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The potential of ecoenzymes on vegetative and generative growth in curly chili plants (*Capsicum annuum*)

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ABSTRACT
Background: Curly red chili (*Capsicum annum*) is an important commodity for society. The use of inorganic fertilizers in the long-term cultivation of curly chilies can disrupt the balance of the soil. So that soil aggregation and soil particles can easily bind organic matter and organic fertilizer. One alternative liquid organic fertilizer that can be used is ecoenzyme (EE). This research is to obtain the optimal concentration of EE on growth and chlorophyll levels in Curly red chili plants. **Methods:** There were 6 treatments, namely E0 (without treatment as a negative control), E1 (giving a manure with a ratio of soil: husk: fertilizer 1:2:1 as a positive control), and a different concentration of EE, namely, E2 (0.01%), E3 (0.5%), E4 (1%) and E5 (1.5%). Ecoenzyme as a fertilizer in this study was carried out at the age of 1 to 7 month. Those treatment (each 100 mL/polybag) were given at intervals of once a week, then watered every day. **Findings:** The results with Duncan at the 5% level showed that treatment E1 has good vegetative growth compared with other EE treatments, significantly. Among EE treatment, E4 (1% EE) give better results than other EE treatment, based on vegetative growth parameters. **Conclusion:** The conclusion of this research was that the optimal EE concentration to increase growth and chlorophyll levels in curly chili plants may be at dose of 10ml/1 liter of water. **Novelty/Originality of this Study:** The novelty of this investigation lies in its examination of the effects of ecoenzyme, an organic liquid fertilizer derived from fermented kitchen waste, on the growth and chlorophyll content of curly chili (*Capsicum annuum*) plants. This research is unique as it applies ecoenzyme to a horticultural crop that has not been extensively studied in this context, offering insights into sustainable agriculture practices and nutrient recycling.

KEYWORDS: ecoenzyme; plant growth; chlorophyll content; liquid organic fertilizer.

1. Introduction

Chili is a vegetable that is widely consumed by a lot of people. According to Wijaya et al. (2020), this plant contains vitamin C, vitamin E, folic acid, carotenoids, phenolic compounds, flavonoids and capsaicinoids. Based on data from the Central Statistics Agency (Badan Pusat Statistika) in 2021, the average person consumes 35 grams of curly chilies per week. This shows that chili production must continue and be improved. Based on data from the Ministry of Agriculture Republic Indonesia (2015), large chili production in Indonesia during the 2010-2014 period tends to continue to increase with an average growth rate of 3.76% per year. Large chili production in 2014 reached around 1,075 million tons. The source of growth in chili production comes from an increase in harvested area of 30% and an increase in productivity of 70%. Even though national chili production continues to increase, chili productivity per plant is still relatively low (0.20-0.33 kg/tree or 6.84 tonnes/ha of wet chili). This productivity is still far from its potential of 20 tons/ha, so

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efforts are needed to increase productivity (Syukur et al., 2010). One effort to increase productivity is by fertilizing.

Fertilization is one of the efforts in cultivation to increase plant productivity. Cultivated plants require relatively large amounts of nutrients, so it is almost certain that without fertilization the plants will not be able to produce the expected results (Raihan, 2000). Fertilization is generally carried out by farmers only through the soil, so that the nutrients are absorbed by the plant roots and transformed into materials that are useful for growth. Providing fertilizer into the soil aims to increase plant nutrition. Good soil for plants is assessed based on the availability of nutrients in the soil, both macronutrients and micronutrients, in an adequate and balanced manner (Bustami et al., 2012). The relationship between the amount of nutrients available in plant tissue and the plant growth response can be used to determine whether a nutrient is in a state of deficiency, optimal or excess (Suhardjo & Kurnia, 1993).

The availability of nutrients in the soil is assisted by the nutrients in fertilizer. So applying fertilizer is very important for providing nutrition for plants. There are two types of fertilizer, namely inorganic fertilizer and organic fertilizer. Inorganic fertilizers, if used in the long term, can disrupt the balance of the soil, increasing the decomposition of organic material which then causes degradation of the soil structure, resulting in low yields. Meanwhile, organic fertilizer can maintain and improve soil aggregation. With the presence of organic material, sufficient nutrients can be replaced from those absorbed by plants, the soil composition does not experience compaction and water binding is better so that water erosion is reduced (Isnaini, 2006).

Organic fertilizer comes from various natural fertilizer-making materials such as animal waste and dead animal or plant body parts. Organic fertilizer is divided into two, namely solid and liquid organic fertilizer. Liquid organic fertilizer can come from extraction from the decomposition of organic materials originating from plant residues, vegetables and fruit. One alternative liquid organic fertilizer used in this research is Ecoenzyme (EE). Ecoenzyme are the result of fermentation of organic waste (fruit and vegetable peel residue), molasses and water. Ecoenzyme liquid can be used to water plants and provide better fruit and flower yields and can repel pest insects (Megah et al., 2018). The potential of ecoenzymes in shallot plants can increase the number of leaves and tuber weight per sample (Gultom et al., 2022). Ecoenzyme may also increase the productivity of edamame soybean plants with an EE: water ratio of 1: 100 (Uli et al., 2020). Therefore, it is necessary to carry out research on other horticultural plants such as curly chilies. Research regarding the use of EE as organic materials to help plant growth and chlorophyll levels has not been carried out before. Even today, the number of Indonesian people, especially rural communities and the younger generation, is still limited who know the benefits of EE, especially in recycling organic waste into EE (Surtikanti et al., 2021). Based on the background above, research was carried out on optimizing the use of EE on growth and chlorophyll levels in curly chili plants.

2. Methods

The research period was carried out for 3 months, namely from November 2022 to January 2023 at the Punclut Hydroponic Garden, Cidadap District, Bandung City. This research consists of four stages, namely preparation, research, observation and data analysis. Preparation includes making ecoenzymes (3 months fermentation) and manure from goat manure; providing tools, materials and planting media. The main ingredient in this research is curly chili seeds obtained from local farmers in Bandung aged 30 days after planting from nurseries with the Chili seeds of the Castillo East-West Seed Cap Panah Merah brand of chili. Planting is carried out in polybags (size 25 x 25 cm) using Lembang soil which had been given fertilizer.

Ecoenzyme is made from fresh organic waste (fruit peels and vegetable waste) with a ratio of water: organic waste: molase (ratio 10:3:1). The mixture is stored in a closed container and fermented for 3 months. Meanwhile, goat manure is obtained from farmers in Cihideung, Bandung West Java. At the research stage, seeds of curly red chili plants (one month old) were treated with negative control, positive control and different concentrations of ecoenzymes. These treatments are:

E0 = No treatment or no fertilizer (negative control)
E1 = Providing goat manure with a ratio of soil: husk: fertilizer, 1:2:1 (positive control).
E2 = ecoenzyme with a concentration of (0.1%) 1 ml/1 liter of water.
E3 = ecoenzyme with a concentration of (0.5%) 5 ml/1 liter of water
E4 = ecoenzyme with a concentration (1%) of 10 ml/1 liter of water.
E5 = ecoenzyme with a concentration (1.5%) of 15 ml/1 liter of water.

This treatment is carried out once a week, while watering is carried out every morning at 10.00 WIB. Observations on vegetative, generative growth and chlorophyll content were done once a week for 2 months after treatment. Observation of vegetative growth is as follows: (a) Plant height is measured from the ground surface to the tip of the top leaf; (b) The number of leaves is calculated. The average number of all leaves that appear on the samplings of each clump (Gultom et al., 2022); (c) The diameter of the stem was measured 10 cm above the ground using a caliper; (d) Leaf length is measured on the second leaf from the main shoot which has been previously marked with a label; (e) Leaf width is measured on the second leaf from the main shoot which has been previously marked with a label; (f) Root length is measured by removing the plant from the polybag and then dipping the plant in water so that the soil is easily separated from the plant roots. This is done carefully so that the plant roots do not break. Roots are measured using a meter or ruler from the base of the root to the tip of the root; (g) Root volume is measured by determining the initial volume of water that will be put into the measuring cup, then putting the roots into the measuring cup and recording the increase in water volume after putting the roots into it; (h) Number of branches by counting all branches that appear on each plant from each treatment at 1 week intervals; (i) The amount of flowers is calculated from each repetition in the treatment. And at last, calculation of chlorophyll using the Wintermans & De Mots (1965) method at the end of the experiment.

Data analysis was carried out using IBM SPSS software. Testing begins with a normality test and a homogeneity test. The data was normally distributed and homogeneous so it was continued with testing using the One Way Anova test and the Tukey test. The significant effect will be continued with the Duncan's Multiple Range Test (DMRT) at the 5% level.

3. Results and Discussion

3.1 Vegetative growth

The results of observations of vegetative growth (plant height, number of leaves, stem diameter, leaf length, leaf width, root length and root volume) showed that the application of goat manure (E1) showed the highest results in all vegetative growth of curly chili plants (Table 1). The E0 treatment for the parameters of plant height and number of leaves showed significantly different results and higher yields when compared with all ecoenzyme treatments. However, plant height with different E4 treatments was not significant. Plant height in the E0 treatment showed higher yields (18.54 cm) and number of leaves (13 pieces) compared to the EE treatments (E2, E3, E4 and E5). This shows that providing sufficient water can fulfill the needs of curly chili plants in the vegetative growth of these plants, because basically water is one of the factors in the photosynthesis process. If the water needed is sufficient, the leaves will carry out the process of photosynthesis. Because water is the main ingredient in the photosynthesis process, it results in leaf growth and the number of leaves increasing. This is in accordance with the statement by Wiroatmodjo and Zulkifli (1988) that the need for sufficient water causes the opening of the stomata and increases the absorption of CO_2 for photosynthesis, resulting in increased growth and number of leaves. The presence of abundant water will be transported more to maintain excessive turgor, namely by forming leaves in large quantities (Jumin, 1989).

Table 1. Average vegetative growth of curly chili plants after treatment two months

Treatment	Average vegetative growth of curly chili plants after treatment two months						
	Plant height (cm)	The number of leaves	The diameter of the stem (cm)	Leaf length (cm)	Leaf width (cm)	Root length (cm)	Root volume (ml)
E0 = Control	18.54c	13c	0.28b	8.48c	1.9b	30.42a	32a
E1 = Goat manure	44.12d	40d	0.66c	18d	4.78c	29.9a	50b
E2 = EE 0.01%	12.52a	10b	0.23a	5.52a	1.5a	33.7a	28a
E3 = EE 0.05%	12.82a	12b	0.25ab	5.66ab	1.6ab	33.38a	36a
E4 = EE 1%	16.4bc	12b	0.3b	6.68bc	1.88b	31.4a	38a
E5 = EE 1.5%	14.52ab	8a	0.22a	5.2a	1.76b	33.82a	24a

Note: Numbers in columns and rows followed by the same lowercase letter are not significantly different according to the Multiple Range Test (Duncan) at the 5% level

Treatment E1 showed significantly different results in all parameters when compared to other treatments (E0, E2, E3, E4 and E5) except for the root length parameter. This is because the nutrients are needed by curly chili plants. It is fulfilled by providing goat manure. Sufficient N nutrients may stimulate plant vegetative growth. That goat manure contains 0.6% Nitrogen (N), 0.3% Phosphorus (P), and 0.17% Potassium (K) (Campbell et al., 2004). Lakitan (2010) states that plants that do not receive N nutrients according to their nutritional needs will be stunted and their leaves will be small, whereas plants that receive N nutrients that meet their needs will grow tall and have wide leaves. Lingga (2007) also states that the element N is needed as a constituent of proteins, enzymes and hormones. At the end of treatment (Table 1), the E1 treatment produces high leaf area index length: width (18 cm x 4.78 cm), while the E2 treatment only produces (5.52 cm x 1.5 cm). Treatment E1 showed significant differences as well in plant height (44.12 cm) compared to other treatments, the difference (Figure 1).

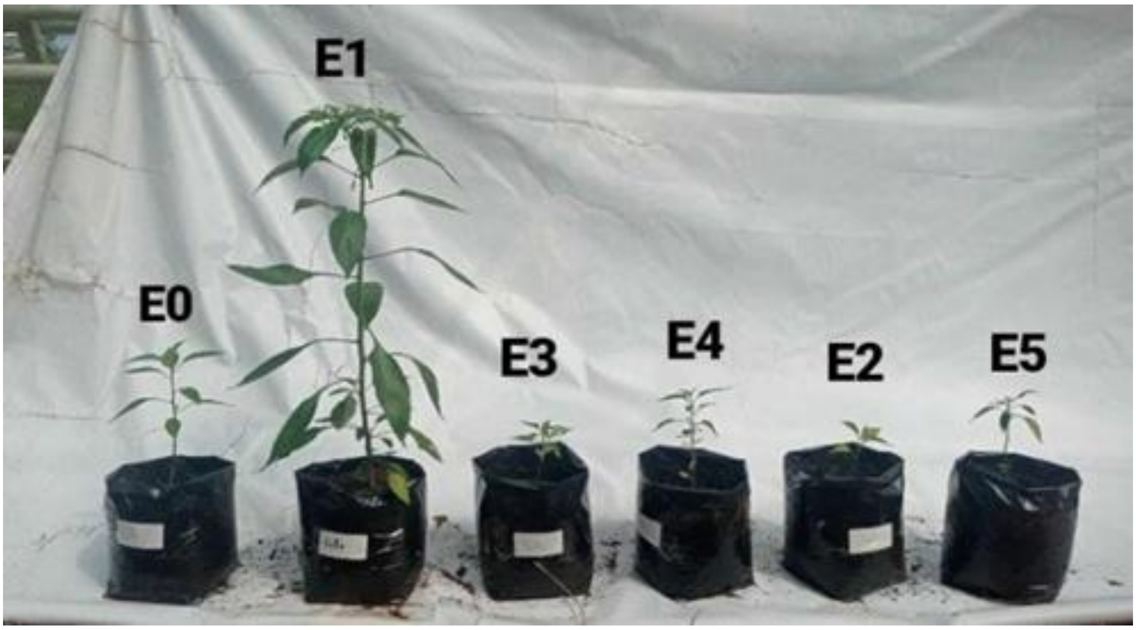

Fig. 1. Difference in height of curly chili plants at the end of treatment

Treatment E1 showed a larger stem diameter (0.66 cm) than the other treatments. The importance of K in increasing stem diameter is related to the function of K, namely to increase sclerenchyma levels in the stem (Silahooy, 2008). Sclerenchyma has a giving function thickening and strength of the stem tissue so that the plant is stronger or does not collapse easily. By adding fertilizer with the right nutrients, the K element increases and sclerenchyma increases. The addition of sclerenchyma causes the stem diameter to also increase. Plant growth is correlated with the addition of K concentration in the stem enlargement area (Rahmianna & Bel, 2001). If a plant lacks K in an area, cell enlargement and elongation is hampered, which will affect the growth of the plant's stem diameter.

Plant height and number of leaves in treatments E2 and E3 were not significantly different, while stem diameter, leaf length and leaf width were different but not significant. This shows that the difference in ecoenzyme concentration does not affect the vegetative growth of curly chili plants, because the nutrient content at ecoenzyme concentrations of 1ml/liter of water and 5ml/liter of water is not optimal enough to fulfill vegetative growth. Hasanah's research (2021) shows that the ecoenzyme contains 0.90% organic C, 0.09% N, 0.01% P and 0.12% K. The N element in the ecoenzyme is smaller than in manure (0.6%). Low N levels in ecoenzymes cause plant height, leaf development and stem diameter to develop less well compared to the use of manure. The difference in element content in manure and ecoenzymes can affect plant growth.

The number of leaves from treatments E3 and E4 at 7 WAP showed the same number (12 pieces) (Table 1). In both treatments, plants have the same ability to absorb nutrients, for example Nitrogen. Lestari's research (2016) shows that almost the same number of leaves is related to photosynthetic ability. Hanafiah (2012) stated that Nitrogen plays a role in vegetative growth such as leaf and shoot growth because Nitrogen is a constituent of amino acids, chlorophyll, growth hormones such as auxin and cytokinin.

The E4 treatment showed higher results compared to other EE treatments (E2, E3 and E5), which shows that the concentration EE 1% is the optimal concentration for vegetative growth of curly chili plants. Based on Table 1 for the parameters of plant height, stem diameter, leaf length and leaf width, the results show no significant difference. Also for the parameters of number of leaves, length and root volume are not significantly different. The E4 treatment showed the highest number of leaves, namely 12 compared to the other EE treatments (E2 and E5). This is because there is an optimal N element to accelerate the photosynthesis process so that the formation of leaf organs becomes faster and an increase in the number of leaves will also result in an increase in the overall length and width of the leaves. Based on Table 1, it can also be seen that the E4 treatment has the highest leaf length (6.68 cm) and leaf width (1.88 cm) compared to other EE treatments. This means that the plant's ability to carry out photosynthesis increases, so that the available photosynthesis yield (photosynthate) will also increase and be allocated to other parts of the plant. The abundance of N also encourages rapid growth including the development of leaves, larger and dark green stems and encourages vegetative growth (Foth et al., 1998).

The E4 treatment showed a higher root volume (38 ml) than the E5 treatment (24 ml). This happens because the N element at this concentration is optimal for root development, thus increasing the volume. The N nutrient contained in EE can be absorbed well by plants because the N elemenquid organic material can reduce the C:N ratio in the soil, so that the N nutrient becomes more easily mobilized. The low root volume in treatment E5 was caused by a lack of nutrient availability in the soil and nutrient uptake was hampered because the medium did not support plant roots to develop properly in the soil. This is in accordance with Sarief (1986) statement that the N element absorbed by plants plays a role in supporting the vegetative growth of plants such as roots. Benyamin & Maruapey (2015) stated that N plays a role in accelerating the conversion of carbohydrates into protein which affects the division, elongation and enlargement of plant roots.

The highest ecoenzyme treatment (E5) at 7 WAP showed the lowest number of leaves (8 pieces), while E1 produced the highest number of leaves (40 pieces). This is because the N content in manure can fulfill the plant's need to form leaves, whereas the high concentration of ecoenzymes in the E5 treatment does not ensure that the N element is met, on the contrary it causes the leaves to fall off more quickly (abscission). Abscission is caused by several factors including water, nutrients and hormones in plants. According to Salisburry

& Ross (1995), cells that experience a lack of water, nutrients, enzymes or hormones will have their metabolic processes hampered so that the cells will experience damage. If the leaf tissue is damaged, the leaves die and will fall. Nutrient elements that influence leaf shedding include N, P, K, Ca, Mg and Molybdenum (Mo). If cell metabolism does not work, the tissue will die (necrosis), the leaves will dry out and eventually the leaves will fall. The element N is also a component of the hormones auxin, cytokinin, ethylene, gibberellin and abscisic acid (ABA). Hormones that play a role in leaf shedding include auxin, ethylene, and abscisic acid (ABA).

Plant height at E4 (16.4 cm) is more optimal than at EE5 (14.5 cm). This shows that the higher the ecoenzyme concentration is not directly proportional to the increase in plant height. Based on these results, an ecoenzyme concentration of 15 ml/liter of water can inhibit growth. It is suspected that increasing EE concentrations could be toxic to the growth of curly chilies because they have a soil pH of 6.3. The low pH value is caused by the high content of organic acids in the ecoenzyme. Basically, soil conditions that are too acidic can affect or inhibit the growth of a plant and make it worse. This is in accordance with research by Kidd & Proctor (2001) that plants do not grow optimally if the soil is too acidic.

Research by Hafner et al. (1993) that food crops planted in acidic soil cause P element adsorption and a decrease in its availability as the main factor in plant growth. This research is in line with Foy (1992) that in soil with an excess of H+ ions, plants will compete with other cations for root absorption sites, disrupting the transport and absorption of ions. Low soil pH can also affect the rate of root elongation (RER) or root growth rate and cause structural changes in the root system which ultimately can reduce the plant's ability to absorb water and nutrients (Gunse et al. 1997). Sopandie's research (2014) shows that the impact of acidic soil, such as the impact of drought, means that nutrients and nutrients in the soil become reduced or almost non-existent, which can cause plants to grow stunted and even die. Acidic soil is not good when used for growing plants because it can inhibit growth. Disturbances in plant growth and development in acidic conditions are caused by a decrease in the soil's osmotic solution potential so that the availability of water for plants is reduced, increased concentrations of ions that are toxic to plants and can trigger an imbalance in nutrient metabolism, changes in the chemical and physical structure of the soil.

3.2 Generative growth

The results of observations of generative growth in this study focused on the timing and number of flowers on curly chili plants. The results showed E1 treatment produced flowers (5.6 flowers) earlier two weeks than E4 treatment (0.6 flowers). The average increase in flower appearance on *Capsicum annuum* is presented in Table 2.

Table 2. Average number of flowers of curly chili in 6 treatments

Treatment	Average number of flower in the week after planting			
	6	7	8	9
EE0	0	0	0.60	1.60
EE1	5.60	12.80	16.60	27.20
EE2	0	0	0	0
EE3	0	0	0	0
EE4	0	0	0	1.8
EE5	0	0	0	0

At treatment E1 (Table 2), flowers appeared at week six. This happens because the vegetative growth process has been completed and continues with generative growth. The high number of flowers in treatment E1 (5.60) was also influenced by the number of plant branches. The more branches that appear, the more flowers will be produced. Flowers grow at the tips of the branches (Tjitrosoepomo, 2001). The number of flower buds on a plant is in line to meet the needs of the nutrient content in the plant's environment. One of the main nutrient content for flower growth is element P. The element P content in EE is only 0.01% (Salsabila and Winarsih, 2023). This is in accordance with research by Novizan (2002) that the element P influences the growth and development of plants, and P is found in all living plant cells which function to form nucleic acids, stimulate cell defense and help the assimilation and respiration processes. Previous research conducted by Lingga (2007) stated that P element as a basic ingredient for the formation of certain amounts of fat and accelerates flowering and ripening of seeds or fruit.

Treatment of E1 showed branch growth, while the other treatments in this study did not show any branch growth. Whereas plants that are only given EE and the water, then the nutrients obtained are focused on stem elongation. If a plant tends to experience stem growth, the plant will be tall but the branch growth will be less (Hidayati, 2014).

The EE treatment (E4) at week 9 showed the appearance of flowers (1.8 flowers), whereas the other EE treatments (E2, E3 and E5) did not show the appearance of flowers. This shows that the plant can only continue growth from vegetative to generative at the age of week 9 and an E4 is the optimal concentration for ecoenzymes to fulfill the nutrients needed for flower growth. This is in accordance with research by Darjanto & Satifah (1990) that the transition from the vegetative to the generative phase is partly determined by the genotype and external factors such as temperature, water, fertilizer and light. Further research by Evita (2009) shows that by fulfilling the elements needed by plants and being supported by good environmental conditions, photosynthesis results will increase so that they can be used to form flowers in the generative phase.

Treatments E0, E2, E3 and E5 did not show any flower appearance during the planting period until week 9. This happens because plants that are only given water do not meet the nutritional requirements and giving ecoenzymes that are too low or too high does not mbasic ingredient for the formation of certain fats and accelerates flowering and ripening of seeds or fruit. Research by Kamis (2015) shows that the P element plays a very important role in increasing the production of chili plants, because the P element plays a role in stimulating and accelerating the percentage of flower formation.

4. Conclusions

This study concluded that among the EE treatments, EE treatment with a concentration of 1% showed an optimal concentration compared to other ecoenzymes. This condition is shown in the vegetative growth parameters (plant height, number of leaves, stem diameter, leaf length, leaf width, and root volume). In addition, generative growth (flower emergence time and number of flowers) also showed the same thing, namely EE treatment with a concentration of 1% showed an optimal concentration compared to other ecoenzymes.

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Author Contribution

H.S.K., K., and S.S.S. conceived the study, carried out all research activities, analyzed the data, wrote the manuscript, and were responsible for the final content. The authors approved the final version and agreed to be accountable for all aspects of the work.

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