Journal of Crop and Weed 8(1): 114-117 (2012)

Crucial reproductive characters as screening indices for tomato [*Solanum lycopersicum*] under high temperature stress

S. AKHTAR, [1]S. H. ANSARY, [2]A. K. DUTTA, C. KARAK, AND P. HAZRA

Department of Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741252, WestBengal
[1] Hoogly Krishi Vigynan Kendra, Bidhan Chandra Krishi Viswavidyalaya, Chinsura, Hoogly, West Bengal
[2] IRTDM Faculty, Ramkrishna MissionVivekananda University, Morabadi, Ranchi, Jharkhand-834008

Received: 03.12.2011, Revised: 13.04.2012, Accepted : 25.05.2012

ABSTRACT

The field experiment was carried out with 38 tomato genotypes grown under normal (October-February) and high temperature stress (February-May) seasons, the average day and night temperature were 27.6 & 15.1°C and 34.5 & 19.2°C, respectively. Several floral and fruit characters have been adversely affected due to chronic high temperature stress which clearly indicated specific physiological processes of flower development were especially sensitive to high temperature stress and limited fruit-set. The mean number of truss plants^{-1} and flowers truss $^{-1}$under high temperature condition were drastically reduced and so was the number of fruitset truss^{-1}. The genotype CLN-2413R resulted in maximum fruit-sets. Few genotypes like Ratan, Patharkuchi, Parul did not set fruit at all under stress condition. Pollen viability and germination were drastically reduced under excessive heat of spring-summer season. Pollens of the genotype CLN 2413R showed maximum viability (59.23%) whereas CLN 2116B recorded highest pollen germination (82.40%). Pollens of as high as 22 genotypes did not germinate at all in vitro which made the major difference in fruit set in the genotypes. Fruit number and fruit weight were the important yield components, which were severely affected under high temperature stress and ultimately yield was markedly reduced. Under high temperature stress conditions, conspicuous correlations found were pollen viability and number of fruits plant^{-1}, pollen germination and number of fruits plant^{-1}, pollen germination and yield plant^{-1}, fruit weight and yield plant^{-1}. Considering different correlations and path coefficient analyses, the most crucial characters identified for high temperature fruit-set and fruit yield in tomato are flower trusses/plant, flowers/truss, fruit-set/truss, fruits/plant, average fruit weight, pollen viability and pollen germination.

Key words: High temperature, reproductive characters, screening indices

Tomato is one of the most important vegetable crops grown widely in tropical and sub-tropical regions. Though tomato is basically warm season crop, it often experiences high temperature stress during fruit-set when grown beyond its optimal temperature range of 21-24°C. Moderately elevated temperature stress (28-29°C) may not disrupt biochemical reactions fundamental for normal cell functioning since the temperature are still in the range that a tomato plant would grow normally. However, reduced fruit-set is the common response to such elevated temperature mainly due to reduced pollen germination and release and disturbed microsporogenesis (Sato *et al*, 2002).

High temperature is a major constraint to tomato production in the tropics and sub-tropics of the world. The vegetative and reproductive responses of tomato are strongly modified by temperature alone or in conjunction with other environmental factors like light, nutrition and moisture (Abdalla and Verkerk, 1968). However, for many species like that of tomato reproductive processes appeared to be much more sensitive to temperature stress than vegetative growth (Sato *et al.*, 2002). Exposure of most tomato cultivars to 30/20°C day/night temperature prevents fruit-set and as little as 3hr exposure to 40°C can cause blossom drop in most cultivars (Rudich, 1978). Heat tolerance is regarded as a genetically controlled attribute of the plant because of significant genotype-environment interaction for this character (Rudich *et al.*, 1977; Palta *et al.*, 1979). Expression of different crucial characters under high temperature is responsible for heat tolerance and heat tolerant genotypes posses these inherent characters. The present investigation aimed to study on different floral and fruit-set characters manifested in normal and heat stress condition to identify the crucial characters to be considered for high temperature tolerance in tomato.

MATERIALS AND METHODS

The field level research experiment on screening tomato genotypes under high temperature stress condition was carried out in the Department of Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya. The experimental site was situated at 22°57' N latitude and 88°20' E longitude at an elevation of 9.75m above MSL. Thirty eight genotypes comprising of commercial varieties, exotic collections, local cultivars and wild species have been employed in a RBD with three replications in two distinct seasons *viz.*, Autumn-Winter (October-February) under optimal temperature condition, the average day/night temperature being 27.6/15.1°C and spring-summer (February- May) under heat stress condition in average day/night temperature of 34.5/19.2°C. Different observations on floral and fruit characters evaluated were flower trusses plant^{-1}, flowers truss $^{-1}$, fruit-set struss $^{-1}$, fruits plant^{-1}, average fruit weight, yield plant^{-1}, length of style, pollen

Email: shirin.0410@gmail.com

viability percentage and in-vitro pollen germination percentage.

Pooled data from 5 samples were utilized for statistical analysis. In the laboratory, pollen viability was estimated with 1% acetocarmin and in-vitro pollen germination was measured with solution mixture of 5 % sucrose and 1 % boric acid. Simple linear correlation coefficient was measured for different characters for detecting the intensity and direction of association among the characters. The direct and indirect effects by path analysis on some important characters were also estimated.

RESULTS AND DISCUSSION

Floral and fruit-set characters

It was revealed clearly that the reproductive characters were highly sensitive to high temperature stress and the degree of sensitivity varied greatly among the genotypes. Flower production capacity reduced severely in all the genotypes under high temperature stress condition. Mean number of trusses plant $^{-1}$ was reduced from 41.29 in autumn-winter to 26.88 in spring-summer season. Flower number truss^{-1} was also reduced from the mean of 5.97 in autumn-winter to 4.47 in spring-summer although the reduction was not so marked (Table 1).

Results of the experiment clearly indicated that fruit setting ability in the genotypes was reduced drastically in high temperature condition and in this regard, different genotypes responded differently showing their relative tolerance or susceptibility to heat stress. Mean fruit-set truss $^{-1}$ was markedly reduced from 4.71 in autumn-winter to 2.26 in spring-summer. Under stress condition, the genotype CLN-2413R produced maximum fruit-sets (3.93 truss^{-1}). Few genotypes like Ratan, Patharkuchi, Parul did not set fruit at all under high temperature stress condition. The day/night temperature of more than 32°C and 21°C are known to limit fruit-set of tomato due to impairment of complex physiological process involved during flowering and fruit developmental stages (Muthuvel *et al.*, 2000). Data presented in table- 1 clearly showed that most of the genotypes showed marginally increased style length under high temperature condition (mean 7.34mm) as compared to normal season (mean 7.31mm). So, stigma exersion which was recorded as one of the major floral manifestation due to high temperature sensitivity by some earlier workers was not apparent in the present investigation.

Pollen characters

Pollen viability and germination were drastically reduced under high temperature condition of spring-summer season and it varied greatly among the genotypes (Table 1). Viability of the pollens was highly sensitive to heat stress and mean percentage decreased from 87.90% under autumn-winter to 36.61% under spring-summer. In spring-summer, pollens of the genotype CLN 2413R showed maximum viability (59.23%) and a minimum of 19.60% viability was recorded in Feb-2. Pollen viability is drastically reduced due to desiccation in high temperature (Arora, 1977; Rudich *et al.,* 1977; Abdalla and Verkerk, 1968; Levy *et al.*, 1978). *In vitro* germination of pollens was excessively reduced from the mean 63.99% in autumn-winter to 19.39% in spring-summer season. CLN 2116B recorded highest pollen germination in both the seasons (82.40% and 28.50% in autumn-winter and spring-summer respectively). In spring-summer season, pollens of as high as 22 genotypes did not germinate at all *in vitro* which made the major difference in fruit set in the genotypes. Pollen germination is very much reduced under high temperature condition as reported by Charles and Harris (1972), Rick and Dempsey (1969), El-Ahmadi and Stevens (1979).

In the present investigation pollen viability and germinability emerged as one of the major limiting factors for fruit set under chronic high temperature stress. However, pollen release may be a better factor for determining response to high temperatures since failure of pollen release will prevent fruit set regardless of the viability of pollen grains. Results of the present investigation also recorded some fruit set in the genotypes, pollens of which did not at all germinate *in vitro.*

Fruit and yield characters

Fruit number and fruit weight were the important yield components, which were severely affected under high temperature stress and ultimately yield was markedly reduced (Table 1). Mean fruit number per plant was drastically reduced from 50.61 in autumn-winter to 14.32 in spring-summer. In spring-summer season, as high as 13 genotypes had no fruits in the plant in the advanced growth stage *i.e.* fruit retention stage. In other 10 genotypes fruit drop occurred with the advancement of age which might have been due to lack of fertilization, enhancement of pedicels abscission etc. Marked reduction of fruit weight was also observed under spring-summer (27.63 g) as compared to autumn-winter (52.87 g). Yield potential of the genotypes which was dependent on fruit set and fruit weight severely reduced under heat stress of spring-summer and the mean yield decreased from 1.87 kg plant^{-1} in autumn-winter to 0.32 kg plant $^{-1}$ in spring-summer. In spring-summer condition higher yield was recorded in CLN 2413 R (0.67 kg plant $^{-1}$) and CLN 2116B (0.48 kg plant $^{-1}$).

Marked reduction in number of trusses plant $^{-1}$ (35%), number of flowers truss^{-1} (25%), fruit set truss $^{-1}$ (53%) and fruits plant^{-1} (71%) indicated the possible involvement of disturbed carbohydrate supply and carbohydrate transport pathway, especially in specific organs and /or at specific development stages (Sato *et al.*, 2000), reduced allocation of assimilates under high temperature stress compared with normal temperature condition (Aloni *et al.*, 1991) and reduced supply of photosynthates and poor production of growth regulators in sink tissues (Kinet and Peet, 1997). The reduction of photosynthesis and translocation was more pronounced in a heat sensitive cultivar than in a heat resistant cultivar (Stevens and Rudich 1978). Fruit set under high temperature condition emerged as a specific character and it did not depend on how many flowers were produced in the plant. However, pollen viability and pollen germination seemed to be one of the most sensitive physiological processes to such stress as recorded earlier (Peet *et al.*, 1998; Sato *et al.*, 2002).

Table 1: Expression of different floral and fruit characters under high and normal temperature condition

Characters	Flower trusses plant $^{-1}$		Flowers truss $^{-1}$		Fruit-sets truss $^{-1}$		Fruits plant $^{-1}$		Style length (mm)	
	A-W	S-S	A-W	S-S	A-W	S-S	A-W	S-S	A-W	S-S
High temperature tolerant lines										
CLN 2413R	39.60	25.97	6.53	5.77	5.27	3.93	36.00	19.07	7.77	7.60
CLN 2116B	31.13	22.80	4.97	4.73	4.37	3.87	38.77	20.43	7.13	7.07
High temperature susceptible lines										
Ratan	30.00	21.63	4.87	3.20	3.53	0.00	29.30	0.00	7.33	7.80
Patharkuchi	42.43	25.77	5.83	4.23	4.47	0.00	39.93	0.00	7.17	8.13

Characters	Fruit weight (g)		Yield plant $^{-1}$ (kg)		Pollen viability (%)		Pollen germination (%)	
	A-W	S-S	A-W	S-S	A-W	S-S	A-W	S-S
High temperature tolerant lines								
CLN 2413R	65.50	36.77	2.41	0.67	92.20	59.23	75.53	22.80
CLN 2116B	43.27	26.00	1.65	0.48	96.07	53.30	82.40	28.50
High temperature susceptible lines								
Ratan	59.03	--	1.66	0.00	85.46	33.56	65.87	0.00
Patharkuchi	51.30	--	1.17	0.00	85.56	25.63	62.33	0.00

*Note: * A-W = Autumn-Winter, S-S = Spring-Summer*

Association of different characters in high temperature condition

Considering different correlations and path coefficient analyses carried out with the data for growth and reproductive characters manifested under high temperature condition (Table 2 and 3), the characters emerged as the most important selection indices for fruit-set and fruit yield in high temperature condition of spring-summer season were 1. flower trusses plant^{-1}, 2. flowers truss^{-1}, 3. pollen viability percentage, 4. pollen germination percentage, 5. fruit set truss^{-1}, 6. fruits plant^{-1} and 7. fruit weight. Lin *et al.* (2006) found significant and positive correlations between yield and fruit weight, fruit number, seed number, flower etc. in tomato. Different set of characters identified previously for high temperature condition *viz.*, fruits plant $^{-1}$, fruits cluster $^{-1}$, percent fruit set and pollen viability (Dhankar *et al.*, 2001), fruit weight and seed number/fruit (Hanna and Hernandez, 1980), pollen germination and pollen tube length and release of number of pollen grains (Sato *et al.*, 2000) agreed well to the present findings.

Table 2: Prominent phenotypic correlations among the characters of 38 genotypes under high temperature condition

Character pairs	Correlation coefficient (r)
Flower trusses plant^{-1} and style length	-0.452*
Flower trusses plant^{-1} and fruits/plant	0.475*
Flowers truss $^{-1}$ fruit-set truss $^{-1}$	0.712**
Flowers truss $^{-1}$ and pollen viability	0.447*
Fruit-sets truss $^{-1}$and pollen viability	0.559**
Fruit-sets truss $^{-1}$and pollen germination	0.454*
Fruit-sets truss $^{-1}$and fruits plant $^{-1}$	0.424*
Pollen viability and pollen germination	0.610**
Pollen viability and fruits plant $^{-1}$	0.413*
Pollen germination and fruits plant $^{-1}$	0.541**
Fruits plant^{-1} and fruit weight	-0.543**
Fruit weight and yield plant $^{-1}$	0.645**

*Note: *,** Significant at 5% and 1% level of probability, respectively*

Table 3: Characters showing high and positive direct effect on yield and fruit- sets/truss in spring-ummer season

Dependent character	Characters	Effect
Fruit yield plant $^{-1}$	Average fruit weight	1.017
	Number of fruits plant^{-1}	0.603
	Pollen germination	0.258
Fruit sets truss $^{-1}$	Number of flowers truss^{-1}	0.612
	Pollen viability	0.185
	Pollen germination	0.146

REFERENCES

Abdalla, A.A. and Verkerk, K. 1968. Growth, flowering and fruit-set of the tomato at high temperature, *Netherland J. Agric. Sci.,* **16**: 71-76.

Aloni, B., Pashkar, T. and Karni, L. 1991. Partitioning of 14C sucrose and acid invertase activity in reproductive organs of pepper plants in relation to their abscission under heat stress. *Ann. Bot.,* **67**: 371-77.

Arora, S. K. 1977. Studies on the production problem of tomatoes (*Lycopersicon esculentum* Mill.) during summer season. *Ph. D. Thesis*, Haryana Agricultural. University. Hisar. India, pp.143.

Charles, W. B. and Harris, R.E. 1972. Tomato fruit set at high and low temperature. ***Canadian** J. Plant Pl. Sci.,* **52**: 497.

Dhankar, S. K., Dhankhar, B. S. and Sharma, N. K. 2001. Correlation and path analysis in tomato under normal and high temperature conditions. *Haryana J. Hort. Sci.*, **30**: 89-92.

El-Ahmadi, A. B. and Stevens, M. A. 1979. Genetics of high temperature fruit set in the tomato. *J. American. Soc. Hort. Sci.,* **104**: 691-96.

Hanna, H.Y. and Hernandez, T. P. 1980. Response of six tomato genotypes under summer and spring weather conditions in Louisiana. *Hort. Sci.,* **17**: 75-59.

Kinet, J. M. and Peet, M. M. 1997. Tomato. *In: The Phisiology of Vegetable crops Crops* (edEd. H.C. Wein, H. C.), Commonwealth Agricultural Bureau (CAB) International, Wallingford, U.K., pp. 207-58.

Levy, A., Rabinowitch, H. D., and Kedar, M. 1978. Morphological and physiological characters affecting flower drop and furit set of tomatoes at high temperature. *Euphytica,* **27**: 211-18.

Lin, K.H., Lo, H.F., Yeh, W.L. and Chen, J.T. 2006. Identification of quantitative trait loci associated with yield of tomato under heat stress, *Acta Hort.*, **760**: 269-76.

Muthuvel, I., Thamburaj, S., Veeraragavathatham, D. and Kanthaswamy,V . 2000. Performance of tomato genotypes under normal season and high temperature simulated glass house condition. *South Indian Hort.*, **48:** 96-99.

Palta, J.P., Chen. H.H., and Li, P.H. 1979. Relationship between heat and frost resistance of several *Solanum* species, *Pl. Physiol.,* **63**: 102.

Peet, M. M., Sato, S. and Gardner, R.G. 1998. Comparing heat stress effects on male-fertile and male-sterile tomatoes. *Plant Pl. Cell Env.*, **21:** 225-31.

Rick, C. M. and Dempsey, W. H. 1969. Position of the stigma in relation to fruit setting of the tomato. *Bot. Gaz.,* **130**: 180-86.

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

Sato, S., Peet, M. M. and Thomas, J. F. 2000. Physiological factors limit fruit set of tomato under chronic mild heat stress. *Plant Pl. Cell Env.,* **23**: 719-26.

Sato, S., Peet, M.M. and Thomas, J. F. 2002. Determining critical pre- and post-anthesis periods and physiological process in *Lycopersicon esculentum* Mill. Exposed to moderately elevated temperatures. *J. Exp. Bot.*, **53**:1187-95.

Stevens, M. A. and Rudich, J. 1978. Genetic potential for overcoming physiological limitations on adaptability, yield, and quality in tomato. *Hort. Sci.*, **13**: 673-78.