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EFFECT OF DIFFERENT STAKING METHODS AND STEM PRUNING ON YIELD AND QUALITY OF SUMMER TOMATO

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Abstract

The study was carried out during summer of 2012 with BARI hybrid tomato 4, planted in the Olericulture farm of Bangladesh Agriculture Research Institute, Joydebpur, Gazipur, Bangladesh to find out the response of plants to some staking and pruning treatments on yield, fruit quality and cost of production. A two factor experiment consisting of three staking methods and four level of pruning, laid out in complete block design with three repetitions. Plants were staked on inverted 'V' shaped staking, high platform and string. The plants were pruned to two stem, three stem, four stem and no pruning as control. Results showed that significantly the highest total number of fruits per plant (37.1), marketable fruits per plant (33.7), yield per plant (1.68 kg) and total yield (44.6 t/ha) were produced by the plants having the treatment string staking with four stem. The highest fruit set (43.50%) was found in the plants staking with string having three stems. Plants grown on string staking allowing two stem gave the maximum length (4.71 cm), diameter (4.83 cm) and weight (53.4g) of single fruit as well as maximum fruit firmness (3.43 kg-f cm^{-2}). From the economic point of view, it was apparent that summer tomato produced by string staking with four stem pruning exhibited better performance compared to other treatment combinations in relation to net return and BCR (2.10).

Keywords: Different staking, Stem pruning, Yield, Quality, Summer Tomato.

Introduction

Yields of summer tomato do not always reach the full production potential. This is probably because of inadequate management. Improved management such as, staking and pruning could improve the yield of tomatoes. Staking refers to support of plants with sturdy material to keep the fruits and foliage off the ground. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits, prevents disease and fruit rot, allows better aeration and better exposure of the foliage to sunlight and photosynthetic activities (Anon., 2007). Akoroda *et al*. (1990) and Amina *et al*. (2012) recommended staking of crops for higher yield, quality fruits, easy harvesting and exposure of leaves for effective light reception. In Bangladesh inverted 'V' shaped staking is most common. Now-a-days farmers are using high

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platform system in some areas. In many countries tomato plants are staked by jute or nylon string hanging from the top of the tunnel which is less costly.

Pruning 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. Pruning in tomatoes has been reported to increase yields and quality of fruits (Hadfield, 1989; Preece, 1995; Srinivasan *et al*., 2001). In order to maximize the efficiency of photosynthesis and minimize the risk of diseases pruning is necessary when the growth is extremely dense. Franco *et al*. (2009) stated that choosing a proper pruning system was important to keep a balance in the relationship's source/sink and the carbon/nitrogen (C/N) ratio. Cockshull *et al*. (2001) found a tendency for side shoots to reduce the yield of marketable fruit produced on each cluster in greenhouse production. Guan and Janes (1991) also reported that pruning tomato plants regulate N:CHO ratio within the plant, and enhance fruiting. Literature indicates that productivity per area increases when pruning tomato plants to two stems. Aung (1999) reported that greater marketable yield/area was obtained by pruning indeterminate tomato plants to two stems rather than one stem. Rughoo and Govinden (1999) reported that yield of pruned and staked tomato plants was significantly lower than unpruned and unstaked plants, in a determinate variety, but significantly higher in indeterminate and semi-indeterminate varieties. So, the requirements of stem pruning and staking system are variable for different variety and growing conditions. In this context, selection of proper staking method and stem pruning for the BARI hybrid tomato 4 especially in hot humid climates of summer season in Bangladesh is important to ensure higher yield and economic return. Therefore, the study was undertaken to assess the influence of various staking methods and level of pruning on the yield and fruit quality of tomato.

Materials and Method

The experiment was carried out in summer of 2012 on BARI hybrid tomato 4, planted in the Olericulture farm of Bangladesh Agriculture Research Institute located at Joydebpur, Gazipur, Bangladesh to study the response of plants to staking and pruning on yield and fruit quality. The treatments consisted of a factorial combination of three staking methods and four levels of pruning, laid out in complete block design with three replications. Plants were staked on inverted 'V' shaped staking (S_1), high platform (S_2) and string (S_3), hanging from the top of the poly tunnel. Plants were pruned to two stem (B_2), three stem (B_3) and four stem (B_4) with no pruning (B_1) as control. Seeds were sown on May 1, 2012, in seed bed having mixture of soil and cowdung (1:1 ratio). After germination, at two true leaves stage the seedlings were shifted to second seed bed at a spacing of 5x5 cm to ensure better seedling growth. Twenty nine days old seedlings were transplanted in the main field under poly tunnel on May 29,

2012. Poly tunnels and beds were prepared prior to transplanting. Every single tunnel was 20 m long and 2.3 m wide with a height of 1.40 m along the sides and 2.0 m along the middle covering 0.10 mm thick transparent polyethylene sheet. Each tunnel had two beds of 1 m width separated by a 30 cm drain. Plants were spaced at 60x40 cm distance from each other thus a single tunnel accommodated 200 plants. Plants were staked 10-15 days after transplanting when plants reach a height of 25-30 cm. Bamboo sticks (1.5 m long and 2.5 cm diameter) were used for making inverted "V" shaped staking. High platform were made by bamboo over the bed. Platform was 40 cm of height, 1m width and as long as necessary. Plants were allowed to grow freely over the platform. Jute rope (5 mm thickness) was used as string staking hanging one end from the top of the tunnel and the other end was tied with the stem of the plant. Plants were twisted with the string gradually with the increasing of plant height. Different string was used for every single branch. Tomato plants were pruned to retain two stems, three stems and four stems. Pruning was done at weekly interval from 20 to 30 days after transplanting. While pruning, weak branches were removed retaining the strong branches. All the shoots appearing at the base of the plants were removed as they are not productive. Pruning was done by hand or using sharp knife in the morning. Data were recorded on the plant height at last harvest, days to flowering, days to first harvest, days to last harvest, fruit set, number of marketable fruits per plant, number of non marketable fruits per plant, fruit size (length and diameter), fruit firmness, total soluble solid, individual fruit weight and fruit yield. The digital fruit firmness tester "PENFEEL" (Model- DFT 14, Agro-Technologie, France) with flat head stainless-steel cylindrical probe of diameter 2 mm was used for the measurement of tomato fruit firmness. Collected data were analyzed statistically by using MSTAT-C to find out the variation among different treatments. Treatment means were separated using Least Significant Difference (LSD) test at 5 % level of significance (Gomez and Gomez, 1984).

Results and Discussions

Plant height: Types of staking had not much influence on plant height but plant height varied significantly for stem pruning (Table 1). The two stems plants were the tallest (147 cm) while no pruning was the shortest (123 cm). Treatment combinations had a great effect on plant height. Significantly the tallest (152 cm) plants were produced by inverted 'V' shaped staking with two stem whereas the shortest (121 cm) plants were produced by inverted 'V' shaped staking with no pruning. Results revealed that two stems plants significantly increased plant height followed by pruning treatment of three stems per plant and four stems per plant, while the non-pruned plants were the poorest. These results are in harmony with the findings of Malash and Gawish (1989) on tomato. The increase in plant height of tomato might be due to removal of branches that leads to supply

nutrients in the remaining branches. Similar observations were noticed by Mangal *et al.* (1981) and Srinivasan *et al.* (2001) in tomato. Saen and Pathom (1998) recorded increased plant height with three pruning methods on pepper.

Table 1. Effects of staking type and stem pruning on plant height at last harvest, days to flowering, fruit set, days to first harvest and days to last harvest of summer tomato

Staking type	Plant height (cm)	Days to flowering	Fruit set (%)	Days to first harvest	Days to last harvest
S_1	135	46	37.15	86	122
S_2	133	47	35.10	87	121
S_3	133	46	38.29	83	119
LSD (5 %)	ns	ns	2.542	3.298	ns
Stem pruning					
B_1	123	47	31.97	86	122
B_2	147	46	38.64	83	116
B_3	135	45	41.47	85	123
B_4	129	46	35.31	86	122
LSD (5 %)	4.332	ns	2.935	ns	ns
Combined effect					
S_1B_1	121	46	36.20	86	125
S_1 B_2	152	46	38.00	84	114
S_1 B_3	136	45	39.60	86	125
S_1 B_4	132	47	34.82	88	124
S_2 B_1	122	45	28.12	88	121
S_2 B_2	144	46	37.56	85	118
S_2 B_3	137	48	41.32	87	124
S_2 B_4	127	47	33.40	87	120
S_3B_1	125	47	31.60	84	119
S_3 B_2	145	45	40.35	81	115
S_3 B_3	132	46	43.50	83	120
S_3 B_4	129	45	37.70	83	122
LSD (5 %)	5.521	ns	5.084	ns	ns
CV(%)	2.44	3.87	5.99	4.57	5.28

Note: S_1= Inverted 'V' shaped staking; S_2= High platform; S_3= Staking with string; B_1= No pruning; B_2= Allow two branches; B_3= Allow three branches; B_4= Allow four branches.

Days to flowering: Data on days to 50% flowering, presented in Table 1. Type of staking, stem pruning and their combinations had no significant effect on the parameter. The plants took 45 to 48 days to 50% flowering for different treatments and treatment combinations.

Fruit set: Data presented in Table 1 clearly demonstrated the effect of the different treatments and their combined effects on fruit set of tomato. Percent

fruit set differed significantly by staking type. The highest fruit-set (38.29%) was obtained from the plants staked with string and the lowest (35.10%) from the plants staked with high platform. Stem pruning influenced significantly on percent fruit-set. The maximum fruit set (41.47%) was counted in plants with three stems followed by plants with two stem (38.64%) which were statistically at per. The minimum (31.97%) fruit set was counted in no pruning treatment. Combination of treatments differed significantly in respect fruit set. The highest fruit set (43.50%) was found in the plants staking with string having three stems. The lowest fruit set (28.12%) was recorded in the plants staking on high platform with no pruning. Light becomes a limiting factor in crowded branches where pruning with string staking improves light access. Adjustments must be made in the height, row width, and hedging angle to maximize sunlight penetration through the canopy. Staking with string and stem pruning provide enough space among the branches to enter sunlight and good aeration which might be a good reason to increase fruit set. Sunlight not only influences the flowering and fruit set but also enhances fruit quality and colour development of fruit (Ahmed *et al.*, 2006). Similarly high fruit set percentage were recorded by Mangal *et al.* (1981); Sharfuddin and Ahmed (1986) in pruning treatments. Lim and Chen (1988) studied the effect of training on tomato and found double stems had increased proportion of fruit setting, size and quality than single stem.

Days to first harvest: A significant variation was observed in respect of days to first harvest among different types of staking. Fruits harvested the earliest from plants those staked with string (83 days) and the most delayed (87 days) from the plants sprawl over high platform. Effect of stem pruning was not significant on the parameter. The treatment combinations also showed no significant differences on days to first harvest but the earlier harvest was done in string staking with two stems (81 days) and delayed in high platform staking with no pruning (88 days). Mangal *et al.* (1981) stated that pruned tomato plant cropped earlier which is closely similar to the findings of present study.

Days to last harvest: Days to last harvest was not affected significantly by staking types, stem pruning and their combinations (Table 1). It ranges 119 to 122 days for different type of staking and116 to 123 days for stem pruning. Among the treatment combinations, days to last harvest ranges from 114 to 125 days. This might be due to higher number of active leaves that continue photosynthetic activity which regulate the plant to retain fruit for longer period.

Number of marketable fruits per plant: Number of marketable fruits per plant varied remarkably with staking type (Table 2). The maximum marketable fruits per plant (29.5) were obtained from the treatment string staking and the minimum were recorded from inverted "V" shaped staking (26.2). Results in respect of marketable fruits per plant were found to be statistically significant as influenced by stem pruning. The plants pruned with four stem produced the highest marketable fruits per plant (32.6) and the lowest from the plants pruned with two stem (22.5). Combined effects of staking type and stem pruning showed

wide variation in this parameter. It was maximum in the plants managed by string staking having four stems (33.7) and minimum in inverted "V" shaped staking having two stems (21.2). String staking facilitates exposure of branches and leaves for aeration and effective light reception as a result number of marketable fruits increased. Akoroda *et al.* (1990) and Amina *et al*. (2012) recommended staking of crops for higher yield of quality fruits. Staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits (Anon. 2007). Ramirez *et al.* (1977) reported that punning to two or three stems produced the best quality fruits. Salinas *et al.* (1997) subjected tomato plants, that were pruned produced significantly higher per cent of good quality fruits than unpruned ones. Singh (1994) recorded, lower unmarketable yield, higher marketable fruits and higher net return from rainy season tomato crop with raised bed and staking at Ranchi, Bihar, India. These results are in agreement with the presents findings.

Number of non marketable fruits per plant: Staking type had significant effect on the number of non marketable fruits per plant. Plants staked with inverted "V" shaped staking (4.6) produced the maximum non marketable fruits per plant closely followed by plants sprawl over high platform (4.3). The minimum non marketable fruits per plant were found in string staking (3.5). Stem pruning also varied significantly for this parameter. The highest and the lowest number of non marketable fruits per plant were obtained from the treatments no pruning (5.9) and with two stem pruning (3.1) respectively. Combined effect of staking type and stem pruning had significant effect on number of non marketable fruits per plant. It was the maximum in the plants managed by inverted "V" shaped staking with no pruning (7.5) and the minimum in string staking with two stem (2.6). The plants managed by inverted "V" shaped staking with no pruning was crowded with branches where light becomes a limiting factor with less aeration which enhance disease and fruit rot resulted higher non marketable fruits. Cordt (1999a) reported that non marketable fruits were the maximum in unpruned plants while staking increases fruit yield, reduces the proportion of unmarketable fruit, enhances the production of high quality fruits (Anon. 2007). Amina *et al*. (2012) and Akoroda *et al*. (1990) observed the similar findings. Hanson (1998) suggested staking the tomato plants increases the fruit yield, reduces the proportion of cull fruit.

Individual fruit weight: Individual fruit weight was significantly the largest with string staking (50.2 g) and the *lowest* with high platform (44.7 g). Stem pruning had the much influence on individual fruit weight. Significantly the highest weight of fruit was obtained from the plant with two stems (50.1 g) and the lowest from no pruning treatment (45.0 g). Treatment combination differed significantly for the trait. Plants grown on string staking with two stems (53.4 g) gave the maximum weight of single fruit while plants grown on high platform staking with no pruning gave the minimum (42.6 g) fruit weight

(Table 2). Photosynthetic activities may be enhanced due to better exposure of the foliage to sunlight as a result, fruits accumulate higher assimilates which might be responsible for higher fruit weight in the plants staked with string staking. The results are in agreement with Kumar *et al.* (2001) who found increased mean fruit weight of tomato by staking. Ara *et al*. (2007) noticed that removal lateral branches resulted in increasing fruit weight of tomato plants. The competition for assimilates among the fruits lead to reduced fruit size. Plants pruned to two stems resulted in significantly higher number and mass of large fruits compared to plants pruned to three stems, four stems and no pruning. The results of increased average fruit weight by pruning side shoots was in conformity with the findings of Cebula (1995) who also reported that the fewer shoots per plant produced heavier fruits in peeper. Cordt (1999b) reported that maintenance of additional one stem per plant in an area of one square meter resulted in increased production of 12 fruits per square meter. However, there was a reduction of average fruit weight (1.5g).

Fruit firmness: The firmness of tomato fruits varied significantly as influenced by staking type, stem pruning and their combinations (Table 2). Significantly the highest firmness was measured from string staking (3.07 kg-f cm^{-2}) and the lowest from high platform staking (2.88 kg-f cm^{-2}). It was also found that firmness of tomato was the highest in the plants with two stems (3.31 kg-f cm^{-2}) and the lowest in the plants received no pruning (2.52 kg-f cm^{-2}). Among the treatment combinations, the maximum (3.43 kg-f cm^{-2}) fruit firmness was found in the combination of string staking with two stems and the minimum (2.42 kg-f cm^{-2}) in high platform staking with no pruning. Results of the experiment showed that string staking produced the larger fruit due to accumulation of photo-assimilates which might be a possible reason to produce more firmness of fruit. It was observed that two stem pruning resulted in a significant increase in fruit firmness while three stem, four stem and no pruning treatment decreased in fruit firmness. These results agreed with Bennewitz *et al.* (2011) who found that removal of lateral branches resulted in increasing fruit firmness of sweet cherries.

TSS: Total soluble solid (%) was not affected significantly by staking types (Table 2). TSS ranges from 4.32% to 4.35% for different staking methods. Stem pruning significantly influenced the TSS. The maximum (4.44%) and the minimum (4.24%) total soluble solid were obtained in the fruits harvested from plants with two stems and no pruning, respectively. Among the treatment combinations no significant variation was observed. Fruits from the plants with inverted 'V' shaped staking having two stems gave the highest (4.46%) total soluble solid and fruits from the plants staked with high platform having no pruning gave the lowest (4.23%) total soluble solid. Fruits harvested from the plants with lower number of stems gave higher TSS. The results agreed with those obtained by Malash and Gawish (1989) and Hesamil *et al*. (2012), who noticed that removal of lateral branches resulted in increasing fruit TSS of tomato.

Table 2. Effects of staking type and stem pruning on marketable and non marketable fruits per plant, individual fruit weight, fruit firmness and TSS of summer tomato

Staking type	Marketable fruits per plant	Non marketable fruits per plant	Individual fruit weight (g)	Fruit firmness (kg-f cm^{-2})	TSS (%)
S_1	26.2	4.6	47.8	2.90	4.35
S_2	26.6	4.3	44.7	2.88	4.32
S_3	29.5	3.5	50.2	3.07	4.35
LSD (5 %)	1.615	0.4019	1.112	0.1261	ns
Stem pruning					
B_1	28.7	5.9	45.0	2.52	4.24
B_2	22.5	3.1	50.1	3.31	4.44
B_3	25.9	3.4	48.0	3.20	4.37
B_4	32.6	4.0	47.1	2.78	4.30
LSD (5 %)	1.865	0.4641	1.283	0.1456	0.096
Combined effect					
S_1B_1	28.3	7.5	45.4	2.48	4.23
S_1B_2	21.2	3.2	49.6	3.26	4.46
S_1B_3	22.6	3.4	48.1	3.28	4.38
S_1B_4	32.7	4.1	48.3	2.58	4.32
S_2B_1	26.9	5.3	42.6	2.42	4.23
S_2B_2	21.8	3.4	47.4	3.24	4.43
S_2B_3	26.4	3.8	44.5	3.10	4.36
S_2B_4	31.3	4.5	44.2	2.78	4.26
S_3B_1	31.0	4.9	47.1	2.65	4.27
S_3B_2	24.6	2.6	53.4	3.43	4.43
S_3B_3	28.7	3.1	51.5	3.22	4.38
S_3B_4	33.7	3.4	48.8	2.97	4.33
LSD (5 %)	2.377	0.8.39	1.636	0.1855	ns
CV(%)	5.12	8.53	2.03	3.77	1.96

Note: S_1= Inverted 'V' shaped staking; S_2= High platform; S_3= Staking with string; B_1= No pruning; B_2= Allow two branches; B_3= Allow three branches; B_4= Allow four branches.

Fruit length: Fruit length was significantly influenced by staking types, stem pruning and their combinations (Table 3). The highest fruit length was measured from string staking (4.47 cm) and the lowest from high platform (4.25 cm). Fruit length differed significantly for stem pruning. The maximum fruit length was found in plants with two stems (4.47 cm) where no pruning treatment (4.21 cm) gave the minimum. Among treatment combinations, significantly the highest fruit length (4.71 cm) was obtained from string staking with two stems. The lowest (4.15 cm) fruit length was measured from high platform staking with no pruning treatment followed by inverted "V" shaped staking with no pruning (4.20

cm) and string staking with no pruning (4.25 cm). Staking with string allows plant for better aeration and better exposure of the foliage to sunlight that enhance photosynthetic activities which might be responsible for larger fruit size. However, the competition for assimilates among the fruit lead to reduced fruit size. Plants pruned to two stems had lower number of fruits resulted less competition for assimilates leads significantly higher length of fruits compared to plants pruned to three stems, four stems and no pruning. The results agreed with those obtained by Hesamil *et al*. (2012), who noticed that removal of lateral branches resulted in increasing fruit size of tomato plants. Saen and Pathom (1998) also found increased fruit length when studied the effect of three pruning methods (no pruning, two branch pruning and four branch pruning) on peeper. Ledo *et al.* (1998) reported that tomato with the maximum shoots removed, produced larger sized fruits (52 mm) than control.

Fruit diameter: Fruit diameter was also influenced by staking types, stem pruning and their combinations (Table 3.). The highest fruit diameter was found in string staking (4.55 cm) and the lowest in high platform staking (4.36 cm) which were statistically significant. The variation was observed for stem pruning treatment also significant. Two stem gave the highest (4.59 cm) diameter and no pruning treatment gave the lowest (4.32 cm) fruit diameter. Treatment combinations were significantly differed for this parameter. The maximum (4.83 cm) diameter was obtained from string staking with two stems and the minimum (4.26 cm) from high platform staking with no pruning treatment. Kumar *et al.* (2001) noticed higher fruit diameter of tomato obtained by staking. Results revealed that plant pruned to fewer stem resulted in a significant increase in fruit diameter. The results supported with those obtained by Hesamil *et al*. (2012). The competition for assimilates among the fruits might be the cause of reduced fruit size. Hernanden *et al*. (1992) also found increased fruit diameter of tomato when plants were pruned.

Yield per plant: Highly significant variations were recorded for fruit yield per plant among staking methods (Table 3). The highest yield per plant was obtained from plants staking with string (1.52 kg) and the lowest from high platform (1.25 kg). Stem pruning had a pronounced effect on yield per plant. The plants allowed to grow with four stems gave the highest yield (1.54 kg) and the lowest yield (1.19 kg) from the plants with two stems. Among the treatment combinations, significantly the maximum yield (1.68 kg) per plant was obtained in the plants staking with string having four stems and the minimum (1.05 kg) in the plants staking with high platform having two stem. The findings of the present investigation are in agreement with Kumar *et al.* (2001) who found increased mean fruit weight of tomato by staking. In South-West Nigeria, Adelaine (1976) reported that staking increases fruit yield by 18 to 25% and Quinn (1973) showed at Samaru, Nigeria that under wet conditions marketable yields were significantly increased by staking the tomato crop. The increased yield per plant induced by pruning may be due to the increased average fruit weight and number of fruit per plant. The result agreed with those obtained by Ara *et al*. (2007) and Huat *et al*.

(2013). This increased yield per plant is due to presence of more stem, increased number of clusters per plant, high fruit set percentage and large number of leaves which intern increases the photosynthetic activity and ultimately leads to higher yield per plant. Similar results were reported by Mangal *et al.* (1981); Sharfuddin and Ahmed (1986). Joshi *et al*. (1992) studied effect of training on six winter grown indeterminate tomato cultivars and observed training the plants to three main stems gave the best yield.

Table 3. Effects of staking type and stem pruning on fruit size and yield of summer tomato

Staking type	Fruit length (cm)	Fruit diameter (cm)	Yield per plant (kg)	Yield (t/ha)
S_1	4.36	4.50	1.37	38.1
S_2	4.25	4.36	1.25	34.3
S_3	4.47	4.55	1.52	40.9
LSD (5 %)	0.1856	0.1409	0.0514	1.398
Stem pruning				
B_1	4.21	4.32	1.33	36.3
B_2	4.47	4.59	1.19	31.7
B_3	4.37	4.46	1.46	40.5
B_4	4.40	4.50	1.54	42.5
LSD (5 %)	0.2143	0.1627	0.0594	1.614
Combined effect				
S_1B_1	4.20	4.32	1.38	37.4
S_1 B_2	4.54	4.67	1.15	32.3
S_1 B_3	4.32	4.46	1.44	40.2
S_1 B_4	4.40	4.53	1.51	42.6
S_2 B_1	4.15	4.26	1.16	30.4
S_2 B_2	4.29	4.28	1.05	28.5
S_2 B_3	4.25	4.36	1.36	38.7
S_2 B_4	4.31	4.41	1.42	39.4
S_3B_1	4.25	4.37	1.45	41.2
S_3 B_2	4.71	4.83	1.38	34.3
S_3 B_3	4.53	4.57	1.57	42.3
S_3 B_4	4.50	4.55	1.68	44.6
LSD (5 %)	0.273	0.2819	0.0757	2.795
CV(%)	3.69	2.76	3.43	3.22

Note: S_1= Inverted 'V' shaped staking; S_2= High platform; S_3= Staking with string; B_1= No pruning; B_2= Allow two branches; B_3= Allow three branches; B_4= Allow four branches.

Yield (t\ha): Remarkable variation was observed among the staking types in respect of yield (t/ha). Significantly the highest yield (40.9 t/ha) was measured from the treatment string staking, while the lowest yield (34.3 t/ha) from high platform staking. Yield (t/ha) differed significantly for stem pruning. The highest total yield (42.5 t/ha) was obtained from the treatment four stem pruning and the lowest (31.7 t/ha) with two stem. Combined effect was also significant for this

trait. The combination string staking with four stems produced the highest yield (44.6 t/ha) and the high platform with two stems produced the lowest (28.5 t/ha). Staking of tomatoes gives higher yield, and good quality fruits with higher market value (Amina *et al*. 2012; Anon., 2007). Hui *et al*. (2003) reported that staked tomato plants yielded roughly a total of 20% over unstaked plants. In their experiment, they observed that the highest total yield was obtained by the 'Castelleto' system in which the plants were staked individually which is closely similar to string staking. Adelaine (1976) reported that staking increases fruit yield by 18 to 25%. The increased total yield observed in four stem pruning was due to higher yield per plant in the same treatment. Sharfuddin and Ahmed (1986) investigated the response of cv. Marglobe to four levels of pruning. The highest yield of 123.26 tons per ha was obtained in plants pruned to three stems. Mangal *et al.* (1981) reported that pruned plants gave higher total yield than un-pruned and un-staked ones. Ayas *et al*. (1981) observed that field grown tomato cv. Chonta Liceto when pruned to leaving six branches per plant produced 65.99 tons fruits per ha. Whereas, plants pruned to level of two branches produced 55.90 tons fruits per ha. Joshi *et al*. (1992) studied effect of training on six winter grown indeterminate tomato cultivars and observed training as marked effect on yield of tomato, training enhances yield by 9.13 to 114.33 percent depending on the cultivars. Training the plants to three main stems gave the best yield. In a greenhouse trial of tomato, training (no pruning, training at 5 and 6 stems) five stems per plant resulted in higher net fruit yield with least wastage, while, training to six stems per plant resulted in equivalent total yield, but with more waste production (Cordt, 1999a).

Table 4. Cost and return analysis of summer tomato as influenced by staking methods and stem pruning

Treatment	Marketable yield (t/ha)	Gross return (Tk./ha)	Total cost of production (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio (BCR)
S_1B_1	37.4	1683000	1043192	639808	1.61
S_1 B_2	32.3	1453500	1041030	412470	1.40
S_1 B_3	40.2	1809000	1044380	764620	1.73
S_1 B_4	42.6	1917000	1045397	871603	1.83
S_2 B_1	30.4	1368000	1019560	348440	1.34
S_2 B_2	28.5	1282500	1018754	263746	1.26
S_2 B_3	38.7	1741500	1023079	718421	1.70
S_2 B_4	39.4	1773000	1023376	749624	1.73
S_3B_1	41.2	1854000	1008742	845258	1.84
S_3 B_2	34.3	1543500	954301	589199	1.62
S_3 B_3	42.3	1912500	954302	958198	1.99
S_3 B_4	44.6	2052000	954303	1097697	2.10

Note: S_1= Inverted 'V' shaped staking; S_2= High platform; S_3= Staking with string; B_1= No pruning; B_2= Allow two branches; B_3= Allow three branches; B_4= Allow four branches. Tomato sale @ Tk 45/kg (Farm gate price)

Cost and return analysis

Partial cost-benefit analysis was done in this experiment. Variation on cost and return analysis was found for tomato produced with different staking methods and stem pruning. Inverted "V" shaped staking with four stems pruning incurred the highest cost of production TK. 1045397/ha, whereas staking with string with two stems incurred the lowest (TK. 954301/ha) cost of production. The gross return was proportionate to marketable yields. It was the maximum (Tk. 2052000/ha) in tomato produced by string staking with four stems and the minimum was obtained from tomato grown by high platform with two stems (Tk. 1282500/ha). In case net return and benefit cost ratio (BCR), it was observed that crop produced by string staking with four stem pruning gave the highest (Tk. 1097697/ha) net return as well as the maximum BCR (2.10). The minimum net return (TK. 263746/ha) and BCR (1.26) was found in tomato grown on high platform with two stem. From the economic point of view, it was apparent that summer tomato produced by string staking with the plant having four stems exhibited better performance compared to other treatment combinations in relation to net return and BCR.

Conclusion

The study demonstrated that yield, quality and profitability of tomato can be effectively manipulated by staking methods and stem pruning. Plants managed by string staking having four stem produced significantly the highest number of fruits per plant and yielded the highest. From the economic point of view, the above treatment combination exhibited better economic performance compared to farmers' practices. The results need to be confirmed with other cultivars.

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