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COMBINATION OF SHOTS NUMBER MAINTENANCE AND STEM BENDING TECHNIQUES ON THE GROWTH AND YIELD OF TOMATO PLANTS (Solanum lycopersicum)

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Abstract
This study aims to determine the effect of a combination of shoot number maintenance and stem bending techniques on the growth and production of tomato plants (Solanum lycopersicum) variety Servo F1, analyze the feasibility of farming, and design the dissemination of research results to farmers. The study used a factorial randomized block design (RAK) with two factors: shoot number maintenance (all shoots, 1 shoot , 2 shoots, and 3 shoots) and stem bending techniques (without bending and bent). Data were analyzed using ANOVA at the 5% level and continued with Duncan's test. The results showed that the treatment of shoot number maintenance significantly affected plant height only at 63 days after planting, with the treatment without shoot restriction producing the tallest plants (129.17 cm). Stem bending treatment did not significantly affect plant height or number of leaves, but significantly affected fruit weight and number of fruits. There was a significant interaction between shoot maintenance and stem bending. to heavy fruit (total harvest) and number fruit . The A1B0 combination (1 shoot, without layering) produced the highest total fruit weight (1.1950 kg/planting season). Financial feasibility analysis at a scale of 1,000 m² showed that all treatments were feasible with an R/C Ratio > 1, and A1B0 provided the highest efficiency (R/C = 3.53; net profit Rp26,994,500). Dissemination to 20 farmers through video media proved effective with an average N-Gain of 0.51 (Medium category).

Keywords: Adventitious Roots, Farming Feasibility, Shoot Pruning, Stem Bending, Tomatoes

INTRODUCTION

Tomatoes (Solanum lycopersicum) are a leading horticultural commodity with high economic value and increasing demand. FAO data (2022) shows that global tomato production in 2021 reached approximately 189 million tons, with a harvested area of approximately 5 million hectares, making it the second-largest fruit and vegetable commodity in the world. In Indonesia, the average tomato productivity among farmers remains far below the potential of available superior varieties. (Central Statistics Agency , 2024). The Servo F1 variety, widely used by farmers in Malang, East Java, is a determinate variety with rapid vegetative growth and a short harvest period. However, this variety tends to form numerous water shoots (lateral shoots) in the leaf axils, which, if left unchecked, will increase canopy density, reduce light penetration, and encourage competition between plant organs, resulting in smaller fruit size and reduced harvest uniformity (Hapsari et al., 2017).

Shoot pruning is a cultivation technique aimed at limiting the growth of unproductive branches and directing photosynthesis to fruit formation. Meanwhile, stem layering is a vegetative method that utilizes the tomato's ability to form adventitious roots from buried stems, potentially expanding the root system and increasing water and nutrient uptake (Steffens & Rasmussen, 2016; Guan et al., 2019). Although shoot pruning and stem bending are both well-known in cultivation practices, studies simultaneously examining the combination of these two techniques on tomato growth and yield, particularly of the Servo variety, in East Java are still very limited. This research aims to fill this gap and provide a scientific basis for disseminating the technology to farmers.

LITERATURE REVIEW

Tomato (Solanum lycopersicum) is a member of the Solanaceae family and is one of the most widely consumed fruit vegetables worldwide. Determinate varieties such as Servo F1 terminate their vegetative growth with terminal flowering, making them suitable for intensive cultivation with strict canopy management (Heuvelink et al., 2020). Water shoot pruning (wiwil) is the removal of unnecessary lateral shoots to maintain productive branches and reduce canopy density. Agronomic studies indicate that shoot regulation plays a crucial role in efficiently distributing photosynthates to generative organs. Hapsari et al. (2017) reported that branch reduction in tomatoes was positively correlated with fruit quality, although it does not always significantly increase the number of fruits. Ahmad et al. (2023) added that pruning at the right time (20 days after planting) can increase the percentage of marketable fruit. Navarrete & Jeannequin (2000) showed that the frequency of axillary shoot pruning directly affects fruit yield and vegetative growth in greenhouse tomato cultivation. Hidayat & Lestari (2023) also confirmed that water shoot control has a significant effect on the quality of tomato harvests. This study also considers the control of bacterial wilt disease (Ralstonia solanacearum) attack tomatoes in East Java as reported Navitasari et al. (2022) as one of the background behind importance management good canopy

Submission technique stem utilise The ability of tomatoes to produce adventitious roots. Adventitious roots are roots that form from non-root tissue (e.g., stems) in response to specific environmental conditions (Steffens & Rasmussen, 2016). By burying part of the stem, adventitious root formation can be stimulated, thereby increasing the plant's water and nutrient absorption capacity. On the other hand, physiological studies by (Kevei et al., 2024 and Kim et al., 2019) confirm that adventitious roots play a strategic role in expanding the root system, increasing nutrient and water absorption, and enhancing plant vigor. However, their studies were conducted in a genetic and laboratory context, rather than through an agronomic approach in the field. In fact, the potential for adventitious root formation can also be stimulated through simple cultivation techniques such as stem bending, which involves bending and burying part of the stem so that it comes into contact with the soil, thereby stimulating new root formation at the buried stem nodes. Farming business feasibility analysis includes calculating the R/C Ratio, B/C Ratio, Break Even Point (BEP), and net income. These indicators are used to evaluate whether intensive cultivation techniques provide profits commensurate with the input costs incurred (Soekartawi , 1994; Gittinger, 1982; Hernanto , 1991).

METHOD

The research was conducted on the PWMP land of the Polbangtan Malang Campus from December 15, 2025, to February 20, 2026, covering a full tomato planting cycle. The materials used included Servo F1 tomato seeds, fertilizers (Ultradap, NPK, MKP), pesticides (Curacron, Tandem, adhesive), plastic mulch, and bamboo stakes.
The research used a Factorial Randomized Block Design (RAK) with two treatment factors: Factor A (maintenance of the number of shoots: A0 = all shoots are maintained; A1 = 1 shoot is maintained; A2 = 2 shoots; A3 = 3 shoots) and Factor B (stem bending: B0 = no bending; B1 = stem is bent), resulting in 8 treatment combinations each with 4 replications (32 units) . experiment ; 256 plants total).

Table 1. Factorial RAK Treatment Code Combinations

Factor A (Shoot Maintenance)	Factor B (Descent)	Code	Information
A0 (All Shoots)	B0 (Without Bending)	A0B0	All shoots, without Bending
A1 (1 Shoot)	B0	A1B0	1 shoot , without bending
A2 (2 Shoots)	B0	A2B0	2 shoots, without bending
A3 (3 Shoots)	B0	A3B0	3 shoots, without bending
A0 (All Shoots)	B1 (Bent)	A0B1	All shoots, bent
A1 (1 Shoot)	B1	A1B1	1 shoot , bent
A2 (2 Shoots)	B1	A2B1	2 shoots, bent
A3 (3 Shoots)	B1	A3B1	3 shoots, bent

Observed parameters included : (1) plant height (cm), measured every week from 7 to 63 Days After Planting (DAP); (2) number of leaves (strands), measured every week from 7-63 DAP; (3) fruit weight (kg/planting season, accumulated over 4 harvests); and (4) number of fruits (fruits/planting season). Data were analyzed using Analysis of Variance (ANOVA) at the 5% level, and if there was a significant effect, it was continued with Duncan's Multiple Range Test (DMRT) at 5%.

The feasibility analysis of the farming business was conducted by converting the experimental plot data (65 m²) to a scale of 1,000 m² using a conversion factor of 15.38. Feasibility indicators include Total Production Cost (TC), Total Revenue (TR), Income (Net Profit), B/C Ratio, BEP Volume, BEP Price, and R/C Ratio. The selling price was determined using a fruit quality grading system (Grade A: Rp8,000/kg; Grade B: Rp7,500/kg; Grade C: Rp6,500/kg; Grade D: Rp6,000/kg).

Dissemination was conducted using a hybrid extension approach (cyber extension via WhatsApp video and personal approach) to 20 target farmers in Pacitan and Malang Regencies. The questionnaire evaluation instrument was validated through expert judgment by three expert panelists. Knowledge gain was measured using N-Gain (Hake, 1998).

RESULTS AND DISCUSSION

Plant Height

The results of the analysis of variance (ANOVA) showed that the treatment of shoot maintenance, stem bending, and the interaction of the two did not significantly affect plant height from 7 to 56 HST ($p > 0.05$). The only significant effect of shoot maintenance only occurred at 63 HST (Sig. $0.022 < 0.05$), while the interaction of the two factors was only significant at 14 HST (Sig. $0.038 < 0.05$).

Table 2. Average Plant Height (cm)

Treatment	7 HST	14 HST	21 HST	28 HST	35 HST	42 HST	49 HST	56 HST	63 HST
Shoot Maintenance									
All Shoots (A0)	13.96 a	24.83 a	43.29 a	67.25 a	96.88 a	107.29 a	117.58 a	121.75 a	129.17 b
1 Shoot (A1)	13.67 a	25.00 a	42.96 a	76.04 a	92.50 a	101.79 a	111.79 a	115.38 a	122.54 ab
2 Shoots (A2)	14.54 a	27.08 a	44.75 a	77.21 a	98.33 a	106.17 a	114.08 a	118.12 a	123.54 b
3 Shoots (A3)	14.06 a	26.17 a	44.71 a	74.38 a	91.04 a	97.62 a	107.42 a	109.33 a	113.08 a
Stem Bending									
Without Bending (B0)	13.38 a	24.90 a	43.19 a	73.13 a	95.42 a	103.90 a	113.50 a	117.71 a	124.21 a
Bent (B1)	14.74 a	26.65 a	44.67 a	74.31 a	93.96 a	102.54 a	111.94 a	114.58 a	119.96 a

Description : DAP = Days After Planting. Numbers followed by the same letter in the same column indicate no significant difference in the Duncan test at the 5% level.

Table 2a. Average Plant Height (cm) at 14 HST - Interaction

Treatment	Without bending (B0)	Bent (B1)
All Shoots (A0)	24.92 a	24.75 a
1 Shoot (A1)	25.59 a	24.42 a
2 Shoots (A2)	23.59 a	30.58 b
3 Shoots (A3)	25.50 a	26.84 ab

Description: Numbers followed by the same letter indicate no significant difference in the Duncan test at the 5% level.

The lack of a significant effect of shoot maintenance on plant height during most of the observation period is explained by the mechanism of apical dominance. The hormone auxin from the apical meristem suppresses the growth of lateral shoots so that variations in shoot number do not directly affect the growth of lateral shoots. elongation stem (Wardani, 2022; Lubis et al., 2023; Yukiman et al., 2025). The significant effect that only occurred at 63 DAP in the A0 treatment (all shoots; 129.17 cm) was likely due to lower sink competition due to the large number of active vegetative shoots, so that vertical growth was relatively more dominant compared to the treatment with shoot restriction.

The significant interaction at 14 days after planting indicates that in the early vegetative phase, the plant response to the treatment combination is still active before the apical dominance mechanism fully takes over. The stem-layering technique had no significant effect on plant height because the effect of stem-layering is more directed at the development of adventitious roots in the lower stem, rather than on vertical elongation (Sari & Nugroho, 2021).

Number of Leaves

Statistical analysis showed that neither shoot maintenance, stem bending, nor the interaction of the two significantly affected leaf number during 7-63 days after planting ($p > 0.05$). Leaf number increased from 4.00-4.25 leaves at 7 days after planting to a peak of 34.13-41.67 leaves at 42 days after planting, then decreased as the final generative phase entered.

The apparent lack of effect of treatment on leaf number can be explained by a compensatory mechanism for vegetative growth. Plants tend to maintain sufficient leaf surface area for photosynthesis even though the number of shoots is reduced (Sari & Gunawan, 2020). The pattern of decreasing leaf number in the final phase reflects the shift in assimilate allocation from vegetative organ formation to fruit ripening (Sarlikioti et al., 2011).

Fruit Weight

The single shoot maintenance treatment did not significantly affect the total fruit weight per growing season (Sig. 0.975 > 0.05). In contrast, single stem bending had a very significant effect (Sig. 0.006 < 0.05): plants without bending produced a higher total fruit weight (1.0725 kg/growing season) than those that were bent (0.8575 kg/growing season). There was a significant interaction between shoot maintenance and bending on fruit weight (Sig. 0.028 < 0.05).

Table 3. Average Fruit Weight (kg/ season) planting) Single Factor

Treatment	Average Fruit Weight (kg/planting season)	Notation
Shoot Maintenance		
All Shoots (A0)	0.9587	a
1 Shoot (A1)	0.9900	a
2 Shoots (A2)	0.9713	a
3 Shoots (A3)	0.9400	a
Stem Bending		
without bending (B0)	1.0725	b
Bent (B1)	0.8575	a

Description: Numbers followed by the same letter indicate no significant difference in the Duncan test at the 5% level.

Table 4. Average Fruit Weight (kg/planting season) — Shoot Maintenance × Stem Bending Interaction

Shoot Maintenance	Without bending (B0)	Bent (B1)
All Shoots (A0)	1,1500 bc	0.7675 a
1 Shoot (A1)	1.1950 c	0.7850 a
2 Shoots (A2)	0.8575 abc	1.0850 bc
3 Shoots (A3)	1.0875 bc	0.7925 ab

Description: Numbers followed by the same letter indicate no significant difference in the Duncan test at the 5% level.

Based on Table 4, the A1B0 treatment combination (1 shoot, without bending) produced the highest total fruit weight (1.1950 kg/planting season) and included the notation c (significantly different from group a). The decrease in fruit weight in the stem hilling treatment is explained by two physiological mechanisms. First, mechanical stress due to hilling diverts the plant's metabolic energy to tissue repair and adventitious root formation, thereby reducing the supply of assimilates to the fruit (Sparke et al., 2022). Second, Bao et al. (2026) demonstrated that hilling activates the JA-ABA pathway, which promotes intensive lignification, diverting photoassimilates towards stem structural strengthening and potentially reducing supply to generative organs.

Interestingly, in the A2B1 combination (2 shoots, bent), the total fruit weight was actually higher (1.0850 kg/planting season) compared to A2B0 (0.8575 kg/planting season). This indicates that in the 2-shoot condition, the additional root system from the bending successfully compensates for the assimilate needs for the fruit. Pruning lateral shoots reduces internal competition between vegetative and generative organs for photosynthetic assimilates (Ulyatus et al., 2024; Yukiman et al., 2025).

Number of Fruits

The single treatment of shoot maintenance did not significantly affect the number of fruits (Sig. 0.359 > 0.05). However, single stem bending significantly reduced the number of fruits (Sig. 0.028 < 0.05): plants without bending produced an average of 29.8769 fruits/planting season compared to 24.7188 fruits/planting season in those that were bent. The interaction between shoot maintenance and bending also significantly affected the number of fruits (Sig. 0.032 < 0.05).

Table 5. Average Number of Fruits (fruits/growing season) — Single Effect

Treatment	Average Number of Fruits (fruits/growing season)	Notation
Shoot Maintenance		
All Shoots (A0)	30,5800	a
1 Shoot (A1)	25,6488	a
2 Shoots (A2)	26,8988	a
3 Shoots (A3)	26,0638	a
Stem Bending		
Without bending (B0)	29,8769	b
Bent (B1)	24,7188	a

Description: Numbers followed by the same letter indicate no significant difference in the Duncan test at the 5% level.

Table 6. Average Number Fruit (fruit / season) plant) _ Interaction Shoot Maintenance × Propagation

Shoot Maintenance	Without Bending (B0)	Bent (B1)
All Shoots (A0)	36.0825 b	25,0775 a
1 Shoot (A1)	30,1700 ab	21.1275 a
2 Shoots (A2)	23.6725 a	30,1250 ab
3 Shoots (A3)	29.5825 ab	22.5450 a

Description: Numbers followed by the same letter indicate no significant difference in the Duncan test at the 5% level.

Based on Table 6, the combination without shoot maintenance and without layering (A0B0) produced the highest number of fruits (36.0825 fruits/planting season; notation b). The high number of fruits in A0B0 is thought to be due to the large number of shoots maintained, which encourages the formation of more axillary flowers, although the size per fruit is smaller (Mbonihankuye et al., 2013).

The apparent ineffectiveness of stem bending treatment on plant height and leaf number can be explained by the physiological mechanisms revealed by Bao et al. (2026). The study demonstrated that stem bending causes increased expression of mechanical stress response genes in stem tissue, encouraging intensive lignification, so that more metabolic energy is directed towards structural strengthening rather than generative growth or increasing fruit number.

Furthermore, Cochavi et al. (2020) explained that adding roots does not necessarily increase nutrient uptake if the roots have not yet developed into an active and functional root system. This explains why stem bending in this study did not significantly improve production parameters. in a way general .

Other aspects that are involved contribute is characteristic response age dependent thigmomorphogenesis network (age-dependent), where only the internode is currently running developing which shows response real to stimulation mechanics, while network stem that has been ripe No Again responsive . In overall, subordination stem in research This produce response physiological trade - off between potential improvement nutrient uptake and inhibition growth based hormonal pathways, so that No produce significant difference in a way statistics on all observation parameters. Bao et al. (2026).

Farming Business Feasibility Analysis

The feasibility analysis of the farming business was projected on a scale of 1,000 m² using a conversion factor of 15.38 from the experimental plot area (65 m²). The selling price was determined using a fruit quality grading system based on visual size: Grade A (large) Rp8,000/kg, Grade B (medium) Rp7,500/kg, Grade C (small) Rp6,500/kg, and Grade D (very small/damaged) Rp6,000/kg. All eight treatment combinations showed financial feasibility with an R/C Ratio value > 1.0.

Table 7. Financial Feasibility Analysis of Servo Tomato Farming Business (1,000 m² Scale)

Treatment	Price (Rp/kg)	TC (Rp)	TR (Rp)	Net Profit (Rp)	BEP Vol (kg)	Break Even Price (Rp/kg)	B/C	R/C
1 Shoot, Without Bending (A1B0)	8,000	10,653,500	37,648,000	26,994,500	1,332	2,264	2.53	3.53
All Shoots, No Bending (A0B0)	6,000	9,500,000	27,174,000	17,674,000	1,583	2,098	1.86	2.86
2 Shoots, Bended (A2B1)	7,500	12,960,500	32,047,500	19,087,000	1,728	3,033	1.47	2.47
3 Shoots, Without Bending (A3B0)	6,500	11,807,000	27,839,500	16,032,500	1,816	2,757	1.36	2.36
2 Shoots, Without Bending (A2B0)	7,500	11,230,250	25,327,500	14,097,250	1,497	3,326	1.26	2.26
1 Shoot, Bended (A1B1)	8,000	12,383,750	24,728,000	12,344,250	1,548	4,006	1.00	2.00
All Shoots, Ducked (A0B1)	6,000	11,230,250	18,132,000	6,901,750	1,872	3,716	0.61	1.61
3 Shoots, Bended (A3B1)	6,500	13,537,250	20,286,500	6,749,250	2,083	4,337	0.50	1.50

Treatment A1B0 (1 shoot, without layering) showed the highest economic efficiency with an R/C Ratio of 3.53 and a net profit of Rp26,994,500/1,000 m². This superiority stems from the dominance of Grade A fruit which is obtained at a selling price of Rp8,000/kg. The BEP production volume of 1,332 kg/1,000 m² is far below the actual harvest yield of 4,706 kg/1,000 m², while the BEP price of Rp2,264/kg provides a very high safety margin against market price fluctuations.

The control treatment A0B0 (all shoots, no stem bending) showed a production paradox: although it produced the highest number of fruits, the fruit size was relatively small (Grade D, Rp6,000/kg) resulting in a lower revenue value (Rp27,174,000) with a profit of Rp17,674,000. This proves that pursuing production volume without paying attention to quality actually narrows profit margins. Treatments A3B1 and A0B1 showed the lowest R/C Ratio (1.50 and 1.61), indicating that stem bending tends to increase production costs (additional labor costs) without balanced improvement proportional acceptance .

Dissemination Results Study

Instrument questionnaire dissemination validated through expert judgment by 3 panelists experts in charge as practitioners and extension workers . And using Likert scale 1-5 for 13 indicators covering three aspects: agronomic technical substance, extension evaluation design, and language readability.

Table 9. Summary of Instrument Feasibility per Aspect

Aspect	Total Score	Max Score	Percentage	Category
A. Agronomic Technical Substance	111	150	74.00%	Valid
B. Extension Evaluation Design	22	30	73.33%	Valid
C. Language Readability	11	15	73.33%	Valid
Overall	144	195	73.85%	Valid

Validation results show percentage The overall feasibility of the questionnaire instrument reached 73.85% (Valid category). Dissemination activities were carried out with 20 target farmers in Pacitan and Malang Regencies through a video-based extension method (Cyber Extension) distributed via WhatsApp.

Table 10. Summary of Pre-Test and Post-Test Score Results

No	Category	Pre-Test (%)	Post-Test (%)	Improvement	N-Gain
1	High (5 people, 25.0%)	70.00%	94.00%	+24.00%	0.80
2	Moderate (12 people, 60.0%)	77.08%	89.58%	+12.50%	0.58
3	Low (3 people, 15.0%)	78.33%	71.67%	-6.67%	-0.43
	Average (20 people)	75.50%	88.50%	+13.00%	0.51

The average Normalized Gain (N-Gain) value of 20 respondents was 0.51, included in the Medium category (Hake, 1998). A total of 17 of the 20 respondents (85.0%) experienced an increase in their scores. A total of 5 people (25.0%) reached the High N-Gain category (average 0.80) with an increase from 70.00% to 94.00%, while 12 people (60.0%) were in the Medium category (average 0.58). Three people (15.0%) with Low N-Gain (-0.43) experienced a decrease in their scores, which was suspected to be due to the relatively high pre-test score (78.33%) so that room for improvement was limited, as well as the possibility that the level of difficulty of the questions was not appropriate to the respondents' educational background.

The results of the Moderate N-Gain group indicate that Cyber Extension video media is quite effective as a tool for disseminating agricultural technology. Asadullah et al. (2018) emphasized that video media is an effective extension tool for increasing farmer knowledge under conditions of time and distance constraints. The high proportion of the Moderate N-Gain group indicates that most of the target farmers were able to absorb the dissemination material well.

CONCLUSION

1. The combination of 1 shoot maintenance treatment without stem bending (A1B0) is the most optimal treatment in increasing the production of tomato plants of the Servo F1 variety, indicated by the highest total fruit weight (1.1950 kg/planting season). Overall, the treatment of maintaining the number of shoots and stem bending did not significantly affect the growth of plant height (except at 63 HST) and the number of leaves, but significantly affected the weight of the fruit and the number of fruits, with a significant interaction in both production parameters.
2. All combinations of tomato cultivation treatments tested were financially feasible with an R/C Ratio value of > 1. Treatment A1B0 provided the highest economic efficiency with an R/C Ratio of 3.53 and a net profit of Rp26,994,500/1,000 m², proving that increasing the quality of the harvest (Grade A) is more profitable than simply pursuing production volume.
3. The dissemination questionnaire instrument was declared valid with a feasibility percentage of 73.85% based on the assessment of three expert panelists. The dissemination activity to 20 target farmers in Pacitan and Malang Regencies was proven to be effective in increasing farmers' knowledge with an average N-Gain value of 0.51 (Moderate category), indicating that the implemented dissemination design was able to transfer innovative tomato cultivation techniques to target farmers.

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