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Screening of tomato genotypes underhigh temperature stress for reproductive traits

Umesh Singh, Pradeep Kumar Patel, Amit Kumar Singh, Vivek Tiwari, Rajesh Kumar, N Rai, Anant Bahadur, Shailesh K Tiwari, Major Singh and B Singh

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Abstract

Twenty-one tomato lines were evaluated under summer season in the field condition, the average day and night temperature were 38.4 and 19.7°C, respectively. Several floral and fruit traits were adversely affected due to chronic high temperature stress which clearly indicated specific physiological processes of flower development were especially sensitive to high temperature stress. Flower drop are highly associated with styler exertion rate percentage. A significant increase in flower drop (19.30% to 74.36%), styler exertion (20.37% to 83.72%) and significantly decrease in pollen viability (14.78-74.55%) and fruit set truss^{-1} (15.45 to 75.37) were noted among the genotypes. On the basis of initial screening with respect to fruit set at high temperature stress, three lines i.e. CLN-2026, EC-538439 and EC-538148 emerged as high temperature tolerant genotypes. These lines, along with highly susceptible varieties *i.e.* Arka vikas, were critically observed for the stress tolerance traits. Most of the genotypes showed stigma exertion or tip burn under high temperature condition. Fruit number and fruit weight were the important yield components, which were severely affected under high temperature stress and ultimately yield was markedly reduced. Yield potential of the genotypes which was dependent on fruit set and fruit weight severely reduced under high temperature stress and yield varied from 386 g plant^{-1} (EC-538380) to 1832 g plant^{-1} (CLN-2026) in summer. On the basis of initial selection, it was concluded that the traits like fruit setting, pollen and yield attributes traits could be used in selection of high temperature tolerant genotypes for better fruit setting and tomato genotypes, *i.e.* CLN-2026 can be used as a source of high temperature tolerance genes for further breeding programs.

Keywords: High temperature, floral traits, screening, yield attributes traits, pollen traits, stigma exertion

Division of Crop Improvement, ICAR-Indian Institute of Vegetable Research, PB- 01, PO- Jakhini (Shahanshahpur), Varanasi- 221305 (U.P.) India

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable crop all over the world. Lack of tolerance to high temperature in most tomato genotypes presents a major limitation for growing an economic crop in regions where the temperature reaches above 38°C or higher in growing season. High day and night temperature are known to cause drastic reductions in tomato flowering and fruit set and in fruit size and quality (Singh *et al*., 2014). Flowering phases most sensitive to high temperature (38°C for 3 to 4 h) were during meiosis and fertilization (Iwahori, 1965). Failure of fertilization after exposure to heat mainly could be attributed to decreases in pollen germination and pollen tube elongation. Wide genotypic variation among cultivars has been observed in the effect of high temperature on pollen and ovule production and viability, pollen dehiscence, pollination effectiveness, style, splitting of the antheridial cone and stigma exsertion (Levy *et al*., 1978).

Objective of these study was to evaluate putative high temperature-tolerant tomato genotypes for their response to high-temperature field conditions, to select the best high temperature-set lines as genetic sources for incorporation in a breeding program.

Materials and Methods

Twenty one tomato genotypes were used to evaluate their performance under high temperature stress condition. The tomato lines were naturally grown in the field condition. The average day/night mean temperature in summer seasons were 38.4/19.7°C, respectively. Seeds were sown on nursery bed in first week of January, 2013 and seedlings were transplanted in the third week of February, 2013 in Research Farm, Indian institute of Vegetable Research, Varanasi.

The experiment was laid out in Completely Randomized Block Design with three replications. Ten plants of each genotype were evaluated of high temperature stress

tolerance. All cultural practices were performed to raise a good crop. The observations were recorded on the different flower, fruit, plant and yield traits. Flower drop was expressed in percentage by counting the total number of drop flowers as well as total number of flower cluster^{-1}. Fruit set was also expressed in percentage by counting the total number of flowers as well as total number of fruits plant^{-1}.The exertion rate per cluster was computed by the following formula-

$$\text{Styler exertion rate}(\%) = \frac{\text{No. of exerted style per cluster}}{\text{No. of total flower per cluster}} \times 100$$

Percentageof pollen viability was tested a day before anthesis at day/night temperature 38.4/19.7°C and there was no rain, cloudy weather or storm during the sampling (Figure 1). Flower buds were collected from 10 plants per genotype by removing pollens from the anthers using a needle. The pollen grains were touching on glass slide for determining the number of viable pollen grains through triphenyltetrazolium chloride (TTC) test as per Eti (1991). A Graph was constructed using SystatSigmaPlot v11.

Results and Discussion

Floral and phenology traits

The experiment was conducted with twenty one tomato genotypes, which were evaluated under high temperature conditions. 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. In general, flower characters were strongly associated with fruit characters and yield. At the high temperature regime significant increase in the flower drop and styler exertion rate percentage was observed in all genotypes, which varied from 19.30% (CLN-2026) to 74.36% (D-5-2) in flower drop whereas, 20.37% (CLN-2026) to 83.72% (D-5-2) in styler exertion rate (Figure 2).

Results of the experiment clearly indicated that fruit setting ability in the genotypes was reduced drastically in high temperature condition and genotypes responded differently showing their relative tolerance or susceptibility to high temperature stress. Fruit setting percentage was markedly varied from 15.45 (Arkavikas) to 75.37 (CLN-2026).

Genotypes like Arka vikas, EC-381263 and EC-177371 showed less than 25% fruit set at all under high temperature stress condition.The day/night temperature of more than 38.4°C and 19.7°C are known to limit fruit-set of tomato due to impairment of complex physiological process involved during flowering and fruit developmental stages (Muhammed *et al*., 2015). Data presented in Table1 clearly showed that most of the genotypes showed stigma exertion or tip burn under high temperature condition. 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 traits

Pollen viability were drastically reduced under high temperature condition of summer season and varied greatly among the genotypes (Figure 3). Viability of the pollens of the genotype CLN-2026 showed maximum viability (74.55%) and a minimum of 14.78% viability was recorded in EC-381263 in summer seasons. Pollen viability is drastically reduced due to desiccation in high temperature (Abdalla and Verkerk, 1968). In the present investigation pollen viability emerged as one of the major

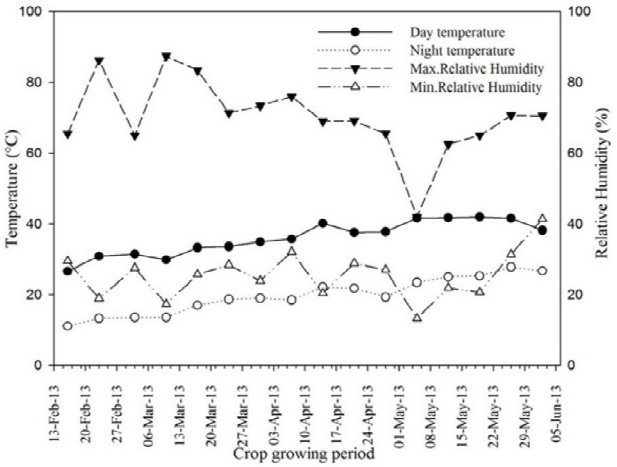

Figure 1. Average temperature (Day and night) and relative humidity during crop seasons, 2013 (February to June)

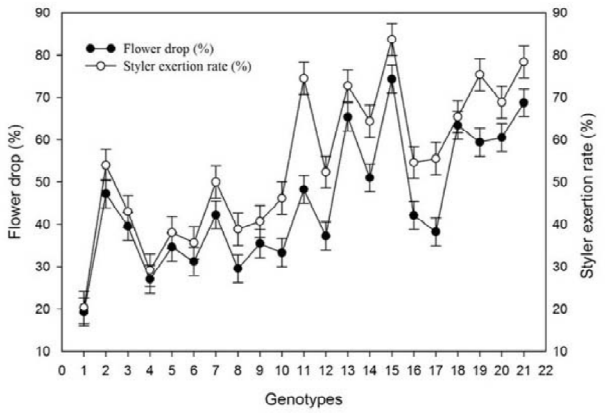

Figure 2. Flower drop and styler exertion rate percentage of 21tomato genotypes under high temperature stress

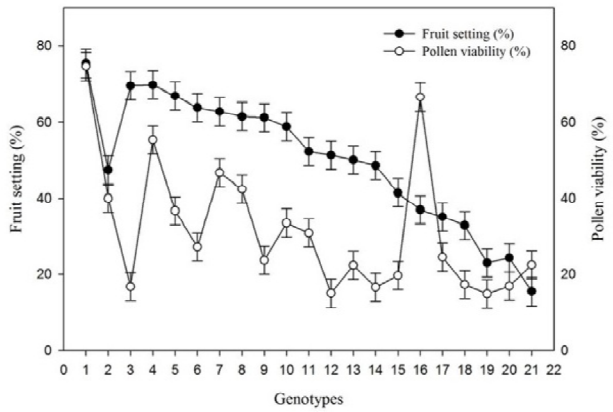

Figure 3. Fruit setting and pollen viability percentage of 21 tomato genotypes under high temperature stress

limiting factors for fruit set under chronic high temperature stress. However, pollen release may be abetter factor for determining response to high temperatures since failure of pollen release will prevent fruit set regardless of the viability of pollen grains (Figure 1, 2 and 3).

Yield related traits

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). Fruit number^{-1} drastically varied from 10.67(H-88-78-4) to 109.00 (EC-538380). In summer season, as high as eight genotypes had showed less than 20 fruits in the plant in the advanced growth stage *i.e.* fruit retention stage. In other seven genotypes fruit drop occurred with the advancement of age which mighthave been due to enhancement of pedicels abscission. Marked reduction of fruit weight was also observed under summer. Fruit weight was drastically varied from 4.7 (EC-538380) to 55.1 (EC-538148). Yield potential of the genotypes which was dependent on fruit set and fruit weight severely reduced under high temperature stress and yield varied from 386 g plant^{-1}(EC-538380) to 1832 g plant^{-1}(CLN-2026) in summer.

Marked reduction in plant height, fruit setting (%), styler exertion rate (%), pollen viability (%), number of branches plant^{-1}, fruit length and width, number of fruit plant^{-1}and weight 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*., 2006), reduced allocation of assimilates under high temperature stress compared with normal temperature condition (Singh *et al*., 2005) and reduced supply of photosynthates and poor production of growth regulators in sink tissues. Fruit setting percentage under high temperature condition emerged as a specific character and it did not depend on how many flowers were produced in the plant (Table 1). However, pollen viability and pollen germination seemed to be one of the most sensitive physiological processes to such stress as recorded earlier (Patel *et al*., 2014 and Singh *et al*., 2014).

Table 1. Performance of tomato genotypes at high temperature

Genotypes	Plant height (cm)	No. of branches	Fruit width (mm)	Fruit Length (mm)	No. of fruit/plant	Average fruit weight	Yield/plant (g)	Stigma exertion
CLN-2026	87.3	7	3.58	3.88	89.67	31.7	1832.0	N
EC-538380	96.8	13	1.04	1.05	109.00	4.7	386.0	Y
EC-538148	91.4	8	2.79	3.04	38.67	55.1	1382.4	Y
EC-538439	57.8	5	4.68	3.81	27.67	45.3	980.7	N
EC-620521	86.2	7	2.27	3.41	24.67	36.7	837.3	Y
D-1-1	52.3	8	3.95	3.70	26.33	30.0	980.0	N
EC-620518	87.8	11	4.33	3.67	21.67	29.0	805.0	Y, TP
EC-363948	86.7	6	3.19	2.82	26.67	28.0	754.7	Y
EC-620402	61.8	9	4.35	4.02	21.00	26.3	726.0	Y
EC-520053	66.7	6	2.63	2.80	20.00	35.3	719.3	Y, TP
EC-620403	62.8	9	3.73	3.67	12.33	51.7	671.3	Y
EC-620406	60.0	5	5.32	3.87	14.67	44.7	664.7	P
EC-318801	62.3	4	3.35	2.45	20.00	33.3	658.7	Y
EC-620513	91.8	8	4.10	4.18	13.67	44.0	601.3	y
D-5-2	74.8	5	3.15	3.08	15.67	28.0	594.0	Y
H-88-78-4	58.8	7	3.59	3.16	10.67	45.0	586.7	Y, TP
EC-620598	82.7	5	4.53	4.53	18.00	29.3	586.7	Y
EC-620571	80.4	6	2.96	2.56	14.67	30.0	586.7	Y, TP
EC-381263	83.1	4	3.01	2.44	26.00	20.3	546.7	Y
EC-177371	112.4	10	2.87	2.94	46.67	9.3	540.0	Y, TP
ArkaVikas	66.5	8	2.65	3.43	18.67	29.7	536.7	Y
C.V.	20.66	32.50	27.97	23.72	85.08	37.96	42.57	-
C.D. 5%	11.01	1.62	0.67	0.54	17.34	8.62	224.90	-

On the basis of initial selection, it was concluded that the traits like fruit setting, pollen and yield attributes traits could be used in selection of high temperature tolerant genotypes for better fruit setting and tomato genotypes, i.e. CLN-2026 can be used as a source of high temperature tolerance genes for further breeding programs.

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सारांश

टमाटर की 21 पंक्तियों का प्रक्षेत्र मूल्यांकन ग्रीष्म काल में किया गया जब दिन व रात्रि का औसत तापमान 38.4 तथा 19.7 डिग्री सेन्टीग्रेड, क्रमशः था। अनेको पुष्पीय तथा फल सम्बन्धित गुण विपरीत रूप से क्रान्तिक उच्च तापमान के कारण प्रभावित हुए। इससे संकेत मिलता है कि पुष्प विकास की विशिष्ट कार्यकी प्रक्रिया विशेष रूप से उच्च तापमान प्रतिबल के प्रति संवेदनशील है। वर्तिका के बाहर निकलने का प्रतिशत पुष्प झड़ने से ज्यादा सम्बन्धित है। ज्यादा पुष्प झड़ना (19.30 से 74.36 प्रतिशत), वर्तिका का बाहर निकलना (14.78 से 74.55 प्रतिशत) तथा प्रति गुच्छ फल धारण (15.45 से 75.37) को प्रभेदों में अंकित किया गया। उच्च तापमान प्रतिबल पर फल धारण करने के प्रारम्भिक छंटनी से तीन प्रभेदों सी एल एन – 2026, ई सी – 538439 तथा ई सी – 538148 को उच्च तापमान सहनशील पाया गया। इन पंक्तियों के साथ उच्च तापमान संवेदनशील प्रजातियों जैसे– अर्का विकास को प्रतिबल सहनशील गुण की गम्भीरता से देखा गया। लगभग सभी प्रभेदों में वर्तीका का बाहर आना अथवा अग्र भाग का उच्च तापमान में झुलस जाना सामान्य रूप से पाया गया। फल संख्या एवं फल भार सबसे महत्वपूर्ण घटक हैं जो अधिक तापमान प्रतिबल से प्रभावित होते है और परिणामतः उपज में भारी कमी हो जाती है। प्रजाति की उपज क्षमता जो फल धारण तथा फल भार पर आधारित है, जो उच्च तापमान प्रतिबल पर अधिक घट जाती है और ग्रीष्म काल में उपज 386 ग्राम/पौध (ई सी – 538380) से 1832 ग्राम/पौध (सी एल एन – 2026) पायी गई। प्रारम्भिक चयन में यह निष्कर्ष निकला कि जैसे– फल धारण, परागकण व उपज घटक के द्वारा उच्च तापमान प्रतिबल के प्रति सहनशील प्रभेदों का चयन किया जाना चाहिए। टमाटर की प्रजाति सी एल एन – 2026 को उच्च तापमान सहिष्णु प्रभेद के प्रजनन में शामिल किया जाना चाहिए।

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