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Application of Ecoenzymes from Various Fruit Peels on the Growth and Yield of Tomato Plants (*Solanum lycopersicum* L.)

Niken Ledi Andra[1], Zuyasna[2], Bakhtiar[3]
[123]Departemen Agroteknologi Fakultas Pertanian Universitas Syiah Kuala, Banda Aceh, Indonesia
Corresponding Author: zuyasna@usk.ac.id

Abstract:
Background. Tomato production is unreliable due to declining soil fertility. Ecoenzymes, made from fruit peels, are a sustainable agricultural alternative to reduce chemical overuse. This research was conducted at Experimental Garden 1, Faculty of Agriculture, Syiah Kuala University, Darussalam, Banda Aceh, from 1 June 2025 to 24 April 2026.
Aims. The present study was conducted to investigate the effect of applying an ecoenzyme prepared from a mixture of fruit peels on tomato plant growth and yield.
Methods. The experiment was laid out in a non-factorial randomized block design with 7 treatments and 3 replications, giving 21 experimental plots. The experimental unit consisted of 4 plants. There were 84 experimental tomato units.
Result. The ecoenzymes from different fruit peels had a highly significant effect on the stem diameter at 15 DAP and had no significant effect on the plant height at 15, 30, and 45 DAP, stem diameter at 30 and 45 DAP, number of productive branches at 50 DAP, flowering age, number of fruits per plant, fruit weight per plant, fruit diameter, and length of fruit.
Conclusion. The best number of productive branches was obtained by application of 10 mL-1 of E3, whereas the best number of fruits per plant, fruit weight per plant and fruit length were obtained by E2.

Key Words: fruit skin, organic fertilizer, tomatoes

INTRODUCTION

Tomatoes (Solanum lycopersicum L.) are a prominent horticultural product of considerable economic importance in Indonesia. Tomatoes are a category of fruit vegetables with significant potential for agribusiness advancement owing to their substantial economic and nutritional worth (Wales et al., 2023). Each 100 g of tomatoes comprises 3.6 g of carbohydrates, 1 g of protein, 0.2 g of fat, 10 g of calcium, 0.6 g of iron, 10 g of magnesium, 16 g of phosphate, 94 g of water, 1700 IU of vitamin A, 0.1 g of vitamin B1 (thiamine), 0.02

g of vitamin B2 (riboflavin), 21 g of vitamin C, and 0.6 g of niacin (Daroini et al., 2024). The market demand for fresh and processed tomatoes is steadily rising annually, prompting farmers to plant tomatoes efficiently to attain high yields (Agustina et al., 2025).

The Central Statistics Agency (2026) reported that tomato production in Aceh Province was 11,706 tons in 2021, declining to 8,846 tons in 2022. In 2023, tomato production in Aceh rose to 14,431 tons. Nonetheless, it diminished to 10,943 tons in 2024 and further to 10,211 tons in 2025. Assadiyah et al. (2023) assert that the unpredictability of tomato production is attributable to a deterioration in agricultural land quality, leading to diminished soil fertility. This impacts the soil's physical characteristics, encompassing diminished organic matter concentration, vitamin depletion, and reduced microbial activity. The efficacy of tomato cultivation is determined by variables like cultivar, arable area, and fertilizer application. The provision of vital nutrients in appropriate proportions by fertilization is crucial for enhancing tomato yield. (Afifah, 2025). Farmers typically depend on inorganic fertilizers to enhance tomato yield, despite the detrimental impact on the soil's physicochemical characteristics (Shirin et al., 2023). The persistent use of inorganic fertilizers, absent the incorporation of organic fertilizers, can deteriorate soil quality in physical, chemical, and biological aspects. The deterioration of soil quality can impact soil fertility (Nurnawati et al., 2022).

Organic fertilizer is derived from natural sources, such as plant residues, animal waste, and other organic materials. Organic fertilizers augment soil fertility, promote soil structure, and gradually provide nutrients to plants (Rachmadtullah et al., 2024). Organic fertilizers markedly augment agricultural productivity for both quality and quantity, reduce environmental pollution, and sustainably promote soil health. Organic fertilizers provide various advantages, such as the supply and replenishment of organic matter in the soil, accessibility and affordability, increased farmer autonomy by reducing reliance on chemical fertilizers, cost-effectiveness, and environmental sustainability (Siregar et al., 2024).

The application of agricultural techniques employing ecoenzymes seeks to advance sustainable agriculture and provide an alternative to excessive dependence on fertilizers and chemicals (Wulan et al., 2024). Ecoenzymes are fermented solutions consisting of intricate organic compounds derived from organic waste, such as vegetables and fruits, amalgamated with a blend of sugar and water. Fermentation produces a dark brown liquid rich in beneficial compounds, suitable for various domestic and agricultural applications (Aditya et al., 2024). Ecoenzymes function as organic fertilizers owing to their enzymatic composition, which includes trypsin and amylase, alongside organic acids like acetic acid (H3COOH). Moreover, ecoenzymes comprise several plant nutrients and minerals, such as nitrogen, phosphorus, and potassium, in addition to bacteria that decompose organic matter, facilitate growth, and act as agents for pest and plant disease management (Swari et al., 2025).

Sinaga et al. (2023) indicate that the analysis of macronutrient concentrations in ecoenzymes sourced from dragon fruit, orange, papaya, mango, and banana peels shows carbon, nitrogen, phosphorus, and potassium levels of 5.62%, 0.17%, 0.01%, and 0.44%, respectively. Dondo et al. (2023) found that the utilization of various ecoenzyme base materials, such as pineapple peels, banana peels, soursop peels, papaya peels, and a mixture of four types of fruit peel waste, at a consistent concentration of 3% or 30 ml L-1, markedly affected the leaf count of lettuce plants. A study by Salsabila and Winarsih (2023) demonstrated that the use of ecoenzymes from orange and pineapple peels as liquid organic fertilizers at a concentration of 10 ml L-1 significantly impacted the growth of pak choy mustard plants, influencing parameters such as plant height, leaf count, wet biomass, and root length. Halimah (2025) indicated that a 1:1 mix of soil and manure, along with an ecoenzyme dosage of 20 ml L-1, markedly affected the height of eggplant plants.

Ecoenzymes obtained from fruit peels may offer organic nutrients for plants; yet, the impact of various ecoenzyme formulations on the growth and yield of tomato plants remains inadequately investigated. Investigation is required to assess the effects of diverse ecoenzyme formulations sourced from the peels of papaya, orange, dragon fruit, banana, mango, pineapple, watermelon, and melon on the growth and yield of tomato plants.

METHOD

Place and Time

This research was conducted at Experimental Garden 1 (5º32'09"N 95º22'15"E), located at an altitude of 4 meters above sea level, and at the Horticulture Laboratory, Faculty of Agriculture, Syiah Kuala University, Darussalam, Banda Aceh. This research was conducted from June 1, 2025, to April 24, 2026.

Tools and materials

This study employed hoes, digital scales, watering cans, 26-liter buckets, Vernier calipers, tape measures, scissors, a pH meter, a 1-liter measuring cup, a hand sprayer, a sieve, a camera, and stationery. This study employed 300 Servo F1 tomato seeds and 8 organic ecoenzymes, consisting of 113 g each from papaya, orange, dragon fruit, banana, mango, pineapple, watermelon, and melon peels, 300 g each from brown sugar, and 3 L of water. Additionally, it included 7 organic materials ecoenzymes (129 g each from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels, 300 g each from brown sugar, and 3 L of water), alluvial soil, cow manure, rice husk charcoal, 126 g of NPK fertilizer, 150 cm wooden stakes, raffia rope, label paper, 300 sheets of 12 cm x 12 cm polybags, 147 sheets of 35 cm x 40 cm polybags, insecticides containing Lambda Cyhalothrin and Thiametoxam, and a fungicide with Difenoconazole as the active ingredient.

Research Design

This study utilized a non-factorial Randomized Block Design (RBD) including 7 treatments and 3 replications, yielding a total of 21 experimental units. Each experimental unit consisted of four plants, resulting in a total of 84 tomato experimental units. The data underwent additional analysis using ANOVA. Following the analysis of variance revealing a substantial treatment effect at the 5% level, the Duncan New Multiple Range Test (DNMRT) was utilized.

Research Implementation

Ecoenzyme Production

Ecoenzyme synthesis was conducted with three compositions of organic materials. Ecoenzyme 8 has 113 g each of eight organic materials: pineapple peel, melon, mango, orange, papaya, dragon fruit, banana, and watermelon. An ecoenzyme was developed utilizing seven organic elements in varying compositions: one formulation included watermelon peel excluding melon peel, while the other comprised melon peel excluding watermelon peel, with each formulation totaling 129 grams. All items were meticulously diced, and each organic component was deposited into a 5 L container. Subsequently, a 300 g brown sugar solution was incorporated into 500 ml of water, followed by the addition of 2,500 ml of water to each ecoenzyme container. Fermentation transpired throughout a three-month duration, from June 1 to September 1, 2025. The bottle cap was opened daily for the first 10 days to release the fermentation gas. Following a three-month period, the ecoenzyme was filtered to separate the ecoenzyme liquid from the fruit peel pulp. An effective ecoenzyme is characterized by a dark brown color and a strong, sweet-and-sour aroma typical of fermentation. The pH of each ecoenzyme was later evaluated using a pH meter. Ecoenzyme 8, produced from organic materials (papaya, orange, dragon fruit, banana, mango, pineapple, watermelon, and melon peels), demonstrated a pH value of 2.80. Ecoenzyme 7, composed of organic materials (papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels), exhibited a pH value of 2.79. Furthermore, ecoenzyme 7, composed of organic materials (papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels), exhibited a pH value of 2.77.

Research Site Preparation

The site designated for tomato cultivation was initially cleansed of weeds to avert their role as hosts for pests and illnesses that could threaten the tomato plants.

Seed Sowing

The tomato seeds employed in this study were of the Servo F1 variety. The seeds were soaked in water for 1 to 2 hours before planting. Tomato seeds were sown in a seedling medium consisting of alluvial soil, cow dung, and rice husk charcoal in a 1:1:1 ratio, housed in 12 cm × 12 cm polybags. One seed was planted in each polybag at a depth of 0.5 cm. The seedling phase lasted 21 days from sowing to transplanting.

Preparation of Planting Media

The planting medium comprised soil, cow manure, and rice husk charcoal in a 1:1:1 ratio. The soil utilized was alluvial, fine-textured, dark-hued, and comparatively rich in organic matter, sourced from Indrapuri District, Aceh Besar Regency. Prior to use, the alluvial soil and bovine dung were pulverized and extricated from small stones and extraneous materials, including soil, plant detritus, and weeds. The planting medium was thereafter placed in a polybag of 35 cm x 40 cm until it attained a height of 35 cm, and the polybags were organized in accordance with the experimental layout in the research area.

Planting

Establishing the seedlings necessitates excavating a planting hole 5–10 cm in depth. Seedlings are prepared for planting when they possess five leaves and exhibit robust growth. The polybags are severed prior to the insertion of the seedlings into the planting hole. Each planting hole is populated with a single seedling, thereafter enveloped with soil up to the root collar (base of the stem) around the polybag. Subsequently, the planted seedlings are irrigated with a watering can. Transplanting occurs in the afternoon to mitigate heat stress on the seedlings.

Fertilization

The advised fertilizer application for tomato plants is 243 kg per hectare (6 grams per plant) of NPK fertilizer. Fertilization was administered solely to the control plants (E0) by distributing the fertilizer in a circular pattern around the root zone. NPK fertilizer was administered thrice: 3 g at the onset of planting, 1.5 g at the flowering phase, and 1.5 g at the fruiting phase.

Application of Ecoenzyme

Ecoenzyme was administered to tomato plants weekly, with 200 cc of the solution injected per polybag in the afternoon to mitigate excessive evaporation. Moreover, certain bacteria engaged in breakdown and nutrient absorption exhibit heightened activity at lower temperatures. The pH of the ecoenzyme was assessed using a pH meter at intervals of 7, 14, 21, 28, 35, 42, 49, and 56 days post-planting. The treatments employed included a control (E0) of 0 ml L^{-1}, 8 organic materials (E1) at 10 ml L^{-1}, 7 organic materials (E2) at 10 ml L^{-1}, 7 organic materials (E3) at 10 ml L^{-1}, 8 organic materials (E4) at 30 ml L^{-1}, 7 organic materials (E5) at 30 ml L^{-1}, and 7 organic materials (E6) at 30 ml L^{-1}. A 10 ml dose of ecoenzyme was administered with the addition of 990 ml of water, whereas a 30 ml dose was administered with 970 ml of water.

Maintenance

Plant maintenance encompasses irrigation, transplantation, weeding, stake installation, pruning of water shoots, and pest and disease management.

Harvesting

Tomato plants are harvested 60 days after planting, determined by parameters of vivid red hue, ideal size, and tactile hardness. Harvesting is executed by carefully separating the fruit from the stem to reduce damage and extend its shelf life. Harvesting transpires eight times at three-day intervals.

Observation Variables

The observed variables comprised plant height at 15, 30, and 45 hours since transplanting (HST), stem diameter at 15, 30, and 45 HST, number of productive branches per plant at 50 HST, flowering age, number of fruits per plant, fruit weight per plant, fruit diameter, and fruit length.

DISCUSSION

Plant Height

The variance analysis indicated that ecoenzymes derived from different fruit peels did not significantly influence plant height at 15, 30, and 45 days post-planting. Table 1 presents the average plant height at 15, 30, and 45 days post-planting, subsequent to ecoenzyme treatment with different fruit peels.

Table 1. Average plant height due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Plant Height (cm)		
		15 DAP	30 DAP	45 DAP
E_0	Control (without ecoenzyme)	55,73	106,29	131,47
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	50,99	108,28	127,63
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	53,57	109,96	129,44
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	49,88	110,97	131,62
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	48,70	107,83	130,59
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	49,21	107,91	126,57
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	48,89	108,46	130,17

Table 1 indicates that the average plant height at 15 days post-planting is greatest in the E0 (control) treatment, measuring 55.73 cm, but it is not statistically distinct from the other treatments. The mean plant height at 30 and 45 days post-planting is greater in the E3 treatment (ecoenzyme peels of papaya, orange, dragon fruit, banana, mango, pineapple, and melon at a concentration of 10 ml L-1), measuring 110.97 cm and 131.62 cm, respectively, although this difference is not statistically significant compared to the other treatments. This phenomenon is attributed to the ecoenzyme treatment, which facilitates the slow release of nutrients. The study's results indicated that the use of ecoenzymes derived from different fruit peels had no impact on the height of tomato plants.

The utilization of ecoenzyme as the exclusive fertilizer necessitates a greater concentration compared to its application in conjunction with other fertilizers (Wulan et al., 2024). A higher concentration of ecoenzyme results in increased nitrogen availability, which can influence plant growth and yield (Salsabila & Winarsih, 2023). Ardiansyah (2025) asserts that the use of liquid organic fertilizer in minimal quantities leads to suboptimal plant height due to inadequate nitrogen for vegetative growth. Plants predominantly employ nitrogen for shoot development rather than root formation, so nitrogen significantly influences plant height. Fadilah et al. (2025) reported that the application of an ecoenzyme derived from papaya, mango, cucumber, jicama, kedondong, and pineapple peels did not significantly influence the height of lettuce plants; nonetheless, it exhibited the greatest average value across all observation phases descriptively.

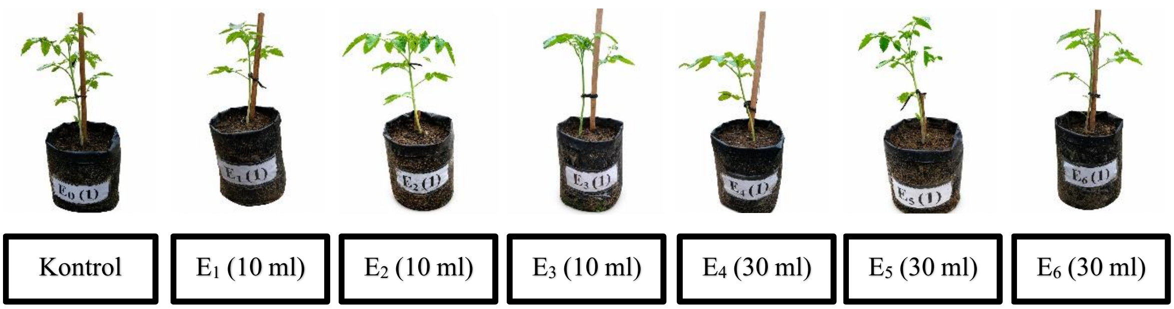

Figure 1. Height of tomato plants at 15 days after planting due to the ecoenzyme treatment of various fruit skins

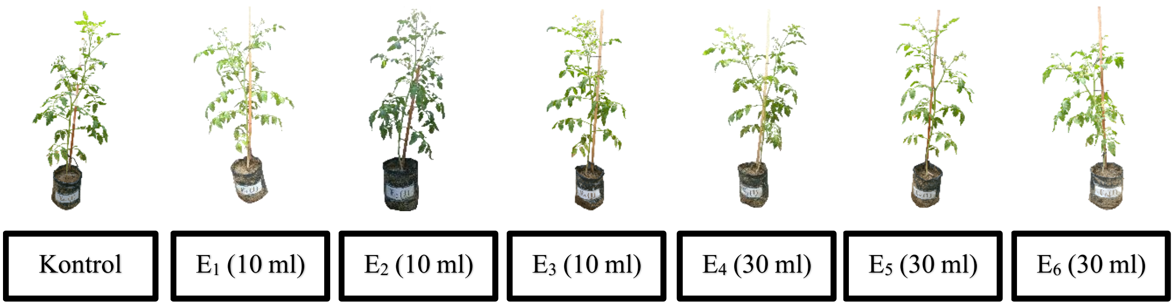

Figure 2. Height of tomato plants at 45 days after planting due to ecoenzyme treatment of various fruit skins

Stem Diameter

The analysis of variance revealed that ecoenzymes derived from different fruit peels significantly influenced stem diameter at 15 days post-planting, but had no significant impact at 30 and 45 days post-planting. Table 2 presents the mean plant height at 15, 30, and 45 days post-planting, subsequent to ecoenzyme treatment with different fruit peels.

Table 2. Average stem diameter due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Stem Diameter (mm)		
		15 DAP	30 DAP	45 DAP
E_0	Control (without ecoenzyme)	7,96 b	9,37	10,58
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	6,98 a	8,00	10,32
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	7,16 a	9,11	10,54
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	6,69 a	8,86	10,05
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	6,79 a	8,89	10,26
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	6,97 a	9,06	10,15
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	6,74 a	8,91	10,50

Note: Numbers followed by the same letter in similar columns are not significantly different at the 5% level (DNMRT test 0.05)

Table 2 shows that the average stem diameter at 15 days after planting is larger in the E0 (control) treatment (7.96 mm) and differs significantly from the other treatments. The same letter notation in the results indicates that the ecoenzyme treatment did not significantly increase stem diameter. This is suspected because the effect of the ecoenzyme treatment tends to be slower than that of the control treatment or when NPK fertilizer is applied without ecoenzyme. According to Adien et al. (2024), the appropriate NPK fertilizer dose can significantly increase stem enlargement, especially during the active vegetative phase.

Meanwhile, Pangalila et al. (2023) stated that nutrients from liquid organic fertilizer are not directly absorbed by plants for stem diameter growth. At the beginning of planting, nutrients will be directed towards plant height growth, while during the final vegetative phase, nutrients will be absorbed for stem diameter growth.

The mean stem diameter at 30 and 45 days post-planting was greater in the E0 (control) treatment, measuring 9.37 mm and 10.58 mm, respectively, however the differences were not statistically significant when compared to the other treatments. Ramli (2022) asserts that this phenomenon is attributable to the impact of liquid organic fertilizer that has not completely decomposed, hence hindering the direct utilization of its nutrients by the plant due to the ongoing decomposition process. Sundari et al. (2023) indicated that tomato plants necessitate nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), within a limited timeframe to facilitate vegetative growth, including the development of roots, stems, and leaves; thus, these elements must be consistently present in the soil.

Number of Productive Branches of Plantations

The analysis of variance indicated that ecoenzymes derived from different fruit peels exerted no significant influence on the quantity of productive branches per plant. Table 3 displays the average quantity of productive branches per plant resulting from ecoenzyme treatment with different fruit peels.

Table 3 indicates that the mean number of productive branches per plant was greater in the E3 treatment (ecoenzyme for papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels at a concentration of 10 ml/L), at 3.08 branches, although this difference was not statistically significant relative to the other treatments. Sembiring et al. (2021) asserted that the application of ecoenzyme at a concentration of 1% can promote the growth of plant branches due to the nutrients and phytohormones present in the ecoenzyme. This finding aligns with Listiana et al. (2024), who indicated that the application of 10 mL/L of ecoenzyme can enhance plant development. This conclusion is corroborated by Al-afif and Damaiyanti (2023), who asserted that the ecoenzyme content resulting from the decomposition of vegetables and fruits can generate nitrogen, hence augmenting the population of organisms and microbes in the soil.

Table 3. Average number of productive branches due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Number of Productive Branches
E_0	Control (without ecoenzyme)	2,83
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	2,75
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	2,75
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	3,08
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	2,83
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	2,83
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	2,75

Nurfadilah et al. (2024) asserted that the nitrogen in ecoenzyme can synthesize amino acids essential for plants to generate new stems and shoots. Ecoenzymes encompass protease enzymes that facilitate nitrogen mineralization, hence affecting the availability of nitrogen for plant development. Pasaribu and Idris (2025) assert that nitrogen is integral to chlorophyll synthesis, hence augmenting the quantity of chlorophyll that absorbs sunlight for photosynthesis. Thus, if the nitrogen concentration in ecoenzymes is enough, the plant's photosynthesis will enhance, resulting in increased food production and the development of vegetative structures such as leaves and branches.

Flowering Age

Table 4 indicates that the average flowering time was generally more rapid in the E0 (control) and E2 treatments (ecoenzymes derived from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels at a concentration of 10 ml L-1), at 19.00 days; however, the statistical difference was not significant in comparison to the other treatments. This is probably due to the ecoenzymes being sourced from organic materials, including papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels, which undergo fermentation to yield organic acids. The presence of organic acids renders the ecoenzymes acidic. Jia et al. (2024) assert that extremely low pH diminishes nutritional availability to plants, disrupts plant growth, impedes soil microbes and root development, obstructs proper nutrient absorption, and consequently hinders flower formation.

Table 4. Average flowering age due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Flowering age (day)
E_0	Control (without ecoenzyme)	19,00
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	19,83
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	19,00
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	19,08
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	19,17
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	20,00
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	19,25

Conversely, ecoenzyme treatments obtained from diverse fruit peels have demonstrated an enhancement in tomato blooming relative to the Servo F1 variety. Rasyid and Sitawati (2024) assert that the nitrogen and phosphorus elements found in ecoenzymes will expedite floral appearance in plants. Moreover, the nutritional and energy composition in ecoenzymes can stimulate the hormones auxin, cytokinin, and gibberellin, so expediting cell division. According to Al-afif and Damaiyanti (2023), the hormones auxin, cytokinin, and gibberellin can expedite cell division, resulting in the initial emergence of flowers at a concentration of 10 ml L-1 ecoenzyme.

Number of Fruits Per Plant

The variance analysis indicated that ecoenzymes derived from different fruit peels did not significantly influence the fruit yield per plant. Table 5 displays the average quantity of fruits per plant resulting from ecoenzyme treatments applied to different fruit peels. Table 5 indicates that the quantity of fruits per plant was generally greater in treatment E2 (ecoenzymes derived from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels at a concentration of 10 ml L-1), with a mean of 15.75; however, this difference was not statistically significant compared to the other treatments. This is likely due to ecoenzymes supplying essential elements that are crucial for fruit production, yet are insufficiently sized to fulfill the plant's nutritional requirements during the generative phase. Consequently, the utilization of ecoenzymes derived from diverse fruit peels did not markedly influence the fruit yield per plant. Suryawati et al. (2024) assert that the rate of photosynthesis governs fruit production, which is regulated by the availability of nutrients and water.

Table 5. Average number of fruits per plant due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Number of Fruits (fruits)
E_0	Control (without ecoenzyme)	14,58
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	14,83
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	15,75
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	14,00
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	15,00
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	11,83
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	14,17

Deningsih (2025) asserted that potassium enhances photosynthesis and sugar transfer, both essential for fruit development. Phosphorus facilitates floral development and growth, and contributes to seed maturation and fruit production. Surtikanti et al. (2024) indicated that the low pH of ecoenzymes results from their elevated organic acid content, which acidifies the soil and influences the availability of phosphorus, a critical determinant for plant growth.

Optimal photosynthesis facilitates robust plant growth by enhancing the absorption rate. The assimilation is subsequently allocated to the crop area, leading to enhanced tomato yield. An abundance of leaves can enhance the photosynthetic rate, which is essential for growth. Photosynthates generated by photosynthesis are utilized by plants for growth and, during the reproductive phase, are directed towards fruit development, enhancing both the quantity and mass of the fruit (Sari & Lusmaniar, 2023).

Fruit Weight Per Plant

The analysis of variance revealed that ecoenzymes derived from different fruit peels had no significant effect on fruit weight per plant. Table 6 presents the average fruit weight per plant for ecoenzyme treatments of different fruit peels.

Table 6. Average fruit weight per crop due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Fruit Weight (g)
E_0	Control (without ecoenzyme)	484,63
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	440,63
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	500,61
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	442,32
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	477,16
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	403,12
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	457,45

Table 6 indicates that the fruit weight per plant was generally greater in treatment E2 (ecoenzymes derived from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels at a concentration of 10 ml L-1), measuring 500.61 g; however, this difference was not statistically significant compared to the other treatments. This is likely due to the balanced availability of nutrients, namely phosphorus and potassium, which satisfied tomato plants' requirements for fruit development, resulting in fruit weights that were not significantly different from those in the control treatment or the treatment without ecoenzymes. The weight of fruit per plant correlates with the quantity of fruits per plant; an increased number of fruits per plant leads to a rise in fruit weight.

This corresponds with Ernawati's (2022) assertion that fruit size and quality are affected by the availability of phosphorus (P) and potassium (K). Phosphorus (P) is essential for blooming and fruit development, whereas potassium (K) facilitates carbohydrate synthesis and the transfer of photosynthates, enhancing fruit quality and weight. Viégas (2025) asserts that sufficient phosphorus (P) availability can enhance metabolism and photosynthesis, leading to greater assimilate production for translocation to food stores and ultimately increasing fruit weight.

In addition to available nutrients, the mass of tomato fruit is influenced by environmental factors such as sunlight, temperature, and humidity. Sunlight is crucial for photosynthesis and significantly influences the production of proteins and carbohydrates during fruit development (Kesmayanti et al., 2025). Soekamto (2026) posits that mineral elements utilized in plant metabolism cannot function independently; they depend on the plant's internal and external environment.

Fruit Diameter

The analysis of variance indicated that the ecoenzymes derived from different fruit peels exerted no significant influence on fruit diameter. Table 7 presents the mean fruit diameter following ecoenzyme treatment of several fruit peels.

Table 7. Average fruit diameter due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Fruit Diameter (mm)
E_0	Control (without ecoenzyme)	39,26
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	37,59
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	39,15
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	38,56
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	38,90
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	38,17
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	38,92

Table 7 indicates that the fruit diameter was greater in the E0 (control) treatment, measuring 39.26 mm, however the difference was not statistically significant when compared to the other treatments. The diameters of the tomato fruits in this investigation varied from 3.75 to 3.92 cm, but the Servo F1 variety exhibited dimensions ranging from 4.82 to 5.13 cm. Al-Farisi et al. (2023) indicate that ecoenzymes derived from fermented organic waste possess elevated concentrations of organic acids, including acetic acid, citric acid, and lactic acid, along with various micro-decomposers; however, they lack the macronutrients essential for promoting fruit diameter growth. Phosphorus (P) facilitates metabolic processes, including the synthesis of proteins and carbohydrates, which function as energy sources. Moreover, phosphorus (P) can enhance root development, allowing plants to assimilate additional nutrients to augment fruit diameter. The size and quality of fruit are affected by potassium (K) availability, whereas phosphorus (P) contributes to flower and fruit development (Putra & Maizar, 2023).

This aligns with Tanari et al. (2023), who asserted that soil nutrient availability is a contributing factor to fruit production and size in plants. Crop yields will be suboptimal if nutritional requirements are unmet, particularly during the plant's reproductive phase. Lestari et al. (2025) asserted that fruit diameter is controlled by various factors, including genetics and environmental conditions. The genetic potential of each tomato variety or line will differ in terms of fruit size and shape, especially fruit diameter.

Fruit Length

The variance analysis indicated that the ecoenzymes derived from fruit peels exerted no significant influence on fruit length. Table 8 displays the average fruit length resulting from the ecoenzyme treatment of various fruit peels.

Table 8. Average fruit length due to the ecoenzyme treatment of various fruit skins

Code	Treatment	Fruit length (mm)
E_0	Control (without ecoenzyme)	42,43
E_1	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (10 ml L^{-1})	39,84
E_2	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (10 ml L^{-1})	43,25
E_3	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (10 ml L^{-1})	41,74
E_4	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, melon, and watermelon peels (30 ml L^{-1})	41,51
E_5	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels (30 ml L^{-1})	41,48
E_6	Ecoenzyme from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels (30 ml L^{-1})	40,38

Suryawati et al. (2024) assert that fruit length is determined by the plant's capacity to utilize assimilates generated by photosynthesis for fruit development. The quantity of assimilates is contingent upon various parameters, including the volume, type, and equilibrium of nutrients received by the plant, which are associated with nutrient availability in the soil. In the reproductive phase, the reproductive utilization zone significantly enhances its use of photosynthetic products, hence restricting the allocation of assimilates to the vegetative development zone. The resultant photosynthetic product, photosynthate, is translocated throughout the plant to facilitate tomato fruit elongation. Moreover, an insufficient and disproportionate application of liquid organic fertilizer may hinder plants from yielding fruit of appropriate size. Suryani and Utami (2025) assert that modifications and enhancements in optimal concentration require meticulous management. Overly concentrated ecoenzyme solutions can impede nutrient absorption by plant roots. The concentration of the solution impacts root absorption, as nutrient uptake is governed by osmosis and diffusion.

CONCLUSION

The utilization of ecoenzymes derived from diverse fruit peels did not significantly influence all variables, except for stem diameter at 15 hours after treatment, which had a highly significant effect. Ecoenzymes derived from papaya, orange, dragon fruit, banana, mango, pineapple, and melon peels at a concentration of 10 ml L-1 (E3) yielded the highest quantity of productive branches, while ecoenzymes from papaya, orange, dragon fruit, banana, mango, pineapple, and watermelon peels at the same concentration (E2) resulted in the optimal number of fruits per plant, fruit weight per plant, and fruit length. Ecoenzymes extracted from diverse fruit peels can serve as substitutes for inorganic fertilizers.

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