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Effect of Plant Spacing and Pruning on the Growth and Yield of Cucumber (*Cucumis sativus*L.)

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ABSTRACT

This study aimed to evaluate the effects of planting distance and main stem pruning, as well as their interaction, on the growth and yield of cucumber plants. The research was conducted in Mattampapole Village, Mallawa District, Maros Regency, from April to June 2025. The experiment was arranged in a randomized block design (RBD) with a two-factor factorial scheme. The first factor was planting distance, consisting of 20 × 60 cm, 30 × 60 cm, and 40 × 60 cm. The second factor was pruning treatment, including no pruning and pruning by retaining 8, 10, and 12 nodes on the main stem. A total of 12 treatment combinations were obtained and replicated three times, resulting in 36 experimental units. The results showed that the 40 × 60 cm planting distance produced the highest number of leaves (28.33 leaves). In contrast, the 30 × 60 cm planting distance resulted in the highest number of productive branches (5.64 branches) and the greatest fruit weight, reaching 1,027.33 g per plant or equivalent to 10.27 t ha^{-1}. Pruning by retaining 10 nodes on the main stem produced the highest number of leaves (29.33 leaves). An interaction was observed between the 30 × 60 cm planting distance and pruning at the eighth node, which resulted in the highest fruit weight.

INTRODUCTION

Kailan Cucumber (*Cucumis sativus* L.) is a widely distributed crop in Indonesia. The cucumber plant originates from the Asian continent and subtropical regions. It is classified as an annual plant belonging to the Cucurbitaceae family. Cucumbers are adaptable to both hot and cool climates and can grow optimally from lowland to highland areas (Mari & Noni, 2022). Due to its broad adaptability and relatively easy cultivation, cucumber farming is widely practiced across various regions of Indonesia.

Cucumber production in Indonesia has shown fluctuations over recent years. In 2021, cucumber production in South Sulawesi reached 8,404 tons and increased to 9,151 tons in 2022. However, production declined again in 2023 to 8,717 tons. This decrease was attributed to insufficient cultivation intensification, inefficient fertilizer use, and the selection of less superior varieties (BPS-Statistics Indonesia, 2024). Efforts to increase cucumber yield require improvements in cultivation techniques, including appropriate fertilization, selection of superior varieties, optimal plant spacing, and proper pruning practices. These factors are interrelated and have a direct impact on both the quality and quantity of yield.

Cucumber plants exhibit a vining growth habit and develop dense foliage, which necessitates relatively wide plant spacing. Low plant density can hinder growth, while excessively high density may reduce plant population and encourage weed development (Loleh et al., 2018). Therefore, appropriate plant spacing is essential to minimize competition among plants and weeds for water, sunlight, and nutrients. In addition, proper spacing can reduce the incidence of pests and diseases by improving air circulation around the plants.

Plant spacing is one of the agronomic factors that significantly influences crop productivity. When plants are grown too closely, competition for air, water, and nutrients increases, which can suppress plant growth. Conversely, excessively wide spacing leads to inefficient land use and may reduce yield per unit area. Thus, determining the appropriate planting distance is crucial in crop cultivation. Optimal spacing can enhance yield

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by improving light interception and nutrient use efficiency, and it can promote better plant height and leaf development (Suwarti & Suwardi, 2020). Overly dense planting has been shown to negatively affect plant growth and productivity (Rasyid, 2023); therefore, planting distance must be carefully planned to achieve optimal results.

On the other hand, excessively wide spacing can also have adverse effects on plant growth. Wider spacing may increase soil evaporation, leading to reduced soil moisture and water stress for plants. Furthermore, vacant spaces between plants can be easily occupied by weeds, resulting in increased competition for soil nutrients. This condition also decreases land-use efficiency and may lead to reduced overall yield. To address this issue, Masitoh et al. (2018) recommended a planting distance of 30 cm × 60 cm as agronomically optimal, as it reduces interplant competition while enhancing land-use efficiency. This spacing also facilitates cultivation practices such as pruning and weed control and improves air circulation around plants, which plays an important role in suppressing plant pest and disease incidence.

Research conducted by Randi et al. (2024) indicated that a planting distance of 40 cm × 60 cm was the most effective treatment for cucumber growth and yield. The results showed no significant interaction between planting distance and the number of seeds per planting hole for all observed growth and yield variables. This indicates that the response of cucumber plants to planting distance is independent of seed number per planting hole. These findings are consistent with Sulfa et al. (2017), who reported that a spacing of 40 cm × 60 cm produced the longest fruit length, reaching 28.89 cm. Wider spacing provides plants with sufficient space to grow optimally without excessive competition for nutrients, water, and sunlight. Similarly, Tyandra et al. (2020) concluded that a spacing of 40 cm × 60 cm is more suitable for cucumber cultivation, allowing optimal nutrient absorption with minimal competition among plants.

The regulation of plant spacing is therefore a strategic approach to significantly increasing cucumber yield. Optimizing planting distance helps create favorable conditions for both healthy vegetative growth and maximum generative production.

In addition to plant spacing, cucumber production can be enhanced through growth regulation via pruning. Pruning involves the removal of certain plant parts, such as branches, shoots, or leaves, to prevent undesirable growth patterns. Pruning aims to reduce excessive vegetative growth and promote generative growth (fruit formation), increase light penetration, reduce humidity around the plant, control excessive plant height for easier management, and improve fruit quality (Wawo et al., 2019). Proper pruning stimulates the growth of more productive shoots, enabling plants to produce more flowers and fruits. By removing old and unproductive plant parts, resources can be redirected to healthier tissues with greater yield potential.

Plants with excessive foliage tend to allocate more energy to vegetative growth rather than fruit production. Therefore, pruning in cucumber cultivation is carried out to regulate the development of the main stem and lateral branches, allowing more efficient light distribution to leaves and flowers. This condition positively affects flowering quality and yield (Simamora, 2025).

The primary objective of pruning is to limit vegetative growth-such as excessive leaves, stems, and roots-that does not directly contribute to fruit yield. Excessive vegetative growth diverts energy away from reproductive development, thereby inhibiting flower and fruit formation. Through pruning, plant energy is redirected toward the production of more flowers and fruits, ultimately increasing yield.

Moreover, pruning improves land-use efficiency by creating a more orderly plant structure, which facilitates crop management activities such as irrigation, fertilization, and weed control. According to Mading et al. (2021), branch pruning increases leaf surface area, light distribution, and photosynthetic potential compared to unpruned plants. An interaction between plant spacing and pruning treatments has been reported, where their combination resulted in a total yield of up to 1.5 tons per hectare. These findings suggest that both practices play a significant role in optimizing crop performance (Hadiet al., 2015). Based on the above background, it is necessary to conduct research on appropriate plant spacing and pruning techniques to optimize cucumber cultivation and improve productivity.

MATERIALS AND METHODS

This study was conducted in Mattampapole Village, Mallawa District, Maros Regency, at an altitude ranging from 700 to 881 meters above sea level. The research was carried out from April to June 2025. The materials used in this study included Urea fertilizer, SP-36, KCl, NPK Mutiara (16:16:16), chicken manure, cucumber seeds of the Hercules variety, 70% alcohol and insecticides (Sevin and Regent). The equipment used consisted of a platform scale, machete, hoe, rake, shovel, measuring tape, bucket, raffia rope, wood stakes, plant stakes, scissors, knife, cutter, caliper, ruler, camera, and stationery.

The experiment employed a Randomized Block Design (RBD) with a two-factor factorial arrangement. The first factor was plant spacing (J), consisting of J1 = 20 cm × 60 cm, J2 = 30 cm × 60 cm, J3 = 40 cm × 60 cm The second factor was pruning treatment (P), consisting of, P0 = No pruning, P1 = Retaining 8 nodes on the main branch, P2 = Retaining 10 nodes on the main branch, P3 = Retaining 12 nodes on the main branch. Based on these two factors, there were 12 treatment combinations. Each treatment was replicated three times, resulting in a total of 36 experimental units

RESULTS AND DISCUSSION

1. Plant Height

The results of plant height observations under different planting spacing and pruning treatments are shown in the figure below.

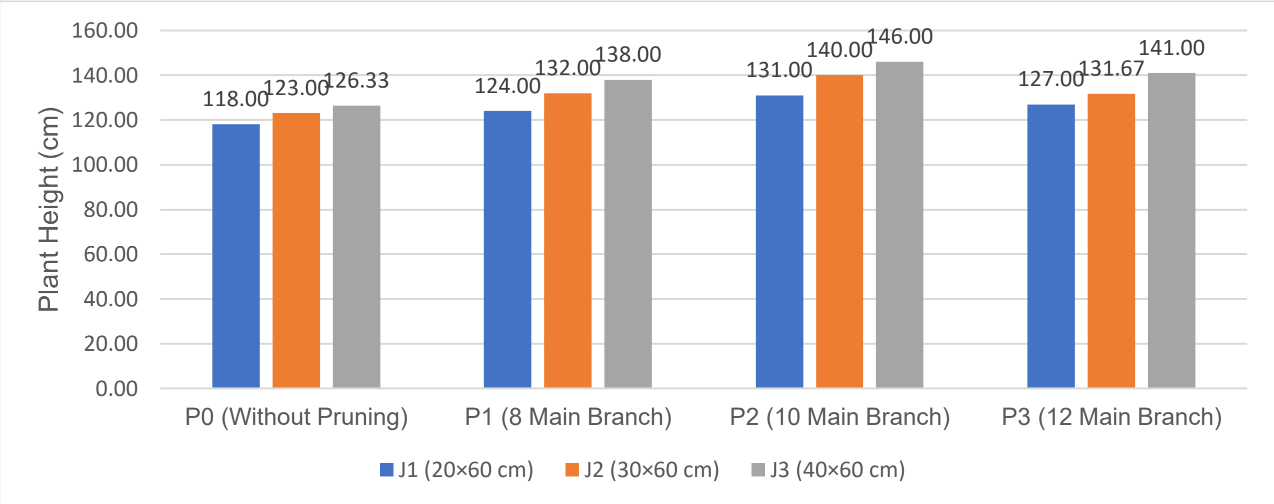

Figure 1. Diagram of the Average Plant Height of Cucumber

The data showing that the combination of a 40 cm × 60 cm planting spacing and pruning by retaining 12 nodes (J3P2) resulted in the highest average plant height of 146.00 cm indicates a significant synergy between planting density and pruning practices in cucumber (*Cucumis sativus* L.) cultivation. These results underscore the potential of such agronomic practices to optimize cucumber growth and yield, which is an important concern for farmers seeking to improve productivity under varying environmental conditions.

Plant Spacing and Its Effect on Growth The selection of planting density is a crucial factor in managing canopy development in cucumber plants. Numerous studies have shown that wider spacing, such as the 40 cm × 60 cm applied in the J3P2 treatment, allows better air circulation and light penetration, which are essential for maximizing photosynthesis and overall plant growth. Loleh et al. (2018) emphasized that adequate plant spacing can reduce interplant competition for essential resources, which, when excessive, may suppress plant height and vigor (Reddy et al., 2023). Moreover, appropriate spacing promotes healthy vegetative growth, enabling plants to reach optimal height and potentially reducing the incidence of pests and diseases that commonly develop in dense canopies (Reddy et al., 2023; Purwaningrahayu & Kuntyastuti, 2023).

In contrast, the combination of closer spacing (20 cm × 60 cm) without pruning (J1P0) resulted in a lower average plant height of 118.00 cm. Such crowded conditions likely increased competition among plants for light, water, and nutrients, thereby constraining plant growth. This finding is consistent with Suwarti and Suwardi (2020), who reported that excessive planting density can significantly inhibit growth due to intensified resource competition, as densely grown plants often experience insufficient light and nutrient availability, leading to suboptimal development (Jalani et al., 2024).

Pruning and Its Role in Enhancing Growth, Pruning practices play a critical role alongside plant spacing in supporting the health and growth of cucumber plants. Selective removal of branches and leaves through pruning helps direct assimilates and energy toward productive shoots, thereby potentially enhancing overall plant productivity. Wawo et al. (2019) reported that properly managed pruning in cucumber can improve light distribution and reduce humidity around the plant canopy, which is important for maintaining healthy growth and increasing fruit production (Choi et al., 2023). This practice also helps prevent excessive vegetative growth that may divert resources away from generative functions (flowering and fruiting) (Choi et al., 2023; Nath et al., 2024).

The pruning treatment retaining 12 nodes (J3P2) reflects effective crop management because it stimulates the development of more productive lateral branches, thereby increasing yield potential without compromising plant height. The findings of Mading et al. (2021) support this observation, showing that appropriate pruning is associated with increased leaf area and improved light interception (Kisman et al., 2025). This contrasts with the unpruned treatment (J1P0), where growth limitations were more pronounced due to uncontrolled vegetative growth patterns under limited resource availability.

Overall, the results strengthen the evidence for a clear relationship between optimal planting distance and pruning methods in cucumber cultivation, both of which significantly influence plant height and overall productivity. A strategy that combines wider spacing with efficient pruning can produce healthier plants that utilize resources more effectively, leading to improved yields. Kisman et al. (2025) suggested that the adoption of integrated agronomic practices can support sustainable agricultural production amid challenges posed by fluctuating environmental conditions. Therefore, the strategic implementation of proper spacing and pruning management remains key to achieving optimal growth in cucumber farming.

2. Number of Leaves

The results of Number of leaves observations under different planting spacing and pruning treatments are shown in the figure below.

Tabel 1. Interaction Effect of Plant Spacing and Pruning Intensity on Productive Branch Number

Plant Spacing	P0 (0)	P1 (8)	P2 (10)	P3 (12)	Average	LSD 5%
J1 (20 cm × 60 cm)	19.00	23.00	26.00	24.67	23.17[c]	0.56
J2 (30 cm × 60 cm)	21.00	26.33	29.00	27.67	26.00[b]	
J3 (40 cm × 60 cm)	22.00	28.00	33.00	30.33	28.33[a]	
Average	20.67[d]	25.78[c]	29.33[a]	27.56[b]		
LSD 5%	0.75					

Note: Values followed by different letters within the same row (a, b, and c) indicate significant differences at the 5% LSD test level.

The results of the 5% Least Significant Difference (LSD) test presented in Table 2 indicate that planting spacing and pruning techniques had a significant effect on the number of leaves produced by cucumber plants (Cucumis sativus L.). Specifically, a planting spacing of 40 cm × 60 cm resulted in an average of 28.33 leaves per plant, which was significantly higher than the closer spacing of 20 cm × 60 cm, which produced only 23.17 leaves per plant. Similarly, the pruning treatment retaining 10 nodes on the main stem (P2) showed superior results, with an average of 29.33 leaves per plant, compared to the unpruned treatment (P0), which produced only 20.67 leaves per plant. These findings confirm a synergistic effect of both agronomic practices in enhancing leaf development, which is a critical factor for overall plant growth and productivity.

Differences in leaf number based on planting spacing can be explained by the physiological response of cucumber plants to competition for growing space. Numerous studies have shown that wider spacing allows better light penetration and more optimal air circulation around plants, both of which are essential for photosynthesis and growth. This is supported by studies reporting that optimal spacing reduces competition for light, water, and nutrients, thereby promoting better leaf development (Tomasoa, 2025; Sole et al., 2022). Tomasoa (2025) reported that increasing plant density can reduce leaf development due to intensified interplant competition, ultimately resulting in lower leaf numbers under denser planting conditions. This evidence indicates that planting configuration plays a critical role not only in leaf production but also in overall plant health and yield potential of cucumber crops.

Pruning also significantly influenced leaf development, as demonstrated by the pruning treatment retaining 10 nodes (P2), which resulted in the highest leaf number. Pruning promotes greater leaf production by allowing plants to redirect energy from excessive vegetative growth toward the development of more vigorous leaves and fruits. In contrast, the unpruned treatment (P0) likely caused plant energy to be dispersed into less productive canopy growth, making it less efficient in supporting the development of generative organs. This is consistent with the findings of Sole et al. (2022), who emphasized the importance of pruning in optimizing plant resource allocation by influencing leaf retention and overall growth characteristics, ultimately leading to improved yield outcomes.

The data demonstrate that both planting spacing and pruning are important factors that can be strategically utilized to enhance cucumber productivity. Integrating optimal spacing with effective pruning not only increases leaf number but also contributes to the formation of healthier plant architecture and potentially higher yields. Numerous studies continue to emphasize that these agronomic strategies, when properly implemented, can significantly improve cucumber growth and yield (Tomasoa, 2025; Sole et al., 2022). These findings highlight the importance of adopting a multifactorial approach in cucumber cultivation to maximize productivity and resource-use efficiency.

3. Time to 50% Male Flowering

The results of time to 50% male flowering under different planting spacing and pruning treatments are presented in the figure below.

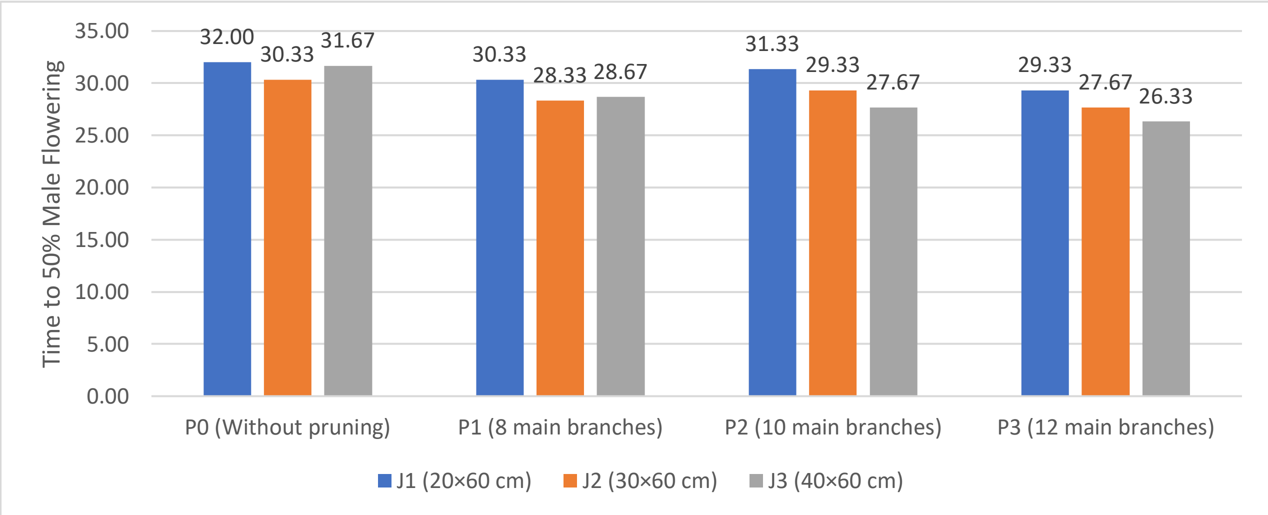

Figure 2. Average Time to 50% Male Flowering in Cucumber

Based on Figure 2, the flowering time in relation to planting spacing and pruning techniques provides important insights for optimizing the cultivation of flowering plants. Specifically, the combination of a planting spacing of 40 cm × 60 cm with a pruning treatment of 12 nodes on the main stem (J3P3) showed a significant effect on the timing of male flower emergence, with an average of 26.33 days. In contrast, closer spacing of 20 cm × 60 cm combined with no pruning (J1P0) resulted in delayed flowering, reaching 32.00 days. This clear difference emphasizes the importance of planting arrangement and crop management practices, such as pruning, in influencing the phenological traits of flowering plants.

Pruning plays a crucial role in regulating plant growth and development, including influencing flowering time through changes in resource allocation within the plant. In cassava, studies have shown that flower induction can be enhanced through environmental modifications, such as extending the photoperiod with red-light supplementation, as well as through cultural practices like pruning (Baguma et al., 2023). The physiological mechanisms underlying this phenomenon are associated with hormonal signaling pathways that are stimulated by light and are also modulated by the removal of plant tissues through pruning (Nateshkumar et al., 2025). This relationship underscores the potential to manipulate flowering time through targeted agronomic practices, which can be aligned with market demands for earlier-flowering cultivars or to optimize fruit yield.

In addition to pruning, planting spacing also influences flowering time. Studies on guava have shown that high-density planting combined with appropriate pruning can increase flower bud formation and accelerate flowering (Nautiyal et al., 2023). Similar findings in other crops, such as long melon and cucumber, indicate that closer spacing accompanied by controlled pruning can significantly hasten flowering through improvements in microclimatic conditions and enhanced resource acquisition (Singh et al., 2022; Gyawali et al., 2025). In contrast, wider spacing, although suitable for certain crops, may result in less efficient resource competition, which can delay phenological events such as flowering.

4. Time to 50% Female Flowering

The results of time to 50% female flowering under different planting spacing and pruning treatments are presented in the figure below.

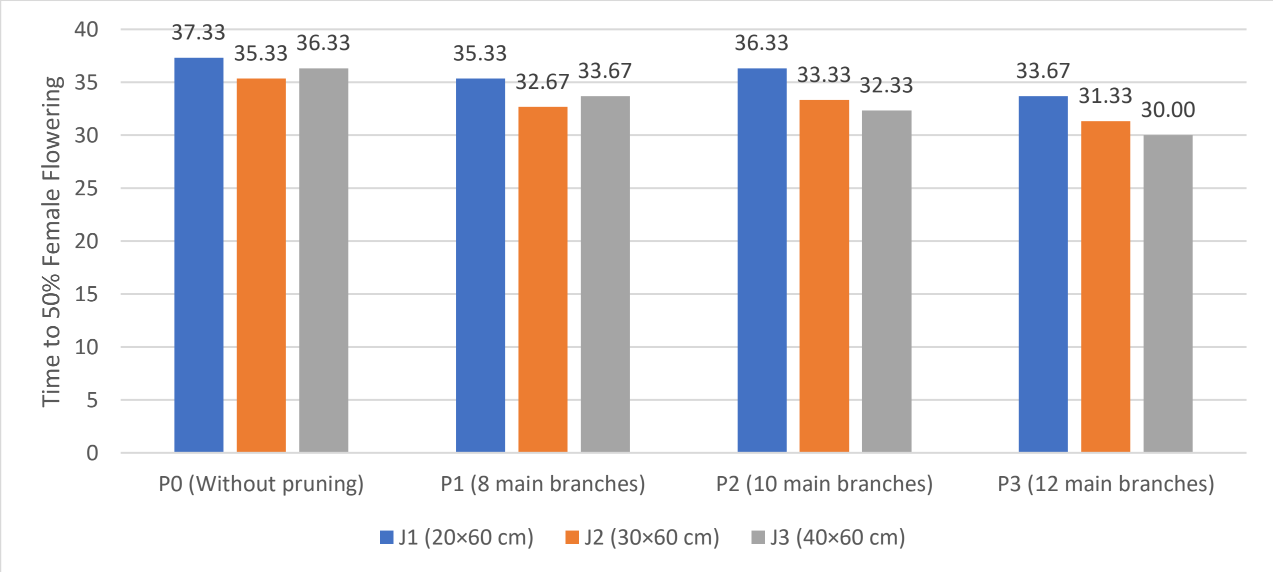

Figure 3. Average time to 50% female flowering in cucumber plants.

Based on Figure 3, there were significant differences in the time required to reach 50% female flowering across treatments of planting spacing and pruning practices. Specifically, the treatment with a planting spacing of 40 cm × 60 cm (J3P3) reached 50% female flowering earlier, at 30.00 days, whereas the denser planting spacing of 30 cm × 60 cm without pruning (J1P0) resulted in delayed flowering, reaching 50% female flowering at 37.33 days. These results indicate that the regulation of planting spacing and horticultural management practices can significantly influence flowering phenology in flowering plants.

Previous studies have shown that manipulation of plant density and crop management techniques such as pruning play an important role in flowering induction. Optimal planting spacing combined with shoot pruning (pinching) has been reported to positively affect flowering and seed yield, highlighting that appropriate spatial arrangement not only enhances flowering rate but also improves overall plant performance (Pant et al., 2022). Similarly, Baral et al. (2022) reported that the application of various plant growth regulators combined with pruning in cucumber plants could accelerate flowering time. These findings suggest that plant physiological responses to external interventions are strongly influenced by genetic factors and environmental conditions.

The benefits of wider plant spacing can be attributed to improved microclimatic conditions that support the flowering process. Optimal spacing minimizes inter-plant competition for light and nutrients, thereby promoting better growth and accelerating the onset of flowering (Aftab et al., 2024). The earlier flowering observed in the J3P3 treatment is likely associated with increased resource availability under wider spacing, enabling plants to allocate more energy to reproductive processes rather than vegetative growth.

In contrast, the delayed flowering observed in the non-pruned treatment is likely related to higher competition for resources. Denser planting generally increases competition among plants for light, water, and nutrients, which can ultimately delay the transition to the reproductive phase, as reported in several studies on cucumber and tomato (Hussien & Ahmed, 2023). This underscores the critical role of crop management practices in ensuring timely flowering and overall production success, and reinforces the importance of adjusting planting configuration according to specific cultivation objectives.

5. Number of Productive Branches

Based on the results of observations on the number of productive branches under different planting spacing and pruning treatments, the data are presented in the table below.

Table 2. Interaction between Plant Spacing and Pruning on the Number of Productive Branches

Plant Spacing (cm)	Prunning Main Branches				Average	LSD 5%
	P0 (0)	P1 (8)	P2 (10)	P3 (12)		
J1 (20x60)	3.78	4.11	4.56	5.55	4.50^c	0.07
J2 (30x60)	4.67	5.44	6.22	6.22	5.64^a	
J3 (40x60)	4.45	4.67	5.78	6.22	5.28^b	
Average	4.30^d	4.74^c	5.52^b	6.00^a		
LSD 5%	0.1					

Note: Numbers followed by different letters within rows (a, b, and c) and within columns (a, b, c, and d) indicate a significant difference at the 5% Least Significant Difference (LSD) test level

The results of observations on the effects of planting spacing and pruning on the number of productive branches presented in Table 2 indicate that these factors significantly influence plant productivity. The results showed that a planting spacing of 30 cm × 60 cm (J1P0) produced a significantly higher average number of productive branches, namely 5.64 branches. This result differed from the narrower spacing of 20 cm × 60 cm, which produced an average of only 4.50 productive branches, as well as from the wider spacing of 40 cm × 60 cm. These findings indicate that optimal planting spacing plays a major role in determining branching architecture and overall plant productivity.

The influence of planting spacing on vegetative characteristics, such as branch number, has been widely reported in various crops. Differences in planting spacing significantly affect the number of fruits, indicating that appropriate spatial arrangement creates more favorable growth conditions for the formation of productive structures (Altundag & Karademir, 2021). Similarly, planting spacing influences not only branch number but also yield and crop quality, highlighting the importance of adjusting agronomic inputs according to crop type and local growing conditions (Pradhan et al., 2023).

The pruning treatment at 12 nodes (P3) resulted in the highest number of productive branches, with an average of 6.00 branches. This value was significantly higher than that obtained with pruning at fewer nodes (P2 at 10 nodes and P1 at 8 nodes) and markedly higher than the no-pruning treatment (P0), which produced only 4.30 productive branches on average. Appropriate crop management practices, including effective pruning, have been shown to significantly enhance vegetative growth in cucurbit crops (Nmor et al., 2025). Pruning effectively redirects plant assimilates toward the formation of productive structures, as reflected in the increased number of branches with the potential to bear flowers and fruits.

6. Fruit Length of the Crop

The effect of planting spacing and pruning techniques on fruit length can be seen in the following figure.

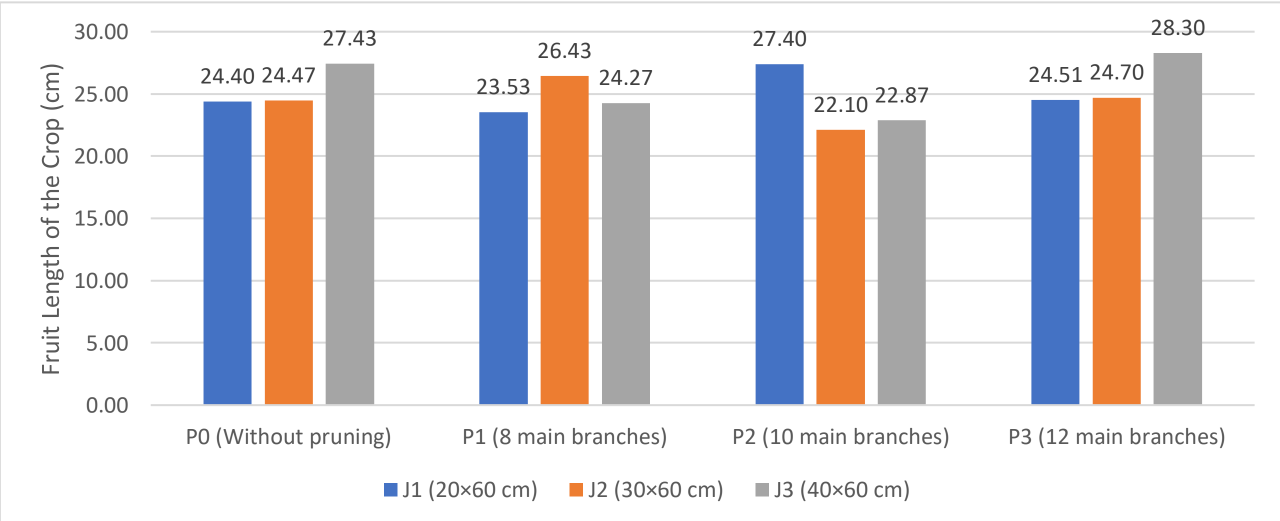

Figure 4. Average length of cucumber fruits

The results presented in Figure 4 show a significant pattern regarding the effects of planting spacing and pruning on fruit length in flowering plants. Specifically, the treatment with a planting spacing of 40 cm × 60 cm combined with pruning at 12 nodes on the main branch (J3P3) produced the longest average fruit length, reaching 28.30 cm. In contrast, the treatment with a planting spacing of 30 cm × 60 cm and pruning at 10 nodes (J2P2) resulted in shorter fruits, with an average length of only 22.10 cm. These findings underscore the importance of the interaction between planting spacing and horticultural management practices in determining fruit development and overall crop productivity.

The observed pattern of fruit length can be explained by plant physiological dynamics and resource allocation influenced by differences in planting spacing and pruning intensity. Wider spacing, as in the J3P3 treatment, allows more efficient utilization of light, nutrients, and water, thereby creating optimal growth conditions that contribute to larger fruit size. Wider plant spacing has been reported to positively affect yield and quality in long gourd, particularly by increasing fruit size (Singh et al., 2021). Similarly, appropriate spatial arrangement in seedless watermelon has been positively correlated with fruit yield and its components, further emphasizing the importance of spatial configuration in crop management (Agić et al., 2022).

In terms of pruning, the 12-node pruning treatment (P3) was more effective in promoting fruit development than the lower pruning intensity of 10 nodes (P2). Several studies have shown that pruning can reduce competition among branches and redirect plant resource allocation toward fruit development, resulting in larger fruit size. Systematic pruning has been reported to improve fruit quality and size in cucumber, indicating that the timing and intensity of pruning are critical factors in maximizing yield potential (Gyawali et al., 2025). The substantial difference in fruit length between the J3P3 and J2P2 treatments illustrates how crop management techniques can have a tangible impact on agricultural outcomes.

The interaction between pruning and planting spacing is an important aspect, as demonstrated in various horticultural studies. Reduced planting spacing combined with appropriate pruning techniques has been shown to increase yield in Jatropha hybrids, indicating that combined crop management practices can optimize plant performance (Arunyanark et al., 2023). Dense planting systems balanced with proper pruning can shape more favorable plant architecture, thereby positively affecting fruit quality and quantity (Nautiyal et al., 2023). This suggests that the greater fruit length observed under wider spacing with more intensive pruning is likely attributable to more optimal allocation of growth resources to productive branches.

7. Fruit Number per Plant

The effect of planting spacing and pruning techniques on Fruit number per plantcan be seen in the following figure.

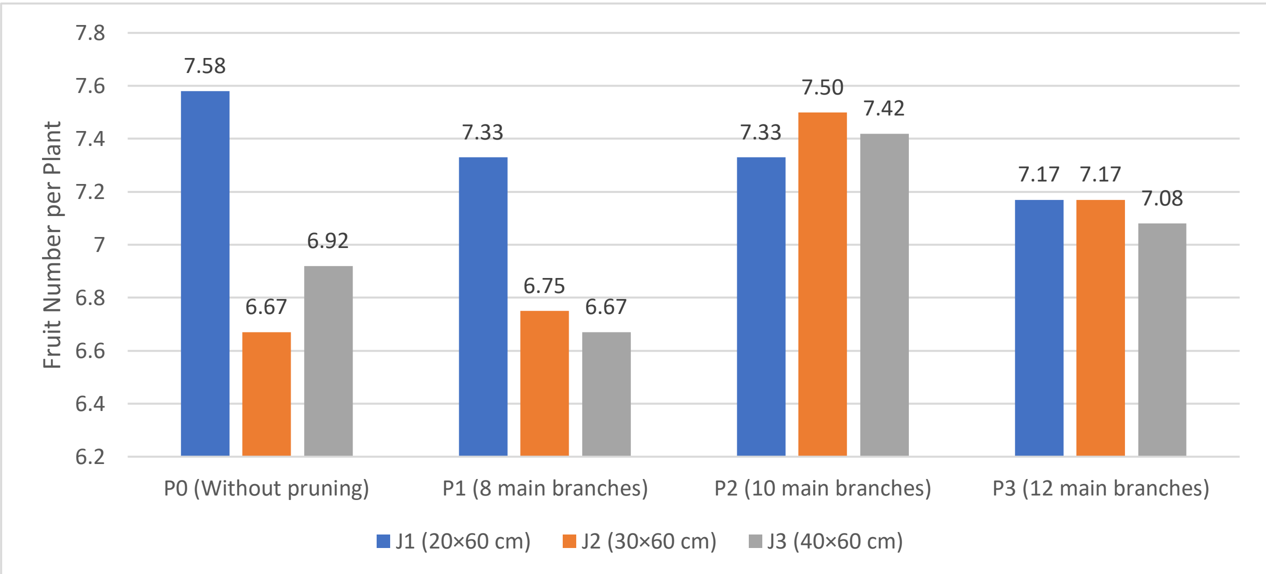

Figure 5. Average number of fruits per plant in cucumber

The results presented in Figure 5 show a clear trend regarding the effects of planting density and pruning practices on fruit yield in flowering plants. The treatment with a spacing of 20 cm × 60 cm without pruning

(J1P0) produced a higher average number of fruits per plant, reaching 7.58 fruits, whereas the combination of a spacing of 40 cm × 60 cm with pruning at 8 nodes on the main branch (J3P1) resulted in a lower fruit number, with an average of 6.67 fruits per plant. These findings indicate that variations in crop management practices can significantly influence fruit production outcomes.

The relationship between planting density and fruit yield has been widely discussed in agricultural literature. Closer spacing, as in the J1P0 treatment, often increases competition among plants for light, water, and nutrients. However, under appropriate management conditions, high-density planting systems can produce relatively higher fruit yields per plant or per unit area due to more efficient resource utilization (Sogam et al., 2024). Increasing planting density has the potential to enhance yield per unit area when properly managed, suggesting that high-density systems can be applied in intensive fruit production (Singh et al., 2022).

Under wider spacing combined with pruning, fruit formation may decrease due to a shift in resource allocation toward lateral vegetative growth, thereby reducing reproductive output. Although pruning is beneficial for controlling plant size and improving light penetration, it must be carefully calibrated to avoid reducing the number of productive growing points. Several studies have shown that inappropriate or excessive pruning can delay flowering or significantly reduce fruit numbers because plants allocate more energy to vegetative structures rather than reproductive ones (Mooy & Ali, 2022).

The interaction between planting spacing and pruning is directly associated with growth and yield characteristics. Previous studies have indicated that although pruning may improve fruit quality in certain contexts, it can also limit yield if not balanced with appropriate spacing arrangements (Reddy et al., 2023). Fruit number is influenced not only by individual plant health but also by plant density and spatial arrangement within a given area, as plant interactions can create microclimatic variations that affect flowering and fruiting patterns.

The observed differences in yield further emphasize the importance of optimizing planting spacing and pruning strategies to maximize productivity effectively. Interactions among plants under different planting densities can serve as a basis for more targeted agronomic interventions to enhance yield across diverse cropping systems (Chaitra et al., 2024).

8. Yield

Effects of plant spacing and pruning techniques on cucumber yield were analyzed in this study. The results of the observations are concisely presented in Table 5, which shows the average yield of cucumber plants under various combinations of spacing and pruning levels.

Table 5. Average yield of cucumber plants under different spacing and pruning treatments

Plant Spacing (cm)	P0 (Without pruning)	P1 (8 main branches)	P2 (10 main branches)	P3 (12 main branches)	LSD 5%
J1 (20 × 60)	9.21^{a}	9.50^{a}	9.25^{a}	9.94^{a}	
J2 (30 × 60)	10.24^{a}	10.27^{a}	8.87^{b}	9.07^{a}	1.30
J3 (40 × 60)	6.31^{b}	10.12^{a}	10.00^{a}	9.57^{ab}	

Note: Values followed by different letters within rows (a and b) differ significantly at the 5% LSD level

The results of the 5% LSD test indicate that planting spacing and pruning practices significantly affected the yield of flowering plants. Specifically, the treatment with a planting spacing of 30 cm × 60 cm combined with pruning at 8 nodes on the main branch (J2P1) produced the highest average yield, reaching 10.27 tons ha^{-1}, whereas the treatment with a planting spacing of 40 cm × 60 cm without pruning (J3P0) resulted in a lower yield of only 6.31 tons ha^{-1}. This marked contrast highlights the important role of planting configuration and crop management practices, such as pruning, in enhancing crop productivity.

The positive relationship between relatively denser planting spacing and increased yield, as observed in the J2P1 treatment, is consistent with previous studies reporting that increased plant density can optimize yield per unit area by improving light interception and resource use efficiency. Appropriate spacing significantly influences yield attributes, indicating that closer spacing enables plants to utilize nutrients and water more efficiently (Rahman et al., 2023). These findings support the notion that the 30 cm × 60 cm spacing allows plants to experience more controlled resource competition, thereby promoting better growth and higher yield.

In contrast, the substantial yield difference between J2P1 and J3P0 illustrates the potential limitations of wider spacing combined with the absence of pruning. The lower yield observed under J3P0 may be attributed to suboptimal utilization of growing space and less effective canopy management, which can limit photosynthetic efficiency and fruit set. Moreover, the absence of pruning likely exacerbated excessive vegetative growth at the expense of reproductive development. Pruning is known to redirect plant assimilates from excessive vegetative growth toward generative development, thereby supporting fruit and seed formation. Proper regulation of plant architecture through appropriate spacing and pruning is therefore a critical factor in achieving maximum yield potential (Ia et al., 2022). Consequently, the lack of pruning in J3P0 likely constrained yield potential, further emphasizing the importance of integrated crop management strategies.

Previous studies have also emphasized the need to balance planting spacing and pruning to maximize agricultural yields. Significant yield improvements in African marigold cultivation have been achieved through optimal combinations of spacing and pruning, underscoring the importance of integrated agronomic practices in enhancing productivity (Pant et al., 2022). This perspective aligns with the view that effective crop management requires agronomic interventions tailored to specific cultivation contexts to achieve optimal yields.

In the context of sustainable agriculture, these findings suggest that the application of appropriate planting spacing and well-planned pruning can enhance crop productivity while potentially reducing resource inputs per unit of yield. This has important implications for food security and farm profitability, as it provides an evidence-based framework for farmers and practitioners to optimize yields through informed management decisions.

CONCLUSIONS

Based on the results of this study, it can be concluded that the use of a spacing of 40 cm × 60 cm resulted in a higher number of leaves, while a spacing of 30 cm × 60 cm increased the number of productive branches, fruit weight per plant, and leaf area. Pruning by retaining 10 nodes on the main branch increased the number of leaves in cucumber plants. There was an interaction between a spacing of 30 cm × 60 cm and pruning by retaining the 8th node on the main branch, which resulted in higher fruit weight per plant and a yield of 10.27 t ha^{-1}.

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