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Response of Two Varieties of Shallot (*Allium ascalonicum* L.) to Sulfur Addition in a Floating Raft Hydroponic System

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***Abstract*— *This paper contains information about the effects of differences in varieties and concentrations of sulfur given to shallots cultivated hydroponically. Currently, shallot cultivation in open fields has challenges that must be faced, such as the narrowing of agricultural land and disease due to planting off season which can affect the quantity and quality of shallots. Therefore, hydroponic cultivation of shallots using a floating raft system is a solution that can overcome this problem. Variety selection and fertilizer management are factors that can increase shallot yields. One of the varieties that can be used is the Super Phillip and Tajuk varieties. The increase in yield that can be done is by adding sulfur from $MgSO_4$. Sulfur can increase the weight of shallot bulbs because sulfur plays an important role in increasing the translocation of assimilates to enlarge the bulbs, forming essential amino acids, forming protein, and giving shallots a rich aroma and level of spiciness. This research aims to obtain the optimum concentration of sulfur to obtain good quantity and quality of shallots in the floating raft system.*

Keywords*— *Allicin, Hydroponic, Shallots, Sulfur

I. INTRODUCTION

Shallots are usually planted in the dry season, while in the rainy season, shallot production decreases. Low productivity of shallots in the rainy season is caused by pests and plant diseases (Suwandi, 2014). Limited land, labor costs for weed and pest management, and soil-borne diseases, such as soft rot, are encountered in shallot cultivation in open fields. Based on research conducted by Mouroutoglou *et al*. (2021), these problems can be overcome by soilless cultivation or cultivation with a hydroponic system. Cultivating shallots with hydroponics can grow shallots even during the off-season. There are several hydroponic systems that can be used, but based on research conducted by Mouroutoglou *et al*. (2021) the floating system is the best system compared to the NFT (Nutrient Film Technique), DFT (Deep Flow Technique), aeroponics, and water culture systems.

The selection of a hydroponic system in shallot cultivation is important to be able to produce high quantities and weights of shallots, but the selection of varieties and fertilizer management is very important in plant cultivation management. Variety selection is one of the important steps in the plant cultivation process. Varieties can determine the potential yield and resistance of plants to environmental conditions of cultivation. According to Azmi *et al*. (2022), the Super Phillip variety has a bulb diameter of around 1,83 cm and the Tajuk variety is 1,74 cm with a stronger level of spiciness of the Tajuk variety than the Super Philip variety.

Shallots are plants that require a lot of sulfur in their growth and development. This is in accordance with the opinion of Hasanah *et al*. (2021) who said that sulfur plays an important role in increasing assimilates translocation to enlarge bulbs, form essential amino acids (cysteine, thianine, and methionine), form proteins, and give a distinctive aroma and level of spiciness to shallots. Sulfur is the fourth important nutrient after nitrogen, phosphorus, and potassium in plant productivity. According to Farid and Ulinnuha (2022), sulfur plays an important role in amino acids as a component of protein in plants. Sulfur is a precursor component of aroma in shallots.

Based on the description of the variety, the aroma of the Tajuk variety of shallots is stronger than Super Phillip. The more organosulfur compounds contained in the bulbs, the stronger and spicier the aroma will be. Sulfur fertilization can affect the quality of shallots and plays an important role in the growth and development of shallot bulbs (Hasanah *et al*., 2021). Sulfur has been proven to not only increase tuber yield but also improve its quality especially aroma, taste, and pungency (Jaggi and Dixit, 1999). In the same case, Bell (1981) reported that sulfur contains secondary compounds important for nutritional value and taste as well as resistance to pests and diseases, namely allyl propyl disulfide and diallyl disulfide.

II. MATERIALS AND METHOD

This research was conducted from November 2024 until January 2025 in Brawijaya University greenhouse, Veteran Street, Ketawanggede, Lowokwaru, Malang. The experimental design used was Randomized Block Design (RBD) arranged in a factorial, with the first factor being the difference in varieties and the second factor being the concentration of sulfur. The varieties used are Super Philip and Tajuk. The sulfur concentration levels used were 0, 25, 50, 75, 100, and 125 ppm S. The tools used in this study include a floating raft tub measuring 70x50x20 cm, netpot, tweezers, TDS meter, pH meter, LAM (Leaf Area Meter), oven, digital scales, spectrophotometry, SPAD, measuring cups, pipettes, and labels. The materials used in this study include shallot seeds of Super Phillip and Tajuk varieties, AB Mix, $MgSO_4$, phosphoric acid (H_3PO_4), potassium hydroxide (KOH), rockwool, and water. The treatments used were 12 treatments with a floating raft system (75 x 50 x 20 cm) and repeated 3 times, there were 36 floating raft installations used. The research plan is described in Appendix 2. One floating raft consists of 12 plants with a planting distance of 15 cm, so the total plants used were 432 plants. The data obtained were analyzed using analysis of variance (F test) at the 5% level, followed by the Honestly Significance Difference (HSD) test if there were significant differences.

2.1.1 Seedling and Transplanting

1/3 of the shallot bulbs are cut with a knife. Prepare rockwool measuring 3x3x5 cm. Place the bulbs on the rockwool and store until shoots appear for approximately 5 days. Then transplant into the installation.

2.1.2 Installation Preparation

The installation preparation consists of preparing a floating raft tub measuring 70x50x20 cm, 36 pieces. The styrofoam used has a thickness of 3 cm with a length and width of 70x50 cm. The styrofoam used is first given holes with a diameter of 5 cm, totaling 12 holes.

2.1.3 Nutrient Preparation

AB Mix fertilizer is given at the beginning before transplanting. The concentration given is adjusted to the age of the shallot plant. According to Widarawati *et al*. (2022) at 1 week after planting (WAP) requires 450 ppm AB Mix, at 2 and 3 MST requires 800 ppm, at 4 and 5 MST 1000 ppm AB Mix, at 6 to 9 MST requires 1200 ppm.

2.1.4 Sulfur Application

Sulfur addition is carried out 14 days after transplanting. The concentrations given are 0, 25, 50, 75, 100, and 125 mg l^{-1}.

The parameters included the number of tillers per clump, the number of bulbs, bulbs fresh weight per clump, the sulfur and allicin content in the shallot bulbs. Analysis of the level of spiciness of shallots can be done by measuring the allicin content which is done at 56 DAP. Analysis of allicin content is done by extracting each sample which is then analyzed using a UV VIS Spectrophotometer (Shimadzu). The method is starting to make shallot extract and test it using a spectrophotometer.

2.2.1 Non-Purified Extract

The shallots used as samples were the Tajuk and Super Philip varieties that had been cultivated with the addition of sulfur according to the treatment. The extraction process was in accordance with Dana et al., (2024) which had been modified. Preparing the sample began with peeling the shallot skin, for optimal allicin results, the shallot bulb sample was thinly sliced first. Furthermore, the thinly sliced bulb sample was ground using a mortar and pestle. A total of 1,5 g of finely ground shallots was weighed and stored in a freezer at a temperature of 4°C for 5 minutes. After 5 minutes, the sample was removed and put into an Erlenmeyer flask (50 ml) which was then given 20 ml of methanol, then homogenized and put back into the freezer for 5 minutes. The next stage, the sample can be removed from the freezer and filtered using Whatman 42 paper with a diameter of 9 cm. The filtered extract can be analyzed using a UV Vis spectrophotometer.

2.2.2 Allicin Analysis

Determination of UV absorbance using a spectrophotometer for allicin extracted from shallots involves several steps. First, the spectrophotometer is activated, after waiting for a few minutes for the device to warm up, the next step is to use a wavelength of 240 nm to measure the absorbance of allicin. After the allicin absorbance value appears, the allicin content can be calculated using the following formula. The formula comes from the allicin standard calibration curve in Dana *et al.* (2024) shown in Fig. 1.

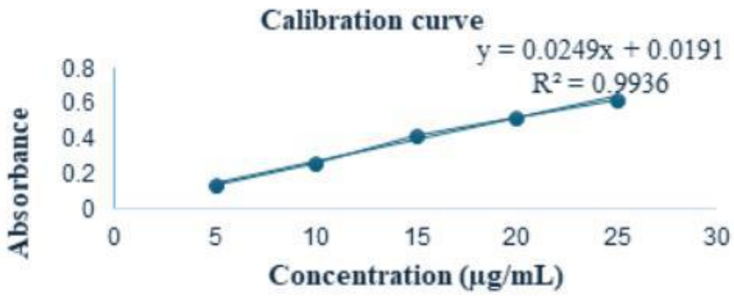

Fig. 1: Allicin Standard Calibration Curve
(Dana *et al*., 2024)

III. RESULT AND DISCUSSION

Differences in shallot varieties affect the number of bulbs and the diameter of the bulbs produced. The largest number of bulbs in the study by Farid and Ulinnuha (2022) were Bima Tarno, Kuning Tablet, and Bima Juna with a bulb diameter of 1,57 to 1,84 cm with a large number of bulbs at 90 ppm. The diameter of the shallot bulbs varies between varieties. Based on the research of Kasim *et al*. (2021) the Super Philip variety bulbs have a diameter of 2.44 cm and the Tajuk variety research by Azmi *et al*. (2022) has a diameter of 1,74 cm. Based on the size of the diameter of the shallot bulbs, they can be categorized into three categories, namely large, medium, and small. According to Farid and Ulinnuha (2022) large shallot bulbs are those with a diameter of more than 2 cm, medium-sized shallot bulbs are those with a diameter of 1,5 to 2 cm, and small-sized shallot bulbs are those with a diameter of less than 1,5 cm.

High production can be achieved with balanced fertilization. Fertilization is one of the activities that is closely related to plant growth and production to increase production. An important nutrient for the growth of shallots is sulfur. Sulfur is one of the important nutrients that plays a major role in the growth and development of shallots. This is in accordance with the opinion of Mustikawati *et al*. (2020) who said that shallots are plants that require a lot of sulfur in their growth and development. According to Hasanah *et al*. (2021), sulfur plays an important role in plant metabolism which is related to several parameters that determine the quality of shallots.

Sulfur is the fourth important nutrient after nitrogen, phosphorus, and potassium in plant growth. Sulfur plays a role in the formation of amino acids as a component of protein in plants. Sulfur in plants is needed for the synthesis of the amino acids cystine, cysteine, and methionine, which then form proteins. In addition, sulfur greatly helps the development of shoots, roots, and shoots (Mustikawati *et al*., 2020). According to Mnayer *et al*. (2014), sulfur is a component of the aroma precursor in shallots, namely S-allyl-L-Cysteine-Sulfoxide (SAC). Sulfur fertilization can affect the quality of shallots and plays an important role in the growth and development of shallot bulbs (Hasanah *et al*., 2021). In shallot plants, the S requirement is 120 kg ha^{-1}. According to Hadiawati *et al*. (2017), giving S with a concentration of 20-60 ppm can increase the absorption of S, P, Zn, and Cn. In a study conducted by Farid and Ulinnuha (2022) it was shown that the wet weight of the bulbs showed the effect of sulfur absorption. Likewise, in the study of Muhammad *et al*. (2003) at 30 ppm sulfur can increase the dry weight of plants and dry weight of bulbs, while at a sulfur concentration of more than 30 ppm it will reduce the dry weight of plants and dry weight of shallot bulbs. Sulfur is an essential component that makes up amino acids in plant cells, especially in the plant development stage (Chattoo *et al*., 2019).

The spicy taste of shallots is correlated with the concentration of dry matter production. The carbohydrates that play a major role in forming the sweet taste of shallots are fructose and sucrose. Sulfur has a compound that affects the taste and spiciness of shallots, namely the alliin compound. Based on research by Bloem *et al.* (2004) showed that the increase in allicin content in shallot leaves and bulbs was influenced by an increase in sulfur. The sulfur content in shallot bulbs observed at 28 weeks after planting (WAP) was highest at 250 mg pot^{-1}, which was around 3,6-4,0 mg g^{-1} with an allicin content of 0,4-1,7 mg g^{-1}, while according to Ţigu *et al*. (2021), the allicin levels in A. Sativum and A. fistulosum were 380 µg ml^{-1} and 145 µg ml^{-1}, respectively.

Number of Tillers per Clump

At 49 HST, the Super Philip variety produced more tillers than the Tajuk variety at concentrations of 25 and 50 ppm. However, at 0, 75, 100, and 125 ppm S, the number of tillers between the Super Philip and Tajuk varieties was not significantly different. The number of tillers of the Super Philip variety at concentrations of 25 and 50 ppm S produced a number of tillers that were not significantly different compared to 0 and 75 ppm S. At 75 ppm S, the number of tillers produced was not significantly different compared to 0, 25, 50, 100, and 125 ppm S. In the Tajuk variety treatment, the number of tillers produced was not significantly different at 0, 25, 50, 75, 100, and 125 ppm S.

At 56 HST, the Super Philip variety produced more tillers than the Tajuk variety at concentrations of 25, 50, and 75 ppm. However, at 0, 100, and 125 ppm S, the number of tillers between the Super Philip and Tajuk varieties was not significantly different. The number of tillers of the Super Philip variety at concentrations of 25 and 50 ppm S produced more tillers than 0 and 125 ppm S, but produced a number of tillers that were not significantly different from 0, 75, and 100 ppm S. In the Tajuk variety treatment, the number of tillers was not significantly different at 0, 25, 50, 75, 100, and 125 ppm S.

The number of tillers, or shoots that grow from shallot bulbs, is one of the important factors that determine the productivity of this plant. In general, the number of tillers per clump of shallots can vary, influenced by various genetic and environmental factors. The Super Philip variety produces more tillers than Tajuk. According to Hadiawati *et al.* (2017) the sulfur requirement in shallot plants ranges from 20-60 ppm. Based on this statement, the number of tillers in the Super Philip variety with a concentration of 25 to 100 ppm is not significantly different, but produces a higher number of tillers than 0 and 125 ppm (Table 3). Based on the results of observations, it was found that the number of tillers in the Tajuk variety did not increase at the level of sulfur concentration given. According to Idly *et al*. (2024) giving sulfur at a certain dose can increase the number of tillers in shallots. Sulfur plays an important role in the synthesis of amino acids and proteins that support cell growth and plant development. By increasing the availability of sulfur, shallot plants can produce more tillers through increased vegetative growth and leaf formation. Increasing the sulfur content in shallots can increase the fresh weight of the bulbs. According to Coolong and Randle (2003), the fresh weight of the bulbs continues to increase along with the increase in the concentration of S given. Sulfur has been proven to not only increase the yield of bulbs but also improve their quality, especially taste and spiciness (Jaggi and Dixit, 1999).

Table 1. Interaction of Number of Tiller on Differences Varieties and Sulfur Concentration at 49 and 56 DAP

Number of Shallot Tiller (tiller $clump^{-1}$)							
Age (DAP)	**Varieties**	**S Concentration (ppm)**					
		0	**25**	**50**	**75**	**100**	**125**
49	Super Philip (V1)	9,51 ab A	13,83 b B	14,08 b B	9,50 ab A	9,33 a A	8,25 a A
	Tajuk (V2)	6,33 a A	6,58 a A	6,58 a A	6,91 a A	6,50 a A	6,25 a A
BNJ-Var 5%		**3,62**					
CV (%)		**15,38**					
56	Super Philip (V1)	10,91 ab A	14,08 b B	15,00 b B	12,34 ab B	11,75 ab A	9,00 a A
	Tajuk (V2)	6,58 a A	7,33 a A	7,75 a A	7,78 a A	7,83 a A	8,67 a A
BNJ-Var 5%		**4,53**					
CV (%)		**18,31**					

Description: Numbers followed by the same lowercase letters indicate no significant difference horizontally, while numbers followed by the same uppercase letters indicate no significant difference vertically, based on the 5% BNJ Test. DAP: Days After Planting, CV: Coefficient of Diversity

Number of Bulbs per Clump

Observations on the number of shallot bulbs using the Super Philip variety yielded a higher number of bulbs compared to the Tajuk variety at concentrations of 25, 50, and 75 ppm. However, at 0, 100, and 125 ppm S, the number of bulbs between the Super Philip and Tajuk varieties was not significantly different. The number of tubers of the Super Philip variety at concentrations of 25 and 50 ppm S was not significantly different from the concentrations of 75 and 100 ppm S, but produced a greater number of tubers than 0 and 125 ppm S. At 75 and 100 ppm S, the Super Philip variety produced a number of tubers that were not significantly different from 0, 25, 50, and 125 ppm S. At 125 ppm S, it produced a number of tubers that were not significantly different from 0, 75, and 100 ppm S, but had a smaller number of tubers than 25 and 50 ppm S. In the Tajuk variety, concentrations of 0, 25, 75, 100, and 125 ppm S had a number of tubers that were not significantly different.

In the observation of the number of shallot bulbs, there was an interaction between the factors of variety differences and sulfur concentration. The number of Super Philip variety bulbs decreased when sulfur administration increased. Based on Table 1 the number of bulbs at 25 and 50 ppm S produced a greater number of bulbs than 0 and 125 ppm S. The number of Tajuk variety bulbs increased the number of shallot bulbs at 50 ppm S. Based on the results of these observations, it was found that the number of bulbs of the variety would decrease at a certain concentration. The decrease in the number of shallot bulbs at a concentration of 125 ppm S may be caused by excessive sulfur levels, which can cause nutritional imbalances or poisoning. High sulfur concentrations can have a negative impact on plant physiology, inhibit growth and reduce bulb formation. This is in accordance with the opinion of Mustikawati *et al*. (2020) who stated that sulfur administration affects the number of bulbs per clump and bulb diameter. According to Narayan *et al*. (2023) excess sulfur can interfere with the absorption of other nutrients that are important for growth, such as nitrogen, phosphorus, potassium, and molybdenum. Basically, one of the elements that affects the number of red onion bulbs is phosphorus. The role of phosphorus is related to the biochemical mechanism that stores energy and then transfers it into living cells, including as a component of ATP, nucleic acids, and many metabolic substrates, as well as an enzyme cofactor. In addition, phosphorus also participates in the phosphorylation of various intermediary compounds of photosynthesis and respiration (Mustikawati *et al*., 2020).

Table 2: Interaction between Varieties and Sulfur Concentration on the Number of Shallot Bulbs

Varieties	Number of Shallot Bulbs (bulbs clump^{-1})					
	S Concentration (ppm)					
	0	**25**	**50**	**75**	**100**	**125**
Super Philip (V1)	9,11 a A	13,91 b B	14,91 b B	12,25 ab B	11,67 ab A	8,91 a A
Tajuk (V2)	6,58 a A	7,25 a A	8,58 a A	7,69 a A	7,75 a A	7,67 a A
BNJ-Var 5%	**4,22**					
CV (%)	**14,28**					

Description: Numbers followed by the same lowercase letters indicate no significant difference horizontally, while numbers followed by the same uppercase letters indicate no significant difference vertically, based on the 5% BNJ Test. DAP: Days After Planting, CV: Coefficient of Diversity

Bulb Diameter

The diameter of shallot bulbs based on Table X, Super Philip and Tajuk varieties produce significantly different bulb diameters. The Super Philip variety produces a larger bulb diameter compared to Tajuk. Based on the differences in sulfur concentrations given, at concentrations of 25, 50, and 75 ppm S, the bulb diameters are larger than 0 and 125 ppm S but not significantly different from 100 ppm S. At 100 ppm S, the bulb diameters are not significantly different from 0, 25, 50, 75, and 125 ppm S. The bulb diameter at 125 ppm S is not significantly different from 0 and 100 ppm S, but has a smaller diameter when compared to concentrations of 25, 50, and 75 ppm S.

The diameter of shallot bulbs is influenced by differences in variety and sulfur concentration. Based on the variety, Super Philip has a larger bulb diameter than Tajuk. The bulb diameter of the 25 ppm S concentration treatment has a larger bulb diameter. At this concentration, sulfur plays a role in increasing the weight of the shallot bulb diameter. Sulfur is an important component of the amino acids cysteine, cystine, and methionine, which are the main components of protein in plants. Protein is essential for cell growth and development, including shallot bulb cells. With sufficient sulfur availability, protein synthesis runs optimally, resulting in denser and heavier bulbs (Mnayer et al., 2014). Bulb size decreased at 100 and 125 ppm S. This may be due to the fact that the addition of sulfur at these concentrations will disrupt N absorption.

Bulbs Fresh Weight per Clump

Observations on the fresh weight of tubers per clump showed that the Super Philip variety produced a higher fresh weight of tubers per clump compared to the Tajuk variety at concentrations of 0, 25, and 50 ppm. However, at 75, 100, and 125 ppm S, the fresh weight of tubers per clump between the Super Philip and Tajuk varieties was not significantly different. The fresh weight of tubers per clump of the Super Philip variety at concentrations of 25 and 50 ppm S produced a higher fresh weight of tubers per clump compared to 0, 75, 100, and 125 ppm S. The fresh weight of tubers at 75 ppm S of the Super Philip variety produced no significant difference with 0, 100, and 125 ppm S. In the Tajuk variety, concentrations of 25, 50, and 75 ppm S produced a fresh weight of tubers per clump that was not significantly different from concentrations of 100 and 125 ppm S, but produced a higher fresh weight of tubers per clump compared to 0 ppm S. At concentrations of 100 and 125 ppm S, the fresh weight of tubers per clump was not significantly different from 0 ppm S.

Table 3: Average Diameter of Shallot Bulbs for Different Varieties and Sulfur Concentrations

Bulb Diameter (cm bulb^{-1})	
Varieties	**28 HST**
Super Philip (V1)	1,967 b
Tajuk (V2)	1,513 a
HSD-Var (5%)	0,08
S Concentration (ppm)	
0 (S1)	1,628 a
25 (S2)	1,968 b
50 (S3)	1,854 b
75 (S4)	1,866 b
100 (S5)	1,672 ab
125 (S6)	1,452 a
HSD-S (5%)	0,220
CV (%)	**8,07**

Description: Numbers accompanied by the same letter in the same column and treatment indicate no significant difference based on the Honestly Significant Difference Test (HSD). DAP: Days After Planting, tn: Not Significant, CV: Coefficient of Diversity

Table 4: Interaction between Varieties and Sulfur Concentration on Fresh Weight of Bulbs per Clump

Bulbs Fresh Weight per Clump (g clump^{-1})						
Varieties	**S Concentration (ppm)**					
	0	**25**	**50**	**75**	**100**	**125**
Super Philip (V1)	30,65 b B	39,33 c B	37,14 c B	28,51 ab A	25,11 ab A	24,04 a A
Tajuk (V2)	20,43 a A	28,27 b A	28,20 b A	27,80 b A	25,52 ab A	23,50 ab A
BNJ-Var 5%	**6,18**					
CV (%)	**7,39**					

Description: Numbers followed by the same lowercase letters indicate no significant difference horizontally, while numbers followed by the same uppercase letters indicate no significant difference vertically, based on the 5% BNJ Test. DAP: Days After Planting, CV: Coefficient of Diversity

Based on the Table 4, concentrations of 25 and 50 produced the highest fresh weight of bulbs in shallot. At these concentrations, sulfur plays a role in increasing the fresh weight of shallot bulbs. Sulfur is an important component of the amino acids cysteine, cystine, and methionine, which are the main components of protein in plants. Protein is essential for cell growth and development, including shallot bulb cells. With sufficient sulfur availability, protein synthesis runs optimally, producing denser and heavier bulbs (Mnayer *et al*., 2014).

This is in line with the results of observations on the total fresh weight of plants and the number of bulbs. The total fresh weight of plants can be influenced by the fresh weight of bulbs and the number of bulbs in shallot plants. Based on the regression graph of fresh bulb weight, the optimum concentration of sulfur for shallot varieties Super Philip and Tajuk were 29,17 and 58,23 ppm, respectively. Increasing the concentration of S in shallots can essentially increase the N content in the leaves. Nitrogen can increase the length of shallot plants. The increase in leaf N content at increasing doses of S was also reported by Karimizarchi *et al*. (2014) which can be associated with the synthesis of compounds such as amino acids, proteins, coenzymes, lipids, sulfoxides, and nucleotides containing S and N. However, based on research conducted on shallots at increasing concentrations of S which according to Karimizarchi *et al*. (2014) interact with N does not result in a linear increase in plant bulb weight. This is in accordance with the research of de Paula (2002) and de Souza *et al*. (2015) where the addition of S concentration is not always synergistic with N elements due to competition between S and N. This causes disruption of N absorption if the addition of S is too high.

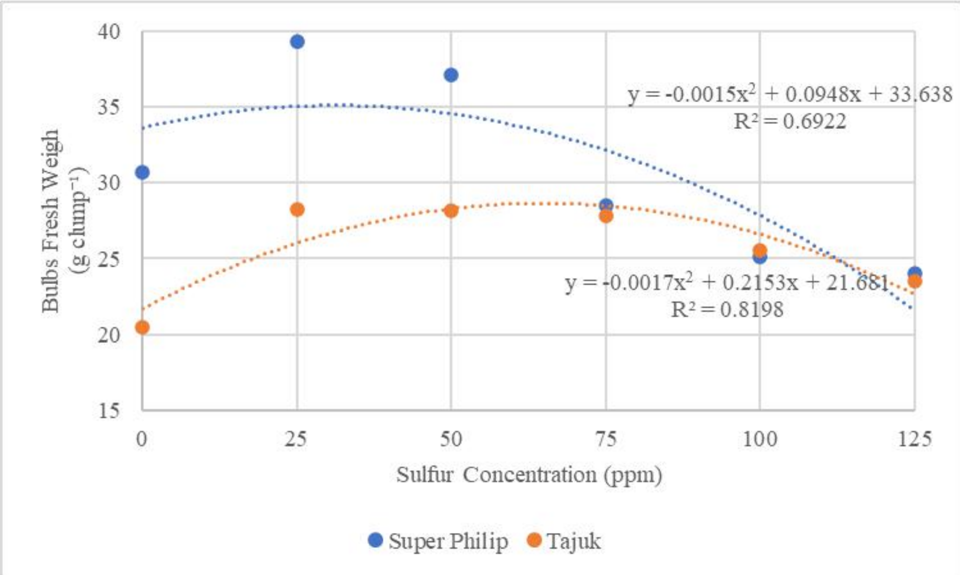

Fig. 2: Regression Graph between Varieties and Sulfur Concentration Differences on Bulbs Weight

Sulfur Content of Shallot Bulbs (mg g^{-1})

Shallots have a higher S content than other plant species. Roots actively absorb S in the form of SO^{4-} (Mengel and Kirkby, 1982). SO^{2-} is translocated to the leaves and reduced in the chloroplasts to organic forms. In onions, S-alk(en)yl cysteine sulfoxides (ACSO) produce many volatile S compounds that cause shallots to be valued as herbal medicine and as food (Lancaster *et al*., 2001). Onion bulbs (Allium sp.) have no odor, but when the cells are disturbed, the enzyme alliinase (EC 4.4.1.4) hydrolyzes ACSO to produce pyruvate, ammonia, and many volatile S compounds related to taste.

The results of the analysis of sulfur content in the shallot bulbs of the Super Philip variety show that the more sulfur is given, the more sulfur content is in the shallot bulbs. In the Super Philip variety, the lowest sulfur content value in the 0 ppm S treatment was 0,367 mg g^{-1}. The sulfur content value from the addition of 0 to 125 ppm S increased with the highest sulfur content value at 125 ppm S of 1,403 mg g^{-1}. The results of the analysis of sulfur content in the shallot bulbs of the Tajuk variety show that the more sulfur is given, the more sulfur content is in the shallot bulbs. In the Tajuk variety, the lowest sulfur content value in the 0 ppm S treatment was 0,434 mg g^{-1}. The sulfur content value from the addition of 0 to 125 ppm S increased with the highest sulfur content value at 125 ppm S of 1,071 mg g^{-1}.

Allicin Content of Shallot Bulbs (µg ml^{-1})

The increased S levels also increased the level of pungency of shallots observed at 56 DAP. Shallots contain a source of organosulfur compounds that are responsible for taste and aroma and have pharmacological benefits. In particular, allicin, an organosulfur compound is responsible for most of the pharmacological activity when shallot cloves are crushed (Lawson and Hunsaker 2018). The formation of allicin from alliin is catalyzed by the enzyme alliinase. Allicin is produced by the precursor molecule, alliin (amino acid) which is converted into allicin by the enzyme alliinase (Chhabria and Desai, 2018). The alliinase enzyme is located in the intercellular space of shallot cells, while alliin is located inside the shallot cells. This means that alliin and the alliinase enzyme can only interact to form allicin after the shallot cell wall is broken.

Based on Fig.4 concentration of 0 ppm S Super Philip variety produced the lowest allicin value, which was 97,06 µg ml^{-1}. The highest allicin content was obtained at 125 ppm S, which was 125,13 µg ml^{-1}. At concentrations of 75 and 100 ppm S, the same allicin content was obtained at 118,06 µg ml^{-1}. The results of the analysis of allicin content in the shallot bulbs of the Tajuk variety continued to increase. The lowest allicin content was at 0 ppm S, which was 111,04 µg ml^{-1}. The allicin content at 25, 50, and 75 ppm S was 114,57 µg ml^{-1}. The highest allicin content was obtained at the addition of 100 and 125 ppm S, which was 118,06 µg ml^{-1}.

Organosulfur compounds such as allicin, propyl propane thiosulfinate (PTS), and propyl propane thiosulfenate (PTSO) have been traditionally used to combat arthritis, constipation, and parasitic infestations. Most of these beneficial effects have been confirmed experimentally in vivo and in vitro. In addition, in vitro studies have reported that supplementation of a formula containing garlic and onion concentrates exhibited broad-spectrum antimicrobial activity against multidrug-resistant bacteria isolated from human samples and was also effective against porcine reproductive and respiratory syndrome virus (PRRS) (Liu *et al*., 2012). A study of 146 participants who took a supplement containing allicin for 12 weeks revealed that its intake could reduce the incidence and prevent symptoms associated with the common cold (Josling, 2001). Another similar study involving 65 patients diagnosed with COVID-19 showed that taking allicin capsules for 2 weeks could have a significant impact on improving clinical symptoms and accelerating the healing process (Yaghoubian *et al*., 2021). Thus, a higher potential activity of allicin-rich onion extract in controlling viral infections has been reported.

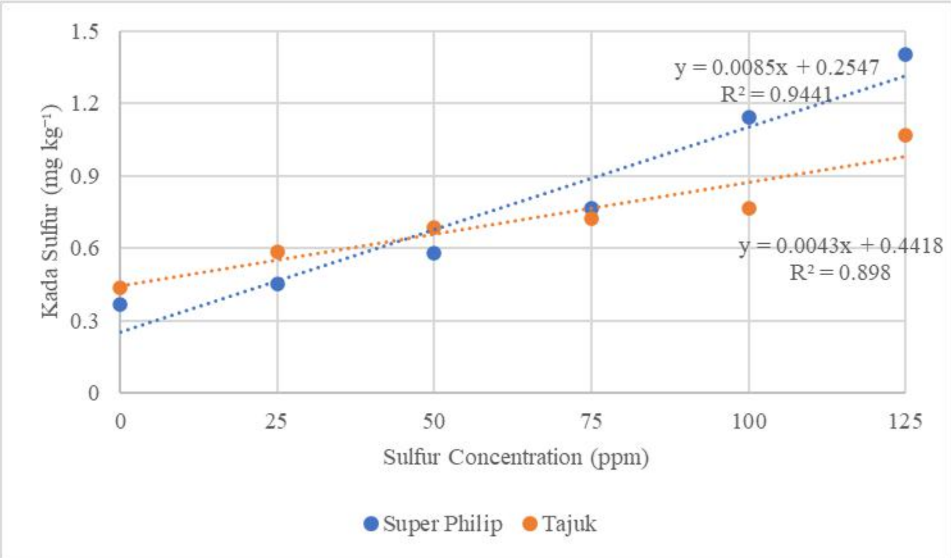

Fig. 3: Response of Sulfur Levels in Bulbs of Two Shallot Varieties to Sulfur Application

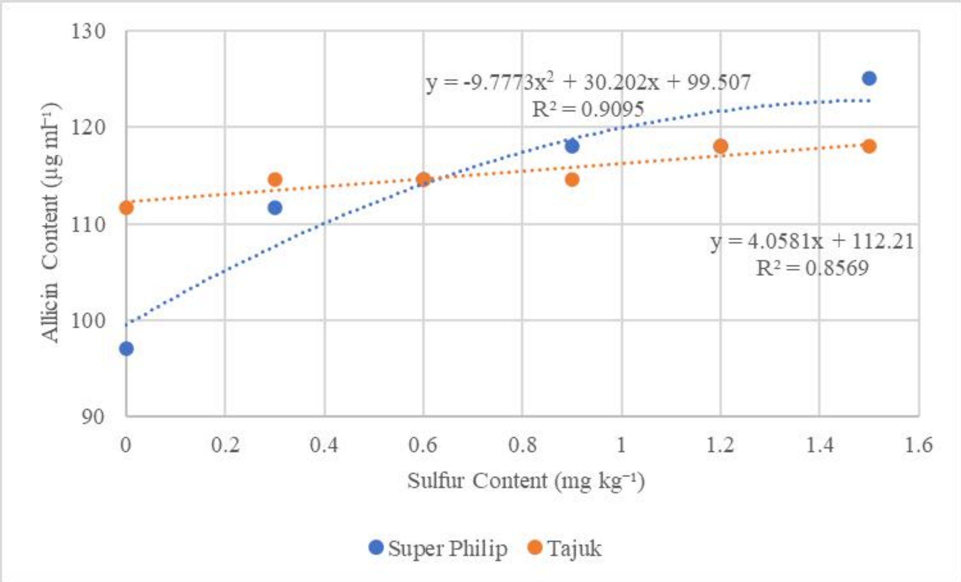

Fig. 4: Response of Allicin Levels in Bulbs of Two Shallot Varieties to Sulfur Levels in Bulbs

IV. CONCLUSION

The addition of sulfur concentration to two varieties of shallots can increase the number of tillers, the number of bulbs, and the fresh weight of bulbs per clump. Based on the research results, the optimum sulfur addition concentration from the regression of fresh weight of bulbs per clump of shallots in the Super Philip variety is 29.17 ppm S and the Tajuk variety is 63.29 ppm S. The addition of sulfur concentration to the Super Philip and Tajuk varieties increases the allicin content in the bulbs up to an addition of 125 ppm.

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