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Research Article

Influence of Variety, Beneficial Fungi, and Application on The Growth and Production of Shallot (*Allium ascalonicum* L.)

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Shallot,
Trichoderma asperellum

Abstract: One effort to increase shallot production is the use of beneficial fungi. This research aims to determine the interaction between variety, type of fungus, and application dose on the growth and yield of shallot plants. The experimental design was a split-split-plot design consisting of 3 treatment factors. The main plot of varieties consists of Maserati, Sanren F1, Lokananta, and Tuk-Tuk. The subplots are types of fungi consisting of *Trichoderma asperellum*, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Glomus* sp. The sub-subplots, namely fungus application doses, consist of 0 g, 7 g, and 14 g. The interaction between the three treatment factors variety, fungus type, and application dose is only significant in the chlorophyll index parameter. This significant interaction was observed in the combination of the Maserati variety with the application of *Metarhizium anisopliae* at a dose of 7 g. Growth characteristics such as plant height and number of leaves were individually affected by the variety and the type of fungus used. Likewise, regarding production parameters, bulb diameter was only influenced by the interaction between the variety and the type of fungus and the variety and the application dose. Observations of the stomata opening area were only influenced individually by the variety. In contrast, the density of the stomata was influenced by the interaction between the variety and the type of fungus. Overall, the influence of varieties is highly dominant, so cultivar selection is an important aspect to consider in shallot cultivation.

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1. Introduction

Shallots are one of the essential crops in Indonesia and several countries in Southeast Asia and on the African continent. Shallots are utilized in culinary preparations and across multiple industrial sectors. Shallots are also known to contain multivitamins, minerals, and antioxidants. In addition to its use as a spice, it is reported that this plant can reduce cancer risk, manage diabetes, improve heart health, boost immunity, and prevent obesity (Sun et al., 2019).

Rising population numbers have driven a significant increase in the market demand for shallots. The research by Arista et al. (2024) shows the demand trend for shallots in Indonesia for the 2020-2024 period shows an increasing trend of 45 798 tons/year. Increasing or maintaining shallot productivity is something that needs attention. The process of cultivating shallots needs to be considered carefully. One effort to increase shallot production is the use of beneficial fungi. Beneficial fungi are known as microorganisms that have many roles in plant growth, both directly and indirectly (Devi et al., 2020). Various fungal species such as *Trichoderma asperellum*, *Beauveria bassiana*, *Metarhizium anisopliae,* and *Glomus* sp. can be used as biological agents. The use of beneficial fungi is an essential part of agricultural sustainability, where inputs such as synthetic fertilizers and pesticides can be reduced

Application of *Trichoderma asperellum* can increase plant growth. Several *Trichoderma* species have been revealed to produce various growth hormones for plants including, cytokinins, gibberellins, abscisic acid, salicylic acid, auxins, and zeatin. (Illescas et al., 2021). Tomato seedlings treated by *Trichoderma asperellum* had a significantly greater height, stem diameter, protein content, and sugar content. Furthermore, their nitrate reductase and catalase activity significantly increased (Yu et al., 2021). Additionally, Fu et al. (2020) have found that applying *Trichoderma asperellum* could increase corn production by 4.87 to 20.26% on saline-alkaline soil. *Beauveria bassiana* has been proven to have a positive impact on plant growth. Yusniwati et al. (2023) found that the application of *Beauveria bassiana* could act as a biological agent that could stimulate growth in cayenne pepper plants in the form of plant height and the number of leaves. Additionally, Staffa et al. (2020) found an effect of *Beauveria bassiana* inoculation on the plant height of *Tulbaghia violacea* plants. On the other hand, *Metarhizium anisopliae* was also proven to have a positive effect on corn plants, characterized by an increase in cob biomass and several other parameters (Liao et al., 2014). Research conducted by Gonzalez-Perez et al. (2022) found that *Metarhizium anisopliae* stimulated growth in tomato, corn, and Arabidopsis plants. Furthermore, research conducted by Liu et al. (2017) found the effect of *Metarhizium anisopliae* inoculation on root development in peanut plants. Root length and number of lateral roots were recorded to be greater in plants inoculated with *Metarhizium anisopliae* than in control plants.

Application of Mycorrhiza to *Citrum aurantinum* plants can promote plant growth, chlorophyll levels, improved water status, gas exchange capacities (increased photosynthetic rate, stomatal conductance, and transpiration rate), and an enhanced oxidative stress defense system (Hadian-Dejuo et al., 2020). Furthermore, Huang et al. (2020) discovered that different Mychorrhiza species could increase the growth of walnut plant roots, including length, projected area, surface area, and volume, when compared to uninoculated plants. Moreover, Arbuscular Mycorrhiza can increase plant performance even under saline condition (Salih and Abdulrraziq, 2024). Based on the description above, it is necessary to review the interactions between plant varieties, types of fungi, and application doses on shallot plants so that a treatment combination can be obtained that positively impacts growth and production.

2. Material and Methods

2.1. Study area

This research was carried out at the Teaching Farm, Faculty of Agriculture, Hasanuddin University, from August to November 2023. Experimental plots were formed in a greenhouse with a 14% ultra-violet plastic roof. The characteristics of microclimate in the planting area are outlined in Table 1. The soil properties of the research site are described in Table 2.

Table 1. Microclimate characteristic

Growth Phase	Temperature (°C)	Relative Humidity (%)
1-20 DAT	40.35	80.50
21-40 DAT	43.00	76.00
41-60 DAT	42.00	75.55
60-70 DAT	43.60	74.30

Note: DAT (the day after transplanting).

Table 2. Soil properties

Properties	
Texture	Clay loam
pH (H_2O)	6.58
C (Walkey & Black)	3.52
N (Kjeldahl)	0.28
C/N	13
P_2O_5 (Olsen)	12.28
K (NH_4-Acetat 1N. pH7)	0.28
Ca (NH_4-Acetat 1N. pH7)	6.92
Mg (NH_4-Acetat 1N. pH7)	1.68
Na (NH_4-Acetat 1N. pH7)	0.46
CEC (NH_4-Acetat 1N. pH7)	19.65

2.2. Experimental design

This research was organized into separate plots consisting of 3 treatment factors. The first factor is that the varieties consist of Maserati, Sanren F1, Lokananta, and Tuk-Tuk. The second factor is the type of fungus consisting of *Trichoderma asperellum* (isolated from cocoa plant at Soppeng Regency, South Sulawesi, Indonesia), *Beauveria bassiana* (isolated from maize plant at Soppeng Regency, South Sulawesi, Indonesia), *Metarhizium anisopliae* (isolated from rubber plant at Banyuwangi, East Java, Indonesia), and *Glomus* sp. The third factor is the fungus dose, consisting of 0 g, 7 g, and 14 g. These three treatment factors resulted in 48 treatment combinations repeated three times, so there were 144 experimental plots. Beneficial fungal isolates are multiplied on rice media (*Trichoderma asperellum*, *Beauveria bassiana*, and *Metarhizium anisopliae*) and corn media (*Glomus* sp.).

2.3. Cultivation process

First, the shallot seeds were sown in the bed, containing soil and chicken manure. After 45 days, shallot seedlings are ready to be transplanted. The experimental plots are 1 m^2 with a height of 30 cm. The plots were covered with plastic mulch. The planting distance used was 15 x 10 cm, so each plot had a population of approximately 70 plants. Before transplanting, primer fertilization was carried out in 10 t ha^{-1} of chicken manure and 347.2 kg ha^{-1} of SP-36. Follow-up fertilization with NPK (16:16:16) as much as 750 kg ha^{-1} and uea as much as 43.47 kg ha^{-1} (15, 30 and 45 days after transplanting (DAP)).

Glomus sp. Was applied before transplanting by sowing it in the planting hole according to the treatment dose. The application of *Glomus* sp. is carried out per plant. *Trichoderma asperellum*, *Beauveria bassiana*, and *Metarhizium anisopliae* are applied using the spray method. The fungus was then dissolved in water and sprayed on plants at ages 14, 21, 28, 35, 42, 49, and 56 DAT, with volumes of 500, 700, 900, 1100, 1300, 1500, and 1700 mL respectively. The application of the three types of fungi is conducted per plotThe difference in application methods is due to *Glomus* sp., a fungus that grows in the root area of plants. Therefore, it is applied before planting in the planting hole. Weed control is carried out using physical methods by pulling them using hands. Watering is done two times a day, morning, and evening. After harvest criteria (stems falling and leaves dry) appeared, at 70 DAT, the plants were uprooted and cleaned of remaining soil and dirt.

2.4. Data collection and analysis

The parameters observed included plant height (cm), measured using a ruler; number of leaves; bulb diameter (mm), measured using a caliper; fresh bulb weight (g), measured using a digital scale; dry bulb weight (g), measured using a digital scale, after being dried for 7 days under sunlight, production per hectare (t) based on dry weight, stomatal opening area (μm^2) measured under a microscope, stomatal density determined under a microscope, and chlorophyll index measured using a CCM-200. Plant height and number of leaves were measured at 60 days after transplanting (DAT). Bulb diameter, fresh bulb weight, dry bulb weight, and production per hectare were measured after harvest. Stomatal opening area, density, and chlorophyll index were measured at the age of 45 DAT.

Data were analyzed with RStudio software. A three-way analysis of variance (ANOVA) was used to perform statistical analysis, with a p-value of 0.05 considered significant. The difference in effect on each type of growing media was then evaluated using the Duncan Multiple Range test with a p-value of 0.05.

3. Results

3.1. Growth traits

3.1.1 Plant Height and number of leaves

Based on the results of the analysis of variance, it shows that only a single factor, variety and type of fungus, influences shallot plant height (Table 3). The Tuk-Tuk variety recorded the highest average plant height (48.86 cm), statistically similar to Sanren F1 (47.26 cm), while the lowest was the Maserati variety (43.55 cm). The best effect on fungus application was recorded in the *Beauveria bassiana* application, which recorded the highest average plant height (48.40 cm), statistically similar to *Trichoderma asperellum* and *Metarhizium anisopliae*, and the *Glomus* sp. application recorded the lowest average plant height (41.63 cm). Moreover, based on the results of the analysis of variance, it shows that only variety and type of fungus influence the number of shallot leaves (Table 3). The Sanren F1 variety recorded the highest average number of leaves (9.20), while the lowest was the Tuk-Tuk variety (6.02), statistically similar to Maserati (6.44). The best effect on fungus application was recorded in the *Trichoderma asperellum* application, which recorded the highest average number of leaves (7.34), and the *Glomus* sp. application recorded the lowest average number of leaves (6.7).

Table 3. Effect of variety and type of fungus on plant height

Variety	**Plant Height (cm)**	**Number of Leaves**
Maserati	43.55 b	6.44 c
Sanren F1	47.26 a	9.20 a
Lokananta	45.12 b	6.89 b
Tuk-Tuk	48.86 a	6.02 c
Fungus	**Plant Height (cm)**	**Number of Leaves**
Trichoderma asperellum	47.33 a	7.34 a
Beauveria bassiana	48.40 a	7.33 a
Metarhizium anisopliae	47.42 a	7.15 ab
Glomus sp.	41.63 b	6.70 b

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.2. Yield traits

3.2.1. Bulb diameter

The analysis of variance shows that only variety and dose of fungus, as well as the interaction of variety with dose of fungus, influence the diameter of shallot bulbs (Table 4). The interaction between the Tuk-Tuk variety and the fungus application at a dose of 7 g recorded the largest average bulb

diameter (32.62 mm) (Table 5). In contrast, the interaction between the Lokananta variety and without the fungus application recorded the smallest average bulb diameter (27.82 mm).

Table 4. Effect of interaction between variety and fungus dose on bulb diameter

Variety	Dose		
	0 g	**7 g**	**14 g**
Maserati	28.80 cd	29.81 bc	31.03 ab
Sanren F1	28.11 d	30.03 bc	30.84 b
Lokananta	27.82 d	30.30 bc	30.56 b
Tuk-Tuk	31.34 ab	32.62 a	30.27 bc

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.2.2. Fresh bulb weight

The variance analysis showed that only the single factor variety, fungus dose, interaction between variety and fungus type, and interaction between variety and fungus dose influenced the fresh weight of shallot bulbs. The interaction between the Tuk-Tuk variety and the application of the *Trichoderma asperellum* fungus recorded the heaviest average fresh bulb weight (19.23 g) (Table 5). In contrast, the interaction between the Maserati variety and the *Glomus* sp. application recorded the lightest average bulb weight (11.59 g).

Table 5. Effect of interaction between variety and type fungus dose on fresh bulb weight

Variety	Fungus			
	Trichoderma asperellum	***Beauveria bassiana***	***Metarhizium anisopliae***	***Glomus* sp.**
Maserati	12.68 ef	14.36 de	14.21 de	11.59 f
Sanren F1	15.29 cd	15.22 cd	14.68 de	18.73 ab
Lokananta	14.12 de	14.47 de	14.43 de	14.40 de
Tuk-Tuk	19.23 a	17.02 bc	16.16 cd	16.20 cd

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.2.3. Dry bulb weight

The analysis of variance showed that only the single factor variety, fungus dose, interaction between variety and fungus type, and interaction between variety and fungus dose influenced the dry weight of shallot bulbs. The interaction between the Sanren F1 variety and the *Glomus* sp. fungus application recorded the heaviest average dry bulb weight (17.86 g) (Table 7), statistically similar to the interaction between Tuk-Tuk and *Trichoderma asperellum* (17.70 g). The interaction between the Maserati variety and the *Glomus* sp. application recorded the lightest average dry bulb weight (11.10 g).

Table 7. Effect of interaction between variety and type of fungus on dry bulb weight

Variety	Fungus			
	Trichoderma asperellum	***Beauveria bassiana***	***Metarhizium anisopliae***	***Glomus* sp.**
Maserati	11.85 e-f	13.48 c-e	13.22 d-f	11.10 f
Sanren F1	13.37 c-e	13.17 d-f	12.69 ef	17.86 a
Lokananta	13.12 d-f	13.50 c-e	13.54 c-e	13.81 c-e
Tuk-Tuk	17.70 a	16.28 ab	15.27 b-d	15.44 bc

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

The interaction between the Tuk-Tuk variety and the fungus application at a dose of 7 g recorded the heaviest average dry bulb weight (17.73 g) (Table 8). In contrast, the interaction between the

Lokananta variety and without the fungus application recorded the lightest average dry bulb weight (11.04 g).

Table 8. Effect of interaction between variety and fungus dose on dry bulb weight

Variety	Dose		
	0 g	**7 g**	**14 g**
Maserati	11.39 fg	12.21 e-g	13.64 c-e
Sanren F1	12.84 d-f	14.73 bc	15.24 bc
Lokananta	11.04 g	14.42 b-d	15.02 bc
Tuk-Tuk	15.51 b	17.73 a	15.28 bc

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.2.4. Production

The analysis of variance showed that only the single factor variety, fungus dose, interaction between variety and fungus type, and interaction between variety and fungus dose influenced production per hectare of shallot bulbs. The interaction between the Sanren F1 variety and the *Glomus* sp. fungus application recorded the highest average production per hectare (19.84 t) (Table 9).

Table 9. Effect of interaction between variety and fungus dose on production

Variety	Fungus			
	Trichoderma asperellum	***Beauveria bassiana***	***Metarhizium anisopliae***	***Glomus* sp.**
Maserati	13.35 ef	15.30 c-e	14.92 c-e	12.34 f
Sanren F1	14.85 c-e	14.63 de	14.11ef	19.84 a
Lokananta	14.58 e	15.00 c-e	15.04 c-e	15.34 c-e
Tuk-Tuk	19.66 a	18.09 ab	16.96 b-d	17.16 bc

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

The interaction between the Tuk-Tuk variety and the fungus application at a dose of 7 g recorded the highest average production per hectare (19.70 t) (Table 10).

Table 10. Effect of interaction between variety and fungus dose on production

Variety	Dose		
	0 g	**7 g**	**14 g**
Maserati	12.41 e	14.00 de	15.52 b-d
Sanren F1	14.27 cd	15.37 b	16.93 b
Lokananta	12.26 e	16.02 bc	16.69 b
Tuk-Tuk	17.24 b	19.70 a	16.97 b

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.3. Stomata traits

3.3.1. Stomata opening area

Based on the results of the analysis of variance, it shows that only a single variety factor influences the width of the stomata opening of shallots (Table 11). The Lokananta variety recorded the largest stomata opening area (168.27 μm^2), while the Maserati variety recorded the narrowest average stomata opening area (130.75 μm^2).

Table 11. Effect of variety on stomatal opening area

Variety	Stomata Opening Area (μm^2)
Maserati	130.75 b
Sanren F1	149.37 b
Lokananta	168.27 a
Tuk-Tuk	163.32 a

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.3.2. Stomata density

The analysis of variance shows that only a single factor of variety and the interaction of variety with type has an influence on shallot stomata density (Table 12). The interaction between the Sanren F1 variety and the *Beauveria bassiana* fungus application recorded the highest average stomata density (51.16). In contrast, the interaction between the Lokananta variety and the *Beauveria bassiana* application recorded the lowest average stomata density (34.53).

Table 12. Effect of interaction between variety and fungus dose on production

Variety	Fungus			
	Trichoderma asperellum	***Beauveria bassiana***	***Metarhizium anisopliae***	***Glomus* sp.**
Maserati	44.72 a-c	44.23 a-d	44.72 a-c	46.37 a-c
Sanren F1	43.02 b-d	51.16 a	45.85 a-c	41.55 b-d
Lokananta	43.02 b-d	34.53 e	39.06 c-e	46.51 ab
Tuk-Tuk	42.72 b-d	41.19 b-e	43.70 b-d	36.98 de

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.4. Chlorophyll index

Based on the results of the analysis of variance, it shows that the interaction between variety, type of fungus, and application dose influences the chlorophyll index of shallots (Table 13). The interaction between the Maserati variety and the *Metarhizium anisopliae* application at a dose of 7 g recorded the highest average chlorophyll index (33.56). In contrast, the interaction between the Tuk-Tuk variety and without *Glomus* sp. application recorded the lowest average chlorophyll index (7.81).

Table 13. Effect of interaction between variety, type of fungus, and application dose on the chlorophyll index

Variety	Fungus	Dose		
		0 g	**7 g**	**14 g**
Maserati	*Trichoderma asperellum*	14.30 d-h	19.20 b-d	16.50 c-e
	Beauveria bassiana	19.60 b-d	22.56 b	18.80 b-d
	Metarhizium anisopliae	15.90 c-f	33.56 a	14.86 d-g
	Glomus sp.	10.24 f-i	10.90 e-i	12.90 e-i
Sanren F1	*Trichoderma asperellum*	11.03 e-i	21.46 b-c	10.56 e-i
	Beauveria bassiana	11.53 e-i	10.06 f-i	10.83 e-i
	Metarhizium anisopliae	10.30 e-i	11.43 e-i	14.83 d-g
	Glomus sp.	10.90 e-i	11.10 e-i	10.20 f-i
Lokananta	*Trichoderma asperellum*	11.73 e-i	11.46 e-i	10.80 e-i
	Beauveria bassiana	13.00 e-i	8.30 hi	10.70 e-i
	Metarhizium anisopliae	8.13 h-i	8.90 g-i	10.20 f-i
	Glomus sp.	8.53 h-i	10.36 e-i	9.40 g-i

Table 13. Effect of interaction between variety, type of fungus, and application dose on the chlorophyll index (continued)

Variety	Fungus	Dose		
		0 g	7 g	14 g
Tuk-Tuk	*Trichoderma asperellum*	10.03 f-i	10.23 f-i	9.50 g-i
	Beauveria bassiana	10.50 e-i	8.40 h-i	10.33 e-i
	Metarhizium anisopliae	11.63 e-i	8.50 h-i	9.86 f-i
	Glomus sp.	7.86 i	11.80 e-i	10.73 e-i

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Duncan multiple range test.

3.5. Correlation analysis

The relationship between various parameters has diverse correlation values (Figure 1). Correlation values between parameters have positive or negative values. The range of correlation values obtained ranges from -0.206 to 0.988. This value can describe a positive relationship, which means the value of a parameter will increase along with the increase in the value of other parameters. Vice versa, a negative relationship indicates that the value of one parameter will increase if the value of another parameter decreases.

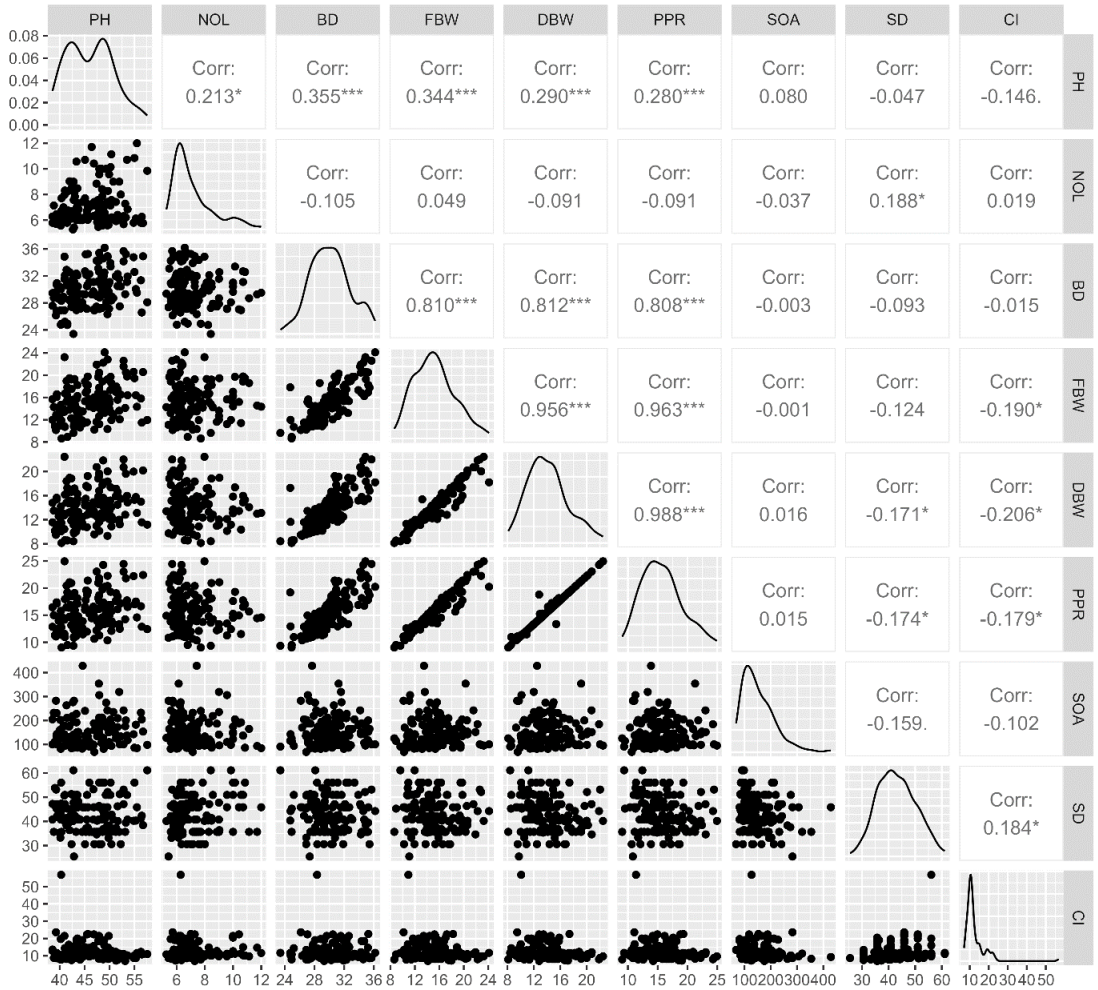

Figure 1. Correlation among parameters. PH (plant height), NOL (number of leaves), BD (bulb diameter), FBW (fresh bulb weight), DWB (dry bulb weight), PPR (production per hectare), SOA (stomata opening area), SD (stomata density), and CI (chlorophyll index).

4. Discussion

The three treatment factors consisting of variety, type of fungus, and application dose each have an influence, either singly or in interaction with each other, on various parameters for observing shallot growth and production. The plant height parameter indicates that the Tuk-Tuk variety achieved the highest average plant height among all the varieties. Then, the application of the *Beauveria bassiana* fungus also recorded the highest average plant height compared to other types of fungus. Indications regarding the influence of *Beauveria bassiana*, which can act as a plant growth promoter, have also been found in several previous studies. Research conducted by Afandhi et al. (2019) found a positive effect of *Beauveria bassiana* inoculation on common bean plants. Inoculation of *Beauveria bassiana* positively affected plant growth parameters, including plant height, number of leaves, and root length. Furthermore, it was noted that *Beauveria bassiana* could colonize grapes, strawberries, and melons, which resulted in increased plant growth and yield (Mantzoukas et al., 2021 and 2022). Saikkonen et al. (2015) stated that *Beauveria bassiana* helps to transfer nutrients from the soil into the plant and helps to stimulate plant growth. Several studies have shown that inoculation of entomopathogenic *Beauveria bassiana* had a positive effect on the growth of cotton plants (Ownley et al., 2008). However, a study by Espinoza et al. (2019) found no difference in the growth of *Allium schoenoprasum* L. plants inoculated with *Beauveria bassiana* compared to those without inoculation.

When observing the number of leaves, it was seen that the Sanren F1 variety had more leaves than the other varieties. Then, the *Trichoderma asperellum* application recorded the highest average number of leaves compared to other types of fungi. As is known, *Trichoderma asperellum* is a type of beneficial fungus that has a positive impact on plant growth. Several previous studies also found increased growth due to the application of *Trichoderma asperellum* to plants. Setyaningrum et al. (2019) found that applying *Trichoderma asperellum* to shallots increased the average plant height, number of leaves, number of roots, and fresh weight of bulbs compared to without the fungus application. In addition, the application of *Trichoderma asperellum* can increase wheat production, soybean biomass, and good photosynthetic performance in sugarcane plants (Illescas et al., 2022; Junior et al., 2019; Scudeletti et al., 2021).

Observation of production components in bulb diameter, fresh weight, bulb dry weight, and production per hectare had almost similar results. In general, the Tuk-Tuk variety dominates various parameters of shallot production. The widest diameter of shallot bulbs was recorded in the Tuk-Tuk variety, the application of beneficial fungus at a dose of 14 g, and the interaction between the Tuk-Tuk variety and the application of beneficial fungi at 7 g. The weight of fresh bulbs was recorded as being the heaviest in the Tuk-Tuk variety, the application of the fungus at a dose of 14 g, the interaction between the Tuk-Tuk variety and the application of *Trichoderma asperellum* and the interaction between the Tuk-Tuk variety and the fungus application at a dose of 7 g. Dry bulb weight and production per hectare are each significantly influenced by variety, application dose, interaction of variety with fungus type, and interaction of variety with application dose. The highest dry weight of bulbs and production per hectare of shallot plants was recorded in the Tuk-Tuk variety, application at a dose of 7 g, interaction between the Sanren F1 variety and *Glomus* sp., and interaction between the Tuk-Tuk variety and application at a dose of 7 g. There is a tendency for the Tuk-Tuk and Sanren F1 varieties to have the best production due to the genetic potential that each variety has. Adding beneficial fungi at a dose of 7 g also increased shallot yields in this study.

In general, the application of beneficial fungi at a dose of 7 g increased shallot production significantly compared to without application. However, it is essential to choose the type of fungus to pay attention to and consider according to its purpose and use. The combination of the Sanren F1 variety and *Glomus* sp. has been shown to increase production, so we believe the two are compatible. It is known that *Glomus* sp. is a type of fungus that lives in the root area of plants and has many positive roles for plants. Research conducted by Saleh et al., (2021) also found that *mycorrhiza* application increased root biomass and shallot plant production. *Mycorhizza* can reduce the use of standard fertilizer on shallots by up to 50% (Hazra et al., 2021).

The variety greatly influenced observations of the opening area and stomata density. The largest stomata opening area was recorded in the Lokananta variety. At the same time, the most significant stomata density was recorded in the Sanren F1 variety and the interaction between the Sanren F1 variety and the application of the *Beauveria bassiana* fungus. The diverse characteristics of stomata are indeed

influenced by variety, and even environmental factors have a significant influence. Boso et al. (2016) found that grape plants have different stomata sizes and densities depending on the plant variety. The density and size of stomata are things that are not related to each other.

The interaction between the three treatment factors was only found in the chlorophyll index parameter. Combining the Maserati variety with the application of *Metarhizium anisopliae* at a dose of 7 g recorded the highest average chlorophyll index compared to other treatment combinations. Variations in the effect of the application of the fungus *Metarhizium anisopliae* on increasing chlorophyll levels in plant leaves have been discovered by various previous studies. Mimma et al. (2023) also found that seed priming with *Metarhizium anisopliae* on okra plants increased plant chlorophyll levels. However, research conducted by Shaalan et al. (2021) did not find an increase in chlorophyll a and b levels in cucumber plants inoculated with *Metarhizium anisopliae*.

Parameters that have a positive correlation with the production per hectare, sorted from the largest to the smallest correlation value, are dry bulb weight (0.988), fresh bulb weight (0.963), bulb diameter (0.808), plant height (0.280), number of leaves (-0.091), stomata density (-0.174), and chlorophyll index (-0.179). From the correlation value, it can be divided into five groups of relationships, namely negligible correlation (0.00 - 0.10), weak correlation (0.10 - 0.39), moderate correlation (0.40 - 0.69), strong correlation (0.70 - 0.89), and very strong correlation (0.90 – 1.00) (Schober and Schwarte, 2018).

Conclusion

Based on the research that has been carried out, it can be concluded that the interaction between the three treatment factors between variety, type of fungus, and application dose is only visible in the chlorophyll index parameter, which was recorded in the combination of the Maserati variety with the application of *Metarhizium anisopliae* at a dose of 7 g. Growth observations, including plant height and number of leaves, were influenced singly by the variety and type of fungus applied. The Tuk-Tuk variety has the highest average plant height, largest bulb diameter, heaviest fresh and dry bulb weight, and highest yield per hectare. Meanwhile, the Sanren F1 variety has the highest average leaf count and high stomatal density. Additionally, the Lokananta variety records the largest stomatal opening area.

Ethical Statement

Ethical approval is not required for this study.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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Author Contributions

Elkawakib Syam'un (conceptualization, methodology, writing original draft), Katriani Mantja (methodology, writing original draft), Fachirah Ulfa (methodology, writing original draft), Muhammad Junaid (methodology, supervision), Muhammad Jayadi (data curation, supervision), Sylvia Sjam (data curation, supervision), Muhammad Irfan Said (data curation), Suhardi (resources), and Syamsia (formal analysis).

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