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Research Article

Assessing morpho-physiological traits of *Solanum lycopersicum* L. genotypes in response to seedlings transplantation intervals

Muhammad Jamal[1], Ghulam Nabi[1], Izhar Ullah[1,2], Abdul Basit[1], Noman Ahmad[1], Syed Aizaz Ali Shah[3], Imran Ahmad[1*], Nasrullah Khan[1], Hassnain[1], Sidra Zeb[4], Sanaullah[5], Intizar Ahmad[1] and Nasar Ali Khan[1]

1. Department of Horticulture, The University of Agriculture, Peshawar-Pakistan
2. Department of Horticulture, Ondokuz Mayis University, 55200, Samsun-Turkey
3. College of Horticulture, Department of Vegetable Sciences, China Agricultural University, Bejing-China
4. Hazara Agriculture Research Station, Abbotabad-Pakistan
5. Department of Environmental and Conservation Science, North Dakota State University-USA

**Corresponding author's email:* imran73pk@gmail.com

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Abstract

Tomato productivity and quality generally relies upon the genotypic and environmental interaction. Varietal assessment plays a significant role in specifying of a potential variety for a specific ecological zone and its adaptability to different soil texture. Different tomato genotypes i.e Red Ruby, TM777, TM1701 and TM1702 were transplanted from 6th March to 27th March at interval of seven days during 2018 at Dargai, district Malakand Khyber Pakhtunkhwa. Among the tested genotypes of tomato, the genotype TM1702 attained highest plant height, stem diameter, days to first flowering, highest number of flowers plant^{-1}, number of fruits plant^{-1}, individual fruit weight, fruit length, fruit diameter, fruit volume, total soluble solid, fruit juice pH and higher yield as compared to other genotypes of tomato. Similarly, the seedlings transplanted on 13th March significantly improved the morphological, yield related traits and quality attributes of tomato. It could be concluded that genotype TM1702 improved most of the studied attributes of *tomato* as compared to genotypes Red Ruby, TM777, TM1701 respectively. Similarly, tomato seedlings transplanted on 13th March was found best time of transplantation for the quality production of tomato under the climatic conditions of Dargai, district Malakand.

Keywords: Climatic adaptability; Genotypes; Growth and development; Varietal assessment

Introduction

Tomato (*Solanum lycopersicum* L.) belongs to family *Solanaceae*. Tomato was originated in South America and reliable histories revealed that tomato was brought to Europe by traveler Cortex in 1523 AD [1]. The world production of tomato experienced a steady and continuous growth in the last decades of the twentieth century. Total tomato production was over

154 million tons in 2009 and 174 million tons in 2015. Pakistan produced 0.566 million tons as the 37th largest producer in the world. According to the FAO, among the top ten producers of tomato were China, USA, India, Turkey, Egypt and Italy and the top fifteen countries produce about 82.21 % of the total world produce. China is the leading producer with 31.47 % global production and 53% of the tomatoes produced in Asia. [2]. The section of the *Lycopersicon* genus *Solanum* consists of 13 species or subspecies: the cultivated tomato, *Solanum lycopersicum*, which is the only domesticated species, and 12 wild species (such as *S. chmielewskii*, *S. habrochaites*, *S. pennellii*, and *S. pimpinellifolium*) [3]. Tomato is the most popular and widely consumed vegetable crop grown in outdoor fields, greenhouses and net houses of world including Pakistan. Tomato fruits are mostly used as a salad or cooked in sauces, soup and meat or fish dishes. It can be processed into purées, juices and ketchup. It grows best in relatively cool, dry climate for achieving better yield and quality. However, it is adapted to a wide range of climatic conditions from temperate to hot and humid tropical. It requires an average monthly temperature of 20-25°C [4] and starts fruit setting abundantly when the night temperature is in the range of 15-20°C and the day temperature is at about 22-25°C [5]. Most of the tomato cultivars are sensitive to heat stress which became the major factor for reducing the ideal productivity of summer tomato crop in Pakistan [6]. Different genotypes of tomato showed variation in morphological, quality and yield traits [7]. Variations in the genetic makeup of a genotype is responsible for disease resistance, higher yield, quality and long-lasting post-harvest storage [8]. The optimal sowing time plays a very vital role in genetic potential of yield, which commonly provides the optimal condition for growth such as light, temperature, humidity and rainfall [9]. Ahmad *et al.* [10] reported that proper sowing date provides satisfactory growth and development, according to the genetic potential of variety, while variant sowing dates provide different environmental conditions within the same location, which manipulate the growth and development rate of variety with respect to yield. It is necessary to determine proper sowing date for the better quality and yield. Like wise to investigate the most suitable transplanting date for improving the possibility of survival and to cope with the existing climatic conditions is also of great importance. Keeping the above facts in view the current experiment was planned to evaluate the response of different genotypes of tomato on different transplantation dates for acquiring higher production and quality tomatoes under the agro-climatic condition of Malakand Dargai Swat.

Materials and Methods

The experiment was carried out at Dargai, Malakand (34°51 N latitude and 71°9 E longitude) during summer season 2018. The seed of tomato genotypes were taken from Siddique seed dealer. These genotypes have been approved for commercial cultivation through FSCRD, Islamabad. Nursery beds were prepared while using standard practices for nursery raising. Seeds were sown in the first week of February and the seedlings were transplanted within row to row distance of 60 cm and plant to plant distance of 30 cm in the first week of March. After transplantation, seedlings were regularly watered to diminish hazards of seedlings wilting. The treatments were arranged in split plots using (RCBD) Randomized Complete Block Design and were replicated three times (Table 1). Genotypes of tomatoes were allotted to main plots, while seedling transplantation dates were assigned to sub plots.

Ten plants were used per replication. FYM at the rate of 250 tons per hectare and N: P: K at the rate of 150: 100: 60 kg ha^{-1} in form of urea, triple super phosphate (TSP) and potassium sulfate (K_2 SO_4) were applied to the field before transplanting of seedlings, while urea was applied in three split doses, with the intervals of 15 to 25 days. Standard cultural practices such as irrigation, hoeing, weeding and earthing up were carried out uniformly in all replications.

The following attributes were studied during experimentation.

Morphological and Yield related attributes of tomato

The height of tomato plant was measured in randomly five selected plants in all replications for all treatment from the surface of land to the apex of plant using graduated scale. The stem diameter (cm), length of each fruit (cm) and fruit diameter (cm^3) of tomato plant were measured with the help of Vernier caliper in five randomly selected plants in each replication for each treatment and their means were determined. Days to first flowering was calculated in five randomly chosen plants for each treatment in each replication from first day of transplantation to first flowering. Numbers of flowers $plant^{-1}$ and number of fruit $plant^{-1}$ were counted in five randomly selected plant of every replication. The weight of ten randomly selected tomato fruits were measured using digital electric balance. Water displacement method was used for calculating fruit volume of ten tomato fruits from randomly selected plants. Tomato yield (tons ha^{-1}) was recorded from first picking till the last harvest in each main and sub plot, then the data was converted to yield per hectare while using following formula;

$$\text{Yield tons ha}^{-1} = \frac{\text{Yield per sub plot (kg)} \times 10000(\text{m}^2)}{\text{Area of sub plot (m}^2) \times 1000}$$

Biochemical characteristics of tomato

The total soluble solids (TSS) (^{0}Brix) of ten randomly selected fruits from each plot was measured with refractometer and fruit juice pH was measured of randomly selected fruits sample with the help of electronic pH meter by putting pH meter electrode in tomato juice for 1-2 mints. The pH meter was standardized with pH buffer solution before taking each data.

Statistical analysis

The collected data were subjected to appropriated method of RCB split plot arrangement using statistical package Statistix 8.1. Means data were compared using least significance difference (LSD) test at 5% level of significance [11].

Results and Discussion

Morphological and yield related traits of tomato

Effect of different genotypes of tomato seedlings and its time of transplantation dates on morphological and yield related traits of tomato were found significant (($P \leq 0.05$), whereas their interaction had non-significant influence on morphological and yield related characteristics of tomato (Table 2 & 3). Tomato seedlings transplantation dates varied from 13th March to 27th March attained plant height from 75.71cm to 71.17cm, stem diameter from 8.41 to 8.23cm, days to 1st flowering from 26 to 22.92, No. of flowers $plant^{-1}$ from 24.03 to 20.08, number of fruits $plant^{-1}$ (24.58 to 21.67), fruit weight (34.08 to 21.67g), fruit length (5.25 to 4.99cm), fruit diameter (4.37 to 4.06cm), fruit volume (42.67 to 39.67 cm^3) and fruit yield (28.03 to 22.09ton ha^{-1}) (Fig. 1).

Table 1. Description of different transplanting dates and genotypes

Transplanting dates	Genotypes
6th March	Red Ruby
13th March	TM777
20th March	TM1701
27th March	TM1702

Table 2. Means Square of various attributes of tomato as influenced by different genotypes and its transplantation dates

SOV	Df	Mean Square (MS)					
		PH	SD	DTFF	NOFP	NOFPP	FW
Reps	2	2.64^{ns}	0.02^{ns}	3.27^{ns}	3.38^{ns}	3.25^{ns}	13.15^{ns}
Genotypes	3	28.05*	0.11*	31.63*	18.55*	22.75*	16.69*
Error (a)	6	5.86	0.01	4.66	3.46	4.75	2.97
Seedling TD	3	33.38*	0.08**	22.13**	37.84**	19.36**	28.41**
G × S	9	0.85^{ns}	0.00^{ns}	0.21^{ns}	0.40^{ns}	0.02^{ns}	0.31^{ns}
Error (b)	24	10.59	0.02	5.34	8.12	4.9	6.54
Total	47						

***:P≤0.001; **:P≤0.01; *:P≤0.05; NS: Non-significant; PH: Plant height; SD: Stem diameter; DTFF: Days to first flowering; NOFPP: Number of flowers plant^{-1}; FW: Fruit weight

Table 3. Means Square of various attributes of tomato as influenced by different genotypes and its transplantation dates

SOV	Df	Mean Square (MS)					
		FL	FD	FV	FY	TSS	FJpH
Reps	2	0.11^{ns}	0.12^{ns}	2.58^{ns}	19.62^{ns}	0.04^{ns}	0.02^{ns}
Genotypes	3	0.23*	0.18*	23.61*	62.98*	0.21*	0.11*
Error (a)	6	0.04	0.03	3.36	9.23	0.03	0.01
Seedling TD	3	0.16**	0.22**	19.38*	79.20**	0.20*	0.08**
G × S	9	0.00^{ns}	0.00^{ns}	0.11^{ns}	0.23^{ns}	0.00^{ns}	0.00^{ns}
Error (b)	24	0.03	0.04	5.97	14.66	0.06	0.02
Total	47						

***:P≤0.001; **:P≤0.01; *:P≤0.05; NS: Non-significant; FL: Fruit length; FD: Fruit diameter; FV: Fruit volume; FY: Fruit yield; TSS: Total Soluble Solid; FJpH: Fruit juice pH

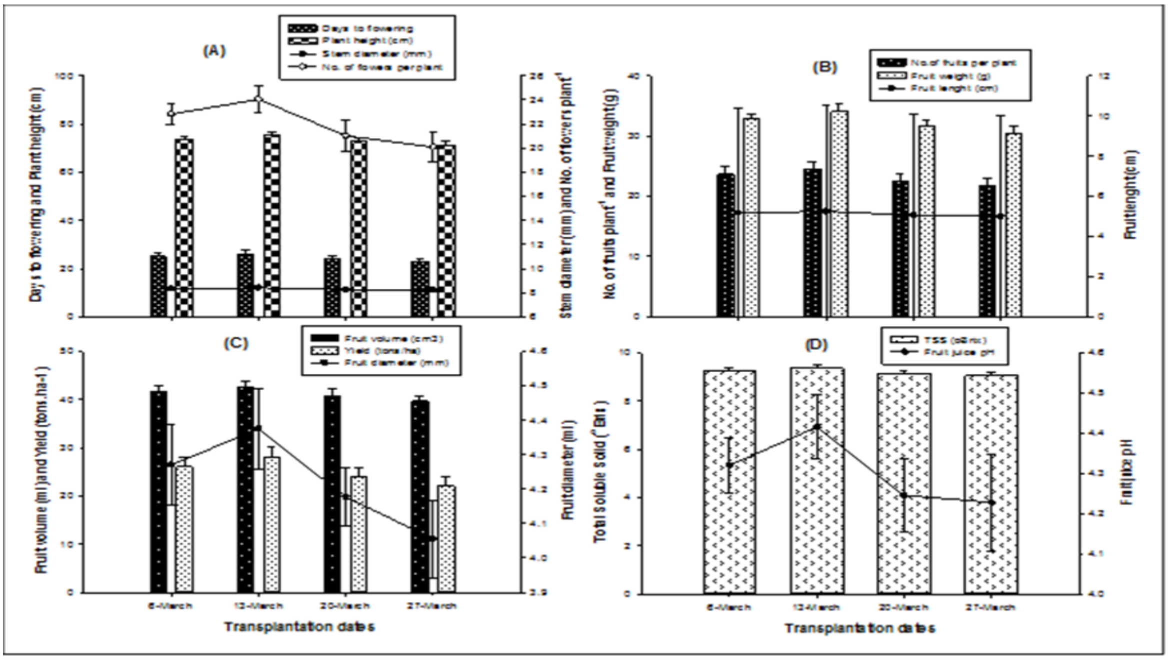

Figure 1. Various attributes of tomato influenced by genotypes transplantation dates

Comparing the means for different genotypes of tomato, the maximum plant height (74.92 cm) was recorded for genotype TM1702, which was statistically at par with plant height (73.83 cm) of genotype TM1701. While genotype Red Ruby attained minimum plant height (71.42 cm). The highest value for stem diameter (8.40 cm) was recorded for genotype TM1702 as compared to other genotypes i.e TM1701, TM777 and Red Ruby (8.33, 8.30 and 8.17 cm). Similarly, late flowering

(26.50) was noticed in genotype TM1702 and early flowering (22.67) was produced by Red Ruby genotype.
The highest number of flowers plant^{-1} (23.43) were recorded for genotype TM1702 as compared to genotype TM1701 (22.49) and genotype Red Ruby (20.59). The highest number of fruits plant^{-1} (24.50), fruit weight (33.75 g), fruit length (5.28 cm), fruit diameter (4.37cm), fruit volume (42.75 cm^3) and fruit yield (27.62 tons ha^{-1}) were recorded for genotype TM1702.While the genotype Red Ruby attained lowest number of fruits plants^{-1} (21.50), fruit weight (31 g), fruit length (4.97 cm), fruit diameter (4.37cm), fruit volume (39.58 cm^3) and fruit yield (22.47 tons ha^{-1}) (Fig. 2).
The morphological and yield related traits of tomato exhibited significant influence for different transplanting dates and genotypes (Table 2 & 3). The expression among the different genotypes is the main factor responsible for variation in plant height **[12]**. **[13]** observed significant variation in plant height among different varieties of tomatoes at different stages of plant growth. These findings are in accordance with the results of Hussain et al and Ambule *et al*. **[14, 15]**. Dash *et al*. **[16]** reported that optimum temperature, water and essential nutrients results in maximum plant growth thus increases plant height. Our results are in line with the findings of Seghatoleslami *et al*. **[17]** who reported that time of sowing had significant effects on plant height. The probable reason for variation in plant height might be due to variation in environmental conditions and growth period which changed with time of sowing or seedling transplantation. The seedlings of tomatoes transplanted on 13 March produced taller plant, it may be due to prolonged vegetative growth. Plant height is vegetative feature and the reason for the variation in the plant height might be due to the ability of cultivars for nutrient uptake like nitrogen which enhanced the vegetative growth and ultimately enhanced the plant height **[18]**. The effect of temperature on the level and activity of growth promoters such as auxin, cytokinin, and gibberellins responsible for maximum plant height in early sown plants. Plants received proper environment, water and other natural resources under early transplantation that resulted maximum plant height **[19]**.
This increase in stem diameter might be due to optimal growth conditions, which favor vegetative growth, thus resulted maximum stem diameter. Our results are in line with the finding of Ishida **[20]** who stated that delayed planting negatively affecting vegetative growth, thus resulted reduction in stem diameter. Increase in growth period allow the plant to sufficiently utilized water, nutrients and solar radiation which increase photosynthesis activity, thus increase the growth of plant.
Flowering is key factor which influence the fruit set and is mainly dependent on photoperiod and temperature. Khan *et al.* **[21]** reported that exposure of late sown plants to high temperature interrupt the normal mechanism of plant growth and resulted in early flowering and poor fruit setting **[22]**. The reason of early flowering in plants might be due to prolong vegetative period and hence the seedlings transplanted on 13th March took maximum days to initiate flowers. Robert and Korkmaz **[23]** reported that high temperature and delay in sowing time initiated early flowers in plants by suppressing its vegetative growth. Delay in sowing time greatly affect the growth and development of plant thus induce flowering in plant and resultantly minimize the lifespan of plant **[24]**. Genetic diversity among the tomato genotypes, soil nutritious status and variation in climatic conditions are influencing factors that affecting the concentration and activities of plant growth promoting hormones like Auxin, Cytokinin and Gibberellins, which in turn affect flowering pattern in plant. Khan *et al.* **[25]** documented similar variation among the genotypes for flowering, that Red stone produce maximum flowers while genotype Roma bear minimum number of flowers.

Balaji and Redd **[26]** reported that delay in sowing time greatly affect the vegetative growth of plant, as a result plants stayed stunted and bear minimum number of branches and flowers buds which resulted minimum number of flowers per plant. Optimal sowing makes available full time for growth and development of plant, hence improve plant height, number of branches per plant as well as produce sufficient flowers buds with dense canopy and maximum photosynthetic activity. According to Saeed *et al.* **[27]** that with the extended period of photosynthetic activity, the plants store adequate amount of photosynthates and later use it for production of maximum number of flower buds.

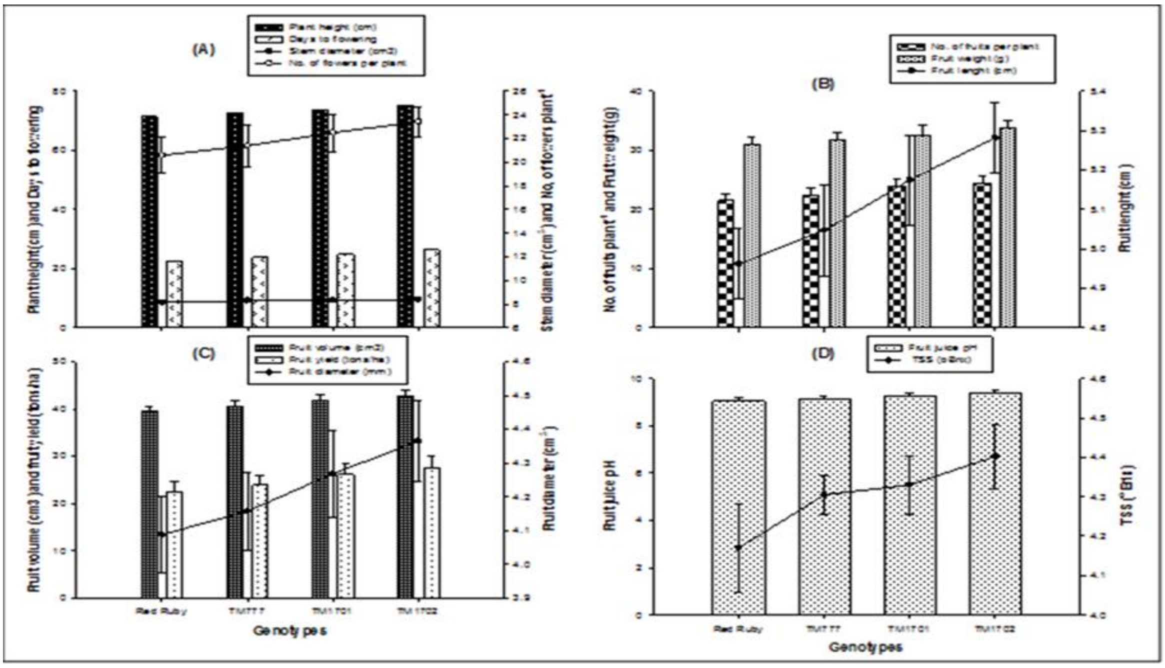

Figure 2. Various attributes of tomato influenced by different genotypes

The difference in number of fruit plant^{-1} among the genotypes might be due to genotypic environmental interaction and chances of fertilization which favored maximum fruit production plant^{-1}. Tipu *et al.* **[28]** observed maximum flower production and fruit setting among the tomato genotypes under heat stress. Similarly, Ali *et al.* **[29]** also exhibited significant variation among the genotypes of tomato for number of fruits plant^{-1}. Likewise, Vazirimehr and Rigi **[30]** also found maximum fruits producing tomato genotype among the tested genotypes. The possible reason of enhancement in number of fruit plant^{-1} is correlated with the increase in number of fertile flowers plant^{-1}. Saglam and Onder **[31]** acknowledged the correlation of fertile flowers with fruits setting per plant. Delay in plantation and higher temperature resulted poor vegetative growth, thus reduce number of fruits per plant. Optimal sowing time favor better vegetative and reproductive growth resulting maximum number of fruits plant^{-1}. Plant did not have enough time for their vegetative growth in delayed sowing because of high temperature and high transpiration rate, due to which plants remained stunted and produced minimum number of branches and ample flowers buds which led to minimum number of fruits plant^{-1}. While, the normal sowing provides full time for vegetative growth and hence, increased plant height, number of branches as well as production of greater fruits with larger canopy and more photosynthates permitted the plant to support more fruits plant^{-1}. Similarly, **[13]** also recorded significant differences among the different tomato varieties for single fruit weight. Likewise, Berenguer *et al*. [32] also noted significant variation in fruit weight among the grown verities of tomato. Differences in fruit weight is actually the genetic expression of gene present in tomato genotypes [33, 34]. Blee [35] stated that under higher temperature plant shift its vegetative growth to reproductive growth in order to survive in stress conditions, thus premature small fruits are formed, and eventually reduce fruit weight resultantly. The variation in fruit length of tomato among the genotypes might be due to the genetic variation and environment conditions of the region. The results of this study are consistent with the finding of Balaji and Redd [26] who reported significant differences for fruit length among the tested lines of tomato. Reduction in fruit length due to late season plantation might be due to inhibition of plant growth promoting hormones such as Auxin, Cytokinin, Gibberellin and Ethylene and activation of abscisic acid (ABA) that inhibited the cellular growth of fruit thus resulted reduction in fruit length. Our results are in line with the findings of Khan *et al.* [36]. Similarly, the decreased fruit length in late sowing might be due to the facts that the growth promoters such as auxin, cytokinin, and gibberellin are inhibited and the growth retardant such as ethylene and ABA may got expressed which stop the cell division and cell enlargement resulting in decreased fruit length [37]. Likewise, Kumar *et al.* [38] also observed smaller tomato fruits due to delay in transplantation of tomato seedling. High phenotypic coefficient of variation and genotypic coefficient of variation cause variation in morphological traits among the genotypes [39, 40]. Similarly, Kumar *et al.* [38] also recorded differences in fruit diameter of tomato in response of planting dates and further explained that existence of variation in fruit diameter might be due variation in environmental conditions. Genetic variation among the genotypes might be the main reason of differences in fruit volume of tomato. Keeping in view the above results, Naveed *et al.* [41] observed significant variation in fruit diameter among the tested genotypes of tomato. Similarly, Sunil and Sarma [42] also reported that fruit volume significantly varied among the tested tomato advance lines. Reduction observed in tomato fruit volume of delayed transplanted seedlings might be due to higher temperature stress and increased rate of transpiration which resulted in poor re-translocation of assimilates to the site of utilization. Furthermore, Kumar *et al.* [38] also noted increase in fruit volume in plants, which were transplanted early, while observed decrease in fruit volume in plants, transplanted late. Yield is economical feature of crop. Relatively high temperature during flowering and early fruit developmental stages in late sowing significantly reduced yield and yield related parameters due to rapid respiration rate and evaporative demand at later stage which could restrict photosynthates partitioning toward fruits, resulting in a considerable decrease in fruit weight and thereby fruit yield plant^{-1} [43]. The significant variation regarding total yield and growth attributes of tomato was recorded among different tested genotypes. The morphological characters like plant height and number of branches are known to influence the yield through the number of fruits and fruit characters [44]. Similarly, Ali *et al.* [45] observed significant variation for yield among the tested tomato genotypes and found Roma higher yielding genotype among the genotypes. The tomato seedlings transplanted on 13th March performed better for higher yield among the planting dates, so time of seedling transplantation depicted influential effect on yielding potential of crop. These results are strongly supported by the finding of Robert and Korkmaz [23].

Biochemical attributes of tomato

Total soluble solids and fruit juice pH were significantly (P≤0.05) influenced by different genotypes and its transplantation dates, whereas their interaction among the genotypes of tomato and seedlings transplantation dates was found non-significant (Table 3). Among the seedling transplantation dates, maximum TSS (9.36 ^{0}Brix) was measured for plants, transplanted on 13th March and minimum TSS (9.06 ^{0}Brix) was observed in plants, transplanted on 27th March. Similarly, minimum value of fruit juice pH (4.23) was observed for plants that were transplanted on 27th March and plant transplanted on 13th March had attained maximum pH of tomato juice (4.41) (Fig. 1). The genotype TM1702 attained highest content of TSS (9.37 ^{0}Brix) and fruit juice pH (4.40), while lowest content of TSS (9.05 ^{0}Brix) and fruit juice pH (4.17) were noted for genotype Red Ruby (Fig. 2).

Washburn and Heflebower **[46]** observed statistically significant variation in fruit juice pH and TSS of different tested genotypes. Time of seedling transplantation significantly affected TSS among the genotypes. Higher content of TSS recorded in early transplanted plants might be the reason of proper fruit development and synthesis of sugar due to prolong growth period. Similarly, Chandler *et al.* **[47]** also observed higher total soluble solids due to suitable environmental conditions. Likewise, Welles and Buitelaar **[48]** also reported that higher temperature and shorter period of growth obstruct the enzymatic activities taking place in the plant, thus reduce the content of TSS. Furthermore, the harsh climatic conditions just happening harvest are also negatively affecting the quality of fruit. The too much warm weather conditions, may also decrease the accumulation of sugar in the fruits. Muez **[49]** stated that quality characteristics of tomato depend upon cultivars, seedling transplantation dates and storage conditions. The determination of fruit juice pH is done by evaluating the hydrogen ion concentration in the fruits **[50]**.

Conclusion

Based on the results, it was concluded that genotype TM1702 showed better performance for growth, yield and yield associated traits compared to other genotypes i.e Red Ruby, TM777, TM1701 respectively. Whereas among transplantation dates, the tomato genotype transplanted on 13th March was found effective for quality production of *tomato* under the climatic conditions of Dargai, District Malakand.

Authors' contributions

Conceptualization: M Jamal & G Nabi, Methodology: M Jamal & G Nabi, Software: I Ullah, Formal analysis: I Ullah, I Ahmad & SAA Shah, Investigation: M Jamal, Resources: N Khan, NA Khan, S Zeb, I Ahmad, Hassnian, N Khan & S Ullah, Writing-original draft preparation: A Basit & I Ullah, Writing-review & editing: A Basit, Supervision: G Nabi.

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