Received: 06 Apr 2022 | Revised: 15 May 2023 | Accepted: 28 May 2023

Electronic Journal of Plant Breeding

Research Note

Genetic variability studies for heat tolerance in tomato (*Solanum lycopersicum* L.) for yield and fruit quality

B H. Varun[1], Rajinder Singh[2] and S K. Jindal[1]

[1]Department of Vegetable Science, Punjab Agricultural University, Ludhiana.
[2]Office of Director Seeds, Punjab Agricultural University, Ludhiana.
***E-Mail**: varunrcbian@gmail.com

Abstract

A detailed study was conducted to evaluate 76 diverse genotypes of tomato for yield and fruit quality under high temperature stress in open condition using randomized block design for two years 2020-2021 during summer season. The ANOVA showed the presence of significant variability among the genotypes for all the traits under study. Higher value for phenotypic and genotypic coefficient of variation was found in yield, number of fruits, average fruit weight. High heritability and genetic advance were observed for yield, number of fruits, average fruit weight, TSS, and pericarp thickness. Hence, during selection of genotypes for heat tolerance these traits must be given importance to get stable and genetically superior genotypes with higher degree of tolerance to heat stress. On the contrary, lower heritability and genetic advance along with lower phenotypic and genotypic coefficient of variation was observed for number of locules, dry matter content, lycopene content, fruit shape index, and titrable acidity.

Keywords: Tomato, PCV, GCV, heritability and genetic advance.

Heat tolerance is one of the important aspects of crop breeding with increasing global temperature. The primary objective of every breeder is to develop a variety with tolerance to biotic and abiotic stress. Tomato (*Solanum lycopersicum* L.) also known as "poor man's orange" belonging to the family Solanaceae is one of the important vegetable crops which is grown throughout the world. Tomato is the second most-consumed vegetable after potato (FAOSTAT 2005). It is rich in vitamin C, potassium, folate, organic acids and, vitamin K. It is a major source of the dietary antioxidant lycopene, which is associated with reducing the risk of heart diseases and cancer. Tomato stands first in processing among vegetables and the products of tomato processing like sauce, ketchup, puree, paste, juice, and chutney are in great demand throughout the year. The major problem faced by the consumers and processing industries is the short supply of fruits during the summer season due to the extreme temperature regimes; which creates the disturbance in the demand and supply chain.

Being a typical sub-tropical to tropical vegetable crop, tomato plant can grow under a wide range of temperatures, and thrives well under 10–30°C and for optimum growth and production it requires about 21–24°C. But the temperatures above 35°C are found to have an undesirable effect on its growth and production. Above 40°C there is no development of any pigment in fruits and also fruits suffer from disorders (Abdalla and Verkerk 1968). High temperature (above 35°C) is the most significant constraint of tomato production, which affects the vegetative and reproductive stages of all tomato cultivars (Abdul 1991).

High temperatures along with high light intensity and dry winds during hotter months of the year lead to drying of the stigmatic surface, deformed flowers, and extreme flower drop resulting in poor fruit set, pre-mature fruit drop, sunscald and, many physiological disorders associated with high temperature (Dorasis *et al.,* 2001). The flowering phase is most sensitive to high temperature; failure of fertilization is due to reduction in pollen viability and decrease in pollen germination percentage and failure in pollen tube elongation (Iwahori 1965, Weaver and Timm 1989).There is a small amount of fruit set under high-temperature parthenocarpically due to intermittent short spells of desirable climatic conditions. However, these fruits are exposed to stress conditions during the later periods of ripening which results in poor color or pigment development, fruit cracking, blotchy ripening and, sun scalding. These fruits do not have any market value and are of no use.

So the possibility of getting higher yield of better quality fruits is either by advanced cultural practices or by manipulation of the genetic make-up of the plant, with the use of breeding tools. There are genotypes in tomatoes that can tolerate or withstand acute thermal stress set fruits at higher temperatures and produce economical yield under stress conditions. The present study is aimed to identify these heat-tolerant genotypes based on the genetic parameters such as phenotypic and genotypic co-efficient of variation, heritability (broad sense) and genetic advance which help in identification of superior and stable genotypes under stress condition, and can be used in breeding programs to evolve heat-tolerant varieties with economic and quality fruit yield.

The present study was conducted in the Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana. The materials used for the study consisted of 76 diverse genotypes including four varieties as check *viz*. Punjab Upma, Punjab Chhuhara, Punjab Ratta and, OS-213. The nursery was sown in January for both the years 2020 and 2021 and the transplanting was done in March for both the years. The research field is located at 30° 55' north latitude, 75° 54' east longitude and is situated 247 m above the mean sea level. It has sandy-loamy soil, the summers are hot and dry and the temperature fluctuates around 25-40°C during the months of March- June and an average of 610 mm rainfall is received annually. The seedlings were transplanted in an experimental field during the first week of March with three replications, in Randomized Block Design. Ten plants of each genotype were planted in every row in all three replications and the spacing of 40-50cm was maintained between plants and 60 cm spacing was maintained between rows.

Observations recorded: Five plants were selected at random in each row of each replication excluding the plants in the border. The observations on Number of days to first anthesis, Plant height (cm) (30-Days, 75-Days respectively), Pollen viability (%)(Pollen viability % test was performed three times at 15 days interval to compare the effect of increase in temperature on pollen viability % *viz*, 30-Days, 45-Days and 60-Days respectively), total number of fruits per plant, total yield per plant (kg), Average fruit weight (g), Fruit shape index, Total Soluble Solids of fruit (°Brix), Pericarp thickness (mm), Lycopene content (µg/100g), Titrable acidity (mg/ml) and Dry matter content (%) were recorded from the selected plants 90 days after transplanting.

Temperature data was recorded during the entire experiment which showed that it ranged from 23-40℃ and during the peak fruiting period it was above 35℃, which is extremely detrimental for tomato during the reproductive stages.

Statistical analysis

Analysis of variance

Pooled analysis of data over years was carried out using OPSTAT software and R-studio.

Co-efficient of Variation (%)

The Phenotypic and Genotypic Co-efficient of Variation were estimated by using the formula given by Burton and Devane (1953).

Co-efficient of Variation (CV) = $\sqrt{\frac{\sigma^2}{\bar{X}}}\, X100$

Phenortypic Co-efficient of Variation(PCV) = $\sqrt{\frac{\sigma^2 p}{\bar{X}}}$ X 100

Genotypic Co-efficient of Variation GCV) = $\sqrt{\frac{\sigma^2 p}{\bar{X}}}$ X100

where,

$\bar{X}$ = population mean of observations under study.

σ^2 = Variance

Heritability in Broad Sense (%):

Heritability in broad sense was computed by using the formula given by Allard (1960).

h^2 (b.s) = $\sqrt{\frac{\sigma^2 g}{\sigma^2 p}}$ X 100

where,

$\sqrt{\sigma^2 g}$ = Genotypic Variance

$\sqrt{\sigma^2 g}$ = Phenotypic Variance

Genetic Advance: Genetic Advance for selection on progeny mean basis was estimated using the formula given by Allard (1960).

Genetic Advance = $h^2_{b.s.}$ X k X σp , Genetic Advance as Percentage of Mean =

$$\frac{h^2 b.s. X\ k\ X\ \sigma p}{\bar{X}} \text{ X } 100$$

where,
$h^2_{b.s.}$ = Heritability in Broad sense
k = Selection Differential.
σP = Phenotypic Standard deviation

Analysis of variance:Analysis of variance is used to exclude variation in the experimental design produced by factors other than genotypic variation from the total variation. The results of the analysis of variance **(Table 1)** revealed significant genotypic variation for all the traits studied, indicating that the material under investigation is highly variable.

All the qualities studied had a substantial degree of variation, according to the findings. The presence of a significant degree of diversity among genotypes demonstrated the presence of needed variability, which may be used in the individual selection process. For all the features, the Mean Sum of Squares (MS) owing to replication was determined to be non-significant. For all the variables studied, the pooled analysis of variance revealed a substantial degree of heterogeneity among genotypes. Significant diversity was identified among genotypes, as well as a high degree of heterogeneity in the interaction between year and genotypes. For years and replications within the year, there was no significant change.

Mohamed *et al.* (2012) reported significant variation among genotypes for all the traits studied; Nalla *et al.* (2016) discovered significant variation among genotypes for average fruit weight and total yield per plant; Singh and Cheema (2005) reported significant variation among genotypes for pericarp thickness, TSS, titrable acidity, lycopene content, and dry matter content.

Phenotypic co-efficient of variation (%): For all the traits, the genotypes revealed a large range of favorable phenotypic variability. The phenotypic co-efficient of variance ranged from 7.35 and 85.22. The phenotypic coefficient of variation for parameters like number of fruits per plant (85.21), average fruit weight (48.04), and yield per plant was found to be greater (40.83).

For traits like the number of locules (29.97), titrable acidity (23.51), plant height(30-Days) (19.1352), fruit shape index (18.72), pericarp thickness(18.45), plant height(75-Days) (16.63), and TSS, the phenotypic coefficient of variation was found to be considerable (15.77).

The phenotypic coefficient of variation was found to be low for traits like lycopene content (13.504), number of days to first anthesis (13.49), dry matter content (11.69), pollen viability (60-Days) (9.67), pollen viability (45-Days) (9.23) and pollen viability (30-Days) (7.35). Kumar *et al.* (2015) also reported similar results in tomato, in which there was a higher magnitude of genotypic and phenotypic coefficient of variation for pericarp thickness (20.58 and 20.94) respectively). Ara *et al.* (2009) also obtained similar results, high phenotypic coefficient of variation was found for yield per plant, the number of fruits for plant and titrable acidity.

Genotypic coefficient of variation (%): Phenotypic variation is not the true measure of variability present in the population. Hence, different components of genetic parameters were estimated. The range of genetic variation for the study varied from 7.341 to 85.19.

Significantly high genotypic variation was estimated for the traits number of fruits per plant (85.19), seed yield per plant (60.40), average fruit weight (44.88), yield per plant (40.63) and, number of locules per fruit (29.71). Relatively moderate genotypic variation was found for traits titrable acidity (23.27), 1000 seed weight (20.89), plant height (19.06), fruit shape index (18.47), pericarp thickness (18.40) and TSS (15.70).

A comparatively lower amount of genotypic variation was found for the traits such as the number of days to first anthesis (13.40), lycopene content (13.37), dry matter content (11.62) and pollen viability (60-Days) (9.66), pollen viability (45-Days) (8.7), pollen viability (30-Days) (7.34). These results are identical with the conclusions drawn from earlier study for fruit shape index and TSS by Singh *et al* (2015), for Pericarp thickness and Lycopene content by Rai *et al* (2016). Prajapati *et al* (2015) also reported identical results for GCV, PCV, Heritability, and Genetic advance, in which they found high PCV and GCV for the number of fruits per plant and number of seeds per plant. Similarly, Ara *et al* (2012) also reported a study in which they found moderate to low GCV and PCV for all the traits under study.

Heritability and Genetic Advance:Heritability is a measure of the genetic relationship between parents and their offspring which is often used to ascertain the degree or level of a trait or a character that can be passed down across generations by the parents. In a broad sense, estimating heritability offers us a notion of the variability of traits or characters which is heritable for succeeding generations. When the heritability of a given characteristic is high, it permits the breeder to make effective single plant selections; conversely, when the heritability of the trait under study is low, it is necessary to use progeny-based selection rather than single plant selection. The results pertaining to Heritability, Genetic Advance, and genetic Advance as percentage mean are shown in the **Table 1** below.

Heritability (Broad sense) [h^2 (b.s)]: In the present study, the range of heritability varied from 85.29 to 94.93. Very

https://doi.org/10.37992/2023.1402.060

Table 1. Pooled Analysis of Variance for all the traits under study (Mean Sum of squares)

Source of Variation	DF	No. of Days to Anthesis	Pollen Viability (%)			Plant Height (cm)		Fruit Shape Index	Number of Locules
			30-Days	45-Days	60-Days	30-Days	75-Days		
Year	1	0.0053	0.01582	0.041	0.0657	0.0418	0.0175	0.052	0.009
Replication within Year	4	0.111	0.0164	0.2833	0.0722	0.0234	0.058	0.003	0.013
Treatment	75	150.658**	330.772**	304.146**	300.758**	191.265**	583.935	0.174**	3.409**
Year X Treat	75	69.594**	368.161**	179.387*	227.819**	18.689**	90.573	0.037**	0.004
Pooled Error	300	0.578	2.824	12.226	0.196	0.423	0.468	0.01	0.006

Source of Variation	DF	Pericarp Thickness (mm)	TSS (°Brix)	Titrable Acidity (mg/100ml)	Lycopene content (mg/100 gm)	Dry Matter (%)	Number of Fruits	Yield (kg/ plant)	Average Fruit Wt.(gm)
Year	1	0.167	0.173	0.003	0.02	2.39	0.233	1316.21	4.279
Repliction within Year	4	0.006	0.026	0.001	0.0009	0.06	0.327	857.58	5.445
Treatment	75	8.054**	3.26**	0.141**	0.961**	2.862**	1577.317**	977496.497**	3909.809**
Year X Treat	75	0.658**	0.024**	0.005**	0.027**	0.287**	4.688**	395461.451**	564.05**
Pooled Error	300	0.013	0.01	0.001	0.01	0.01	0.504	1250588.43	177.516

**, * significant @ 1 % and 5% level of significance.

high heritability was observed for all the traits under the study due to high level of genotypic variation and also variation of individual traits. The heritability for the number of fruits per plant (94.93) was found to be the highest followed by plant height (30-Days) (93.80), plant height (75-Days) (91.79), pollen viability (60-Days) (89.77), pollen viability (30-Days) (89.57), pericarp thickness (88.55), TSS(88.16), yield per plant (87.04), dry matter content(86.79), number of days to anthesis (86.72), number of locules (86.28), lycopene content (86.09), titrable acidity (85.91), fruit shape index (85.29), pollen viability(30-apr) (85.76) and average fruit weight (85.29). The findings are in agreement with those of Kumar *et al.* (2015), who discovered greater heritability (broad sense) values for pericarp thickness (97 percent) and a significant level of genetic advance from plant height (25.68%). Meena and Bahadur (2014), Singh *et al.* (2015), and Rai *et al.* (2015) all arrived at identical outcomes on heritability (2016). The number of fruits per cluster (99.70), the number of seeds per fruit, average fruit weight (90.90), and fruit yield per plant (75.4) all had substantial amount of heritability, according to Aralikatti *et al.* (2018).

Genetic Advance: Heritability alone is not precise; consequently, when heritability is researched in tandem with genetic advance, heritable variation can be evaluated with more precision. For the selection of a superior individual from a diverse population, a trait with high heritability coupled with a higher value of genetic advance is essential. The purpose of estimating advance is that, the trait or character is selected based on phenotype or phenotypic expression, but the phenotype is a composite entity resulting from interactions of genotype and favorable environmental factors.

As a result, selecting a character only based on its phenotypic expression may lead heritability estimates to deviate. In such cases, genetic advance provides with a good picture of the true behavior of the genotype and allow to make appropriate selection decisions.

The results for genetic advance for the traits under investigation are presented in **Table 2**. The genetic advance spanned from 0.31 to 67.79. Yield per plant (67.79) had the greatest rating for genetic advance, followed by average fruit weight (47.97) and the number of fruits per plant (33.38). For yield, average fruit weight and number of fruits per plant, Singh *et al* (2001); Shashikanth *et al* (2010); Chernet *et al* (2013) confirmed similar findings.

Similarly, moderate genetic advance was observed for the traits such as plant height (75-Days) (20.29), pollen viability (60-Days) (14.56), pollen viability (45-Days) (13.56), pollen viability (30-Days) (13.04), plant height (30-Days) (11.57) and the number of days to anthesis (10.23).

For variables like pericarp thickness (2.37), the number of locules (1.54), TSS (1.51), dry matter content (1.41), lycopene concentration (0.81), fruit shape index (0.42), and titrable acidity (0.31), there was significantly less genetic advance. The findings were comparable to Jindal and Khan (2015), who reported a significant level of genetic advance for average fruit weight, total yield, and lycopene content. The findings are in agreement with Meena *et al* (2018), which demonstrated that high levels of PCV, GCV, heritability and genetic advance

Table 2. Genetic Variability Components.

S.No.	Traits/ Characters	Range	GCV%	PCV%	h^2 (b.s)%	GA	GAM%
1	Number of days to 1st anthesis (days)	28.5 - 49.2	13.40	13.49	86.72	10.23	27.43
2	Pollen viability (30-Days) (%)	46.25 – 94.5	7.34	7.35	89.77	13.04	15.09
3	Pollen viability (45-Days) (%)	44.15 - 91.5	8.70	9.23	89.57	13.56	16.89
4	Pollen viability (60-Days) (%)	55.8 - 88.9	9.66	9.67	85.76	14.56	19.89
5	Plant height (30-Days)(cm)	17.2 - 44.03	19.06	19.13	93.80	11.57	39.14
6	Plant height (75-Days) (cm)	42 - 88.87	16.61	16.63	91.79	20.29	34.19
7	Fruit shape index	0.76 - 1.81	18.47	18.72	85.29	0.42	37.52
8	Number of locules	2.00 - 5.6	29.71	29.97	86.28	1.54	60.68
9	Pericarp thickness (mm)	3.62 – 8.70	18.40	18.45	88.55	2.37	37.83
10	TSS (°Brix)	3.54 – 6.08	15.70	15.77	88.16	1.51	32.22
11	Titrable acidity (mg/100ml)	0.38 – 1.16	23.27	23.51	85.91	0.31	47.43
12	Lycopene content (mg/100g)	1.20 – 3.93	13.37	13.50	86.09	0.81	27.28
13	Dry matter (%)	4.36 – 8.13	11.62	11.69	86.79	1.41	23.80
14	Number of fruits per plant	13.90 – 125	85.19	85.22	94.93	33.38	45.42
15	Average fruit weight (g)	14.76 – 143	44.88	48.04	85.29	47.97	86.38
16	Yield per plant (kg/plant)	0.172 -1.77	40.63	40.83	87.04	67.79	83.30

CV = Coefficient of variation,
PCV = Phenotypic Coefficient of variation,
GCV = Genotypic Coefficient of variation,
h2 (b.s) = Heritability in broad sense,
G.A = Genetic Advance

were assessed for fruit yield per plant, number of fruits per plant, and plant height. Similarly, Sherpa *et al* (2014) reported identical results in tomato, where high genetic advance and heritability were found for the traits plant height, number of fruits per plant, pericarp thickness, total soluble solids, titrable acidity, lycopene content and yield per plant. Venkadeswaran *et al* (2020) reported similar findings for heritability and genetic advance for plant height, number of fruits per plant, pericarp thickness, TSS, titrable acidity and lycopene content.

The findings of variability study revealed a significant amount of phenotypic and genotypic coefficient of variation. In traits like yield per plant, number of fruits per plant, and average fruit weight, the phenotypic and genotypic coefficient of variation was found to be highest. This guarantees that there is plenty of room for improvement through selection. Similarly, for yield per plant, number of fruits per plant, average fruit weight, TSS, and pericarp thickness, high heritability and higher genetic advance were noted. This means that these traits are controlled by additive gene action; hence there will be a greater response to the selection of individuals based on these traits. Also, lower levels of heritability and genetic advance were observed for traits like number of locules, dry matter content, lycopene content, fruit shape index, and titrable acidity. This indicates that these traits could be given least importance during selection for heat tolerance in Tomato.

REFERENCES

Abdalla, A. A. and Verkerk, K. 1968. Growth, flowering and fruit-set of the tomato at high temperature. *Netherlands Journal of Agricultural Science,* **16**(1):71-76. [Cross Ref]

Allard, R.W. 1960. Principles of plant breeding. John Willey and Sons. *Inc. New York*, *485*.

Ara, A., Narayan, R., Ahmed, N. and Khan, S.H. 2009. Genetic variability and selection parameters for yield and quality attributes in tomato. *Indian Journal of Horticulture*, **66**(1):73-78.

Aralikatti, O., Kanwar, H.S., Chatterjee, S., Patil, S. and Khanna, A. 2018.Genetic variability, heritability and genetic gain for yield and quality traits in tomato (*Solanum lycopersicum* L.) *International Journal of Chemical Studies*, **2**(7):238-244.

Burton, G.W. and Devane, D.E. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material 1. *Agronomy journal*, **45**(10):478-481. [Cross Ref]

Chernet, S., Belew, D. and Abay, F. 2014. Genetic diversity studies for quantitative traits of tomato (*Solanum lycopersicon* L.) genotypes in Western Tigray, Northern Ethiopia. *Journal of Plant Breeding and Crop Science*, **6**(9):105-113. [Cross Ref]

Dorais, M., Papadopoulos, A.P. and Gosselin, A. 2001. Greenhouse tomato fruit quality. *Horticulture Reviews*, **26**:239-49. [Cross Ref]

FAOSTAT.2005. Food and Agriculture Organization Corporate Statistical Database Available from https://www.fao.org/3/cb1329en/CB1329EN.pdf

Iwahori, S. 1965. High temperature injuries in tomato. Development of normal flower buds and morphological abnormalities of flower buds treated with high temperature. *Journal of the Japanese Society for Horticultural Science*, **34**(1):33-41. [Cross Ref]

Jindal, S.K. and Khan, A. 2015. Genetic variability in tomato grown in autumn season. *Vegetable Science*, **42**(2):98-100.

Kumar, R., Singh, S.K., Srivastava, K. and Singh, R.K. 2015. Genetic variability and character association for yield and quality traits in tomato (*Lycopersicon esculentum* Mill). *Agriways*, **3**(1):31-36.

Meena, O. P. and Bahadur, V. 2014. Assessment of correlation and path coefficient analysis for yield and yield contributing traits among tomato (*Solanum lycopersicum* L.) germplasm. *Agriculture Res*earch *Journal*, **34**:245-250. [Cross Ref]

Meena, R.K., Kumar, S., Meena, M.L. and Verma, S. 2018. Genetic variability, heritability and genetic advance for yield and quality attributes in tomato (*Solanum lycopersicum* L.). *Journal of Pharmacognosy and Phytochemistry,* **7**(1): 1937-1939.

Mohamed, S.M., Ali, E.E. and Mohamed, T.Y., 2012. Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicon* L.). *International Journal of Scientific & Technology Research,* **1**(2): 55-58.

Nalla, M.K., Pandav, A.K., Aslam, T.A.R.I.Q.U.E. and Rana, M.K. 2016. Studies on variability, heritability and genetic advance in tomato (*Solanum lycopersicon* L.). *Advances in Life Sciences,* **5**(4):1536-1539.

Prajapati, S., Tiwari, A., Kadwey, S. and Jamkar, T. 2015. Genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicon* Mill.). *International Journal of Agriculture, Environment and Biotechnology,* **8**(2):245-251. [Cross Ref]

Singh, H. and Cheema, D.S. 2005. Studies on genetic variability and heritability for quality traits of tomato (*Lycopersicon esculentum* Mill.) under heat stress conditions. *Journal of Applied Horticulture,* **7**(1):55-57. [Cross Ref]

Singh, U., Patel, P.K., Singh, A.K., Tiwari, V., Kumar, R., Rai, N., Bahadur, A., Tiwari, S.K., Singh, M. and Singh, B. 2015. Screening of tomato genotypes under high temperature stress for reproductive traits. *Vegetable science*, **42**(2):52-55.

Shashikanth, N.B., Hosamani, R.M. and Patil, B.C. 2010. Genetic variability in tomato (*Solanum lycopersicon* [Mill]. Wettsd.). *Karnataka Journal of Agricultural Sciences,* **23**(3):536-537.

Sherpa, P., Pandiarana, N., Shende, V. D., Seth, T., Mukherjee, S. and Chattopadhyay, A. 2014. Estimation of genetic parameters and identification of selection indices in exotic tomato genotypes. *Electronic Journal of Plant Breeding*, **5**(3):552-562.

Venkadeswaran, E., Vethamoni, P. I., Arumugam, T., Manivannan, N., Harish, S., Sujatha, R. and Rani, E. A. 2020. Genetic variability studies in cherry tomato [*Solanum lycopersicum* (L.) var. cerasiforme Mill.] for growth, yield and quality. *Electronic Journal of Plant Breeding*, **11**(04):1222-1226.