



Effect of planting geometry and training on growth and seed yield of tomato (*Solanum lycopersicum* L.)

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Abstract: The study was conducted to evaluate the effect of planting geometry and training on growth and seed yield of tomato (*Solanum lycopersicum* L.) using cultivar Solan Lalima during *Kharif* 2013 at Experimental Farm of Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). The treatments comprised of four training levels i.e. Y₁ (single stem), Y₂ (double stem), Y₃ (unpruned with horizontal string) and Y₄ (unpruned bush stakes (control)) and eight plant densities viz. S₁ (60×15 cm), S₂ (60+30×15 cm), S₃ (60×30 cm), S₄ (60+30×30 cm), S₅ (90×15 cm), S₆ (90+30×15 cm), S₇ (90×30 cm) and S₈ (90+30×30 cm). Analysis of variance showed that the treatment combination Y₁S₇ (single stem and plant spaced at 90×30 cm) resulted in maximum ripe fruit length and width (5.86 cm and 5.06 cm, respectively), maximum number of seeds/fruit (110.67), minimum days to ripe fruit harvest (71.00) and maximum harvest duration (59.84 days) but gave the low seed yield. The combination Y₂S₅ (double stem and 90×15 cm) resulted highest seed yield i.e. 519.71 kg per hectare. Therefore, planting density S₅ (90×15 cm) in combination with training system Y₂ (double stem) may be recommended for commercial seed production of tomato.

Keywords: Cultivar, Plant density, Seed Yield, Training levels

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important warm season solanaceous vegetable crop that cannot tolerate frost and freezing temperatures. Tomato is a good source of vitamins, minerals and antioxidants so it is an important ingredient of traditional and modern days' food. The tomato pulp and juice are mild aperients (laxative), a promoter of gastric secretion and act as blood purifier and intestinal antiseptic (Hazra *et al.*, 2011).

Seed is the primary factor which determines the performance of the plants in the field and final yield. So there is need to focus on factors which help in increasing the yields of quality seed. Among various agro-techniques, planting density and training system play a crucial role in quality seed production in tomato as both of these factors helps in preventing overcrowding and reduces the competition between and within the plants for nutrients, light and water thus helps in avoiding poor fruit set and delayed maturity. Also, these factors by improving air circulation through the plants especially in humid areas prevent the proliferation of disease. Maximum yield is resulted at optimum plant density which depends upon cropping system and cultivar (Dong *et al.*, 2006). It is believed that yield per

unit area tends to increase with plant density up to certain threshold value, and then tends to decline due to competition between the plants (Duthie *et al.*, 1999). Plant density determines the optimal above ground conditions that allows the plant to get the essential growth elements such as light, CO₂, etc. that influence the productivity (Ibrahim, 2012).

Similarly, training and pruning in later stages of plant growth reduces the competition amongst fruits for sunlight and photosynthesis products. For making training more effective, staking is another most important operation being practiced especially during rainy season for improving quality, yield and protecting the crop from attack of soil borne pathogens. Moreover, the traditional system of staking makes plants more bushy posing problems in accommodating more number of plants per unit area. Patil *et al.* (1973) pointed out that indeterminate plants have unnecessary leaf load and can be severely pruned without effecting yield. By proper pruning and staking, more number of plants can be accommodated per unit area thereby increasing the yields. Keeping in view the above perspectives, the present studies were thus planned to find out optimum training system and plant spacing for commercial seed production of tomato.

MATERIALS AND METHODS

The experiment was laid out on 14th March 2013 in split plot design with thirty two treatments (4 x 8) replicated three times at Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) situated between 30.51°N latitude and 77.09°E longitude in the mid- hill zone of Himachal Pradesh (India). The seedlings of tomato var. Solan Lalima were transplanted at eight different spacings (S₁- 60×15cm, S₂ - 60+30×15cm, S₃ - 60×30cm, S₄ - 60+30×30cm, S₅ - 90×15cm, S₆ - 90+30×15cm, S₇ - 90×30cm, S₈ - 90+30×30cm) in a plot having size of 3.6 m × 1.8 m. After the plants established, they were trained to four levels i.e. Y₁ (single stem), Y₂ (double stem), Y₃ (unpruned with horizontal string) and Y₄ (unpruned bush stakes (control)). FYM and fertilizers were applied as per package of practices for vegetable crops, Directorate of Extension Education, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.).

The observations were made on five randomly selected plants from each replication. The growth characters studied were plant height (cm) before the senescence, days to ripe fruit harvest and harvest duration. Fruits from the selected plants were collected to record fruit characters such as ripe fruit weight (g), ripe fruit length (cm), ripe fruit width (cm) and number of ripe fruits per plant. Seeds from the harvested fruits were extracted and dried to safer moisture limit i.e. 6-8% and seed yield attributes like number of seeds per fruit, seed yield per plant (g) and seed yield per hectare (kg) were calculated. Statistical analysis of the recorded data was carried out as per design of the experiment as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on growth characters: All the growth characters were influenced by the given treatments as revealed in Table 1. Plant height is an important character as it leads to the production of quality fruits and ultimately high yield of quality seeds. However, plant height being a genetically controlled character also influenced by the environment to a great extent. In the present studies, the plant height decreased with decrease in spacing. The tallest plants (159.02 cm) were recorded with widest plant spacing of 90×30 cm (S₇), whereas, among the training systems single stem trained plant resulted in tallest plants (150.19 cm). Aminifard *et al.* (2012) reported maximum plant height and lateral stem length at wider plant spacing (30x100 cm) in capsicum. Lal *et al.* (2014) also reported tallest plants with wider spacing and single stem pruned plants in capsicum. This may be due to the pinching shoots at their emergence and ultimately diverting the flow of nutrients and manufactured food

Table 1. Effect of planting geometry and training on growth characters of tomato during the year 2013.

Partic- lars	Plant height (cm)								Days to ripe fruit harvest								Harvest duration															
	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	Mean Y	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	Mean Y	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	Mean Y					
Y ₁	137.53	134.27	157.10	154.64	153.23	136.30	165.62	162.80	150.19	76.48	77.02	72.40	74.20	74.30	76.82	71.00	72.70	74.37	50.80	43.80	59.00	54.60	54.80	50.60	59.84	59.20	54.08					
Y ₂	132.50	130.67	151.53	150.45	148.80	131.73	158.20	152.40	144.54	77.40	78.06	73.00	74.70	75.06	77.80	71.70	73.00	75.09	49.00	43.50	58.00	53.50	54.00	48.80	58.82	58.43	53.01					
Y ₃	129.42	126.57	146.53	145.20	143.67	127.13	156.40	149.20	140.52	79.84	81.02	73.20	75.20	75.60	80.42	71.80	73.60	76.33	47.00	42.00	56.40	51.80	52.00	46.00	57.70	57.00	51.24					
Y ₄	125.93	122.60	141.34	140.10	138.60	124.43	155.87	142.48	136.42	81.06	83.21	73.80	75.80	76.00	82.04	72.00	74.00	77.24	45.00	41.00	55.00	51.00	51.40	44.00	58.00	55.40	50.10					
Mean S	131.35	128.53	149.13	147.60	146.08	129.90	159.02	151.72	142.92	78.70	79.83	73.10	75.0	75.24	79.27	71.63	73.33	75.76	47.95	42.57	57.10	52.73	53.05	47.35	58.59	57.51	52.11					
CD at 5% (Y)	2.54																															
CD at 5% (S)	2.21																															
CD at 5% (Y×S)	NS																															
	0.71								0.44								0.74								0.73							

Table 2. Effect of planting geometry and training on fruit characters of tomato during the year 2013.

Particulars	Ripe fruit weight (g)								Ripe fruit length (cm)								Ripe fruit width (cm)								Number of ripe fruits per plant																
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	Mea n Y
Y1	51.67	50.00	64.17	60.00	59.17	51.82	71.66	70.83	59.91	3.34	3.25	4.17	3.90	3.83	3.26	5.86	4.34	4.00	4.40	4.76	5.02	4.79	4.71	4.40	5.06	4.90	4.76	22.60	26.33	21.0	21.8	21.3	22.2	20.2	20.8	22.03					
Y2	49.17	45.53	58.33	57.97	57.50	47.50	63.33	59.10	54.80	3.18	3.11	3.99	3.98	3.95	3.15	4.16	4.02	3.69	4.09	4.10	4.86	4.81	4.87	4.35	4.97	4.96	4.63	25.47	27.43	24.8	26.4	26.0	26.3	23.6	24.2	25.53					
Y3	45.39	43.10	57.35	56.20	54.93	43.46	54.61	62.70	52.22	3.09	3.03	3.88	3.86	3.84	3.08	4.15	3.89	3.60	4.30	4.03	4.94	4.54	4.21	4.97	4.88	4.55	27.00	25.80	24.6	26.0	25.3	26.8	23.4	24.0	25.36						
Y4	42.98	42.50	53.33	52.70	52.50	42.86	62.50	54.17	50.44	3.03	2.95	3.95	3.60	4.03	2.97	4.10	3.82	3.56	4.19	3.93	4.52	4.51	4.49	4.12	4.89	4.88	4.44	27.20	24.78	24.4	25.8	25.0	22.8	23.1	23.8	24.61					
Mean S	47.30	45.28	58.29	56.72	56.02	46.41	63.02	61.70	54.34	3.16	3.08	4.00	3.84	3.91	3.12	4.57	4.02	3.71	4.25	4.21	4.83	4.66	4.65	4.27	4.97	4.91	4.60	25.57	26.08	23.7	25.0	24.4	24.6	22.6	23.2	24.38					
CD at 5% (Y)									3.37								0.21								0.13								0.45								
CD at 5% (S)									3.61								0.19								0.13								0.62								
CD at 5% (Y×S)									N/S								0.18								0.12								0.59								

Table 3. Effect of planting geometry and training on seed yield of tomato during the year 2013.

Particulars	Number of seeds per fruit								Seed yield per plant (g)								Seed yield per hectare (kg)															
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Y1	72.00	59.00	98.50	81.27	93.6	66.50	110.67	95.33	84.61	4.79	4.35	7.78	6.34	7.42	4.30	8.72	7.42	6.39	423.69	513.68	344.46	374.53	437.78	380.78	257.55	328.43	382.61					
Y2	74.00	56.00	98.33	80.00	92.0	64.90	103.00	94.77	82.88	5.41	4.24	8.88	7.44	8.80	4.88	9.43	8.25	7.17	478.99	500.65	393.00	439.05	519.71	432.33	278.43	365.53	425.96					
Y3	70.87	55.53	97.80	79.00	90.0	62.00	101.90	92.40	81.19	5.43	3.93	8.42	7.15	8.31	4.69	8.82	7.67	6.80	481.27	463.54	372.82	421.91	490.70	414.91	260.46	339.65	405.66					
Y4	68.40	46.27	96.47	78.00	88.0	61.87	99.47	91.73	78.78	5.21	3.09	7.77	6.88	7.97	3.93	8.04	8.19	6.38	461.40	365.34	343.96	406.29	470.27	348.41	237.41	362.55	374.45					
Mean S	71.32	54.20	97.78	79.57	90.9	63.82	103.76	93.56	81.87	5.21	3.90	8.21	6.95	8.12	4.45	8.75	7.88	6.69	461.34	460.80	363.56	410.45	479.61	394.11	258.46	349.04	397.17					
CD at 5% (Y)									0.48								0.18							7.93								
CD at 5% (S)									0.49								0.23							10.40								
CD at 5% (Y×S)									0.46								0.22							9.90								

material towards apical growing point and greater exposure of plants to light leading to higher photosynthetic activities.

Minimum number of days to ripe fruit harvest (71.00) and maximum harvest duration i.e. 59.84 days were reported with the interaction Y_1S_7 (single stem and 90×30 cm) which may be because of availability of sufficient nutrients and light to the plant due to wider spacing that results in accumulation of maximum photosynthates and induction of early flowering compared to closer spacing and thus enhancing better growth and development of the fruit. The results are in conformity with Tanaka and Komachi (1982) who reported that high plant density delays fruit ripening by seven days. Lal *et al.* (2014) also reported minimum number of days to ripe fruit harvest with wider spacing and low shoot density in bell pepper. Similar findings were also observed by Bhatnagar and Pandita (1979) who have reported that least number of days was taken for ripening in closely spaced tomato plants. Similar results were obtained by Verma (2014) who reported that double row ($75+45$) \times 45 cm and triangle method of planting was superior in terms of growth characters such as plant height and days to ripe fruit harvest.

Effect on fruit characters: The treatments significantly affect different fruit characters as depicted in Table 2. Ripe fruit weight is an important character which contributes to the fruit/seed yield and seed quality. Spacing 90×30 cm (S_7) gave the highest average ripe fruit weight (63.02 g) whereas in case of training single stem trained plants resulted in highest ripe fruit weight i.e. 59.91 g. The increased fruit weight at widest spacing may possibly be due to more availability of light, reduced competition for nutrients and moisture, hence, more assimilation of carbohydrates. Similar results has been recorded by Sharma (2001) who have reported that widely spaced paprika plants produces more number of fruits per plant and heavier fruit weight and Elattir (2002) reported that increased plant density in tomato results in increased number of clusters per m^2 and fruit yield but mean fruit weight decreases. Similarly, Buitelaar and Eelhart (1986) reported that each ten centimeters of closer spacing tended to decrease average tomato fruit weight by about 5 grams but increase yield by 1.6 kg/m^2 . Results are also in conformity with Lal *et al.* (2014), who have an increase in average fruit weight when plants were pruned to single stem in *Capsicum annum*.

Fruit length and width determine the size of the fruit and correlated to the number of seeds per fruit (Kinet and Peet, 1997). Maximum fruit length and width (5.86 cm and 5.06 cm, respectively) were obtained with interaction level Y_1S_7 (single stem and 90×30 cm). The possible explanation remains the same as the plants at wider spacing has less competition between and within the plants for nutrients, sunlight and aerial

space resulting in better growth and development of the plant. Papadopoulos and Pararajasingham (1997) also concluded that narrow spacing was found to have a detrimental effect on the fruit size in tomato. Similarly, Neamati and Kruchkov (2002) reported that plants with more fruits are positively correlated to less growth and smaller fruits. The results are also in agreement with Lal *et al.* (2014), who reported maximum fruit length and width with single stem trained plant and wider spacing in capsicum. Sumiati (1987) concluded that highest yield was obtained from plants pruned to two or three stems; however pruning to single stem produces larger size fruits.

Number of ripe fruits per plant is a major seed yield contributing character. Interaction Y_2S_2 (double stem and $60+30 \times 15$ cm) resulted in maximum number (27.43) of ripe fruits. Similar findings were observed by Hassan (1991) who concluded that highest number of fruits per plant was recorded in plants pruned to double stem. This could be due to the double stem character along with close spacing accommodate more number of plants that results in more number of fruits per unit area.

Effect on seed yield characters: The treatments have significant effect on the seed yield attributes as shown in the Table 3. The main and important objective of any seed production experiment is to have optimum seed yield per unit area and to have better returns. Number of seeds per fruit is one of the characters contributing to final seed yield. Maximum numbers of seeds per fruit (110.67) were recorded with treatment combination Y_1S_7 (single stem and 90×30 cm). Lal *et al.* (2016) reported similar results in bell pepper. This might be due to the reasons that wider spaced and single shoot trained plants bear larger sized fruits while closer spaced and dense shoots per plant resulting in small sized fruits and size of fruit is correlated to number of seeds (Kinet and Peet, 1997).

Treatment combination Y_2S_7 (double stem and 90×30 cm) recorded maximum (9.43 g) seed yield per plant while interaction Y_2S_5 (double stem and 90×15 cm) gave the highest seed yield per hectare (519.71 kg) which was at par with Y_1S_2 (single stem and $60+30 \times 15$ cm). Sanchez *et al.* (1993) reported lower seed yield with closer spacing in bell pepper. However Singh *et al.* (1989) and Khurana *et al.* (2002) reported lower seed yield with wider spacing in chilli. Double stem trained plants resulted in larger sized fruits with bold seeds having more test weight. Genard *et al.* (2009) who reported that there is a positive correlation between fruit weight, 1000 seed weight and germination. Lal *et al.* (2016) reported plants trained to two stems and spaced at 45×30 cm resulted in higher seed yield. Also the appropriate spacing accommodated more number of plants which increase per unit yield as well as profit of the producers.

Conclusion

From the present investigations it can be concluded that treatment combination Y₁S₇ (single stem and plant spaced at 90×30 cm) resulted in maximum ripe fruit length and width (5.86 cm and 5.06 cm, respectively), maximum number of seeds/fruit (110.67), minimum days to ripe fruit harvest (71.00) and maximum harvest duration (59.84 days) but gave the low seed yield. Whereas Y₂S₅ (double stem and 90×15 cm) was found superior over all other treatments except Y₁S₂ (single stem and 60+30×15 cm) which was found statistically at par in terms of economic character i.e. seed yield per hectare (519.71 kg) which is an ultimate goal of any experiment. Therefore, planting density S₅ (90x15 cm) in combination with training system Y₂ (double stem) can be recommended for commercial cultivation after multi-location testing for getting the higher yield of quality seeds in tomato under open field conditions in Himachal Pradesh.

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