INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 09 Issue 02 February 2026

DOI: 10.47191/ijmra/v9-i2-12, Impact Factor: 8.266

Page No. 511-522

Effect of Formulation and Concentration of Liquid Organic Fertilizer from Enriched Fish Waste Trichoderma on the Growth and Yield of Tomato Plants (*Solanum Lycopersicum*)

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ABSTRACT: Tomato production in Bali Province in 2023 reached 5,218 tons, but decreased by 16.04% in 2024 to 4,381 tons. Declining productivity is often associated with nutrient limitations in the soil. This study aims to evaluate the formulation and concentration of liquid organic fertilizer (POC) made from fish waste enriched with Trichoderma sp. on the growth and yield of tomato plants. The experiment used a factorial randomized block design (RAK) with two factors, namely formulation (J0: control, J1: POC + Trichoderma, J2: POC without Trichoderma) and concentration (P0: control, P1: 5 ml/L, P2: 10 ml/L, P3: 15 ml/L). The variables observed included plant height, leaf chlorophyll content (SPAD), number of productive branches, number of fruits per plant, fruit diameter, and fruit weight per plant. The results showed that fish waste POC enriched with Trichoderma increased tomato growth and yield compared to other treatments. A concentration of 15 ml/L had the most significant effect on plant height, number of productive branches, chlorophyll content, and fruit yield. The best interaction was obtained with the combination of POC + Trichoderma at a concentration of 15 ml/L, which resulted in the highest plant growth, fruit diameter, and fruit weight.

KEYWORDS: Tomatoes, liquid organic fertilizer, fish waste, and *Trichoderma* sp.

I. INTRODUCTION

Tomatoes (*Solanum lycopersicum*) are annual herbaceous plants belonging to the Solanaceae family. Tomatoes are generally used for their fruit, which is consumed. Tomatoes are quite popular among Indonesians. Every 100 g of tomatoes contains 23 calories, 2 g of protein, 3.3 g of carbohydrates, 5 mg of calcium, 27 mg of phosphorus, 0.5 mg of iron, 120 IU of vitamin A, 0.07 mg of vitamin B1, and 30 mg of vitamin C (Sugiharto *et al*., 2023). Public demand for tomatoes is increasing, but production is still insufficient. In Bali Province, tomato production in 2023 reached 5,218 tons, but decreased by 16.04% in 2024 to 4,381 tons (Central Statistics Agency, 2024). Tomato crop productivity is often hampered by suboptimal nutrient availability in the soil. Innovations in fertilization are needed to increase crop yields sustainably, one of which is through the use of liquid organic fertilizer (POC).

Liquid organic fertilizer (POC) is a solution produced from the decomposition of organic materials from plant, animal, and human waste that has been decomposed and is more easily absorbed by plants, thereby having a greater effect on plant growth (*Amir et al*., 2025; Anggraeni *et al*., 2024). The advantages of liquid organic fertilizer are that it can quickly overcome nutrient deficiencies, does not experience nutrient leaching problems, and can provide nutrients quickly (Sutriana *et al*., 2022). The use of organic fertilizers can also increase soil organic matter content, soil structure, water holding capacity, cation exchange capacity, nutrient availability, soil fauna communities, and microbial activity, resulting in a significant increase in crop productivity (Culas *et al*., 2025). One organic material that can be used as POC is fish waste enriched with *Trichoderma*.

Liquid organic fertilizer made from fish waste contains nutrients needed by plants, such as nitrogen (N) 1.26%, phosphorus (P) 4.37%, potassium (K) 0.36%, and organic C 15.42% (Waryanti *et al*., 2013). Fish waste can also induce *Actinomycetes* spp. and *Rhizobacteria* spp., which play a role in producing growth hormones such as auxin, cytokinin, and gibberellin around plant roots (Amir *et al*., 2025), while *Trichoderm*a sp. is known as a biological agent that can help decompose organic matter to improve soil fertility, control plant pests, stimulate various plant growth-promoting substances, enhance nutrient absorption by releasing organic acids to dissolve minerals and activate nutrients in the soil, and indirectly improve soil structure (Syamsiyah *et al*., 2024). Research on the formulation and concentration of fish waste POC enriched with *Trichoderma* sp. that is most effective in improving

tomato plant growth and yield has not been widely conducted in Bali Province. Therefore, research is needed on the best formulation and concentration of fish waste-based liquid organic fertilizer enriched with *Trichoderma* sp. to improve tomato plant growth and productivity.

II. RESEARCH METHODS

The research was conducted from May to July 2025 at Pt. Bali Organik Internasional Kinar Village, Br. Jelijih Pondoh, Megati Village, East Selemadeg District, Tabanan Regency. The materials used in this study included Servo tomato seeds, fish waste, Trichoderma, brown sugar, planting media: soil and compost, and water for irrigation. The tools used in this study were hoes, buckets, fertilizer containers, sprayers, measuring tapes, rulers, analytical scales, cameras, and writing instruments.

The experimental design used in this study was a randomized block design (RBD). The factorial pattern consisted of two factors, namely formulation and concentration. The first factor was formulation with the following treatments: J0 = control (250 ml of water/plant), J1 = liquid organic fertilizer from fish waste with *Trichoderma*, J2 = liquid organic fertilizer from fish waste without *Trichoderma*. The second factor is concentration with the following treatments: P0 = no treatment, P1 = 5 ml POC/L, P2 = 10 ml POC/L, P3 = 15 ml POC/L. From the above treatments, there are 12 treatment combinations that are repeated 3 times, resulting in 36 types of experiments.

The process of making liquid organic fertilizer from fish waste involves washing the fish waste (heads, bones, and unused parts) thoroughly, chopping it up, and then putting it in a container with 5–10 L of water for every 1 kg of fish. The mixture is then added with 5–10 g of Trichoderma for every 10 L of water and 100–200 g of brown sugar/molasses as a source of energy for microorganisms. The mixture is stirred until well blended, then the container is tightly closed to create anaerobic conditions. Fermentation is carried out for 7-14 days, with stirring every three days to release the fermentation gas and ensure that the microorganisms work evenly throughout the mixture.

Cultivation activities began with clearing the land of weeds and plant debris, then plowing the land to a depth of 30 cm, applying KCl base fertilizer, leveling the soil, and creating 36 experimental plots measuring 3 × 2 m. The seedling medium used a mixture of black soil and cow manure in a 1:1 volume ratio, which was placed in trays. Tomato seeds that had been soaked for 1 hour were then sown in a mixture of soil and bokashi in a 1:1 ratio. The seeds were then placed in a shaded area and watered every morning and evening. Three-week-old seedlings with 4–5 leaves were transferred to the field in the afternoon with a planting distance of 50 × 50 cm. Liquid organic fertilizer was applied by spraying at 7, 14, 28, and 63 days after planting according to the dosage. Maintenance includes watering twice a day (500 ml per plant), weeding, transplanting at 1–7 days after planting, installing stakes at 1 month after planting, pruning water shoots at 14 days after planting, and controlling pests and diseases mechanically or using plant-based pesticides. Harvesting is done at 65–70 days after planting when the fruit changes from green to yellowish-green.

Observation variables included plant height, leaf chlorophyll content (SPAD), number of productive branches, number of fruits per plant, fruit diameter, and fruit weight per plant. The data obtained were analyzed using analysis of variance (ANOVA) and if there were significant differences between treatments, a BNJ (Significant Difference) test was performed at a 5% error rate (Gomes and Gomez, 1980).

III. RESULTS AND DISCUSSION

1) Plant Height (cm)

Further testing of BNJ 5% (Table 1) showed that the combination of liquid organic fertilizer (POC) formulation enriched with *Trichoderma* from the outset and supplemented with an additional 15 ml/l of Trichoderma produced the highest growth, namely 33.50 cm at 2 MST, 45.92 cm at 4 MST, and 64.00 cm at 6 MST, which was significantly different from all other treatments, thus making it the most effective combination in supporting early vegetative growth. The increasing growth response in the combination treatment of POC and Trichoderma at later observation times indicates that these microorganisms successfully adapted and colonized the rhizosphere. This condition is supported by the availability of organic matter from POC, which serves as an energy source for microbial activity. This is consistent with the results of chemical analysis showing that POC has a moderate to low organic carbon content, which still allows microorganisms to obtain substrates for metabolism. Research by Noviana *et al*. (2024) and Firdaus *et al*. (2024) reported that the effectiveness of *Trichoderma* is greatly influenced by the availability of organic matter and an environment that supports its biological activity, so that the addition of POC strengthens microbial colonization and function in dissolving phosphate, producing growth-promoting hormones, and increasing nutrient uptake. In the same formulation, concentrations of 10 ml/l, 5 ml/l, and without the addition of Trichoderma showed relatively close values and were not statistically significantly different, although they were still higher than most treatments in other formulations. The POC

formulation without Trichoderma initially showed a medium growth response with values ranging from 29.17–30.50 cm at 2 MST, 42.58–43.58 cm at 4 MST, and 60.95–62.03 cm at 6 MST, where the addition of Trichoderma from outside did not produce consistent improvements. Conversely, the treatment without POC application resulted in the lowest growth at all observation times, with the control only reaching 25.67 cm at 2 MST, 38.58 cm at 4 MST, and 56.95 cm at 6 MST.

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Table 1. Average height of tomato plants at 2, 4, and 6 MST due to treatment with liquid organic fertilizer formulations and concentrations from fish waste and Trichoderma test BNJ 5%

Formulation Factors	Concentration Factor														
	2 MST				Average	4 MST				Average	6 MST				Average
	P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3	
J0	25,67 c B	28,17 b C	29,17 a B	26,17 c C	27,29 B	38,58 d C	41,50 b C	41,92 a B	39,67 c C	40,42 B	56,95 c B	60,30 a B	60,38 a C	59,00 b C	59,16 A
J1	30,50 a A	29,17 b B	30,50 a A	29,58 ab B	29,94 B	43,58 a A	42,58 b A	43,08 c A	42,67 c B	42,98 A	61,75 a A	60,95 c A	62,03 a A	61,43 b B	61,54 B
J2	30,17 b A	30,25 b A	30,33 b A	33,5 a A	31,06 A	42,83 b B	42,08 c B	42,75 b A	45,92 a A	43,40 A	61,65 b A	60,58 c B	61,35 b B	64,00 a A	61,90 A
Average	28,78 a	29,19 a	30,00 a	29,75 a		41,67 a	42,06 a	42,58 a	42,75 a		60,12 b	60,61 ab	61,26 a	61,48 a	
BNJ 5% Formulation			**2,14**					**1,38**					**1,19**		
BNJ 5% Concentration			**1,78**					**1,14**					**0,98**		
BNJ 5% Interaction			**0,66**					**0,43**					**0,37**		

Note: Treatment means followed by the same lowercase letter in the same row and the same uppercase letter in the same column indicate no significant difference at the 5% level (P<0.05).

2) Number of Productive Branches

The results of the BNJ 5% follow-up test (Table 2) show that at 2 MST the number of productive branches was in the range of 0.38–0.51, increasing to 1.42–1.52 at 4 MST, and reaching 2.23–2.56 at 6 MST. Although there was a numerical increase in some treatments, the differences between treatments were not statistically significant. At the formulation level, control plants produced 0.38 productive branches at 2 MST, increasing to 1.43 at 4 MST, and 2.24 at 6 MST. Liquid organic fertilizer without Trichoderma gave slightly higher values, namely 0.42; 1.44; and 2.33 at each observation time.

Table 2 Average number of productive branches of tomato plants 2, 4, and 6 MST due to treatment with liquid organic fertilizer formulations and concentrations of fish waste and Trichoderma test BNJ 5%

Productive Branches 2, 4 and 6 MST															
Treatment	2 MST				Average	4 MST				Average	6 MST				Average
	P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3	
J_0	0,37	0,40	0,33	0,43	0,38 A	1,40	1,40	1,50	1,43	1,43 A	1,93	2,30	2,30	2,43	2,24 A
J_1	0,37	0,33	0,43	0,53	0,42 A	1,40	1,43	1,40	1,53	1,44 A	2,27	2,27	2,30	2,50	2,33 A
J2	0,43	0,43	0,53	0,57	0,49 A	1,53	1,43	1,50	1,60	1,52 A	2,50	2,43	2,50	2,73	2,54 A
Average	0,39 a	0,39 a	0,43 a	0,51 a	0,43	1,44	1,42	1,47	1,52	1,46	2,23 a	2,33 a	2,37 a	2,56 a	
BNJ 5% Formulation	0,33					0,39					0,75				
BNJ 5% Concentration	0,27					tn					0,63				

Note: Figures followed by the same letter in the same column indicate no significant different in the 5% BNJ test

The liquid organic fertilizer formulation enriched with *Trichoderma* showed consistently high values, namely 0.49, 1.52, and 2.54, although it remained in the category of no significant difference. Physiologically, *Trichoderma* sp. is known to produce growth-promoting compounds such as auxin, cytokinin, and other bioactive metabolites that stimulate lateral root formation and increase nutrient uptake (Contreras-Cornejo *et al*., 2024). These conditions support branching development because adequate nitrogen and phosphorus availability plays an important role in the activation of axillary buds and the formation of new meristematic tissue. These findings are in line with Lisnawati's (2020) report that the application of *Trichoderma* sp. can increase branching and tomato fruit yield, confirming the role of these microbes in improving vegetative organ performance. The role of liquid organic fertilizer from fish waste as a source of nutrients can also support this mechanism. Liquid organic fertilizer contains phosphorus and potassium, both of which play an important role in the formation of new tissue and the translocation of photosynthates. Although this increase did not directly trigger a statistically significant surge in the number of productive branches, the high availability of nutrients provided stable physiological conditions for the plants to develop productive branching.

At the concentration level, the number of productive branches at 2 MST was relatively close, with a value of 0.39 at concentrations of 0 and 5 ml/l, 0.43 at 10 ml/l, and 0.51 at 15 ml/l. A similar pattern was observed at 4 MST with a range of 1.42–1.52, and at 6 MST with a range of 2.23–2.56, where a concentration of 15 ml/l consistently gave the highest value. The positive but statistically insignificant response to Trichoderma-enriched treatments can be attributed to the physiological stability of plants after their nutrient requirements were met. Physiologically, the formation of productive branches is controlled by the balance of endogenous hormones, mainly auxin and cytokinin, which determine the activation of axillary buds. When nutrient and environmental conditions are adequately supported, additional increases in microbial inoculants often do not result in drastic changes in branching due to physiological limits of the plant. These findings are in line with the report by Riwukaho *et al*. (2025), which confirms that lateral branching in tomatoes is limited by internal regulation even though external factors such as fertilizers and microbes support its initial development. The study by Mouden *et al*. (2022) also shows that *Trichoderma asperellum* increases biomass and vegetative growth, but the plant's response to branching still follows a pattern of physiological regulation that is not entirely linear to the addition of stimulation.

3) Leaf Chlorophyll (SPAD)

The results of the 5% BNJ follow-up test (Table 3) show that the chlorophyll content of tomato leaves exhibits consistent dynamics between the vegetative and generative phases, although each phase displays a different response to the treatment with liquid organic fertilizer formulated from fish waste and Trichoderma concentration. In the vegetative phase, chlorophyll content ranged from 35.50 to 38.25, while in the generative phase it increased to a range of 37.27 to 44.80. This increase reflects more intense photosynthetic activity as the plant shifts from the growth phase to fruit formation and filling, resulting in a relatively higher need for chlorophyll in the generative phase. In the context of liquid organic fertilizer (POC) formulation from fish waste, the fermentation process produces organic nitrogen, phosphorus, and easily absorbed micro nutrients, which can accelerate chlorophyll biosynthesis (Rafidah *et al*., 2023). The presence of Trichoderma also strengthens this response through nutrient mobilization, secretion of growth-promoting metabolites, and the ability to improve root health, which allows for greater energy allocation for chlorophyll formation (Febriza *et al*., 2024).

Table 3. Average chlorophyll content of tomato leaves in the vegetative and generative phases due to treatment with formulations and concentrations of liquid organic fertilizer from fish waste and Trichoderma test BNJ 5%

Formulation Factors	Concentration Factor									
	Vegetative Phase				Average	Generative Phase				Average
	P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3	
J0	35,50 c	36,00 b	36,12 b	37,20 a	36,20	37,27 c	38,37 b	39,37 a	38,60 b	38,40
	B	B	B	B	A	B	B	B	B	B
J1	35,95 b	36,22 b	36,02 b	37,07 a	36,31	37,27 c	37,20 c	39,27 a	38,47 b	38,05
	A	B	B	B	A	B	C	B	B	B
J2	36,28 d	37,02 c	37,83 b	38,25 a	37,35	38,30 d	40,22 c	40,97 b	44,80 a	41,07
	A	A	A	A	A	A	A	A	A	A
Average	35,91 b	36,41 ab	36,66 ab	37,51 a		37,61 c	38,59 bc	39,87 ab	40,62 a	
BNJ 5% Formulation			**1,83**					**1,83**		
BNJ 5% Concentration			**1,52**					**1,52**		
BNJ 5% Interaction			**0,57**					**0,57**		

Note: Treatment means followed by the same lowercase letter in the same row and the same uppercase letter in the same column indicate no significant difference at the 5% level (P<0.05).

During the vegetative phase, the best interaction was obtained with a combination of liquid organic fertilizer made from fish waste enriched with *Trichoderma* at a concentration of 15 ml/l, which produced a chlorophyll content of 38.25. This value was the highest in the vegetative phase and was significantly different from all other treatments. Fish waste POC contains phosphorus and potassium. High phosphorus availability plays a direct role in the chlorophyll formation process because phosphorus supports enzymatic activity and cell division in leaf tissue. When POC is enriched with Trichoderma, the colonization of these microbes becomes more optimal because the carbon- and nutrient-rich medium accelerates their activity in dissolving phosphate and increasing nutrient uptake by the roots. This is in line with the reports by Noviana *et al*. (2024) and Febriza *et al*. (2024), which show that *Trichoderma* is more effective in organic media with adequate nutrient content.

Entering the generative phase, the increase in chlorophyll was more pronounced in the combination treatment of fish waste POC and *Trichoderma* at a concentration of 15 ml/l. This increase reflects the cumulative physiological effects of organic nutrients and microbial activity since the vegetative phase, which supports the increased energy requirements for flower and fruit formation (Arifuddin *et al*., 2024). The stability of the rhizosphere environment, rich in nutrients from fish waste POC and supported by the biological activity of *Trichoderma*, enhances the plant's ability to maintain the rate of photosynthesis rate in the later phase. This finding aligns with Soetedjo *et al*. (2023), who demonstrated that the combination of organic materials and biological agents can gradually and cumulatively enhance the photosynthetic performance of horticultural plants.

4) Number of Fruits per Plant

The results of the BNJ 5% follow-up test (Table 4) show that the number of fruits per plant in the first harvest was relatively uniform across all treatments, ranging from 2.00 to 2.17 fruits per plant. A similar condition occurred in the second harvest with a range of 3.78 to 4.33 fruits per plant. This indicates that tomatoes in the early fruiting phase still utilize photosynthetic reserves from the vegetative phase and the basic physiological conditions of the plant. At this stage, flower differentiation is more influenced by environmental conditions and the health of reproductive tissues than by differences in external nutrient supply (Fatmawati *et al*., 2022).

Table 4. Average number of fruits per tomato plant in the first, second, and third harvests due to formulation and concentration

Number of Harvests I, II, and III															
Treatment	I Harvest				Average	II Harvest				Average	III Harvest				Average
	P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3	
J_0	2,00	2,00	2,00	2,00	2,00 A	4,00	3,33	4,00	4,00	3,83 A	6,33	6,00	6,67	6,33	6,33 A
J_1	2,00	2,00	2,00	2,00	2,00 A	4,00	4,33	4,00	4,00	4,08 A	6,00	6,33	6,33	7,00	6,42 A
J2	2,00	2,00	2,33	2,33	2,17 A	3,67	3,67	4,33	5,00	4,17 A	6,33	6,67	7,67	9,67	7,58 A
Average	2,00a	2,00a	2,11a	2,11a		3,89a	3,78a	4,11 a	4,33 a		6,22a	6,33 a	6,89 a	7,67a	
BNJ 5% Formulation		tn			tn				4,58						
BNJ 5% Concentration		tn			tn				3,80						

Note: Figures followed by the same letter in the same column indicate no significant difference in the 5% BNJ test.

The difference in yield began to widen in the third harvest, where the formulation treatment yielded 6.33 to 7.58 fruits per plant, while the concentration treatment yielded 6.22 to 7.67 fruits per plant. In the third harvest, the best formulation was shown by fish waste POC enriched with *Trichoderma* with a value of 7.58 fruits per plant, although this increase was not significantly different from other formulations. When POC is enriched with Trichoderma, its biological effectiveness increases because these microbes help dissolve phosphate, increase nitrogen uptake, and improve rhizosphere conditions through increased enzymatic activity and competition with pathogens. Randawati *et al*. (2024) confirmed that the integration of organic matter with *Trichoderma* increases the supply of mineral nitrogen, growth hormones, and root absorption, especially during the intensive fruiting phase, a mechanism consistent with the pattern observed in the third harvest of this study.

In terms of concentration, the highest value was achieved at a concentration of 15 ml/l with 7.67 fruits per plant. This phenomenon illustrates that when nutritional requirements increase in the late generative phase, additional nutrients from higher POC concentrations begin to have a more noticeable physiological impact. This pattern is consistent with the findings of Sumarni *et al*. (2020), who explained that plant response to liquid fertilizer doses is more apparent during the peak production phase when the demand for photosynthates and nutrients for fruit filling is at its highest.

5) Fruit Diameter

Further testing of BNJ 5% in Table 5 shows that, in the first and second harvests, the highest values were obtained in the fish waste POC treatment enriched with Trichoderma at a concentration of 15 ml/l. In the first harvest, the fruit diameter was 44.33 cm, while in the second harvest it was 45.33 cm. This response is relevant when linked to the chemical characteristics of fish waste POC, which is rich in nitrogen, phosphorus, potassium, and organic compounds such as peptides and amino acids that play a role in fruit cell formation. Simanjuntak *et al*. (2023) explain that the presence of these dissolved organic compounds increases fruit metabolic activity, thereby enlarging cell size. The addition of *Trichoderma* further strengthens this mechanism through its ability to dissolve phosphate, increase nitrogen mineralization, and produce enzymes and metabolites that enhance nutrient uptake by the roots. This is in line with the findings of Hamzah *et al*. (2020), who reported that microbial-based organic fertilizer formulations can accelerate fruit enlargement through root growth stimulation and nutrient uptake efficiency.

Table 5. Average diameter of first, second, and third tomato harvests due to treatment with liquid organic fertilizer formulations and concentrations of fish waste and Tricoderma from further testing of BNJ 5%

Formulation Factors	Concentration Factor													
	I Harvest				Average	II Harvest				Average	III Harvest				Average
	P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3		P_0	P_1	P_2	P_3	
J0	41,67 a A	40,33 b A	41,67 a AB	40,67 ab B	41,08	41,33 ab A	40,67 b B	41,67 a B	42,00 a B	41,42 A	40,33	40,67	40,33	41,33	40,58
J1	41,00 b A	42,00 ab A	43,00 a A	40,33 b B	41,58	41,33 b A	41,33 b A	42,33 a B	42,00 ab B	41,75 A	40,67	40,67	40,67	40,67	40,67
J2	41,00 b A	41,67 b A	41,33 b B	44,33 a A	42,08	41,33 c A	42,00 c A	43,67 b A	45,33 a A	43,08 A	40,67	41.00	41,33	42,33	41,33
Average	41,22	41,33	42.00	41,78		41,33 a	41,33 a	42,56 a	43,11 a		40,40	40,80	40,80	41,40	
BNJ 5% Formulation			**tn**					**3,89**					**tn**		
BNJ 5% Concentration			**tn**					**3,23**					**tn**		
BNJ 5% Interaction			**1,50**					**1,21**					**tn**		

Note: Treatment means followed by the same lowercase letter in the same row and the same uppercase letter in the same column indicate no significant difference at the 5% level (P<0.05).

In the third harvest, fruit diameter generally decreased compared to the previous harvest, and all treatments showed no significant differences. Diameter values ranged from 40.33 to 42.33 cm, with the highest value found in the combination of fish waste POC formulation enriched with Trichoderma at a concentration of 15 ml/l. This phenomenon can be explained by the decline in the physiological capacity of plants in the late fruiting phase. According to Marlina *et al*. (2022), a decrease in functional leaf area, increased competition between flowers and fruits, and reduced photosynthetic efficiency cause the accumulation of assimilates in the fruit to no longer increase even though nutrients are still available. Thus, the additional nutritional benefits of POC or *Trichoderma* activity no longer provide a significant response to fruit diameter enlargement in the late production phase. *Trichoderma*-enriched fish waste POC provides the greatest benefits in the early and middle production phases, while its effectiveness in the late phase depends on the physiological condition of the plant, which naturally begins to decline.

6) Fruit Weight (gr)

The results of the BNJ 5% follow-up test (Table 6) show that the weight of tomatoes in the first harvest, in terms of concentration, the best treatment was at a concentration of 15 ml/l with a fruit weight of 101.67 grams, and this difference was proven to be significant compared to lower concentrations. The 10 ml/l concentration yielded a weight of 93.22 grams and was within the group that was not significantly different from the highest concentration. The 5 ml/l concentration had a weight of 88.89 grams, while the 0 ml/l concentration produced the lowest weight of 85.22 grams. The positive response of plants to an increase in POC concentration up to 15 ml/l in the first harvest is in line with the chemical characteristics of fish waste POC, which has a higher nitrogen and phosphorus content than soil. The availability of macro nutrients in larger quantities allows plants to form and fill fruits more optimally in the early generative phase. This is in line with the findings of Sulaiman (2024), who stated that POC made from easily degradable organic waste can increase tomato fruit weight due to its readily available nutrients that support fruit biomass formation.

Table 6. Average weight of first harvest tomatoes due to treatment with liquid organic fertilizer formulations and concentrations of fish waste and *Tricoderma* from BNJ 5% testing

Weight of First Harvest Fruit (g)					
Treatment	P_0	P_1	P_2	P_3	Average
J_0	84,00	87,67	86,33	96,00	88,50 A
J_1	85,33	87,67	94,33	101,33	92,17 A
J_2	86,33	91,33	99,00	107,67	96,08 A
Average	85,22 b	88,89 b	93,22 ab	101,67 a	

Note: Figures followed by the same letter in the same column indicate no significant difference in the 5% BNJ test.

In terms of formulation, the best treatment was obtained in the formulation of liquid organic fertilizer from fish waste enriched with *Trichoderma*, with a weight of 96.08 grams. The formulation of liquid organic fertilizer without *Trichoderma* produced a weight of 92.17 grams, while the treatment without the application of liquid organic fertilizer produced a weight of 88.50 grams. At this stage, the POC formulation enriched with *Trichoderma* did not show any significant difference compared to other treatments, possibly because the microbial inoculum needed time to develop and dominate the root zone so that its biological benefits were not fully apparent in the first harvest. This finding is in line with Abror and Harjo (2018), who explained that the effect of *Trichoderma* usually increases after the microbes have colonized stably in the rhizosphere.

The results of tomato fruit weight measurements in the second and third harvests after further testing with BNJ 5% (Table 7) showed that the best treatment at both harvest times was consistently provided by the liquid organic fertilizer formulation enriched with *Trichoderma* at a concentration of 15 ml/l. In the second harvest, this combination produced a fruit weight of 241.00 g, while the third harvest reached 300.33 g and was significantly different from all other combinations. The success of this combination can be attributed to the very high POC phosphorus content enriched with *Trichoderma*. Phosphorus is a key element in energy formation and metabolic processes during the generative phase, so increasing its availability can accelerate fruit filling. Trichoderma also plays a role in increasing the solubility of organic phosphate, thereby increasing the fraction of nutrients that can be absorbed by plants, as explained by Ikawati *et al*. (2022) in their study on tomatoes in Ultisol soil.

Table 7. Average weight of second and third harvests due to treatment with liquid organic fertilizer formulations and concentrations of fish waste and Tricoderma from further testing of BNJ 5%

Fruit Weight (g)									
Concentration Factor									
II Harvest				Average	III Harvest				Average
P_0	P_1	P_2	P_3		**P_0**	P_1	P_2	P_3	
163,67 c C	171,33 b B	173,33 b C	185,00 a B	173,33 B	230,67 c B	243,67 b B	260,33 a B	257,00 a C	247,92 B
166,00 d B	173,33 c B	190,67 a B	179,00 b C	177,25 B	240,33 d A	246,67 c B	262,33 b B	287,67 a B	259,25 B
172,67 d A	191,33 c A	201,00 b A	241,00 a A	201,50 A	244,67 c A	266,00 b A	296,33 a A	300,33 a A	276,83 A
167,44 c	178,67 b	188,33 b	201,67 a		238,56 c	252,11 b	273,00 a	281,67 a	
		13,10					17,26		
		10,88					14,33		
		4,06					5,36		

Note: Treatment means followed by the same lowercase letter in the same row and the same uppercase letter in the same column indicate no significant difference at the 5% level (P<0.05).

The liquid organic fertilizer formulation without the addition of *Trichoderma* produced a moderate response. In the second harvest, the highest value for this formulation was achieved at a concentration of 10 ml per liter, amounting to 190.67 g, while in the third harvest, the highest value reached 287.67 g at a concentration of 15 ml per liter. The increase between concentrations in this formulation was mostly significant, although not as strong as the increase in the *Trichoderma*-enriched formulation. This is in line with the nutritional characteristics of fish waste POC, which has a fairly high available potassium content. Potassium is an important element in regulating cell turgor and transporting photosynthates to the fruit, thereby contributing to weight formation. However, without the support of biological agents, the utilization of these nutrients is not as efficient as *Trichoderma*-enriched POC. This condition is in line with the conclusion of Fateha, *et al*. (2022), who stated that organic fertilizers without microbial inoculants show fluctuating effectiveness depending on soil conditions and biological activity within it.

The formulation without treatment or control produced the lowest fruit weight in both harvests. In the second harvest, fruit weight ranged from 163.67 g at the control concentration to 185.00 g at a concentration of 15 ml per liter. At the third harvest, fruit weight in the untreated formulation ranged from 230.67 g to 260.33 g. This condition can be attributed to limited nutrient availability, which prevented the plants from maintaining optimal fruit filling. This difference was even more apparent in the third harvest, where the increase in fruit weight in the control treatment could not match the increase in the POC and microbe-enriched POC treatments. These findings reinforce the study by Syamsiah, *et al*. (2025), which showed that the absence of additional nutrient supply caused tomato plants to fail to reach maximum production even though their vegetative growth was still ongoing.

IV. CONCLUSIONS

The formulation of liquid organic fertilizer from fish waste enriched with *Trichoderma* provides the best results for most parameters of tomato plant growth and production. A concentration of 15 ml/l is the most effective concentration for increasing plant height, number of productive branches, leaf chlorophyll, and fruit yield. The best interaction was obtained with a combination of liquid organic fertilizer from fish waste enriched with *Trichoderma* at a concentration of 15 ml/l, which produced the highest plant growth, fruit diameter, and fruit weight compared to other treatments.

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