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The Effect of Peptide Concentration on the Productivity of Robusta Coffee (*Coffea Canephora* L.)

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ABSTRACT: This study is descriptive experimental research aimed at determining the effect of different peptide concentrations on the productivity of Robusta coffee (Coffea canephora L.) plants. The experiment was conducted using a Randomized Block Design (RBD) with a single factor treatment, namely peptide concentration (P), consisting of three levels: P_0 = 0 ml peptide/L water (control), P_2 = 2 ml peptide/L water, and P_4 = 4 ml peptide/L water. Each treatment was replicated ten times, resulting in a total of 30 Robusta coffee plants as samples. The observed variables included the number of flowers per plant, number of fruits per plant, fruit weight per plant, and bean weight per plant. The results showed that peptide application had a significant effect on all observed productivity parameters. The treatment with a concentration of 4 ml/L water (P_4) produced the best results compared to other treatments, as indicated by a significant increase in the number of flowers, number of fruits, as well as fruit and bean weight per plant. Peptide acts as a natural biostimulant that improves hormonal balance, enhances photosynthetic efficiency and nitrogen absorption, and strengthens plant tolerance to environmental stress. Therefore, the application of peptide at a concentration of 4 ml/L water is recommended as an effective and sustainable cultivation strategy to improve the productivity of Robusta coffee plants.

KEYWORDS: Peptide, Concentration, Flowering, Fruiting, Productivity.

INTRODUCTION

Coffee is one of the most strategic plantation commodities that plays an important role in Indonesia's economy. As the fourth largest coffee producer in the world, Indonesia produces various high-quality coffee types that serve as leading export commodities. One of the prominent coffee-producing regions is Bali Province, particularly in Kintamani, Buleleng, and Tabanan, which are well-known for producing high-quality Arabica and Robusta coffee. However, although Bali's coffee production once reached around 14,600 tons in 2022, the figure sharply declined to 9,922 tons in 2023 (BPS Bali Province, 2023). This decrease indicates underlying issues within the coffee production system at the farmer level.

The decline in coffee production is largely triggered by agronomic factors, especially climate change, which directly affects plant growth and productivity at the farm level. Unstable rainfall patterns, prolonged dry seasons, and increased air temperatures disrupt the flowering cycles of coffee plants, cause premature fruit drop, and intensify pest and disease attacks. According to Rizqi et al. (2020), extreme climate fluctuations can reduce the yield and quality of Robusta coffee by up to 8% in several production regions. Meanwhile, Saragih et al. (2021) stated that irregular rainfall and rising temperatures accelerate evapotranspiration rates, reducing water availability in dryland areas and negatively affecting coffee plant growth.

In addition to climate factors, cultivation techniques also represent a significant problem. The implementation of Good Agricultural Practices (GAP) among farmers remains suboptimal, particularly in fertilizer management, irrigation systems, pruning, and pest and disease control. This condition directly contributes to the decline in productivity and quality of coffee beans produced (Suryani et al., 2022). Furthermore, excessive use of chemical fertilizers worsens soil conditions. Handayani et al. (2023) explained that continuous use of chemical fertilizers can reduce soil fertility, inhibit microbial activity, and ultimately decrease plant productivity.

Considering these challenges, eco-friendly fertilization innovations are needed to maintain soil health, improve plant vitality, and enhance the growth and yield of Robusta coffee. One promising alternative being developed is Keratin Hydrolysate

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Peptide, an organic product derived from the decomposition of poultry feathers and fish scales, rich in nitrogen, sulfur, and essential amino acids. According to CH Biotech (2023), this peptide functions as a bio-protectant, bio-stimulant, and bio-fertilizer that can improve plant physiological functions, enhance tolerance to biotic and abiotic stress, and strengthen cell metabolism through increased protein and enzyme synthesis. Zhang et al. (2023) reported that peptide application on coffee plants in China increased flowering by up to 20%, reduced flower drop, boosted fruit set, and improved fruit quality—indicating its potential as an innovative solution to sustainably increase Robusta coffee productivity.

These findings suggest that peptide application can enhance the productivity of Robusta coffee, particularly by increasing the number of flowers and fruits formed. The appropriate concentration of peptide is expected to optimize plant physiological processes, accelerate flowering, promote fruit formation, and maintain a balance between vegetative and generative growth. Based on this background, this study was conducted to examine the effect of various peptide concentrations on the flowering and fruiting of Robusta coffee (Coffea canephora L.) as an effort to sustainably improve productivity.

RESEARCH METHOD

Research Design

This study employed a Randomized Block Design (RBD) with a single factor, namely peptide concentration, consisting of three treatment levels and ten replications. The use of RBD aimed to minimize variation caused by differences in environmental conditions in the field, ensuring that each replication group had similar variability.

The factor tested in this study was the peptide concentration, with three levels as follows:

- 0 ml peptide/L water (control)
- 2 ml peptide/L water
- 4 ml peptide/L water

Each treatment level was replicated ten times, resulting in a total of 30 experimental plots. Each plot was represented by one Robusta coffee tree as the research sample, thus requiring a total of 30 Robusta coffee trees.

Research Location and Time

The research was conducted in Tambakan Village, Kubutambahan District, Buleleng Regency, Bali Province, at an altitude of 900–1300 meters above sea level. The study was then continued at the Agronomy and Horticulture Laboratory, Faculty of Agriculture, Udayana University.

The research was carried out from November 2024 to July 2025, covering all phases from the initial stage to harvest.

Tools and Materials

The tools used in this study included a sprayer, measuring cylinder, pruning shears, ruler, label paper, digital camera, stationery, analytical balance, and a computer for data analysis. The materials used were Robusta coffee plants (*Coffea canephora* L.), peptide solution (product of CH Biotech Co., Ltd, Taiwan), and clean water as the solvent and control.

Research Implementation

The implementation of the study consisted of several stages as follows:

1. **Selection of Sample Trees**

   The Robusta coffee trees selected as samples were mature, fully productive plants aged between 5–8 years. The selected trees were taken from the same plantation area under a single ownership and with a uniform maintenance history. Trees were chosen based on having relatively uniform height and canopy size. These selection criteria were crucial to ensure that the sample trees had homogeneous soil conditions, microclimate, and canopy density.

2. **Plant Maintenance**

   Maintenance of the sample trees was carried out following the Standard Operating Procedures (SOP) for Robusta coffee cultivation, which included weed control, pruning, fertilization, and pest and disease management.

3. **Peptide Treatment Application**

   The peptide treatment was applied four times, with specific timing and methods as follows:

   1. 15 days before the flowering phase (pre-anthesis),
   2. During the fruit-set phase (when flowers begin developing into young fruits),
   3. 1.5 months after the second application, and
   4. When the fruits began to change color from green to red (early ripening stage).

Treatment **P_0** used only water without peptide as a control. The peptide solutions in treatments **P_2** and **P_4** were applied by spraying evenly on the entire plant canopy (foliar spray) during the first three applications, while the fourth application was done by soil drenching around the base of the trunk.

4. **Harvest and Post-Harvest**

   The harvest of Robusta coffee was conducted using the selective red-picking method, in which only fully ripe red cherries were harvested. Harvesting was carried out regularly at 5-day intervals. After harvesting, sorting was performed to separate ripe coffee fruits from branches, leaves, and other debris collected during picking. The coffee cherries were then pulped to separate the beans from the fruit skin. Additional sorting was conducted using the flotation method to separate empty or defective beans from well-filled beans. The final stage was bean drying, which was done by sun-drying the coffee beans directly under sunlight.

Observation Variables

The observation variables in this study included:

1. Number of Flowers per Plant

   The number of flowers per plant was calculated by multiplying the number of flowers per cluster by the number of flower clusters per plant.
2. Number of Fruits per Plant

   The number of fruits per plant was calculated by multiplying the number of fruits per cluster by the number of fruit clusters per plant.
3. Fruit Weight per Plant (kg)

   The fruit weight per coffee plant was measured by weighing all harvested fruits from each tree during the harvest period of the study.
4. Bean Weight per Plant (kg)

   The coffee bean weight was measured by weighing all harvested beans from each tree during the harvest period of the study.

Data Analysis

The data obtained from the study were tabulated and analyzed using Analysis of Variance (ANOVA) to test the effect of peptide concentration (P_0, P_2, P_4) on the observed variables. If the analysis showed a significant effect, it was followed by the Least Significant Difference (LSD) test at a 5% significance level to determine detailed differences among treatments.

RESULTS

Results of Variance Analysis

The results of the analysis of variance (Table 1) showed that the peptide treatments had a significant effect on several observed yield parameters. The treatments had a highly significant effect ($p < 0.01$) on the number of flowers per plant, number of fruits per plant, and fruit weight per plant, indicating a significant difference among treatments. In addition, the bean weight per plant showed a significant effect ($p < 0.05$), suggesting that peptide application also influenced reproductive development and seed formation.

To further determine detailed differences among treatments, a Least Significant Difference (LSD) test was conducted at a 5% significance level. The results of the LSD test indicated that peptide application significantly increased growth and yield parameters compared to the control treatment. The mean values of each treatment based on the 5% LSD test results are presented in Table 2.

These findings demonstrate that peptide application has great potential to enhance both the quantity and quality of crop yield. Practically, the results of this study can serve as a basis for developing peptide application technology in crop cultivation systems to improve productivity efficiency and harvest quality.

1. The Effect of Peptides on Robusta Coffee Yield Based on the 5% Least Significant Difference (LSD) Test

No	Parameter	Peptide
1	Number of flowers per plant	**
2	Number of fruits per plant	**
3	Fruit weight per plant (kg)	**
4	Bean weight per plant (kg)	*

Note: ** = Highly significant difference

** = Significant difference
ns = Not significant

2. The Effect of Peptides on the Yield of Robusta Coffee Plant

Observed variables	Peptide treatment			BNT 5%
	P0	P2	P4	
Number of flowers per plant	4485,47 b	9134,37 a	10346,99 a	1647,31
Number of fruits per plant	4169,97 b	8282,14 a	9361,54 a	1696,61
Fruit weight per plant (kg)	4297,16 b	8353,89 a	10141,90 a	2021,67
Bean weight per plant (kg)	1187,45 b	2523,90 a	3008,76 a	1204,59

Note: Numbers followed by the same letter in the same row indicate no significant difference based on the Least Significant Difference (LSD) test at the 5% significance level.

DISCUSSION

1. Number of Flowers per Plant

The results of the 5% LSD test showed that peptide application had a highly significant effect on the number of Robusta coffee flowers per plant. The treatment with a concentration of 4 ml/L of water (P_4) produced the highest number of flowers, reaching 10,346.99, which was significantly different from the 2 ml/L (P_2) treatment with 9,134.37, and markedly higher than the control treatment (P_0) with 4,485.47. This indicates that the concentration of 4 ml/L of water is the optimal dose to support maximum flower formation in Robusta coffee. Peptides function as natural biostimulants that activate plant physiological processes, particularly during the flowering formation phase.

The increase in the number of flowers in Robusta coffee plants is related to the active role of peptides in improving hormonal balance. Peptides contain essential amino acids such as tryptophan and methionine, which serve as precursors for the plant hormones auxin and cytokinin—both crucial for flower initiation and development. Colla et al. (2014) stated that protein hydrolysates rich in peptides can stimulate plant metabolism by enhancing the synthesis of growth hormones, which accelerates the transition from the vegetative to the generative phase. This effect results in faster and more uniform flower formation.

In addition to their hormonal function, peptides also act as metabolic regulators that enhance photosynthetic activity and protein synthesis in generative meristem tissues. Peptides accelerate chlorophyll formation and improve photosynthetic rates, leading to greater production of photosynthates used for flower organ development. Pasković et al. (2024) explained that the application of protein hydrolysates to plants can improve nitrogen use efficiency and redox enzyme activity, both of which are essential for generative organ formation. Thus, sufficient energy and protein availability promote the development of more abundant and healthier flowers.

From an environmental resilience perspective, peptides also help prevent flower abscission caused by heat or drought stress. Perkins et al. (2025) reported that peptide signaling within plant tissues enhances reproductive thermotolerance, maintains flower viability, and extends flower longevity under extreme environmental conditions. This is highly relevant for Robusta coffee grown in dryland areas, where environmental stress often disrupts the flowering process. Peptides help maintain water balance within tissues, ensuring optimal flower development.

Furthermore, Malécange et al. (2023) emphasized that peptide-based biostimulants can improve flowering synchronization and reduce flower drop in horticultural crops. The increased uniformity and flower quantity in the P_4 treatment indicate that this concentration effectively maximizes the plant's physiological activity—hormonally, metabolically, and structurally. Therefore, the application of peptides at a dose of 4 ml/L of water can be recommended to enhance the production potential of Robusta coffee through increased flower quantity and quality.

2. Number of Fruits per Plant

The Least Significant Difference (LSD) test at the 5% level showed that the application of peptides had a highly significant effect on the number of Robusta coffee fruits per plant. The treatment with a concentration of 4 ml/L of water (P_4) produced the highest number of fruits, 9,361.54, which was significantly different from the 2 ml/L treatment (P_2) with 8,282.14 fruits, and very significantly different from the control without peptides (P_0) with 4,169.97 fruits. These results indicate that the 4 ml/L peptide concentration is the optimal dose that supports successful fruit set and fruit formation in Robusta coffee plants.

The increase in the number of fruits is closely related to the greater number of flowers that successfully developed into fruits and to the improved efficiency of pollination and fertilization. Peptides play an important role in enhancing flower tolerance to environmental stresses such as high temperature and drought, which often inhibit successful fertilization. Henderson et al. (2025) explained that amino acids produced from protein hydrolysis in peptides can strengthen flower cell structures and increase antioxidant enzyme activity, thereby reducing flower and young fruit drop rates.

Moreover, Ertani et al. (2014) reported that the application of peptide-based biostimulants to *Capsicum chinensis* increased photosynthetic efficiency, carbon translocation, and nitrogen metabolism, which directly influenced the increase in fruit number. This physiological effect was also evident in Robusta coffee plants, where enhanced photosynthate availability supported the formation and growth of young fruits. Peptides also strengthen ovary tissues and stabilize the activity of gibberellin and cytokinin hormones, which play important roles in fruit development.

In addition to their physiological functions, peptides act as metabolic regulators that coordinate the flow of photosynthetic products between source (leaves) and sink (fruits) organs. Xiao et al. (2024) demonstrated that small peptides can enhance the activity of sucrose phosphate synthase and invertase enzymes, accelerating carbohydrate translocation to developing fruits. This explains why plants treated with P_4 were able to produce more fruits with uniform size. Thus, peptide application plays a major role in improving fertilization efficiency and increasing the number of Robusta coffee fruits per plant.

3. Fruit Weight per Plant

The Least Significant Difference (LSD) test at the 5% level showed that the application of peptides had a highly significant effect on the fruit weight of Robusta coffee per plant. The treatment with a concentration of 4 ml/L of water (P_4) produced the highest fruit weight of 10,141.90 g, which was significantly different from the 2 ml/L treatment (P_2) with 8,353.89 g, and very significantly different from the control without peptides (P_0) with 4,297.16 g. These results indicate that a concentration of 4 ml/L of water is the best dose to support optimal fruit formation and development in Robusta coffee plants.

The increase in fruit weight is due to the role of peptides in accelerating photosynthesis and improving the efficiency of organic nitrogen uptake, which is essential for the formation of proteins and carbohydrates within the fruit. Pasković et al. (2024) explained that protein hydrolysates, as a source of peptides, can enhance nitrogen metabolism and increase redox enzyme activity, which plays an important role in fruit filling. The amino acids contained in peptides also strengthen cell walls and slow down the rate of fruit senescence, allowing fruits to develop more fully.

In addition, Malik et al. (2021) emphasized that peptide-based biostimulants can increase fruit size and weight by enhancing photosynthetic efficiency and resistance to oxidative stress. The increase in fruit weight observed in the P_4 treatment was also supported by higher physiological activity and hormonal coordination involving auxin and gibberellin, which stimulate fruit enlargement. Thus, the application of peptides at the optimal dose produces Robusta coffee fruits with greater weight and improved quality.

4. Seed Weight per Plant

The Least Significant Difference (LSD) test at the 5% level showed that the application of peptides had a highly significant effect on the seed weight of Robusta coffee per plant. The treatment with a concentration of 4 ml/L of water (P_4) produced the highest seed weight of 3,008.76 g, which was significantly different from the 2 ml/L treatment (P_2) with 2,523.90 g, and very significantly different from the control without peptides (P_0) with 1,187.45 g. These results indicate that the 4 ml/L concentration is the most effective dose for increasing the seed weight of Robusta coffee.

The increase in seed weight occurs due to the role of peptides in improving the seed-filling process and accelerating the translocation of photosynthetic products to the seed tissues. Peptides provide essential amino acids such as proline, glycine, and lysine, which are required for the synthesis of seed proteins and lipids. Colla et al. (2014) stated that protein hydrolysate-derived peptides can enhance the physiological efficiency of plants, while Malécange et al. (2023) emphasized that these compounds also regulate gene expression related to protein synthesis and seed filling. Thus, the application of peptides at a concentration of 4 ml/L of water can significantly improve both the weight and quality of Robusta coffee beans.

CONCLUSION

The results of the study showed that the application of peptides had a significant effect on all productivity parameters of Robusta coffee plants, including the number of flowers, number of fruits, fruit weight, and seed weight per plant. The treatment with a concentration of 4 ml/L of water (P_4) produced the best results compared to the 2 ml/L treatment (P_2) and the control without peptides (P_0).

The use of peptides at a concentration of 4 ml/L was able to increase the number of flowers by more than twice compared to the control, enhance fruit-setting success, and produce fruits and seeds with greater weight. This improvement is attributed to the active role of peptides as natural biostimulants that help balance plant growth hormones, enhance photosynthetic activity, improve nitrogen uptake efficiency, and strengthen plant resistance to environmental stress.

ADVICE

1. For field application, it is recommended to use peptides at a concentration of 4 ml/L of water, as this dosage has been proven effective in enhancing flowering, fruit set, and Robusta coffee bean yield without causing material waste.
2. For coffee farmers, the use of peptides can serve as an environmentally friendly and sustainable alternative to organic fertilization, particularly in dryland areas that are vulnerable to abiotic stresses such as drought and high temperatures.

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