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Research Article

Growth response of pak choi (*Brassica rapa* L.) on different concentrations and intervals of eco-enzyme applications

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ABSTRACT

Vegetable cultivation using eco-enzyme application is one way to improve its production. The study aimed to evaluate the growth response of pak choi using eco-enzyme in several concentrations and its interval. The experiment used a randomized complete block design with two factors (concentrations and interval of eco-enzyme applications). The results showed that the application of eco-enzyme with a concentration of 30 mL L^{-1} indicated an optimal growth stimulator in pak choi, but it was not significantly different as compared to 50 mL L^{-1}. The application of eco-enzyme twice a week was able to stimulate plant growth including plant height, number of leaves, leaf area, shoot fresh weight, and root fresh weight. Furthermore, there was a linear correlation between leaf area and plant height, leaf number, shoot fresh weight, and root fresh weight that ranged from weak to strong levels. It is recommended to apply eco-enzyme at a concentration of 30 mL L^{-1} twice a week for optimal pak choi production.

Keywords: correlation, leafy vegetable, green olericulture, organic fertilizer, plant booster

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INTRODUCTION

Increasing demand for vegetables is evident as part of healthy diets. Miladinov (2023) confirmed that population growth is a major challenge to food security. In addition, the phenomenon of shifting consumer behavior has recently led to organic vegetable products. It is indicated by the increasing demand for organic vegetables in many regions of Indonesia (Rahman et al., 2021). Eyinade et al. (2021) emphasized that issues of food safety, health, and environmental concerns are the main reasons people switch to organic products.

Pak choi (*Brassica rapa* L.) is a leafy vegetable that has been known and consumed by the broader community in Indonesia. This is associated with the content of vitamins, minerals, and food fiber that are able to provide a nutritional diet. In 100 g of fresh pak choi, it contains 95.32 water, 1 g dietary fiber, 13 cal energy, 1.5 g protein, 105 mg calcium, 27 mg phosphorus, 252 potassium, vitamins A, C and E, and other antioxidant activities (USDA, 2019). Moreover, pak choi has been cultivated in several cultivation practices through hydroponic cultivation (Maludin et al., 2020; Gobilik et al., 2021; Lynn et al., 2022).

Eco-enzyme is a fermented organic material that is easy to produce and has various advantages. Eco-enzyme has been widely reported to have benefits as liquid organic fertilizer and disinfectant (Hasanah et al., 2020; Fadlilla et al., 2023; Vidalia et al., 2023). Fadlilla et al. (2023) reported that 1 mL L^{-1} eco enzyme from fruit and vegetable waste

contains 0.01% N, 0.08 ppm P, 0.08 ppm K, and 0.01% C-organic. Eco-enzyme is commonly produced from anaerobic fermentation.

The potential of eco-enzyme in increasing plant growth has been proven in several crops such as celery (Elisabet and Titisari, 2023) and chickpeas (Narang et al., 2023). Moreover, Novianto et al. (2022) found eco-enzyme formulation to improve the growth of *Allium ascalonicum*. As an organic nutrient provider, eco-enzyme can be used as a liquid organic fertilizer to reduce or even replace chemical fertilizers. Jiang et al. (2022) revealed that the use of organic fertilizers to replace chemical fertilizers needs to be continuously improved to support sustainable agriculture. Moreover, eco-enzyme production is the recent method to reduce organic waste (Muliarta and Darmawan, 2021). The application of eco-enzyme in pak choi also supports organic vegetable production. The study aimed to evaluate the growth response of pak choi using eco-enzyme in several concentrations and its interval.

MATERIALS AND METHODS

Research site and agro-climatology conditions

The research was conducted at Teaching and Research Farm (1°370'129" S, 103°312'0.501" E), Faculty of Agriculture, Jambi University, Muaro Jambi, Jambi. The research started from May to June 2023. The research was a field experiment with monthly averages of agroclimatic conditions as represented by Table 1.

Research procedure

Nauli as a commercial variety was used in our study. Nauli is a pak choi variety that is commonly cultivated and consumed. Before planting, the seed was sown in a seedling tray with a planting medium of soil and chicken manure mixture (3:1 v/v). After the seedlings were 7 days after sowing (DAS), it was transplanted to each experimental plot. Each experimental plot measured 1.0 m (length) x 1.0 m (width) x 0.3 m (height). The seedlings were planted in experimental plots with a spacing of 20 cm (length) x 20 cm (width).

Table 1. Monthly averages of temperature, relative humidity, and rainfall in the research location.

Month	Temperature (°C)	Relative humidity (%)	Rainfall (mm)
May	28.03	85.26	8.00
June	27.85	84.63	3.76

Source: Indonesian Meteorology, Climatology, and Geophysics Agency

The eco-enzyme treated in this study was made from a mixture of fruit and vegetable waste that had been chopped into smaller pieces. The mixture composed of mustard leaves (500 g), water spinach (300 g), spinach (300 g), moringa (300 g), pandanus (200 g), lemongrass (200 g), pineapple peel (200 g), papaya peel (200 g), watermelon peel (200 g), orange peel (200 g), banana peel (200 g) and mango peel (200 g). These selected materials were collected from household waste. The mixture was added with molasses (1000 g) and water (10 L), then fermented anaerobically for 90 days. Thus, the composition of the eco-enzyme was organic material (3000 g): molasses (1000 g): water (10 L). The eco-enzyme contained N-total = 0.02%, P-total = 0.01%, K-total = 0.02%, and water pH = 3.91 (Analyzed in Jambi Agricultural Instrument Standards Implementation Center Laboratory).

This study adhered to the factorial randomized block design consisting of two factors. The concentration of eco-enzyme was determined as the first factor consisting of 3 (three) treatment levels, namely 10 mL L^{-1} (C1), 30 mL L^{-1} (C2), and 50 mL L^{-1} (C3). Meanwhile, the application interval was the second factor consisting of once a week (I1) and twice a week (I2). Each treatment was repeated 4 times. The application of eco-enzyme was started at 1 week after planting (WAP) which was done by spraying on the

leaves. The pak choi was watered in the morning and evening as part of routine maintenance. In the meantime, a 10 g/plot of NPK fertilizer (16:16:16) was used. Plot size was 1 m^2.

Data collection

The data was collected weekly and at harvest. The number of leaves, leaf area, shoot fresh weight, and root fresh weight were carried out destructively. Plant height measurement was carried out starting at 1 to 4 WAP. The measurement was carried out at the base of the stem to the tip of leaf. Destructive observation was carried out at 5 WAP. Measurement of leaf area was done using the gravimetric method.

Statistical analysis

All data collected were analyzed by analysis of variance (ANOVA) and significant differences between treatments were tested by the Duncan Multiple Range Test (DMRT) at 5% level. Furthermore, selected parameters were also analyzed for their level of correlation using simple regression. Data analysis was performed using Rstudio software for Windows 10.

RESULTS AND DISCUSSION

Pak choi growth

Application interval of eco-enzyme triggers the growth of plant height of pak choi as seen by significant differences between C1 and C2 or C3 (Figure 1). Pak choi applied with higher concentrations of eco-enzyme will increase plant height. Furthermore, although there was an increase in pak choi height after the application of eco-enzyme at a concentration of 50 ml L^{-1} (C3), it did not show a significant difference with the height of pak choi applied with 30 ml L^{-1} (C2). However, the interval of application did not affect plant height (Figure 1B).

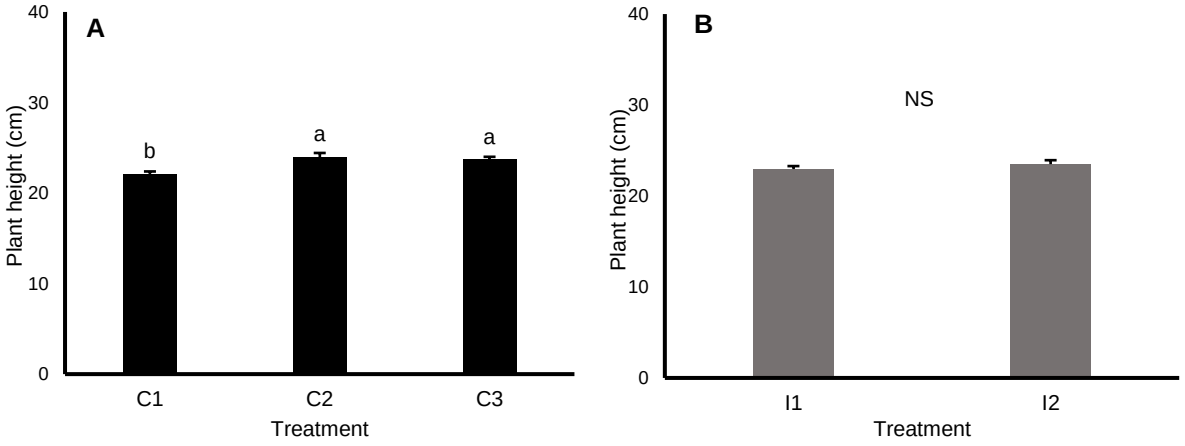

Figure 1. Plant height on several concentrations (A) and intervals (B) of eco-enzyme application. C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

Leaf is a commercially valuable organ in pak choi. The consentration of eco-enzyme increased to 30 mL L^{-1} (C2) has been able to trigger the initiation of new pak choi leaves than C1 (Figure 2). It seems that 30 mL L^{-1} (C2) concentration was the optimum level in increasing pak choi production. A higher application of eco-enzyme did not increase leaf number. Furthermore, more frequent application of eco-enzyme (I2) was able to provide nutrients sustainably for pak choi; resulting in a higher number of leaves (Figure 2B).

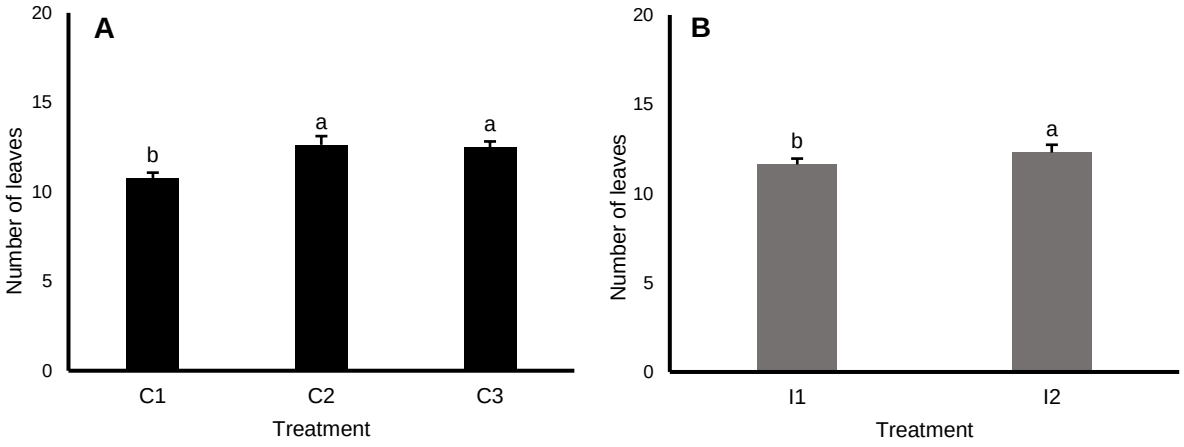

Figure 2. Number of leaves on several concentrations (A) and intervals (B) of eco-enzyme application. C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

Pak choi applied with higher concentrations of eco-enzyme showed changes in characteristics mainly related to leaf area. Leaves applied with high concentrations of C2 and C3 eco-enzymes appeared broader. However, both concentrations had similar leaf areas. On the other hand, more frequent application of eco-enzyme (I2) also affected the increase in leaf area. Leaves applied with eco-enzyme with the I2 interval had a significantly higher area than I1 (Table 2).

Table 2. Leaf area on several concentrations (A) and intervals (B) of eco-enzyme application.

Treatment	Leaf area (cm^2)
Concentrations	
C1	2,372.14 ± 78.34b
C2	3,005.54 ± 94.21a
C3	2,994.64 ± 52.76a
Intervals	
I1	2,683.45 ± 117.02b
I2	2,898.10 ± 87.73a

Note: C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

Plant height, number of leaves, leaf area, shoot fresh weight, and root fresh weight are vegetative indicators that are often used to evaluate plant growth. Pedersen et al. (2022) revealed that plant height is a morphometric indicator that can represent the condition of plants during the early growth period. Gao et al. (2020) proved that nutrient sufficient will improve plant height.

Leaf initiation begins with active cell division in meristematic tissues. Cell division involves several important phytohormones such as auxins and cytokinins (Xue et al., 2021). However, the role of phytohormones in cell division will decrease dramatically if nutrient availability is inadequate. Furthermore, El Sabagh et al. (2022) stated that phytohormone activity will be disrupted under abiotic stress conditions including nutrient deficiency stress.

The accumulation of increased leaf and stem growth in pak choi will have implications for increased shoot growth. This condition was represented through the fresh weight of the shoot at C2 and C3 which was significantly higher than the shoots at C1. Furthermore, the eco-enzyme applied more frequently (I2) was consistently able to increase the shoot growth of pak choi (Figure 3).

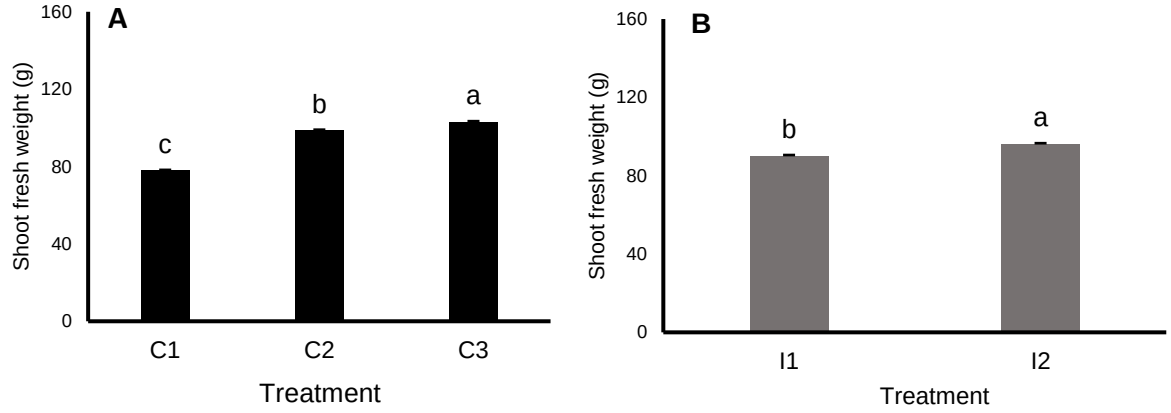

Figure 3. Shoot fresh weight on several concentrations (A) and intervals (B) of eco-enzyme application. C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

Based on the observations, the eco-enzyme treatment with a concentration of 30 mL L^{-1} and an application interval of two times per week was able to provide balanced nutrients for plant growth. Shrestha et al. (2020) revealed that balanced nutrients will trigger plant growth. Furthermore, macro and micronutrients contribute to plant growth (Kumar et al., 2021). Several nutrients have been identified as playing an important role in plant growth. Nitrogen and phosphorus are nutrients that can enhance plant growth (Ichihashi et al., 2020; Schleuss et al., 2020). Mu et al (2021) claimed that several components involved in photosynthesis have decreased function due to nitrogen deficiency. The effect of nitrogen on photosynthesis has been proven in several leafy vegetables such as cabbage and lettuce (Song et al., 2021). Meanwhile, Meng et al. (2021) stated that nutrient deficiencies, including phosphorus, reduce photosynthetic performance through a decrease in the amount of chlorophyll and electron transfer activity in photosystem II (PS II). The impact of this nutrient deficiency occurs with inhibited root growth as has been reported in spinach (Ma et al., 2022) and tomatoes (Lopez et al., 2023).

The root is an important organ of a plant including pak choi. With the higher concentration of eco-enzyme applied, the fresh weight of the root also increased (Figure 4), especially in C2. The application of eco-enzyme with a more frequent interval (I2) also significantly increased the fresh weight of pak choi root (Figure 4B).

The root-shoot ratio indicates the effectiveness of pak choi growth. Based on the eco-enzyme concentration treatment, C2 and C3 treatments play an important role in increasing the shoot and root growth of pak choi (Figure 5). More frequent application (I2) is able to increase the shoot and root growth of pak choi. However, the proportion of pak choi growth generally looks more dominated by the shoot organ. This is because the stem and leaf growth of pak choi might grow more active as compared to their root growth.

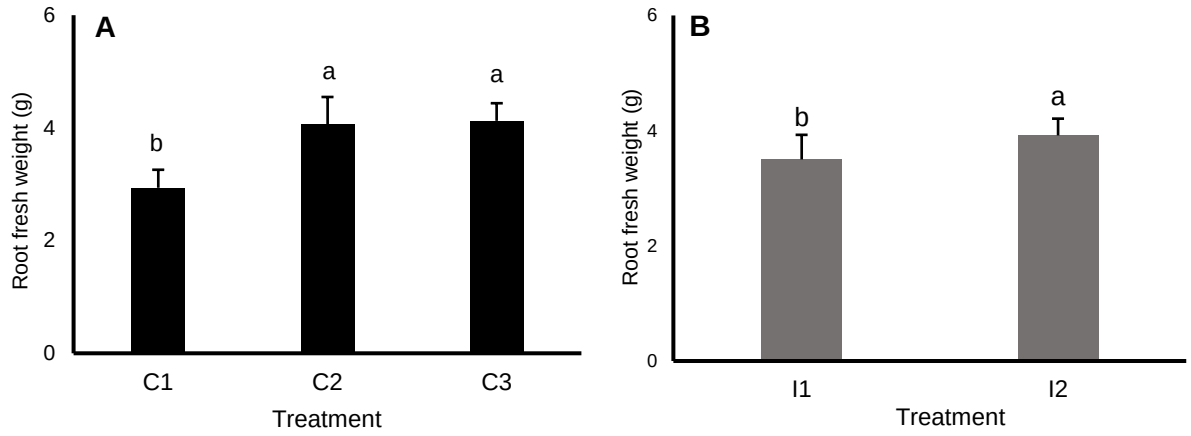

Figure 4. Root fresh weight on several concentrations (A) and intervals (B) of eco-enzyme application. C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

The results showed that eco-enzyme application increased the growth of pak choi. Eco-enzyme has potential as an organic fertilizer because it provides N, P, and K nutrients (Vama & Cherekar, 2022; Zuhro et al., 2023). Furthermore, Satrio (2023) stated that the application of eco-enzymes improves plant metabolism. Putri et al. (2022) reported that the application of eco-enzymes increases root and leaf growth. Meanwhile, eco-enzymes made from several types of fruit are very effective for lettuce growth (Dondo et al., 2023).

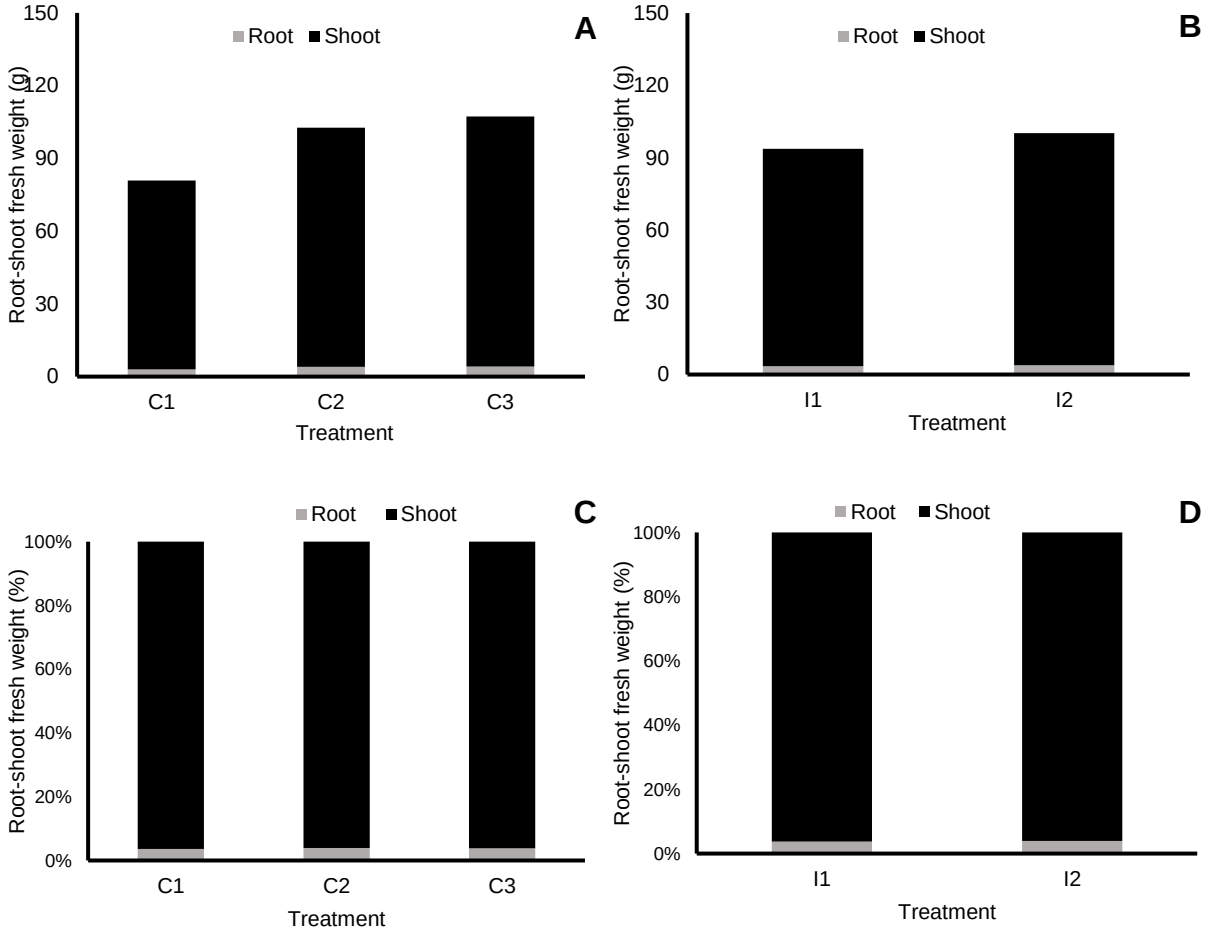

Figure 5. Root-shoot fresh weight (A-B) and their partition (C-D) on several concentrations and intervals of eco-enzyme application. C1= 10 mL L^{-1}; C2= 30 mL L^{-1}; C3= 50 mL L^{-1}; I1= once a week; I2= twice a week (I2).

Correlation between leaf area and some pak choi organs

Leaf area is an important variable that can be used as an approach for determining the photosynthetic ability of pak choi. Plant with broader leaves generally has higher photosynthetic capacity. The results of photosynthesis will accumulate in plant organs such as stems, leaves, and roots. Based on observations, leaf area is generally positively related to plant height, number of leaves, shoot fresh weight, and root fresh weight. However, the strongest relationship was indicated for shoot fresh weight (Figure 6). This justified that the flow of accumulated photosynthetic products of pak choi was more directed towards to shoot organ, namely leaves and stem.

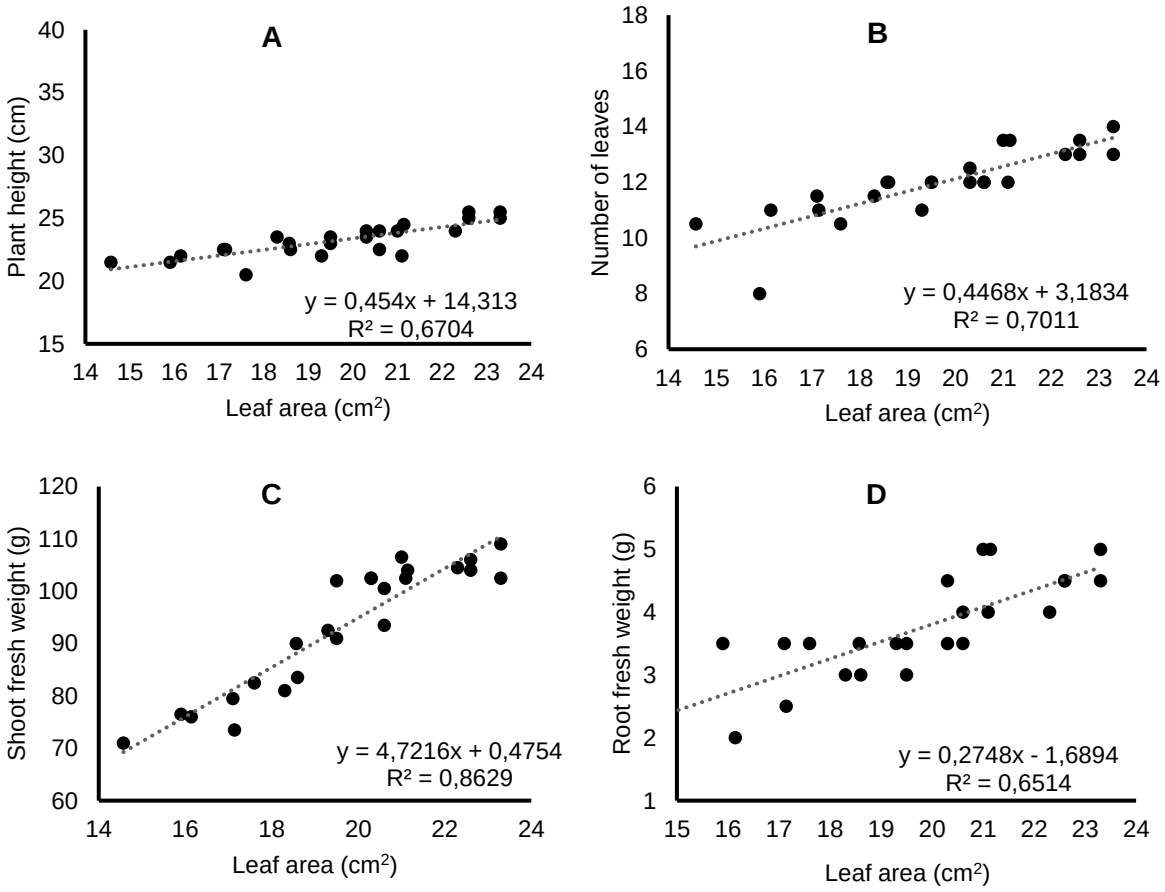

Figure 6. Regression between leaf area with plant height (A), number of leaves (B), crown fresh weight (C), and root fresh weight (D).

Leaf area is a useful estimate for plant growth. Hu et al. (2020) reported that there was a decrease in leaf area first before a decrease in photosynthetic capacity. By knowing the leaf area, the growth status of the plant can be estimated. Leaf area has been reported to be positively related to plant growth (Dong et al., 2020; Tao et al., 2020). Meanwhile, leaf area also reflects adequate water and nutrient availability. Thus, leaf area can indicate stress conditions in plants. Zhou et al. (2020) revealed that plants under drought stress experience changes in leaf characteristics, namely the leaves become narrower. On the other hand, plants show their morphological response by reducing leaf area when under nutrient deficiency stress conditions (Abbas et al., 2021).

CONCLUSIONS

The application of eco-enzyme at a concentration of 30 mL L^{-1} was effective in improving pak choi growth and yield. Spraying eco-enzyme twice a week is recommended for reaching optimum pak choi growth. The morphological characteristics of pak choi are

interesting as evidenced by the linear correlation found between leaf area with plant height, number of leaves, shoot fresh weight, and root fresh weight.

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