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Effectiveness of Trellis Model and Propagation Direction in Optimizing Growth and Yield of Long Bean Plants (*Vigna sinensis* L)

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Abstract. *The research aims to study the effect of a combination of the trellis model and the direction of plant propagation on the growth and yield of long beans. The environmental design used a randomized block design with six treatments, repeated 5 times. The treatment are the trellis models (fence, triangle and para-para) and plant propagation directions (vertical and mixed). Growth variables include plant length, number of leaves, leaf area, and net assimilation rate. Yield variables include pod length, number of pods, pod weight, and yield per hectare. The results of the research showed that the treatment of different models of trellis and the direction of propagation of long bean plants in the mixed propagation direction resulted in higher plant length, leaf area, net assimilation rate, pod length per plant, pod weight per plant and yield per hectare compared to the vertical propagation direction with the model. the same trellis. The para-para trellis model treatment with mixed propagation directions produced a pod length and number of pods per plant of 60.76 cm and 57.59 pods per plant, 19.30% and 14.31% higher than the para-para trellis model with vertical propagation direction. 58.29 cm and 56.05 pods. The treatment of para-para trellis model with mixed creeping directions produced pod weight per plant and yield per hectare of 1.64 kg per plant and 7.3 ton.ha-1, which was 15.49% and 15.37% higher than the para-para trellis model with vertical propagation direction, which produces 1.42 kg per plant and 6.70 tons ha^{-1}.*

Keywords: *Long bean plant, Stake, Tendril, Vine*

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INTRODUCTION

Long beans (*Vigna sinensi*s L.) are an essential horticultural crop in Indonesia. They are rich in nutrients such as fiber, vitamins C, A, folate, and iron and play a role in maintaining body health. Even though demand for long beans is high, productivity in Indonesia is still fluctuating. Based on data from BPS, extended bean productivity ranges from 7 to 10 tonnes-1, with factors such as climate change and pest attacks significantly affecting crop yields. One technique that can potentially increase productivity is using appropriate supports to support plant growth.

The main challenge in cultivating long beans is using less than optimal cultivation techniques, especially in using trellis and the direction of plant propagation. Improper vine styling often results in the accumulation of tendrils at the top, reducing solar radiation reception and increasing the risk of disease. The solution offered is to modify the trellis and adjust the direction of the vines so that the plants receive more solar radiation and better air circulation, thereby increasing plant productivity.

Some trellis models commonly used in long bean cultivation are the perpendicular, triangle, and para-para modles. Research shows that para-para trellis model with mixed propagation directions can increase crop yields by maximizing solar radiation reception and increasing air circulation around the plants. It is hoped that the combination of the trellis model and the direction of plant propagation can reduce excess air humidity, which can cause disease attacks on plants. The research results show that pruning lateral branches on plants using the para-para trellis model can significantly increase the productivity of long beans.

Even though there have been several studies related to the trellis model, there is still a research gap regarding the best combination of the trellisg model and the optimal direction of plant propagation. Most farmers still use uprights with a vertical propagation direction, which does not fully maximize crop yields. In addition, mixed propagation directions that combine vertical and horizontal have not been widely explored in long bean cultivation. Therefore, further research is needed to find the most practical combination of trellis models and plant propagation directions in increasing extended bean productivity.

The research aims to study the combination of the trellis model and plant propagation direction that is effective in the growth and yield of long bean plants. The research provides practical recommendations for farmers regarding more effective cultivation techniques for increasing long bean yields, especially in the East Java region. It can increase extended bean productivity nationally and support more environmentally friendly and sustainable agricultural practices. In addition, it is hoped that innovative technical solutions will be obtained to increase extended bean productivity through better trellis models and propagation directions.

LITERATURE REVIEW

Long Bean Plant (*Vigna sinensi*s L.)

Long beans (*Vigna sinensi*s L.) are one of the legume plants that are widely developed in Indonesia. This plant has many benefits as a source of vegetable protein and can grow in various soil types. Several factors, such as climate, soil, and cultivation techniques, influence the growth of long beans. Previous research, namely Yosriah (2023), shows that properly managing these factors can increase the yield and quality of long bean plants. Long beans have high economic value and stable market demand, so they are a potential commodity to be developed sustainably.

Trellis Model in Plants

The trellis model is a cultivation technique that supports plant growth by guiding the plant to extend vertically or horizontally. This trellis model is usually applied to vines such as long beans to optimize space use and prevent damage from contact with the ground. Using a trellis model can improve air circulation around plants, reduce disease risk, and make plant maintenance easier (Iskandar, 2022). Using the trellis model has several main benefits, including optimizing the use of planting space and increasing the intensity of solar radiation received by the leaves so that the photosynthesis process can run more efficiently (Hakim, 2021). In addition, this technique also helps maintain plant cleanliness by preventing direct contact between fruit and soil, thereby reducing the risk of contamination, pest attacks, and soil diseases such as root rot and bacterial wilt.

Plant Vine Direction

The direction of vines, including long beans, significantly influences plant growth and yield. Long bean plants generally have a propagation pattern that can be adjusted to maximize solar radiation reception and increase photosynthetic efficiency (Panunggul et al., 2023). The direction of propagation that is adjusted to climatic conditions and spatial arrangement can produce more optimal results. Apart from that, adjusting the direction of plant propagation also contributes to managing the microclimate around the plant. Good vine management can increase air circulation, reduce excess humidity, and prevent diseases caused by fungal infections such as Fusarium and Rhizoctonia. The optimal propagation direction also helps reduce competition between plants regarding lighting so that growth is more even and uniform.

The Effect of Linear Model and Propagation Direction on Plant Growth and Yield

More in-depth research regarding the influence of the slope model and the direction of creeping on long bean crop yields shows that proper regulation can improve the quality and quantity of agricultural products. A slant model that optimizes the use of space and a creeping direction that supports maximum lighting has great potential to increase productivity. Several studies, such as Yekti et al. (2019), show that this technique can improve the quality of the results and reduce post-harvest losses. The Trellis model not only supports plants but also increases the efficiency of solar radiation absorption. Several studies show that long bean plants planted with a vertical trestle system produce faster growth than those without trellises. This is caused by increasing access to solar radiation to all parts of the plant, thereby accelerating the process of photosynthesis and vegetative growth.

The Relationship between the Effectiveness of the Trellis Model and the Direction of Propagation in Long Bean Plants

Several studies suggest that combining an appropriate trellis model with the regulation of plant propagation direction can produce synergies that support the growth of long bean plants. This can increase crop yields significantly. For example, a trellis model with optimal propagation direction can improve the root system, facilitate air circulation, and increase disease resistance (Amin, 2014). Another advantage of the trellis system combined with controlling the direction of propagation is the increase in photosynthetic efficiency. By adjusting the direction of propagation to the sun's position, plants can receive more even light exposure, thereby increasing the energy production needed for flower and fruit formation (Panunggul et al., 2023). This technique can also help reduce the risk of etiolation, where plants grow weak and elongated due to lack of adequate light exposure. Overall, the combination of the right trellis model and optimal propagation direction has been proven to increase the yield and quality of long bean plants. Modern agricultural technology, such as sensor systems for monitoring humidity and light, can also be an innovative solution in optimizing long bean cultivation strategies in various environmental conditions.

RESEARCH METHODS

The research was carried out from October to December 2023. The research was conducted in Tiru Lor Village, Gurah District, Kediri Regency, East Java. The research used long bean seeds of the Bravo variety. The research used a Randomized Block Design (RBD) with six combinations of treatment the trellis model and direction of propagation, which were repeated five times. There were 30 experimental plots, each consisting of 84 planting holes. Each hole consists of 2 plants, a total of 5,040 plants. The trellis models used are the fence model, the triangle model, and the para-para model (Figure 1), and the direction of plant propagation is the vertical propagation direction and the mixed propagation direction (Figure 2). The treatment combinations are fence trellis model + vertical propagation direction, triangle trellis model + vertical propagation direction, para-para trellis model + vertical propagation direction, fence trellis model + mixed propagation direction, triangle trellis model + mixed propagation direction, and para-para trellis model + mixed propagation direction.

Stakes are installed after the plants are 5 – 10 HST so as not to damage the plant's root system. Trellis bamboo has a height of 1.6 m; 1 bamboo is used for each plant. Plant bamboo trellis into beds to a depth of 0.15 m at a distance of 0.05 m from the plants. The research uses three trellis models: fences, triangles, and para-para.

The fence trellis model (Figure 1.A) is installed by attaching bamboo to each plant; then, within the row of plants, the bamboo is tied and connected using a rope resembling a fence. The distance between bamboos is 0.6 m. The triangle trellis model (Figure 1.B) is installed by attaching bamboo to each plant and tilting it. Each bamboo and the tip of the bamboo are tied and connected with a war rope, thus forming a triangle. The length of each bamboo is 1.6 m, and the distance between bamboo is 0.6 m. The para-para trellis model (Figure 1.C) is installed by attaching 1.6 m of bamboo to each plant. The bamboo between the lower plants is connected with gawar ropes, while the bamboo between the rows at the top is connected with bamboo 0.6 m long. The distance between bamboos in a row is 0.6 m.

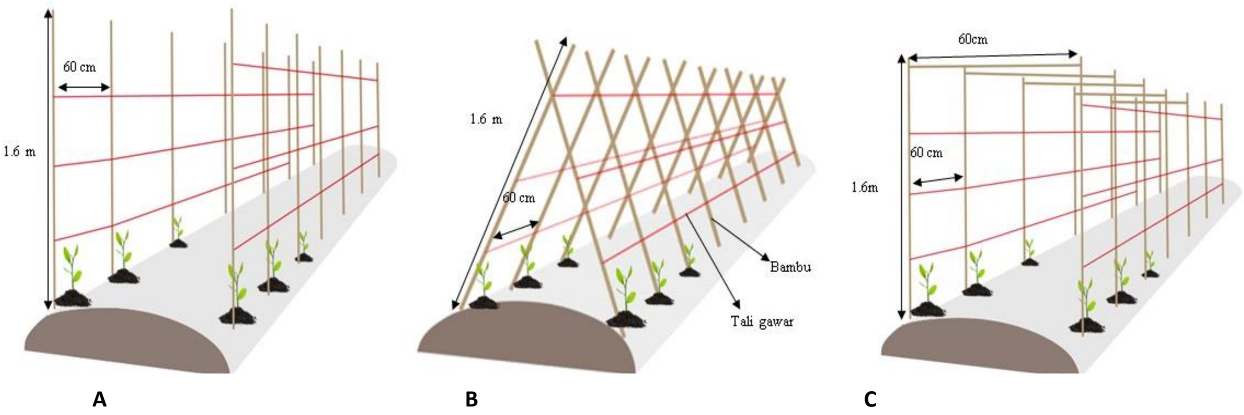


Figure 1. Trellis model used in research.

A. Fence trellis model. B. Triangle trellis model. C. Para-para trellis model

Setting the direction of plant propagation (Figure 2) on plants is carried out at the age of 14 HST. The direction of plant propagation is divided into 2, namely, the vertical propagation direction and the mixed propagation direction (vertical + horizontal). The vertical direction of propagation is carried out by directly propagating the plant on the trellis bamboo (Figure 2.A), while the mixed direction of propagation (Figure 2.B) is carried out by turning the plant onto the rope and again onto the trellis bamboo.

Observations include plant growth variables and plant yield variables. Plant growth variables include observations of plant length (cm), number of leaves (cm), and leaf area (cm^2). Observations were carried out every seven days from the time the plants were 14 HST to 56 HST. Plant yield variables included observations of the number of pods per plant (pods), pod length per plant (cm), pod weight per plant (kg), and harvest yield per hectare (ton ha^{-1}). Observations were made from the first harvest to the twenty-fourth harvest.

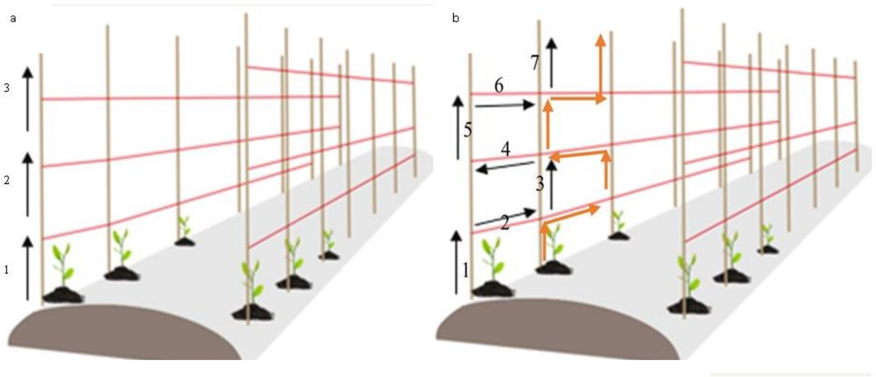
Harvesting is carried out from 43 HST to 89 HST. The characteristics of long beans that are ready to harvest are that the pods are filled, and the color of the pods is light green to dark green. Harvesting is done every 2 days for up to 24 harvests. The 2-day interval is still carried out even though it nears the end. The harvest yields per hectare of plants are calculated by calculating each sample's total harvest from the first harvest to the 24th harvest. According to Suminarti et al. (2021), the formula for harvest yields per hectare is as follows.

$$\text{HYPH} = \frac{\text{Area 1 ha}}{\text{Map Area}} \text{ x Harvest Yield per Plot x Effective Land Area (\%)}$$

Note: Effective land area is obtained from:

$$\text{Effective Land Area (\%)} = \frac{\text{Map Area x number of plots}}{\text{Total land area}}$$

The data obtained were analyzed using the ANOVA (Analysis of Variance) test with a significance level of 5% to determine the effect of the treatment. If treatment has an effect, it will be continued with a further HSD (Honestly Significant Difference) test with a fundamental level of 5% to determine the difference between treatments.



A B

Figure 2. The direction of propagation on the trellis used in the research. A. vertical propagation direction. B. mixed propagation direction

RESULTS AND DISCUSSION

Different trellis models with different plant propagation methods produce different solar radiation reception. Receiving different amounts of solar radiation will also affect the photosynthesis process that occurs in plants. The research results of Solikin (2017) show that tying Dioscorea sansibarensis plants on trellis causes an increase in photosynthesis because there is optimal solar radiation capture due to the position of the leaves that grow vertically. The results of the research show that there is an influence of the treatment of the trellis model and the direction of plant propagation given to long bean plants on plant growth variables, namely plant length, number of leaves, and leaf area (Table 1) and plant yield variables, namely pod length per plant, number of pods per plant.

, pod weight per plant (Table 2), and yield per hectare (Table 3). Further test results showed significant differences between treatments in all plant growth and yield observation variables.

Plant Growth Variables

Receiving solar radiation has a significant influence on plant growth because it is the primary source in the photosynthesis process. Research by Widyawati (2023) shows that the intensity of solar radiation received by plants is directly related to chlorophyll content and plant growth. Plants that receive more solar radiation tend to have higher photosynthesis rates, contributing to plant growth in length. The results showed that the length of the plant in the mixed propagation direction was higher than in the vertical propagation direction in all trellis models. The higher mean value of plant length in the mixed propagation direction (Table 1) indicates the receipt of higher solar radiation in the mixed propagation direction.

Table 1. Average plant length, number of leaves, and leaf area of long bean plants in various combinations of plant growth models and direction of propagation at the observation age of 56 days after planting

Treatment	Observation Age 56 Days After Planting (DAP)		
	Plant Length (cm)	Number of Leaves (pieces)	Leaf area (cm^2)
Fence+vertical propagation direction	347,22 ab	44,65 ab	1213,12 ab
Triangle+vertical propagation direction	310,10 a	34,04 a	1099,10 a
Para-para+vertical propagation direction	367,44 b	44,63 ab	1286,68 ab
Fence+mixed propagation direction	411,19 c	59,54 c	1580,29 c
Triangle+mixed propagation direction	380,82 bc	47,09 b	1481,10 bc
Para-para+mixed propagation direction	418,44 c	60,26 c	1603,47 c
HSD 5%	42,00	10,89	275,48

Note: Numbers accompanied by the same letter in the same column are not significantly different based on the HSD test with levels of 5%

Increasing the number of leaves and leaf area in plants significantly influences the photosynthesis process, which is key to plant growth and productivity. A larger leaf area allows plants to capture more solar radiation, the primary energy source for photosynthesis. A larger leaf area increases a plant's capacity to capture solar radiation. According to Khamidi et al. (2022), the capacity of leaves to carry out photosynthesis is influenced by their chlorophyll content, and increasing the leaf area index and chlorophyll content can increase the plant growth rate. The results showed that the number of leaves and leaf area of long bean plants in the mixed propagation direction was higher than in the vertical propagation direction in all trellis models. Higher leaf area values in the mixed propagation direction (Table 1) indicate higher receipt of solar radiation when applying mixed propagation directions in long bean plants.

Crop Yield Variables

The results showed that the length of the pods per plant, the number of pods per plant, the weight of the pods per plant (Table 2), and the yield per hectare (Table 3) in all trellis models and mixed propagation directions had higher yields compared to the same trellis model but at vertical propagation direction. The mixed propagation directions in various trellis models allow more effective reception of solar radiation on the leaves of long bean plants so that it will affect the number of pods per plant, pod length per plant, pod weight per plant (Table 2), and crop yield per hectare (Table 3). Receiving optimal solar radiation through the mixed propagation direction allows the plant to carry out photosynthesis efficiently, contributing to an increase in pods. This is in line with the research results of Noor et al. (2021) on corn plants, which showed an increase in corn plant yields at different planting distances and receiving different amounts of solar radiation. Research by Raksun and Japa (2019) shows that plants that receive optimal solar radiation have better pod length than plants blocked by light. Mixed propagation directions can increase leaf exposure to light, thereby supporting longer pod growth.

Table 2. The average length of pods per plant, number of pods per plant, and weight of pods per long bean plant in treatments with various combinations of trellis models and plant propagation directions

Treatment	Pod Length per Plant (cm)	Number of Pods per Plant (pods)	Pod Weight per Plant (Kg)
Fence+vertical propagation direction	48,01 ab	49,31 ab	1,32 ab
Triangle+vertical propagation direction	44,72 a	45,33 a	1,24 a
Para-para+vertical propagation direction	50,93 ab	50,38 b	1,42 bc
Fence+mixed propagation direction	58,29 cd	56,05 c	1,61 d
Triangle+mixed propagation direction	52,10 bc	51,11 b	1,48 c
Para-para+mixed propagation direction	60,76 d	57,59 c	1,64d
HSD 5%	6,21	4,62	0,11

Note: Numbers accompanied by the same letter in the same column are not significantly different based on the HSD test with a level of 5%

Table 3. Yield per hectare of long bean plants treated with various combinations of trellis models and plant propagation directions

Treatment	Harvest Yield per Hectare (ton.ha $^{-1}$)
Fence+vertical propagation direction	6,24 ab
Triangle+vertical propagation direction	5,84 a
Para-para+vertical propagation direction	6,70 bc
Fence+mixed propagation direction	7,59 d
Triangle+mixed propagation direction	6,97 c
Para-para+mixed propagation direction	7,73 d
HSD 5%	0,53

Note: Numbers accompanied by the same letter in the same column are not significantly different based on the HSD test with a level of 5%

CONCLUSION

Changing the direction propagation to a mixed propagation direction results in variable values of plant length, number of leaves, leaf area, pod length per plant, number of pods per plant, pod weight per plant, and yield per hectare of long beans to be higher compared to the vertical propagation direction with the same trellis model. The combination of the para-para trellis model and mixed propagation direction shows a yield per hectare of 1.64 ton.ha^{-1} and 1,61 ton.ha^{-1}, which is 15.49% and 21.96% higher than the para-para trellis model and the vertical propagation direction which shows the yield perhectare 1,42 ton.ha^{-1} and 1,32 ton.ha^{-1}.

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