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Influence of Different Training Levels on Fruit Quality and Yield of Tomato (*Solanum lycopersicum* L.) under the Mid-hill Conditions of Himachal Pradesh

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ABSTRACT

Background: Yield of summer tomato do not always reach the full production potential. Improved management such as, training and pruning could improve the yield and fruit quality of tomatoes. The production of the healthy and improved quality tomato crop depends on various cultural practices like training systems as it prevents overcrowding for sunlight thus improves air circulation under humid and moist conditions where tomato plants are more prone to fungal diseases, avoids poor fruit set and assimilates competition.

Methods: The study was carried out during *kharif* seasons of 2017 and 2018 with Solan Lalima variety, in the Research Farm of Dr. YSP UHF Nauni, Solan, HP to find out the response of plants to management practices on yield, quality and cost of production. The experiment consisting of two planting methods, three mulching treatments, two level of training system, laid out in randomized complete block design with three repetitions.

Result: Plants trained to two stem gave the maximum fruit TSS (4.75°B), ascorbic acid content (30.79 mg/100 g), lycopene content (5.84 mg/100 g) and shelf life (11.35 days). From the economics, it was apparent that tomato produced by the two stem training system exhibited better performance in terms of benefit cost ratio.

Key words: Quality, Staking, Stem pruning, Tomato, Training.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the most important vegetable of every kitchen in the world. Tomato belongs to family solanaceae with diploid chromosome number (2n=24) and is a typical self-pollinated as well as day neutral plant Yadav *et al.* (2017). Though the centre of origin is Peru and Ecuador region, it was introduced to India in the early 16th century by eastern countries Bhujbal *et al*. (2015). Tomato is consumed in a variety of ways, raw as salad, cooked in various dishes and as various other processed products like sauce, catch-ups; *etc.* It is considered as 'protective food' due to its nutritive value having antioxidant molecules like carotenoids (ascorbic acid, lycopene, vitamin E and phenol compounds, particularly flavonoids) Septa *et al.* (2013). 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. The major tomato growing countries are China, India, the USA, Turkey and Egypt. India is the second largest producer of tomato in the world.

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. It is important to maintain sufficient foliage on the plant for adequate rates of photosynthesis. In this study, the main emphasis was given in appropriate cultural practices in order to enhance the production per unit area by utilizing the available space and resources. Keeping, in view the above perspectives, the present studies were conducted to investigate the effects of different planting methods, mulching system and training levels on fruit quality and yield in the tomato fruit production programme.

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MATERIALS AND METHODS

To assess the effects of intercultural operations on quality and yield of tomato an experiment was laid out on 12th April 2017 and 12th 2018 in RBD (Factorial) with thirty-six treatments (Table 1) replicated thrice at the Department Farm of Vegetable Science, Dr YSP UHF, Nauni, Solan (HP). Mean temperature during the cropping season varied from 21.30 to 24.00°C (2017) and 19.80 to 24.30°C (2018).

Table 1: Detail of treatments used in the studies.

Treatment code	Treatment details
$P_1M_1T_1$	Raised bed + Black mulch + Two stem training
$P_1M_1T_2$	Raised bed + Black mulch + Three stem training
$P_1M_2T_1$	Raised bed + Silver/black mulch + Two stem training
$P_1M_2T_2$	Raised bed + Silver/black mulch + Three stem training
$P_1M_3T_1$	Raised bed + No mulch + Two stem training
$P_1M_3T_2$	Raised bed + No mulch + Three stem training
$P_2M_1T_1$	Flat bed + Black mulch + Two stem training
$P_2M_1T_2$	Flat bed + Black mulch + Three stem training
$P_2M_2T_1$	Flat bed + Silver/black mulch + Two stem training
$P_2M_2T_2$	Flat bed + Silver/black mulch + Three stem training
$P_2M_3T_1$	Flat bed + No mulch + Two stem training
$P_2M_3T_2$	Flat bed + No mulch + Three stem training

The seeds of 'Solan Lalima' were sown in the nursery beds on 15th March during both the years and the seedlings were transplanted on 12th April 2017 and 12th April 2018. The soil structure was characterized as gravelly loam to gravelly clay loam comprised of sand (46.09%), silt (32.12%) and clay (25.01%). The plot size of 1.8 × 6.3 m and a spacing of 90 cm × 30 cm was followed. The height of the raised beds was 15 cm above ground level and two beds were separated by 45 cm for proper drainage. The recommended cultural practices and plant protection measures were followed as per package of practices right from sowing up to harvest index. Farm yard manure and fertilizers were applied as per package of practices for vegetable crops (RDF: 100 N: 75 P: 55 K kg/ha). The seeds of 'Solan Lalima' were procured from the Seed Sale Counter of the Directorate of Extension Education, Dr YSP UHF, Nauni, Solan.

The observations were made on total soluble solids, ascorbic acid content, lycopene content, shelf life and yield per plot. Fruits from the selected plants were collected to record fruit TSS (°Brix), ascorbic acid content (mg/100 g), lycopene content (mg/100 g), shelf life (in days) and yield per plot (kg). The fruits harvested from five tagged plants were weighed separately on each harvest and sum total of each harvesting was computed for getting total yield per plant. Total soluble solids were estimated with the help of a refractometer and expressed as °Brix. Ascorbic acid content was estimated by using 2, 6-dichlorophenol-indophenol dye by the visual method given by AOAC (1970). Aliquots were prepared by grinding well mixed fruit samples along with the metaphosphoric acid solution and titrated against 2, 6-dichlorophenol indophenol dye to the pink endpoint.

The lycopene content of ripe tomato fruits was determined according to the method described by Ranganna (1995). Tomato pulp was repeatedly extracted with acetone using pestle and mortar until the residue was colourless. The acetone extracts were transferred to a separating funnel containing about 20 ml of 5 per cent sodium sulphate solution until two layers appeared. These layers were separated and petroleum ether extracts were kept in a brown bottle containing about 10 g anhydrous sodium sulphate. Petroleum ether extracts were then decanted into 100 ml volumetric flasks and absorbance was measured in Spectrophotometer at 503 nano-meter using petroleum ether as blank. For determining the shelf life of the fruits that is vine ripe fruits of each treatment were kept at room temperature (22 + 2°C) and their firmness was recorded at harvest and subsequently after a gap of two days. The data pertaining to the present investigation were statistical analyzed using OP STAT at 5 per cent level of significance.

$$\text{Yield per hectare (q)} = \frac{\text{Yield per plot}}{\text{Plot size}} \times 100 \times 0.8$$

Economics of treatments

Gross return was worked out for each treatment on the basis of market price of the produce at the time when the produce was ready for sale.

Net return (Rs/ha) was calculated by deducting cost of cultivation (Rs/ha) from gross income. Benefit: cost ratio was worked out as follows:

$$\text{B: C ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

RESULTS AND DISCUSSION

Data revealed the (Table 2) significant effects of individual treatments on quality characteristics of the tomato. The fruits harvested from the plants grown on raised bed planting method (P_1) had recorded maximum TSS (4.79 degree Brix), ascorbic acid content (31.11 mg/100 g), lycopene content (5.96 mg/100 g) and shelf life (11.67 days). The best possible reason for the high total soluble solids in the raised bed planting method was the more exposed surface area which allows more absorbance of radiations and greater photosynthetic activities within the plant cells. Therefore, the photosynthates are better partitioned resulting into high TSS of tomato fruits by Locher *et al.* (2003) and Nicoletto *et al.* (2016). Zhang *et al.* (2012) were of the opinion that the raised bed planting system achieved higher vitamin C content in vegetables due to increased soil microorganism's activity which enhances

nitrogen fixation, mineralization and enzyme activity and ultimately increased quality tomato crop. The increased lycopene content of the fruits in the raised bed planting system might be due to more absorbance of sunlight

Table 2: Effect of different planting methods, mulching treatments and training systems on the TSS, ascorbic acid content, lycopene content and shelf life of tomato (pooled data for the year 2017-18 and 2018-19).

Treatments	TSS (°Brix)	Ascorbic acid content (mg per 100 g of fresh weight)	Lycopene content (mg per 100 g of fresh weight)	Shelf life (days)
Planting methods (P)				
P_1	4.79	31.11	5.96	11.67
P_2	4.62	29.57	5.50	10.38
$CD_{0.05}$	0.06	0.34	0.20	0.23
Mulching treatments (M)				
M_1	4.93	31.67	6.09	12.09
M_2	4.88	31.17	5.95	11.59
M_3	4.31	28.17	5.15	9.41
$CD_{0.05}$	0.07	0.41	0.25	0.28
Training systems (T)				
T_1	4.75	30.79	5.84	11.35
T_2	4.66	29.89	5.62	10.71
$CD_{0.05}$	0.06	0.34	0.20	0.23
Interaction (P×M)				
P_1M_1	5.03	32.42	6.31	13.01
P_1M_2	4.98	31.89	6.26	12.44
P_1M_3	4.35	29.02	5.32	9.57
P_2M_1	4.83	30.93	5.86	11.16
P_2M_2	4.78	30.44	5.64	10.74
P_2M_3	4.25	27.33	4.99	9.25
$CD_{0.05}$	NS	NS	NS	0.13
(M×T)				
M_1T_1	4.98	32.19	6.20	12.45
M_1T_2	4.88	31.15	5.98	11.72
M_2T_1	4.93	31.50	6.09	12.05
M_2T_2	4.83	30.83	5.81	11.13
M_3T_1	4.35	28.66	5.23	9.53
M_3T_2	4.27	27.69	5.08	9.28
$CD_{0.05}$	NS	NS	NS	0.39
(P×T)				
P_1T_1	4.84	31.51	6.06	12.00
P_1T_2	4.74	30.71	5.87	11.35
P_2T_1	4.66	30.06	5.62	10.69
P_2T_2	4.58	29.07	5.38	10.07
$CD_{0.05}$	NS	NS	NS	NS
(P×M×T)				
$P_1M_1T_1$	5.10	33.08	6.42	13.41
$P_1M_1T_2$	4.96	31.76	6.21	12.62
$P_1M_2T_1$	5.03	32.16	6.38	12.81
$P_1M_2T_2$	4.94	31.61	6.14	12.08
$P_1M_3T_1$	4.39	29.29	5.39	9.79
$P_1M_3T_2$	4.32	28.75	5.25	9.35
$P_2M_1T_1$	4.86	31.31	5.98	11.50
$P_2M_1T_2$	4.79	30.54	5.74	10.82
$P_2M_2T_1$	4.83	30.85	5.80	11.30
$P_2M_2T_2$	4.83	30.85	5.80	11.30
$P_2M_3T_1$	4.73	30.04	5.49	10.18
$P_2M_3T_2$	4.23	26.63	4.91	9.22
$CD_{0.05}$	NS	NS	NS	NS

radiations during the growth and the harvest period of the crop. The high firmness of tomato fruits immediately after harvesting is due to skin strength, which gradually weakens upon ripening and senescence, thus shortens the shelf life of the tomato fruit by Kere *et al.* (2003).

On the other hand, maximum total soluble solids (4.93 °Brix), ascorbic acid content (31.67 mg/100 g), lycopene content (6.09 mg/100 g) and the shelf life of fruits (12.09 days) found in those fruits which were produced by the plants grown on black polythene mulch (M_1). The reflection of more light on the tomato shoots due to black plastic is known to increase the transpiration rate, amount of the photosynthesis available to fruits and sugar: acid ratio, and hence the higher TSS of fruits which has been reported by Dorais *et al.* (2001). The results are in line with Moursi (2003) in pepper, Ashrafuzzaman *et al.* (2011), Helaley *et al.* (2017) in tomato. Abhivyakti and Kumari (2015) also reported that mulches also affect the lycopene content of tomato fruits. Extended shelf life with the use of plastic mulch may be due the thicker flesh of the fruits as reflected by the higher dry matter content and also due to the presence of essential nutrients. The high firmness of tomato fruits immediately after harvesting was due to skin strength, which gradually weakens upon ripening and senescence, thus shortens the shelf life of the tomato fruit by Kere *et al.* (2003).

Maximum total soluble solids (4.75 °Brix), ascorbic acid content (30.79 mg/100 g), lycopene content (5.84 mg/100 g) and the shelf-life of fruits (11.35 days) was recorded from the fruits produced by the two stem training system (T_1). The results are in agreement with those obtained by Hesamil *et al.* (2012), Razzak *et al.* (2013), Khoshkam *et al.* (2014), Mbonihankuye *et al.* (2013) and Alam *et al.* (2016) in tomato. The present results of increased vitamin C content could be attributed to the high assimilate supply associated with the good light conditions for the plants trained more intensively to double stem by Ambroszczyk *et al.* (2008). Similar findings were reported by Ece and Darakci (2009), who found a positive correlation between the vitamin C and the amount of incident light. According to Wien (1997), carotenoids production such as lycopene, got influenced by light exposure. Another possible reason could be that the two stem training system resulted in plants with fewer branches; but with larger leaves thus consequently with more self-shadowing. In the present study, the increase in the shelf life of tomato fruits harvested from the two stem trained plants could be attributed to the accumulation of photo-assimilates Alam *et al.* (2016).

Among the various treatment combinations for three way interactions the raised bed planting method, black polythene mulch and two stem training system ($P_1M_1T_1$) was found superior from all other treatment combinations in terms of quality attributes which recorded maximum TSS (5.10 °Brix), ascorbic acid (33.08 mg/100 g), lycopene (6.42 mg/100 g) and shelf life (13.41 days).

Fruit yield (q/ha), net returns (Rs/ha) and benefit: Cost ratio

The adoption of technology in modern agriculture can only be feasible and acceptable to the farmers if it is economically viable. The relevant treatment-wise cost of cultivation, gross returns, net returns and benefit: cost ratio (B: C ratio) of tomato cv. Solan Lalima has been worked out and depicted in Table 3 respectively. The economic analysis showed that the highest net return of Rs. 1,18,1364.19/ha was obtained from, treatment combination $P_1M_1T_1$ (raised bed + black mulch + two stem training system) on account of the highest yield (992.64 q/ha) with a highest benefit: cost ratio of 3.84. Statistically, $P_1M_1T_1$ is significantly superior from all other treatment combinations w.r.t. net returns and benefit: cost ratio.

Table 3: The effect of different treatment modules on economics of tomato production.

Treatment code	Net return (Rs/ha)	B: C ratio
$P_1M_1T_1$	1181364.19	3.84
$P_1M_1T_2$	1082968.69	3.43
$P_1M_2T_1$	1125286.19	3.57
$P_1M_2T_2$	1054262.69	3.25
$P_1M_3T_1$	963060.36	3.78
$P_1M_3T_2$	911476.86	3.46
$P_2M_1T_1$	1031629.69	3.45
$P_2M_1T_2$	951948.19	3.09
$P_2M_2T_1$	999995.69	3.26
$P_2M_2T_2$	918284.69	2.91
$P_2M_3T_1$	911854.86	3.70
$P_2M_3T_2$	859071.36	3.37
$CD_{(0.05)}$	0.10	

The present results are in line with the findings of Anand *et al.* (2016) in ashwagandha, Dasa *et al.* (2014) in various vegetable crops, Reddy *et al.* (2015) in tomato and Anand *et al.* (2018) also regarding the benefit cost ratio.

CONCLUSION

The quality and yield parameters studied in this paper indicated a positive response to the intercultural operations. Based on the findings of this study, raised bed planting, black mulch and two stem training in tomato could be practiced for improved yield and quality and economical production of tomato in the study area. Studies also revealed that the highest net returns of Rs 1,18,1364.19/ha were obtained for treatment combination of $P_1M_1T_1$ (raised bed, black mulch and two stem training system) which was also best for yield (992.64 q/ha), gross returns (Rs 1488955.50/ha) and benefit cost ratio (1:3.84).

On the basis of two years studies, it can be concluded that the treatment combination $P_1M_1T_1$ (raised bed, black mulch and two stem training system) which produced maximum values of yield, gross returns, net returns and cost benefit ratio may be recommended to the farmers after testing the authenticity of results in the farmer's field for another two years.

Author(s) contribution

Conceptualization and designing of the research work (Shilpa); Execution of field/lab experiments and data

collection (Shilpa); Analysis of data and interpretation (Shilpa and Priyanka Bijalwan); Preparation of manuscript (Shilpa and Priyanka Bijalwan).

Conflict of interest

All authors declare that they have no conflict of interest.

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