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Growth Response of Robusta Coffee Seedlings (*Coffea canephora* ex A. Froehner) to Inorganic Fertilizer and Golden Apple Snail Extract Applications

Sepdian Luri Asmono[1], Akhfin Putra Pratama[1], Rahmawati[2], Nisa Budi Arifiana[2]
[1]Coffee Plantation Management Study Program, Department of Agricultural Production, Politeknik Negeri Jember, Indonesia
[2]Plantation Crop Cultivation Study Program, Department of Agricultural Production, Politeknik Negeri Jember, Indonesia
Mastrip Street, Sumbersari, Kencong District, Jember Regency, East Java 68101, Indonesia.
*)Correspondence author: sepdian@polije.ac.id

Abstract

This study aims to determine the effect of the application of inorganic fertilizer types with golden apple snail extract on the growth of robusta coffee seedlings which was carried out at the Politeknik Negeri Jember Field from August 2023 to February 2024. The research method used was a Non-Factorial Randomized Block Design consisting of 4 treatment levels, namely P0 (control), P1 (Inorganic dose of 1g of Urea, 2g of TSP, 2g of KCl), P2 (golden apple snail extract application once every 4 weeks), and P3 (golden apple snail extract application once every 2 weeks Fertilization was carried out by pouring 200ml/polybag around the surface area of the coffee seedlings. The research data were analyzed using ANOVA with a further contrast test. The results of the 16 WAP (Weeks After Planting) study showed that the application of fertilizer types had a very significant effect on leaf chlorophyll content, leaf area, fresh weight, dry weight, and root length, but had no significant effect on seedling height and the number of leaf pairs. The use of fertilizer (P123) generally gave the best results on the parameters of leaf chlorophyll content, leaf area, fresh weight, dry weight, and root length of coffee seedlings. In the comparison of the application of golden snail extract, the application once every 2 weeks (P3) was effective in increasing dry weight. Meanwhile, the application of golden snail extract once every 4 weeks had the best value on the parameters of leaf area and fresh weight.

Keywords: *Extract, fertilization, golden apple snail, inorganic, robusta.*

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INTRODUCTION

Indonesia is known as one of the world's largest producers and exporters of coffee beans. In 2020, robusta coffee dominated Indonesian coffee production, accounting for 70.15%, while arabica coffee contributed 29.85%. This coffee production comes from 1.26 million hectares of plantations, of which 95.64% are managed by smallholder plantations (PR), while the remainder is managed by large state-owned plantations (PBN) at 2.07% and large private plantations (PBS) at 2.29% (BPS, 2020).

Robusta coffee is the most widely cultivated coffee variety in Indonesia, accounting for approximately 90% of the total coffee plantation area. One of Robusta's advantages is its greater resistance to leaf rust compared to Arabica coffee. Furthermore, Robusta coffee farmers report that this plant tends to be easier and less complicated to care for (Sakiroh *et al.*, 2021).

Factors contributing to Indonesia's low coffee productivity include relatively low technology, inadequate plant maintenance, poorly maintained shade trees, and inadequate fertilization, all resulting in low yields. Efforts are needed to address low coffee production by improving the quality of superior

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coffee seedlings to increase productivity. The nursery period is a crucial period in coffee plant growth, determining yield levels. Nutrient deficiencies can be addressed through fertilization. Fertilization for coffee plants is divided into two types: organic and inorganic. Organic fertilizers are made from compounds derived from plant and animal remains, while inorganic fertilizers are synthetic fertilizers produced through a synthetic process in the chemical industry (Herawati *et al.*, 2020).

Inorganic fertilizers generally contain essential elements such as nitrogen (N), phosphorus (P), and potassium (K). Applying inorganic fertilizers has a positive impact on plant nutrition and growth because they contain macronutrients that support the growth phase and can stimulate root growth in plant seedlings. NPK fertilization of coffee plants is necessary from the nursery stage to ensure the production of high-quality, fhealthy seedlings (Rismanto, 2020).

Although the use of inorganic fertilizers (NPK) has been shown to accelerate the vegetative phase, previous research has shown significant limitations in long-term use in the seedling phase. The use of synthetic fertilizers alone tends to cause compaction of the growing medium (polybags) and soil microbial imbalances that actually inhibit the absorption of essential micronutrients (Velmourougane, 2016). Furthermore, nutrient absorption efficiency in Robusta coffee seedlings is often low due to evaporation and nutrient leaching, so organic stimulants are needed to increase the cation exchange capacity (CEC) of the growing medium. Previous research by Iskandar et al. (2017) found that single application of NPK was unable to optimize seedling growth, whereas the combination of NPK with liquid organic fertilizer or biofertilizer can increase vegetative growth through nutrient availability and growth hormone stimulation.

Liquid organic fertilizer is a solution produced from the decomposition process of organic materials, such as plant waste, animal waste, and human waste. According to Asmono *et.al.,* (2025), the fermentation of golden apple snail extract contains 12 amino acid compounds including Arginine, Aspartic Acid, Tyrosine, Valine, Glutamic Acid, Alanine, Glycine, Leucine-isoleucine, Cysteine, Methionine, Proline, and Threonine; the auxin hormone is 0.838%. This fertilizer has a higher nutritional content than other liquid organic fertilizers, is safe for soil and plants, and contains micronutrients (Idaryani dan Warda, 2018).

One type of organic fertilizer that can be used to increase the growth of coffee seedlings is Liquid Organic Fertilizer in the form of golden apple snail extract. This is emphasized in Andriani (2018) explaining that the elements contained in golden apple snails can maximize plant growth and yield through the administration of golden apple snail extract. Every 100g of golden snails contain 64 kcal, 12g of protein, 1g of fat, 2g of carbohydrates, and other nutrients such as iron, phosphorus, and calcium (Asmono et al., 2020).

The novelty of this research lies in the use of animal-based biostimulant sources, which offer advantages over inorganic fertilizers. Physiologically, golden apple snail (*Pomacea canaliculata*) extract contains a much more complete and concentrated amino acid profile that is readily absorbed by plants. Specific amino acids, such as glutamic acid and alanine, which are abundant in golden apple snails (S L Asmono et al., 2024), act as natural chelating agents, making soil micronutrients, such as iron and zinc, more available to Robusta coffee seedling roots than if inorganic fertilizers were used alone. Furthermore, the extracted golden apple snail shells contribute organic calcium (Ca) in a more soluble form, which is crucial for strengthening the cell walls of coffee seedlings, making them more resistant to soil-borne pathogens.

Globally, the golden apple snail is recognized as one of the 100 most dangerous invasive species in the world by the Global Invasive Species Database (Lei et al., 2017).Transforming this destructive pest into an agricultural input represents a breakthrough that has not been widely explored in Robusta coffee cultivation. Another pressing issue relates to global climate change, which causes extreme temperature fluctuations in nurseries. Proline, a compound found in golden apple snail extract, functions as an osmoregulator, protecting coffee seedling cells from drought stress (Rahmawati et al., 2024). This advantage is not found in inorganic fertilizers such as urea, SP36, and KCl. Therefore, this study aims to test the effect of golden apple snail extract on the growth of coffee seedlings while comparing it with inorganic fertilizers.

MATERIALS AND METHODS

Place and Time

The research was conducted from August 2023 to February 2024 at the Politeknik Negeri Jember Practice Area, 100m above sea level, with coordinates 8°09'29.8"S 113°43'31.1"E.

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Materials and Tools

The materials used in this study were 2-month-old propelegitim hybrid robusta coffee seedlings (BP 42 x BP 358), 25 x 30 cm polybags, 3 x 7 m paranet, 2 x 3 x 7 m bamboo, sand planting media with top soil 2: 1, N (Urea), P (TSP 46), K (KCl), 21-day-old golden apple snail extract, buckets, paper envelopes, plastic labels and plastic covers.

The tools used in this study were digital scales, ruler, 1000ml measuring cup, 200ml measuring cup, oven, and SPAD (Soil Plant Analysis Development).

Research Methods

The research method used a Non-Factorial Randomized Block Design (RBD) consisting of one factor, namely the type of fertilizer consisting of 4 levels, namely: P0 (control / without additional fertilizer), P1 (inorganic fertilizer application once every 4 weeks: 1g Urea, 2g TSP, 2g KCL), P2 (golden snail extract application once every 4 weeks: 10ml), and P3 (golden snail extract application once every 2 weeks: 10ml).

Each treatment was repeated 6 times, a total of 24 experimental units. Each replication consisted of 2 plant seedlings, so that there were 48 experimental plant units in total. Observation variables for robusta coffee seedlings for 16 Weeks After Planting (WAP) included: seedling height (cm), number of leaves (strands), leaf area index (LAI), fresh weight (g), dry weight (g), root length (cm), chlorophyll content measured using a SPAD-502 chlorophyllmeter, with the criteria of chlorophyll value <50 Low; 50-53 Medium; >53 High (Prabowo *et al*., 2018).

Golden apple snail extract was prepared according to previous research, and contains nutrient components, amino acids, and plant phytohormones, including: Total N (1.473%), P_2O_5 (0.130%), K_2O (0.142%), Organic C (6.016%), auxin hormone (0.838%), and several amino acids such as aspartic acid, glutamic acid, arginine, tyrosine, methionine, glycine, alanine, valine, threonine, proline, leucine-isoleucine, and cysteine (Rahmawati *et al., 2024*).

The experimental data will be analyzed using analysis of variance (ANOVA), and if a significant effect is found, further testing will be conducted using the Orthogonal Contrast method.

RESULTS AND DISCUSSION

Seedling Height

Based on the latest observation data, namely 16 WAP, the treatment of fertilizer types did not have a significant effect on the growth of coffee seedlings, as shown in the data shown in the following figure.

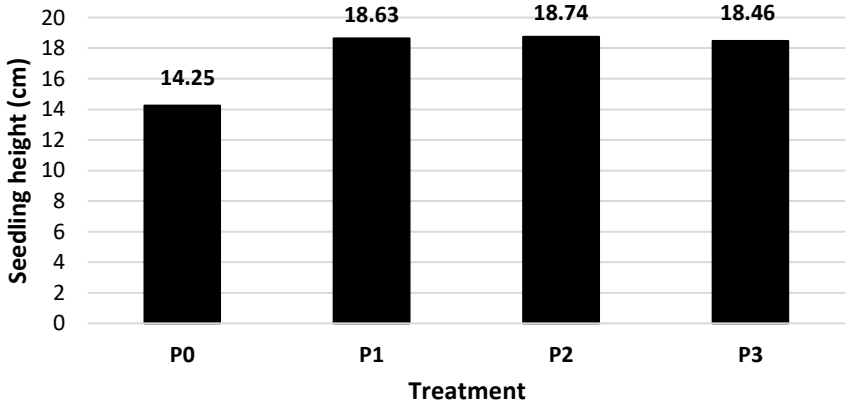

Figure 1. Results of Analysis of Seedling Height 16 WAP

Note: Control (P0), Inorganic Fertilizer (P1), Golden Apple Snail Extract applied once every 4 weeks (P2), Golden Apple Snail Extract applied once every 2 weeks (P3)

Based on observations of seedling height (Figure 1) with the control (P0), inorganic fertilizer (P1), golden apple snail extract applied once every four weeks (P2), and golden apple snail extract applied once every two weeks (P3), ANOVA analysis results showed no significant difference in seedling height.

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Although height did not show significant differences, it significantly affected plant dry weight. This suggests that fertilization may have increased biomass accumulation (e.g., thicker stems or larger leaves) rather than stem elongation (Yang et al., 2021) .

This result may be related to the adequate availability of nutrients supplied by both fertilizer sources. The application of golden apple snail extract and inorganic fertilizer is thought to have adequately met the nutritional needs to stimulate seedling growth under similar conditions. This may be because both the inorganic fertilizer and the golden apple snail extract served as adequate nutrient sources or biostimulants for plant growth at the observed stage, resulting in no significant difference in seedling height.

Inorganic fertilizers provide macro and micro nutrients that are directly available to plants, such as nitrogen (N), phosphorus (P), and potassium (K), which are essential for vegetative growth, including increasing plant height (Amalia et al., 2023). Meanwhile, golden apple snail extract, which contains organic matter and bioactive substances such as plant hormones and potential microorganisms, acts as a biostimulant that can support plant metabolism and stress tolerance, which is also effective in promoting plant growth (Asmono et al., 2024).

Number of Leaves

Fertilizer type did not significantly affect the number of leaves until the end of the observation period (16 WAP).

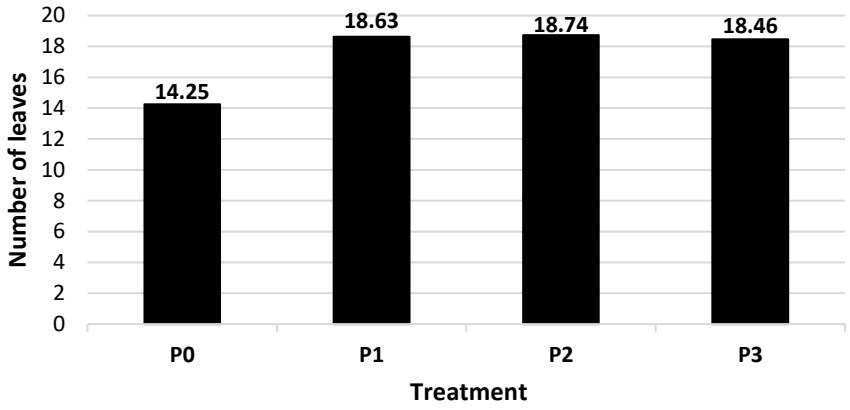

Figure 2. Effect of Fertilizer Treatments on Leaf Number of Robusta Coffee Seedlings at 16 WAP.

The application of inorganic fertilizer and golden apple snail extract as biostimulants in this study is thought to provide relatively adequate nutritional conditions and growth stimulation for leaf formation in plant seedlings, resulting in no significant differences in the number of leaf pairs between treatments. The average number of leaves formed was 18 in the treatment supplemented with inorganic fertilizer and golden apple snail extract, but only 14 in the control treatment.

Nutrition plays a crucial role in plant growth, particularly leaf formation and growth. The inorganic fertilizers used were urea, TSP, and KCl, which are generally known to be essential nutrients for nitrogen, phosphorus, and potassium, readily available to plants to support protein synthesis, tissue growth, and leaf organ formation (Kirkby, 2023). Meanwhile, golden apple snail extract, in addition to providing macro and micro elements, also contains the auxin hormone IAA and beneficial microorganisms that act as biostimulants in increasing nutrient efficiency and stimulating cell division in leaf meristems (Posaluk & Junkasiraporn, 2017; Rahmawati *et al*., 2024).

Leaf Chlorophyll Levels

Physiologically, there were significant differences in leaf chlorophyll levels between fertilizer treatments. Therefore, to further understand the effects, the results of the Orthogonal Contrast test are presented in Table 1.

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Table 1. Results of Further Tests on the Contrast of Leaf Chlorophyll LevelsiIn Robusta Coffee Seedlings on 16 WAP

Treatment Comparison	Mean Value	Notation
P0 Vs P123	27,83 Vs 53,24	**
P1 Vs P23	50,89 Vs 54,42	ns
P2 Vs P3	55,50 Vs 53,34	ns

Note: P0: Control, P1: Inorganic Fertilizer, P2: Golden Apple Snail Extract applied once every 4 weeks, P3: Golden Apple Snail Extract applied once every 2 weeks

Chlorophyll is a key pigment in photosynthesis. Plants with optimal and healthy growth generally have higher chlorophyll levels than plants that are not growing optimally. Chlorophyll levels measured using a SPAD chlorophyll meter can be categorized into three categories: low, medium, and high. According to Prabowo *et al*., 2018, a chlorophyll value <50 is categorized as low; 50-53 as medium; and >53 as high. Table 1 shows that the average chlorophyll content in the P0 (control) treatment is low, while the P123 treatment is high.

A comparison between the P0 and P123 treatments shows a significant difference. The leaf chlorophyll content in the control was 27.83, while the average value in the fertilizer treatment was 53.24. The increase in chlorophyll levels due to fertilizer treatment indicates an improved role in photosynthesis, as chlorophyll is a key pigment involved in capturing light energy. This indicates that the type of fertilizer (P123), both inorganic fertilizer and golden apple snail extract, significantly increases the chlorophyll content of leaves.

This increase is thought to be due to the availability of macronutrients N, P, and K, as well as organic compounds from golden apple snail extract, which play a role in chlorophyll formation. The P123 treatment achieved the highest value, as N plays a crucial role in chlorophyll formation (Rasyidi et al., 2024), and endogenous hormones such as cytokinins and auxins, which stimulate cell division and elongation (George & Sherrington, 1984; Takahashi & Kinoshita, 2016). Given the significant role of N in fertilization in plant metabolism, it can be concluded that N is a key element that significantly influences seedling growth and development (Lakitan, 1996).

Meanwhile, a further contrast test comparing P1 (inorganic fertilizer) with P23 (golden apple snail extract) showed a chlorophyll content of 50.89 for the inorganic fertilizer and 54.42 for the golden apple snail extract, but neither had a significant effect on Robusta coffee seedling growth. Table 1 indicates that golden apple snail extract can be an alternative substitute for NPK fertilizer in maintaining chlorophyll levels, it is suspected that there is support from the amino acid and mineral content in golden apple snail extract which is comparable to that found in chemical fertilizers. According to Jatsiyah (2020) the Potassium (K) element in organic fertilizers plays a role in the leaf formation process. This shows that variations in fertilizer types affect leaf growth, the taller the plant, the more leaves will be formed.

Similarly, the comparison of P2 with P3 or the comparison of the application time of golden snail extract once every 4 weeks and once every 2 weeks. The comparison of the application time also did not have a significant effect (Table 1). The chlorophyll content of the golden snail extract application once every 4 weeks was 55.50, slightly higher than the golden snail extract application once every 2 weeks, which was 53.34. It is suspected that both application intervals are still within the optimal parameters for nutrient absorption by plants. According to Dewantara *et al.* (2017), the provision of POC with sufficient and appropriate concentrations can increase nutrients such as N, P, K, Ca, and Mg. Phosphorus (P) is a nutrient that functions as a plant growth trigger, strengthening leaves so they do not fall off easily.

Leaf Area

Based on the leaf area parameters measured at the last observation, 16 weeks after planting (WAP), ANOVA analysis showed significant differences. Therefore, further leaf area analysis is presented in Table 2.

Table 2. Results of Further Tests on Leaf Area Contrast in Robusta Coffee Seedlings on 16 WAP

Treatment Comparison	Mean Value	Notation
P0 Vs P123	27,25 Vs 74,08	**
P1 Vs P23	79,90 Vs 71,17	ns
P2 Vs P3	86,00 Vs 56,34	*

Note: P0: Control, P1: Inorganic Fertilizer, P2: Golden Apple Snail Extract applied once every 4 weeks, P3: Golden Apple Snail Extract applied once every 2 weeks

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Based on Table 2, the analysis of leaf area parameters shows a comparison from the further contrast test between P0 and P123. The control area was 27.25cm², while the fertilizer application (P123) averaged 74.08cm², indicating a highly significant difference in the growth of Robusta coffee seedlings. This difference is likely due to the nutritional content of the P123 treatment, namely inorganic fertilizer and golden apple snail extract. The seedlings were not fertilized in P0.

The comparison of fertilizer treatments (P1 vs. P23) did not significantly affect Robusta coffee seedling area, as the nutrients from the inorganic fertilizer and golden apple snail extract presumably had the same positive impact on leaf growth. Furthermore, the comparison of golden apple snail extract treatments P2 (once every four weeks) and P3 (once every two weeks) showed a significant difference in the mean leaf area of 86.00 cm² and 56.34cm², respectively.

The application of golden apple snail extract once every four weeks (P2) resulted in the highest average leaf area compared to other treatments. Golden apple snail extract is known to contain nutrients and bioactive compounds that can stimulate plant growth, including increasing leaf area. These compounds play a role in improving plant physiology, such as increasing photosynthesis, stimulating cell division and elongation, and improving plant metabolism in general. Regular application of this extract every four weeks has a positive impact on leaf tissue, resulting in a larger leaf area compared to other treatments or those without golden apple snail extract. This also aligns with previous studies that indicate that golden apple snail extract has the potential to be an effective biostimulant to increase plant growth, including leaf area and plant weight. Nurshanti et al. (2021) stated that the biostimulant treatment of *Pomacea canaliculata* extract significantly increased plant growth, including an increase in the number of leaves and average leaf area.

Fresh Weight

Based on the ANOVA analysis, the application of inorganic fertilizer with golden apple snail extract showed a very significant difference at 16 weeks after planting on the fresh weight of Robusta coffee seedlings. The results of the further contrast test on the fresh weight of Robusta coffee are shown in the following table:

Table 3. Results of Further Fresh Weight Contrast Tests on Robusta Coffee Seedlings on 16 WAP

Treatment Comparison	Mean Value	Notation
P0 Vs P123	15,65 Vs 22,99	**
P1 Vs P23	19,97 Vs 24,50	ns
P2 Vs P3	19,03 Vs 29,97	**

Note: P0: Control, P1: Inorganic Fertilizer, P2: Golden Apple Snail Extract applied once every 4 weeks, P3: Golden Apple Snail Extract applied once every 2 weeks

The results of the contrast analysis showed significant differences between the treatments without fertilization (P0) and those using inorganic fertilizer or golden apple snail extract. The fresh weight value at P0 was 15.65 grams, while the average value with fertilizer was 22.99 grams. These results also showed no significant difference between the use of inorganic fertilizer and golden apple snail extract (P1 vs P23), indicating that both types of fertilizers are equally effective. Golden apple snail extract, as an organic fertilizer, can produce yields comparable to those of inorganic fertilizers, possibly due to the nutrient content in golden apple snail extract, which is ideal for building plant mass.

The fresh weight of seedlings reflects the amount of water and nutrients absorbed. Air makes up over 70% of the total plant weight. Robusta coffee plants will grow and produce more if they are supplied with potassium. The function of potassium is to facilitate meristem growth. Plant water content can increase due to nutrients that support photosynthesis, which in turn increases the amount of photosynthates produced and distributed to plant parts (Opaladu *et al.,* 2021).

In addition, the comparison of P2 with P3 with a fresh weight of 4-week golden snail extract of 19.03 grams and 2-week golden snail extract of 29.97 grams also showed a significantly different effect on the increase in fresh biomass of robusta coffee seedlings. Table 3 indicates that the frequency of application every 2 weeks (P3) is more effective in increasing fresh weight than the frequency of 4 weeks (P2), this may occur because the shorter application interval is able to maintain a more stable nutrient availability in the soil, so that plants can absorb nutrients more optimally for their growth. In other studies, the application of golden apple snail POC once every 2 weeks has also been shown to be good for the growth of oil palm seedlings (Siregar & Lubis, 2017).

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Dry Weight

Based on the ANOVA analysis results, there were significant differences in the dry weight parameters of the seedlings. Therefore, further contrast tests were conducted on the dry weight of Robusta coffee, as shown in the following table.

Table 4. Results of Further Dry Weight Contrast Tests On Robusta Coffee Seedlings on 16 WAP

Treatment Comparison	Mean Value	Notation
P0 Vs P123	2,27 Vs 4,27	**
P1 Vs P23	3,75 Vs 4,53	ns
P2 Vs P3	3,88 Vs 5,18	*

Note: P0: Control, P1: Inorganic Fertilizer, P2: Golden Apple Snail Extract applied once every 4 weeks, P3: Golden Apple Snail Extract applied once every 2 weeks

From the analysis results listed in Table 4, between the treatment without fertilizer (P0) and the treatment with all types of fertilizer (P123) produced a very significant difference, the average dry weight in the control treatment was 2.27 grams and the dry weight in the fertilizer treatment was 4.27 grams. These results indicate that the availability of complete nutrients supports optimal organic compound synthesis, increasing photosynthetic efficiency for the formation of permanent tissue. According to Jatsiyah (2020), dry weight is an important indicator in evaluating plant growth and health. Plant dry weight is the weight obtained after all water in the plant is removed, usually through a drying process in an oven at a certain temperature until the weight is stable. The nutrients in liquid organic fertilizer play an active role in plants and can increase the dry weight of seedlings. One of the important nutrients in POC is potassium (K), which plays a specific role in the formation of new roots. Good and strong roots are very important because they play a role in absorbing water and nutrients from the soil, which are then used in the process of photosynthesis.

The relationship between the nutrients nitrogen (N), phosphorus (P), and potassium (K) in fertilizer is synergistic in increasing photosynthetic efficiency and organic matter accumulation in plants. Nitrogen plays a vital role in the formation of chlorophyll, photosynthetic enzymes, and structural and functional proteins that support the capture of light energy. Phosphorus contributes to energy transfer via ATP, thus supporting metabolic reactions related to carbon fixation and the biosynthesis of organic compounds. Potassium, on the other hand, plays a role in enzyme activation, osmotic regulation, and the opening and closing of stomata, which determine CO2 diffusion and air use efficiency. A balanced N and K balance has been shown to increase leaf photosynthetic capacity by increasing N allocation to photosynthetic components and improving leaf physiological parameters. In general, adequate N, P, and K are known to support plant energy status and increase biomass production efficiency by increasing photosynthetic capacity (Xu et al., 2024).

Furthermore, the presence of bioactive compounds in golden apple snail extract can enhance plant physiological responses. Bioactive compounds such as amino acids, phenolic compounds, phytohormones, and other growth-promoting compounds have the potential to increase nutrient uptake, stimulate enzymatic activity, and support chlorophyll formation. The integration of chemical fertilizers and biofertilizers has been reported to increase photosynthetic pigment content and improve photosynthetic efficiency without reducing plant production capacity. In golden apple snail extract, bioactive compounds are also associated with increased secondary metabolites and plant functional components (Moradi & Siosemardeh, 2025).

Increasing photosynthetic efficiency will ultimately increase the production of photosynthates, which are used for the synthesis of organic matter, including carbohydrates, proteins, lipids, and dry biomass. Thus, the combination of NPK macronutrients and bioactive compounds not only supports vegetative growth but also enhances the plant's capacity to convert light energy into higher organic matter accumulation (Jiaying et al., 2022).

Meanwhile, a comparison of inorganic fertilizer (P1) with golden apple snail extract (P23) showed no significant effect on the growth of Robusta coffee seedlings. These results demonstrate the superiority of golden apple snail extract, which contains sufficient nutrients to support plant growth. The mineralization process of organic matter in golden apple snail extract occurs optimally, allowing plants to adapt to various nutrient sources. According to Hikmah *et al.* (2024), nutrient content significantly impacts plant dry weight, and nutrient uptake by plants determines whether the plant has a high or low dry weight. The insignificant difference between P1 and P23 indicates that organic fertilizers may provide comparable

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benefits to inorganic fertilizers, particularly in the potential of amino acids, bioactive compounds, and biostimulant effects in the extracts that may serve as effective alternative fertilizers.

A comparison between golden apple snail extract applied for 4 weeks (P2) and 2 weeks (P3) also showed a significant difference in the dry weight of Robusta coffee seedlings. This is suspected to be due to the presence of the IAA hormone, which stimulates cell division and elongation in the root area. This is consistent with the statement by Nurshanti *et al.* (2021) that golden apple snail extract contains biostimulant compounds such as the IAA hormone which plays a role in increasing root capacity so that it maintains and increases water and nutrient absorption, which ultimately can affect plant biomass and dry weight more significantly with more frequent application frequencies.

Root Length

Based on the ANOVA analysis, a significant difference was observed in root growth. Providing nutrients from both inorganic fertilizer and golden apple snail extract significantly increased root length compared to unfertilized treatments. The results of further contrast tests on Robusta coffee root length are shown in the following table.

Table 5. Results of Further Contrast Tests of Root Length in Robusta Coffee Seedlings on 16 WAP

Treatment Comparison	Mean Value	Notation
P0 Vs P123	19,68 Vs 32,61	**
P1 Vs P23	31,07 Vs 33,38	ns
P2 Vs P3	32,43 Vs 34,33	ns

Note: P0: Control, P1: Inorganic Fertilizer, P2: Golden Apple Snail Extract applied once every 4 weeks, P3: Golden Apple Snail Extract applied once every 2 weeks

In Table 5, the average root length of unfertilized seedlings (P0) was 19.68cm, while that of fertilized seedlings (P123) was 32.61cm. Optimal nutrient provision, such as P, stimulates root meristem development. Furthermore, IAA can also stimulate rooting (Rahmawati *et al*., 2020). According to Choi *et al.* (2025)phosphorus plays a role in root growth and the formation of a strong root system, while potassium plays a role in photosynthesis and carbohydrate metabolism. The balance between these processes is influenced by external factors, one example of which is the availability of essential nutrients for plants.

Meanwhile, the comparison of the P1 and P23 contrast tests did not significantly affect the root growth of Robusta coffee seedlings. Table 5 indicates that golden apple snail extract is suspected to contain elements capable of supporting root growth equivalent to N, P, K fertilizers. The mineral and IAA hormone content in golden apple snail extract has the effect of stimulating root growth. In line with the opinion of Sopiana *et al.* (2022), the increase in root length is a root response to the availability of water and nutrients. Observation of root length aims to provide information on the ability of a plant's roots to absorb water and nutrients. Root length growth is further accelerated if nitrogen (N) nutrients are available and water is sufficient. Phosphate elements play a role in the development of meristem tissue and cell division, with this phosphate elements can stimulate the growth of roots and leaves of Robusta coffee plants.

Likewise, a comparison of the application of golden apple snail extract once every four weeks (P2) with once every two weeks (P3) showed no significant difference in the growth of robusta coffee seedlings. This also indicates that the frequency of application is not a factor in increasing root length. According to Posaluk & Junkasiraporn (2017), golden apple snail bioextract contains macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients such as calcium. In addition, it also contains hormones that are beneficial for plant growth. Root length affects the effectiveness of the roots in carrying out their duties, because root length impacts the root surface area.

CONCLUSION

The results of this study demonstrate that fertilization significantly improved the growth performance of robusta coffee seedlings compared with the unfertilized control. Both inorganic fertilizer and golden apple snail extract enhanced several growth parameters, including chlorophyll content, leaf area, fresh weight, dry weight, and root length. No significant differences were observed between inorganic fertilizer and golden apple snail extract in most growth parameters, indicating that golden apple snail extract has the potential to serve as an alternative organic fertilizer for robusta coffee seedlings. In

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terms of application frequency, the two-week interval increased seedling dry weight, whereas the four-week interval produced larger leaf area. These findings suggest that golden apple snail extract can be utilized as a sustainable nutrient source to support the growth of coffee seedlings.

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