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PERFORMANCE OF TOMATO UNDER PROTECTED CULTIVATION WITH DIFFERENT TRANSPLANTING TIME, PLANT SPACING AND TRAINING SYSTEM

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ABSTRACT

Cultivation shift towards the cash crops becomes a major thrust area for generating higher incomes but the approach requires scientific attention. Therefore, a study was conducted during 2021-22 and 2022-23 to access the effect of different transplantation time, spacing and training system on soil nutrients status and growth of tomato. The results showed that early transplanting on 15th March, with a spacing of 75 cm × 30 cm and training the plants to two shoots, led to the highest fruit length and breadth, indicating a significant improvement in fruit development under these conditions. Similar treatment combinations resulted in the highest values across various yield parameters. These included fruits per cluster at 5.0, 4.6, and 4.5; fruits per plant at 26.8, 25.1, and 25.7; average fruit weight of 75.6 g, 71.5 g, and 79.9 g; and fruit yield per plant of 2.04 kg, 1.81 kg, and 1.75 kg. In another observation, similar treatments achieved fruits per cluster of 5.3, 5.0, and 5.0; fruits per plant of 32.0, 28.9, and 28.5; fruit weights of 76.8 g, 72.9 g, and 71.8 g; and fruit yields per plant of 2.22 kg, 1.91 kg, and 1.89 kg. Additionally, the maximum fruit yield per 100 m² was registered with 1007.5 kg and 1100 kg, and thus, highlighting the effectiveness of these treatment combinations in enhancing fruit productivity. However, plants spaced at 60 cm ×30 cm attained maximum yield which was 10.6-14.4% higher over 75 cm ×30 cm. No significant difference was found on soil available nutrient content. Study identified the treatment combination of early transplanting along with wider planting with 75 cm ×30 cm and two shoots training as an eminent approach for growing tomato hybrids under poly house.

Keywords: Tomato, growth, nutrients, training system, polyhouse

INTRODUCTION

The world's population is expected to outreach 9.6 billion by 2050, posing a major challenge for global food production. To meet this growing demand, food production must increase by 70% compared to current levels. This is not just about producing abundant food but also ensuring it is nutritious, affordable, and sustainable. Achieving this goal will require advancements in farming techniques, efficient resource management, and better food distribution. At the same time, challenges like climate change, shortages of water and soil degradation must be addressed to secure long-term food supplies (Shubham *et al.,* 2022).

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One of the most effective ways to boost agricultural growth is by developing improved crop varieties and increasing cropping intensity. In India, vegetables are cultivated on 10.86 million hectares, producing around 200.45 million tonnes annually. Among these, tomatoes (*Solanum lycopersicum* L.) are among one of the most widely consumed vegetables. They are highly nutritious, rich in vitamins A and C and valued for their taste and colour making them an important cash crop globally (Ughade *et al.,* 2016).

Despite their widespread use, tomato plants are difficult to grow in open field conditions due to their sensitivity to prevailing harsh environmental factors such excessive humidity, wind and temperature swings. High-yield hybrid tomato varieties have greatly increased productivity while strengthening resilience to unfavourable weather and disease.

With shrinking farmland and rising global temperatures, protected cultivation has emerged as an efficient solution. Growing crops like tomatoes, cherry tomatoes, coloured capsicum, cucumbers, muskmelons, and summer squash in greenhouses or polyhouse leads to higher yields and better quality produce. It is hybrid tomato varieties that have truly revolutionized tomato production. In addition to its superior yield, disease resistance, adaptability to harsh environments, uniformity of production, and increased plant vigour, hybrids also hold considerable promise for addressing the problem of the rising demand for both fresh and processed goods. Its development, output, and produce quality are, nevertheless, constrained by production constraints. An alternative to raising tomato yield while preserving a greater level of fruit quality is shielded culture. From an economic and environmental perspective, high-value crops cultivated under protection are now irreplaceable. There are several advantages to producing higher-quality, high-value crops even in marginal and unfavourable circumstances. The ideal time to transplant is crucial because it promotes healthy plant growth and development, which maximizes agricultural yield and makes economical use of available land (Islam *et al.,* 2010). In addition to making training easier, training plants to produce two or three branches will allow for closer planting, earlier fruit ripening, and increased yields of larger fruits.

Tomato cultivars have varied development tendencies and varying plant densities requires different training approaches. In certain foreign nations, such as Europe and Japan, it is common practice to train indeterminate and semi-determinate cultivars to produce two or three shoots under glass house or open field circumstances. Other than cutting off lower leaves and branches, there is no training procedure in India. Tomato greenhouse production system places a strong emphasis on the necessity of appropriate density to maximize production per unit area by making use of the available space and applied fertilizers. Information about greenhouse horticulture and how it reacts to changing plant populations is scarce. In light of this, a study was carried out to evaluate the performance of tomato with varying plant spacing, training and transplanting time.

MATERIAL AND METHODS

Poly house trials were conducted in 2021-22 & 2022-23 at research farm of University Institute of Agricultural Sciences (UIAS), at Chandigarh University, Gharuan, Punjab situated at longitude (76°34’28" E) and latitude (30°46’ 05" N). The Trans Gangetic plains region of India’s Agro-climatic Zone-I, which has a semi-arid to sub-humid environment with an average annual temperature of 23.1°C and rainfall of 792 mm during the crop season, is where the experimental site is located. The crop trial site was situated 296.86 meters above mean sea level in the Punjab plains, which are undulating. To preserve the variability of the outcomes, a completely randomized block design (CRBD) was chosen for the experiment. The sandy loam soils were discovered with sand (54.70%), silt (31.05%), and clay (14.25%). Furthermore, the soils were found to be nearly neutral in reaction (7.8) and to have a medium electrical conductivity (EC; 0.47 dS/m).

Summer trials were conducted during March to August months inside poly house conditions. Tomato hybrid namely Rakshita was selected as crop cultivar and further tested for its growth and yield attributes to different transplanting time, plant spacing and training systems. For treatments, three dates of transplanting were selected with 15 days gap i.e. 15^{th} March, 30^{th} March & 15^{th} April for both study years, two plant spacing i.e. 60 cm×30 cm & 75 cm×30 cm and two training systems i.e. two shoots and three shoots were selected. Overall, the treatment combinations were replicated thrice to maintain heterogeneity in results. Nursery seeds were sown during 1^{st} fortnight of February in plug trays where it took around 30 days to get ready for transplantation. Raised beds of size (1.8×1.2 m^2) were prepared and treatment selection done on factorial randomized block design basis. Soil of beds were sterilized thoroughly with 40 % formalin solution (1:7 formalin: water), for removal of formalin fumes the beds were covered for 7 days using polyethylene sheets and then followed by rakings operations.

After 30 to 35 days after transplanting, the plants were trained and then staked with threads. As irrigation source, drip system was aligned and crop was watered on daily basis. Nutrient requirement of NPK @100 kg ha^{-1} were applied through straight fertilizers *i.e.* Urea (21.5 g m^{-2}), Single Super Phosphate (62.5 g m^{-2}) and Murate of Potash (16.5 g m^{-2}). Water soluble fertilizer polyfeed (19:19:19) was applied to serve the purpose. Fertigation with polyfeed@ 5 kg/1000 lts water was given from the 3rd week after transplanting and up to 15 days prior to final harvest with frequency of twice a week. Data on plant attributes have been taken as number of fruits/cluster (count method), number of fruits/plant (count method), fruit weight (g) (using high-precision digital scale), fruit length (cm), fruit breadth (cm) (using a vernier caliper), fruit yield/ plant (kg/ plant) and fruit yield (kg/100m^2) were recorded using standard procedures. After estimating the soil texture using the Hydrometer method, the textural class was determined using the USDA-developed soil textural triangle. The pH and EC of the soil were measured using a digital pH meter and an EC meter, and the results showed that the soil reaction was 1:2 (Soil: Water suspension). The amount of organic carbon in the soil was measured using the wet digestion method (Walkley and Black, 1934). The amount of soil accessible N (kg/ha) was calculated using the alkaline potassium permanganate method (Subbiah and Asija, 1956). A Spectronic-20D at 660 nm was used to estimate the quantity of phosphorus accessible in the soil (kg/ha) using the Stannous chloride (SnCl2) reduced ammonium molybdate method. The amount of potassium accessible in the soil (kg/ha) was determined using the neutral normal ammonium acetate method, and its quantity was measured using a flame photometer.

RESULTS AND DISCUSSION

Fruit length, breadth and shape index

Data pertaining to effect of transplanting dates, training systems and spacing on fruit growth presented in Table. 2 showed that the crop transplanted on 15^{th}March increased the fruit length and breadth by 11.11 and 5.26 per cent over the later transplanting dates. However, crop transplanted at 30th March and 15th April were found non-significant variations among themselves on fruit growth, moreover, tomato fruit length was found significantly higher with 6.77 percent in crop transplanted on 30th March (6.3 cm) over 15th April (5.9 cm). Fruit shape index during both the years remained non-significant. Results on spacing showed that the crop responded very well with 75 cm×30 cm with highest of fruit length (6.1 and 6.6 cm), fruit breadth (5.4 and 5.9 cm) which was 12.96 and 11.86 per cent higher than plant spaced with 60 cm×30 cm. However, highest fruit shape index of 1.13 and 1.12 was recorded with plant spacing of 60 cm×30 cm. Furthermore, plant trained with two shoots recorded higher fruit length breadth as compared to three shoots and therefore, showed the supremacy of tomato hybrids for growth with two shoots.

The data also showed that early plantation provided better tomato growth attributes *i.e.* length and breadth during the study period. Major reasons behind such growth hikecould be attributed to translocation of more photosynthates from source to sink and furthermore, availability of favorable microclimate throughout the crop growth. Fruits grown under wide spacing *i.e.* 75 cm×30 cm attained more length and breadth as compared to closer spaced plants. Availability of moisture, light, essential nutrients and lesser plant intra competition with wider spacing might have facilitated plants with better growth conditions. In double shoot plants, there were enough assimilates available for the early fruits; but, in triple shoot and unpruned plants, the sink to source ratio was high. As a result, availability of lesser assimilation directly affected fruit length. Furthermore, the fruit form index was not significantly affected by the transplanting date or the plant spacing. In both years, training techniques also had no discernible impact on the fruit shape index.

Growth attributes

As the data illustrated in table 3 it is evident that early transplanting brought a significant increase in fruits/cluster with a maximum of 5 as compared to late sowing dates. Least fruit count was recorded with 15th April transplantation date during both the years (3.8 and 4). Similar trend was observed on fruit count per plant, where early transplanting recorded significantly higher fruit count of 26.8 which was 12.13 and 18.08 per cent over 30th March and 21.81 and 34.45 per cent higher than the 15th April transplanting, during both the study years respectively. Furthermore, highest tomato fruit weight (75.6 g and 76.8 g), highest fruit yield/plant (2.04 kg and 2.22 kg) and fruit yield/100m^2 (1000.7 kg and 1100.3 kg) were recorded with the early transplantation treatment (15th March) during 2021-22 and 2022-23, respectively. Plants performed very well when spaced at 75 cm×30 cm, growth attributes *i.e.* fruits/cluster (4.6), fruit/plant (25.1 and 28.9), fruit weight (71.5 and 72.9 g), fruit yield/plant (1.81 and 1.91 kg), but here interestingly higher plant yield/100m^2 of 887.2 and 968.6 kg was recorded with closer spacing of 60 cm×30 cm and registered a per cent increase of 10.58 and 14.37 per cent over 75×30 cm during study years, respectively. Training the plants to two shoots recorded significantly higher fruit yield/100 m^2 (866.5 and 939.0kg) than plants trained to three shoots with a per cent increase of 5.28 and 7.13 during 2021-22 and 2022-23, respectively. The higher yield from the plants trained to two shoots may be attributed to its better performance in yield per plant which ultimately resulted in increase in yield/100 m^2 (Ara *et al.* 2007).

Highest fruits count was recorded in plants which were transplanted on 15th March, trained to two shoots with spacing 75 cm ×30

Table 1. Initial physical and chemical properties of the experimental soil

S.No	Physico-chemical properties	Initial values
1	Soil texture	Sandy loam
	Sand (%)	54.70
	Silt (%)	31.05
	Clay (%)	14.25
	Textural class	Sandy loam
2	Bulk density (g cm^{-3})	1.51
3	Particle density (g cm^{-3})	2.46
4	Soil pH	7.76
5	EC (dSm^{-1})	0.46
6	Organic carbon (g kg^{-1})	8.54
7	Available N (kg ha^{-1})	522.18
8	Available P (kg ha^{-1})	20.8
9	Available K (kg ha^{-1})	212.48

Table.2 Effect of different transplanting dates, spacing and training systems on fruit length, breadth and shape index of tomato during both the years

Treatments	Fruit length (cm)		Fruit breadth (cm)		Fruit shape index	
Date of transplanting	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
15th March	6.0	6.7	5.5	6.0	1.11	1.10
30th March	5.7	6.3	5.0	5.5	1.13	1.12
15th April	5.4	5.9	4.8	5.3	1.14	1.12
SE m+	0.1	0.1	0.1	0.1	0.02	0.03
CD (P=0.05)	0.3	0.3	0.3	0.3	NS	NS
Spacing						
60 cm×30 cm	5.4	5.9	4.7	5.2	1.13	1.12
75 cm× 30 cm	6.1	6.6	5.4	5.9	1.12	1.11
SE m+	0.1	0.1	0.1	0.1	0.01	0.01
CD (P=0.05)	0.2	0.2	0.2	0.2	NS	NS
Training systems						
Two shoots	5.9	6.5	5.3	5.8	1.12	1.11
Three shoots	5.5	6.1	4.9	5.4	1.13	1.12
SE m+	0.1	0.1	0.1	0.1	0.01	0.01
CD (P=0.05)	0.2	0.2	0.2	0.2	NS	NS

Table. 3 Effect of different transplanting dates, spacing and training systems on growth parameters and yield of tomato during both the years

Treatments	Fruits/cluster		Fruits/plant		Fruit weight (g)		Fruit yield/plant (kg)		Fruit yield (kg/100 m^2)	
Date of transplanting	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
15th March	5.0	5.3	26.8	32.0	75.6	76.8	2.04	2.22	1007.5	1100.3
30th March	4.0	4.5	23.9	27.1	68.9	70.2	1.65	1.75	821.8	869.8
15th April	3.8	4.0	22.0	23.8	64.3	66.1	1.42	1.52	705.1	753.1
SE m±	0.1	0.1	0.4	0.6	0.6	0.5	0.03	0.03	17.3	21.7
CD (P=0.05)	0.2	0.3	1.2	1.8	1.7	1.5	0.09	0.10	50.8	63.7
Spacing										
60 cm×30 cm	3.9	4.2	23.3	26.4	67.7	69.3	1.60	1.75	887.2	968.6
75 cm× 30 cm	4.6	5.0	25.1	28.9	71.5	72.9	1.81	1.91	802.3	846.9
SE m±	0.1	0.1	0.3	0.5	0.5	0.4	0.02	0.03	14.2	17.7
CD (P=0.05)	0.2	0.2	1.0	1.5	1.4	1.2	0.07	0.08	41.5	52.0
Training systems										
Two shoots	4.5	5.0	25.7	28.5	70.9	71.8	1.75	1.89	866.5	939.0
Three shoots	4.0	4.2	22.7	26.8	68.3	70.3	1.66	1.76	823.0	876.5
SE m±	0.1	0.1	0.3	0.5	0.5	0.4	0.02	0.03	14.2	17.7
CD (P=0.05)	0.2	0.2	1.0	1.5	1.4	1.2	0.07	0.08	41.5	52.0

Table. 4 Effect of different transplanting dates, spacing and training systems on soil physico-chemical properties after the harvest of tomato during both the years

Treatments	**pH**		**SOC***		**ASN***		**ASP***		**ASK***	
Date of transplanting	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
15th March	7.79	7.81	0.93	0.94	578.7	588.8	21.1	23.4	235.4	249.7
30th March	7.81	7.82	0.91	0.91	579.7	591.2	21.7	24.8	236.7	251.2
15th April	7.84	7.85	0.90	0.90	581.2	593.6	23.4	26.8	238.2	253.1
SE m±	0.12	0.12	0.04	0.04	1.5	1.6	1.2	1.3	2.0	2.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spacing										
60 cm×30 cm	7.81	7.82	0.91	0.92	579.1	589.8	21.7	24.1	239.7	250.6
75 cm× 30 cm	7.85	7.86	0.93	0.94	580.6	592.6	23.2	25.9	242.3	252.1
SE m±	0.10	0.10	0.02	0.02	1.3	1.4	0.9	1.0	1.8	1.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Training systems										
Two shoots	7.82	7.83	0.93	0.94	580.0	592.7	23.0	26.1	233.1	252.2
Three shoots	7.84	7.85	0.91	0.92	579.7	589.7	21.9	23.9	231.4	250.5
SE m±	0.10	0.10	0.02	0.02	1.3	1.4	0.9	1.0	1.8	1.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**SOC= Soil organic carbon (%), ASN= Available soil nitrogen (kg ha^{-1}), ASP= Available Soil phosphorus (kg ha^{-1}), ASK= Available soil potassium (kg ha^{-1})*

cm. The major reason could be due to increased availability of growth promoting components *viz,* less intra-plant competition among plants for nutrients, air and moisture. Higher fruit weight under the similar conditions could be explained on the basis of higher fruit length and breadth of fruits, where plants were transplanted on 15th March. Plants wide spacing provides better exposure to sunlight lead to better carbohydrates and protein assimilation and therefore, buildup of sufficient photosynthates which might have improved the nutrient uptake and the fruit size (Hossain *et al.* 2013; Ara *et al.* 2007; Shubham *et al.,* 2023). Significant improvement on tomato yield was observed, when the crop was early transplanted and spaced 60 cm ×30 cm and two shoots, such significant rise of yield could be attributed to favorable climatic conditions prevailed throughout the crop growth period. Moreover, more fruits cluster^{-1}, more diameter, fruit volume ultimately leads to highest yield per area.

One of the most crucial elements influencing the yield per unit area is the yield per plant. The practicality of implementing various training systems in conjunction with changing plant populations per unit area as spacing in tomatoes will eventually be determined by improvements in quality and production. In our study, plants taught to two shoots outperformed those trained to three shoots on all growth criteria. An additional explanation might be that the two productive branches are making greater use of the photosynthates. It's possible that training to three shoots caused excessive branch retention, which would have reduced the total photosynthetic capacity (Abriham and Kefale, 2020).

Soil physico-chemical properties

A perusal of data presented in table 4 highlighted that the soils of the experimental field were silty clay loam in textural analysis. Results showed that there were no significant effects encountered between different transplanting dates, spacing and training systems on soil pH, OC, soil available N, P and K during both years**.** Since the crop was grown in a protected environment, the inefficiency of treatments to change the available soil nutrient content may be the cause of the lack of significance in the available nutrients.

CONCLUSIONS

In the present study, early transplantation (15th March) of tomato hybrid Rakshita plants trained to 2 shoots planted with 60 cm × 30 cm instead of 75cm × 30 cm spacing registered the maximum yield as compared to rest of the treatments. However, growth attributes were found to be improved with 75cm × 30 cm spacing under 2 shoots trained early plants. Lower yield in widely spaced treatment could be attributed to less plant count per area which might have lowered the overall yield. Therefore, two year field study identified the treatment combination of early planting along with wider plant spacing of 75 cm×30 cm and two shoots training as a superior approach for growing tomato hybrids under poly house conditions for achieving higher crop growth and productivity.

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