Research Article

Synergistic Effects of Fermented Young Coconut Water and *Trichoderma* sp. on the Growth and Productivity of Shallots from Botanical Seeds

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Abstract | Shallots are one of the horticultural crops that affect Indonesia's economy with fluctuating prices and production. This problem is partly caused by using seeds that only focus on bulbs. True Shallot Seed (TSS) offers greater efficiency, higher yield potential, and disease-free plants as an alternative solution to bulb seeds. However, the concept of TSS cultivation still needs to be developed. Fermented young coconut water and Trichoderma sp. have been widely reported to provide independent advantages in bulb seed-based shallots. Therefore, the combination of the two must be studied in depth in TSS. The objective of this study was to assess the effect of the combination on the growth and productivity of shallots grown on TSS with the application of fermented young coconut water and Trichoderma sp.. This study was arranged in a 2-factor factorial design in a completely randomized block design as the environmental design. The first was fermented coconut water (0%, 20%, 40%, 60%), and the second was Trichoderma sp. (0 g m^{-2}, 30 g m^{-2}, 60 g m^{-2}) repeated three times. So, there were 36 experimental plots. Each treatment combination consisted of 9 plant samples. Based on this study, the combined application of Trichoderma fertilizer and fermented coconut water significantly improved the growth and productivity of shallots from TSS. The best synergistic effect was achieved with 30 g m^{-2} Trichoderma fertilizer and 30% fermented coconut water. These findings offer a basis for future research on biofertilizers and natural growth enhancers in sustainable onion cultivation.

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Introduction

Shallot (*Allium ascalonicum* L.) is one of the leading vegetable commodities in Indonesia that plays an important role in household consumption as a seasoning, raw material for the food industry, and herbal medicine. Bioactive contents such as allicin provide antiseptic benefits and support heart health. In addition, shallots have high nutritional value. This nutritional content per 100 grams consists of carbohydrates (71.76 g), protein (9.07 g), fat (5.17 g), and minerals such as calcium, magnesium, potassium, and iron that support various body functions (Ichwan *et al*., 2022; Adeyemo *et al*., 2023).

Onion cultivation techniques in Indonesia generally use bulbs as seedlings because they are considered practical. However, this approach has disadvantages, such as high seedling costs and low productivity. Alternatively, onion seeds from seeds or True Shallot Seed (TSS) offer great potential for increasing cultivation efficiency. TSS is more economical, produces pathogen-free plants, and produces larger bulbs. The use of TSS is known to double yields compared to conventional bulb seeds (Dewi *et al*., 2023).

National shallot production increased from 2018 to 2021 but decreased by 2% in 2022 to 1,974,291 tons (Statistics Indonesia, 2023). This decline is a challenge because shallot consumption continues to increase as the population grows, reaching an average of 3.024 kg/capita in 2022. Effective cultivation technology is needed to answer this challenge, including fermented young coconut water and *Trichoderma* sp.

Fermented young coconut water has the potential to be an effective natural growth regulator. Besides containing hormones such as auxins and cytokinins that stimulate cell elongation and division, coconut water is also rich in essential nutrients such as potassium, magnesium, and phosphorus that support tuber formation. The fermentation process increases the bioavailability of active compounds in coconut water, doubling as a natural phytohormone and a source of plant nutrients (Rajiman, 2020; Hambur *et al*., 2023). The results showed that applying fermented coconut water could increase plant height, number of leaves, and weight of shallot bulbs (Arjuna *et al*., 2017; Nurman *et al*., 2017). Meanwhile, *Trichoderma* sp. is an effective biological agent in improving soil quality, controlling soil-borne pathogens, and increasing nutrient uptake efficiency by roots. *Trichoderma* sp. also produces enzymes that accelerate the decomposition of organic matter, thus improving soil conditions to support plant growth (Juniawan, 2019; Mahfud *et al*., 2021). The combination of fermented coconut water and *Trichoderma* sp. is believed to have a significant synergistic effect on shallot growth and yield. This study aims to evaluate the impact of a combination of fermented young coconut water and *Trichoderma* sp. on shallots grown from TSS growth and production. This approach is expected to support the development of shallot cultivation technology that is more efficient, environmentally friendly, and sustainable to meet national needs.

Materials and Methods

This research was conducted in Experimental farm, Faculty of Agriculture, Hasanuddin university during November 2024 to February 2025. The materials used in this research are shallot seeds of Lokananta variety, soil, compost, cocopeat, urea, NPK, SP-36, young coconut water, anthracol fungicide, insecticide, and Trichoderma sp. The tools used in this research are seedling trays, analytical scales, tweezers, glass jars, sprayers, rulers, hoes, paddles, plastic mulch, aisle frames, and hand tractors.

This study was arranged in a 2-factor factorial design in a completely randomized group design as the environmental design.

The first factor is fermented coconut water (A), consisting of 4 levels, namely:

$$a0 = 0\%,\ a1 = 20\%,\ a2 = 40\%,\ a3 = 60\%$$

The second factor is *Trichoderma* sp. (T) consists of 3 levels, namely:

$$t0 = 0\ g\ m^{-2},\ t1 = 30\ g\ m^{-2},\ t2 = 60\ g\ m^{-2}$$

Based on the number of treatments tried, 12 experimental combinations were obtained, which were repeated three times, resulting in 36 experimental plots. Each treatment combination consisted of 9 plant samples, resulting in 324 plant samples.

Implementation of research

The implementation of the research included land processing, seed sowing, fermented young coconut water processing, planting, application of fermented young coconut water and *Trichoderma* sp., maintenance, harvesting, and drying.

Land processing

The land is first cleared of garbage and weeds that grow around it. Then, the land was tilled using a hand tractor. Then, 36 plots of beds were made, measuring 100 cm x 100 cm, with a height of 20 cm and a distance between beds of 30 cm. After that, basic fertilizer was in the form of chicken manure, burnt husk, and dolomite, which was then covered with black silver plastic mulch.

Seeding the seeds

Lokananta variety shallot seeds were soaked using warm water and Atonik for approximately 8 hours. After that, shallot seeds that have been soaked are given Antracol 70 WP fungicide and stirred well so that all seed surfaces are covered with fungicide. Before seeding, the seedling tray was filled with a mixture of soil, compost, and cocopeat in a ratio of 2:2:1, which was stirred well. Then, shallot seeds were sown by placing one seed per hole of the seedling tray. The seedlings were maintained in the nursery for 30 days until they reached the appropriate size for field transplantation.

Young coconut water treatment

Coconut water processing is carried out based on the utilization of coconut water as fermentation in Ulfa's Research (2014), the stages are: (1) young coconut water is prepared from the same tree, green coconut type with the criteria that the flesh is very soft like mucus if spooned; (2) 1 L of young coconut water plus 1 L of distilled water is mixed then stirred (3) 30 g of granulated sugar is dissolved in the mixture and then stirred then filtered to ensure that no sugar grains are left behind; (4) put into a container in the form of a 1.5 L bottle, the container is only filled to 80% of the height so that there is room to accommodate the fermentation gas; (5) the container is closed properly and then stored in a place that is not exposed to sunlight; (6) after 5 days, the bottle cap is opened slowly and after that it is done every 2 days to remove excess gas from fermentation; (7) fermentation is carried out for 15 days, the criteria are ready for use, namely that the solution has an alcoholic aroma.

Planting

Planting is done when the seedlings are 30 days after sowing. Before transplanting, shallot leaves were pruned. Each planting hole had 1 plant with 3 leaves, good growth, and free from pests and diseases. The planting distance was 15 cm x 15 cm, so there were 25 plants per bed, and the total population of all treatments was 324 plants.

Application of fermented young coconut water and Trichoderma sp.

Fermented coconut water is applied to plants aged 7, 14, 21, 28, 35, 42, 49, and 56 DAP by mixing with water first according to the treatment level, namely 0%, 20%, 40%, and 60% concentrations. Coconut water was applied by evenly spraying it directly onto the shallot plants, covering the leaves and stems without targeting the soil. The spray volume per plant is adjusted to the age of the plant so that the consecutive application volumes are 400 mL per plant, 500 mL per plant, 600 mL per plant, 700 mL per plant, 800 mL per plant, 900 mL per plant, 1,000 mL per plant, and 1,100 mL per plant. The application of *Trichoderma* sp. is carried out following the predetermined dose, namely without *Trichoderma* sp. (t0), 30 g m^{-1} *Trichoderma* sp. (t1), and 60 g m^{-1} *Trichoderma* sp. (t2), by sowing around the roots of shallot plants at the age of 1 DAP.

Monitoring

Onion plant management consists of: Watering is done twice a day in the morning and evening (depending on weather conditions). Shallot seedlings were replanted before the application of the treatment materials. Shallots that died or had poor growth were replaced with the remaining seedlings. Weeding is done by pulling weeds around the plants to avoid competition for nutrients in shallot plants. Pest and disease control is carried out by several methods, namely destroying by hand, spraying Curacon 500 EC insecticide at a dose of 2 mL/L to avoid pest attacks, and anticipating disease attacks by spraying Antracol 70 WP fungicide at a dose of 2 g/L. Onion fertilization is done by adding half the recommended dose of onion fertilizer which is Urea 150 kg ha^1, SP-36 200 kg ha^1, and NPK 200 kg ha^1 so that the fertilizers applied are Urea 75 kg ha^1, SP-36 100 kg ha^1, and NPK 100 kg ha^1. Urea, SP-36, and NPK fertilizers were applied 3 times, namely 1/3 dose at the age of 11 DAP, 1/3 dose at the age of 24 DAP, and 1/3 dose at the age of 45 DAP. Plant fertilization dose per plot urea 7.5 g, SP-36 10 g, NPK 10 g.

Harvesting and drying

Harvesting was carried out when the shallot plants reached physiological maturity, which occurred approximately 75-90 days after transplanting. The criteria for harvesting shallots include the leaves of the plant have withered, the leaves have turned yellow 70-80% of the number of plants, the base of the stem is hardened, some of the bulbs have poked out of the soil, and the layers of the bulbs are fully filled and red in color (Kurnia *et al*., 2023), Harvesting is done by pulling out the entire plant until the bulbs are lifted to the surface of the soil. Then, the tubers are cleaned from the remaining soil that sticks. Harvested tubers are separated from the leaves according to the treatment. Then, it is placed on paper and air-dried for 10 days.

Observation parameters and data analysis

The parameters observed in this study include Plant height (PH) (cm), number of leaves (NL), chlorophyll index (CI), stomatal density (SD), stomatal opening area (SOA), number of tubers per clump (NTC), fresh tuber diameter (FTD) (cm), DTD: fresh tuber diameter (DTD) (cm), fresh tuber weight (FTW) (g), dry tuber weight (DTW) (g), fresh biomass weight per plant (FBWP) (g), dry biomass weight per plant (DBWP) (g), and tuber yield (t ha^{-1}). The overall data obtained were analyzed using an ANOVA variance analysis. After that, data affected by one or both treatments were continued into correlation analysis and polynomial-polynomial interaction analysis using RStudio software.

Results

The analysis of variance showed that the highest coefficient of variance (CV) in error a is owned by FBWP by 19%, while tuber yield owns the lowest CV by 2% (Table 1). The highest CV in error b was owned by NTC by 13%, while tuber yield owned the lowest CV by 1%. Based on the source of diversity, all characters were significantly affected by Trichoderma fertilizer treatment, except The measured parameters included Chlorophyll Index (CI), Standard Deviation (SD), Non-Treated Control (NTC), and Days to Harvest (DTD).Based on the effect of the concentration of fermented water coconut, all dominant growth characters were strongly influenced by the treatment, the measured parameters included Chlorophyll Index (CI), Non-Treated Control (NTC), and Days to Harvest (DTD) (see Table 1 for full list of symbols used). Standard Deviation (SD) was also measured, but its abbreviation is commonly understood in this context. Meanwhile, the significant interaction effect of *Trichoderma* sp. and concentration of fermented water coconut was shown in Fresh Biomass Weight per Plant (FBWP), Dry Biomass Weight per Plant (DBWP), Days to Wilt (DTW), and For The Win (FTW), and tuber yield characters. The results of this analysis are considered for in-depth analysis in evaluating the combination of *Trichoderma* fertilizer dosage and concentration of fermented water coconut in this study.

Table 1: *Analysis of variance on shallot growth characters TSS.*

Character	TF	CVa	FCW	TF*FCW	CVb
PH	7.33*	4	3.17*	1.25	7
NL	8.95*	11	10.22**	1.78	10
CI	2.44	12	9.88**	1.3	7
SD	1.29	9	3.01	0.37	6
SOA	12.62*	17	6.02**	0.82	8
NTC	0.18	16	9.57**	1.72	13
FTD	10.12*	6	66.54**	2.65	4
DTD	5.56	8	45.65**	1.39	5
FTW	17.48*	11	77.30**	4.21**	9
DTW	13.86*	16	75.69**	3.7*	12
FBWP	7.67*	19	65.48**	3.80*	11
DBWP	10.25*	18	83.50**	3.71*	11
Yield	11.07*	2	71.82**	4.24**	1

*TF: Trichoderma fertilizer, CV = coefficient of variance, FCW: fermented coconut water, FCC = * significant at 5% error level, ** significant effect at 1% error level, PH: Plant height, NL: number of leaves, CI: chlorophyll index, SD: stomatal density, SOA: stomatal opening area, NTC: number of tubers per clump, FTD: fresh tuber diameter, DTD: fresh tuber diameter, FTW: fresh tuber weight, DTW: dry tuber weight, FBWP: fresh biomass weight per plant, DBWP: dry biomass weight per plant.*

Correlation analysis was conducted on the characters that significantly influenced the treatment of Trichoderma fertilizer and or concentration of fermented water coconut (Figure 1). Based on the correlation analysis of all characters, in general, each growth character is significantly correlated with each other. In particular, the correlation with productivity was shown in all characters, with a very significant correlation above 0.9, except SOA (0.82), Chlorophyll Index (0.84), and Non-Treated Control (0.83). The measured parameters included Fresh Biomass Weight per Plant (FBWP), Dry Biomass Weight per Plant (DBWP), Days to Wilt (DTW), and For The Win (FTW), as shown in Figure 1. The correlation coefficient for FBWP and DBWP was 0.95, as shown in Figure 1, which has been updated in this description for accuracy

Based on Table 2, plant height, number of leaves, stomatal opening area, and fresh tuber diameter are characteristics that can be independently analysed through polynomials to determine the effect of *Trichoderma* fertilizer dosage. The four characters showed a quadratic polynomial pattern with a high determination value. The optimum dose of Trichoderma fertilizer on the three characters was found at 30 g m^{-2}.

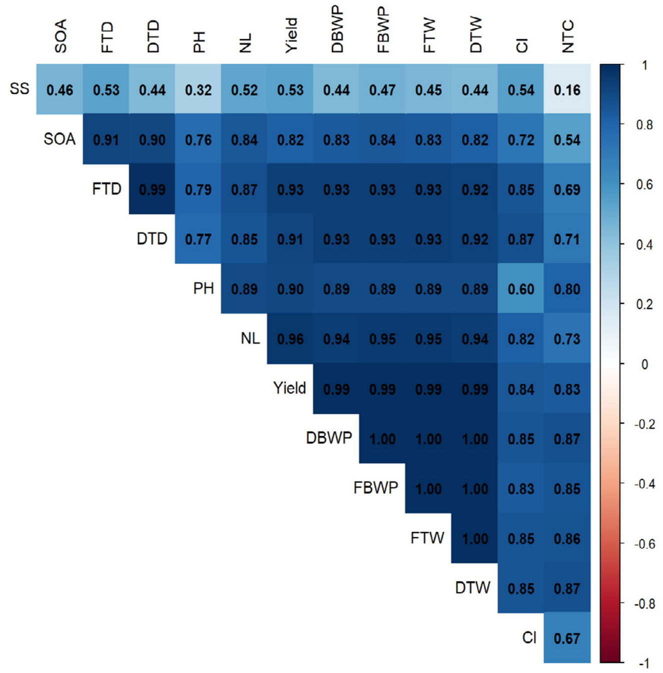

Figure 1: *Correlation analysis of all growth characters was significantly influenced by the dose of Trichoderma fertilizer and/or the concentration of fermented coconut water. PH: Plant height, NL: number of leaves, CI: chlorophyll index, SOA: stomatal opening area, NTC: number of tubers per clump, FTD: fresh tuber diameter, DTD: fresh tuber diameter, FTW: fresh tuber weight, DTW: dry tuber weight, FBWP: fresh biomass weight per plant, DBWP: dry biomass weight per plant.*

The results of the polynomial further analysis on the concentration of fermented water coconut are shown in Table 3. Based on the table, plant height, number of leaves, chlorophyll content, stomatal opening area, number of tubers per clump, fresh tuber diameter, and dry tuber diameter are characters that can be independently analyzed through the concept of a polynomial to the effect of the concentration of fermented water coconut. All characters showed a quadratic polynomial pattern with a high determination value above 0.9. In addition, all characters show that the optimum concentration of fermented coconut is 40%, except for the area of stomatal openings. The character of the stomatal opening area shows the optimum concentration at 20%.

The results of the polynomial-polynomial interaction analysis of Trichoderma fertilizer dose and concentration of fermented water coconut on TSS are shown in Table 4 and Figure 2. Based on the table, fresh tuber weight, dry tuber weight, fresh stalk weight per plant, dry stalk weight per plant, and yield are the optimal characters that can be analyzed through polynomial-polynomial interaction. All characters showed quadratic-quadratic interactions with good determination values. The best determination value among these characters belongs

Table 2: *Polynomial analysis of Trichoderma fertilizer dosage.*

Character	Formulation	R^2	Dosage of Trichoderma fertilizer (g m^{-2})		
			0	30	60
PH (cm)	$-0.0019x^2+0.1344x+35.204$	1.00	35.20	37.50	36.32
NL (cm)	$-0.0008x^2 + 0.0674x + 6.5185$	1.00	6.52	7.79	7.55
SOA (µm²)	$-0.0067x^2 + 0.6149x + 75.142$	1.00	75.13	87.55	87.88
FTD (cm)	$-0.0021x^2 + 0.1797x + 31.246$	1.00	31.25	34.74	34.45

R^2: Determination value, PH: Plant height, NL: number of leaves, SOA: stomatal opening area, FTD: fresh tuber diameter.

Table 3: *Polynomial analysis of fermented coconut water concentration.*

Character	Formulation	R^2	Optimum concentration (%)			
			0	20	40	60
PH (cm)	$-0.0027x^2 + 0.1862x + 34.511$	0.94	34.64	36.76	38.07	35.89
NL (cm)	$-0.0015x^2 + 0.0988x + 6.3519$	0.96	6.41	7.58	8.16	7.00
CI	$-0.0024x^2 + 0.1716x + 15.219$	0.99	15.19	17.80	18.13	16.89
SOA (µm²)	$-0.0229x^2 + 1.5086x + 70.294$	0.93	69.13	94.79	90.54	79.62
NTC	$-0.0004x^2 + 0.0293x + 1.514$	0.94	1.53	1.89	2.14	1.87
FTD (cm)	$-0.0059x^2 + 0.431x + 28.79$	0.99	28.76	35.14	36.53	33.49
DTD (cm)	$-0.006x^2 + 0.4308x + 24.473$	0.99	24.43	30.80	31.93	28.65

R^2: Determination value, PH: Plant height, NL: number of leaves, CI: chlorophyll index, SOA: stomatal opening area, NTC: number of tubers per clump, FTD: fresh tuber diameter, DTD: fresh tuber diamete.

Table 4: *Polynomial-polynomial interaction analysis of trichoderma fertilizer dose and fermented coconut water concentration on true shallot seed (TSS).*

Charac-ters	Formulation	R2	Optimized combination
FTW	24.57 + 6.94 TF – 6.56 TF2 + 10.98FC – 15.33FC2 + 2.27 TF*FC – 1.28 TF2*FC – 14.17 TF*FC2 + 14.34 TF2*FC2	0.86	30 g/m^2 TF dan 30% FC
DTW	18.11 + 6.36 TF – 6.23 TF2 + 10.11FC – 14.61FC2 + 1.02 TF*FC + 0.57 TF2*FC – 12.71 TF*FC2 + 12.40 TF2*FC2	0.83	30 g/m^2TF dan 30% FC
FBWP	29.91 + 10.17 TF – 7.69 TF2 + 14.34FC – 21.16FC2 + 4.81 TF*FC – 4.35 TF2*FC – 22.49 TF*FC2 + 16.88 TF2*FC2	0.81	30 g/m^2TF dan 30% FC
DBWP	20.23 + 7.09 TF – 6.66 TF^2 + 11.35FC – 16.69FC^2 + 1.49 TF*FC – 6.30 TF^2*FC – 14.86 TF*FC^2 + 12.69 TF^2*FC^2	0.85	30 g/m^2TF dan 40% FC
Yield	4.581 + 1.964 TF – 1.558 TF^2 + 2.350 FC – 3.176 FC^2 – 0.102 TF*FC – 0.310 TF^2*FC – 2.780 TF*FC^2 + 3.340 TF^2*FC^2	0.84	30 g/m^2 TF dan 40% FC

R^2: Determination value, FTW: fresh tuber weight, DTW: dry tuber weight, FBWP: fresh biomass weight per plant, DBWP: dry biomass weight per plant.

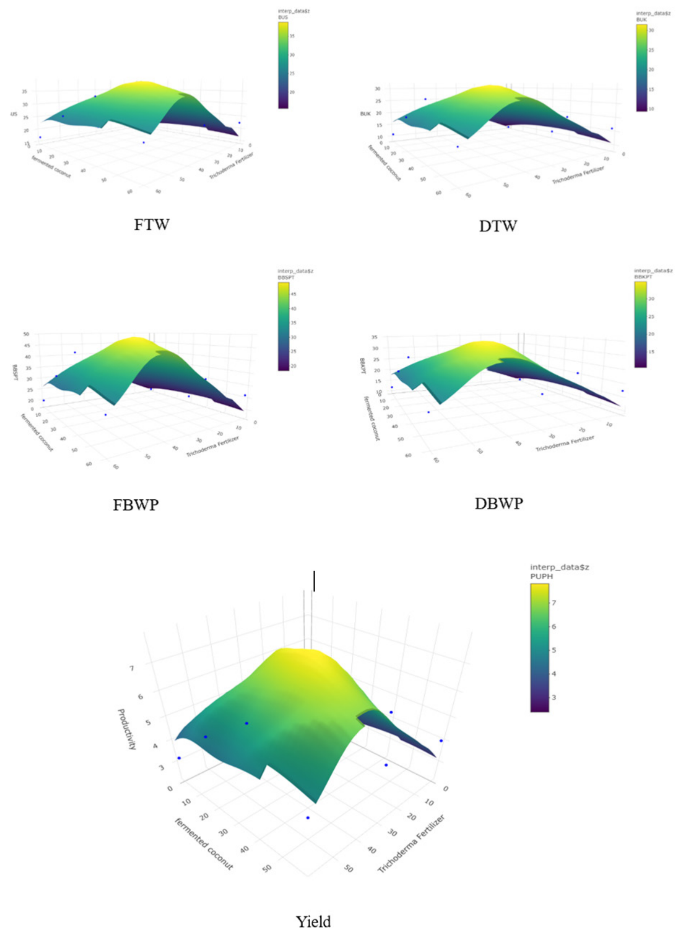

Figure 2: *Polynomial-polynomial interaction curve of Trichoderma fertilizer dose and fermented coconut water concentration on true shallot seed (TSS). FTW: fresh tuber weight, DTW: dry tuber weight, FBWP: fresh biomass weight per plant, DBWP: dry biomass weight per plant.*

to fresh tuber weight (0.86). In addition, all characters showed interaction peaks on the yellow response surface curve in the middle, combining a 30 g m-2 dose of Trichoderma fertilizer with a 30% fermented coconut concentration.

Discussion

The analysis of variance showed that several characters were singularly influenced by the treatment of Trichoderma Fertilizer and or concentration of fermented water coconut. In addition, the characters related to the yield component showed a significant interaction pattern. This indicates that the two treatments show synchronization in supporting the growth and yield of true shallot seed (TSS) tubers. However, in some characters, the effect of the concentration of fermented coconut water was more dominant than in Trichoderma Fertilizer. This was also reported by Ulfa *et al.* (2022) in the treatment of the concentration of fermented coconut water with the type of planting media in large chili peppers. The two treatments' influence pattern needs to be evaluated in depth by considering the variance pattern between each character, especially on the yield as the main character. Based on this correlation, all characters show a very significant positive correlation with each other, especially in productivity. This was demonstrated by Darini (2020). However, in other studies, several characteristics are insignificant to productivity (Susilawati *et al.*, 2018; Atman *et al.*, 2021). This indicates that the research was conducted in a relatively well-controlled area, so the correlation between fellow growth characteristics is harmonious, especially with productivity. The highly significant positive correlation pattern also indicates that each character has multicollinearity between characters. Therefore, this study's evaluation pattern should consider all characters' potential.

In a structured manner, the sole effect of Trichoderma

Fertilizer showed a quadratic pattern on the characters of plant height, number of leaves, stomatal opening width, and fresh tuber diameter of TSS. In general, Trichoderma has an indirect role in inducing plant growth, especially in interaction with plant roots (Yao *et al*., 2023; Pozo *et al*., 2024). Trichoderma secretes metabolites that act as elicitors for growth that support the increase of various plant hormones, especially auxin, cytokinin, ABA, and gibberellin (Sánchez-Montesinos *et al*., 2020; Agbessenou *et al*., 2022; Liu *et al*., 2022; Pozo *et al*., 2024). This has been proven in several horticultural studies (Kumar *et al*., 2025), including bulbous plants (Patkowska *et al*., 2020; Sánchez-Montesinos *et al*. 2020; Dutta *et al*., 2024; Kumar *et al*., 2025). The role of plant regulator induction has increased the growth potential of plants, especially in the vegetative phase and onion bulb formation (Dutta *et al*., 2024). This is the basis for why the role of Trichoderma is more dominant in vegetative characters in this study. Based on the quadratic curve on the effect of Trichoderma, the optimum dose in this study was around 30 g $m^{-2,}$ or equivalent to 300 kg ha^{-1}. This is more efficient than the results of Lasmini *et al*. (2022) and Gofar *et al*. (2023) who gave Trichoderma doses of 400 kg ha^{-1} and 500 kg ha^{-1}, respectively. Therefore, this dose can be one of the recommendations for considering the dose of Trichoderma for TSS in its single effect of inducing growth, especially in the vegetative phase.

The single effect of the concentration of fermented water coconut became the main single effect of this study. This was also reported by Ulfa *et al*. (2022), where the concentration of fermented water coconut is more dominant than the influence of other factors in affecting the growth of chili. This phenomenon proves the significant role of fermented water coconut concentration in supporting the growth and yield of horticultural crops, including in this study. In general, a concentration of fermented water coconut has a very high content of nutrients and phytohormones (Chutimanukul *et al*., 2023). The nutrient content that is abundant in water coconut includes calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), and cuprum (Cu), as well as in protein and sugar (Darmawan *et al*., 2020; Tiwery, 2021). The content supports photosynthesis and tuber formation (Koch *et al*., 2020; Ahmed *et al*., 2024). Based on the potential of phytohormones, the concentration of fermented water coconut is rich in cytokinin and gibberellin (Yong *et al*., 2009; Tan *et al*., 2014; Darmawan *et al*., 2020). Cytokinin phytohormones can induce the cell division process to be more effective. This also plays a role in the germination and induction of sprouts in TSS (Atif *et al*., 2020; Pangestuti *et al*., 2024). Such effectiveness was also reported by Pangestuti *et al*. (2024) in seed priming of true seed shallot onion. The mashing process is more effective, supported by the gibberellin content possessed by the concentration of fermented water coconut. The gibberellin content plays a big role in the bulb formation process, both in the number of bulbs and the weight of bulbs (Castro-Camba *et al*., 2022; Chen *et al*., 2022). All of these benefits are the basis for the effect of the concentration of fermented water coconut to dominate compared to several other treatments in horticultural products, including in this study.

Based on the effect of the concentration of fermented water coconut, the concentration of fermented water coconut shows a quadratic pattern in response to TSS growth and yield. The quadratic concept was also reported by Ulfa *et al*. (2022). This indicates that the application of the concentration of fermented water coconut also has a peak point, like fertilizer application in general (Hayati *et al*., 2021; Sitorus *et al*., 2025). A very high concentration or dose of fertilizer will cause ineffectiveness and even poisoning for plants (Swify *et al*., 2024). Determining the optimum concentration is also key in applying fermented water coconut fertilizer. Meanwhile, the optimum concentration of fermented water coconut fertilizer in this study is found at a concentration of 40%. This dose can be part of the recommendation on the single effect of fermented water coconut concentration in supporting TSS tubers' growth and yield.

The interaction effect of Trichoderma Fertilizer and fermented coconut water is a key part of this study. Based on the previous explanation, the two treatments have a synergistic pattern in supporting the growth and yield of TSS plant tubers. The effect of elicitors and resistance of Trichoderma bioagents becomes a trigger in stimulating the role of fermented coconut water as a source of phytohormones (Jaroszuk-ściseł *et al*., 2019; Ali *et al*., 2024). In addition, fermented coconut water can also stimulate the colony growth of Trichoderma (Vidhya *et al*., 2015; Hewavitharana *et al*., 2018), so this role can support the effect of Trichoderma in this study. Although, the effect was not as great as that of fermented coconut water. This makes the interaction pattern between the two significant in the quadratic pattern on the response surface visualization. This is characterized by an increasing and decreasing response pattern that reflects the interaction effect between factors (Rafiuddin *et al*., 2024; Kucharska *et al*., 2024). The color of the graph indicates the intensity of change in the interpolated values. The yellow areas indicate the highest values, while the purple areas indicate the lowest values. Based on the surface curve, all characters show a peak point in the middle of the curve or at the combination of a 30 g m^{-2} Trichoderma Fertilizer dose and 30% concentration of fermented coconut water. This combination showed a difference in the concentration of fermented coconut water compared to the single effect. This indicates that the interaction with Trichoderma Fertilizer alleviates the role of fermented coconut water in inducing TSS growth. This is also supported by the difference in the concentration of 20% and 40% fermented coconut water, which is not too different. Hence, the concentration of fermented coconut water is optimal at 30% when combined with Trichoderma Fertilizer. Therefore, the combination of a dose of 30 g m^{-2} Trichoderma fertilizer and a concentration of 30% fermented coconut water is a recombination in supporting the growth and yield of TSS.

The combination recommended in this study is not an absolute recommendation. This is due to the limitations of this study. This research is still considered preliminary and needs to be intensified in a wider experimental area with more environmental diversity. Several studies have shown that seasonal and location-based Genetics x Environment interactions are an essential part of determining the policy of a crop technology (Dick, 2011; Musa *et al*., 2023; Anshori *et al*., 2024). In addition, the larger the plot, the more complex the environmental influences (He *et al*., 2022). These will increase the precision in determining the best Trichoderma Fertilizer dosage and fermented coconut water concentration. This is a challenge for future research. Nevertheless, the results of this study can already be an initial recommendation to determine the more precise role of the combination of the two treatments in this study. Therefore, the results of this study can be one of the milestones for more complex research in the future.

Conclusions and Recommendations

This study shows that the combination of Trichoderma fertilizer dosage and fermented coconut water concentration effectively supports true shallot seed (TSS) growth and yield. Trichoderma fertilizer has a single effect on TSS growth, especially in the vegetative phase. The optimal Trichoderma Fertilizer single effect dose was found at 30 g m^{-2} or equivalent to 300 kg ha^{-1}. The effect of fermented coconut water concentration became the dominating single effect of TSS growth and yield. The optimal concentration of the single effect was found at 40%. Meanwhile, the best combination of the two treatments was at a 30 g m^{-2} Trichoderma Fertilizer dose and a 30% concentration of fermented coconut water. This combination can be a milestone for more compreshensive research in extending the combined effect of Trichoderma Fertilizer dosage and fermented coconut water concentration in the future.

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Novelty Statement

This study is the first to evaluate the synergistic effects of fermented young coconut water and Trichoderma sp. on onion cultivation using True Shallot Seeds (TSS), a new alternative to conventional bulb-based propagation. Although both inputs have shown benefits independently in traditional systems, their combined application in TSS-based cultivation has not been previously explored. The findings showed significant improvements in growth and yield, thus creating an innovative and environmentally friendly approach to increase the productivity and sustainability of TSS cultivation, especially a combination of 30 g m^{-2} Trichoderma fertilizer and 30% fermented coconut water.

Author's Contribution

Fachirah Ulfa, Ambo Ala, Muh. Irfan: Conceptualization
Methodology: **Fachirah Ulfa, Ambo Ala, Muh. Irfan:**
Fachirah Ulfa and Muhammad Fuad Anshori: Software and Data curation
Muhammad Fuad Anshori and Nirwansyah Amier: Validation and formal analysis.

Fachirah Ulfa and Muh. Irfan: Investigation.
Fachirah Ulfa, and Ambo Ala: Resources
Fachirah Ulfa: Writing-original draft.
Muhammad Fuad Anshori: Visualization.
Fachirah Ulfa: Funding acquisition.
All co-authors reviewed the final version and approved the manuscript before submission.

Conflict of interest
The authors have declared no conflict of interest.

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