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Effect of eco-enzyme application on soil nutrient and plant productivity of green mustard-peanut in inceptisol

Abstract. Appropriate land management has a long-term impact on soil performance and is believed to improve soil fertility. This study investigated the effect of eco-enzymes on soil nutrients and plant productivity of green mustard-peanut in inceptisol. The research was conducted from February to April 2025. The experiment used a randomized block design (RBD) consisting of 5 treatments and replicated 3 times, so that there were 15 units, including N0 = without Eco-enzyme, N1 = Eco-enzyme 2cc/L. N2= Eco-enzyme 4cc/L, N3= Eco-enzyme 6cc/L, and N4= Eco-enzyme 8cc/L. The commodities used were green mustard (*Brassica juncea* L) and peanut (*Arachis hypogaea* Linn). Soil properties variables included soil pH, N-total, and P-available, while plant productivity variables included plant height, number of leaves, leaf area, fresh weight, and pod production. The results showed that the concentration of eco-enzymes had a significant effect on N-total, P-available, green mustard plant height, and peanut plant height. However, eco-enzyme concentration had no significant effect on soil pH, number of green mustard leaves, green mustard fresh weight, green mustard leaf area, number of peanut branches, and peanut pod production. The lowest production of green mustard was 0.85 tons/ha, and the highest was 3.29 tons/ha. While the lowest production of Peanut pods was 4.3 tons/ha and the highest was 6.67 tons/ha.

Keywords: Eco-enzyme · Inceptisol · Nitrogen and phosphorus nutrients · Productivity

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Introduction

The primary objective of sustainable agriculture is to enhance crop productivity while preserving ecosystem balance. A significant challenge in implementing a sustainable agricultural system is the limited soil fertility, particularly regarding the availability of essential nutrients such as nitrogen (N) and phosphorus (P), which are crucial for plant growth. Improper land management methods, especially the overapplication of synthetic fertilizers, may result in soil degradation (Aji et al., 2020), therefore diminishing soil fertility (Hartati et al., 2023). Notwithstanding the extensive endeavor for agricultural intensification, its effects have been minimal in various locations, leading to detrimental outcomes including soil compaction, reduced organic carbon levels, increased evapotranspiration, and heightened erosion rates (Lal, 2004; Rofita et al., 2022). Inceptisol soil, prevalent in Indonesia, demonstrates fluctuating fertility levels. Its presence in Indonesia is predicted to be 52 million hectares (Kasno, 2013), indicating a potential for agricultural development (Swardana et al., 2023). However, the level of development of this immature soil is indicated by problems with its fertility level (Hartati et al., 2020). Consequently, the utilization of organic fertilization technology emerges as a pivotal strategy to foster environmentally sound and sustainable agricultural systems, capable of enhancing soil fertility through natural means (Soobhany, 2019; Xiang et al., 2022; Zhang et al., 2023).

The use of eco-enzymes is one of the alternative approaches that is considered more environmentally friendly in organic-based land management. Eco-enzyme is derived from the fermentation of organic waste materials, comprising a range of bioactive components (Bashir et al., 2023). Eco-enzyme provides clear advantages for plantations by improving plant growth, soil health, pest management, and environmental sustainability. Its use supports both higher productivity and eco-friendly agricultural practices. In rice, eco-enzyme application increased plant height up to 25% in some cultivars, accelerated harvest time by 2 –3 weeks, and improved tiller number and grain yield compared to commercial liquid fertilizers (Defiani & Astarini, 2023). In soil, eco-enzyme enriches soil with essential nutrients (N, P, K, organic carbon) and beneficial enzymes such as amylase, protease, lipase, promoting nutrient cycling and root uptake (Kriswantoro et al., 2022). Its use in composting accelerates organic matter decomposition, resulting in high-quality compost with neutral pH and improved plant growth (Narang et al., 2023). They provide a sustainable way to recycle organic waste, reducing landfill burden and transforming waste into valuable products for cleaning, agriculture, and wastewater treatment (Hasanah, 2021). These components include enzymes, natural growth hormones, organic acids, and microorganisms. The combined action of these components has been proven to accelerate the breakdown of organic matter while also boosting the availability of nutrients in the soil. A substantial body of prior research has shown that the use of eco-enzymes improves soil nutritional quality (Hemalatha & Visantini, 2020; Rochyani et al., 2020) and has the potential to increase plant productivity (Yuliandewi et al., 2018; Salsabila & Winarsih, 2023).

Green mustard (*Brassica juncea* L.) and peanuts (*Arachis hypogaea* Linn.) are crops in high demand. National demand for both has been rising annually due to population growth, which increases food requirements, nutritional needs, food diversification, and industrial demand (Mahyiddin et al., 2025). Besides the source is easily obtained, this horticultural plant has a lot of content. According to data 100 g of peanuts provide approximately 567 kilocalories of energy, with a nutrient composition including 49 g of total fat, 7 g of saturated fat, and no cholesterol content. Additionally, peanuts contain 18 mg of sodium, 16 g of total carbohydrates, including 9 g of dietary fiber and 4 g of sugar. Notably, peanuts' protein content is estimated at 26 g, accompanied by notable micronutrient contributions, including 4.6 mg of iron, 0.3 mg of vitamin B6, and an impressive 168 mg of magnesium (USDA, 2019; Yeri et al., 2024). Meanwhile, 100 grams of green mustard contain the following nutrients: fat 0.3 g, protein 2.3 g, carbohydrate 4.0 g, Ca 220 mg, P 38 mg, Fe 2.9 mg, vitamin A 1,940 mg, vitamin B 0.09 mg, and vitamin C 120 mg (Haryanto et al., 2007; Sulistyawati et al., 2024). Despite the implementation of various initiatives aimed at enhancing the productivity of horticultural crops, empirical evidence in the field indicates the persistent utilization of the monoculture system by farmers. Intercropping systems have been implemented to enhance crop productivity and

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yield. A substantial body of research has emerged on the subject, and its findings are quite robust. For instance, intercropping systems have been shown to enhance crop productivity by 62% (Nurhayati et al., 2013), suppress weed growth (Pujisiswanto, 2011), and increase the yield of plant growth (Murdiono et al., 2016). While eco-enzymes and related organic amendments show promise for improving soil health and crop productivity, there is a clear research gap regarding their application in green mustard-peanut rotations on Inceptisol soils. Direct, system-specific studies are needed to validate and optimize these benefits for this context.

This study aims to study the effect of eco-enzymes on soil nutrient and on soil nutrients and plant productivity of green mustard-peanut in Inceptisol. The study's findings are expected to provide empirical evidence for the efficacy of eco-enzymes in improving soil fertility and crop yields, incorporation as a component of a sustainable agricultural system.

Materials and Methods

This field experiment research was conducted from February to April 2025 in Sasa Village, South Ternate, Ternate City. The analysis of soil properties was carried out at the Chemistry and Soil Fertility Laboratory, Department of Soil Science, Faculty of Agriculture, Universitas Hasanuddin, Makassar. Materials used in the study were soil, green mustard (*Brassica juncea* L) seeds cv. Shinta, peanut (*Arachis hypogaea* Linn) seeds cv. Talam 1, water, chicken manure, and eco-enzyme. The tools used are treatment signboard, hand sprayer, hoe, shovel, meter, crossbar, camera, stationery. This study used a Randomized Block Design (RBD) consisting of 5 treatments and repeated 3 times, so that there were 15 experimental units, including (1) N0 = without eco-enzyme; (2) N1 = eco-enzyme 2 cc/L; (3) N2 = eco-enzyme 4 cc/L; (4) N3 = eco-enzyme 6 cc/L; and (5) N4 = eco-enzyme 8 cc/L.

The research variables measured soil property analysis, with soil pH (1:5) measured using the electrometric method and a pH meter; total nitrogen (N-total) measured using the Kjeldahl titrimetric method; and available phosphorus (P-available) determined by the Olsen method and measured with a spectrophotometer. All soil chemical analyses followed the laboratory measurement standards of the Agricultural Instrument Standardization Agency, Ministry of Agriculture. In addition to edaphic factor analysis, plant responses were measured. For green mustard, plant height (cm) and leaf number were recorded at 7, 14, 21, and 28 days after planting (DAP). Leaf area was calculated using the L × W × CF method, where L is leaf length, W is leaf width, and CF is the correction factor. Fresh weight was measured at harvest. For peanuts, plant height and branch number were recorded at 7, 14, 21, and 28 DAP, and pod number was counted at harvest. The data analysis technique used was analysis of variance (ANOVA) and followed by Tukey's HSD post hoc test.

Results and Discussion

Initial Soil Chemical Properties. As illustrated in Table 1, Inceptisol exhibits a soil pH range of 5.84 to 5.96, within the criteria for slight acidity. Furthermore, the soil total nitrogen content ranges between 0.16% and 0.22%, falling within the low-to-medium range, as defined by the criteria. Soil pH values affect nitrogen levels in the soil. Imbalanced pH can reduce TN by affecting microbial activity and nitrogen retention (Tian et al., 2024). Similarly, the phosphorus availability spans from 12.97 ppm to 19.51 ppm, categorizing it as very low or low, as delineated by the specified criteria.

Table 1. Results of initial soil chemical analysis

Soil Properties	Value	Criteria
Soil pH (1:5)	5.84 – 5.98	Slightly Acidic
Total Nitrogen (%)	0.16 – 0.22	Low - Moderate
P - Availability (ppm)	12.97 – 19.51	Very Low - Low

Source: Soil Chemistry Laboratories, Faculty of Agriculture, Universitas Hasanudin (2025)

Various concentrations of eco-enzyme exerted no significant effect on soil pH, as illustrated in Figure 1. As shown in Figure 1, the soil pH analysis indicates that the N0 treatment typically yields a higher soil pH value in comparison to the other treatments. In general, low pH is caused by strong acids, such as sulfuric acid, dissolved carbon dioxide, or organic compounds, including humic acid (Bolan et al., 2021). Furthermore, the ion concentration of the soil solution can vary significantly depending on the soil's characteristics. The fluctuation in hydrogen ion concentration within the soil solution affects its pH level. An increase in hydrogen ion concentration typically leads to a decrease in soil pH, indicating an acidic condition. Conversely, a decrease in hydrogen ion concentration increases soil pH, indicating an alkaline condition (Nopriani et al., 2023).

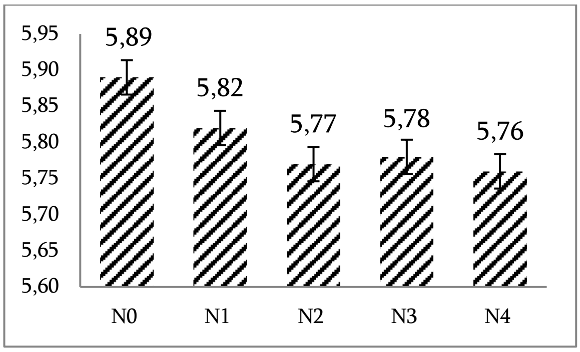

Figure 1. Effect of eco-enzyme concentration on soil pH
Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Various concentrations of eco-enzymes had a significant effect on the N-total and P-availability of Inceptisol (Table 2). The N-total and P-availability levels of Inceptisol revealed a marked difference in response to the N4 treatment in comparison to the other treatments. The results showed that the concentration of eco-enzyme increased on soil total nitrogen, where the lowest initial soil total nitrogen range was 0.16% and the highest 0.26%, while the lowest final soil total nitrogen analysis was 0.11 and the highest 0.26 (%). Increased enzyme activity in the soil can increase the availability of total nitrogen through its role in nutrient cycling and soil biogeochemical processes (Yang et al., 2023). Eco-enzymes can produce bacterial sources of enzymes such as nitrogenase and reductase, in addition to playing a role in the process of nitrogen fixation. These enzymes also act as biocatalysts to accelerate the breakdown of Nitrogen compounds into macro nutrients, Nitrogen needed for soil fertility (Lubis et al., 2022). The analysis showed that eco-enzyme concentration affected soil P-availability, with 8 cc/L (N4) having a significant effect (Table 2). Eco-enzyme, produced from organic waste through a fermentation process, increases phosphorus levels in soil by helping with decomposition and nutrient uptake, including phosphorus. This process produces CO_2, which affects soil phosphate solubility (Nopriani et al., 2023). Organic matter influences soil phosphate availability, especially through weathering products like organic acids and CO_2. These acids can metals like Al, Fe, and Ca from the soil solution (Pasaribu et al., 2014).

Table 2. Effect of eco-enzyme concentration on soil total nitrogen and P-availability

Treatment	Average	
	Soil Total Nitrogen Total (%)	P-Availability (ppm)
N0 (Without Eco-enzyme)	0.11 d (l)	11.12 d (vl)
N1 (Eco-enzyme 2 cc/L)	0.16 c (l)	13.18 c (vl)
N2 (Eco-enzyme 4 cc/L)	0.19 bc (l)	15.33 b (l)
N3 (Eco-enzyme 6 cc/L)	0.22 ab (m)	16.37 ab (l)
N4 (Eco-enzyme 8 cc/L)	0.26 a (m)	17.09 a (l)
HSD 0.05	0.04	1.39

Note: Mean numbers followed by the same letter in the same column mean not significantly different at the Tukey's HSD test α 0.05 level; (vl) = very low; (l) = low; (m) = moderate.

Green mustard plant height. Various concentrations of eco-enzyme gave a significant effect on the height of green mustard plants at 7 and 28 DAP, but the eco-enzyme treatment gave no significant effect at 14 and 21 DAP. Table 3 shows plant height at 7 days after planting (DAP), where the N2 treatment did not differ significantly from N1 but was significantly different from the other treatments. At 28 DAP, the N4 treatment showed a significant difference compared to all other treatments.

Tabel 3. Effect of eco-enzyme concentration on green mustard plants height (cm)

Treatment	Plant Height	
	7 DAP	28 DAP
N0 (Without Eco-enzyme)	4.21 c	19.93 e
N1 (Eco-enzyme 2cc/L)	5.83 ab	24.99 b
N2 (Eco-enzyme 4 cc/L)	5.85 a	22.75 c
N3 (Eco-enzyme 6 cc/L)	5.47 bc	20.65 d
N4 (Eco-enzyme 8 cc/L)	3.27 d	25.56 a
HSD α 0.05	1.43	4.28

Note: Mean numbers followed by the same letter in the same column mean not significantly different at the Tukey's HSD test α 0.05 level.

The concentration of eco-enzyme had no significant effect on the green mustard plant height at 14 and 21 DAP (Figure 2). However, N2 treatment tended to show a higher height than others at 14 DAP. While at 21 DAP, N1 treatment gave the highest plant height compared to other treatments. Plant height is also influenced by the availability of nitrogen in the soil to support plant growth. Using an eco-enzyme concentrate on green mustard plants provides nutrients for the plants. The nitrate in eco-enzyme liquid organic fertilizer helps the growth phase and development phase of green mustard plants (Novianto & Bahri, 2023). Nitrogen nutrients are important for plant growth and development, especially when the plant is growing new cells and making food for itself. Several plant nutrients play crucial roles in cell development and enlargement. Nitrogen, phosphorus, potassium, calcium, and magnesium are essential for cell growth and division, while micronutrients like zinc and boron are also vital for specific aspects of cell development, such as root growth and elongation. The process will happen quickly as more carbohydrates are added to promote plant growth, including plant height, the number of leaves, and leaf area (Suwandi et al., 2024).

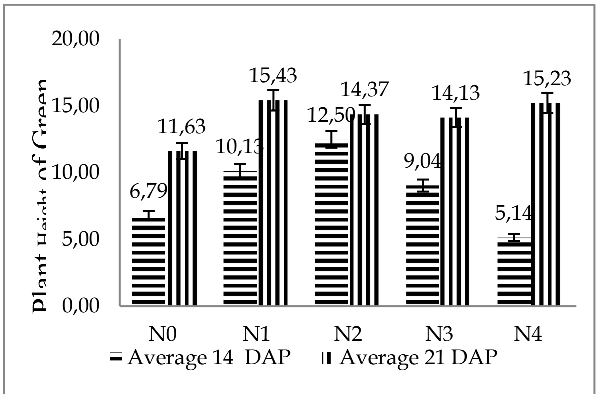

Figure 2. Effect of eco-enzyme concentration on green mustard plant height
Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Number of Leaves of Green Mustard Plants. Various concentrations of eco-enzyme exerted no significant effect on the parameter of the number of leaves of green mustard at 7, 14, 21, and 28 DAP. At 7 and 14 DAP, the N4 treatment tended to produce the highest number of leaves compared to other treatments. By 21 and 28 DAP, the N3 treatment resulted in a greater number of leaves than the other treatments.

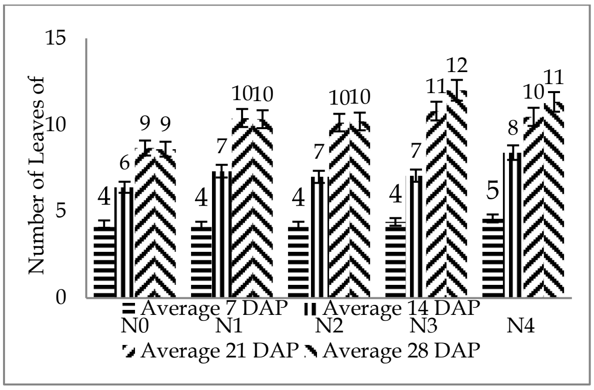

Figure 3. Effect of Eco-enzyme Concentration on the Number of Leaves of Green Mustard
Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Figure 3 shows that there is a relationship between eco-enzyme concentration and plant growth parameters, like plant height, number of leaves, root length, and wet biomass of green mustard plants. The more eco-enzymes you give to plants, the more valuable their growth will be. The same thing happened with the results of mustard plants. The highest dose had a positive impact on the growth and yield of pakcoy (Salsabila & Winarsih, 2023). Nitrogen plays an important role in plant growth. It is needed for every bud formation, stem development, and leaf development in plants. When there is enough N supply, plant leaves will grow large and increase the surface area for photosynthesis (Syifa et al., 2020).

Fresh Weight of Green Mustard Plants. The results of the analysis of variance showed that the concentration of eco-enzyme on the fresh weight of green mustard plants exerted no significant effect; however, the N1 treatment exhibited a tendency to yield the optimal effect on the fresh weight, as illustrated in Figure 4. The N1 treatment exhibited a tendency to possess the highest fresh weight in comparison to the N0, N2, N3, and N4 treatments.

Fresh weight is generally related to stem diameter. Water content in the stem affects the uptake of nutrients during the metabolic process because water plays a role in cell turgidity, so that leaf cells will enlarge and increase in number (Novianto & Bahri, 2023). From the results of plot/hectare conversion production, the lowest fresh weight production was treatment N0 = 266.67 g/plot or equivalent to 0.93 tons/ha. While the highest weight production was treatment N1 = 1028.67 g/plot or equivalent to 3.57 tons/ha. This condition illustrates that there is an influence from the provision of eco-enzymes, even though it is not significant, but the provision of eco-enzymes tends to increase the fresh weight of green mustard plants. Previous research mentioned that the application of liquid organic fertilizer has a positive impact on increasing the fresh weight of flowers by 137% (Widnyana et al., 2023), pakcoy plants up to 83.33 g/plant (Mustofa et al., 2022), and green spinach plants (Nurseha, et al., 2023).

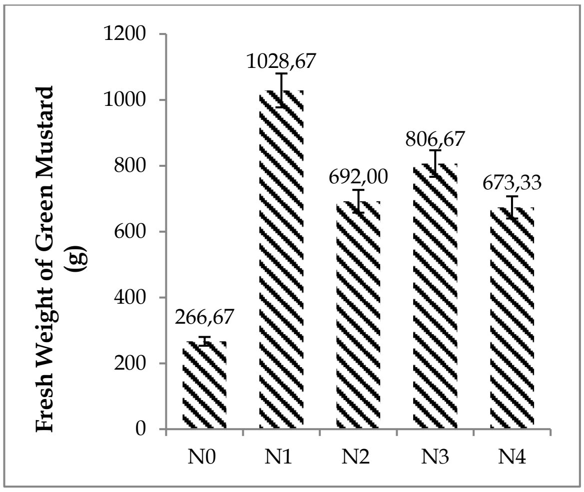

Figure 4. Effect of eco-enzyme concentration on fresh weight of green mustard plants
Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Leaf Area of Green Mustard Plants. The results of the analysis of variance showed that the concentration of eco-enzyme had no significant effect on the leaf area of green mustard plants, but the N1 treatment was able to produce a larger leaf area than the others, as shown in Figure 5. The N1 treatment tended to provide the widest leaf area compared to the N0, N2, N3, and N4 treatments. Generally, vegetative parts of plants, such as leaves, stalks, and roots, have a very high mineral composition compared to fruits, tubers, and seeds. The N1 treatment has optimal absorption of N by the roots, so that it affects the growth of leaf area, while plants that do not meet their nitrogen needs well will grow stunted and have a small leaf area. The provision of nutrients should be appropriate and balanced because nutrient deficiencies or excess nutrients can cause non-optimal growth in plants (Syifa et al., 2020).

Furthermore, several studies have revealed that proper application of liquid organic fertilizer can have a positive effect on plants, though their effects can vary by crop type, fertilizer source, and application rate, and are sometimes less pronounced than those of chemical fertilizers. Previous research states that liquid organic fertilizer can increase the leaf area of lettuce plants by 5% to 40% (Shaik *et al*., 2022) and potato plants (Zhuravel *et al*., 2023).

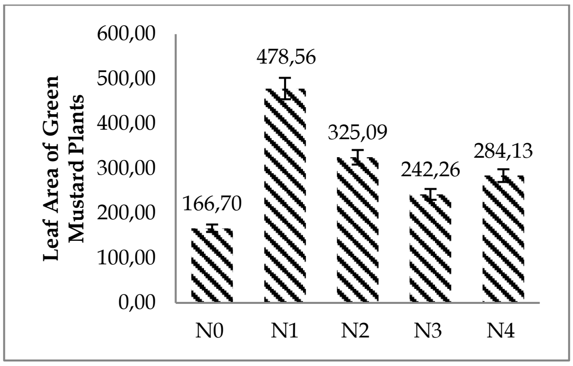

Figure 5. Effect of eco-enzyme concentration on leaf area of green mustard plants.
Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Peanut Plant Height. Various concentrations of eco-enzyme exhibited a significant effect on peanut plant height at 28 DAP. At 28 DAP, treatments N4 and N3 exhibited higher plant height compared to N2, N1 and N0.

Table 5. Effect of eco-enzyme concentration on peanut plant height (cm)

Treatment	Average (cm)
N0 (Without Eco-enzyme)	26.67 c
N1 (Eco-enzyme 2cc/L)	27.99 bc
N2 (Eco-enzyme 4 cc/L)	30.82 ab
N3 (Eco-enzyme 6 cc/L)	33.44 a
N4 (Eco-enzyme 8 cc/L)	33.51 a
HSD α 0.05	3.06

Note: Mean numbers followed by the same letter in the same column mean not significantly different at the Tukey's HSD test α 0.05 level; (vl) = very low; (l) = low; (m) = moderate.

As illustrated in Figure 6, the concentration of eco-enzymes exhibited no substantial impact

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on the height of peanut plant. However, the N3 treatment tended to show a higher plant height at 7 DAP in comparison to the other treatments. the N4 treatment exhibited the highest plant height compared to the other treatments at 14 and 21 DAP. The application of liquid organic fertilizer with different doses will have a different effect on plant growth and yield, while the right dose will have a significant effect on plant growth and yield (Silalahi et al., 2024). Eco-enzyme functions to fertilize the soil. Because the element nitrogen is very important during the growth of a plant, so that by giving eco-enzymes can accelerate the breakdown of N needed for soil fertility (Lubis et al., 2022).

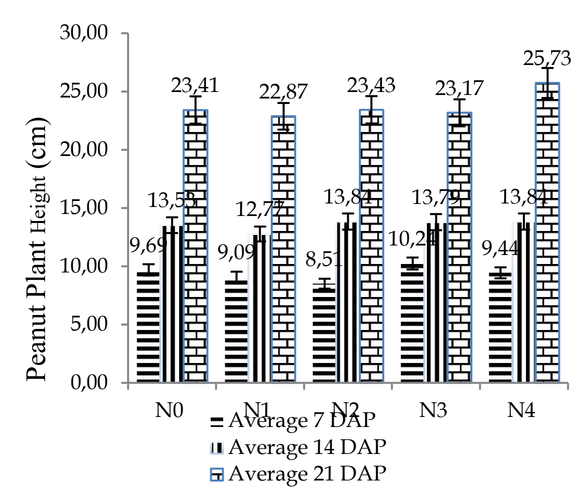

Figure 6. Effect of eco-enzyme concentration on peanut plant height

Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Number of Branches of Peanut Plants. The analysis of variance indicated that eco-enzyme concentration had no significant effect on the number of peanut branches at 7, 14, 21, or 28 days after planting (DAP) (Figure 7). However, trends were observed: N1 tended to produce more branches at 7 DAP, N2 at 21 DAP, and N4 at 14 and 28 DAP. These differences are likely related to the adequate and balanced availability of macro-nutrients, which are essential for cell division and contribute to increased growth during the generative phase. Additionally, macro-nutrients present in the planting medium are believed to support both cell division and enlargement (Ngantung et al., 2018).

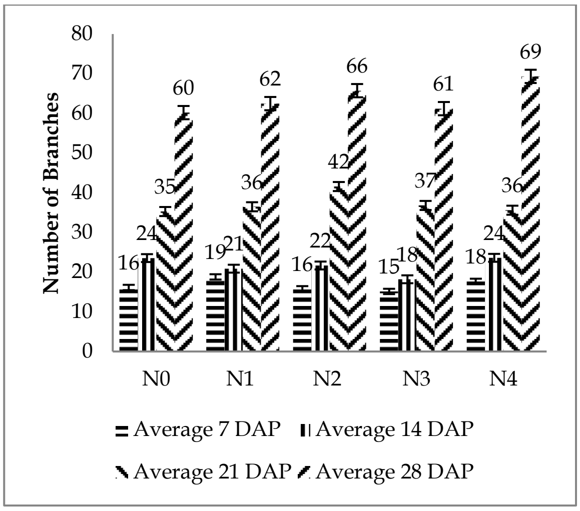

Figure 7. The effect of eco-enzyme concentration on the number of branches of peanut plants

Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

Number of Peanut Pods Production. The results of the analysis of variance showed that the concentration of eco-enzyme had no significant effect on peanut pod production. However, the N4 treatment gave the highest pod production compared to the other treatments, as shown in Figure 8. The N4 treatment tended to give more peanut pod weight compared to the other treatments.

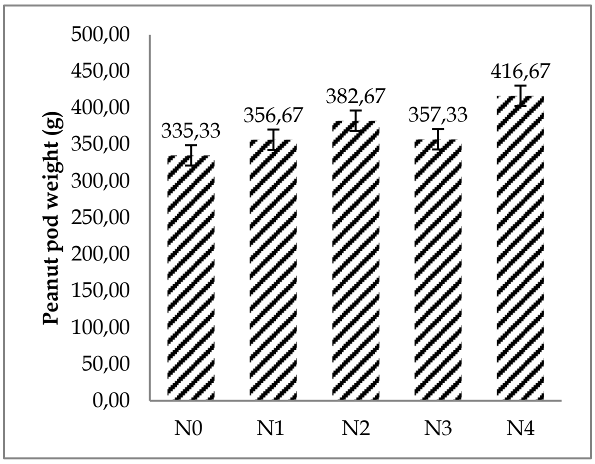

Figure 8. Effect of Eco-enzyme Concentration on Peanut Pod Weight

Note: N0: without eco-enzyme; N1: eco-enzyme 2cc/L; N2: eco-enzyme 4 cc/L; N3: eco-enzyme 6 cc/L; N4: eco-enzyme 8 cc/L

The application of eco-enzyme with a concentration of 8 cc/L(N4) was able to provide sufficient phosphate, where the P element plays a role in the formation of flowers, fruits, seeds, and pods. This is in line with the statement of Salsabila and Winarsih (2023), which states that eco-enzyme given directly to plants by spraying can also increase P-availability in the soil. In addition, the application of liquid organic fertilizer can increase pod production, seed yield, and mineral composition in peanut plants (Ozaktan and Doymaz, 2022), okra plants (Chotaliya, 2020), and long bean plants (Rusnaini et al., 2023).

Conclusion

The application of eco-enzyme concentration had a significant effect on soil total nitrogen, P-available, plant height of green mustard, and peanut. However, the concentration of eco-enzymes had no significant effect on soil pH, number of green mustard leaves, green mustard leaf area, green mustard fresh weight, number of peanut branches, and peanut pod production. Furthermore, the concentration of eco-enzyme treatment of 8 cc/L (N4) gave a significant effect on soil total nitrogen available, P-available, green mustard plant height at 7 and 28 DAP, and peanut plant height at 28 DAP. Meanwhile, the lowest production of green mustard was 0.85 tons/ha, and the highest was 3.29 tons/ha.

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