Hindawi
Advances in Agriculture
Volume 2021, Article ID 5570567, 7 pages
https://doi.org/10.1155/2021/5570567

Research Article

The Role of Staking and Pruning Methods on Yield and Profitability of Tomato (*Solanum lycopersicum* L.) Production in the Guinea Savanna Zone of Ghana

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Received 19 February 2021; Revised 14 July 2021; Accepted 2 September 2021; Published 18 September 2021

Academic Editor: Amelia Salimonti

Tomato is one of the most widely consumed and produced vegetables in Ghana. The low yield of tomatoes in Ghana has resulted in huge importation of the produce from neighboring countries. Good agronomic practices are among the key strategies involved in increasing the yield of horticultural produce. This study seeks to evaluate the response of staking and pruning on tomato fruit yield, quality, and cost of production. To achieve this, a field experiment was conducted to investigate the effect of staking and pruning methods on fruit yield and profitability of tomato (*Solanum lycopersicum L.*) produced in the northern region of Ghana. Treatments were applied in a randomized complete block design with three replications. Treatments were no pruning + no staking (control), single pole staking (SPS), wire trellis (WT), one-stem pruning (1SP), one-stem pruning + single pole staking (1SP + SPS), one-stem pruning + wire trellis (1SP + WT), two-stem pruning (2SP), two-stem pruning + single pole staking (2SP + SPS), and two-stem pruning + wire trellis (2SP + WT). Results showed that 2SP + WT increased fruit diameter, fruit length, and marketable fruit weight by 52%, 32%, and 69%, respectively, compared to the control. The maximum number and weight of marketable fruits obtained from 2SP + WT increased total fruit yield by 76% compared to the control. In all, the performance of the treatments in terms of yield was in the following order: 2SP + WT > 1SP + WT > SPS > WT > 2SP + SPS > 1SP > 2SP > control. Though 2SP + WT increased production cost by 42%, it greatly increased yield by 69% which resulted in 83% net profit compared to the control. Thus, 2SP + WT could be tested on-farm for possible adoption to increase tomato yield, quality, and profit.

1. Introduction

Tomato is an important component of every Ghanaian meal, and its cultivation contributes significantly to livelihood improvement. Schippers [1] asserts that tomato is the most important vegetable in Ghana, compared to all the other vegetables. The total consumption of fresh tomato in 2016/2017 was 240,000 tons per annum [2]. However, domestic production has not kept up with demand [3]. The tomato sector is unable to attain its potential productivity as compared to other countries [4]. The average tomato yield in Ghana is 7.5 t/ha which is far less than the potential yield of 20 tons per hectare [5]. Ghana imports close to 100,000 tons or one-quarter of its domestic supply from a neighboring country (Burkina Faso) to meet the domestic demand [6, 7]. This has resulted in large sums of money spent annually on the importation of the vegetable crop. For example, 7,000 tons was imported annually between 2010 and 2016, mostly originating from Burkina Faso [3, 8]. Major contributing factor to the low tomato yield in Ghana is the use of traditional methods of farming or low adoption of improved husbandry practices (such as sustainable staking and pruning).

It is asserted that improved management practices such as staking and pruning could yield over 32.5–46.0 t/ha in the forest zones of Ghana [9]. Staking is a means of providing supports to ensure clean and unblemished fruits by keeping fruits off the ground, thereby increasing marketable yield [6]. Akoroda [10] and Amina [11] suggested staking as an appropriate method to effectively expose leaves to sunlight for

efficient photosynthetic activities and improved yield of crops. Pruning and staking indeterminate tomato plants can result in early fruits maturity and larger fruits. The most common method of staking among small holder farmers in Ghana is the single-pole staking where each crop is supported with stake (wood). This has resulted in scarcity of stakes [12], especially in Guinea savanna. Besides, this method is labor intensive and contributes greatly to deforestation resulting in an unsustainable production system. In pruning, there is the selective removal of side shoots or stem to limit plant growth and to divert nutrients to flower clusters on the remaining shoot or stem. According to Franco et al. [13], appropriate pruning method is relevant to maintain a balance in the relationship's source/sink and the carbon/nitrogen (C/N) ratio. Alam et al. [14] recorded increased marketable yield/area by pruning indeterminate tomato plants to two-stem rather than one-stem. Alternative staking technique that would reduce the quantity of stakes (wood) used without compromising on yields would address the problem of scarcity of stakes and deforestation associated with tomato production in Ghana. The objective of the study was to evaluate staking and pruning options to suggest alternatives for sustainable tomato production without compromising on yield and profitability. This is to address the problem of scarcity of stakes and deforestation associated with tomato production in Ghana.

2. Materials and Methods

2.1. Study Area and Experimental Design. The field study was conducted at the University for Development Studies (UDS) experimental fields, Nyankpala campus, from June to October 2019 under rain fed. Nyankpala is located on latitude 009° 25′ 41″ N, longitude 000° 58′ 42″ W, and altitude 183 m above sea level (SARI, 2007). The experiment was laid out in a randomized complete block design (RCBD) with nine treatments and three replications. There were a total of twenty-seven (27) experimental plots. The plot size for each experimental unit was 4 m × 3 m with spacing of 1 m between plots and 2 m between blocks. A total field size of 33 m × 13 m was demarcated for the experiment.

2.2. Nursing and Transplanting of Seedlings. A nursery trough measuring 10 m × 1.3 m was prepared and filled with sandy loam soil mixed with biochar for nursing the seeds. Pectomech tomato seeds were thinly sown in drills on the nursery trough on 8th July 2019. Nursed seeds were mulched with dry grass and watered twice a day at 3 days interval until germination. Ridges of 75 cm apart were prepared prior to transplanting with each plot having 4 ridges. Seedlings were transplanted four weeks after germination at a height of 15 cm with about 5-6 leaves. Transplanting was done late in the afternoon to prevent transplanting shock. Seedlings were planted at a spacing of 40 cm within rows and 75 cm between rows, with each ridge accommodating 10 seedlings. A total of 40 seedlings were planted on each plot. With the trellis, wires were run from one end pole to another and back again at different heights after transplanting. When the plant reached about 25 cm in height, the stem of the tomato was loosely tied to the wires for support.

With the single-stem staking, wooden stake of about 60–80 cm was inserted about 20 cm into the soil, just outside the diameter of the tomato seedling after transplanting. When the plant reached about 25 cm in height, the stem of the tomato was loosely tied to the supporting stake. Pruning started four weeks after transplanting (WAT) and continued to twelve weeks. All the suckers were removed to one below the first flower cluster to get one stem per plant or two stems per plant.

2.3. Data Collection. Data on yield parameters were taken five weeks after transplanting and at harvest. Five plants were selected from the two middle ridges from each treatment for the measurement of yield data, and their averages were computed. The yield parameters determined were as follows.

2.3.1. Number of Marketable and Nonmarketable Fruits. Marketable fruits were fruits of good quality in firmness with no blemish. Mature and ripped, unrotten and sizable (without blemish) tomato fruits were harvested from the five randomly selected plants from the two middle rows. Harvested fruits were counted and averaged to represent number of fruits per plant. Nonmarketable fruits were further sorted out into the following components:

(a) Sun-scalded, deformed, unevenly ripped, and whitish areas appearing on the exposed surface
(b) Fruits diseased or eaten by rodents
(c) Fruits eaten by birds, mainly full-ripe tomatoes

2.3.2. Fruit Diameter and Length. Three ripped fruits were randomly selected from the harvested fruits per the five tagged plants. With the aid of a caliper, the three fruits diameter was measured, and their means were calculated in mm at 9 weeks after transplanting. With the aid of a meter rule in cm, the three fruits lengths were measured, and their means were determined at 9 weeks after transplanting.

2.3.3. Marketable Fruits Weight. Matured, ripped, unrotten, and sizable (without blemish) tomato fruits harvested from the five tagged plants were weighed and averaged at 8, 9, and 10 weeks after transplanting (WAT) to determine the weight of marketable fruits per plant at 8, 9, and 10 WAT. The mean weight in kilograms per hectare was extrapolated.

2.3.4. Total Fruits Yield. Tomato fruits were harvested 6 times on weekly basis per plot by hand picking and weighed. Fruit yield was determined by summing up all the weight of the six times harvest which includes marketable and nonmarketable fruits and measured in Kg/plot and later converted to Kg/ha.

2.3.5. Economic Analysis. Production cost was calculated for each treatment by estimating the gross returns (total returns after production), net returns (gross return minus cost of production), and benefit cost ratio (net return divided by the production costs). Price of input and the market price of produce were used in calculating production cost, returns, and benefit:cost ratio.

2.4. Data Analysis. Data on all parameters, except economic analysis, were subjected to ANOVA using GenStat statistical package (GenStat, 20TH Edition). The means were separated using LSD (0.05).

3. Results

3.1. Fruit Length and Diameter. The result indicates that there was a significant ($p < 0.002$) difference among treatments on the fruit length at 9 WAT. Single pole staking (SPS), wire trellising (WT), one-stem pruning plus wire trellising (1SP + WT), and two-stem pruning plus single pole staking (2SP + SPS) showed no difference in fruit length, likewise one-stem pruning plus single pole staking and two-stem pruning plus wire trellising. However, 2SP + WT had the highest (5.1 cm) fruit length compared to the control (2.2 cm) at 9 WAT (Figure 1).

There was a difference ($p < 0.049$) in fruit diameter between 2SP + WT (4.64 cm) and the control (2.21 cm) at 9 WAT (Figure 2). However, there was no difference between single pole staking (SPS), wire trellising (WT), one-stem pruning plus single pole staking (1SP + SPS), one-stem pruning plus wire trellising (1SP + WT), one-stem pruning (1SP), two-stem pruning (2SP), and two-stem pruning plus single pole staking (2SP + SPS).

3.2. Marketable Fruits Weight and Number. At 8, 9, and 10 WAT, there were significant differences ($p < 0.001$, $p < 0.001$, and $p < 0.0019$, respectively) among treatments on the weight of marketable fruits. Plots treated with 2SP + WT recorded the highest (369 Kg/ha) weight of marketable fruits compared with the control giving the least weight (65 kg/ha) of marketable fruits at 8 WAT. 2SP + WT, 1SP + WT, and 2SP + SPS increased marketable fruit weight by 82%, 71%, and 60%, respectively, compared to the control at 8 WAT. A similar trend was observed in 9 and 10 WAT (Table 1).

There was a significant ($p < 0.001$) difference among treatments on the number of marketable fruits at harvest with 2SP + WT recording the highest (11449.6 kg/ha) and 2SP + SPS, the next greatest (7866.3 kg/ha). This resulted to 70% and 57% increase in number of marketable fruits by 2SP + WT and 2SP + SPS, respectively, compared to the control (Figure 3).

3.3. Number of Nonmarketable Fruits. The analysis revealed that there was a significant ($p < 0.001$) difference among treatments on the number of nonmarketable fruits of tomato at harvest. Two-stem pruning plus wire trellising (2SP + WT) plots recorded the least number of nonmarketable fruits of 2089 kg/ha, while the control had the highest number of nonmarketable fruits of 7478 kg/ha at harvest (Figure 4).

3.4. Total Fruit Yield. The analysis of variance indicates that there was a difference ($p < 0.001$) among treatments on total fruits yield. There was no difference between one-stem pruning (1SP), one-stem pruning plus single pole staking (1SP + SPS), and two-stem pruning (2SP). There were significant differences between two-stem pruning plus wire trellising (2SP + WT), two-stem pruning plus single-pole staking (2SP + SPS), and no pruning no staking. Two-stem pruning plus wire trellising (2SP + WT) increased total fruits yield by 75% compared to control (Figure 5).

3.5. Cost and Return Analysis. Cost analysis showed that 2SP + WT incurred the highest ($411/ha) cost of production, whereas the control incurred the lowest of $175/ha (Table 2).

In the case of net return and benefit cost ratio (BCR), it was observed that 2SP + WT recorded the highest ($598/ha) net return as well as the maximum benefit cost ratio (1.46), whereas the control recorded the minimum net return ($63/ha) and BCR (0.36).

4. Discussion

Staking and pruning methods greatly affected fruit diameter and length with the highest fruit diameter and length recorded in 2SP + WT. Staking with wire trellis might have allowed better aeration and exposure of the foliage, thereby, enhancing photosynthetic activities which might be responsible for larger fruit size. Hesamil et al. [15] reported increased fruit size of tomato because lateral branches were removed. The result obtained by staking tomatoes is in agreement with Kumar et al. [16] who reported higher fruit diameter in staked tomato.

The improved fruit diameter and length in 2SP + WT resulted in 82%, 66%, and 65% increase in marketable fruit weight in 8, 9, and 10 WAT, respectively, compared to control. 1SP + WT and 2SP + SPS also increased marketable fruit weight by 71% and 60%, respectively, compared to the control at 8 WAT. Staking increases fruit yield, reduces the proportion of nonmarketable fruit, and enhances the production of high-quality fruits [17]. Ramirez et al. [18] reported that two or three stem pruning produced the best quality fruits. The result of this study is in agreement with [19] who reported that removal of lateral branches resulted in increasing fruit weight of tomato plants. The pruning and staking prevented tomato fruits from coming into contact with wet soil [20] and, therefore, reduced the number of nonmarketable yield due to fruit rot [21]. This resulted in increased fruit size thereby increasing weight and number of marketable yield of tomatoes. Kumar et al. [16] reported an increase in fruit weight of tomato by staking. Salinas et al. [22] reported higher good quality fruit in pruned tomatoes compared to no pruning.

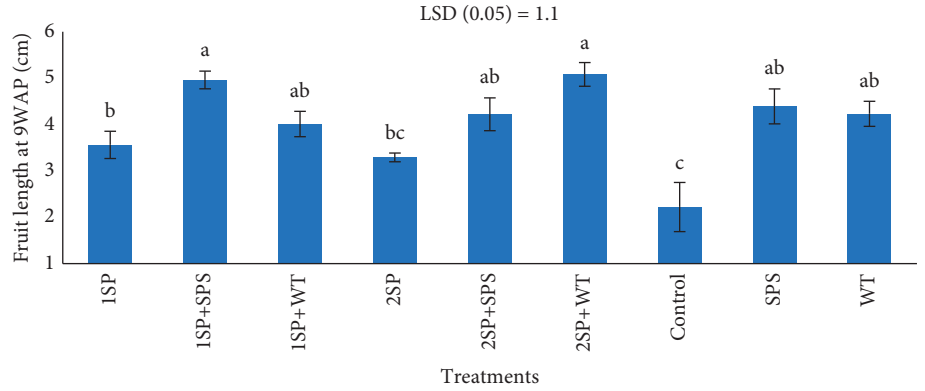

Figure 1: Effect of pruning and staking on fruit length. Bars with different letters denote significance at $p < 0.05$. Error bars denote the standard error of means. Means comparison was conducted using the least significant difference ($p < 0.05$).

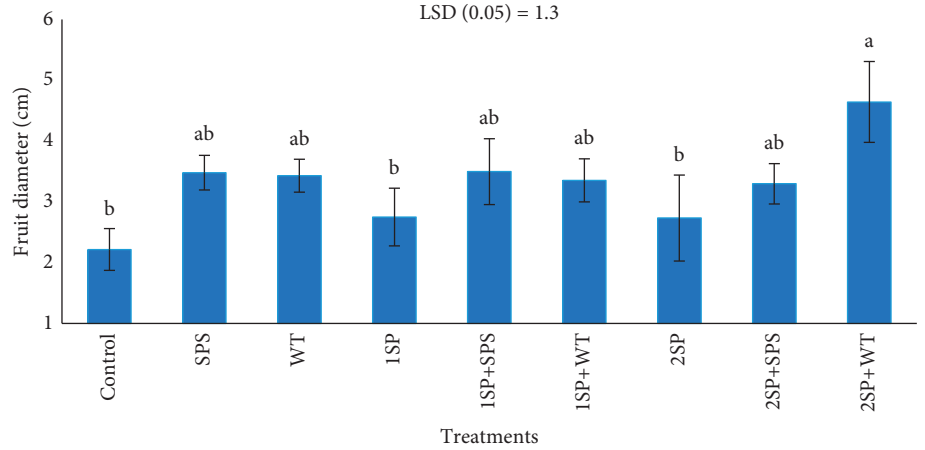

Figure 2: Effect of pruning and staking on fruit diameter. Bars with different letters denote significance at $p < 0.05$. Error bars denote the standard error of means. Means comparison was conducted using the least significant difference ($p < 0.05$).

Table 1: Marketable fruits weight (kg/ha) of tomato under different pruning and staking methods. Means comparison based on the least significant difference (0.05).

Treatments	8 WAT	9 WAT	10 WAT
Control	65	145	258
SPS	140	253	443
WT	151	254	519
1SP	82	178	258
1SP + SPS	91	251	333
1SP + WT	226	291	503
2SP	85	256	219
2SP + SPS	161	301	631
2SP + WT	369	424	728
LSD (0.05)	**39.76**	**37.86**	**39.23**
CV (%)	15.1	8.4	5.3

LSD, least significant difference (0.05).

The maximum (7472 kg/ha) number of nonmarketable fruits recorded on control plots might be attributed to fruits not supported and kept off the floor. This increased disease and rotting of fruits, thereby, increasing nonmarketable fruits. In studies conducted by [23], no pruning plants recorded the maximum nonmarketable fruits. Anonymous [17] reported an increase in fruit yield, a reduction in nonmarketable fruit and enhanced high-quality fruits because of staking. Staking of tomatoes gave higher yield and good quality fruits with higher market value in a study conducted by [10, 11] and suggested staking for quality and higher yield of tomato. The current result is also in accordance with [24] who reported increased tomato yield under pruning and staking.

2SP + WT and 1SP + WT increased production cost by 53% and 57%, respectively, compared to the control plots. This may be attributed to high cost of staking and pruning. The highest and the second highest gross return of $1010 and $771 per hectare recorded from 2SP + WT and 2SP + SPS, respectively, may be attributed to increased marketable fruits number and weight recorded in these treatments. The highest net return ($598) per hectare was recorded in 2SP + WT and the second highest net return ($381) per hectare. From the economic point of view, 2SP + WT and 2SP + SPS were more profitable with increased benefit cost ratio of 75% and 63%, respectively, compared to the control. Lower nonmarketable yield, higher marketable fruits, and higher net return were recorded by Singh [25].

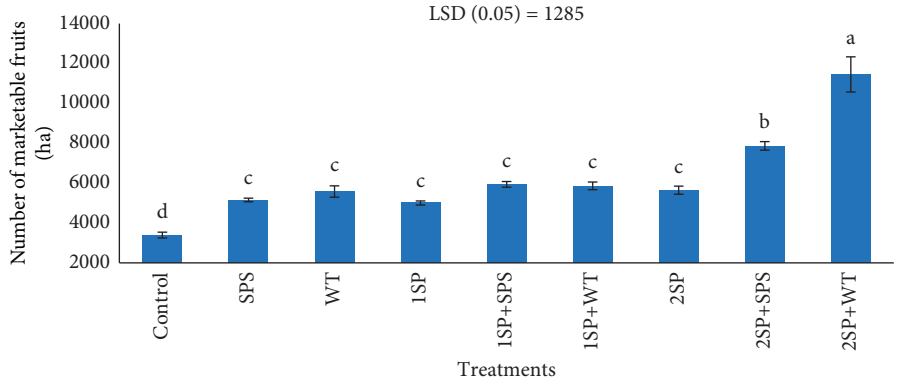

Figure 3: Effect of pruning and staking on number of marketable fruits at harvest. Bars with different letters denote significance at $p < 0.05$. Error bars denote the standard error of means. Means comparison was conducted using the least significant difference ($p < 0.05$).

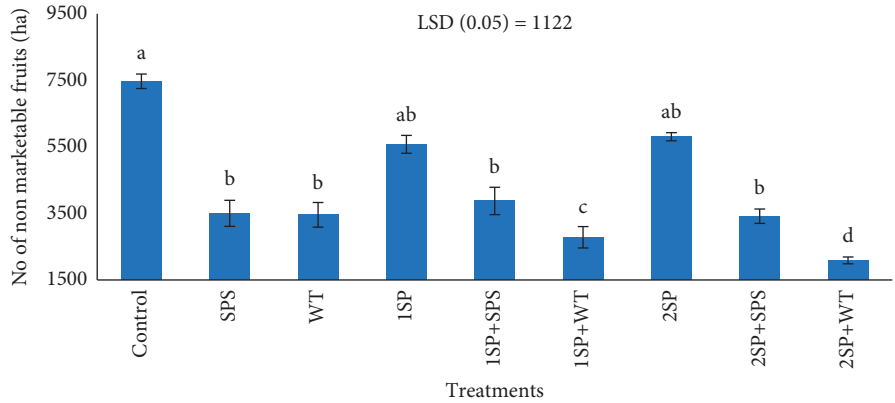

Figure 4: Effect of pruning and staking on the number of nonmarketable. Bars with different letters denote significance at $p < 0.05$. Error bars denote the standard error of means. Means comparison was conducted using least significant difference ($p < 0.05$).

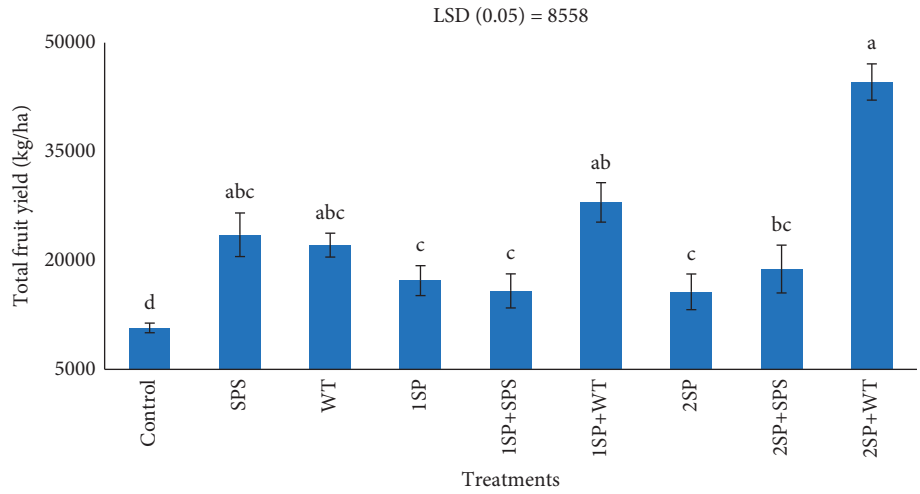

Figure 5: Effect of pruning and staking on total fruit yield. Bars with different letters denote significance at $p < 0.05$. Error bars denote the standard error of means. Means comparison was conducted using least significant difference ($p < 0.05$).

Table 2: Cost of production, gross return, net return, and benefit/cost ratio of tomato as affected by pruning and staking.

Treatments	Production cost ($/ha)	Gross return ($/ha)	Net return ($/ha)	BCR
Control	175.4	238.4	63.0	0.36
SPS	205.3	288.0	82.6	0.40
WT	226.7	407.1	180.4	0.80
1SP	180.7	321.2	140.5	0.78
1SP + SPS	407.4	600.7	214.6	0.53
1SP + WT	386.1	635.5	228.1	0.56
2SP	184.5	360.6	176.1	0.95
2SP + SPS	398.8	771.1	381.2	0.96
2SP + WT	411.2	1010	598.3	1.46

5. Conclusion

Pruning and staking significantly influenced fruit diameter, fruit length, marketable fruits weight, number of marketable fruits, and cost and benefit of tomato production. However, among the different pruning and staking treatments, 2 stem pruning + wire trellising (2SP + WT) increased fruit length and diameter, increased marketable fruit weight and number, and net return with a consequential greater cost benefit compared to other treatments. The study has demonstrated that there is hope of sustaining tomato production on highly reduced stakes compared with the current unsustainable staking practice. This would reduce the pressure on the forest to address the problem of deforestation. The two-stem pruning + wire trellising (2SP + WT) are recommended for sustainable increased yield and profit.

Data Availability

The data used to support the findings of this study are included within this article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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