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Heat Tolerance Studies in Tomato (*Lycopersicon esculentum* Mill.)

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ABSTRACT

The experiment was carried out to assess heat tolerance and correlation studies in tomato (*Lycopersicon esculentum* Mill.). The data were recorded for membrane thermostability values, stigma elongation, antheridial cone splitting, number of flowers shed per plant and yield per plant. Data indicated highly significant differences among the traits under study. Among the genotypes; Cchaus was the best followed by was 2413L with greater tolerance to heat stress showing high membrane thermostability and lowest number of flowers shed whilst producing highest fruit yield during hot period. Association of fruit yield was positive with membrane thermostability but negative with number of flowers shed, stigma tube elongation and antheridial cone splitting. In crux Roma with a lowest membrane thermostability, was the most sensitive genotype to heat.

Key Words: Membrane thermostability; Regression-correlation; Stigma

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and is an important vegetable crop all over the world. It is used in various forms, such as fresh salad, cooked foods and in processed forms like ketchup, paste etc., Tomato thrives well under tropical and subtropical regions. It can grow vigorously and is highly productive within the temperature range of 18 – 28^{o}C. Fruit yield of tomato crop is far low in Pakistan as compared to advanced countries. Various cultural practices and different doses of fertilizers have been tried in the past to increase the yield of tomato in the country, but improvement in fruit yield has not been substantial.

Tomato is usually produced during the winter season in Pakistan and fruit production is gradually dropped as the temperature increases by the end of the winter season. In summer due to high temperatures, tomato production almost ceases and shortage of tomatoes is common. High temperatures during the growing season have been reported to be detrimental to growth, reproductive development and yield of several crops (Hall, 1992; Hussain *et al.*, 2006 Singh *et al*., 2007). In tomato high temperature during reproductive development caused significant increment in flower drop (Hanna & Hernandez, 1982) and significant decrease in fruit set (Berry *et al.*, 1988) and consequently fruit yield decreased to a great extent. At high temperature, the reproductive part of the flower is adversely affected. Stigma tube elongation, poor pollen germination, poor pollen tube growth and carbohydrate stress are the main reasons for poor fruit set at high temperature in tomato.

Under the circumstances, there is a need to develop varieties that can withstand to high temperature stress to sustain tomato production during the warmer months. Before embarking upon breeding programme aiming at the development of heat tolerant cultivars, information regarding the extent of genetic variability and association of various characters conferring heat tolerance is necessary. The present study was conducted to obtain basic information on the extent of variability for heat tolerance in tomato varieties, as a prerequisite for synthesis of heat tolerant genotypes in the crop. Information on heritability, regression and correlation were also sought to determine the degree of genetic determination and association between the characters studied.

MATERIALS AND METHODS

In order to assess heat tolerance in tomato (*L. esculentum* Mill.), the experimental material used in the studies was comprised Rio-Grande, Nagina, Cchaus, Roma, CLN2318F, CLN2443A, CLN2443B, 2413L, 2418A and 1466EA. The experiment was conducted at experimental areas of Vegetable Research Institute, Ayub Agriculture Research Institute, Faisalabad. The nursery of each accession was transplanted in the field in three replications following Randomized Complete Block Design. The seedlings were planted in rows having 10-plants per row keeping row to row and plant to plant distances of 60 cm and 30 cm, respectively. The data were taken from the middle 5 plants leaving plants on either ends of the row to avoid the border effects. Normal agronomic and plant protection measures were adopted to obtain healthy plants.

Heat tolerance in terms of membrane thermostability (MTS) in the experimental material at flowering stage was measured using electrolyte leakage from leaf tissue as described previously used for measuring heat tolerance in wheat (Saadalla, 1990), cotton (Malik *et al.*, 1999), brassica

(Morrison & Stewart, 2002) and tomato (Shen & Li, 1982). In addition to following MTS test, some other parameters as number of flowers per plant, stigma elongation, antheridial cone splitting, number of flowers burnt/shed, number of days for fruit setting and yield per plant were also used to assess heat tolerance. The measurements on the parameters were taken during June-July with average temperature 42 – 45^{o}C.

Statistical analysis. The data for all traits were analyzed following analysis of variance technique. Simple linear correlation between the characters and regression analysis between yield and other traits was carried out, again following Steel and Torrie (1980).

RESULTS AND DISCUSSION

Measurement of heat tolerance using membrane thermostability (MTS). In the present assessment of heat tolerance using electrolyte test, highly significant ($P < 0.01$) differences were revealed between the tomato genotypes (Table I). Comparison of genotypic means for MTS values showed that the genotype 2413L had the highest value for MTS (26.83), while the genotype Roma had the minimum value of (4.73) for this parameter (Table II). While rest of the genotypes had MTS values varying from 6.26 to 20.00 and the coefficient of variability was 13.23%. The value of broad sense heritability was high (0.9254), which indicated that the variation observed in the character has strong genetic basis (Table I). The varieties showing high MTS values are more likely to tolerate high temperature and relatively longer exposure to high temperature would cause damage to leaf tissues (Shen & Li, 1982).

Measurement of Heat Tolerance Using Floral Characteristics

Stigma tube elongation. Tomato is a highly self-pollinated crop and cross-pollination does not exceed 1 - 2% (Levy *et al.*, 1978). At high temperature stigma tube of the flower extends out of the antheridial cone and thus prevents pollination and causes reduction in fruit set (Rick & Dempsey, 1969). Reduction in fruit yield of tomato has been reported at 1 mm extension of the stigma tube (Rudich *et al.*, 1977). An-other report (Dane *et al.*, 1991) showed a negative correlation between stigma tube elongation and tomato fruit yield. In the present study, data revealed significant ($P < 0.01$) differences among genotypes for stigma tube elongation (Table I). Furthermore, coefficient of variability and heritability were 9.82% and 0.815, respectively (Table I), which suggested that considerable proportion of the variation in the character was genetically determined. The number of flowers with stigma tube elongation ranged between 25.00 to 55.00%. The genotype Roma had the highest value (55%), while the genotype CLN2318F had the lowest mean value (25%) for stigma tube elongation. Other than this there was a difference among the genotypes for this character from 28.83% to 51.30% (Table II). Dane *et al.* (1991) and Hanna and Hernandez, (1982) observed that in tomato the flowers with elongated stigma tube had low pollination and thus affected the yield per plant. Therefore, in the light of previous studies it may be suggested that the genotypes producing flowers with normal stigma tube under high temperature would produce high fruit yield.

Table II. Comparison of different genotypes for various traits related to heat tolerance

Genotype	Membrane thermo stability	Stigma tube elongation (%)	Anther-idial cone splitting (%)	Number of flowers shed (%)	Yield/ plant (g)
1.Cchaus	20.00 a	33.26 ab	25.00 ab	15.00 a	2703.0 a
2.2413L	26.83 b	29.93 abc	19.17 b	26.20 b	2295.0 b
3.Rio-Grande	18.12 ac	31.26 abc	20.03 b	21.16 c	2016.0 c
4.CLN2318F	15.96 cd	25.00 c	24.23 ab	27.30 db	1537.0 d
5.Nagina	12.00 e	36.06 ad	20.00 b	32.00 ef	1506.0 d
6.CLN2418A	13.25 de	28.83 bc	30.00 ac	29.43 fd	1693.0 d
7.CLN2443B	9.93 e	41.60 d	34.00 cd	28.43 db	1005.0 e
8.CLN2443A	6.26 f	48.40 e	37.10 cd	33.16 e	840.0 e
9.1466EA	12.50 e	51.30 e	40.30 d	36.30 g	448.3 f
10.Roma	4.73 f	55.00 e	35.00 cd	33.40 e	66.6 g

Means sharing similar letters in a column are statistically non-significant ($P>0.05$).

Antheridial cone splitting. Table I showed highly significant differences ($P < 0.01$) between the tested genotypes for flowers with antheridial cone splitting. The value of heritability (0.7343) showed that about 73% of the variation was genetically determined, which was confirmed from the data in Table II. This revealed that genotype 1416EA had the highest mean value (40.3%), while 2413L had minimum value for this attribute. These results suggested that the genotype with split antheridial cone in less number of flowers were relatively more stable at high temperature. Hence the anthers with more split cones are un-able to produce viable pollens and as a result of impeding the process of fruit formation ultimately fruit yield

Table I. Mean squares for various characters related to heat tolerance

	Mean Squares			+	++
Traits	Replication (df = 2)	Genotype (df = 9)	Error (df = 18)		
Membrane thermostability	6.523	130.227**	3.410	0.9254	13.23
Stigma tube elongation	13.129	325.609**	13.971	0.8815	9.82
Antheridial cone splitting	44.477	183.157**	19.716	0.7343	15.59
Number of flowers shed/burnt	1.143	120.618**	2.377	0.9431	5.46
Yield /plant (g)	62893.272	2048730.633**	19868.053	0.9715	9.99

*= Significant ($P<0.05$), ** = highly significant ($P<0.01$)
+ h^2 (B.S) = Broad sense heritability
++CV= Coefficient of variability

Table III. Correlation among different characters related to heat tolerance

Character	Membrane thermo-stability	Stigma tube elongation	Antheridial cone splitting	Number of flowers shed	Yield
Membrane thermostability					0.845**
Stigma tube elongation	-0.717*			0.608ns	-0.835**
Antheridial cone splitting	-0.723*	0.810*		0.608ns	-0.793**
Number of flowers shed	-0.649*				-0.852**

Fig. 1. Regression line between yield and membrane thermostability

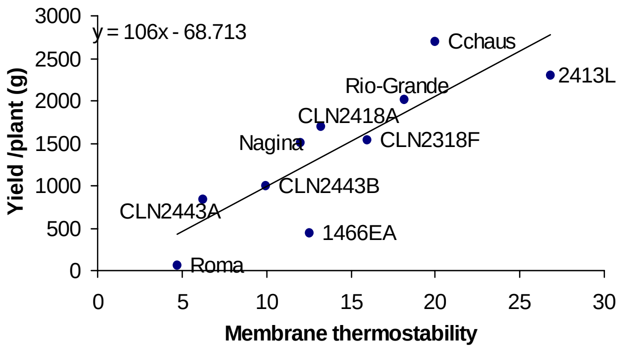
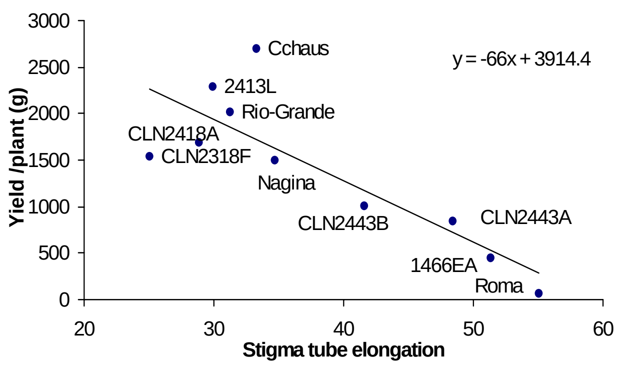


Fig. 2. Regression line between yield and stigma tube elongation



is affected. Fernandez and Cuartero (1990) and Baki and Stommel (1995) also argued that antheridial splitting reduces plant yield by effecting the natural fertilization process.

Number of flowers shed/burnt. Mean squares for number of flowers shed per plant was highly significant (Table I), which indicated differences among the ten tomato genotypes to retain flowers at high temperature. High broad sense heritability value (0.9431) indicated that most of the variation in the character was under genetic control.

Data further indicated that there was a considerable variation existed between the 10 genotypes for number of flowers shed (Table II). The genotype Cchaus had the minimum number of flowers shed having a value of 15.00, whereas the genotype 1466EA had the highest number of flowers shed having a value of 36.30 (Table II). Rest of the genotypes had mean values from 26.20 to 33.40. The results indicated that the genotype, Cchaus, Rio-Grande and 2413L with flower shed percentage 15, 21.16 and 20.20, respectively had retained more flowers at high temperature and thus would produce greater yield. Rahman *et al.* (1998) also argued that due to increase in temperature, the flower drop per plant is increased, which ultimately caused reduction in yield.

Fruit yield per plant (g). Means squares for genotypes were highly significant at ($P < 0.01$) for yield per plant during high temperature conditions (Table I). This revealed that the value of heritability was 0.9715, which showed that the observed variation among the genotypes had strong genetic basis. The coefficient of variability was 7.92%.

Comparison of the varieties for yield revealed that genotype "Cchaus" had maximum mean fruit yield (2703 g) produced during the high temperature conditions among the genotypes, while Roma produced fruit yield (66.6 g $plant^{-1}$) and rest of the genotypes produced yield ranging from 448.3 to 2295.0 g $plant^{-1}$. These results suggested that the genotype, which will produce better yield under high temperature conditions, would be heat tolerant. The value of high broad sense heritability (0.9715) that showed that about 90% of the variation observed was genetically determined.

Correlation Coefficient and Linear Regression Analysis Between Yield and Different Floral Characters in Tomato During High Temperature Conditions

Membrane thermostability. Simple linear regression and correlation analysis given in (Table III) during heat period revealed that MTS was positively correlated ($r = 0.845$) with tomato yield. Regression line indicated a linear increase in fruit yield with increase in MTS (Fig. 1), which corroborates findings of Akimova *et al.* (1992) and Shen and Li (1982).

Stigma tube elongation. A negative correlation between yield and flowers with stigma tube elongation was observed (Table III). Line of regression indicated a linear decrease in yield with increase in number of flowers with stigma tube elongation (Fig. 2). These results are similar to Ahmadi and Stevens (1979), Hanna and Hernandez (1982).

Antheridial cone splitting. A negative correlation coefficient "r" - 0.793" between yield and flowers with splitted antheridial cone was observed (Table III). Line of regression indicated a linear decrease in yield with increase in number of flowers with splitted antheridial cone (Fig. 3), which is concurrence with the previous reports (Dane *et al.*, 1991).

Number of flowers shed/burnt. A negative correlation was found between number of flowers shed and yield per plant (Table III). Regression line indicated a linear decrease in yield with the number of flowers shed during heat period (Fig. 4). These results showed similarity with previous studied (Hanna & Hernandez, 1982; Rahman *et al.*, 1998).

Fig. 3. Regression line between yield and antheridial cone splitting

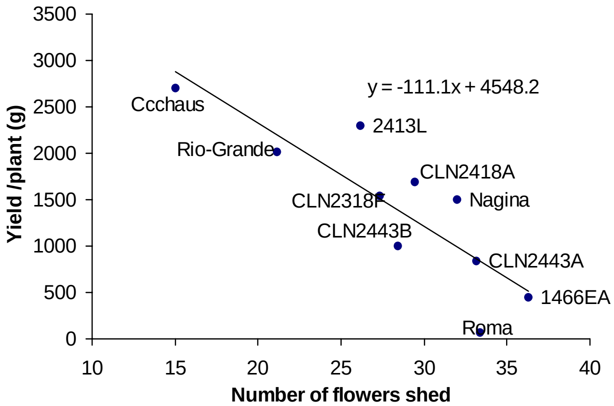
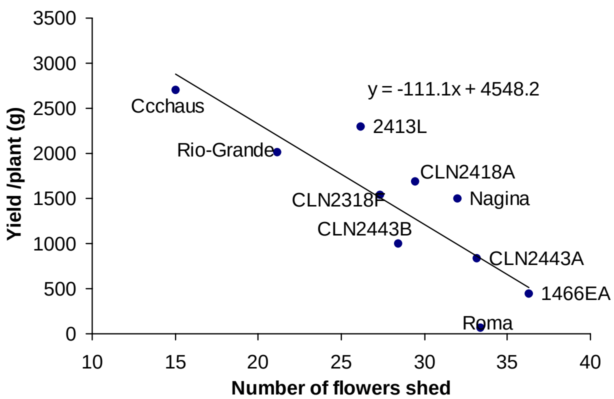


Fig. 4. Regression line between yield and number of flowers shed



CONCLUSION

Variation for tolerance to heat stress exists in tomato. Although a limited number of germplasm was assessed, the genotypes appeared to have differences in tolerating heat stress. The genotypes Cchaus and 2413L showed higher degree of tolerance to the heat stress. Thus, potential exists for breeding tomato genotypes with increased tolerance to heat stress to sustain tomato production in the hot conditions.

REFERENCES

Ahmadi, A.B.E. and M.A. Stevens, 1979. Genetics of high-temperature fruit set in the tomato. *J. American Soc. Hort. Sci.*, 104: 691–6

Akimova, T.V., N.I. Balagurova and A.F. Titov, 1992. Possible transmission of heat hardening “signal” within the plant. *Soviet-Pl.-Physiol.*, 38: 873–7

Baki, A.A.A. and J.R. Stommel, 1995. Pollen viability and fruit set of tomato genotypes under optimum and high temperature regimes. *Hort. Sci.*, 30: 115–7

Berry, S.Z. and M. Rafique-Ud-Din, 1988. Effect of high temperature on fruit set in tomato cultivars and selected germplasm. *Hort. Sci.*, 23: 606–8

Dane, F., A.G. Hunter and O.L. Chambliss, 1991. Fruit set pollen fertility and combining ability of selected tomato genotypes under high temperature field conditions. *J. American Soc. Hort. Sci.*, 116: 906–10

Fernandez, M.R. and J. Cuartero, 1990. The effects of temperature and illumination on stigma level in the three varieties of tomatoes (*Lycopersicon esculent*um Mill.). *Proceedings of 11th Eucarpia meeting on Tomato Genetics and Breeding*, pp: 105–10

Hall, A.E., 1992. Breeding for heat tolerance. *Pl. Breed. Rev.*, 10: 129–68

Hanna, H.Y. and T.P. Hernandez, 1982. Response of six tomato genotypes under summer and spring weather conditions in Louisiana. *Hort. Sci.*, 17: 758–9

Hussain, T., I.A. Khan, M.A. Malik and Z. Ali, 2006. Breeding Potential for high temperature tolerance in corn (*Zea mays*. L.). *Pakistan J. Bot.*, 38: 1185–95

Levy, A., H.D. Rabinowitch and N. Keder, 1978. Morphological and physiological characters affecting flower drop and fruit set of tomatoes at high temperatures. *Euphytica*, 27: 211–8

Malik, M.N., F.I. Chaudhary and M.I. Makhdum, 1999. Cell membrane thermostability as a measure of heat tolerance in cotton. *Pakistan J. Sci. Ind. Res.*, 42: 44–6

Morrison, M.J. and D.W. Stewart, 2002. Heat stress during flowering in summer brassica. *Crop Sci.*, 42: 797–803

Rahman, S., E. Nawata and E. Sakuratani, 1998. Effects of temperature and water stress on growth, yield and physiological characteristics of heat-tolerant tomato. *Japanese J. Trop. Agric.*, 42: 46–53

Rick, C.M. and W.H. Dempsey, 1969. Position of the stigma in relation to fruit setting of the tomato. *Bot. Gaz.*, 130: 180–6

Rudich, J., E. Zamski and Y. Regev, 1977. Genotypic variation for sensitivity to high temperature in tomato: pollination and fruit set. *Bot. Gaz.*, 138: 448–52

Saadalla, M.M., J.F. Shanahan and J.S. Quick, 1990. Heat tolerance in winter wheat: hardening and Genetic effects on membrane thermostability. *Crop Sci.*, 30: 1243–7

Shen, Z.Y. and P.H. Li, 1982. Heat adaptability of the tomato. *Hort. Sci.*, 17: 924–5

Singh, R.P., P.V. Vara Prasad, K. Sunita, S.N. Giri and K.R. Reddy, 2007. Influence of high temperature and breeding for heat tolerance in cotton. *Adv. Agron.*, 93: 313–85

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics: A Biological Approach*, 2nd edition, McGraw Hill, Book Co., New York USA

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