined perception of farmers on climate change and adaptation strategies used to enhance rice production in Taraba State. Specifically, the study sought to determine the awareness level of rice farmers about climate change, perception of rice farmers regarding climate change and adaptation strategies used by the farmers in rice production in Taraba State. The study was guided by three research questions and three null hypotheses. The study employed survey research design. The population of the study was 608 rice farmers; using multi stage random sampling technique a sample size of 315 was selected and used for the study. Instrument used for data collection was a researchers' designed structured questionnaire. The instrument was face validated by 3 experts, a field trial of the instrument was done using 20 rice farmers in Mayo Belwa Local Government Area, Adamawa state; using Cronbach Alpha technique, a reliability coefficient of 0.82 was obtained. The researchers administered 315 questionnaire instruments but 300 were retrieved (95% return rate). The data generated were analyzed using mean and standard deviation to answer research questions while z-test was used to test the three null hypotheses at 0.05 levels of significance. Findings showed that the perception of farmers about climate change is positive, their level of awareness is high and multifarious adaptation strategies were used by rice farmers in Taraba State to combat the menace of climate change. The study concluded that the meteorological agency should keep on creating awareness for farmers. The study recommended among others, an up-to-date and continuous flow of information about climate change from government agencies to local farmers and vice versa for better use of current adaptive strategies to enhance rice production in Taraba State. Also, Farmers need supports regarding climate change which would help them to apply different mitigating measures against climate change for enhanced rice production in Taraba State.*

Keywords— ***Perception, Climate Change, Adaptation Strategies, Enhanced Rice Production***

I. INTRODUCTION

Agriculture is the major occupation of people in Taraba State, and this has been going on for years. Though, majority of the farmers are subsistence farmers and are making profits over the years. Bako (2013) reported that over 70% of Taraba population are into farming of different kinds both crops and animals, although majority of them are subsistent farmers but few that are into commercial farming are making maximum yields. The land is fertile and can easily be cultivated,

hence crops especially cereals, legumes, root and tuber yield maximally (Iwena, 2008 & Bako, 2013). But few years ago farmers have been facing different types of challenges ranging from high temperature, drought, fluctuating rainfall, floods, incidence of pest and diseases etc. (Mohammed, *et al* 2013). The challenges are severe and its effects to farmers are injurious and cannot be handled easily by the farmers.

Climate change is perhaps the greatest challenge facing our planet today. According to Adebayo and Oruonye (2003) some of these challenges manifest themselves in the form of drought, flooding, and low agricultural productivity, alteration of surface and ground water and devastation of eco-system among others. It has been observed by Intergovernmental Panel on Climate Change (IPCC) (2007) that Africa is one of the most vulnerable regions to the effect of global climate change due to her low human adaptability to anticipated increases in extreme events like drought, flood etc resulting from widespread poverty, illiteracy, heavy reliance on rain-fed agriculture, lack of economical and technological resources, insufficient safety nets and slow educational progress (Bako, 2013).

Climate change is a marked change in the long-term average of region weather. According to Bello (2013), the climate system is an open system and is in a steady state over a given period of time. If this steadily state is disturbed as a result of changes in one or more component making up the system or there are changes in the amount of solar radiation powering system, the climate will move over to a new state of equilibrium to produce a new climatic state. Bello further defined climate change as the long-term persistence of either positive or negative anomalies of a given or combination of climate events above or below the norm that characterizes climate change. Climate change is the statistics of weather over a long period of time.

Looking at the Nigerian situation where about $^{2}/_{3}$ of the population depend on rain-fed agriculture and fishing activities for their food and livelihood, the problems become worsened as a result of the high population pressures of 140 million people surviving on the physical environment through various activities within an area of 923,000 square kilometers (Nigerian Environmental Study Team) (NEST) (2004); (IPCC, 2007).

Several studies have shown that temperature is rising and rainfall frequency and intensity is fluctuating (Mendelsohn, *et al* 2000). The world temperature rise has been given as 0.91^{o}C, available meteorological data in the country shows evidence of increasing air temperature since about 1920s (NEST, 2003). Mohammed, *et al* (2003) observed that in Adamawa State of Nigeria climatic change data (temperature and rainfall) analysis over the past 25 years (1980 – 2005) showed that temperature has increased by 0.3^{o}C and rainfall fluctuated over the years (Adebayo, 2010; Audu, 2013).

In Taraba State, evidence of climate change include delayed onset date of rains, increase in number of dry days during the rainy season and increase in maximum temperature (Mohammed 2013, Audu 2013). This leads to warmer seasons, increased frequency and intensity of weather extreme events such as drought, decline in rainfall amount by about 15 – 20% increased incidence of dry spell (Adebayo 2012; Mohammed 2013). The problems of flood, high temperature, incidences of pests and diseases have also aggravated the farmers' losses which consequently increases the incidence of poverty and malnutrition in the state (Ifejika, Kiteme & Opondo, 2009; Adebayo, 2012). Perception and adaptation to climate change are two basic solutions to avoid the ill effects of climate change but with distinctly different responses. Farmers' attitudes towards these two general responses to climate change must be understood.

Adaptation to climate change involves changes in agricultural management practices in response to changes in climate conditions (International Meteorological Institute, 2014). To adapt to the climate change, farmers are required first to notice that climate has altered and then identify potential useful adaptation measures and implement them. To enhance policy towards tackling the challenges that climate poses to farmers, it is important to have knowledge of farmers' perception on climate change, potential adaptation strategies and factors affecting adaptation to climate change (Adebayo, 2012; Mohammed 2013).

Climate change adaptation refers to spontaneous or organized process through which human beings and societies adjust to change in climate thereby making changes in the systems of operation of land use or natural resources use and other forms of social and economic organization (Issa, *et al* 2015). Adapting to climate entails the right measures to reduce the negative effects of climate change (or exploit the positives uses) by making the appropriate adjustment and change (Gutu, Bezebih & Mengistu, 2012).

Many farmers in Nigeria are facing problem of extreme weather events such as floods, drought, pests and diseases, weeds insurgence, climate change as its affect health, ocean as well as global warming effects and causes biodiversity, carbon cycle, which are responsible for low farmers' productivity (Issa, *et al*, 2015). These challenges

called for adaptation to climate change or variability in order to maintain optimal level of production (International Food Policy Research Institute, 2009).

Climate change adaptation is a policy response to climate change that seeks to reduce the vulnerability of social and biological systems to climate change effects. Adaptation means anticipating the adverse effect of climate change and taking appropriate actions to prevent or minimize the damage it can cause, or taking advantage of opportunities that may arise. Adaptation has the potentials to reduce adverse impacts of climate change and to enhance beneficial impacts (Apata, Samuel & Adeola, 2009). Adaptation to climate change in agriculture production is the adjustment of farming activities or methods to suit the changes in climatic conditions in order to lessen the potential change that are caused. It involves changes in agricultural management practices in response to changes in climatic conditions.

Climate change challenge is a major issue affecting both male and female farmers over the world and these has reduced yield and increased disease and pest manifestation (Mohammed, 2013). Climate change causes low productivity in agriculture, the low productivity is aggravated due to poor implementation of agricultural policies and strategies. This poor implementation of policies has also caused many farmers not to be competent in climate change adaptation. To solve this problem and attain food security, International Food Policy Research Institute (2009) observed that farmers are making efforts to adapt to climate change in various ways such as planting tolerant varieties, altering planting schedules, planting early maturing varieties and crop diversification. This effort may be futile if the agricultural extension services system do not assist farmers to initiate more and effective strategies to cope with the changing climate. Most agricultural research on climate change has tended to focus on assessing the sensitivity of various attributes of crop systems without evaluating the role of the agents of change and crop adaptation strategies to changes in climate. Thus, this call for more attention in order to improve in adaptive strategy to the fast climate changing impacts on agriculture.

Taraba state government over the years has embarked on awareness campaign on the effects of climate change on farming activities through Ministry of Agriculture and Rural Development, and Media Houses; Radio, Television etc. And also encourages farmers to embark on plantation of trees and avoidance of harmful farming practices such as bush burning, indiscriminate felling of trees and extreme use of chemicals (Mohammed, 2013). Taraba state is an agrarian state with over 75 percent of its inhabitants depends on agriculture as their main source of livelihood. This makes them most prone to the effects of climate change and variability. Although climate change has begun to create havoc in the study area, there is paucity of research work that examines the pattern of climatic change and local awareness and knowledge of this problem. This knowledge gaps may greatly reduce the failures in measures to develop effective monitoring, adaptation and mitigation measures to climate change in the study area.

It has been observed that climate change and agriculture are both interrelated processes, as they take place on global scale (Parry, *et al* 2007), hence, increasing temperature of the earth (global warming) which is projected to have significant impacts on conditions affecting agriculture, including precipitation and glacing run-off (McCarthy, 2001). Recently food crises in countries such as Nigeria are reminders of the continuity in vulnerability of the region to the vicissitudes of climatic conditions (Apatu, 2009).

Over the years temperature is rising, flood is becoming frequent, drought is increasing and crop yield is decreasing (Nyanganji, 2012). Most farmers are not aware of the climate change, they rather attribute their losses to handy work of enemies who transformed into witches and wizards and attack their farms (Nyanganji, 2012). Some of the farmers also do not believe their harmful farming practices like bush burning, indiscriminate tree cuttings, and extreme use of chemicals are the causes of climate change. Majority of the farmers do not adhere to the strategies suggested by experts as adaptive measures to climate change (Apata, 2010, Bako, 2013). It was against this background that, this study examined the level of Farmers' awareness and their adaptation strategies to climate change and its implication to enhanced rice production in Taraba State.

II. PURPOSE OF THE STUDY

The main purpose of this study was to examine the perception of Farmers on climate change and adaptation strategies employed to enhance rice production in Taraba State.

Specifically, the study sought to determine:

1. awareness level of Rice Farmers about climate change in Taraba State.
2. perception of Rice Farmers regarding climate change in Taraba State.
3. adaptation strategies being used by the Farmers in Rice production in Taraba State.

Research Questions

a) What is the awareness level of rice farmers about climate change in Taraba State?

b) What is the perception of the rice farmers regarding climate change in Taraba State?

c) What are the adaptation strategies being used by farmers in rice production in Taraba State?

Hypotheses

I. There is no significant difference in the mean responses of Male and Female Farmers on their awareness level about climate change in Taraba State.

II. There is no significant difference in the mean response of Male and Female Farmers on their perception regarding climate change in Taraba State.

III. There is no significant difference in the mean responses of Male and Female Farmers on the adaptation strategies being used by the Farmers to mitigate climate change in Taraba State.

This study was based on Diffusion of Innovation (DOI) Theory, propounded by E. M. Rogers in 1962. The theory is one of the oldest social science theories. It originated in communication to explain how, overtime an idea or product gain momentum and diffuses (or spreads) through a specific population or social system. The end result of this diffusion is that people as part of a social system, adopt a new idea, behavior, or product. Adoption means that a person does something differently than what they had previously (i.e. purchased or used a new product, acquire and perform a new behavior etc). The key to adoption is that the person must perceive the idea, behavior or product as new or innovative. It is through this that diffusion is possible.

Adoption of a new idea, behavior, or product (i.e. "innovation") does not happen simultaneously in a social system rather it is a process whereby some people are more apt to adopt the innovation than others. Researchers have found that people who adopt an innovation early have different characteristics compared to people who adopt innovation later. When promoting an innovation to a target population, it is important to understand the characteristics of the target population that will help or hinder adoption of the innovation.

According to Diffusion of Innovation Theory, there are five established adopter categories, but majority of the general population tends to fall in the middle categories. These categories include:

1. Innovators: These are people who want to be the first to try the innovation. They are venturesome and interested in new ideas. These people are very willing to take risk and are often the first to develop new ideas. They need very little appeal to convince them adopt an innovation if anything.
2. Early Adopters: These individuals have the highest degree of opinions leadership among the adopter categories. They have a higher social status, financial liquidity, advanced education and are more socially forward than late adopters. They are more discrete in adoption choice than innovators. They use judicious choice of adoption to help them maintain a central communication position.
3. Early Majority: They adopt a innovation after a varying degree of time that is significantly longer than the innovators and early adopters. They have above average social status, contact with early adopters and seldom hold position of opinion leadership in a system.
4. Late Majority: They adopt an innovation after the average participants. These individuals approach an innovation with a high degree of skepticism and after the majority of society have adopted the innovation. Late majority are typically skeptical about an innovation, have below average social status, little financial liquidity, in contact with others in late majority and they have little opinions leadership.
5. The Laggards: They are the last to adopt an innovation. Unlike some of the previous categories, individuals in this category show little to no opinion leadership. These individuals typically have an aversion to change agent. Laggards typically tend to be focused on "traditions" lowest social status, lowest financial liquidity, oldest among adopters, and in contact with only family and closed friends.

This theory was adopted because it is talking about adoption of information and innovation of a new system. Hence, it is relevant to the study because the study is focused on the awareness, perception and *adaptation* to climate change.

III. METHODOLOGY

This study employed survey research design. The design is considered appropriate for this study because the study was carried out directly at the farmers' area; the questionnaires were distributed to them directly at their place of residence. The area of the study is Taraba State of Nigeria. Taraba state is located at the North East zone of Nigeria. It lies between Latitude 6º and 8º 00'0 00" North of the Equator and between Longitude 9º and 12º 30"0 00" East of the Greenwich Meridian. The state has a population of about 2.5 Million people (National Population Census (NPC), 2006). The state shares boundary with Bauchi and Gombe States in the North, Adamawa State in the east and the Cameroon Republic in the South. The major tribes of the people in the state includes Mumuye, Wurkum, Jukun, Hausa Fulani, Jenjo, Kuteb, Mambila, Kaka, Kona, and Ndola/Ichen among others. Their occupations include: crops farming, pastoral farming, commercial activities and public service.

About 75% of the populations are farmers while the other percent are into businesses and Civil Services. Interestingly, both male and female are into these farming enterprises. The state has a land area of 60,291 KM^2 (NPC, 2006). Taraba state has sixteen local government areas (LGAs) subdivided into three senatorial districts (Taraba North, Central and South). The researcher carried out the study in Taraba State because majority of the farmers cultivate rice and the land is fertile, virtually, all the farmers in the study area cultivate rice.

The population of this study was 608 Rice Farmers. 315 rice farmers were randomly selected from the farming communities in the study area. Majority of the people of Taraba State are farmers but mainly at subsistence level. The multi-stage sampling techniques were adopted for this study. The first stage involved the delimitation of the state in to zones. The second stage involves the selection of local government areas. The last stage involves the selection of farmers from the chosen settlements in the Local Government Areas (LGAs).

Three local governments each Senatorial district were purposively selected and these include: Zing, Karim-Lamido and Ardo-Kola LGAs (Taraba North); Bali, Gassol and Gashaka LGAs in (Taraba Central); and Wukari, Ibbi and Takum LGAs (Southern Taraba). A total of nine LGAs were sampled out of the sixteen LGAs of the state. In each LGA 35 questionnaires were administered to rice farmers; giving a total of 315 questionnaires that was administered. The instrument used for the collection was a five-point scale researchers' deigned structured questionnaire (instrument) having options categorized as: Very High Extent (VHE) = 5points, High Extent (HE) = 4 points, Medium Extent (ME) = 3 points, Low Extent (LE) = 2 points, and Very Low Extent (VLE) = 1 points respectively; administered to the sampled rice farmers in the study area. The instrument was titled "Climate Change Awareness and Adaptation Questionnaire" (CCAAQ). It has three parts: Part 1 which has 15 items (number 1 – 15), focused on the perception of the rice farmers on the effects of climate change on rice production; Part 2 which has number 18 items (number 16 – 33) focused on the awareness level of rice farmers about climate change; and Part 3 which has 19 items (number 34 – 52), focused on the adaptation strategies employed by rice farmers to mitigate climate change.

The instrument was validated by three (3) experts, two from the Department of Vocational Education and one from the Department of Crop Protection Faculty of Agriculture Modibbo Adama University of Technology Yola. The observations and suggestions made by the experts were integrated into the modified copy of the instrument. To establish the reliability of the instrument, field trial was carried out on 20 rice farmers (10 males and 10 females) in Mayo-Belwa of Adamawa State. The data generated were analyzed using Cronbach Alpha Technique which yielded a reliability index of 0.82. This is considered a highly reliable index for using the instrument to collect data for the study.

The researchers distributed 315 copies of the instrument to 185 male and 130 female rice farmers from the selected farming communities in the study area. After the retrieval of the questionnaire from the respondents, 15 copies (5 male and 10 female instruments) were missed out; 300 completed instruments were retrieved and returned from 120 female and 180 male rice farmers. These were used in analyzing data to generate results from the study. Means, standard deviation and z-test were used to analyze the data. Means and standard deviation were used to answer the research questions while z-test was used to the three null hypotheses at 0.05 levels of significance. Any mean value < 2.00 is Very Low Extent, 2.00 to 2.49 is Low Extent, 3.00 to 3.49 is Medium Extent, 3.5 to 4.49 is High Extent; and ≥ 4.5 is Very High Extent.

IV. RESULTS

Research Question 1: What is the awareness level of rice farmers about climate change in Taraba state?

Table 1: Awareness level of rice farmers about climate change in Taraba State

n = 300

S/n	Items/Statements	Mean	SD	Decision
1	Rice production is affected	3.80	1.07	HE
2	Affect date of plantation of the crop	3.62	1.11	HE
3	Temperature has increased	3.80	0.92	HE
4	Delayed crop maturity	3.90	0.88	HE
5	Affecting number of irrigations	3.85	0.97	HE
6	Rainfall has decreased	3.78	0.86	HE
7	Flood has become frequent	3.92	0.85	HE
8	Infestation of new weeds in the crop	3.86	0.93	HE
9	Affecting the control measures of insect pest	3.88	0.95	HE
10	More infestation with diseases	3.88	0.91	HE
11	Increase in crop pest population	3.81	1.06	HE
12	Crop quality affected	4.00	0.79	HE
13	Affect the net income from the crop	3.86	0.95	HE
14	Soil Nutrients decreased	3.83	1.01	HE
15	Sun intensity has increased	3.87	0.94	HE
16	Indiscriminate trees cutting	3.92	0.87	HE
17	Precipitation decreases	3.87	0.94	HE
18	Transpiration decreases	3.82	1.03	HE
	Grand Mean	**3.85**	**0.9**	**HE**

Table 1 shows that the awareness level of rice farmers about climate change in Taraba state is high and positive with grand mean of 3.85 and the means were close with SD 0.9

Research Question 2:

What is the perception of rice farmers regarding climate change in Taraba state?

Table 2: Perception of rice farmers regarding climate change in Taraba state

n = 300

S/n	Items/Statements	Mean	SD	Decision
1	How often have you heard of climate change	3.62	0.98	HE
2	Delay raining season setting	3.86	0.93	HE
3	There is increase in temperature over the years	3.79	0.89	HE
4	Indiscriminate felling of trees causes climate change	3.84	0.99	HE
5	More usage of chemicals also causes climate change	3.86	0.95	HE
6	There is general reduction of crop yield	3.84	0.98	HE
7	There is general reduction of water level	3.89	0.89	HE
8	Flooding is becoming frequent	3.93	0.87	HE
9	There is general reduction in the quality of Agricultural produce	3.96	0.82	HE
10	Farmers attribute climate change as work of enemies	3.86	0.95	HE

11	Farmers see bush burning as major causes of climate change	3.86	0.93	HE
12	Farmers often attribute increase flood to climate change	3.78	1.11	HE
13	Farmers hear about climate change through Radio	3.84	0.97	HE
14	Extension agents are the major sources of Information about climate change	3.94	0.81	HE
15	Improper usage of natural resources causes climate change	3.85	0.97	HE
	Grand Mean	**3.85**	**0.93**	**HE**

Table 2 shows that the level of perception of rice farmers regarding climate change in Taraba state is high and positive with a grand mean of 3.85 and the means were close with SD of 0.9.

Research Question 3:

What are the adaptation strategies being used farmers in rice production in Taraba state?

Table 3: Adaptation strategies being used by the farmers in rice production in Taraba **state**

n = 300

S/n	Items/Statement	Mean	SD	Decision
1	Use of resource conservation technologies	3.87	0.94	HE
2	Adopting the strategies of Nigeria metrological agencies	3.84	1.00	HE
3	Adopting irrigation methods	3.92	0.89	HE
4	By adopting soil moisture conservation methods	3.80	0.07	HE
5	Site specific nutrient management techniques	3.86	0.98	HE
6	By using short duration crop varieties	3.83	1.01	HE
7	By practicing integrated farming system	3.82	1.04	HE
8	By changing planting dates	3.84	1.00	HE
9	By changing the cropping pattern	3.82	1.03	HE
10	Land management practices	3.86	0.95	HE
11	By using insect pest management strategies	3.85	0.98	HE
12	Availing weather forecast service	3.89	0.89	HE
13	By stopping burning of crop residue	3.87	0.94	HE
14	By reducing tillage practices	3.92	0.88	HE
15	By reducing usage of chemical fertilizers	3.80	1.09	HE
16	By practicing crop diversification	3.86	0.96	HE
17	By controlling environmental pollution	3.84	0.99	HE
18	By trees plantation (afforestation)	3.62	0.90	HE
19	By educating farmers through Extension Agents	3.86	0.93	HE
	Grand Mean	**3.84**	**0.92**	**HE**

Table 3 shows that all respondents concur with all the mitigating strategies listed in the study as the adaptation strategies being used by the farmers in rice production in Taraba state with mean of 3.84 and SD of 0.9 revealed the closeness of their agreement to one another.

Testing Hypothesis

$H0_1$: There is no significant difference in the mean responses of male and female rice farmers on their awareness level about climate change in Taraba state

Table 4: Z-test of male and female rice farmers on their awareness level about climate change in Taraba State

	Variables	N	Mean	SD	SE	DF	t	Sig	Decision
PERCEPTION	MALES	180	56.16	7.12					
					1.26	298	1.76	0.08	Not Sig.
	FEMALES	120	57.71	7.96					

Table 4 revealed that there is no significant difference in the mean responses of male and female rice farmers on their awareness level about climate change in Taraba state with t = 1.76 (df 298); P = 0.08 since the computed p-value (0.08) is greater than 0.05 level of significance, the null hypothesis is upheld.

$H0_2$: There is no significant difference in the mean response of Male and Female rice Farmers on their perception regarding climate change in Taraba State

Table 5: Z-test of male and female rice farmers on the awareness level to climate change in Taraba state

	Variables	N	Mean	SD	SE	DF	t	Sig	Decision
AWARENESS LEVEL	MALES	180	73.99	8.46					
					1.36	298	1.76	0.08	Not Sig.
	FEMALES	120	75.70	7.98					

Table 5 revealed that there is no significant difference in the mean responses of male and female rice farmers on their perception regarding climate change in Taraba state with t = 1.76 (df 298); P = 0.08 since the computed p-value (0.08) is greater than 0.05 level of significance, the null hypothesis is upheld.

$H0_3$: There is no significant difference in mean responses of Male and Female rice Farmers on the adaptation strategies being used by them to mitigate climate change in Taraba State

Table 6: Z-test of male and female rice farmers on the adaptation strategies being used by the farmers to mitigate climate change in Taraba state

	Variables	N	Mean	SD	SE	DF	t	Sig	Decision
ADAPTATION STRATEGIES	MALES	180	73.43	7.45					
					1.28	298	0.75	0.45	Not Sig.
	FEMALES	120	75.75	7.88					

Table 6 revealed that there is no significant difference in the mean responses of Male and Female rice Farmers on the adaptation strategies being used by them to mitigate climate change in Taraba State with t = 0.75 (df 298); P = 0.45. Since the computed p-value (0.45) is greater than 0.05 level of significant, the null hypothesis is upheld.

V. FINDINGS OF THE STUDY

1. The awareness level of rice farmers about climate change in Taraba state is high
2. The perception of rice farmers regarding climate change in Taraba state is high and positive
3. The respondents concur with all the mitigating strategies listed in the study as the adaptation strategies being used by the farmers in rice production in Taraba state
4. There was no significant difference in the mean responses of male and female rice farmers on their awareness level about climate change in Taraba state
5. There was no significant difference in the mean responses of male and female rice farmers on their perception regarding climate change in Taraba state
6. There was no significant difference in the mean responses of Male and Female rice Farmers on the adaptation strategies being used by them to mitigate climate change in Taraba State

VI. DISCUSSION OF FINDINGS

The finding that awareness level of rice farmers about climate change in Taraba state is high and positive; and the corresponding hypothesis that there was no significant difference in the mean responses of male and female farmers on their awareness level about climate change in Taraba state indicates that the respondents have the similar opinions. This finding is corroborated by Ishaya and Abase (2008) who reported that majority of farmers perceived climate change as a critical environmental issue that needs immediate attention. The farmers also affirmed that climate change had led to various forms of drought, thereby reducing the quality and quantity of crops produced which were very significant factors that increase cost of food crops.

In addition, IPCC (2007) reported in the 4th Assessment Report that many farmers perceived climate change as mere phenomenon that comes from time to time whose effects are very damaging in crop cultivation, animals rearing, fishing and other agricultural activities. Nyangaji and Aminy (2011) reported that farmers perceived an increase in the duration of the cold season were more than the one they knew. Furthermore, most farmers perceived no change in the duration of the hot season. Some of the negative effects perceived by farmers include: poor crop production, droughts, poor livestock production due to flooding, prolonged dry spells and increased food insecurity. Other negative effects include increased pests and diseases, destruction of physical infrastructure, difficulty in planning because of increased variability of the weather and reduced access to inputs due to low income from poor crop production.

Another finding that perception of rice farmers regarding climate change in Taraba state is high and positive; the hypothesis showed there was no significant difference in the mean responses of male and female farmers on their perception regarding climate change in Taraba state. This implies that the rice farmers in Taraba state are convergent in their opinions on climate change. In conformity to this finding, Kisauzi (2012) found out that majority of male and female farmers were aware of climate change and their perception largely resonates with scientific meteorological data. Both male and female farmers had observed the length of seasons had changed, temperatures had increased, rainfall had decreased, floods, droughts and strong winds had become more frequent and severe. Ringler and Kohlin, (2008) also reported that farmers understand that turbulent weather is attributed to a climate shift, culminating in extreme weather events, heat waves and drought. However, Benedicta (2012) reported that there was no significant difference in perceptions regarding changes on all climate parameters between men and women with the exception of perceived frequency and severity of droughts.

According to Nyangaji (2012) majority of the educated and non-educated farmers are aware of the climate change, its effect on crops, humans and animals as well as strategies of adapting to climate. On the contrary note some of the illiterate farmers interviewed in the rural farming communities don't have knowledge of climate change rather attribute their low crop yield, pests and diseases of crops, flooding to the handy work of enemies who transformed into witches and wizards to destroy farm produce and livestock (Issa, et al 2015).

The finding that respondents concur with all the mitigating strategies listed in the study as the adaptation strategies being used by the farmers in rice production in Taraba state and the hypothesis that there was no significant difference in the mean responses of Male and Female Farmers on the adaptation strategies being used by the Farmers to mitigate climate change in Taraba State. This finding is in tandem with Oruonye and Adebayo (2015) who found out that the common adaptation measures applied by the local farmers include altering of planting season, use of different tillage system, use of tolerant seed varieties, planting early matured varieties and crop diversification.

According to World Bank (2010), Nzeadibe and Egbule, (2011) and Nest (2004) suggested several adaptation technologies and strategies which include: Planting of early maturing crops varieties, planting pest/diseases resistance varieties, planting drought resistant varieties, crop diversification, irrigation, agro-forestry practices, mixed farming/cropping, provision of water through boreholes/tube wells, forestation, composting use of organic manure, construction of dams, embankment, labor migration, shifting cultivation, rain water harvesting, raising high yielding varieties, job diversification, seeking government assistance, reduction in socking rate or livestock density, restoration of degraded areas (soils habits) awareness creation and sensitization.

In support of this findings, Bartels and Furman (2016) indicated that common adaptation methods in agriculture include use of new crop varieties and livestock species that are better suited to drier conditions, irrigations, crop diversification, mixed cropping and livestock farming systems; and changing planting dates, using different crop varieties, changing planting and harvesting dates, increasing use of water and soil conservation techniques and diversifying from farm to non-farm activities to cope up with climate change.

Oruonye and Adebayo (2015) analyzed the choice of adaptation measures employed by the local farmers and

the constraints to such measures and found that most of the farmers living in rural communities have been affected negatively by recent changes in climate through low rainfall, flooding, drought, high temperature and other factors. The findings show that most of the farmers' opinions, observation and adaptation measures to climate change agrees with expert's report. The study findings show that the common adaptation measures applied by the local farmers include altering of planting season, use of different tillage system, use of tolerant seed varieties, planting early maturing varieties and crop diversification. Regrettably, Irrelevantly, Apata (2010), reported that majority of the farmers do not adhere to the strategies suggested by experts as adaptive measures to mitigate the menace of climate change.

VII. CONCLUSION

Climate change and agriculture are both interrelated processes. Climate change has significant impacts on conditions affecting agriculture which is vulnerable to the vicissitudes of climatic conditions. The awareness and perception of farmers about climate change becomes very paramount for enhanced productivity by farmers including rice farmers. However, most farmers are not aware of climate change and many farmers do not adhere to the strategies suggested by experts as adaptive measures to militate against climate change. Therefore, meteorological agency should keep on creating awareness to farmers as well as stating the effects of climate change on rice production and other crops. Farmers need more education on their perception regarding climate change which would help them to apply different methods in rice production. There should be more enlightenment to all farmers by the extension agents on the adaptation strategies to militate against climate change.

RECOMMENDATIONS

On the basis of the findings and conclusions, the following recommendations were made:

1. More awareness should be created among rice farmers on climate change. Farmers should have more access to up-to-date and continuous information on climate change from the agencies concerned with providing it through jingles in mass media and local farm exhibitions.
2. Farmers should apply the adaptation strategies suggested by experts wisely such as planting early maturity crops, diseases resistance varieties, forestation and farm yard manure application to boost their outputs *et cetera.*
3. There is need to improve extension services to increase farmers' accessibility to information on adaptive research findings on early maturing, insect/pest tolerant, and high yielding varieties among others through increase extension services in the study area.
4. Government should provide required assistance to farmers for training them on new innovations of adaptation technologies for effective rice production in Taraba state.

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Analyzing dynamic of changes in Land Use and Land Cover in Semi-arid of Eastern Sudan, Using Remote Sensing and GIS

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Abstract**—***Mapping land use and land cover (LULC) changes at regional scales is essential for a wide range of applications, including landslide, erosion, land planning, global warming etc. LULC alterations (based especially on human activities), negatively affect the patterns of climate, the patterns of natural hazard and socio-economic dynamics in global and local scale. However, LULC change, especially those caused by human activities, is one of the most important component environmental changes (Jensen, 2005). LULC is an important component in understanding the interactions of the human activities with the environment and thus it is necessary to be able to simulate changes. The aim of this study is to identify, evaluate and examines the spatial and temporal change detection of LULC in the study area during the time periods of 1984 to 2018 with emphasis on accuracy assessment to judge the applicability of maximum likelihood classifier (MLC) method in this case of study, and to ensure the accurate change detection. To investigate the (LULCC) changes in the semi-arid of Eastern Sudan from 1984 to 2018, the study has been done through remote sensing and (GIS) approach incorporated with field verifications for extracting information. This was done by downloading free of cloud and processing multi-spectral Landsat satellite imageries covering the study area over successive periods (1984 and 2018). The maximum likelihood classifier (MLC) method applied for mapping of LULC based on pixel-by-pixel and image differencing, which are used to enhance the change assessment. Ground truth observations are also performing to check the accuracy assessment of the classification. The methods employed in this study were, data identification and acquisition, image pre-processing and processing, validation, post classification, matrix of change, interpretation and maps change presentation. The images were classified into five thematic LULC classes which were; Dense trees and shrubs, low dense vegetation, farmland bare/grassland, moving sand and stabilized sand by means of (MLC) based on supervised classification technique with acceptable accuracy assessment. Pre-classification and post-classification change detection (CD) methodologies were executed using image change detection (CD) and image differencing by matrix of change respectively. These methods gave different results in term of LULC areas, and it is generally concluding that supervised classification gave the most accurate results with the images of medium spatial resolution. The present study has brought to light that dense trees and shrubs that occupied an area about 27401.7ha (11.27%) of the study area in 1984 has increased to 46614.3ha (19.17%) in 2018. Whereas, the moving sand occupies an area about 38519.2ha (15.85%) in 1984 has increased to 43198ha (17.76%) in 2018 respectively, which are the most dominant classes in the study area. Low dense vegetation, farm, bare, grassland and stabilized sand also have experienced change. Low dense vegetation has decreases from 20.41% to 19.38%, while the farm, bare, grassland has decreases from*

24.22% in 1984 to 19.75% in 2018, which represented the cultivated land, as well as decreases in stabilized sand from 26.65% in 1984 to 23.84% in 2018 respectively over the 34-year period. Maps of the LULC changes available in GIS platform can be used for enhancement of the available tools for further planning and environmental factor for future in the region.

***Keywords*— Landsat, change detection, remote sensing, semi-arid land, Sudan.**

I. INTRODUCTION

Land is a very important asset and means to sustain livelihood. It is the key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production and through much of the course of human history and has been tightly linked to economic growth. It comprises biophysical qualities such as soil, topography, climate, geology, hydrology, biodiversity and political divisions. Land also defined as consisting of such socioeconomic factors as technology and management.

Land use and land cover in Sudan constrained by a large scale of People and tribal laws and the nature of economic and social activity in the region, such as grazing and agricultural activity and the coal industry and trade activity wood construction. The arable land in Sudan is constitutes about one third of the total area of the country, however only 21% of this arable land is actually cultivated. Over 40% of the total area of Sudan consists of pasture and forests. Natural pasture provides grazing land for nearly all livestock. Forests and woodlands are used to meet the population's demand for consumption of wood products, which estimated by 16.8 million cubic meters in 1996. Moreover, Forests are exposed to continuous removal and clearance either for agricultural expansion or for fire wood consumption. (High Council for Environment and Natural Resources, 2003). Large area of cultivable lands are situated in the region between the Blue Nile and the Atbara River in the east, and in the area between the Blue and White Niles in the center of Sudan, and in the narrow Nile valley above Khartoum and in the valleys of the plains region.

LULC are among the most important application of earth observations (EO) satellite sensor data (Giri and Wang 2012, Chowdhury et al, 2017). It provides a comprehensive and a good understanding of ecosystem monitoring and functioning, and responses to environmental factors (Muttitanon and Tripathi (2005) and Baumann et al, 2014) However, LULC change are terms often used interchangeably but the two have different meanings. Some areas are occupied by the population for their specific purposes such as agriculture, inhabitation, cattle farming is called land use (LU) and some areas are covered by natural vegetation are called land cover (LC) (Basnet and Khadka 2020). LU its resources (Meyer 1995). LC on the other hand has also been defined as that which overlays or currently covers the ground, especially vegetation, permanent snow and ice fields, water bodies or structures (USDA Forest Service 1989).

LC describes the natural and anthropogenic features and biophysical condition that can be observed on the earth's surface. Examples include deciduous forests, wetlands, developed/built areas, grasslands, water, concrete, etc. LU by contrast, describes activities and intention related with the land cover that take place on the land and represented the current use property. Examples include agriculture, cattle, residential homes, shopping centers, tree nurseries, state parks, reservoirs, etc. However, Land use is closely related with the land cover in many forms such as forests are used for both agriculture and animal farming as timber works.

Remote sensing (RS) is the science and to some extent, technology, and art of acquiring information about the Earth's surface or on objects or any phenomena from a distance without actually being in contact with it (Lillesand, et al., 2010 and Jovanovićet al., 2015). RS systems, in the first place those in the satellite platforms, provide continual and consistent view of the earth making the ability of monitoring the earth's system and human influence on the earth easier and it allows identification and classification of objects according to type and spatial distribution. Since the early days of satellite remote sensing in the 1950's, accessibility, quality, and scope of remote sensing image data has been continuously improving, making it a rich data source with a wide range of applications. Since these early days of satellite, remote sensing the availability and quality of image data has been continuously improving. Today, the use of remote sensing techniques and data is commonplace within many disciplines in the natural and environmental sciences and widely acknowledged, which are found in many areas of society. The capacity of remote sensing to identify and monitor the earth's surface and the natural conditions has increased dramatically in the last few years and the sensed data are going to become the crucial instrument in natural resource management. It provides high resolution satellite images with a high accuracy of large areas of land periodically and at various times, which contributes to providing information to assist research and studies on environmental protection, the exploration of natural resources, urban planning, agricultural crop control

and other vital civil and military development areas. RS and GIS technologies are the best tool for researchers from different disciplines (Hoffer, 1978). RS is the main source for several kinds of thematic data critical to GIS analyses; including data of characteristics. Aerial and Landsat satellite images are frequently use to evaluate the LULC distribution and to update existing geospatial features.

In recent years, the applications of RS and GIS have been increasing greatly for the earth surface analysis. The data captured by the sensor set up at the satellite has high capacity to capture in high resolutions, so that the image obtained can give lots of information of the earth's surface, which are far from us and out of reach.

The remote sensor acquires a response, which is based on many characteristics of the land surface, including natural or artificial cover (Anderson, et al., 1976). Many organizations provide and distribute satellite data free of charge, for example, the Global Land Cover Facility http://glcf.umiacs.umd.edu/index.shtml) and the Swedish national satellite database Saccess (http://saccess.lantmateriet.se/) offer state-of-the-art imagery via open access websites. It is a valuable source for data on vegetation composition, structure, landscape ecology, biology, and physical geography, etc.

change detection (CD) is the process detaching difference between objects and phenomena, which can be observed in different time breaks (Pathmanandukumar, 2020). It aims to select and put into practice those land uses, which will meet the need of the people by securing resources for future (Singh & Kumar 2012 and Igbal & Igbal 2018). LULC change detection based on remote sensing data is an important source of information for various decision support systems. Information derived from land use and land cover change detection is important to land conservation, sustainable development, and management of water resources (Tewabe1 & Fentahun, 2020). Furthermore, the LULC change of an area is an outcome of natural and socio-economic aspects and their operation by the human in time and space. Nowadays, the advancement of geospatial technology such as RS and GIS present the best efficient tool for analyzing quantitative evaluation and provide a baseline for monitoring the extent, impacts and trend of LULC as demonstrated by many researchers.

LULC changes are mostly influenced by increase and decrease in population growth in the system (Lambin et al., 2003), economic growth, and physical factors including topography, slope condition, soil type, and climate (Setegn et al., 2009; Yalew et al., 2016). LULC change is a matter of historical process as relating to how people use the land. It modifies the availability of different resources including vegetation, soil, and water (Ahmad, 2014). Land use land cover change is an important issue considering global dynamics and their responses to environmental and socio-economic drivers (Akpoti et al., 2016; Bewket, 2002; Hurni et al., 2005). Land use land cover alterations, negatively affect the patterns of climate, natural hazards and socio-economic dynamics on a global and local scale (Chakilu & Moges, 2017; Hegazy & Kaloop, 2015; Sewnet, 2015; Tewabe1& Fentahun, 2020).

LULC changes play a major role in the study of global change where LULC and human and natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster desertification and flooding (Mas *et al*, 2004 and Dwivedi, et al 2005). The growing population and increasing socio-economic necessities create a pressure on LULC. This pressure results in unplanned and uncontrolled changes in LULC (Seto *et al*, 2002). The LULC alterations are generally caused by mismanagement of agricultural, urban, range and forestlands, which lead to severe environmental problems such as landslides, floods etc. The main reason behind the LULC changes includes rapid population growth, rural-to-urban migration, reclassification of rural areas as urban areas, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies

Rapid expansions of a human activity are becoming serious issues and challenges for land cover conditions (Zaidi et al., 2017). Its direct impact is felt on the environmental and ecological system of the nature. Therefore, the study of the change scenario on land use and land cover is important work. It is not possible in a short year. Study based on decadal time series gives realistic information on the change conditions in a large area rather than a small land use and land cover. Moreover, remote sensing generally enables direct measurements of the earth's surface and the spatial distribution of its physical objects. Social science is generally more concerned with why things happen than where they happen (Turner, 1998). Determining the effects of land use change on the Earth system especially depends on the understanding of past land use practices, present land use patterns, and prediction of future land use, as affected by human institutions, population size and distribution, economic development, technology, and other factors. Past and present studies conducted by organizations and institutions around the world, mostly has concentrated on the application of LULC changes (Reis, 2008).

RS and GIS are powerful and cost-effective tools for assessing the spatial and temporal change of LULC (Herold et al., 2003; Serra et al., 2008). Nowadays, remote sensing data are applicable and valuable for land use and cover change detection studies (Yuan et al., 2005). Remote

sensing data is the most common source and important benefits of the satellite for observing the earth is certainly the change classification and monitoring for detection, quantification, and mapping of LULC patterns due to its repetitive data acquisition, suitable for processing, and accurate geo- referencing (Chen et al., 2005; Jensen, 1996). Remote sensing satellite imagery has given scientists a remarkable way to determine the reasons for LULC changes and the resultant consequences due to human activity (Cardille, Foley, 2003). In the last few years, numerous government agencies all around the world have used the satellite remote sensing to monitor and quantify the changes.

However, in Sudan the increase of population growth rate, led to increase for food crop production with agriculture playing a prominent role in livelihood security. The increase use of irrigation and mechanization has brought an increase in demand for agricultural land use, which, lead to the conversion of other land use types, and vegetation for agricultural land use. This has effect and impact on the vegetation and environment of the country highly exposed to the incidence of environmental, social hazards and disasters including drought and desertification, floods, loss of biodiversity, ethnic conflicts and poverty (Elhaja et al, 2017).

The importance of change detection is to determine which LULC class is changing to the other. The most commonly LULC change detection methods include image overlay, classification comparisons of LULC statistics, change vector analysis, principal component analysis, image rationing and the differencing of normalized difference vegetation index (NDVI) (Han et al., 2009). Moreover, Methods of change detection can be classified into three categories: characteristic analysis of spectral type, vector analysis of spectral changes and time series analysis (Shaoqing, Lu, 2008, Jovanović, et al., 2011). Characteristic analysis of spectral type is change detection based on spectral classification and calculations. The vector analysis is done by using strength and direction characteristics, and time series analysis is used to analyze process and trend of changes of monitored ground objects, based on continuously remotely sensed data.

There are two basic ways of change detection: first by direct overlapping of classified vector classes from both images and then visually analyzing the changes and second by direct change detection of one image made of combined images from different epochs (Jovanović, et al., 2011 and Abualgasim, et al., 2017).

The primary purpose of using remote sensing- based change detection is to monitor land cover change very effectively and efficiently. Change detection is the process of detecting and identifying differences in the state of an objects or phenomenon by observing it at different time intervals (Singh, 1989). Remote sensing-based change detection applies comparison of a set of temporal images covering the period of interest using specific change detection algorithms (Yismaw et al, 2014). LULC change analysis using remote sensing techniques gives an opportunity to obtain results with low costs, less time consumption and good accuracy, and GIS allow updating results whenever new data is available (Jovanovic, 2015 and Juliev et al, 2018). However, nowadays-remote sensing data are applicable and valuable for land use and cover change detection studies (Yuan et al., 2005).

There are several methods for mapping land cover changes using remotely sensed data, conventional MLC (Langford, Bell, 1997), post-classification, image differencing, and principal components change-detection techniques (Macleod, Congalton, 1998), image differencing, vegetative index differencing, post-classification change differencing, multi-date unsupervised classification (Mas, 1999). Determination of the changes which occurs on the Earth in the context of the digital image processing require different procedures and techniques, some of which are standardized, while many other depend on the applications in which the image processing is being done. In order to compare one image to another it is necessary to compare the pixel of one image to the pixel of another. What is necessary to know before the detection process itself is the value of the change phenomenon, which is very important, i.e. it is necessary to conduct the filtration of the certain changes. This can vary from one user to another, and from the purpose of change detection. Assessment of the trends of LULC dynamics using RS and indicators such as anthropogenic activities and the socio-demographic information is essential in order to make proper planning for sustainable management.

II. MATERIAL AND METHODS

Gash agricultural scheme (GAS) (figure1) is considered the first scheme in Kassala state, eastern Sudan, was established in 1926 as a key anchor for the livelihood for the people of the Gash area to contribute to the rural development particularly towards local population around the Gash River area and population settlement in eastern Sudan. The scheme is located between latitudes 15.3 and 16.3 north and longitude 35.5 and 36.3 east, in the semi-desert region, irrigated by the Gash River, with a total area of approximately 900,000 acres, including 750,000 acres covered by the current irrigation system as shown in figure1. Using cultivation in three years cycle (rotations system) 250.000 acres are cultivated each season. This area may increase or decrease depending on the river flooding,

the report of preparations for the season of irrigation operations and the status of cleaning of mesquite trees and weeds. Some forests, villages and other settlements inside the scheme cover the remaining areas. However, the scheme was constructs for poverty reduction by cash economy improvement through cotton and castor cultivation as cash crops, as well as Sorghum as the main staple and cash crop (Anderson, 2011). The area is characterized by semi-arid climatic conditions with rainfall ranges between 50-200 mm. semi-arid ecosystems with a single rainy season there is usually a short growth period followed by a long dry season with a great reduction for material (Hinderson, 2004). The area endures intensive land-use pressures, which make it highly sensitive to climate fluctuations. Various practices in this region, such as changes in fire regimes; removal of vegetation and over-grazing have been linked to many recognized causes of land degradation (Hielkema et al., 1986; IFAD, 2004). In the last decade, the scheme has undergone serious deterioration, further drought spells have led to increased pressure on meager resources, in addition to invasion of unfavorable Mesquite trees. These factors lead to acceleration of the degradation process in the study area.

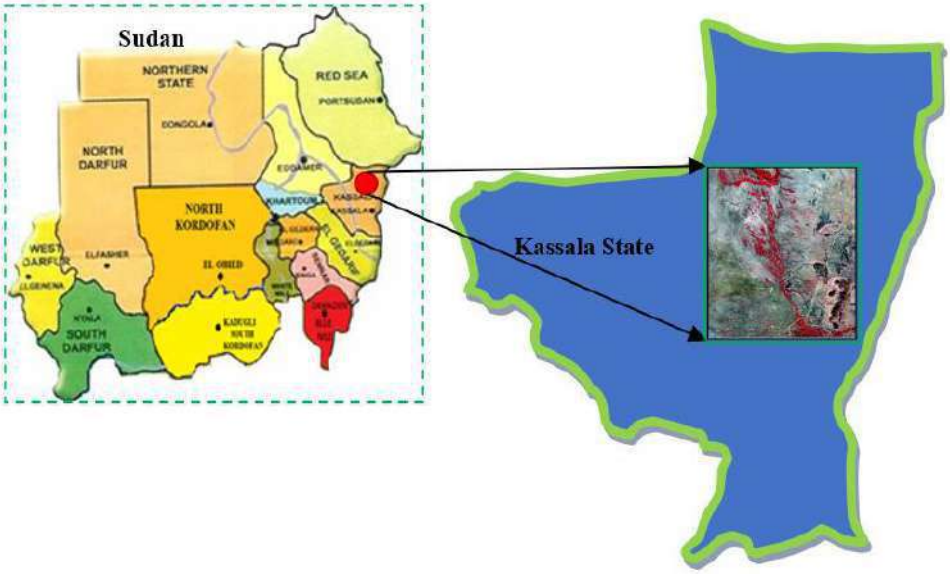

Fig.1: The location of the study area

In this study, different methods of analyzing satellite images are presented, with the aim to identify changes in LULC in a certain period of time (1984 - 2018). The area observed in this study is the region of (GAS) with its surroundings (approximately 2055 km² is the total area of the image subset). The methods represented in this study are image acquisition, image pre-processing (geo-referencing, image corrections, sub-setting, and enhancements), unsupervised classification, supervised classification and post classification (change detection) as shown in figure 2.

The study integrate data from different sources and used different methods and approaches to analyze the long term of LULC changes and trends during the previous four decades in Gash Agricultural Scheme (GAS) area. The study used imageries from different satellites of Landsat and different dates (Landsat 1984 and Landsat 2017) acquired in dry season, were acquired in Path and row 171/49 downloaded from United States Geological Survey (USGS) website as shown in table 1. Therefore, to understanding the strengths and weaknesses of different types of sensor data is essential for the selection of suitable remotely sensed data for image classification (Gomez et al., 2016; Lu & Weng, 2007).

Table (1) lists the source and characteristics of each image including year of capture and spatial resolution (m). The imageries were geo-referenced and radiometrically corrected by using ENVI FLAASH software. Anniversary data acquisition dates were maintained in order to avoid biases that are due to the seasonality, this is essential for CD analysis.

Downloading Landsat images of the required years for the study area, random control points, Erdas imagine 10, ENVI 7 and GIS 11 software, Google earth images for further had used in the LULC classification. The imagery data files had downloaded in zipped files from USGS website and extracted to Tiff format files. The imagery is acquired during the dry season in order to avoid the haze and the distortion seasonality. The imagery then converted to digital image format using Arc-GIS and Erdas imagine software in the pre-processing procedure. To perform image classification, the raw data must be pre-processed and

prepared properly so that error due to the geometry of the earth, radiometric and atmospheric effects could be accounted. The general procedure in the pre-processing stage has included the detection and restoration of bad lines, geometric rectification or image registration, radiometric calibration, atmospheric correction, and topographic correction**.**

In this study, the pre-processing included radiometric, atmospheric and geometric corrections of the satellite images in order to remove the systematical mistakes of the sensing devices. Radiometric correction comprised the process of histogram matching of the satellite images from different times, whereas geometric correction meant co-registration of the satellite images, so that the images could overlap in the best possible way to view. This is important because some of the essential methods are based on the comparison of the two images from different times, e.g. supervised classification. Dark Object Subtraction (DOS) correction used to correct the satellite imagery for atmospheric effects because it is a common simple model, and relies only on scene-derived parameters using thresholds and histograms of image data for implementation (Chavez 1996). The basic assumption is that within the image, at least some pixels should have zero reflectance and any non-zero radiance received at the satellite for these least-value pixels is due to atmospheric scattering (Chavez 1996). In remote sensing studies, representative ground truth data is a pre-requisite to associate this reflectance property to the object and the train classifiers and facilitate accurate automatic classification (Muzein, 2006). Investigate the trend changes in each LULC type, the entire image has classified by supervised classification method using (MLC algorithm) environment.

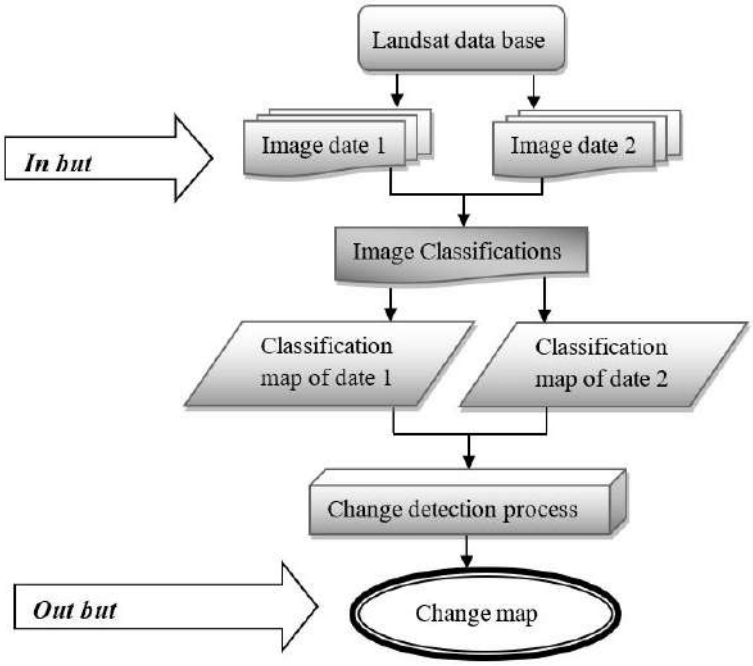

Fig. 2: Flowchart of Change detection (Post-Classification) processing (Adopted by the Author)

RS is one of the tools which is very important for the production of LULC change maps through a process called image classification. For the image classification process to be successfully, several factors should be considered including availability of quality Landsat imagery and secondary data, a precise classification process and user's experiences and expertise of the procedures.

Image classification of six reflective bands of the Landsat images was carried out by using MLC method with the aid of ground truth data obtained from aerial images dated 1984 and 2018 as shown in figure 2. The second part focused on LULC change by using change detection comparison (pixel by pixel) and matrix of change.

In this study, for change detection, classification comparisons of LULC statistics had used. The areas covered by each land cover type for the various periods had compared. Then the directions of the changes (positive or negative) in each land cover type had determined.

Table 1. Data Acquired and Sources

Satellite type	Acquisition date	Spectral bands	Resolution	Source
Landsat	1984	4 bands	5 7 m	United States Geological Survey (USGS)
Landsat	2018	7 bands	15 m	United States Geological Survey (USGS)

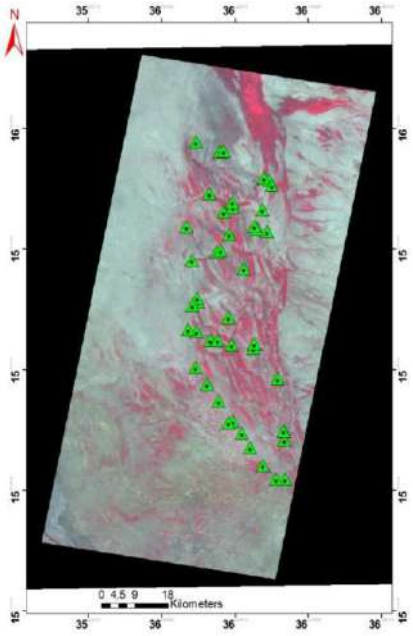

Fig. 2: Locations of the training ground control points samples in the study area

III. RESULTS AND DISCUSSION

The main purpose of this study is to detect, analysis, and assess the dynamic of changes in LULC in semi-arid land of eastern Sudan. Landsat images for 1984 and 2018 a 34-year period were processed and the particular years analyzed for land use and land cover changes were 1984 and 2018. The study area was classified into five land use and land cover classes namely; Dense trees and shrubs, Low dense vegetation, Farmland bare/grassland, Moving sand and Stabilized sand as illustrated in Table (2).

The spatial distributions of LULC classes illustrated in Figures 3 and 4. The cover area and percentage that each LULC classes are show in Table 2. Figures 3 and 4 shows the percentages of each class cover in the study area. According to the results obtained from the classified images dated 1984 and 2018, the results observed that the distribution of dense trees and shrubs covered an area of 27401.7ha (11.27%) in 1984 and 46614.3ha (19.17%) in 2018. Whereas, the moving sand occupies an area from 38519.2ha (15.85%) to 43198ha (17.76%) of the total area in 1984 and 2018 respectively, which are the most dominant classes in the study area, they extremely affect the agricultural and residential areas as well as threaten the Gash River course during the wet and dry seasons together.

According to the analysis of the LULC changes the results revealed that, the dense trees and shrubs as well as moving sand areas and their effects on the farm and cultivated areas over time are the focal point of attention in the study area.

The visual comparison between the Landsat imageries 1984 and 2018 shows that there has been a significant change in LULC classes over the years with transformation occurring from one class to another. The results revealed that; a drastic change occurred during the period of study, showing rapid increase of (dense trees and shrubs) which represented an invasion of invasive species (Mesquite trees) from 11.27% to 19.17%, mobile sand (moving sand) from 15.85% to 17.76%. While the farm, bare, grassland decreases from 24.22% to 19.75%, which represented the cultivated land. Decreases in stabilized sand from 26.65% to 23.84% was also observed during the study period.

Table 2. LULC category for each study year

Land Use and Land Cover	**1984**		**2018**	
	Area (Hec.)	Area%	Area (Hec.)	Area%
Dense trees and shrubs	27401.7	11.27	46614.3	19.17
low dense vegetation	49627.2	20.41	47127.3	19.38
Farm, bare, grassland	62756.4	25.81	48024.1	19.75
stabilized sand	64798.4	26.65	57957	23.84
moving sand	38519.2	15.85	43198	17.76
Total	243102.5	100	243102.5	100

The result obtained from this study (that is; increase in dense trees "forest cover") is in-line with that of Askar et al., 2019 where increase in forest cover was observed in the study area over the period of sixteen years as a resultant effect of successional recovery after forest fire (Askar et al., 2019). The study by Juliev et al., 2019 also revealed increase in forest area of about 5.7% over the 28 years of study in Bostanlik District, Uzbekistan because of reforestation project within the study period. Similarly, the study by Gozdowski et al., 2020 revealed an increase in forested area over the 34 years studied period in Lithuania, though the type of forest species is not mentioned in their studies. The result of our study also observed that the increase of invasive species (mesquite trees) is as a result of miss-use of irrigation water and management. The results also, observed that there is increase of sand area and invasion of mesquite trees at the expense of cultivated land (clay soil), this means a decreased in cultivated land, which leads to decrease the productivity over time. The results observed also the class of farm, bare, grassland area has been greatly converting either to the dense trees and shrubs class or to moving sand class over the period of the study.

Dense trees and shrubs areas have increased from 27401.7 ha in 1984 to 46614.3 ha in 2018 from the total area of the study Table (2). Moreover, in table (2) the results, also shows that the three classes ((low dense vegetation), (Farm, bare, grassland) and (stabilized sand)) respectively were decreased from an areas of ((49627.2 ha in 1984 to 47127.3 ha in 2018), (62756.4 ha in 1984 to 48024.1 ha in 2018) and (64798.4 ha in 1984 to 57957 ha in 2018)) respectively, which is due to an expansion of mesquite trees colonies areas or due to encouragement of sand moving towards the cultivated land in the study area during the period of the study.

The results observed that, during the classification of Landsat images data, the residential areas it does not appear in the class's classification program and it was impossible to detect the small residential places because the people were builds their houses from the trees products (branches) and the local materials. Therefore, it is too difficult to distinguish between the houses and the vegetation cover in the study area during the period of the study.

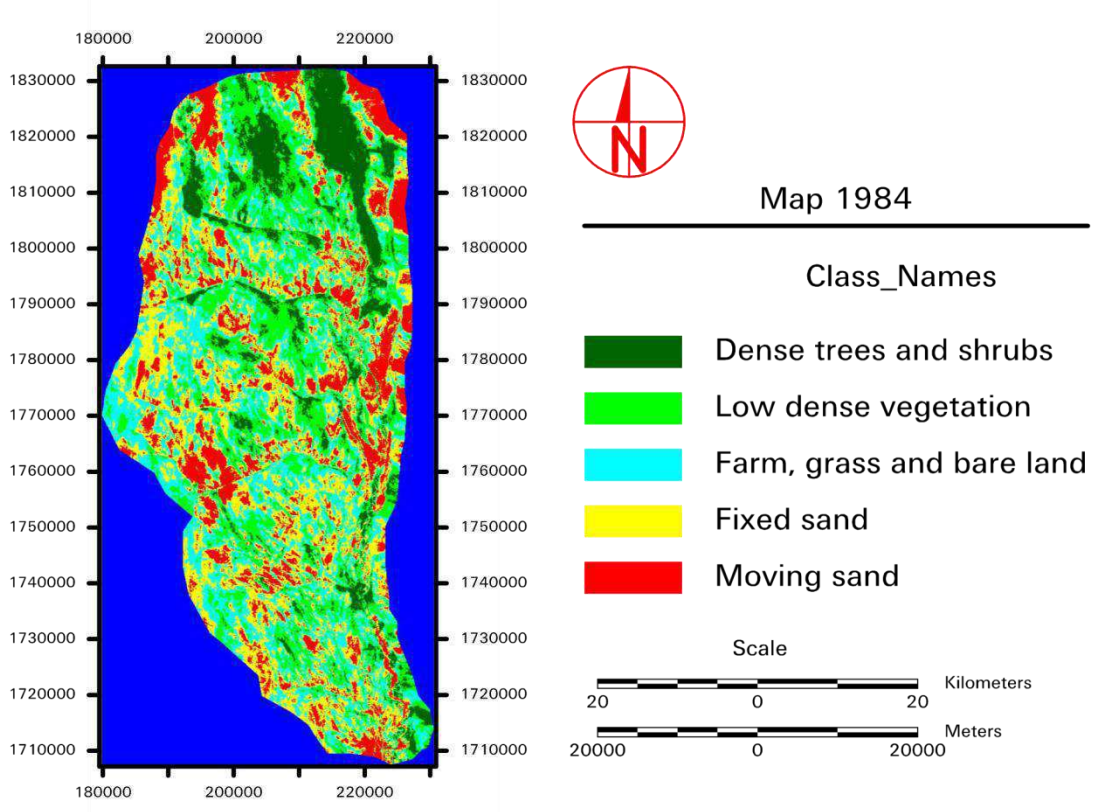

Fig. 3: Classification of LULC based on MLC for image 1984 (Gash Agricultural Scheme)

To compare the land cover percentage during the period of 34 years from 1984 to 2018, Figure 3 was generated and showed that from 1984 to 2018 there were increments in percentage cover of the dense trees and shrubs and moving sand classifications while low dense vegetation, Farm, bare, grassland, and stabilized sand went down. The classification that showed a big percentage cover change was the dense trees and shrubs which increased by slightly over 170% followed by moving sand with about 112%. Low dense vegetation decreased by about 96% from 1984 to 2018

while Farm, bare, grassland and stabilized sand also went down by about 76% and 89% respectively within the same time as shown in figure 5.

Increase in moving sand at the expense of other land cover were observed within the study period, which is an indication of desert encroachment as revealed by the study of Kempf 2021 where extensive expansion of sand land was observed in his study in northern China and Mongolia. Other study such as that of Zang et al., 2020, Turk and Aljughaiman, 2020 linked expansion of bare surface to desertification which has consequential effect on endemic species and biodiversity.

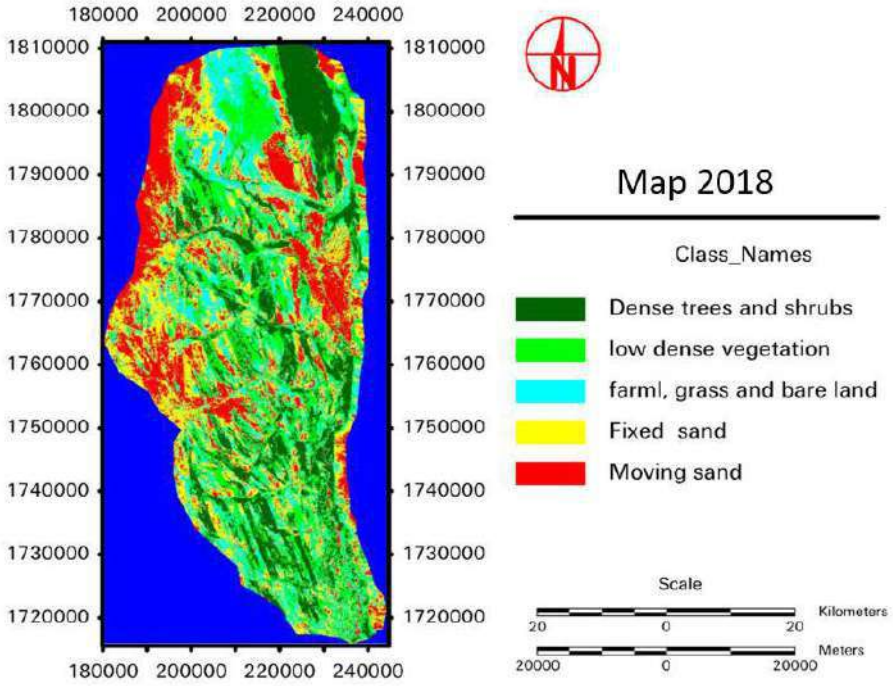

Fig. 4: Classification of LULC based on MLC for image 2018 (Gash Agricultural Scheme)

Change in the global environment affected by various changes in land use and land cover (Qian et al. 2007). Urbanization, population growth, land scarcity and expansion of agricultural land are among the many drivers of LULC change in the world. Therefore, the use of remotely sensed data and applying the analysis techniques provide accurate, timely and detailed information for detecting and monitoring changes in land cover and land use.

In this study, there were five categories of classifications: Dense trees and shrubs, low dense vegetation, farmland bare/grassland, moving sand and stabilized sand. The dense trees and shrubs had a difference in percentage cover of about 8% from 1984 to 2018, while the low dense vegetation had a negative difference in percentage cover -1.03% over the same period. The farmland bare/grassland had a negative percentage cover difference of -6.06% as well as stabilized sand (fixed) had also a negative difference in percentage cover- 2.81% as an indication of decrease, while on the other hand moving sand had a positive increased by about 2% in 2018 as illustrated in figure 5.

Masek et al., 2000) reported that, land use and land cover changes respond to forces, which are largely associated with the high human population such as socioeconomic, political, cultural, demographic and environmental. With the current increase in population, the current rates, extents and intensities of LULCC may also increase and as a result, land resources in Kenya will be strained given that approximately 75% of the population engages in agriculture but only 20% of its land is arable.

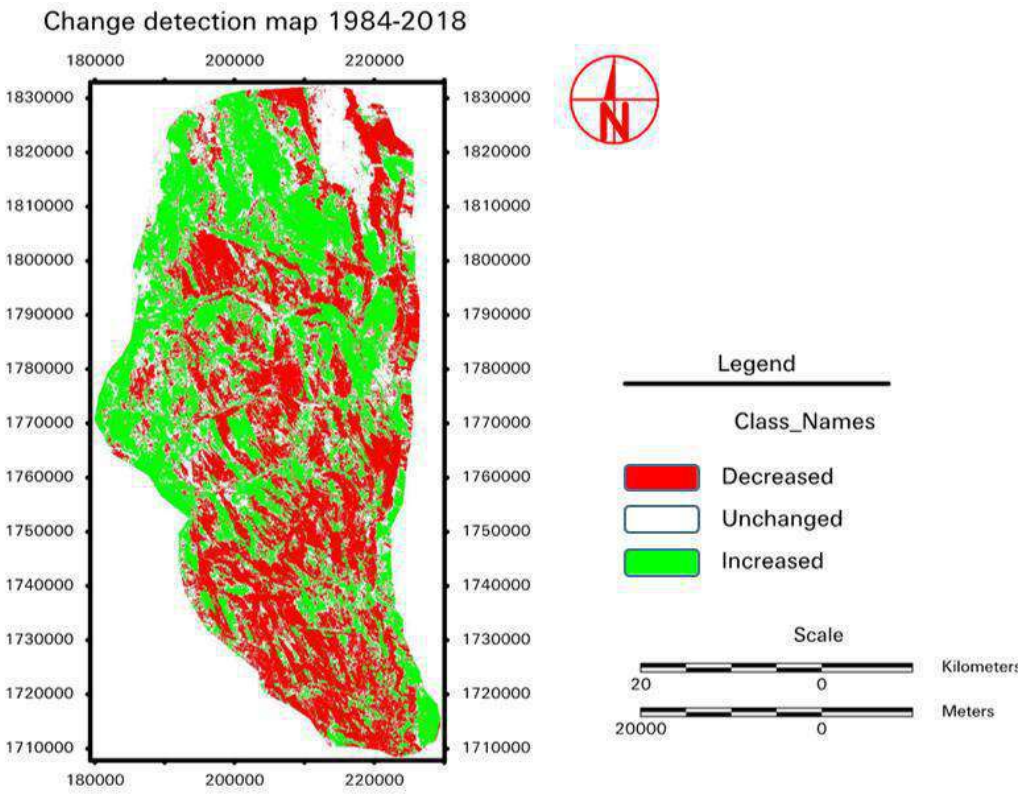

Fig. 5: Change detection between 1984 and 2018

IV. CONCLUSIONS

The 1984-2018, a 34-year period saw a change in the land use in the area with the following classifications increasing: dense trees and shrubs from 11.27% to 19.17%, and moving sand from 15.85% to 17.76%. The classifications that realized a reduction were: low dense vegetation from 20.41% to 19.38%, Farm, bare, grassland from 25.81% to 19.75% and stabilized sand from 26.65% to 23.84%. Therefore, land use and land cover were detected in the area over the 34-year period under review.

V. RECOMMENDATIONS

The use of satellite imageries and other data sources manipulated and integrated a GIS environment provides an essential valuable information base from which the cause and future environmental change can extracted.

Monitoring the trends to which ecosystem is changing by the use of indicators such as LULC and socio-demographic information will be essential in order to make proper planning for sustainable ecosystem management.

Application of spectral land sat satellite imageries of remote sensing data offered an effective opportunity for changes detection and mapping of LULC in the eastern Sudan as well as in semi-arid lands at a relatively low-cost.

Based on the above-mentioned findings, the study recommends in the future need for more studies to evaluate, monitor and mapping the LU/LC dynamics to understand the interaction between the land cover, climate derivers and the human activities in semi-arid region using remote sensing techniques and GIS as an effective, accurate and low-cost techniques. The outcome of this type of studies represents valuable resources for decision makers to guard the environmental changes, and for future development projects in Sudan.

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3D Numerical Simulation of Submerged Vane

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Abstract— *When water is taken from desired parts of the natural or regulated riverbed, it is necessary to use river regulating structures to prevent slope and bed erosion. The main project criterion used in this type of river regulation structures is the flow discharge and velocity. Submerged vane structures are an effective and alternative method used to control the flow in river regulation studies. In this study, the river regulation study with submerged wane structures was modeled in 3D with computational fluid dynamics programs (CFD). Submerged vane model results obtained using 3D computational fluid dynamics were evaluated by comparing them with flow velocities obtained from previous submerged vane experimental results. In the generated numerical model, nonlinear and continuity, turbulence model equations were used. The k-ε turbulence model was used for turbulent viscosity. When the results of the current model were compared with the previous experimental study, it was seen that the experimental results and the modeling analysis results were compatible.*

Keywords— ***Submerged Vane, Experimental model, CFD model, VOF Method, Velocity***

I. INTRODUCTION

It is provided with coastal protection structures for the protection of coasts, river bottoms and slopes. We can call these structures and studies mentioned as flow management. Preservation of the structure of streams such as rivers and canals on the bottom and slopes is also done with the application of submerged vanes.

Among the natural accumulation forms of water, the regions where alluvium is most critical are the curved parts of the streams. Problems are seen more here than in other parts. The growth of meanders formed by a stream on its slightly sloping bases, as well as erosions, pose a problem.

Sediment control in rivers may be required to increase the capacity of the channel, to maintain the most favorable and optimal flow depth, to prevent or divert erosion of river and stream beds and coasts. There are different techniques in this regard. In this study, the submerged vanes technique will be used. It is seen that it is a different technique from the previous applications. The cost of this application provides great advantages as it is very economical compared to physical modeling and trial and error techniques. The first studies on submerged vanes began in 1982 when Odgaard and Kennedy [1] introduced the performance of the submerged vane for slope protection on the Sacremento River as a new method as a technical note. In the past, there are studies on submerged vane structures and their effects on flow [2-11].

Within the scope of this study, the flow discharge of the water in the channel were measured by changing the angle of the submerged vanes, the cross-sections of the vanes. The experiment modelling was carried out on a main channel and its side channel.

In this experiment; Velocity changes in the channel were measured experimentally as well as computational fluid dynamics (CFD). While measuring and analyzing, parameters such as channel geometry, dimensions of main and side channels (length, width, slope), height of water in the channel were carefully and meticulously specified and used to compare measurements. Thus, the results were compared and the error rates were observed

II. DATA AND METHODS

1.Basic Equations

In this study, the continuity equation, momentum equation and k-ε turbulence model equations given below were used to create the numerical model.

Continuity Equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u_i}{\partial x_i} = 0 \quad (1)$$

Momentum Equation

$$\frac{\partial \rho u_i}{\partial t} + \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left[(\mu + \mu_t)\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right] \quad (1)$$

Turbulence Kinetic Energy (k) Equation

$$\frac{\partial \rho k}{\partial t} + \frac{\partial \rho u_i k}{\partial x_i} = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right] + G - \rho\varepsilon \quad (2)$$

Turbulence Dissipation Rate Energy (ε) Equation

$$\frac{\partial (\rho\varepsilon)}{\partial t} + \frac{\partial (\rho u_i \varepsilon)}{\partial x_i} = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}G - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \quad (3)$$

u_i is the velocity component, the coordinate components are denoted by x_i, ρ is the density, μ is the molecular viscosity coefficient. P is the correct pressure, t is the time component, μ_t is the turbulent viscosity coefficient. The turbulent kinetic energy can be found from the ratios k and turbulent dispersion

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \quad (5)$$

$$G = \mu_t\left(\frac{\partial \mu_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} \quad (6)$$

σ_k and σε are prandtl numbers that are dimensionless. $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$, $C_{1\varepsilon}$ and $C_{2\varepsilon}$, ε are constants in the equation. $C_{1\varepsilon} = 1.44$, $C2\varepsilon = 1.92$. C_μ=0.09 are constants determined by experimental measurement.

2.VOF Method

In this study, the volume of fluid (VOF) method was used to calculate the water-air interface. The VOF method essentially determines whether the element volumes in the computational mesh are empty, partially filled, or completely filled with water. Representing the volumetric filling ratio of the mesh elements, the mesh element is fully filled for F=1, empty (filled with air) for F=0, and partially filled with water for 0<F<1 [12](Fig. 1). Previously experimentally setup and initial conditions were given Fig 2 and Table I, respectively.

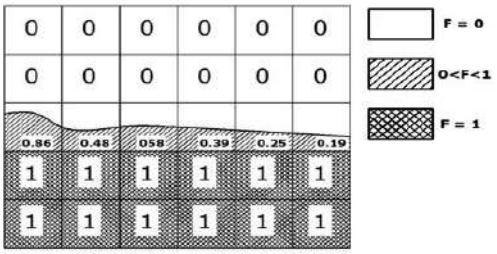

Fig. 1. The occupancy rate of mesh elements

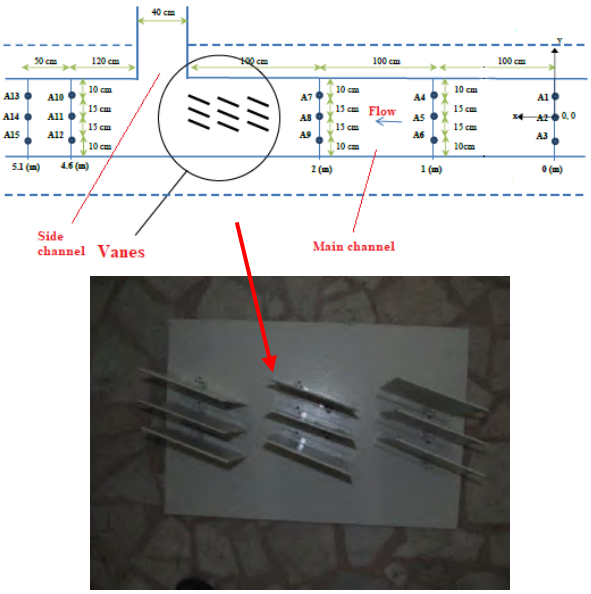

Fig. 2. Submerged vane experiment set-up (top); Submerged vane lined up with 20 degrees (bottom) [13]

Table 1. Submerged vane initial conditions

Velocity Inlet (V_i (m/s))	Water inlet depth (di,m)
0.19	0.23

Since the flow of water in the open channel changes depending on time, the parameters found at the beginning change during the progress of the current modeling. Therefore, the initial values are not very important. The initial values required for the creation of the model are shown in Table 1. The flow rate used during modeling, the flow rate measured in the open channel setup and other boundary conditions were taken from the experimental setup.

The conditions were created by using the model Gambit and Ansys-Fluent modeling and analysis programs designed above, by entering the determined initial and boundary parameters into the program. There are dam reservoir studies created using these programs in the past[14–21]. The solution of the analysis was done with the control volume approach. Numerical analysis of the model was made and

the results were obtained. Submerged vane boundary conditions were given in Fig. 3.

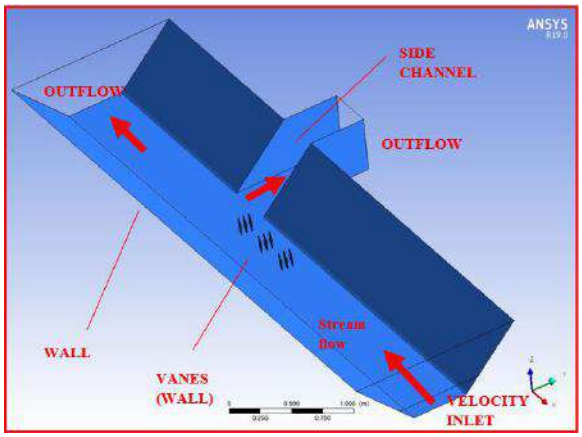

Fig. 3. Submerged vane boundary conditions

III. RESULT AND DISCUSSIONS

After defining the initial and limit values, the contours representing the velocity values of the open channel CFD are shown in Figure 4. According to Fig. 4, it has been determined that the velocities decrease at the locations where the submerged vanes are located. While the velocity values were around 0.17 m/s at the edge points of the main channel, it was observed that this value gradually decreased towards the vanes. It was determined that the velocity values around the vane were around 0.09 m/s. In Figure 4, the vanes affect the direction and velocity of the flow in the open channel. The flow direction of the water is from the main channel to the side channel. In the measurements made when the water from the main channel passes into the side channel, it is measured that the velocity of the water decreases.

The view in plan sections of the flow velocity variation with and without submerged vanes is given in Figure 5. Table 2 and Table 3 show the experimental and CFD results of vanes placed at an angle of 20° and no vane. According to this Table 2 the minimum error rate was 6.47%. The highest error rate was 8.48% at the positions at 0.1- and 2-meters distance. After the vane. The error rates were 15.88% and 15.13% at 4.6 and 5.1 meters. Table 2 shows when looking at the data. Also, experimental-CFD velocity results with submerged vane were given in Fig. 6.

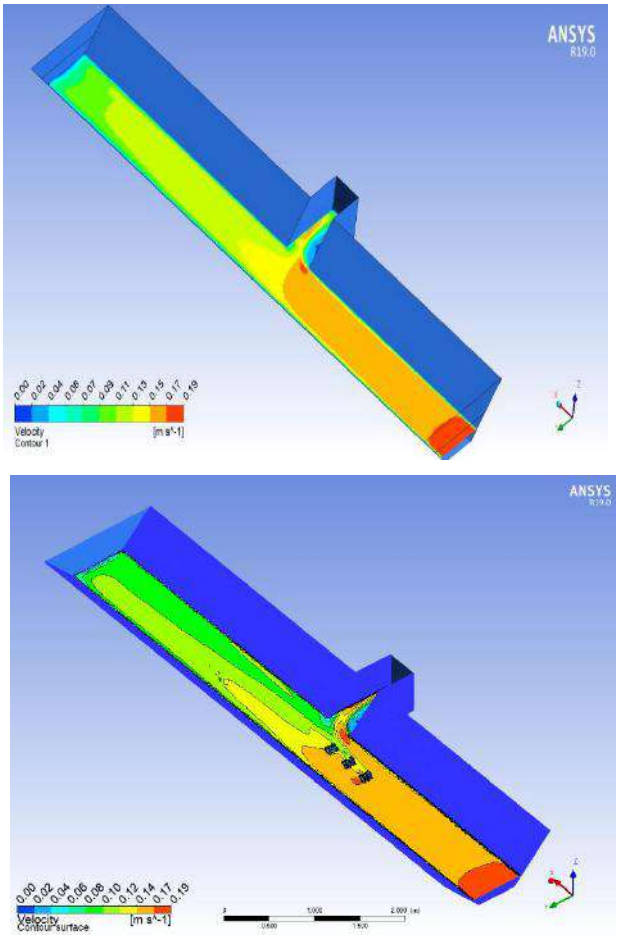

Fig. 4. Velocity contour changes with Submerged vane and no vane

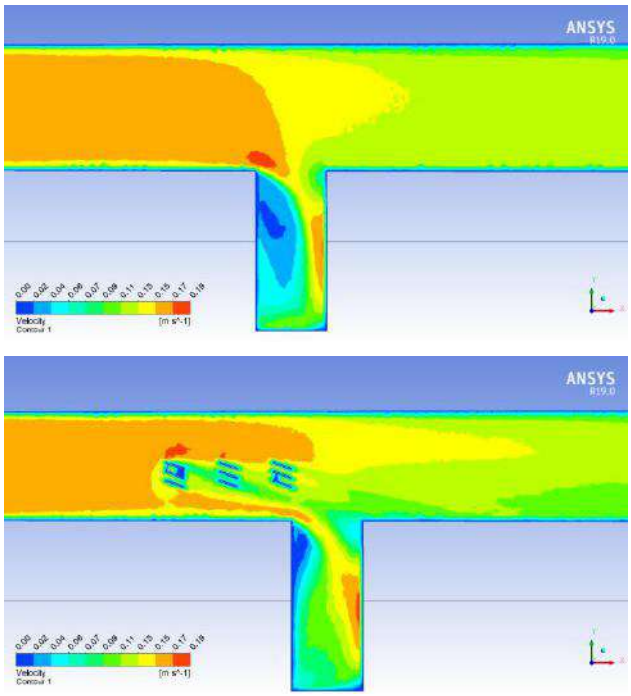

Fig. 5. Flow velocity contour with no vane (top) and submerged vane (bottom)

Table 2. CFD and experimental velocity results using no vane

Section No	Location at x direction (m)	Location at y direction (m)	Location at z direction (m)	Experiment Results (m/s)	Fluent CFD Results (m/s)	Error (%)
1	0.0	0.10	0.13	0.1774	0.1858	4.73
2	1.0	0.10	0.13	0.1737	0.1573	9.44
3	2.0	0.10	0.13	0.1701	0.1528	10.17
4	4.6	0.10	0.13	0.1225	0.1188	3.02
5	5.1	0.10	0.13	0.1182	0.1202	1.69

Table 3. CFD and experimental velocity results using submerged vane

Section No	Location at x direction (m)	Location at y direction (m)	Location at z direction (m)	Experiment Results (m/s)	Fluent CFD Results (m/s)	Error (%)
1	0.0	0.10	0.13	0.1745	0.1858	6.47
2	1.0	0.10	0.13	0.1709	0.1578	7.66
3	2.0	0.10	0.13	0.1673	0.1531	8.48
4	4.6	0.10	0.13	0.1146	0.0964	15.88
5	5.1	0.10	0.13	0.1117	0.0948	15.13

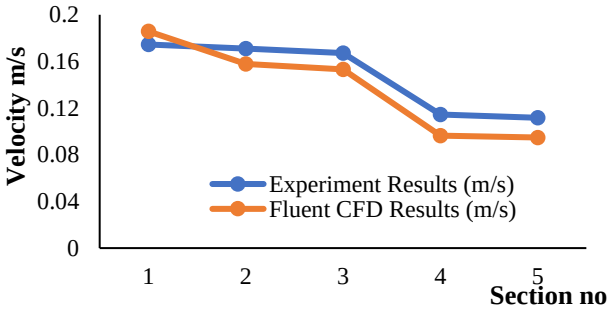

Fig. 6.Examination of in experimental-CFD velocity change results

The velocity distribution in the cross-sections were given Fig. 7. For the cases with and without the vane, the flow and velocity variations are clearly visible in the figures. It has been obtained from numerical models that in the case of the vane, it directs the flow to the side channel and reduces the flow velocity.

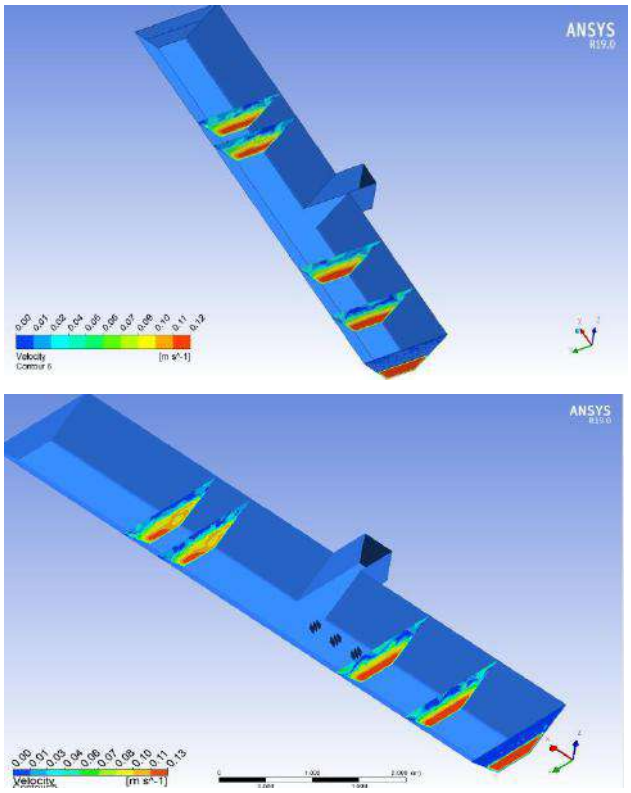

Fig. 7. 5 cross-sectional velocity changes using with no vane (top) and submerged vane (bottom)

IV. CONCLUSIONS

The 3D numerical model of the experimentally studied submerged vane in the open channel was created in this study. The variation of the flow for the cases with and without the Vane was investigated. Numerical model was created for the case with 20° angled Vane in the open channel and compared with the case without Vane. The maximum error between the experiment and the numerical model was found to be between 10-15%. It is seen that the experimental results are compatible with the 3D numerical model. It is thought that such studies can be used in the initial stages of future applications and projects.

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Association of Multi-Drug Resistant Bacteria with Sanitation of Street Vendors Food

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Abstract— *A cross-sectional study was conducted on street-vended food randomly from different areas of Kathmandu Valley to assess the number of viable bacteria in street food, distribution of different bacteria, antibiotics resistance profile of isolated bacteria, Methicillin-resistant S. aureus (MRSA), and Vancomycin-Resistant S. aureus (VRSA) in Kathmandu valley. Altogether 339 isolates were identified from one hundred eighty (180) food samples.The average mean plate count ranges from the highest TMTC to the lowest $3.26*10^8$ CFU/ml. In this study, four different spp. of bacteria were identified from different food samples, among them, Escherichia coli (E. coli) was the most frequent isolate 147(43.36%) followed by Staphylococcus aureus (S. aureus) 120(35.39%), Salmonella spp. 51(15.04%) and Shigella spp. 21(6.19%). S. aureus was susceptible to penicillin (95%) followed by amoxicillin (75%), ciprofloxacin (60%), and nitrofurantoin (57.5%). E. coli was highly susceptible to ciprofloxacin (63.3%) but the Salmonella isolates showed sensitivity towards Amoxicillin which is (76.5%) and Shigella spp. was highly susceptibility towards penicillin (100%) and ciprofloxacin (100%). Distribution of (Multi-Drug Resistant) MDR among total isolates was found to be the highest in Shigella spp. (100%) followed by Salmonella spp. (76.4%), S. aureus (70%) and E. coli (69.38%). Out of 339 isolates, 93 isolates were MRSA and 81 isolates were VRSA, 57 were both MRSA and VRSA. This study showed that the majority of street-vended food items in Kathmandu valley were contaminated with one or more different multi-drug resistant pathogenic bacteria. Therefore, there is a dire need to implement stringent public health measures to mitigate food-borne diseases.*

Keywords— ***Antibiotic Resistance; MDR; MRSA; VRSA; Street Foods; Sanitation.***

I. INTRODUCTION

Street foods, as defined by Food and Agriculture Organization, are ready-to-eatfoods and beverages prepared and or sold by vendors and hawkers in the streetand public places. Street foods are consumed each day by an estimated 2.5 billion people worldwide (FAO, 2007). Preparation and sale of food on street is an old practice in developing countries. Urbanization has augmented the habit of consuming street foods (Tuladhar and Singh, 2012). They are simply eaten as snacks and are an extremely heterogenous food category encompassing drinks, meals, and snacks after being sold from a portable food booth, food cart, or food truck and meant for immediate consumption (FAO, 2007).

In the urban context, the informal sector refers to small enterprise operators selling food and goods or service and thereby involving the cash economy and market transactions to enhance the economy of any country. This so-called "urban informal sector" is more diverse than the rural and includes a vast through which most urban families earn their livelihoods. Street vending is one of the key manifestations of urban poverty, especially in developing countries like Nepal. Now it has become a growing sector of small-scale economic activity due to the lack of alternative sources of income (Bhowmik, 2005). The use of antibiotics,

the spread of antibiotics, and antibiotic resistance in the clinical setting is a well-recognized problem, but antibiotics and antibiotics resistance as environmental problems and pollutants have largely been overlooked. As a result, the increasing incidence of resistance to a wide range of antibiotics by a variety of organisms is a major concern facing modern medicine (Khan et al., 2020). Hospital wastewater can be hazardous to public health and ecological balance since it can contain many and also pathogenic microorganisms (Saud et al., 2019).

Due to the excessive and inappropriate use of antibiotics, there has been a gradual emergence of a population of antibiotic-resistant bacteria, which pose a global public health problem (Birgen et al., 2020). Uncontrolled use of antibiotics by human and animals results in an increase in antibiotic resistance and cause the spread of resistance genes in environmental samples such as hospital wastewater. Studies have demonstrated that hospital wastewater is a highly selective environment and that they contribute to the high rates of resistant bacteria thatare being discharged in the natural environment (Moges et al., 2014). A notorious case is MRSA, which is resistant not only to methicillin but usually also to aminoglycosides, macrolides, tetracycline, and chloramphenicol. Such strains are also resistant to disinfectants, and MRSA can act as a major source of hospital-acquired infections (Nikaido, 2010). MRSA isresistant to entire classes of β-lactams including cephalosporins and carbapenems and has a higher risk of developing of resistance to quinolones, aminoglycosides, and macrolides. However, transferable resistance to vancomycin is now quite common in *Enterococcus* and found its way finally to MRSA in 2002, although such strains are still rare. Another serious threat may be the emergence of gram-negative pathogens that are resistant to essentially all of the available agents (Sivakumar et al., 2019). Bacterial drug resistance is a worldwide problem that is aggravated by the diminishing number of new antimicrobial drugs in the pharmaceutical pipeline (Foster 2004).The effectiveness of currently available antibiotics is decreasing due to the increasing number of resistant strains (Khan and Shah, 2015).

Antimicrobial resistant bacteria can be transferred across by human animal and insect vectors. Pests that develop in decaying organic material may transmit anti-microbial drug resistant bacteria from the manure of animals and other decaying organic substrates to residential settings (Chikere et al., 2008). *Staphylococcus aureus* is an important infectious agent transmitted through various sources including street foods (Lin et al 2018). MRSA is of public health significance; hence the study was taken to assess street foods as a source of MRSA. Large amounts of antibiotics used for human therapy, as well as for farm animals and even for fish in aquaculture, resulted in the selection of pathogenic bacteria resistant to multiple drugs (Adhikari et al., 2017). Multidrug resistance in bacteria may be generated by one of two mechanisms. First, these bacteria may accumulate multiple genes, each coding for resistance to a single drug, within a single cell. This accumulation occurs typically on resistance (R) plasmids. Secondly, multi-drug resistance may also occur by the increased expression of genes that code for multidrug efflux pumps, extruding a wide range of drugs.

The common foodborne pathogens associated with street-vended foods include *Clostridium perfringens*, *E. coli*, *Shigella* species, *Campylobacter jejuni*, *S. aureus*, *Salmonella* species, and *Bacillus cereus*. The prevalent foodborne diseases are also a result of limited training and poor food safety and handling knowledge among the vendors (Birgen et al., 2020). Antimicrobial resistance (AMR) threatens the effective prevention and treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses, and fungi. It is estimated that each year in the United States there are approximately 76 million food-borne illness cases are caused by *Campylobacter* species nontyphoidal *Salmonella*, and pathogenic *E. coli* all colonize the gastrointestinal tracts of a wide range of wild and domestic animals, especially animals raised for human consumption (Hanashiro et al., 2005).

Vendors are often poorly educated, unlicensed, untrained in food hygiene, and they work under crude unsanitary conditions with little or no knowledge about the causes of food-borne disease (Tambekar et al., 2008). In Kenya, approximately 9% of all under-five child deaths are attributable to diarrheal disease. Proper hand hygiene is one of the most effective measures in preventing and controlling the spread of disease. In a recent meta-analysis, hand hygiene was found to reduce diarrheal disease by 31% and respiratory disease by 21% and drying is an important step in the hand-washing process that is often under-emphasized (Mead et al., 2000). *E. coli* is considered a reliable indicator organism of fecal pollution, generally in insanitary conditions of water, food, milk, and other dairy products (Soomro et al., 2002). Cross-transmission of organisms occurs through contaminated hands and using of the same towel. Factors that influence the transfer of microorganisms from surface to surface and affect cross-contamination rates are the type of organism, source and destination surfaces, moisture level, and size of the inoculum (Alanis, 2005). Food handlers, who harbor antibiotic-resistant bacteria in their gastrointestinal tract may contaminate food which is considered as a potential route. MRSA is one of the major human pathogens responsible for mild to serve life-threatening infections worldwide (Zarefel et al., 2014). Harrison and colleagues showed that contaminated hands

could contaminate a clean paper towel dispenser and vice versa. The transfer rates ranged from 0.01% to 0.64% and 12.4% to 13.1%, respectively (WHO Guidelines).

The trend of eating street food is increasing gradually in Nepal. Street food previously consisted of Panipuri and Chatpate while at present, we can find all sorts of Chinese and Indian food here (Bhowmik, 2005). Although there are numerous restaurants offering the same things in the spacious and comfortable station. people through around the small stalls, most of the time standing due tolack of space, in order to fill their appetite. This happens due to the vast difference in cost for them to get attracted to the stalls (Karkey et al., 2013). The growing population of dwellers in Kathmandu has increased the demand for street foods and as such, there has been an increase in the number, and varieties of food sold by vendors. In most places, street foods are sold openly in unhygienic surroundings with houseflies, fruit flies, and dust as the source of contamination. Consumers, on the other hand, have not been aware of the serious problems associated with street foods. Based on the information and the research carried out, it can be presumed that the street food sample may contain pathogenic organisms and is not safe for consumption. Besides all the problems associated with the quality of street foods, there have not been much inspection and control over it by the respective administrative sectors. Therefore, this study was conducted to screen various multi-drug resistant bacteria associated with street food sold in the Kathmandu valley and to develop an understanding of the microbiological aspects of disease factors associated with street vended foods.

II. MATERIALS AND METHODS

Study site

This study was conducted in the microbiology laboratory at the Department of Microbiology in St. Xavier's College, Maitighar, Kathmandu.

Study design

A cross-sectional study was conducted in street-vended food randomly collected from different areas of Kathmandu Valley to examine the microbiological quality.

Sample size

A total of 180 different types of street food samples were collected, each from Drumstick, Samosa, Aloochop, Panipuri, Mo:Mo, and Pakauda from the crossroad, open shops, bus-station, large street markets, and parks of Kathmandu valley.

Duration of study

This study was conducted from November 2019 to March 2020.

Sample transportation and Sampling methods

About 15gm of food was collected from each site in a sterile plastic container and sealed. The samples were then carried to the laboratory for further processing.

Preparation of food homogenate

Ten grams(10g) of each food sample were aseptically weighed and mixed with 90 ml of sterile peptone water and homogenized. Serial dilutions were prepared up to 10^{-10} (Brown, 2007).

Sample processing

Total average plate count

From dilution 10^{-2} to 10^{-10}, 1 ml of diluent was poured in sterile petri plates. About 15ml of molten PCA was added and mixed slowly. The plates were incubated at 37˚C for 24 hours. The colonies were counted and average CFU/ml was calculated (Akter, 2016).

Isolation and Identification of *S. aureus*

About 0.1 ml homogeneous sample from 10^{-1} was aseptically transferred onto the surface of sterile mannitol salt agar media plates and sample was spread all over the plates using a sterile bent glass rod. Then plates were incubated for 24 to 36 hours at 37° C and the plates were examined for *S. aureus* which appeared as small circular and smooth with a shiny surface and golden yellow color.

The isolated organism was picked up and subcultured on the nutrient agar medium plate and incubated at 37°C for 24 hours. After obtaining pure culture, the organism was identified on the basis of its morphological characteristics, Gram staining, and biochemical properties (Akter, 2016).

Isolation and Identification of *E. coli*

About 0.1 ml from 10^{-2}, 10^{-4},10^{-6}, 10^{-8}, and 10^{-10} dilution was aseptically transferred onto the surface of VRBA plates and spread all over the plates using a sterile bent glass rod. Then plates were incubated for 24-36 hours at 37˚C and the plates were examined for *E. coli* which appeared as small and pink colonies.

The isolated organism was picked up and subcultured on Nutrient agar mediumplate and incubated at 37˚C for 24 hours. After obtaining pure culture, the organism was identified on the basis of their morphological, cultural and biochemical characteristics.

Isolation and Identification of *Salmonella* species

About 0.1 ml from 10^{-2} dilution was aseptically transferred onto the surface ofsterile *Salmonella- Shigella* (SS) agar medium plates, and spread all over the plates using sterile

bent glass rod. Then plates were incubated for 24-37˚C and the plates were examined for *Salmonella* species which appeared. Identification of the isolates was done using Catalase test, Oxidase test, Indole tests, Methyl Red test, Voges Proskauer test, Citrate utilization test, Triple Sugar Iron test, Urease test, Sulphide production test and gas production test.

The isolated organism was picked up and subcultured on nutrient agar medium plate and incubated at 37°C for 24 hours after obtaining pure culture the organism was identified on the basis of their morphological characteristics, Gram staining and biochemical properties.

Isolation and Identification of *Shigella* species

About 0.1 ml from 10^{-2} dilution was aseptically transferred onto the surface ofsterile Salmonella- Shigella (SS) agar medium plates, and spread all over the plates using a sterile bent glass rod. Then plates were incubated for 24-37˚C and were examined for *Salmonella* species which appeared.

The isolated organism was picked up and subcultured on nutrient agar medium plate and incubated at 37°C for 24 hours after obtaining pure culture the organism was identified on the basis of their morphological characteristics, Gram staining, and biochemical properties.

Antibiotic sensitivity test by Kirby-Bauer disc diffusion method

Antibiotic sensitivity test was carried out using the Kirby-Bauer disc diffusionmethod. A sterile inoculating loop was used to pick a colony of the isolate and transferred in each of the 5ml normal saline and homogenized properly until it becomes slightly turbid. Turbidity of the suspension was cross-matched with theturbidity standard (0.5 MacFarland turbidity standards). A sterile cotton swabswas dipped into the bacterial test suspension and was used to evenly inoculate the entire surface of the Muller Hinton Agar Plate (MHA). Antibiotic discs such as Amoxicillin, Ciprofloxacin, Nitrofurantoin, Cefoxitin, Vancomycin, Ampicillin, Penicillin, Nalidixic acid, Co-trimoxazole and Chloramphenicol were placed on the surface and press gently using sterile forceps. The plates were incubated inverted for 24 hours at 35˚C. Antibiotic susceptibility was determined after 24 hours by measuring the zone of inhibition in millimeter (Otobo et al., 2018). Isolates which were resistant to 3 or more classes of antibiotics were detected as a Multidrug resistant (MDR) (Magiorakos et al., 2012).

Detection of strains of MRSA by Cefoxitin Disc Diffusion Method

The susceptibility of *S. aureus* isolates to cefoxitin was determined by the modified Kirby-Bauer disc diffusion method following CLSI guidelines. The strains of *S. aureus* which were found to be resistant to Cefoxitin were screened as MRSA.

Detection of VRSA

VRSA was identified using the disc diffusion method. The isolates that were positive cocci, catalase positive, and coagulase-positive were considered *S. aureus.* All the confirmed *S. aureus* was tested for VRSA using oxide antimicrobial susceptibility vancomycin disc (30 µg/disc) by Kirby Bauer disc diffusion method. Muller Hinton agar (MHA) plates were inoculated with the bacterial suspension which was adjusted to 0.5 McFarland standards (Tiwari et al., 2008).

Sterile forceps were used to place the vancomycindisc on the agar plates. The plates were incubated at 37˚C for 24 hours. Zone diameter of bacterial growth inhibition surrounding the disc was measured andcompared with CLSI standard which states that vancomycin is sensitive when zone diameter nearest to whole millimeter is ≥15 (Tiwari and Sen, 2006).

Statistical analysis

The data was analyzed by using MS excel.

Quality monitoring of the laboratory equipment, reagent and media

During the project's experiments, lab incubators, hot air oven, autoclave, etc. were regularly monitored for their performance. The date of expiry of each reagent and biochemical media were checked before preparation and after preparation, each of the media and reagent were labeled properly and stored at suitable condition. Sterility testing of the biochemical media was also performed at each batch of the media prepared.

Hygiene Practices of food vendors during food preparation

Hygiene was observed under the following criteria at Vending site: Personal hygiene of street vendors, Cleanliness of utensils, and the overall environmental conditions nearby vending area as mentioned in the table below.

Y=yes, all the time; N=No, not at all

Vendor	Hairnets	aprons	Gloves	Store food at the correct temperature	Cover food	Clothes clean/ not	Utensil clean before use
1.	N	Y	Y	N	Y	Y	Y
2.	Y	Y	Y	N	Y	Y	Y
3.	N	N	N	N	N	N	Y
4.	N	N	N	N	N	N	Y
5.	N	N	Y	N	Y	N	Y
6.	N	Y	Y	N	Y	Y	Y
7.	N	N	N	N	Y	Y	Y
8.	Y	Y	Y	N	Y	Y	Y
9.	N	Y	Y	N	N	Y	Y
10.	Y	N	N	N	Y	N	Y

III. RESULTS

Total plate count of street food samples.

This study suggests a high total plate count in street foods of Salinadi and Ratnapark which was TMTC followed by Maitighar (mean coliform count = 6.27×10^8) and Balaju (5.77×10^8) respectively. Furthermore, the total plate count in all the samples was high i.e. TMTC except in Pakauda which was $30.21x10^8$ cfu/ml.

Table 1: Total plate count of street food samples.

Location	Sample						Average
	Drumstick	Samosa	Aloochop	Panipuri	Momo	Pakauda	
Kalanki	3.7×10^8	6.71×10^8	2.7×10^8	9.53×10^8	5.7×10^8	3.86×10^8	5.36×10^8
Maitighar	7.13×10^8	7.94×10^8	6.41×10^8	5.42×10^8	3.7×10^8	6.90×10^8	6.27×10^8
Balaju	5.8×10^8	6.1×10^8	6.6×10^8	5.4×10^8	6.9×10^8	6.9×10^8	5.77×10^8
Salinadi	TMTC	TMTC	TMTC	TMTC	TMTC	Nil	TMTC
Ratnapark	TMTC	TMTC	TMTC	TMTC	TMTC	Nil	TMTC
Newroad	3.82×10^8	7.1×10^8	2.8×10^8	7.6×10^8	3.7×10^8	3.7×10^8	3.97×10^8
Koteshwor	4.9×10^8	4.0×10^8	6.8×10^8	7.0×10^8	4.4×10^8	4.4×10^8	4.66×10^8
Subedanagar	Nil	Nil	Nil	9.66×10^8	Nil	Nil	9.66×10^8
Tinkune	6.0×10^8	4.0×10^8	6.8×10^8	7.0×10^8	4.4×10^8	4.4×10^8	4.83×10^8
Gongabu	2.5×10^8	3.9×10^8	3.4×10^8	3.1×10^8	2.8×10^8	2.8×10^8	3.26×10^8
Total	TMTC	TMTC	TMTC	TMTC	TMTC	$30.21x10^8$	

Growth profile of bacteria according to food samples.

A total of 339 bacterial colonies were isolated from 6 different foods collected from 10 different sites in the Kathmandu district. Overall, *E. coli* was the most predominant bacteria in street foods of Kathmandu followed by *S. aureus*, *Salmonella* species, and *Shigella* species. Our study also found that all samples of Panipuri were contaminated with *E. coli*.

Table 2: Growth profile of bacteria according to food sample

Name of foods	No. of Sample	Bacterial Isolates			
		E. coli	*S. aureus*	*Salmonella*	*Shigella*
Panipuri	30	30 (20.41%)	27 (22.5%)	9 (17.65%)	9 (42.86%)
Aloochop	30	27 (18.37%)	27 (22.5%)	9 (17.65%)	0
Pakauda	30	24 (16.33%)	24 (20%)	6(11.76%)	3 (14.29%)
Drumstick	30	24 (16.33%)	12 (10%)	6 (11.76%)	6 (28.57%)
Mo:Mo	30	18 (12.24%)	9 (7.5%)	12 (23.53%)	3 (14.29%)
Samosa	30	24 (16.33%)	21 (17.5%)	3 (5.88%)	0
Total	180	147	120	51	21

Antibiotics susceptibility pattern of the isolated *S. aureus*

S. aureus showed sensitivity to penicillin (95%) using agar disc diffusion method followed by Amoxycillin, Ciprofloxacin, Nitrofurantoin, Ampicillin, Vancomycin, Cefoxitin with 75%, 60%, 57.5%, 32.5%, and 22.5% respectively.

Table3: Antibiotics susceptibility pattern of S. aureus

Antibiotic used	*S. aureus* (n= 120)			
	Sensitive		Resistant	
	N	%	N	%
Ciprofloxacin	72	60	48	40
Nitrofurantoin	69	57.5	51	42.5
Cefoxitin	27	**22.5**	93	77.5
Vancomycin	39	32.5	81	67.5
Ampicillin	45	37.5	75	62.5
Amoxycillin	90	75	30	25
Penicillin	114	**95**	6	5

Antibiotics susceptibility pattern of *E. coli*

E. coli isolates showed higher sensitivity towards Ciprofloxacin 93(63.3%), followed by Amoxicillin 81(55.1%) Nitrofurantoin 69(51.0%), Co-trimoxazole 57(38.8%), Cefoxitin 57(38.8%) and Nalidixic acid 45(30.6%).

Table:4 Antibiotics susceptibility patterns of E. coli

Antibiotics	**E. coli (n= 147)**			
	Sensitive		Resistant	
	N	%	N	%
Amoxicillin	81	55.1	66	44.9
Ciprofloxacin	93	63.3	54	36.7
Nitrofurantoin	75	51.1	72	48.9
Cefoxitin	57	38.8	90	61.2
Co-trimoxazole	57	38.8	78	53.1
Nalidixic acid	45	30.6	102	69.4

Antibiotics susceptibility pattern of *Salmonella* species

Among the six antibiotics tested against the isolates, *Salmonella* isolates showed highly sensitivity to Amoxicillin which is 76.5% followed by Nalidixic acid, Cotrimoxazole, Ciprofloxacin, Cefoxitin 70.6%, 52.9%, 47.1%, 5.9% where as 100% resistivity was shown by Nitrofurantoin.

Table 5: Antibiotics susceptibility patterns of Salmonella species.

Antibiotics	*Salmonella* spp (n= 51)			
	Sensitive		Resistant	
	n	%	N	%
Amoxicillin	39	**76.5**	12	23.5
Ciprofloxacin	24	47.1	27	52.9
Nitrofurantoin	0	0	51	**100**
Co-trimoxazole	27	52.9	24	47.1
Nalidixic acid	36	70.6	15	29.4
Cefoxitin	3	5.9	48	94.1

Antibiotics susceptibility patterns of *Shigella* spp.

Among the six antibiotics used for antibiotics susceptibility tests, *Shigella* isolates show 100% sensitivity to Amoxicillin and Ciprofloxacin whereas 100% resistivity to Nitrofurantoin, Nalidixic acid, Co-trimoxazole, and Chloramphenicol. All *Shigella* spp. were sensitive to Amoxicillin and Ciprofloxacin.

Table 6: Antibiotics resistivity pattern of Shigella spp.

Antibiotic used	*Shigella* spp. (n= 21)			
	Sensitive		Resistant	
	n	%	N	%
Amoxicillin	21	**100**	0	0
Ciprofloxacin	21	**100**	0	0
Nitrofurantoin	0	0	21	**100**
Co-trimoxazole	0	0	21	**100**
Nalidixic acid	0	0	21	**100**
Cefoxitin	0	0	21	**100**

Distribution of multidrug resistance bacteria among total isolates

The overall prevalence of MDR (resistance to <2 classes of antimicrobial agents). The higher rate of MDR was observed in *Shigella* spp. (100%) followed by *Salmonella* spp. (76.4%), *Staphylococcus aureus* (70%) and *Escherichia coli* (69.3%).

Table 7: Distribution of multidrug resistance bacteria among bacterial isolates

Bacteria Isolated	Multidrug resistant	Non multidrug resistant
E. coli	102 (69.3%)	45(30.61%)
Salmonella spp.	39 (76.5%)	12(23.53%)
Shigella spp.	**21(100%)**	0
S. aureus	84 (70%)	36(30%)

Prevalence of MRSA and VRSA among total isolates

Out of total bacteria strain of *S. aureus*, 93(53.5%) were MRSA, 81(46.6%) were VRSA and 57(32.8%) were both MRSA and VRSA

Table 8: Prevalence of MRSA, VRSA, and both MRSA and VRSA

Bacterial isolates	**Numbers (%)**
Methicillin resistance S. aureus (MRSA)	93(53.5%)
Vancomycin resistant S. aureus (VRSA)	81(46.6%)
Both MRSA and VRSA	57(32.8%)

Distribution of multidrug resistant bacteria based on types of foods.

Out of 339 bacteria isolated obtained from six street food samples. The MDR were observed in Panipuri sample 51(68%), followed by Drumstick 45(83.3%), Aloochop 42(66.7%), samosa 36(14.6%) and Mo:Mo 30(71.4%).

Table 9: Distribution of multidrug resistant bacteria based on type of foods.

Name of Foods	No. of MDR		No. of Non-MDR	
	n	%	n	%
Panipuri	51	68	24	32
Aluchop	42	66.7	21	33.3
Pakauda	42	73.7	15	26.3
Drumstick	45	83.3	9	16.7
Mo:Mo	30	71.4	12	28.5
Samosa	36	75	12	25

Distribution of MRSA based on sanitation.

When a relation was statistically determined between growth of MRSA bacteria and poor sanitation, unhygienic and inadequate sanitary situation, it was found statistically insignificant (p-value 0.7432). There was no association between sanitation condition with growth of MRSA bacteria.

Table 10: Distribution of MRSA based on sanitation

Sanitation	No. of MRSA		No. of non-MRSA		P value
	n	%	n	%	
Hygienic	18	75	6	25	0.7432
Unhygienic	75	78.12	21	21.88	

Distribution of VRSA based on sanitation

The relation between MDR with hygienic and non-MDR with hygienic condition was also statistically insignificant.

Table11: Distribution of VRSA based on sanitation

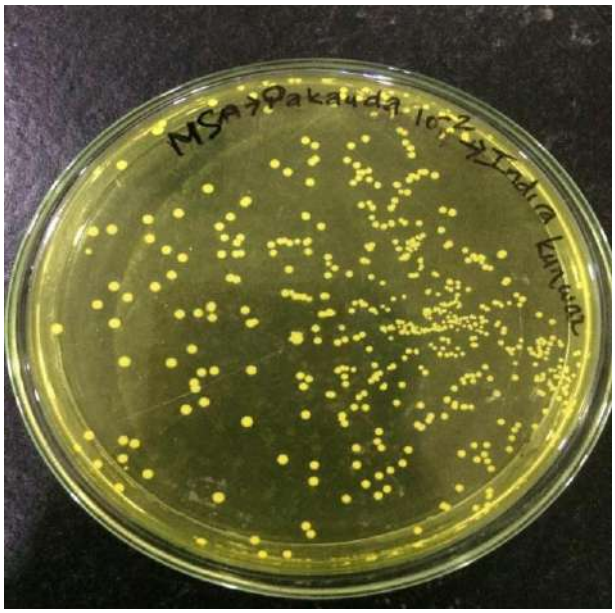
Sanitation	No. of VRSA		No. of non-VRSA		P value
	n	%	n	%	
Hygienic	15	62.5	9	37.5	0.5594
Unhygienic	66	68.8	30	31.3	
Total	81		39		

Distribution of multidrug-resistant bacteria based on sanitation.

The relation between MDR with the hygienic and non-hygienic conditions was statistically insignificant.

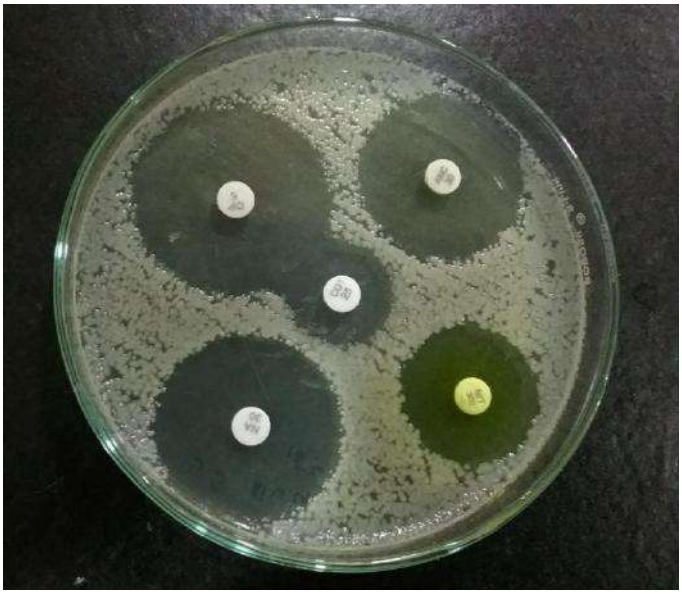
Table12: Distribution of multidrug resistance bacteria based on sanitation

Sanitation	No. of MDR		No. of non-MDR		P value
	n	%	n	%	
Hygienic	45	75	15	25	0.7432
Unhygienic	201	72.04	78	27.9	
Total	246		93		

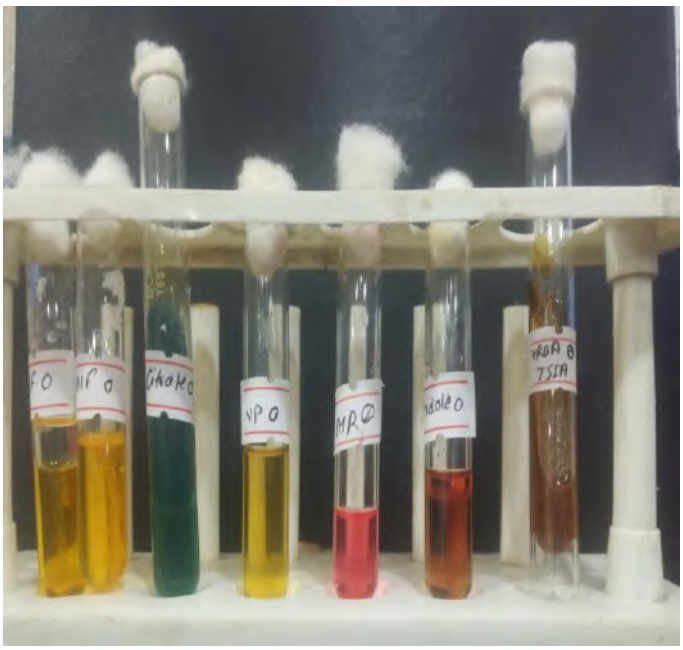


Photograph 1: Growth of S. aureus on MSA

Photograph 2: E. coli on Nutrient Agar



Photograph 3: AST of E. coli



Photograph 4: Biochemical test set of E. coli

IV. DISCUSSION

E. coli, *S. aureus*, *Salmonella*, and *Shigella* are often used as indicator organisms in determining the hygiene level of food handling practices (Walters et al., 2011). At present time, street food vending has become a major community health issue and matter of concern for all of us. A lot of food-borne disease outbreaks are occurring every year worldwide. The reasons behind this include a lack of appropriate knowledge and supervision on street food vending, preparation of food under insanitary conditions, and displaying food openly which also lead to further contamination by dust, insects, rodents, and hands of intending consumers.

In this study, altogether 180 street food samples were processed from which 339 isolates were obtained from the samples. When a total count was performed on the PCA agar plate except very few from Mitranagar samples. All other samples are found to contain microorganisms. The study by Raj Bhandari (2014) in Kathmandu reported that all the samples gave a positive PCA count which coincides with the finding of this study. In a study by Mensh et al., (2002), Ghana reported 69.7% positive, out of a total of 511 samples with a positive total count. Another study by Umoh and Odoba (2000) on Nigerian street foods, has reported 26% out of 160 samples with positive growth. In another

study in west India, 100% samples of hamburger patties were found to contain growth (Badrie et al., 2004).

This is an indication that the presence of organisms is common in street foods but that varies with the place and the practice of vendors. When the individual organisms were enumerated in our sample using selective media it was found that *E. coli* and *S. aureus* were found in the highest number. They were found to be present in all locations as very few in mitranagar. In each category of the food samples, individual organisms (*Salmonella*, *Shigella*, *S. aureus*, *E. coli*) were enumerated. During the total plate count, it was found that different food samples contain the different microbial load. Among the enumeration of microbial loads according to different location food, samples of Salinadi and Ratnanagar were found to have the highest number of organisms i.e. TMTC. Further, the lowest average plate count was found in Gongabu samples i.e. $3.26x10^8$ cfu/ml.

In this study of the distribution of bacteria among different food samples, four bacterial spp. were identified. Among them, *E. coli* 147(43.4%), *S. aureus* 120(35.4%), *Salmonella* 51(15.0%), and *Shigella* 21(6.2%) etc. were the common isolates *S. aureus* and *E. coli* were the major contaminants in the street food samples. Daniels and colleagues (2002) conducted a study in the United States, to describe the epidemiology of food-borne illness outbreaks in schools, colleges, and universities. The data from January 1, 1973, to December 31, 1997, was reviewed and found that in majority (60%) of the outbreaks the etiology was unknown. Among the outbreaks with a known etiology, 36% of outbreak reports *Salmonella* was the most commonly identified pathogen. However, the highest mortality was caused by *Listeria monocytogenes*. Viral pathogens were responsible for 33% of the outbreaks. Among the viral 41 pathogens, norovirus was the most common causative agent.

In another study by Yadav et al., (2019) in Dhanusha, the highest bacterial sample was *S. aureus* 38(45.23%) and *E. coli* 32(38.09%) followed by *Salmonella* spp. 26(30.95%), *Pseudomonas* spp. were 18(121.42%). This study also suggests that bacterial contamination is because of the conditions under which it is prepared and vended. In most of the cases running water is not available at vending sites and thus hand and dishwashing is usually done in buckets and sometimes without soaps *E. coli* spp., *Staphylococcus* spp., *Salmonella* spp., *Shigella* spp. could be due to inadequate hand washing by food workers and the absence of good manufacturing practices crowded areas have a greater number of pathogens than non-crowded areas.

The antibiogram assay of the isolated organism was performed and it was found that *S. aureus* was found to be sensitive to the following antibiotics: Amoxicillin, ciprofloxacin, Nitrofurantoin, and penicillin while it was resistant to Cefoxitin, vancomycin, ampicillin. Out of the 6 antibiotics tested against *E. coli*, it was found that it was more susceptible to Amoxicillin, Ciprofloxacin, Nitrofurantoin while resistance to Nalidixic acid, Co-trimoxazole, and Cefoxitin. Similarly, *Salmonella* was found to be susceptible to Amoxicillin, Nalidixic acid, Co-trimoxazole and was found resistant to Ciprofloxacin, Chloramphenicol, with maximum resistance to 100% to Nitrofurantoin. In a study by Van et al. (2007) in Vietnam the author reported that 50.5% of the Salmonella isolates were found to be resistant to at least one antibiotic, while multidrug resistance was detected in 20.9% of *Salmonella* isolates and in 61.6% of *E. coli* isolates. In another study by Watkinson et al, 2007 in Austria, 59% of the *E. coli* and 25% of *Shigella* isolates were multidrug resistants. In case of *Shigella* spp. it was found that *Shigella* spp. was 100% sensitive to Amoxicillin and Ciprofloxacin while showing 100% resistance to Nitrofurantoin and Nalidixic.

All the samples were subjected to total coliform enumeration over VRBA media and it was found that 147(81.66%) were found to contain *E. coli* from ten different busy streets where the study was done by Mensah et al. (2002). 5.5% of the samples were positive for *E. coli* and in the study done by Badrie et al. (2016). In another report by Bhaskar et al. (2004) in Mangalore, out of the 60 food samples, 35% were found to contain *E. coli.* Similarly, a study done by Van et al. (2007) in Vietnam, has reported *E. coli* was present in more than 90% of all food sources. These data from different places at different times indicate that coliforms, mainly *E. coli* was one of the common contaminants of street foods. This may indicate that the patterns of street food treatments are similar in those places or that the food is processed with little knowledge of hygiene.

However, it is hard to draw a direct comparison with the results of these studies due to differences in the antibiotics investigated, the level of bacterial contamination and the therapeutic drug practices in the study areas, and the food preparation and preservation practices employed. This study opens a few studies like the efficiency and effects of food preserved that is used by the vendors, the type and quality of water used to prepare the foods, the level of hygienic practices of handling food, and also the prevalence of disease that may have been contributed by consumption of street food. Further, the ubiquity of pathogenic organisms along with *E. coli* in street food samples is an indication and question of where our food safety practices stand.

The number of MRSA detected was 93 (53.45%), VRSA was found to be 81(46.55%) where 57(32.76%) were found

to be both. Out of 339 bacterial isolates obtained from six street food sample, the highest MDR were observed in Panipuri sample 51(68%) followed by drumstick, Aloochop, Samosa, and Mo:Mo. The majority of the vendors were found to serve with ungloved hands in our study. The higher amount of organisms in steamed food such as Mo:Mo as detected in this study might be due to the unhygienic nature of utensils used to serve it and the surrounding of the shop. A similar study done by Bantawa et al. (2019), has reported the number of MRSA detected was 93(53.45%), VRSA were found to be 81(46.55%). *S. aureus* in the food samples might be from direct human interaction, such as skin and diseased cuts or indirectly through tools (Bantawa et al., 2019). When a relation was statistically determined between the growth of MRSA, VRSA, and poor sanitation, unhygienic and inadequate sanitary condition. It was found statistically insignificant with a p-value. There was no association between sanitation conditions with the growth of MRSA and VRSA bacteria. So, MDR and MRSA may be due to contamination of hospital waste material or contaminates in patient care equipment (stethoscope, blood, pressure cuff). So, there should be dedicated medical equipment for a single patient with MRSA Shared equipment should be cleaned and disinfected before using it with another patient and medical wastage should be discarded after proper sterilization.

Resistance to antimicrobial drugs causes increased mortality and morbidity due to infectious diseases. Antibiotic resistance becomes a major worldwide problem. In recent days, these issues are generally considered public health problems and have a significant effect on health. The problem of bacterial resistance to antimicrobial drugs is more troublesome in developing countries like Nepal.

This study was performed in proper lab conditions, however, the exact identification of the isolated organisms by conventional method is not highly reliable and the use of molecular identification technology could have improved the study. This study is neither representative of the whole population of organisms present in the street foods nor or the entire street food consumed in Kathmandu.

V. CONCLUSION AND RECOMMENDATIONS

This study concludes that the street foods in Kathmandu are readily contaminated with bacteria. Hence, there is a necessity for strict surveillance of the microbial safety of street foods. There should be public involvement projects for public awareness against the consumption of low-quality and unhygienic street foods in Kathmandu valley. The findings in this study emphasize the importance of studying multiple genera of bacteria from different foods as sources of human exposure to antibiotic-resistant strains. Most street vendors were illiterate and they did not have clear hygienic knowledge about the preparation, storage, and serving of the food. So street vended ready-to-eat foods should be manufactured under Good Hygienic Practices (GHPs) and preservation practices should be developed in order to minimize the microbial contamination of food. In addition to this, the arising socio-environmental problems are also issues. This study also concludes that the presence of *Escherichia coli* in a food sample is strong evidence that it is also contaminated with other potential pathogens. There is a need to screen other varieties of street food products to screen and identify a variety of organisms other than bacteria that may be a cause of several diseases.

On the basis of the conclusion, the following recommendations are suggested:

- The processing of food should be done with proper hygiene so that contamination can be curtailed.
- Vendors are suggested to use new sterile pair gloves on each preparation and maintain hygiene properly. There is also a need for consumer awareness regarding freshness, quality, and hygienic environmental conditions.
- Lastly, the concerned Government authorities should periodically check and monitor the preparatory conditions of the shops/stalls in order to maintain the quality of the street foods.

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Evaluation of the cross-pollination in maize (*Zea mays* L.) synthetic varieties grown in the High Guinean savannah zone conditions

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Abstract— *In Cameroon, maize is the most widely cultivated cereal and is consumed by more than one third of the population. This study aimed to evaluate in the tropical conditions the cross-pollination rate in four recipient synthetic maize varieties by xenia phenomenon depending on distance to the pollen source and wind direction. The experimental design was triplicated split plot with each replication arranged as a 576 m^2 Latin square area. The combined analysis of variance showed a highly significant effect ($p<0.001$) of the gap from pollen source and wind direction on the cross-pollination rate of the recipient varieties. CMS 8704 yellow-grain variety which is the pollen donor and the white grain receiver cultivars CMS 2019, CMS 8501, CMS 9015 and Shaba had one to seven days' difference between the female flowering of the recipient variety and the start of male flowering of the donor. These synthetic varieties differed significantly for the number of leaves per plant, the 100-seeds weight, the plant height, and total kernels weight per plant, with cultivar Shaba showed the highest values. The highest cross-pollination rates were found in the first maize rows facing the donor field and the genetic pollution decreased with increasing distance from the donor source. At the same distance from source, the pollution level higher the North. The implementation of appropriate separation distance (>10 m) is recommended for reducing genetic pollution and ensuring coexistence of different genotypes in maize production field.*

Keywords— ***Cameroon, Cross-pollination, Genetic pollution, High Guinean savannah, Maize.***

I. INTRODUCTION

Maize (*Zea mays* L., 2n=20.) is the most cultivated plant in the world and the first cereal that enters in the diet before wheat (Garcia-Lara and Serna-Saldivar, 2019). It is a versatile multi-purpose crop, primarily used as a feed globally, but also is important as a food crop, especially in sub-Saharan Africa and Latin America, besides other non-food uses (Grote *et al*., 2021). The maize-distilling process has long been used by industry for the production of beverage alcohol. Maize thereby plays a diverse and dynamic role in global agri-food systems and food/nutrition security (Poole *et al*., 2021). Improved maize germplasm plays a prominent role in the advent of maize across the global agri-food system (Brouwer *et al*., 2020). Genetically modified (GM) maize is the second most important GM crop following soybean (Willet *et al.*, 2019). The world's total maize production was estimated at 1.05 million thousand tons in 2020 (Erenstein *et al*., 2022). Maize production of Cameroon was estimated at 2.200 thousand tons in 2020 (FAO, 2021). The current production level of maize in the country is declining and to meet consumption requirements, huge quantities of the commodity are imported (Mvodo Meyo and Mbey Egoh, 2020).

Maize is predominantly cross-pollinated with anemophily as the general rule. Maize is a wind-pollinating crop with about 95% cross pollination (Devos *et al*., 2007). Pollination with insects also takes place to certain extent (Klein *et al.*, 2007). The adaptation for cross-pollination are monoecious inflorescences, unisexual flowers, differences in time of maturity of the male and female inflorescence, silk receptive on entire length and abundant pollen production (Brittan, 2006). The intensification of maize production in order to reduce the food deficit in the face of galloping demographics requires an acceleration of the creation of new, better performing and better adapted varieties. Hybrid maize requires new materials for every crop to maintain its potential and proved a particularly viable and attractive business model for the seed industry (Morris *et al.,* 2003). In sub-Saharan Africa, the development of improved open pollinated varieties (OPVs) and synthetic varieties were recommended to smallholder farmers for their performance, and their seed-recycling potential (Morris *et al*., 2003). Composite or synthetic seeds are the most appropriate for developing countries because they give farmers the possibility to renew the seed from their harvests in addition to their productivity. However, the stability of composite varieties depends in part on the level of genetic pollution which is the accidental transfer of genes between genotypes through inter-pollination (Tsai and Tsai, 1990).

Cross-pollination studies between adjacent maize fields have been conducted all over the world using mainly a color marker system (Messeguer *et al*., 2006; Njountie Tchiengue, 2010). The main focus of these studies was to gather information about adequate separation distances to ensure coexistence and about the dependence of cross-pollination on the distance within maize fields. Several studies have been performed to evaluate the impact of pollen drift from fields containing GM corn to neighboring non-GM cornfields (Byrne and Fromherz, 2003; Devos *et al*., 2005; Weber *et al*., 2007; Njontie Tchiengue, 2010; Viorica *et al*., 2017). The accidental gene flow is more pronounced under the conditions of peasant agriculture, where crop plots are close together and sometimes several varieties are grown in the same plot. The cultivation of maize in Cameroon is predominantly dominated by smallholder farmers who use traditional methods and face drudgery. The effect of genetic pollution on maize can have many consequences in particular considerable variation in vigor as well as seed yield and its components (Denney, 1992). Understanding pollen mediated gene flow is also important to achieve the coexistence measures for farming with and without genetically modified and conventional maize (Messeguer *et al*., 2006; Njountie Tchiengue, 2010). Cross-pollination is affected by many factors inducing distance between donor and recipient fields, wind direction, wind speed, flowering synchronization between donor and recipient plants, field topography, size and orientation of donor and recipient fields, pollen velocity, weather condition like any temperature and air humidity (Devos *et al*., 2005; Vogler *et al*., 2009). Most of pollen settles within 06 to 15 m of the donor plant (Brittan, 2006). The main purpose of the present study was to evaluate on some synthetic maize varieties grown in Dang (Adamawa-Cameroon) the pollen mediated gene flow depending on source-recipient distance and wind direction.

II. MATERIAL AND METHODS

2.1 Study area

The study was carried out from 2020 to 2021 at the University of Ngaoundéré experimental farm, at Dang (Ngaoundéré 3rd subdivision, Adamawa region, Cameroon), which is intersected by 7° 26' 16 4" North latitude and 13° 33' 34" East longitude and has 1115 m above the mean sea level. This region belongs to the Guinea High Savannah agroecological zone (Djoufack *et al.*, 2012). The climate is of the Sudano-Guinean type characterized with a humid trend, an average annual rainfall of 1480 mm distributed over the rainy season (March-October), and a dry season (November-March). The average annual temperature is 22.59°C, while the relative humidity is about 66.47%. The soil in the area is mostly ferruginous type developed on old basalt and has a brown reddish clay texture. There is an immense dependence of agriculture productivity on soil physicochemical properties (Nanganoa *et al*., 2020).

2.2 Plant material

The plant material used consisted of five composite maize cultivars adapted to the Guinea High Savannah agroecological zone, comprising a yellow grain (CMS 8704) using as pollen donor and four recipient white grain (CMS 9015; CMS 8501; CMS 2019; CMS 8806 and Shaba (Table 1). The seeds were obtained from the Institute of Agricultural Research for Development (IRAD, Garoua station, Cameroon).

Table 1. Characteristics of the tested synthetic maize varieties.

Varieties	Cycle (days)	Tasseling (days)	Days to female flowering	Seed color	Seed texture
CMS 2019 (receiver)	110 -115	58 - 60	61 – 64	White	Horned
CMS 8501 (receiver)	105 -110	55 - 58	59 – 62	White	Toothed
CMS 8704 (donor)	105 -110	57 - 59	58 – 61	Yellow	Horned
CMS 9015 (receiver)	90 – 95	55- 58	58 – 62	White	Toothed
SHABA (receiver)	110 – 130	61 - 65	64 – 69	White	Toothed

2.3 Field trials

During the growing season 2020, the sowing was done simultaneously, for the donor and for the pollen receiver's varieties. The experiment was laid out in a triplicated split plot design consisting of eight source-recipient distances (main treatment), four sub-treatments (wind directions), with each replication arranged as a 576 m^2 Latin square area (24.0 m x 24.0 m) (Fig. 1). In the experimental field the three blocks were spaced 120.0 m each other to avoid cross-fertilization. In the center of each square, CMS 8704 yellow-grain variety which is the pollen donor was sown inside an area of 16 m^2 (4 m length x 4 m broad). Recipients white varieties were sown each on an experimental unit consisting of one row of 4.0 m length, respectively at 1.5 m, 2.5 m, 4.0 m, 5.0 m, 6.5 m, 7.5 m, 9.0 m and 10.0 m from the pollen-donor source. Three seeds were sown per hill and one seedling was retained after thinning. Recipient varieties were sown in four different wind orientations (West, East, South and North). Maize plants were spaced 25.0 cm for receiver's plots and 40.0 cm for donor plots. All recommended agricultural practices were adopted throughout the field trials, except the application of pesticides. NPK (20% N, 10% P_2O_5, 10% KO_2) and urea (46% N) fertilizers were applied to the soil at 20 and 45 days after sowing respectively. Regular manual weeding was carried out during the vegetative phase and at flowering. At maturity, a total of 10 plants were randomly selected in each row of the recipient field for the evaluation on cross-pollination rate. On each selected plant, their main ear was collected, and the kernel number determined by counting separately white and yellow grains.

2.1 Characterization of maize genotypes

The characterization of the five synthetic varieties used in the study was done by randomly selecting 20 plants per genotype in each of the replications (five plants for each direction). The experimental design is a triplicated non randomized complete block design. Four characters selected among the maize descriptors were retained: the height of the plant (HP), the number of leaves per plant (NLP), the total kernel weight per plant (KWP), the seeds index or 100-seeds weight (SI) and the difference between the female flowering on recipient's varieties and the start of male flowering of the donor. The time difference between male and female flowering of a single plant is called anthesis-silking interval (ASI). In the case of cross-pollination, the difference in days between the female flowering of the recipient variety and the start of male flowering of the donor is ASI2 (Devos *et al*., 2005). The number of leaves per plant was obtained by manual counting on the sample of 20 plants per variety randomly selected during the flowering. The height of the plant was measured using a graduated decameter. The total kernel weight per plant and the 100-seed mass were determined using an electronic balance of 0.001g sensitivity (Sartorius Prodilab).

2.2 Evaluation of genetic pollution rate

The donor maize was a yellow grain (dominant trait) cultivar CMS 8704 and the recipient maize was white grain (recessive trait) cultivars CMS 2019, CMS 8501, CMS 9015 and Shaba. This would enable us to easily distinguish intra-cultivar pollinated and inter-cultivar pollinated grains through xenia phenomenon as recommended by Denney (1992). The xenia usually refers to a situation in which the genotype of the pollen donor influences the maternal tissue of the fruit so as to produce a phenotypically demonstrable effect upon the seed grains of the recipient. When the ovules of the recipient varieties were fertilized with the pollen of the yellow grain variety, the grains obtained appeared yellow, thereby displaying the xenia effect. Cross-pollination was investigated by the presence of yellow-grains on white-grain varieties at distance up to 17.5 m from the yellow-grain pollen (Vogler *et al*., 2009). By counting the grains showing xenia among the total grains per ear of a recipient, we could easily estimate the cross-pollination rate (P) from the following formula:

$$P = \frac{\text{Number of yellow grains}}{\text{Total number of grains}} \times 100$$

With P: the cross-pollination rate in percentage

2.3 Statistical analysis

Data obtained were subjected to the analysis of variance (ANOVA) using Statgraphics Plus Version 5.0 software. Differences in means performance were tested using the Least Significant Difference (LSD) or by the Student's t-test at 5% level of probability. Pearson linear correlation coefficient was used to assess the relationships between cross-pollination rate and distance from the source of pollen.

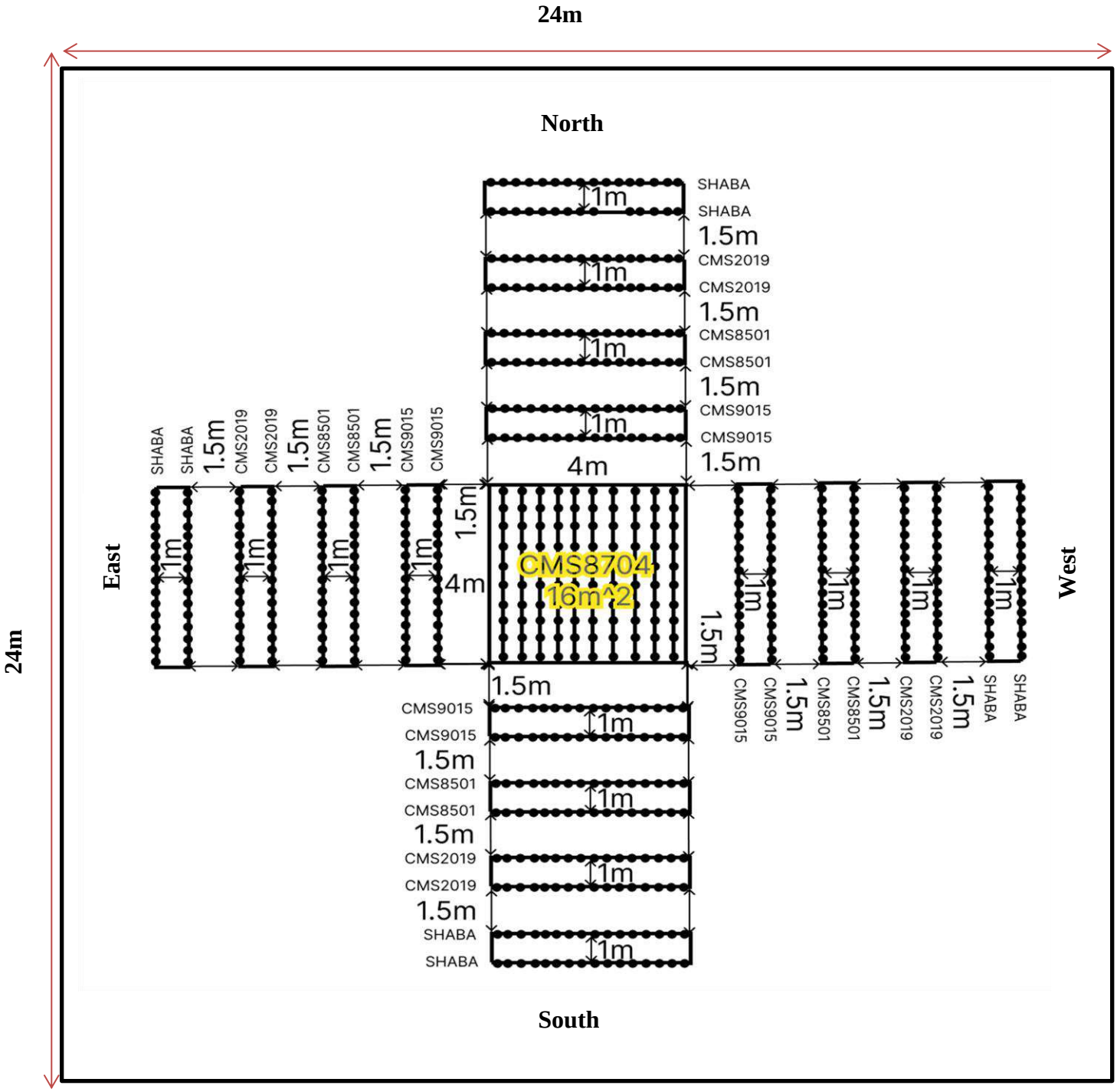

Fig. 1: Experimental layout representing pollen receiver varieties around the donor variety according to the four cardinal points (wind direction).

III. RESULTS AND DISCUSSION

3.1 Variability of tested maize varieties

The analysis of variance showed significant variability ($p<0.05$) among the five maize varieties for plant height, number of leaves per plant, seed index and the total weight of kernels per plant (Table 2). The average plant height varied from 183.0 cm (CMS 8501) to 272.21 cm (Shaba) with a mean of 207.23 cm. The height the yellow donor was slightly greater than those of the white receptor plants except Shaba. Similar results were obtained by Vogler *et al*. (2009) showing that maize height varied between 219 cm and 250 cm for improved varieties. In contrast, Viorico *et al*. (2017) in Romania observed that some improved maize varieties had tallest height.

For the number of leaves, the highest value was noted for popular Shaba cultivar (16.20 leaves) while the lowest was 14.74 leaves (CMS 8501). The stem of maize is commonly composed of 20 internodes and the leaves arise from these nodes. The number of leaves per plant noted in this study at flowering was in agreement of reports of Sangoi and Salvador (1997). The number of leaves per plant seemed to increase with the size of the plant. Plant height is a good indicator to evaluate plant growth and grain yield. The dynamic of plant height during the growing cycle could be used to access critical genetic traits, fundamental plant physiology and environmental effect. The vertical distribution of leaf is important for the analysis of photosynthesis, stress resistance and pollen propagation.

Total kernel weight per plant varied from 154.14 g (CMS 9015) to 204.18 g for Shaba with an average of 169.95 g. Drienovsky *et al.* (2019) recorded a total kernel weight per plant of 144 g to 357 g on improved varieties of maize and noted that the weight of grains could be predicted on the length of ear based on the linear equation $y = 22.5x - 156.9$. The 100-seeds weight ranged from 29.11 g for yellow grain donor variety CMS 8704 to 49.64 g for Shaba with an average of 35.72 g (Table 2). The seed index values recorded in this study were greater than values recorded by Inamullah *et al*. (2011) on maize hybrids. The variability noted for these traits could be due to the genetic diversity and environmental conditions under which the trials were conducted. There is genetic variability within cultivars for most of the agro-morphological traits. The creation and maintenance of growth and developmental homogeneity within maize population is essential.

The synchronization between of the start of male flowering of the donor variety CMS8704 and female flowering of the four white grain recipients ranged from one to seven days (Table 2). As the synchronization of yellow male flowering and white female flowering was much closer than the flowering of white male and female plants except for Shaba, cross-pollination could be expected to be unusually high (Aylor *et al*., 2003) However, rates of cross-pollination were in the expected range (Ma *et al*., 2004; Messeguer *et al*., 2006; Bannert and Stamp, 2007; Della Porta *et al*., 2008). The ASI2 depends on the genotype and environmental factors like water deficit, nutrient light and temperature (Devos *et al*., 2005). The difference in sowing dates may influence the flowering times, and limiting cross-pollination. Synchronization between donor and receiver of pollen is very important for inter-crossing between varieties.

Table 2. Genetic variability of some characteristics of tested maize varieties

Variety	**Parameters**				
	PH (cm)	NLP	KWP (g)	SI (g)	ASI2 (days)
CMS 8704	192.88±6.42^{b}	14.93±0.22^{b}	174.33±7.11^{b}	29.11±3.36^{c}	-
CMS 8501	183.0±4.02^{c}	14.74±0.23^{b}	156.89±2.30^{c}	35.99±3.35^{b}	2.0
CMS 9015	184.33±6.42^{c}	15.12±0.17^{ab}	154.14±4.83^{c}	31.05±3.36^{bc}	1.0
CMS 2019	189.47±5.35^{bc}	14.76±0.48^{b}	166.27±9.11^{bc}	32.81±2.84^{bc}	4.0
Shaba	272.21±14.43^{a}	16.20±0.29^{a}	204.18±6.06^{a}	49.64±4.67^{a}	7.0
Means	**204.37±7.32**	**15.15±0.27**	**170.76±5.88**	**35.72±3.51**	**3.5**
LSD (5%)	**8.20**	**1.01**	**16.52**	**5.22**	

Values followed by the same letter on the line are not significantly different ($p<0.05$). PH: plant height; NLP: number of leaves per plant; KWP: total kernels weight per plant; SI (g): Seed index or 100 seeds weight; ASI2: difference in days between the female flowering of the recipient variety and the start of male flowering of the donor.

3.2 Effect of the distance from pollen source and wind direction on the cross-pollination rate of recipient maize varieties

The analysis of variance showed that the cross-pollination rate of the recipient maize varieties varied significantly ($p<0.001$) with the distance from the pollen source and the wind direction (Table 3). The interaction between wind direction and distance from pollen source and the blocks effects were not significant. These results tell us that allogamy rates depend on the distance from the donor pollen source and the wind direction. Raynor *et al*. (1972) and Ma *et al*. (2004) noted that environmental factors and distance influenced cross-pollination in maize. The highest rates of cross-pollination were found closest to the pollen source and at further distances from the pollen source the decrease in cross-pollination was much stronger (Table 4, Fig. 2). The average pollution rate was 38.6% at 1.5 m from the source and decreased to 5.3% at 10.0 m. Cross-pollination studies between adjacent maize fields were conducted worldwide using mainly a colored marker system. Many recent studies also noted that xenia percentage was highest at the border rows facing the donor and decreased rapidly with increasing distance from the donor field (Aylor *et al*., 2003; Ma *et al*., 2004; Viorica *et al*., 2017). According to Devos *et al.* (2005), most pollen coming from donor field was retained at the border rows of recipient field that constitute a protection band, thus the proportion of donor pollen within the recipient field will decrease. The majority of the pollen deposition took place within the first two meters of the pollen source but the possibility to find a small amount of pollen at larger distances from the source exist. These observations recorded in tropical conditions were close to those obtained in Romania on improved maize varieties by Viorica *et al*. (2017) who noted a xenia percentage of 44.9% at 1 m from pollen source and 0.33% at 20 m. However, Bannert and Stamp (2007) investigated the effectiveness of distance in preventing out-crossing in maize and showed that the rate of cross-pollination ranged from 3% to 15% at 0.8 m from the donor. There is a direct correlation between the level of cross-pollination and to distance to source ($R=0.928$). At larger distance from the source, Aylor *et al*. (2003) noted a cross-pollination rate of 0.1 % at 50 m. Raynor *et al*. (1972) estimated that less than 1% of maize pollen grains traveled beyond 60 m, considering that maize pollen is the largest and heaviest of the Poaceae pollinated species. Dispersal distance is affected by the height of pollen release, and the topography of the surface. From these results, it appeared that at an isolation distance of 10 m, genetic pollution rate was less than 7%. These results demonstrated that spatial isolation is an effective method to reduce outcrossing rates in maize.

Concerning the wind direction (Table 3, Fig. 3), xenia percentage was highest in north (19.27%) and west (17.01%) and decreased in south (13.78%) and east (14.26%). Ma *et al.* (2004), pointed out that the cross-pollination rate was significantly higher downwind than upwind from the pollen source. Weber *et al*. (2007) noted that the influence of wind can change between locations and years, so reliable prediction is not possible. However, wind speed and direction cannot be reliably incorporated into strategies to avoid cross-pollination. Measurements of horizontal wind speed during flowering in relation to the sedimentation rate of maize pollen showed a potential distance for horizontal pollen dispersal (Bannert and Stamp, 2007). The few cross-pollinations observed over longer distances could be due to gusty or vertical wind movements (thermal or turbulence effects). According to Hofmann *et al*. (2014), most corn pollen falls within the first five meters past the edge of the field, but the possibility of finding a small amount of pollen at greater distances from the corn plot depends on wind speed.

Cross-pollination depend on other factors. A difference in flowering between the donor and recipient can reduce the level of cross-pollination (Devos *et al*., 2005). Timing between anthesis of the pollen donor and silking of the recipient is one of the main factors affecting the pollen-mediated gene. Della Porta *et al*. (2008) observed that cross-pollination depends on flowering timing. A difference of 04 to 05 days of flowering time between the pollen source and the recipient reduces the pollen flow pear to 50%. It is clear that flowering synchronization between neighboring fields is the main factor influencing cross-pollination (Messenger *et al*., 2006). The size and the ratio between the pollen source and the receiving field also influence the level of cross-pollination. The deeper the receiving field, the lower the level of cross-pollination of the crop production (Ma *et al*., 2004). Cross-pollination is considered to be responsible for much of the gene flow in maize (Devos *et al*., 2007). Gene flow influences reproductive success and fitness of individuals, and determines the genetic structure of the population.

Table 3. Analysis of variance for cross-pollination rate within the recipient field of maize tested for eight distances from pollen-donor source and four wind directions

Source of variation	Df	SS	MS	F-value
Blocks	2	13.57	6.78	0.78^{ns}
Distance from source (D)	7	2668.32	381.18	43.86^{***}
Wind direction (Wd)	3	483.90	161.30	18.56^{***}
Interaction D × Wd	21	181.22	8.63	0.99^{ns}
Residual	62	539.04	8.69	

Df: Degree of freedom; SS: Sum of square; MS: Mean of square; ns: not significant at 5%; ***: indicates significance at 0.1%.

Table 4. Impact of distance from pollen-source and wind direction on the cross-pollination rate (%) within four recipient maize synthetic varieties

Gap from pollen source (recipient variety)	Percentage of outcrossing (%)				
	North	South	East	West	Average for distance
1.5 m (CMS 9015)	44.64±0.28	34.67±0.41	34.94±0.38	40.24±0.31	**38.62**±0.34^{a}
2.5 m (CMS 9015)	33.33±1.51	23.04±0.62	25.24±1.05	28.23±0.99	**27.46**±1.04^{b}
4.0 m (CMS 8501)	25.31±0.53	14.88±0.57	15.32±0.60	21.92±0.38	**19.35**±0.52^{c}
5.0 m (CMS 8501)	14.97±0.59	11.99±0.85	12.47±0.85	13.35±0.44	**13.19**±0.68^{d}
6.5 m (CMS 2019)	11.92±0.85	9.13±0.39	8.93±0.16	11.02±0.62	**10.25**±0.50^{e}
7.5m (CMS 2019)	9.11±0.41	7.15±0.56	6.63±0.65	7.95±0.55	**7.71**±0.54^{f}
9.0 m (Shaba)	8.21±0.41	5.39±0.56	5.95±0.65	7.59±0.55	**6.78**±0.28^{fg}
10.0 m (Shaba)	6.72±0.43	4.03±0.37	4.65±0.25	5.81±1.00	**5.30**±0.51^{g}
Average value for direction	**19.27**±0.61^{A}	**13.78**±0.51^{C}	**14.26**±0.50^{C}	**17.01**±0.58^{B}	**16.08**±0.55

Means with the same subscript within the same column or line do not differ significantly at 5%.

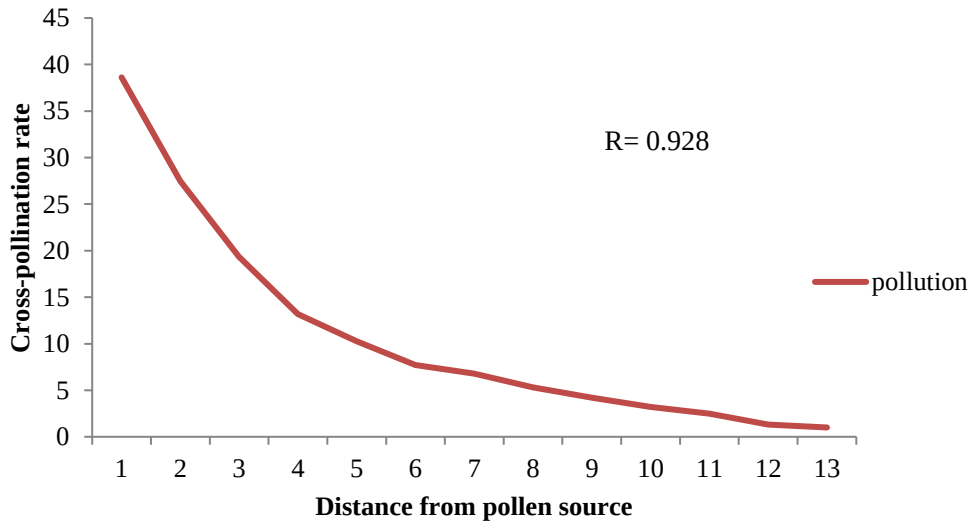

Fig. 2: Impact of gap from pollen source on the cross-pollination rate of recipient varieties.

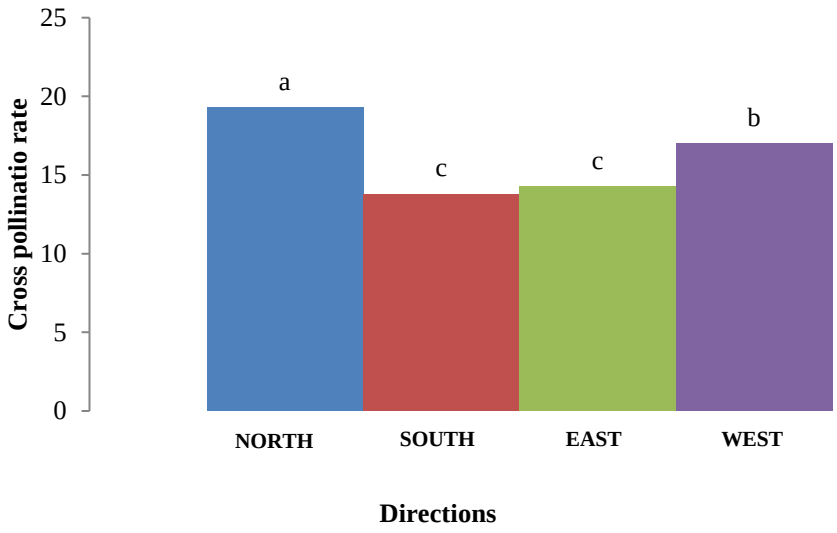

Fig. 3: Impact of wind direction on cross-pollination rate of recipient maize varieties.

IV. CONCLUSION

The main focus of this study was to gather information's about adequate separation distances to ensure coexistence and about the dependence of cross-pollination on the distance within the maize field. Results obtained showed the level of genetic pollution is highest near the pollen source and in the northern direction. At the distance of 10 m from the pollen source, the average level of genetic pollution decreased significantly in the South direction. We can recommend the cultivation at a distance of more than 10 m between maize fields to secure the coexistence of genotypes.

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Trend of Changes in Quantitative and Qualitative Traits in the Next Generation of BC3F2 Genotype from Crosses of Parent of High Protein Corn with Local Waxy Corn

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Abstract— *Corn can be used as an alternative staple food, but it is underdeveloped because it generally does not taste fluffier like rice. Therefore, it is necessary to develop corn that tastes fluffier, has high protein and has high production. The purpose of this study was to determine the trend of changes in quantitative (production) and qualitative (protein and amylopectin levels) traits in the next generation of BC3F2 genotype from a cross between high protein maize parents (Srikandi Putih variety) and high amylopectin maize (Local variety of Waxy corn). Seeds of Waxy corn, Srikandi Putih Varieties, BC2F1 and BC3F1 will be used as basic materials in this study. The study was designed in the form of a Randomized Block Design. The treatments consisted of genotypes BC2F1, BC3F1, Srikandi Putih Variety and Local variety of Waxy Corn. For the BC3F1 genotype, 210 plants were self-treated to produce the BC3F2 genotype. The results showed that there was an increasing trend of high protein and production characters from the inheritance of the Srikandi Putih Variety to the BC3F1 and BC3F2 genotypes. This was supported by an increase in ear length, ear diameter, weight of 100 seeds, seed weight per plot and seed production per hectare and an increase in protein content. The same trend also occurred in the character of amylopectin levels from the inheritance of local waxy corn parents to the BC3F1 and BC3F2 genotypes which were increasing.*
Keywords— *corn, protein, amylopectin, selfing*

I. INTRODUCTION

The need for basic food in Indonesia is increasing along with the increase in population. This shows that the agricultural food sector is still a very important sector. Dependence on rice as the only staple food in Indonesia needs to be anticipated by providing alternative staple foods such as corn. Generally, corn is used for animal feed, only a small part is used for food and industry. Generally, Indonesian people do not like corn as a staple food because the texture of corn rice is rough and hard. Generally only used as a snack. For this reason, it is necessary to improve the quality and taste so that it is delicious and nutritious. The combination of two good traits from two different maize varieties can be done if the genetic diversity is available. High quality protein maize (QPM) is available, but has a rough texture so it is not popular for food.

On the other hand, local waxy corn is also available in South Sulawesi, it is very popular both when the seeds are young and when the seeds are old because of its high amylopectin content, but the drawback is that the production is very low. The shortcomings of these two types of corn need to be eliminated by certain plant breeding techniques in order to obtain high protein corn and fluffier texture. Corn with these special characteristics can be formed through repeated and programmed plant breeding programs [1]. In waxy corn there is a recessive gene wx in a homozygous state (wxwx) which affects the chemical composition of starch causing a delicious and savory taste. Backcross breeding method can be applied to introgress donor genes from special corn with high amylopectin content (waxy corn) to high protein and high productivity (Srikandi Putih variety) in order to obtain

corn that has the desired special characteristics (Varieties with high amylopectin and high protein).

The protein content of corn generally ranges from 8-11%, but the content of lysine and tryptophan is low, 0.225% and 0.05%, respectively, so it is still less than half that recommended by the Food and Agriculture Organization [2]. The QPM varieties released for the first time in Indonesia were Srikandi Kuning-1 and Srikandi Putih-1 free-polluted corn with a productivity of 7.0 t/ha [3]. Srikandi Kuning contains 10.38% protein, 0.477% lysine and 0.093% tryptophan, while Srikandi Putih contains 10.44% protein, 0.410% lysine and 0.087% tryptophan [4].

Generally, corn kernels have amylose content that is higher than their amylopectin content, except for waxy corn. The amylopectin content in waxy corn is almost 100%. Ordinary corn endosperm consists of a mixture of 72% amylopectin and 28% amylose [5]. Almost all of the endosperm content of waxy corn is amylopectin [6]. In waxy corn, there is a recessive gene wx in a homozygous state (wxwx) which affects the chemical composition of starch, causing a delicious and savory taste. Waxy corn yields are generally low, only 2-2.5 t/ha and are not resistant to downy mildew. Corn taste fluffier is closely related to the high content of amylopectin in seed starch. Starch consists of two glucose polymer compounds, namely amylose and amylopectin. The molecular weight of amylose and amylopectin depends on the botanical source of amylose which is a component with straight chains, while amylopectin with branched chains. Amylose is a helical straight chain polysaccharide with -1,4 glycosidic bonds. The branching point of amylopectin is the -1,6 bond. The number of glucose molecules in the amylose chain ranges from 250-350 units [7]. Starch is composed of at least three main components, namely amylose, amylopectin, and intermediates such as lipids and proteins. These components affect the functional and amylographic properties of corn flour [8]. The results showed that the protein content of Maize Pulut Takalar and Corn Pulut Gorontalo were relatively the same, 0.78% and 0.79%, respectively [9]. The composition of amylose and amylopectin in corn kernels is genetically controlled. In general, corn endosperm type horse teeth and pearls contain amylose 25-30% and amylopectin 70-75% of the total starch. Pulut corn has a starch content of almost 100% amylopectin. The presence of an epistatic recessive waxy (wx) gene located on chromosome nine affects the chemical composition of starch so that amylose accumulation is very little [10]. Corn contains about 10% protein, higher than rice (7.5%), and lower than wheat 14%. Other nutrients that corn contains are fat and fiber at 5% and 2%, respectively. The nutritional content per 100 g of seeds is 45 mg calcium, 3 mg iron, 24 mg phosphorus, 11 mg sodium, and 78 mg potassium [11]. Indonesia imports corn as feed, but efforts to meet the needs of corn as a staple food need to be encouraged. The higher the amylopectin content, the softer the corn taste.

II. RESEARCH METHOD

This research was conducted at the Cereal Crops Research Institute Allepolea Village, District. Lau, Maros Regency, South Sulawesi Province, Indonesia, from February to December 2021. The materials used in this study were: Seed of Srikandi Putih variety, waxy corn, genotypes BC2F1, and BC3F1. This study was designed in the form of a randomized block design. The treatments consisted of genotypes BC2F1, BC3F1, Srikandi Putih variety and waxy corn. Repeated 3 times. Specifically for the BC3F1 genotype, 210 plants were selfing to produce the BC3F2 genotype. The soil was treated with a tractor and hoe, then a plot of 8 m x 6 m was made, with 12 experimental units. Seeds of Srikandi Putih, local pulut, BC2F1, and BC3F1 before planting were given the fungicide Saromil to prevent downy mildew. Seeds are planted in a single way as much as 2 seeds / hole with a spacing of 70 cm x 20 cm. Fertilization of Urea, SP-36, KCl and NPK Ponska was carried out after corn plants were 7 days after planting (DAP) with a dose of 200 kg Urea/ha, 150 kg SP-36/ha and 100 kg KCl/ha. Specifically for Urea, it was given 2 times, 50% at 7 DAP and 50% urea at 30 DAP. After the plants were 7 DAP, thinning was done, leaving 1 plant per hole. 210 plants of BC3F1 were selfing to obtain BC3F2 seeds. Observation variables include: (1) plant height (cm), (2) number of leaves (strands), (3) male flowering age 50% (days), (4) female flowering age 50% (days), (5) ear length (cm), (6) ear diameter (cm), (7) dry weight 100 seeds moisture content 15% (g), (8) dry weight of seeds per plot moisture content 15% (g) and (9) Production seeds per hectare moisture content 15% (tons/ha), (10) Protein content (%) and (11) Amylopectin content (%).

III. RESULTS AND DISCUSSION

3.1. Plant height and number of leaves. The analyze of variance showed that the varieties and genotypes had no significant effect on the variables of plant height and number of leaves. Figure 1 shows that both the plant height and the number of leaves of the Srikandi Putih variety tend to be higher than other varieties and genotypes.

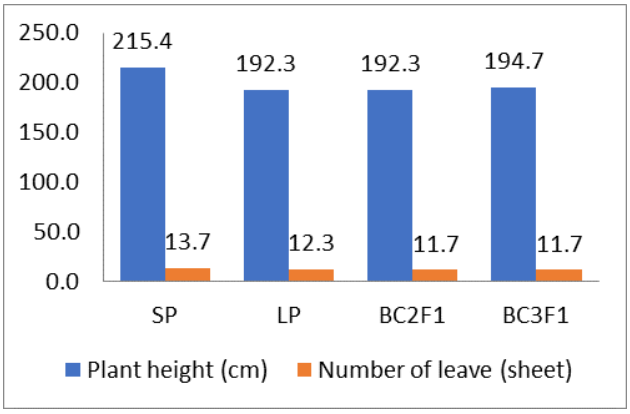

Fig.1. Plant height and number of leaves

Note: SP: Srikandi Putih variety, BC3F1: Genotype Backcross 3 fillial 1, BC2F1: Genotype backcross 2 fillial 1, LP: waxy corn

There was no difference in plant height and number of leaves of Genotypes BC3F1 and BC2F1 with the parent of Srikandi Putih and the parent of waxy corn. This is because the two parents also have no differences in the characters of plant height and number of leaves, as shown in Figure 1. Characters that are passed on by parents to their offspring can be dominant, recessive or codominant. The size of the character of the parents passed on to their offspring is also influenced by the method of crossing used. This is in accordance with the description of the Srkandi Putih variety that the plant height is approximately 195 cm [14]. Another study showed that the number of leaves of the Srikandi Putih variety and waxy corn was not significantly different, namely between 12-14 strands [15].

3.2. Flowering age. The analyze of variance showed that the varieties and genotypes tested had a significant effect on male and female flowering age. Table 1 shows the fastest male flowering age at local pulut and significantly different from all varieties tested except for the BC2F1 genotype. Furthermore, the genotypes of BC2F1 and BC3F1 were not significantly different, but both male flowers released faster and were significantly different from the Srikandi Putih variety. Table 1 also shows the flowering age of local pulut females, BC2F1 and BC3F1 out faster and significantly different from the Srikandi Putih variety, but between the three there is no significant difference.

Table 1. Age of male flowering and female flowering age 50%

Treatment	Average age of flowering males 50% (day)	Average age of flowering female 50% (day)
SP	47.0a	48.0a
LP	43.3c	44.3b
BC2F1	44.0bc	45.3b
BC3F1	44.3b	45.3b
$LSD_{0.05}$	0.88	1.15

Note:

Numbers followed by the same letter were not significantly different at LSD test $_{0.05.}$

SP: Srikandi Putih variety, BC3F1: Genotype Backcross 3 filial 1, BC2F1: Genotype backcross 2 filial 1, LP: waxy corn

The flowering age of males and females in the genotypes BC2F1 and BC3F1 came out faster than the parent of the Srikandi Putih variety. This shows that the characteristics of male and female flowering age are quantitative traits inherited by waxy corn parent. This is in line with the results of previous studies where the male and female flowering age characters which are faster than the parent Srikandi Putih have been slowly inherited from Genotype F1 then to F2 and to F3 which flower faster than the parent Srikandi Putih [16]. This also shows that the age of flowering of males and females remains faster even though they are backcrossed by the parent of Srikandi Putih as much as 2 to 3 times, then selfing 2 times.. This indicates that these two traits have started to stabilize in each generation produced. There is a difference in the data due to environmental influences. This is also in line with research showing the flowering age of males ranging from 43-48 days after planting and female flowering age between 45-52 days after planting [17].

3.3. Ear length and ear diameter. The analyze of variance showed that the varieties and genotypes tested had a significant effect on the length of the ear and the diameter of the ear. Table 2 shows the Srikandi Putih variety, genotypes BC3F1 and BC2F1 all three were higher, such as the length of the ear and the diameter of the ear and significantly different from the waxy corn. Between the Srikandi Putih variety, the genotypes BC3F1 and BC2F1 were not significantly different to the length and diameter of the ears.

Table 2. Ear length and ear diameter

Treatment	Average length of ear (cm)	Average diameter of ear (cm)
SP	15.7a	4.4a
LP	13.7b	3.4b
BC2F1	15.5a	4.3a
BC3F1	15.6a	4.3a
$LSD_{0.05}$	1.44	0.44

Note:

Numbers followed by the same letter were not significantly different at LSD test $_{0.05.}$

SP: Srikandi Putih variety, BC3F1: Genotype Backcross 3 filial 1, BC2F1: Genotype backcross 2 filial 1, LP: waxy corn

The length and diameter of the ear of the Srikandi Putih variety, genotypes BC2F1 and BC3F1 were higher and significantly different from the waxy corn. There was no significant difference between the Srikandi Putih with the BC2F1 and BC3 F1 genotypes. This indicates that the character of the length and diameter of the ear has been inherited by Srikandi Putih as the parent to his offspring, namely the BC2F1 and BC3F1 genotypes. This is also in line with the results of previous studies which showed the length and diameter of the ear of the Srikandi Putih variety were longer and significantly different from the waxy corn [15].

3.4. Weight of 100 Seeds, Weight of Seeds per Plot and Production per Hectare. The analyze of variance showed that the varieties and genotypes tested had a significant effect on 100 seed weight, seed weight per plot and seed production per hectare. Table 3 shows the highest weight of 100 seeds was found in the Srikandi Putih variety, followed by the genotype BC3F1 then BC2F1 and the lowest was in the waxy corn. All varieties and genotypes tested were significantly different to the weight of 100 seeds. Table 3 also shows the highest seed weight per plot and seed production per hectare in the Srikandi Putih variety, genotype BC3F1, genotype BC2F1 and significantly different from waxy corn. There was no significant difference between the Srikandi Putih variety, BC3F1 genotype, and BC2F1 genotype.

Table 3. Weight of 100 seeds, weight of seeds per plot and seed production per hectare

Treatment	Weight of 100 seeds (g)	Seed Weight per plot (kg)	Seed production per ha (t)
SP	28.5a	38.4a	8.0a
LP	25.7d	16.8c	3.5c
BC2F1	27.2c	35.4b	7.4b
BC3F1	27.9b	36.9ab	7.7ab
$LSD_{0.05}$	0.48	1.72	0.38

Note:

Numbers followed by the same letter were not significantly different at LSD test $_{0.05.}$

SP: Srikandi Putih variety, BC3F1: Genotype Backcross 3 filial 1, BC2F1: Genotype backcross 2 filial 1, LP: waxy corn

The highest character weight of 100 seeds started with the Srikandi Putih parent then followed by its derivatives, namely Genotype BC3F1 then Genotype BC2F1 and the lowest was waxy corn parent. This indicates that the more often backcross is carried out with the parents of Srikandi Putih and selfing is carried out 2 times, the inheritance of the character weighing 100 seeds is getting closer to the parent of Srikandi Putih. This is in line with the description of the Srikandi Putih variety with a potential of 32.5 g per 100 seeds under optimum conditions [14]. The character of seed weight per plot and seed production per hectare showed that the Srikandi Putih variety and BC3F1 genotype were not significantly different but both were higher and significantly different from the waxy corn parents. There was no significant difference between BC3F1 and BC2F1 but both were higher and significantly different from the waxy corn parents. This indicates that the more often backcross are carried out with the Srikandi Putih parent and then followed by selfing, the accumulation of inheritance of traits to their offspring occurs. This is in line with the results of previous studies which stated that the seed production per hectare of genotypes F1 and F2 was generally inherited from the Srikandi Putih variety which had high production potential compared to the waxy corn parent which had low production potential [15].

3.5. Protein and Amylopectin Levels. The analyze of variance showed that the varieties and genotypes tested had a significant effect on the variables of protein and amylopectin levels.

Table 4 shows the highest protein content of the BC3F2 genotype and significantly different from all varieties and genotypes tested. There was no significant difference between the Srikandi Putih variety with Waxy corn (LP), BC2F1, BC3F1. Table 4 also shows the highest levels of amylopectin content of waxy corn (LP) and significantly different from all varieties and genotypes tested except for the BC3F2 genotype which was not significantly different. Genotypes BC2F1 and BC3F1 were not significantly different from the Srikandi Putih Variety (SP).

Table 4. Protein and Amylopectin levels

Treatment	Average protein content (%)	Average anilopectin content (%)
SP	9.65b	68.39b
LP	9.49b	82.50a
BC2F1	9.53b	68.92b
BC3F1	9.60b	70.18b
BC3F2	10.42a	79.73a
$LSD_{0.05}$	0.49	6.27

Note:

Numbers followed by the same letter were not significantly different at LSD test $_{0.05.}$

SP: Srikandi Putih variety, BC3F1: Genotype Backcross 3 filial 1, BC2F1: Genotype backcross 2 filial 1, LP: waxy corn

Table 4 shows that there is a trend of increasing protein content as the generation continues to follow the traits of the elders of the Srikandi Putih variety, even the BC3F2 genotype exceeds the protein content of the Srikandi Putih Variety (SP). This is in line with the results of the study, that the protein content of the Srikandi Kuning variety of maize seeds increased as the generation continued from F1, F2 and BC1 with protein content of 7.30 ± 4.31%, 9.54 ± 0.82% and 13.30 ± 2.13% [18]. Another study on the quality diversity of several corn varieties showed that the protein content of extracted corn starch was influenced by the variety, an average of 0.92% with a range of 0.72-1.12% [9]. Furthermore, research on the analysis of protein, lysine and tryptophan levels in the seeds of several corn varieties showed that the Srikandi Kuning variety contained 10.38% protein, 0.477% lysine and 0.093% tryptophan, while the White Srikandi variety contained 10.44% protein, 0.410% lysine and 0.410% protein. tryptophan 0.087%, both higher than other varieties [20].. Another study reported that protein content was increased from 10.9% (original population) to 26.6% in the "Illinois High Protein" maize strain [21]. Likewise with the trend of increasing levels of amylopectin which tends to increase in the next generation which is close to the amylopectin levels of waxy corn elders. The results showed that Gene wx in waxy corn was easily transferred to non-sticky maize [22].

IV. CONCLUSION

The conclusions from the results of this study are as follows:

1. Inheritance of production characters from the parents of the Srikandi Putih Variety to the BC3F1 genotype was formed, which was indicated by an increase in the length of the ear, diameter of the ear, weight of 100 seeds, weight of seeds per plot, and production of seeds per hectare.
2. Inheritance of the protein content of the seeds from the parents of the Srikandi Putih Variety to the genotypes BC3F1 and BC3F2 was formed, which was indicated by an increase in the protein content of the seeds.
3. Inheritance of the character of amylopectin levels from local variety of waxy corn parents to BC3F1 and BC3F2 genotypes has been formed, which is indicated by an increase in seed amylopectin levels.

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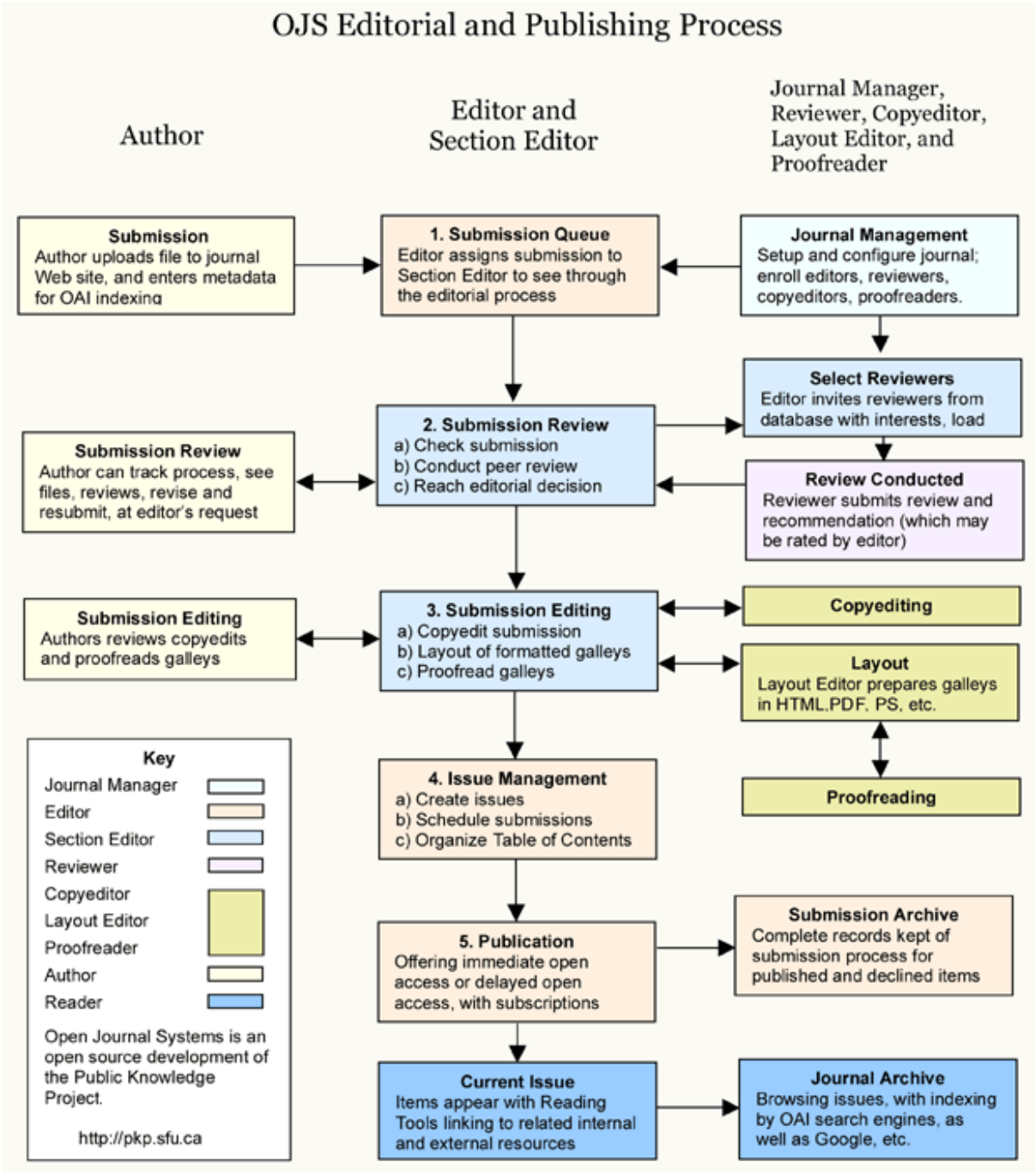

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