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Research Article

EFFECT OF PLANT GEOMETRY AND TRAINING ON SEED QUALITY AND BENEFIT: COST RATIO IN TOMATO (*Solanum lycopersicum* L.) SEED PRODUCTION

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Abstract- The present investigations were carried out to study the effect of different plant geometries and training levels on the seed quality of tomato cultivar Solan Lalima, at the department of Seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan during *Kharif* season, 2013. The treatment combinations comprised of four training levels i.e. Y_1 (single stem), Y_2 (double stem), Y_3 (unpruned with horizontal string) and Y_4 (unpruned bush stakes, control) and eight plant geometries viz. S_1 (60×15 cm), S_2 (60+30×15 cm), S_3 (60×30 cm), S_4 (60+30×30 cm), S_5 (90×15 cm), S_6 (90+30×15 cm), S_7 (90×30 cm) and S_8 (90+30×30 cm). Analysis of variance revealed significant differences among the treatment combinations for all the characters studied. The treatment combination Y_1S_7 (single stem and plant spaced at 90×30 cm) gave the best results for thousand seed weight (3.90 g), germination percentage (89.33 %), seedling length (14.20 cm), seedling dry weight (1.55 mg), seed vigour index-Length & Mass (1269.20 & 138.25, respectively) but it gave a low seed yield per unit area (257.55 kg/ha). The combination Y_2S_5 (double stem and 90×15 cm) gave a higher seed yield per hectare (519.71 kg) over all other treatments. This treatment also gave highest benefit: cost ratio (5.17:1) which is an ultimate goal of any experiment.

Keywords- Plant geometry, Seed yield, *Solanum lycopersicum* L, Tomato, Training.

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Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable of every kitchen in the world. It is a warm season vegetable crop and is killed by chilling temperatures. Tomato is consumed in variety of ways, raw as salad, cooked in various dishes and as various other processed products like sauce, catch-ups etc. It is also important due to its nutritional point of view, such as vitamins (A, B, C and D) and minerals (Ca, P and Fe) [1]. The antioxidant compounds such as lycopene, β carotene and ascorbic acid are present in tomato. The tomato is a promoter of gastric secretion and act as blood purifier and intestinal antiseptic [2]. The major tomato growing countries are China, India, USA, Turkey and Egypt. India is the second largest producer of tomato in the world and it is also the second largest vegetable crop of the country. In Himachal Pradesh, the growing season of tomato coincides with monsoon season thus indeterminate varieties are suitable as determinate types are more prone to diseases due to rain splashes. The production of the healthy tomato crop depends on the quality of seed. To achieve healthy seed production it is necessary to focus on the essential cultural practices, which affect fruit growth and ultimately seed yield. Among different factors, plant geometry and training play an important role as the former helps in preventing overcrowding and competition, thus helps in avoiding poor fruit set and delayed maturity while the latter improves air circulation through the plants under humid and moist conditions where tomato plants are more prone to diseases. Moreover, ideal plant geometry reduces the competition among plants for acquiring nutrients from the soil. According to [3] yield per unit area tends to increase with plant density up to a certain threshold, and then decline due to interplant competition. Optimum plant density allows the plant to acquire the essential growth elements (light, CO_2, etc.) that influence the final yield [4] and with increased plant density, plant growth rate is decreased due to reduced light interception per plant [5]. Similarly, training and pruning of plant growth, reduce the competition among the branches and fruits for sunlight and assimilates. For effective training, staking is the most important operation being practiced especially during the rainy season for improving quality, yield and protecting the crop from attack of soil borne pathogens. It also provides proper space and light for its growth and development. The traditional system of staking accommodates a lesser number of plants per unit area due to bushy growth. The plants with indeterminate growth have surplus leaf load and can be pruned without any loss to the final yield [6]. By proper training, more number of plants can be accommodated per unit area thereby increasing the yield. Vertical training with ropes or wires claimed to result in early ripening, less disease incidence, easier inter-culture and harvesting, clean and healthy fruits and increased yields of better quality fruits. Pruning to produce single-stemmed plants and staking have been claimed to have a higher yield of larger fruits [7]. Keeping in view the above perspectives, the present studies were conducted to investigate the effects of different plant geometries and training levels on seed quality and benefit: cost ratio in the tomato seed production programme.

Materials and Methods

The present investigations were carried out at Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Kharif season 2013. The experiment was laid out on 14th March 2013 in Split Plot Design with thirty two treatments (4 × 8) replicated three times while laboratory experiment was conducted in Completely Randomized Block Design (Factorial). The seedlings of tomato var. Solan Lalima were transplanted at eight different crop geometries (S_1- 60×15 cm , S_2 - 60+30×15 cm, S_3 - 60×30 cm, S_4 - 60+30×30 cm, S_5 - 90×15 cm, S_6 - 90+30×15 cm, S_7 - 90×30 cm, S_8 - 90+30×30 cm) in a plot having size of 3.6 m × 1.8 m i.e. 6.48 m^2. After the plants established, were pruned to achieve four different levels of training *viz.* Y_1 (single stem), Y_2 (double stem), Y_3 (unpruned with horizontal string) and Y_4 (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 (HP). The experimental farm is located in the mid- hill zone of Himachal Pradesh. Climate of the area is generally sub-temperate and semi-humid characterized by cold winters. Generally, December and January months are the coldest while, May and June are the hottest months. During the crop season (March to July), maximum and minimum average temperature recorded was 28.04˚C and 15.72˚C, respectively and average rainfall and relative humidity was 109.66 mm and 55.6% respectively, during the cropping period. The soil texture is loam to clay loam having pH ranging from 6.85-7.05. The samples of seed were collected from fruits of five randomly selected plants from every plot of each treatment. The seeds were dried to safer moisture level i.e. 6-8% and the final seed yield per hectare was calculated. By calculating, the cost of cultivation and net profit the benefit: cost ratio was worked out. With the help of seed counter number of seeds were counted to get 1000 seed weight. 100 seeds from all replications of each treatment were used for conducting the germination test as per International Seed Testing Association rules [8]. On the first and final count per cent germination (%), seedling length and dry weight were recorded. Seedling vigour-Length and Mass (SVI-I & II) were calculated as per the formula given by [9]. Recorded observations were analysed as per design of the experiment.

Results and Discussion

Effect of plant geometry and training on seed yield and benefit: cost ratio

The main and important objective of any seed production programme is to have a higher seed yield per unit area and to have better returns. The treatments significantly affect the seed yield of the tomato [Table-1]. The results revealed that treatment combination Y_2S_5 (double stem and 90×15 cm) gave the highest seed yield per hectare (519.71 kg). While, minimum seed yield per hectare (237.41 kg) was recorded with Y_4S_7 (control and 90×30 cm). Higher yield might be due to reasons that optimum numbers of plants having the appropriate number of branches were accommodated per unit area with this spacing and training level. The results are in line with [10] who reported higher seed yield in two stem trained plants and 45×30 cm spacing. Very close spacing also reduces the yield, yield increases with an increase in density (plants or shoots) to some extent and decrease with further increase in density due to the competition amongst the plants or shoots. On the other hand very wider spacing accommodates a lesser number of plants per unit area thereby decreases the yield. [11] and [12] also reported lower seed yields in chilli with wider spacing.

Table-1 *Effect of training and spacing on benefit: cost ratio in seed production of tomato cv. Solan Lalima under open field conditions*

Treatment Combinations	Seed yield/hectare (kg)	Gross income (Rs/hectare)	Cost of Cultivation (Rs/hectare)	Net returns (Rs/hectare)	B:C ratio
Y_1S_1	423.69	1271070	254400	1016670	4.00:1
Y_1S_2	513.68	1541040	256100	1284940	5.02:1
Y_1S_3	344.46	1033380	251800	781580	3.10:1
Y_1S_4	374.53	1123590	252700	870890	3.45:1
Y_1S_5	437.78	1313340	252700	1060640	4.20:1
Y_1S_6	380.78	1142340	254400	887940	3.49:1
Y_1S_7	257.55	772650	251000	521650	2.08:1
Y_1S_8	328.43	985290	251800	733490	2.91:1
Y_2S_1	478.99	1436970	254400	1182570	4.65:1
Y_2S_2	500.65	1501950	256100	1245850	4.86:1
Y_2S_3	393.00	1179000	251800	927200	3.68:1
Y_2S_4	439.05	1317150	252700	1064450	4.21:1
Y_2S_5	519.71	1559130	252700	1306430	5.17:1
Y_2S_6	432.33	1296990	254400	1042590	4.10:1
Y_2S_7	278.43	835290	251000	584290	2.33:1
Y_2S_8	365.53	1096590	251800	844790	3.36:1
Y_3S_1	481.27	1443810	254400	1189410	4.68:1
Y_3S_2	463.54	1390620	256100	1134520	4.43:1
Y_3S_3	372.82	1118460	251800	866660	3.44:1
Y_3S_4	421.91	1265730	252700	1013030	4.01:1
Y_3S_5	490.70	1472100	252700	1219400	4.83:1
Y_3S_6	414.91	1244730	254400	990330	3.89:1
Y_3S_7	260.46	781380	251000	530380	2.11:1
Y_3S_8	339.65	1018950	251800	767150	3.05:1
Y_4S_1	461.40	1384200	254400	1129800	4.44:1
Y_4S_2	365.34	1096020	256100	839920	3.28:1
Y_4S_3	343.96	1031880	251800	780080	3.10:1
Y_4S_4	406.29	1218870	252700	966170	3.82:1
Y_4S_5	470.27	1410810	252700	1158110	4.58:1
Y_4S_6	348.41	1045230	254400	790830	3.11:1
Y_4S_7	237.41	712230	251000	461230	1.84:1
Y_4S_8	362.55	1087650	251800	835850	3.32:1

Y_1 = single stem, Y_2= double stem, Y_3= unpruned with horizontal string and Y_4 = unpruned bush stakes (control) S_1= 60×15 cm, S_2= (60+30)×15 cm, S_3= 60×30 cm, S_4 = (60+30)×30 cm, S_5 = 90×15 cm, S_6 = (90+30)×15 cm, S_7= 90×30 cm and S_8= (90+30)×30 cm.

- Expenditure was calculated on the basis of input prices (local) prevailing at the time of experiment
- Income was calculated with value of tomato seeds @ Rs 3000/kg, sale price of tomato seeds, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, H.P.

Moreover the optimum plant and shoot density produce healthier and bigger sized fruits which bear bold and sound seeds having more test weight and thus ultimately increase the seed yield. The ultimate aim of the grower is to get higher returns from his produce, therefore the benefit: cost ratio is one of the criteria, which give us an idea about the profits and losses. The B: C ratios vary in similar fashion as that of yield due to different treatments. The highest B: C ratio (5.17:1) was obtained with treatment Y_2S_5 (double stem and 90×15 cm), whereas, lowest B: C ratio (1.84:1) resulted from Y_4S_7 (Unpruned with horizontal string (control) and plant spaced at 90×30 cm) treatment [Table-1].

Table-2 *Effect of plant geometry and training on the seed quality attributes*

Particulars	1000 seed weight (g)								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Mean Y
Y_1	2.94	2.80	3.76	3.58	3.72	2.91	3.90	3.74	3.42
Y_2	2.87	2.76	3.64	3.52	3.68	2.86	3.88	3.60	3.35
Y_3	2.84	2.74	3.50	3.48	3.65	2.82	3.70	3.46	3.27
Y_4	2.80	2.70	3.30	3.42	3.62	2.79	3.50	3.75	3.24
Mean S	2.86	2.75	3.55	3.50	3.67	2.85	3.75	3.64	
CD at 5%									
Y	0.02								
S	0.02								
Y×S	0.02								

Particulars	Germination (%)								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Mean Y
Y_1	83.33 (65.94)	72.67 (58.48)	82.67 (65.43)	88.67 (70.36)	74.00 (59.33)	88.67 (70.42)	89.33 (71.24)	75.33 (60.22)	81.83 (65.18)
Y_2	76.00 (60.65)	77.33 (61.58)	79.33 (63.01)	86.67 (68.70)	76.67 (61.10)	73.33 (58.91)	88.00 (69.75)	80.00 (63.43)	79.67 (63.39)
Y_3	72.00 (58.04)	68.00 (55.54)	76.00 (60.69)	84.00 (66.50)	85.33 (67.60)	82.67 (65.43)	77.33 (61.58)	79.33 (62.97)	78.08 (62.29)
Y_4	68.00 (55.56)	58.00 (49.59)	85.33 (67.78)	68.67 (55.97)	72.00 (58.04)	75.33 (60.20)	78.00 (62.02)	65.33 (53.93)	71.33 (57.89)
Mean S	74.83 (60.05)	69.00 (56.29)	80.83 (64.23)	82.00 (65.38)	77.00 (61.52)	80.00 (63.74)	83.17 (66.15)	75.00 (60.14)	
CD at 5%									
Y	2.48								
S	2.63								
Y×S	5.29								

Particulars	Seedling length (cm)								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Mean Y
Y_1	12.40	12.10	12.15	11.90	12.10	13.10	14.20	11.20	12.38
Y_2	12.00	10.70	13.02	10.60	11.70	12.07	13.60	12.80	12.06
Y_3	10.30	10.00	11.90	11.70	9.70	12.40	12.30	12.10	11.30
Y_4	9.20	9.00	11.73	10.10	11.80	10.20	10.40	11.20	10.45
Mean S	11.00	10.45	12.20	11.08	11.33	11.92	12.63	11.83	
CD at 5%									
Y	0.08								
S	0.12								
Y×S	0.23								

Particulars	Seedling dry weight (mg)								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	Mean Y
Y_1	1.23	1.20	1.07	1.30	1.46	1.12	1.55	1.26	1.27
Y_2	1.24	1.03	1.34	0.89	1.04	1.21	1.26	1.07	1.14
Y_3	0.93	0.99	1.13	1.20	1.31	1.11	1.12	1.27	1.13
Y_4	1.19	0.65	1.01	1.28	1.13	0.95	1.11	1.32	1.08
Mean S	1.15	0.97	1.14	1.17	1.23	1.10	1.26	1.23	
CD at 5%									
Y	0.08								
S	0.11								
Y×S	0.21								

Figures in the parenthesis are angular transformed value

Y_1 = single stem, Y_2= double stem, Y_3= unpruned with horizontal string and Y_4 = unpruned bush stakes (control)

S_1= 60×15 cm, S_2= (60+30)×15 cm, S_3= 60×30 cm, S_4 = (60+30)×30 cm, S_5 = 90×15 cm, S_6 = (90+30)×15 cm, S_7= 90×30 cm and S_8= (90+30)×30 cm.

Table-3 *Effect of plant geometry and training on seed vigour*

Particulars	Seed vigour index-length (SVI-1)									Seed vigour index-mass (SVI-II)								
	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	1033.45	879.27	1004.65	1054.87	895.40	1152.67	1269.20	843.73	1016.66	102.51	87.37	88.52	114.99	108.17	99.03	138.25	94.63	104.18
Y_2	912.00	828.20	1032.92	918.87	897.13	884.87	1196.67	1024.13	961.85	93.99	79.47	106.32	76.73	79.47	88.81	110.89	85.43	90.14
Y_3	741.73	680.00	904.67	982.27	827.67	1024.87	950.87	960.07	884.02	66.95	67.59	85.89	101.15	111.54	91.45	86.61	100.11	88.91
Y_4	625.60	522.00	1000.68	693.53	849.47	768.33	811.27	732.00	750.36	81.12	37.63	86.25	87.81	81.63	71.84	86.13	86.26	77.33
Mean S	828.20	727.37	985.73	912.38	867.42	957.68	1057.00	889.98		86.14	68.02	91.75	95.17	95.20	87.78	105.47	91.61	
CD at 5% (Y)	24.71									4.13								
CD at 5% (S)	32.74									8.64								
CD at 5% (Y×S)	65.48									17.27								

Y_1 = single stem, Y_2= double stem, Y_3= unpruned with horizontal string and Y_4 = unpruned bush stakes (control)

S_1= 60×15 cm, S_2= (60+30)×15 cm, S_3= 60×30 cm, S_4 = (60+30)×30 cm, S_5 = 90×15 cm, S_6 = (90+30)×15 cm, S_7= 90×30 cm and S_8= (90+30)×30 cm.

This was due to higher seed yield in Y_2S_5 resulting from optimum plant population and appropriate training level that compensated the cost incurred in seed production for this particular combination.

Effect of plant geometry and training on seed quality characters

All the seed quality characters were significantly affected by the given treatments [Table-2 and 3]. Thousand seed weight, or test weight is an important parameter, which decides the boldness of the seed. Greater thousand seed weight means bolder seeds and hence more will be the seed vigour, which is one of the most important characters in seed studies. Interaction between plant geometry and training revealed a significant effect with highest 1000 seed weight (3.90 g) in Y_1S_7 (single stem and 90×30 cm) and lowest 1000 seed weight (2.70 g) in Y_4S_2 (control and 60+30×15 cm). This is because a single shoot character of the plant and wider spacing resulted in less competition between and within the plants for light, water, nutrients etc. leading to production of bigger sized quality fruits and ultimately good quality bold seeds. There is a positive correlation between fruit weight, 1000 grain weight and germination [13]. In bell pepper [14] reported maximum 1000-seed weight at wider spacing.

Germination is one of the key criteria for determining the physiological aspect of seed and gives an idea about the ability of seed to produce normal and healthy seedlings under the field conditions. Maximum seed germination (89.33 %) was recorded with the combination Y_1S_7 (90x30 cm and single stem), whereas, interaction Y_4S_2 (control and 60+30×15 cm) resulted in lowest germination (58.00 %). This might be due to the reasons that plants grown at wider spacing has high fruit weight, which results in healthy and quality seed production with high stored reserve which ultimately leads to fast and uniform germination. According to [15] there is a positive correlation between the weight of seeds and the percentage of seed germination. These results were in line with the findings of [16] who reported that bell pepper plants grown at low plant densities produced larger fruit and seeds that results faster germination than plants grown at higher densities.

Treatment Y_1S_7 (single stem and 90×30 cm) gave the maximum seedling length and dry weight (14.20 cm & 1.55 mg, respectively); whereas, lowest (9.00 cm & 0.65 mg, respectively) were recorded with Y_4S_2 (control and 60+30×15 cm). This was due to the reason that larger sized fruits produced from low plant, shoot density resulted in bolder, sound seeds and large seeds produce big seedlings with high fresh and dry weight, and large seeds have faster germination [17]. [15] reported that seed masses with low weight will produce weak seedlings which will result in low dry weight. The results are in conformity with the findings of [16], who reported highest dry weight at wider with in row spacing (45 cm) and [18]who has reported that increase in 1000 seed weight results in increased fresh and dry weight of root and stem seedling.

Vigour status of the seed determines the actual germin ability and performance of seed under the field conditions. Y_1S_7 (Single stem and 90×30 cm) gave the highest seedling vigour index-length and seedling vigour index-mass (1269.20 and 138.25, respectively), whereas, Y_4S_2 (control and 60+30×15 cm) gave the lowest seedling vigour index-length and seedling vigour index-mass (522.00 and 37.63). This may be because seeds harvested from wider spacing and low shoot density have a higher 1000 seed weight with high storage reserve and thus makes them vigorous in terms of their germination, seedling length and dry weight characters. The results are in conformity with the reports of [19] who have reported that increasing the 1000 seed weight results in increasing fresh and dry weight of root and stem seedling. [20] who have reported that seedling vigour index increased with increase in spacing in bitter gourd. Also, there is less competition among the fruits for photosynthates resulting in bigger sized fruits with bold seeds in low density plants.

Conclusion

Taking into consideration all aspects, it is concluded that, the treatment combination Y_2S_5 (plants trained to double stem and 90×15 cm) performed best for seed yield characters and also gave the highest benefit: cost ratio than all other treatment combinations, however this treatment did not give the best results for seed quality characters. Thus we recommended the treatment combination Y_2S_5 for the commercial seed production of tomato after multi-location testing.

Conflict of Interest: None declared

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