

Effect of Transplanting Dates and Training Systems on Fruit, Seed Yield and Quality Attributes in Tomato (*Solanum Lycopersicum*) Under Protected Conditions

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ABSTRACT: The experiment was undertaken during kharif season of 2019-20, inside a plastic greenhouse at experimental farm and laboratory conditions of department of Seed Science and Technology, Dr. Y S P University of Horticulture and Forestry, Nauni, Solan, H.P. in order to determine the effect of planting dates and training systems on fruit, seed yield and quality in tomato cv. Solan Lalima. The treatments comprised of four planting dates (transplanting on 1st April, 15th April, 1st May and 15th May) and four training systems (single stem, two stem, four stem, no training). The different treatments showed differential response but overall transplanting on 1st April with two stem training system was significantly superior or at par with best results for various yield and quality traits in tomato like number of flowers per cluster, number of fruits per cluster, fruit set percent, total number of fruits per plant, average fruit weight, fruit yield, 1000 seed weight, number of seeds per fruit, seed yield, percent seed germination, seedling length, seedling dry weight, SVI-I & II, cold test and accelerated aging test. Hence, for higher quality fresh fruit and quality seed produce, treatment combination comprising of transplanting on 1st April with two stem training system can be recommended for growing tomato under protected conditions on commercial scale in mid hills of Himachal Pradesh.

Keywords: Tomato, Training system, Transplanting dates, Fruit yield, Seed yield, Seed quality.

Tomato (*Solanum lycopersicum* L.) is an annual warm season vegetable crop which is commercially cultivated throughout the world for fresh fruit market as well as for processed food industry [1]. India is the second largest producer of tomato in the world. In India, it is grown on 8,09,000 ha area giving 19.7 metric tons production [2]. In Himachal Pradesh, it is grown both under field and protected conditions as a major off season vegetable having acreage of 11.08 thousand hectares with a production of 489.96 thousand metric tons [3]. From nutrition point of view, tomato is a good source of vitamins, essential minerals, antioxidants lycopene, μg carotene and ascorbic acid [4]. It is very useful in blood purification, promotion of gastric secretion, curing cancer of mouth and sour throat, intestinal antiseptic besides, also improving quality of the cooked foods [5]. Tomato is an important vegetable crop that fetches great remuneration to the farmers. It can be cultivated in open as well in protected conditions. But open field conditions are not very profitable because of prevailing unfavorable climatic conditions during their growth period. Under protected environment, it is extensively grown as a major off-season

vegetables crop to fetch remunerative prices and high economic returns due to increased fruit quality and higher yield. For quality seed production purpose, tomato crop is generally raised both under protected as well as open field conditions however, under open field conditions, the seed production is badly affected by different biotic and abiotic stresses. Hence, seed production nowadays is being carried out under protected conditions. Protected conditions with improved cultural practices such as training and pruning are considered to be helpful to a greater extent in preventing overcrowding and competition for space and food resources and ultimately avoids poor fruit set and delayed maturity. The proper training and pruning operations not only reduce the competition for sunlight and photosynthesis but also accommodate more number of plants per unit area thereby exhibit higher cluster, early crop and higher yield besides producing more uniform and large sized fruits. Training the tomato plant to either two or three shoots is a common practice followed in indeterminate and semi-determinate varieties in some countries such as Japan and Europe. But in India, no standard practice of training

other than removal of lower branches and leaves is generally followed. Furthermore, amongst different agro-technology, planting times show significant influence on improved growth and enhanced reproductive characters of tomato for better fruit set and enhanced seed yield with quality when grown under protected environment. Therefore, this study was planned to standardize the effect of different planting dates and training systems on yield and seed quality parameters in tomato.

MATERIALS AND METHODS

The present investigation was carried out during kharif season, in 2019 inside a plastic greenhouse having natural ventilation at Khaltoo experimental farm and seed quality analysis was done in laboratory of the department of Seed Science and Technology, Dr YS Parmar university of Horticulture and Forestry, Nauni, Solan HP, which is located at an altitude of 1250 meters above mean sea level. Geographically it is situated between 35.5°N latitude and 77.8°E longitude. The area is characterized by sub-temperate to sub-tropical climate where summer is at its peak in the month of May and June, whereas, December and January months are the coldest. However, during the crop season of experiment (April to October), the maximum average rainfall received outside the polyhouse was 225.8mm during the month of August whereas the minimum during the month of October i.e. 5.6 mm. The mean maximum average temperature outside the polyhouse was recorded from 25.6 to 33.7°C whereas inside the polyhouse ranged from 27.2 to 40.3°C during the month of October and June. Similarly, mean minimum temperature outside and inside the polyhouse ranged from 11.3 to 20.1°C (outside polyhouse) and 14.4 to 25.8°C (inside polyhouse), respectively. In case of the average relative humidity, outside the polyhouse ranged from 32 to 85% which was observed highest during the month of August while, lowest during the month of May. The field experiment was laid out in Randomized Complete Block Design while analysis for laboratory experiment was done in Completely Randomized Design. All treatments replicated three times in field conditions and four times under laboratory conditions. The experiment has two factors i.e. planting dates (M) and training systems (S). The healthy, disease free seeds of tomato were sown in pro trays by using growing media having coco peat and sand in the ratio of 3:1 respectively at different sowing dates and then healthy tomato seedlings were transplanted to the experimental plots. The seedlings of tomato cv. Solan Lalima were

transplanted on four different dates (M₁-1st April, M₂-15th April, M₃-1st May and M₄-15th May) which were trained onto four training systems (S₁-Single stem, S₂-Two stem, S₃-Four stem, S₄-No training). All the standard cultural and plant protection practices were followed to raise a healthy crop of tomato inside the greenhouse. Experimental plots were irrigated as and when required. Other plant protection practices were also taken up for the control of insect pest and diseases during experimentation period. The observations for growth and yield parameters were recorded during field experiment and for seed quality parameters in the laboratory experiment. All the data obtained from experiment was statistically analyzed by using the F-test as [6].

RESULTS AND DISCUSSION

The data recorded on various parameters to determine the effect of planting dates and training systems in tomato cv. Solan Lalima is presented in Table 1, 2 and 3. The findings of each parameter have been discussed below.

Number of flowers per cluster

The observations on number of flowers per cluster as affected by different planting dates and training systems have been given in Table 1. Analysis of variance revealed that the effect of the treatments on number of flowers per cluster was highly significant. The treatment M₁S₁ produced significantly higher number of flowers per cluster (5.94) which was statistically at par with M₁S₂, M₁S₃, M₂S₁, M₂S₂ and M₄S₁ and significantly higher than all the other treatments. The treatment M₄S₄ produced lowest number of flowers per cluster (5.09). The higher number of flowers per cluster in the treatment M₁S₁ might be due to the presence of more appropriate day (20-26.5°C) and night temperature (16-19°C) faced by the plants on 1st April besides their better growth and development, less severity to diseases and pest attack, larger assimilation of photosynthesis in single stem plants. However, the crop plants transplanted later witnessed greater fluctuations in day and night temperature thereby resulting in poor growth and development. They also resulted in lower assimilation of photosynthates.

Number of fruits per cluster

Maximum number of fruits per cluster (4.67) was recorded in treatment M₁S₁ which was statistically at par with M₁S₂, M₁S₃ and M₂S₁ and significantly higher than all the other treatments. However, minimum number of fruits per cluster (3.23) was recorded in M₄S₄.

Table 1. Effect of transplanting dates and training systems on flowering, fruit quality and yield in Tomato cv. Solan Lalima

Treatments	Number of flower per cluster	Number of fruits per cluster	Fruit percent per plant	Total number of fruits (g)	Average fruit weight	Fruit yield (kg/plant)	Fruit yield (q/ha)
M ₁ S ₁	5.94	4.67	77.36	20.27	78.7	1.56	499.20
M ₁ S ₂	5.88	4.60	77.02	33.40	77.4	2.24	717.87
M ₁ S ₃	5.84	4.50	76.36	34.73	75.8	2.30	736
M ₁ S ₄	5.50	3.87	70.34	31.73	70.3	2.10	670.93
M ₂ S ₁	5.89	4.53	76.83	19.67	77.1	1.50	478.93
M ₂ S ₂	5.87	4.47	76.57	32.47	75.7	2.22	709.33
M ₂ S ₃	5.70	4.10	72.79	33.60	70.4	2.25	720
M ₂ S ₄	5.38	3.83	67.29	31.27	66.2	2.03	649.60
M ₃ S ₁	5.72	4.30	75.43	18.53	75.8	1.42	453.33
M ₃ S ₂	5.66	4.23	74.70	29.80	74.5	2.18	696.53
M ₃ S ₃	5.41	3.86	69.41	32.87	69.0	2.24	717.87
M ₃ S ₄	5.34	3.67	64.69	28.73	58.7	1.95	624.21
M ₄ S ₁	5.69	4.23	73.40	18.27	73.5	1.23	394.67
M ₄ S ₂	5.64	4.17	73.10	28.40	72.1	2.16	691.20
M ₄ S ₃	5.23	3.57	62.97	31.20	65.4	2.20	702.93
M ₄ S ₄	5.09	3.23	59.16	27.13	56.1	1.86	594.13
CD _(0.05)	0.12	0.17	2.48	1.34	3.08	0.10	32.49

Table 2. Effect of transplanting dates and training systems on seed yield parameters in Tomato cv. Solan Lalima

Treatments	1000 seed weight (g)	Number of seeds per fruit	Seed yield per plant (g)	Seed yield (g/m ²)	Seed yield (kg/ha)
M ₁ S ₁	3.93	83.13	3.08	18.46	147.7
M ₁ S ₂	3.91	82.23	4.53	27.16	217.3
M ₁ S ₃	3.78	77.47	4.51	27.06	216.5
M ₁ S ₄	3.75	70.47	3.94	23.66	189.3
M ₂ S ₁	3.89	82.63	3.00	18.00	144.0
M ₂ S ₂	3.86	81.13	4.49	26.92	215.4
M ₂ S ₃	3.67	75.73	4.45	26.68	213.4
M ₂ S ₄	3.54	69.50	3.46	20.76	166.1
M ₃ S ₁	3.64	81.47	2.93	17.60	140.8
M ₃ S ₂	3.59	80.93	4.35	26.08	208.6
M ₃ S ₃	3.52	73.93	4.27	25.64	205.0
M ₃ S ₄	3.40	66.90	3.40	20.38	163.0
M ₄ S ₁	3.60	80.73	2.89	17.32	138.6
M ₄ S ₂	3.49	80.57	4.24	25.44	203.5
M ₄ S ₃	3.34	72.50	4.16	24.94	199.5
M ₄ S ₄	3.27	61.77	3.32	19.92	159.4
CD _(0.05)	0.08	1.79	0.16	0.96	7.69

Fruit set per cent

A deep insight into the data on fruit set per cent as presented in Table 1 clearly shows that this character has been highly influenced by the planting dates and training systems. Significantly higher fruit set per cent (77.36%) was recorded in M₁S₁ which was statistically at par with M₁S₂, M₁S₃, M₂S₁, M₂S₂, M₃S₁ and M₃S₂ and was significantly superior to all the other treatments. The

lowest fruit set per cent (30.76%) was observed in M₄S₄. It was found that staking with string and stem pruning provides good aeration and enough space among the branches for the sunlight to enter which might be a very good reason of increased fruit set [7]. It has also been reported that fruit setting is poor when the average temperature exceeds 30°C or declines below 10°C [8]. It has been observed that fruit set was found to be in

Table 3. Effect of transplanting dates and training systems on seed quality attributes in Tomato cv. Solan Lalima

Treatments	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Seed vigour index-I	Seed vigour index-II	Cold test	Accelerated aging test
M ₁ S ₁	89.75	19.38	1.80	1738.91	161.79	79.00	76.00
M ₁ S ₂	89.25	19.01	1.77	1696.47	158.10	76.75	75.50
M ₁ S ₃	83.75	18.25	1.67	1528.91	139.99	75.25	72.75
M ₁ S ₄	81.00	14.16	1.39	1146.24	112.42	72.00	66.50
M ₂ S ₁	89.00	17.56	1.78	1561.71	158.17	78.25	74.00
M ₂ S ₂	88.00	17.24	1.72	1516.23	150.84	76.00	73.50
M ₂ S ₃	82.75	17.15	1.37	1418.98	113.22	75.00	72.25
M ₂ S ₄	78.50	14.10	1.35	1106.96	105.89	67.00	64.50
M ₃ S ₁	83.00	17.26	1.68	1433.31	139.66	74.00	71.50
M ₃ S ₂	81.75	16.64	1.56	1360.24	127.79	73.00	71.25
M ₃ S ₃	81.00	15.40	1.28	1247.26	103.28	67.50	64.50
M ₃ S ₄	77.50	14.08	1.26	1089.33	97.95	65.50	61.25
M ₄ S ₁	81.75	16.69	1.42	1363.35	115.86	73.50	70.75
M ₄ S ₂	80.50	16.44	1.40	1324.14	112.31	72.25	69.25
M ₄ S ₃	78.25	14.79	1.24	1157.12	97.31	64.25	60.00
M ₄ S ₄	76.75	12.23	1.19	939.55	91.24	61.25	56.75
CD _(0.05)	2.92	1.17	0.15	102.91	13.31	3.55	3.51

abundance only when temperature was in the range of 15-20°C [9].

Number of fruits per plant

Significantly higher number of fruits per plant (34.73) was observed in M₁S₃ which was statistically at par with M₁S₂ and M₂S₃ and significantly higher than all the other treatments, whereas lowest number of fruits per plant (18.27) was recorded in M₄S₁. This might be due to the fact that the crop transplanted early on 1st April exhibited optimum temperature congenial for growth and development of plants which resulted in better vegetative growth before flower initiation, more number of flowers and fruits per cluster, better pollination and higher fruit set besides less flower and fruit drop, less disease incidence over control.

Fruit weight (g)

The highest average fruit weight (78.7 g) was recorded in M₁S₁ which was statistically at par with M₁S₂, M₁S₃, M₂S₁, M₂S₂ and M₃S₁ and significantly higher than all the other treatments. The lowest average fruit weight (56.1 g) was observed in M₄S₄ which was statistically at par with M₃S₄. The possible reason for this might be the better vegetative growth, greater translocation and partitioning of assimilates from source to sink and accumulation of photosynthates in the fruits obtained from the plants transplanted earlier along with large sized fruits

harvested from single stem plants due to sufficient supply of metabolites to limited number of fruits, proper aeration, proper sunlight and greater supply of available nutrients.

Yield per plant (kg)

Yield per plant is one of the major traits directly influencing the yield per unit area and total yield per hectare and is the resultant of various yield attributing characters of the plant. The data pertaining to the effect of planting dates and training systems on fruit yield (kg per plant) have been illustrated in Table 1. Highest fruit yield per plant (2.30 kg) was recorded in M₁S₃ which was statistically at par with M₁S₂, M₂S₂, M₂S₃, M₃S₃ and M₄S₃ and significantly superior to all the other treatments, whereas the treatment M₄S₁ resulted in lowest fruit yield per plant (1.23 kg). There was a significant interaction effect between transplanting dates and training systems for this trait [10].

Fruit yield (kg/m² and q/ha, respectively)

The maximum fruit yield (13.80 kg/m² and 736 q/ha, respectively) was achieved in M₁S₃ which was statistically at par with M₁S₂, M₂S₂ and M₂S₃ and significantly higher than all the other treatments. Minimum fruit yield (7.40 kg/m² and 394.67 q/ha, respectively) was recorded in M₄S₁. The interaction between transplanting dates and training systems was found to be significant for this attribute [10].

1000 seed weight (g)

The ultimate objective of any seed production programme in any crop is to maximise the seed yield of that crop with good quality of seed. The observations on various seed yield and seed quality attributes were recorded and analysed and the results are depicted in Table 2. Maximum 1000 seed weight (3.93 g) was obtained in M_1S_1 which was statistically at par with M_1S_2 , M_2S_1 and M_2S_2 and significantly higher than all the other treatments, whereas minimum 1000 seed weight (3.27 g) was recorded in the treatment M_4S_4 .

Number of seeds per fruit

The highest number of seeds per fruit (83.13) was recorded in M_1S_1 which was statistically at par with M_1S_2 , M_2S_1 and M_3S_1 and significantly superior to all the other treatments. The lowest number of seeds per fruit (61.77) was observed in M_4S_4 . This might be due to bigger fruits obtained in M_1S_1 , while smaller fruits in M_4S_4 .

Seed yield per plant (g)

Effect of planting dates and training systems on the seed yield per plant (g) has been revealed in Table 2. It is evident from the table that the maximum seed yield per plant (4.53 g) was observed in M_1S_2 which was statistically at par with M_1S_3 , M_2S_2 and M_2S_3 and significantly higher than all the other treatments. Minimum seed yield per plant (2.89 g) was found in M_4S_1 .

Seed yield (g/m² and kg/ha, respectively)

The highest seed yield (27.16 g/m² and 217.3 kg/ha, respectively) was recorded in M_1S_2 which was statistically at par with M_1S_3 , M_2S_2 and M_2S_3 and significantly higher than all the other treatments. The lowest seed yield (17.32 g/m² and 138.6 kg/ha, respectively) was observed in M_4S_1 and was statistically at par with M_3S_1 .

Germination (%)

The data pertaining to the effect of planting dates and training systems on seed quality attributes is depicted in Table 3. It is evident from the table that all the seed quality attributes were significantly influenced by the different planting dates and training systems. The highest germination rate (89.75%) was recorded in the treatment M_1S_1 which was statistically at par with M_1S_2 , M_2S_1 and M_2S_2 and significantly higher than all the other treatments. The lowest germination rate (76.75%) was found in M_4S_4 and was statistically at par with M_2S_4 , M_3S_4 and M_4S_3 . This might be due to temperature and other

environmental conditions very congenial for seed setting and development of healthy seed that existed during planting time of M_1 and M_2 together with comparatively less competition for nutrients and photosynthates in case of single stem plants thereby resulting in large sized healthy fruits which ultimately gave rise to more healthy and bold seeds having better germination. Conversely, lowest results were obtained in M_4S_4 due to small size of fruits because of large partitioning of carbohydrates and other food reserves to different branches which resulted in weak and small sized seeds.

Seedling length (cm)

The maximum seedling length (19.38 cm) was observed in M_1S_1 which was statistically at par with M_1S_2 and M_1S_3 and was significantly superior to all the other treatments, whereas minimum seedling length (12.23 cm) was recorded in M_4S_4 .

Seedling dry weight (mg)

Data on seedling dry weight (mg) as influenced by various treatments have been outlined in Table 3. The highest seedling dry weight (1.80 mg) was recorded in M_1S_1 which was statistically at par with M_1S_2 , M_1S_3 , M_2S_1 , M_2S_2 and M_3S_1 and was significantly higher than all the other treatments. The lowest seedling dry weight (1.19 mg) was observed in M_4S_4 and was statistically at par with M_3S_3 , M_3S_4 and M_4S_3 . This may be due to bolder seeds of high quality registered in the treatment M_1S_1 as a result of which better and healthy seedling growth and development occurred leading to more dry matter accumulation, whereas, M_4S_4 produced the opposite effect.

Seed vigour index-I (Length)

Various treatments revealed highly significant differences for the seed vigour index-I (length). Highest value of SVI-I (1738.91) was recorded in M_1S_1 which was significantly superior to all the other treatments except M_1S_2 . The minimum value of SVI-I (939.55) was observed in M_4S_4 . Maximum seed vigour index-I in bell pepper with planting time of April 11 and minimum with planting time of May 23 [11].

Seed vigour index-II (Mass)

The data presented in Table 3 reveals the effect of planting dates and training systems on seed vigour index-II (mass). Highest value of SVI-II (161.79) was obtained in M_1S_1 which was statistically at par with M_1S_2 , M_2S_1 and

M₂S₂ and significantly higher than all the other treatments. Lowest value of SVI-II (91.24) was observed in M₄S₄ and was statistically at par with M₃S₃, M₃S₄ and M₄S₃. This might be as a result of highest germination per cent and seedling dry weight recorded in M₁S₁ while lowest germination and seedling dry weight seen in M₄S₄.

Germination (%) after cold treatment

Upon cold treatment, maximum germination (79.00%) was recorded in M₁S₁ which was statistically at par with M₁S₂, M₂S₁ and M₂S₂ and was significantly superior to all the other treatments, whereas minimum germination (61.25%) was observed in M₄S₄ which might be due to the small and weak seeds harvested from M₄S₄ which could not tolerate cold conditions as compared to rest of the treatments.

Germination (%) after accelerated aging test

Data pertaining to the effect of planting dates and training systems on accelerated aging test for determining vigour of tomato seeds extracted have been presented in Table 3. Highest germination (76.00%) after accelerated aging was shown by seeds harvested from plants of the treatment M₁S₁ which was statistically at par with M₁S₂ and significantly higher than all the other treatments. The lowest germination (56.75%) after accelerated aging test was observed in seeds extracted from M₄S₄. This might be due to healthy, bold and more vigorous seeds produced in M₁S₁ which were less affected by accelerated aging of seeds as compared to M₄S₄ which were small in size, weak and having minimum vigour and were greatly influenced by accelerated aging of seeds.

CONCLUSION

On the basis of experimental results obtained from the present study, it can be concluded that treatment M₁S₂ (transplanting on 1st April, 2019 and two stem training system) was significantly superior or at par with the best

treatment for all quality and yield traits of fruit and seed in tomato cv. Solan Lalima. Thus, M₁S₂ (transplanting on 1st April and two stem training system) is the best combination for getting higher quality fresh tomato as well as quality seed produce and can be suggested for growing tomato under protected conditions on commercial scale.

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