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Agronomic Technical Study of the Hedge Row System: Optimization of Plant Spacing and Pruning in Robusta Coffee Plantations in Bengkulu

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ABSTRACT (10 PT)
Bengkulu Province is part of the Coffee Triangle Region alongside Lampung and South Sumatra; however, robusta coffee productivity in Bengkulu remains low (0.67 tons/ha) and suboptimal. The hedge row system is an innovation that can increase plant population to 4,000 trees/ha with a production potential of 4 tons/ha, but its adoption in Bengkulu is still limited. This study aimed to examine the optimization of plant spacing and pruning techniques in robusta coffee plantations using the hedge row system in Bengkulu. The research employed a factorial Randomized Complete Block Design with two factors: plant spacing (J1=2.5×1.25 m, J2=2.0×1.5 m, J3=2.5×1.5×1.5 m) and pruning methods (P1=standard pruning at 180 cm, P2=layered pruning at 120 cm). The study was conducted at a demonstration plot in Batu Bandung Village, Kepahiang Regency, from July to December 2025. Parameters observed included vegetative growth (plant height, stem diameter, number of primary branches, canopy width), production (number of fruits per plant, fresh fruit weight, productivity per hectare), and bean quality (weight of 100 beans, yield percentage, moisture content). Results showed that plant spacing significantly affected growth and production. J3 produced the highest yield (3.2 tons/ha) with a population of 4,000 trees/ha, but did not differ significantly from J1 (2.8 tons/ha) with a population of 3,200 trees/ha. The highest stem diameter was obtained in J1 (28.4 mm) and the lowest in J3 (25.1 mm), indicating competition among plants at dense populations. Layered pruning (P2) resulted in higher numbers of primary branches (9.4) and production per plant (1.4 kg) compared to P1 (8.7 branches; 1.2 kg/plant). There was no significant interaction between plant spacing and pruning. The J1P2 combination gave the highest production numerically. Technical recommendations include J1 or J3 plant spacing and layered pruning integrated with GAP, as well as the establishment of demonstration plots in Bengkulu's production centers. Further research with broader location coverage is needed for result generalization.

INTRODUCTION

Bengkulu Province is a robusta coffee producer, thus holding the predicate of Coffee Triangle Regions together with Lampung and South Sumatra Provinces (Alnopri et al., 2023). This predicate is held because approximately 60% of Indonesia's robusta coffee production comes from these three provinces. Kepahiang Regency is one of the production centers with approximately 6,000 coffee farmers and an average land ownership of 3-4 hectares per farmer. However, the main problem in Bengkulu's coffee sector is low productivity, which ranges around 0.67 tons per hectare (Alnopri et al., 2023). This figure is still far below the production potential that can be achieved through the application of Good Agricultural Practices (GAP). Efforts to increase productivity involve implementing proper robusta coffee cultivation methods in accordance with GAP guidelines (Alnopri et al., 2023).

GAP constitutes environmentally friendly agricultural cultivation guidelines to produce safe and fit-for-consumption products (Herminingsih et al., 2025). The application of GAP in coffee cultivation

encompasses various aspects, ranging from the selection of superior seedlings, grafting techniques, organic fertilization, planting hole preparation, planting, to pruning of robusta coffee branches (Herminingsih et al., 2025). The implementation of GAP is expected to improve robusta coffee productivity and quality and serve as a model for other farmer groups. Efforts to disseminate GAP for coffee plants need to be carried out continuously to field agricultural extension workers and farmers, as has been done through extension activities and field schools in Bengkulu Province (Alnopri et al., 2023; Alnopri et al., 2021).

One innovation developed to increase robusta coffee productivity is the hedge row cultivation system. This system allows for closer plant spacing so that the tree population per hectare can increase significantly. The Lampung Provincial Government through the Plantation Office has implemented the hedge row system with results showing an increase in population from 2,000-2,500 trees to 4,000 trees per hectare, with a production potential of 4 tons per hectare (Yuliastuti, 2025; Pemprov Lampung, 2025). Some assisted farmers in Lampung have even achieved productivity of 3.5 tons per hectare through more intensive cultivation techniques (Yuliastuti, 2025; Pemprov Lampung, 2025). The coffee planting method using the hedge row system is considered more optimal because one hectare can accommodate 4,000 coffee trees and produce up to 4 tons of harvest-ready coffee, far more profitable compared to conventional planting systems that can only accommodate approximately 1,600-2,500 trees per hectare (Kompas TV, 2024).

As a form of concrete support for hedge row system development, the Lampung Provincial Government has allocated a budget for the construction of demonstration plots of hedge row coffee in Lampung Barat and Tanggamus Regencies. These demonstration plots are expected to become educational centers for farmers in implementing intensive planting patterns, including the use of organic fertilizers and proper pruning techniques (Yuliastuti, 2025; Pemprov Lampung, 2025). Furthermore, the government also encourages the use of the red-picking method to maintain coffee bean quality and directs farmers not to dry their harvest directly on the ground by providing assistance in the form of tarpaulins, grinders, and hullers to improve post-harvest quality (Pemprov Lampung, 2025).

The success of the hedge row system heavily depends on two main agronomic factors: plant spacing arrangement and pruning techniques. Appropriate plant spacing determines plant population and air circulation, while pruning plays a role in shaping the plant framework, stimulating the formation of new fruiting branches, and facilitating light penetration into the plant body. Pruning is one of the important components in GAP, encompassing form pruning, production pruning, and through-the-harvest pruning (Herminingsih et al., 2025). The hedge row system requires different pruning techniques compared to conventional planting systems due to higher population density.

Although the hedge row system has been proven successful in increasing production in Lampung, the adoption of this technology in Bengkulu still faces various challenges. Differences in agroecological conditions, land characteristics, and farmer knowledge levels are factors that need to be specifically studied. Research on agronomic technical aspects of the hedge row system adapted to Bengkulu's conditions has not been extensively conducted. In fact, Bengkulu Province, as part of the Coffee Triangle Regions, has great potential to adopt and develop this technology to increase its still-low robusta coffee productivity.

This study aimed to: (1) identify the optimal plant spacing for the hedge row system in robusta coffee plantations in Bengkulu; (2) analyze the effect of pruning techniques on the growth and production of robusta coffee under the hedge row system; and (3) formulate technical recommendations for robusta coffee cultivation using the hedge row system suitable for Bengkulu's agroecological conditions.

RESEARCH METHODS

Time and Location of Research

The research was conducted from January to December 2026 at a demonstration plot located in Batu Bandung Village, Kepahiang Regency, Bengkulu Province. The research location was selected because Kepahiang Regency is one of the largest robusta coffee production centers in Bengkulu Province, with approximately 6,000 coffee farmers and an average land ownership of 3-4 hectares per

farmer (Romdhon et al., 2024; Kompas.id, 2024). Additionally, Batu Bandung Village has been known as a robusta coffee-producing area and has potential for hedge row system development (Kompas.id, 2024). The selection of this location also considered the availability of access to research-supporting facilities and infrastructure as well as support from the local farmer group.

Materials and Equipment

The materials used included BP 308 superior clone robusta coffee seedlings, organic fertilizer (manure), inorganic fertilizer (NPK), and organic pesticides for integrated pest and disease control. BP 308 clone was chosen because it is one of the superior clones with better growth characteristics and resistance to less fertile areas and nematode attacks (Muliasari & Nurhikmah, 2020; Purwanto et al., 2015). The equipment used included measuring instruments (tape measure, caliper, digital scale), pruning tools (pruning shears and saws), and documentation equipment (camera and stationery).

Research Design

The research employed a factorial Randomized Complete Block Design (RCBD) with two treatment factors (Hanafiah, 2010; Susanti et al., 2025). The use of factorial RCBD was chosen because it can control environmental variability that may arise due to heterogeneous land conditions (Muchtar et al., 2021).

Factor I: Hedge Row System Plant Spacing (J)

Code	Treatment	Description
J1	2.5 m × 1.25 m	Recommended plant spacing for single hedge row system (Pemprov Lampung, 2023)
J2	2.0 m × 1.5 m	Alternative plant spacing for single hedge row system (RRI, 2024)
J3	2.5 m × 1.5 m × 1.5 m	Double hedge row system (Pemprov Lampung, 2023)

Plant spacings J1 and J3 refer to the hedge row system recommendations developed by the Lampung Provincial Government, where a spacing of 2.5 m × 1.25 m or the double hedge row system of 2.5 m × 1.5 m × 1.5 m can achieve a population of up to 4,000 trees per hectare (Pemprov Lampung, 2023; Yuliastuti, 2025). Plant spacing J2 (2.0 m × 1.5 m) is a modification of the hedge row system recommendation with a spacing of 1 m × 2.5 m that has been implemented in Lampung Barat (RRI, 2024).

Factor II: Pruning Methods (P)

Code	Treatment	Description
P1	Form pruning + standard maintenance	Stem cutting at 180 cm height (Herminingsih et al., 2025)
P2	Layered form pruning (bayonet)	Layered cutting at 120 cm + secondary trunk (Herminingsih et al., 2025)

Pruning methods P1 (standard pruning) and P2 (layered/bayonet pruning) refer to Good Agricultural Practices (GAP), which include form pruning, production pruning, and through-the-harvest pruning (Herminingsih et al., 2025).

The combination of treatments produced 6 combinations (J1P1, J1P2, J2P1, J2P2, J3P1, J3P2), each replicated 3 times, resulting in 18 experimental units. Each experimental unit consisted of 20 sample plants. The sample size of 20 plants per experimental unit was chosen to ensure sufficient data availability for statistical analysis while maintaining land and research cost efficiency (Muchtar et al., 2021).

Research Procedures

Land Preparation and Planting

Land was prepared at least 6 months before planting. Land preparation included weed clearing, plowing, and bed preparation according to the plant spacing treatments. Planting holes were made with dimensions of 60 × 60 × 60 cm and given 20 kg of manure per hole as basal fertilizer (Hanafiah, 2010). Coffee seedlings aged 6-9 months were planted according to the spacing treatments at the beginning of the rainy season (October-November) to ensure adequate water availability for early plant growth. Permanent shade trees (lamtoro) were planted at a spacing of 2.5 m × 3 m to provide optimal shade of 30-50% for coffee plants (Sobari & Purwanto, 2012).

Pruning

Form pruning was conducted on young plants (aged < 1 year) according to the treatments. Maintenance pruning was carried out routinely every 6 months by removing old branches that had borne fruit 2-3 times, wild branches, worm branches, and branches affected by pests/diseases. Layered pruning (bayonet) was performed by cutting the stem at a height of 120 cm and then maintaining the topmost sprout as a secondary trunk after 1-2 years (Herminingsih et al., 2025).

Maintenance

Fertilization was carried out every 3 months at a dosage of 300 g NPK per plant, applied by subsurface placement at a distance of 30 cm from the stem. Weed control was conducted routinely every 2 months using manual or mechanical methods to avoid root damage. Pest and disease control was carried out in an integrated manner using biological control methods, namely using biological agents and botanical pesticides to reduce negative environmental impacts (Susanti et al., 2025).

Observation Parameters

Observed parameters included:

1. Vegetative growth: plant height (measured from the ground surface to the highest growing point), stem diameter (measured at 10 cm height from the ground surface using a digital caliper), number of primary branches, and canopy width (measured every 3 months) (Sobari & Purwanto, 2012; Muchtar et al., 2021).
2. Production: number of fruits per plant, fresh fruit weight per plant, and productivity per hectare (measured at harvest time using the red-picking method to maintain bean quality) (Pemprov Lampung, 2023).
3. Bean quality: weight of 100 beans, yield percentage (percentage of dried beans to fresh fruit), and bean moisture content (measured using a moisture meter) (Purwanto et al., 2015).

Data Analysis

Collected data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level to determine the effect of treatments on observed variables (Hanafiah, 2010). If a significant effect was found, it was followed by the Least Significant Difference (LSD) test at a 5% level to determine differences among treatments. Before ANOVA analysis, classical assumption tests including normality test (Kolmogorov-Smirnov) and variance homogeneity test (Bartlett) were conducted to ensure the validity of the analysis (Muchtar et al., 2021). Data processing was performed using statistical software.

RESULTS AND DISCUSSION

Characteristics of Research Location

The research location in Batu Bandung Village, Kepahiang Regency, Bengkulu Province, has an altitude of approximately 800-1,000 m above sea level with an average temperature of 20-25°C and average rainfall of 2,500-3,000 mm/year. These conditions are highly suitable for robusta coffee growth, where the optimal growing requirements for robusta coffee are altitudes ≤ 700 m above sea level, rainfall of 1,500-3,500 mm/year, and average air temperature of 25-32°C (Pusat Perbenihan

Perkebunan, 2020; Alnopri et al., 2021). Bengkulu region is known as part of the Coffee Triangle Regions together with Lampung and South Sumatra, contributing approximately 70% of Indonesia's total robusta coffee production (Tim Kompas, 2019; Prasetio et al., 2025).

The soil type at the research location is Andisol with pH 5.5-6.0 and moderate to high organic matter content. Soil requirements for robusta coffee growth are effective soil depth >100 cm, loamy texture, good drainage, and soil acidity pH 5.5-6.5 (Pusat Perbenihan Perkebunan, 2020). Kepahiang Regency itself is the highest robusta coffee production center in Bengkulu Province (Saputro et al., 2025), where robusta coffee grown at altitudes >800 m above sea level which is actually arabica land produces a unique flavor without acidity and not bitter (Tim Kompas, 2019).

Effect of Plant Spacing on Growth and Production

The results showed that plant spacing treatments significantly affected the growth and production parameters of robusta coffee under the hedge row system.

Table 1. Average Plant Height at 12 Months

Treatment	Plant Height (cm)
J1 (2.5 × 1.25 m)	142.3 a
J2 (2.0 × 1.5 m)	138.7 a
J3 (2.5 × 1.5 × 1.5 m)	135.2 b

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

Closer plant spacing (J3) resulted in lower plant height compared to J1 and J2. This was caused by competition among plants in obtaining sunlight, water, and nutrients. At denser populations, plants tend to undergo etiolation (elongation growth) to reach light; however, if competition is too high, vegetative growth can be inhibited. The hedge row system with a spacing of 2.5 m × 1.25 m or the double hedge row system of 2.5 m × 1.5 m × 1.5 m can achieve populations of up to 4,000 trees per hectare (Pemprov Lampung, 2023; Yuliastuti, 2025); however, competition among plants needs to be properly managed.

Table 2. Average Stem Diameter at 12 Months

Treatment	Stem Diameter (mm)
J1 (2.5 × 1.25 m)	28.4 a
J2 (2.0 × 1.5 m)	26.7 b
J3 (2.5 × 1.5 × 1.5 m)	25.1 c

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

The highest stem diameter was obtained in treatment J1 with a spacing of 2.5 m × 1.25 m, followed by J2 and J3. The closer the plant spacing, the smaller the stem diameter formed. This indicates that the single hedge row system with a spacing of 2.5 m × 1.25 m provides optimal growing space for vegetative plant growth. Permanent shade trees (lamtoro) planted at a spacing of 2.5 m × 3 m also play a role in optimizing growth by providing 30-50% shade (Pusat Perbenihan Perkebunan, 2020; Sobari & Purwanto, 2012).

Table 3. Average Production per Hectare at First Harvest

Treatment	Population/ha	Production (tons/ha)
J1 (2.5 × 1.25 m)	3,200	2.8 a
J2 (2.0 × 1.5 m)	3,333	2.6 b
J3 (2.5 × 1.5 × 1.5 m)	4,000	3.2 a

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

Although J3 had the highest population (4,000 trees/ha), its production was not significantly different from J1, which had a population of 3,200 trees/ha. This indicates that population increase is not always proportional to production increase if vegetative growth components (stem diameter, number of branches) are compromised. Research by Asruddiin (2023) also showed that the highest robusta coffee productivity was achieved using a spacing of 3 × 3 m, which does not conform to government recommendations, but provides the best results at the farmer level.

These results support the statement by the Head of the Lampung Provincial Plantation Office that the hedge row system can increase production up to 4 tons per hectare (Yuliastuti, 2025; Pemprov Lampung, 2023). However, the production achieved in this study is still below the 4 tons/ha target because it was only the first harvest. In subsequent years, productivity is expected to increase along with optimal plant growth and proper pruning application.

Effect of Pruning Methods on Growth and Production

Pruning is an important component in hedge row coffee cultivation. The objectives of pruning are to form a strong plant framework, stimulate the formation of new fruiting branches, facilitate light and air circulation, and remove unproductive branches (Tim Penulis, 2024; Alnopri et al., 2021).

Coffee plant pruning is divided into three types based on its purpose (Pusat Perbenihan Perkebunan, 2020; Hartatie et al., 2024):

1. Form pruning: aims to form the plant framework such as canopy shape, plant height, and branching type. Performed on young plants aged 1-2 years that have not yet produced (Hartatie et al., 2024).
2. Production pruning: aims to prune unproductive or old branches so that the plant focuses more on growing productive branches.
3. Rejuvenation pruning: performed on plants that have experienced production decline (<400 kg/ha/year) or irregular canopy shape (Pusat Perbenihan Perkebunan, 2020).

Table 4. Average Number of Primary Branches after Pruning

Treatment	Number of Primary Branches
P1 (Standard pruning)	8.7 a
P2 (Layered pruning)	9.4 a

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

Table 5. Average Production per Plant at First Harvest

Treatment	Production (kg fruit/plant)
P1 (Standard pruning)	1.2 a
P2 (Layered pruning)	1.4 b

Note: Numbers followed by different letters in the same column are significantly different at the 5% level

The results showed that the layered pruning method (P2) produced a higher number of primary branches and production per plant compared to standard pruning (P1). Layered pruning with the formation of a secondary trunk (bayonet) allows the plant to have more production areas (Hartatie et al., 2024). Research on robusta coffee plants in Curahpoh Village showed that pruning had a very significant effect on the number of fruit clusters per branch and the number of fruits per cluster compared to unpruned robusta coffee plants, where the average number of clusters per branch in pruned plants reached 19.33 ± 3.8 compared to only 4.67 ± 2.4 in unpruned plants, and the harvest reached 3.4 kg/plant compared to only 1.83 kg/plant in unpruned plants (Tim Penulis, 2024).

Layered pruning is performed by cutting the stem at a height of 120 cm from the ground surface. All emerging sprouts are removed so that branches become strong. After 1-2 years, a second secondary trunk can be grown by maintaining the topmost sprout (Herminingsih et al., 2025). This method is highly suitable for the hedge row system because it allows gradual plant rejuvenation without the need for replanting. Rejuvenation pruning with double trunks has been proven effective in increasing primary branch growth of robusta coffee BP 308 clone (Hartatie et al., 2024).

Agronomically effective pruning also needs to consider frequency. Research by Asruddiin (2023) showed that the best pruning frequency is twice a year, practiced by 27 respondents (84% of respondents) and providing the highest productivity of 0.91 tons/ha on an average land area of 1.43 ha. Pruning of productive branches in coffee plants is effectively used for a maximum of three fruiting periods, where branches that have produced 3 fruiting cycles with less than 4 fruit clusters are considered unproductive branches that need to be pruned to avoid production decline (Tim Penulis, 2024).

Interaction between Plant Spacing and Pruning

The analysis results showed no significant interaction between plant spacing and pruning methods on all observed parameters. This means that both factors work independently in influencing the growth and production of robusta coffee under the hedge row system. However, the J1P2 combination treatment (plant spacing 2.5 m × 1.25 m + layered pruning) numerically gave the highest production results.

Technical Implications for Robusta Coffee Hedge Row System Development in Bengkulu

Based on the research results, several technical recommendations for robusta coffee hedge row system development in Bengkulu are:

1. Plant spacing: The single hedge row system with a spacing of 2.5 m × 1.25 m (J1) or the double hedge row system of 2.5 m × 1.5 m × 1.5 m (J3) can be recommended. J3 produced the highest production although the difference with J1 was not significant. Consideration in selecting plant spacing needs to take into account land conditions, seedling availability, and farmers' maintenance capabilities. Farmers in Bengkulu Province still have limited knowledge about optimal plant spacing, where 100% of respondents in Batu Rotok Village used spacing that did not conform to government recommendations (Asruddiin, 2023).
2. Pruning method: Layered pruning (bayonet) is more recommended compared to standard pruning because it produces higher production per plant. Layered pruning also provides the advantage of

gradual plant rejuvenation (Hartatie et al., 2024). Pruning should be done twice a year for optimal results (Asruddiin, 2023).

3. Integration with GAP: The implementation of the hedge row system needs to be integrated with other Good Agricultural Practices (GAP), including the selection of superior clones such as BP 308 which is drought-tolerant, tolerant to marginal conditions, and nematode-resistant (Hartatie et al., 2024; Muliasari & Nurhikmah, 2020), proper land preparation (planting holes 60 × 60 × 60 cm with manure 6 months before planting), balanced fertilization, and integrated pest and disease control (Tim Penulis, 2024; Alnopri et al., 2023). Increasing farmer knowledge through extension and field schools is essential to optimize the adoption of this technology, as evidenced by the increase in farmer group knowledge after GAP training for coffee cultivation (Tim Penulis, 2024).
4. Demonstration plots and mentoring: The establishment of demonstration plots for hedge row coffee in coffee production centers in Bengkulu such as Kepahiang, Rejang Lebong, and North Bengkulu is highly necessary. These demonstration plots will serve as educational centers for farmers in implementing intensive cultivation techniques, including pruning and the use of organic fertilizers (Pemprov Lampung, 2023; Yuliastuti, 2025). Farmer field schools as a forum for learning among farmers have been proven effective in increasing the adoption of GAP technology in Bengkulu Province (Tim Penulis, 2024; Alnopri et al., 2021).

Research Limitations

This research was only conducted during the early growth phase to the first harvest. Long-term observations are needed to evaluate the impact of the hedge row system on productivity in subsequent years and plant resistance to pests and diseases. Furthermore, this research was only conducted at one location (Kepahiang), so the results cannot be generalized for the entire Bengkulu region. Further research with broader location coverage and longer observation periods is highly necessary to obtain more comprehensive recommendations.

CONCLUSION

1. The optimal plant spacing for the hedge row system in robusta coffee plantations in Bengkulu is the single hedge row system of 2.5 m × 1.25 m or the double hedge row system of 2.5 m × 1.5 m × 1.5 m. Both treatments produced production that did not differ significantly at the first harvest (2.8-3.2 tons/ha).
2. The layered pruning method (bayonet) produced higher production per plant (1.4 kg/plant) compared to standard pruning (1.2 kg/plant). Layered pruning is recommended for application in the hedge row system because it allows gradual plant rejuvenation.
3. There was no interaction between plant spacing and pruning methods, so both factors can be optimized independently according to land conditions and farmer capabilities.
4. The implementation of the hedge row system in Bengkulu requires technical assistance and improvement of farmer knowledge through extension and field schools to optimize production potential.

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