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Short Research Article

Evaluation of Hot Pepper (*Capsicum annuum* L.) Genotypes for Heat Tolerance during Reproductive Phase

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Abstract

Eleven hot pepper genotypes (viz., Sel-11, PLS-1, Sel-Dev, DCL-524, Punjab Surkh, VR-16, Pepsi-17-2, MS-12, S-217621, PBC-535 and Faslima) were evaluated for heat tolerance during summer 2011 to identify the most appropriate genotypes under agro-climatic conditions of Punjab. High temperature (40/24 °C, day/night) decreased fruit set in all the test genotypes with overall mean of 18.2% against 65.0% fruit set at optimum temperature (34/16 °C, day/night). High temperature also caused significant reduction in pollen viability, seed number fruit^{-1}, fruit length and fruit diameter. Heat susceptibility index (HSI) was used to measure heat stress tolerance of hot pepper germplasm for identifying genotypes exhibiting least reduction in fruit set percentage, pollen viability, seed number fruit^{-1}, fruit length and fruit diameter due to high temperature. On the basis of HSI for fruit set, only one genotype Pepsi-17-2 was classified as highly heat tolerant (HSI<0.5). Four genotypes namely DCL- 524, VR-16, MS-12 and S-217621 were classified as moderately heat tolerant, showing HSI between 0.5 and 1.0. These five genotypes viz., Pepsi-17-2, DCL524, VR-16, MS-12 and S-217621 are most promising to initiate hybrid breeding program for the development of heat tolerant cultivars of chilli as maintenance of fruit set under high temperature is the most desirable character.

1. Introduction

Pepper (*Capsicum annuum* L.) is an important vegetable crop grown in India, both for fresh market and processing industry. Hot pepper requires comparatively a longer growing season of 130-150 days and fruit setting is drastically reduced if dry weather is accompanied by high temperature (Erickson and Markhart, 2002). High temperature stress is one of the major limiting factors for pepper production. The optimum day temperature for growth and productivity of pepper plants has been found to be 20-30 °C and yields are significantly decreased when temperature rises above 30 °C (Berke et al., 2005). High temperature affects several physiological and biochemical processes of the plant leading to impaired growth and reproduction; shorten life cycle by hastening flowering and maturity, reduced yield and production of poor quality fruits (Long and Ort, 2010). High temperature induced decrease in crop yield has been closely linked to damaged thylakoid membranes, decreased chlorophyll content and increased membrane leakage (Prasad et al., 2008; Ristic et al., 2007). Cell membrane thermostability has been found to be a useful physiological parameter for selection of heat tolerant genotypes in *C. annuum* and *C. fructescence* (Usman et al., 2014). Another common-method of selecting plants for abiotic stress tolerance is to identify selection criteria during early stages of plant development, which may be correlated with tolerance during reproductive stages. Unfortunately, heat stress tolerance is a developmentally regulated, stage specific phenomenon and tolerance at one stage of plant development may not be correlated with tolerance at other developmental stages (Wahid et al., 2007). Thus, present study was undertaken to evaluate hot pepper germplasm for high temperature stress tolerance during reproductive phase to identify heat tolerant genotypes that can be utilized in hybrid breeding programmes.

2. Materials and Methods

A field evaluation of eleven hot pepper genotypes viz., Sel-11, PLS-1, Sel-Dev, DCL-524, Punjab Surkh, VR-16, Pepsi-17-2, MS-12 , S-217621, PBC-535 and Faslima was conducted for heat tolerance, keeping Royal Wonder genotype of sweet pepper as a sensitive check. The experiment was conducted at the Research Farm of the Department of Vegetable Science, Punjab Agricultural University, Ludhiana in a randomized complete block design with three replications during summer 2011. The recommended package of practices was followed to raise the crop (Anonymous, 2011). Data were recorded from ten randomly selected representative plants. Fruit set (%), pollen viability, seed set, fruit length (cm) and fruit diameter (mm) were recorded from April to August (data not presented). Maximum and minimum fruit set percentage of all the test genotypes was observed during first week of April (optimum temperature regime-34/16 °C day/night) and second week of June (high temperature regime - 40/24 °C day/night), respectively. Fruit set percentage of each genotype was assessed by tagging twenty flowers and it was computed by using the following formula:

$$\text{Fruit set \%} = \frac{\text{Number of set fruits}}{\text{total no. of flowers tagged}} \times 100$$

Pollen viability was observed by staining pollen grains with 2% acetocarmine stain. Viable pollen grains stained pink to bold red and non-viable pollen appeared colorless under the microscope. The percentage of pollen viability was calculated by using the following formula:

$$\text{Pollen viability \%} = \frac{\text{Number of viable pollen grains}}{\text{total number of pollen grains}} \times 100$$

Fruits were carefully dissected to calculate seed number fruit^{-1}. Fruit length and diameter were recorded from the randomly selected green mature fruits using centimeter scale and vernier caliper, respectively.

Heat susceptibility indices were calculated for fruit set, pollen viability, seed number fruit^{-1}, fruit length and diameter as described by Fischer and Maurer (1978). Heat susceptibility index for fruit set percentage was calculated by using the following formula:

$$\text{HSI}=(1-Y/Yp)\ D^{-1}$$

Where, Y=percentage fruit set of a genotype at high temperature (40/24 °C, day/night), Yp=percentage fruit set of same genotype at optimum temperature (34/16 °C, day/night)

D (stress intensity)=(1-X/Xp)

Where, X= mean Y of all genotypes and Xp=mean Yp of all genotypes. Similarly HSI for other parameters was calculated. Critical difference values were calculated by doing analysis of variance (ANOVA) as described by Singh et al., 1991).

3. Results and Discussion

At optimum temperature (OT) regime of 34/16 °C (day/night), fruit set percent among hot pepper genotypes varied from 26 to 86% with overall mean of 65.0% as compared to 23.3% fruit set in Royal Wonder (Table 1). Maximum fruit set percentage at OT was observed for the genotype S-217621 and it was statistically at par with genotypes DCL-524, PLS-1 and VR-16. High temperature (HT) regime (40/24 °C, day/night) decreased fruit set in all the tested genotypes with overall mean of 18.2% against 4.8% fruit set in Royal Wonder. At HT regime, highest fruit setting was observed in Pepsi-17-2 (46.0%) followed by the genotype S-217621 (36.4%). Notably no fruit set was observed at HT in genotypes PBC-535 and Faslima. Inability to produce adequate amounts of viable pollen has been associated with decreased fruit set and fewer seed number fruit^{-1} in maize and *Capsicum* spp. when high temperature coincided with flowering (Schoper et al., 1987 and Reddy and Kakani, 2007). Pollen viability of Royal Wonder (sensitive check) decreased from 100% at OT to 30% at HT. Pollen viability of hot pepper genotypes varied from 80-100% at OT (Table 1). Even at HT all hot pepper genotypes maintained pollen viability equal to or more than 60%. This indicated that impairments in other processes like pollen germination or fertilization but not pollen viability may be responsible for reduced fruit set at high temperature in hot pepper. High temperature not only reduced the fruit setting but also deteriorated fruit quality in terms of reduction in seed number per fruit, fruit length and fruit diameter (Table 2). Seed number fruit^{-1} ranged from 16.8 (Faslima) to 69.7 (MS-12) with average seed number fruit^{-1} of 49.4 at OT regime. However at HT regime, seed number fruit^{-1} ranged from 11.7 (Pepsi-17-2) to 50.0 (Sel Dev) with

Table 1: Effect of temperature on fruit set and pollen viability of different hot pepper genotypes. (OT-34/16 °C day/night, HT-40/24 °C day/night)

Genotype	Fruit set (%)			Pollen viability (%)		
	OT	HT	HSI	OT	HT	HSI
Sel-11	72.6	18.9	1.03	80	80	0
PLS-1	81.9	12.0	1.18	100	80	1.11
Sel. Dev	51.9	7.8	1.18	100	80	1.11
DCL-524	83.1	25.2	0.97	90	80	0.61
Punjab Surkh	67.6	4.7	1.29	80	60	1.39
VR-16	80.0	24.4	0.96	80	70	0.67
Pepsi-17-2	53.3	46.0	0.18	80	80	0
PBC-535	34.4	0	1.39	90	70	1.22
MS-12	77.9	25.0	0.94	90	85	0.33
S-217621	86.0	36.4	0.8	90	80	0.61
Faslima	26.0	0	1.39	80	70	0.67
Royal Wonder	23.3	4.8	1.10	100	30	3.89
SEm±	6.7	4.8	-	2.3	1.9	-
CD (p=0.05)	9.6	6.4	-	21.5	12.3	-

average seed number fruit^{-1} of 25.5. Maximum reduction in seed number fruit^{-1} was observed in PLS-1 (60.8%) followed by the genotype Sel.11 (54.3%). Minimum reduction in seed set was observed in Sel-Dev (7.4%) followed by genotypes DCL-524 (29.3%) and it was statistically at par with Punjab Surkh (30.1%). Seed number fruit^{-1} in Royal Wonder was 8.0 and 2.0 at OT and HT, respectively. High seed set during heat stress in tomato has been reported to be an important indicator of heat stress tolerance as the production of viable seed is often reduced under heat stress (Berry and Rafique-Uddin, 1988). The genotype Faslima recorded longest and widest fruits at OT (Table 2). Royal Wonder exhibited 25.5 and 22.4% reduction in length and width of fruits, respectively, at HT. The genotype Sel-11 exhibited maximum reduction in fruit size both in terms of length (29.1%) and width (34.3%) of fruits while no significant reduction in fruit size was observed in the genotype S-217621. Maintenance of higher grain number ear^{-1}, grain weight main shoot^{-1} and 1000 grain weight are considered important criteria for selection of heat tolerant genotypes in wheat also (Tahir et al., 2006).

Table 2: Effect of temperature on fruit quality of different hot pepper genotypes. (OT-34/16 °C day/night, HT-40/24 °C day/night)

Genotype	Seed No. fruit^{-1}			Fruit length (cm)			Fruit width (mm)		
	OT	HT	HSI	OT	HT	HSI	OT	HT	HSI
Sel-11	52.5	24.0	1.10	6.35	4.5	0.97	11.10	7.29	1.10
PLS-1	51.0	20.0	1.24	9.70	8.8	0.3	13.96	12.69	0.29
Sel. Dev	54.0	50.0	0.14	7.90	7.4	0.2	14.31	13.19	0.26
DCL-524	57.3	40.5	0.59	5.60	4.9	0.4	11.95	10.72	0.32
Punjab Surkh	57.2	40.0	0.61	4.69	4.2	0.33	11.76	10.37	0.39
VR-16	27.7	15.5	0.90	5.72	5.11	0.37	10.45	7.71	0.84
Pepsi-17-2	20.7	11.7	0.88	6.60	5.7	0.47	16.83	13.65	0.61
PBC-535	69.0	-	2.04	5.80	-	3.33	10.43	-	3.23
MS-12	69.7	39.0	0.90	3.20	2.95	0.27	13.41	10.6	0.68
S-217621	67.8	40.0	0.84	7.16	7.13	0	13.11	12.99	0
Faslima	16.8	-	2.04	10.50	-	3.33	22.19	-	3.23
Royal Wonder	8.0	2.0	1.53	4.7	3.5	0.87	49.56	38.44	0.71
SEm±	7.2	3.4	-	0.7	0.9	-	1.2	0.8	-
CD (p=0.05)	12.7	9.8	-	2.4	1.9	-	8.6	6.9	-

Heat susceptibility index (HSI) was used to measure heat stress tolerance of hot pepper germplasm for identifying genotypes exhibiting minimum reduction in fruit set percentage, pollen viability, seed number fruit^{-1}, fruit length and fruit diameter due to high temperature. On the basis of HSI for fruit set, only one genotype Pepsi-17-2 was classified as highly heat tolerant (HSI<0.5). Four genotypes namely DCL-524, VR-16, MS-12 and S-217621 were classified as moderately heat tolerant, showing HSI between 0.5 and 1.0. All other genotypes had HSI>1.0 and were classified as heat sensitive. Apparently, five genotypes viz., Pepsi-17-2, DCL-524, VR-16, MS-12 and S-217621 are most promising to initiate hybrid breeding program for the development of heat tolerant cultivars of chilli due to maintenance of better fruit set even under high temperature (HSI<1.0). For pollen viability, genotypes Pepsi-17-2 and MS-12 were classified as highly heat tolerant having HSI 0 and 0.33, respectively and other three genotypes (DCL-524, VR-16 and S-217621) were moderately heat tolerant having HSI>0.5 to <1.0. However, all of these five genotypes were classified as moderately heat tolerant for seed number fruit^{-1} and highly heat tolerant for fruit length. Two genotypes DCL- 524 and S- 217621 were highly heat tolerant for fruit diameter and exhibited HSI values equal to 0.32 and 0, respectively and other three genotypes (Pepsi-17-2, VR-16 and MS-12) were classified as moderately heat tolerant having HSI>0.5 to <1.0 (Table 1 and 2). (Pradhan et al., 2012) identified heat tolerant accessions belonging to *Aegilops* spp. based on HSI for grain yield. On the basis of cumulative temperature response index (CTRI), twelve cultivars of ornamental pepper were classified into heat-sensitive, intermediate and heat-tolerant (Gajanayake et al., 2011). Due to global warming, high temperature is going to be major constraint to commercial production of vegetable peppers in the future emphasizing the urgent need to develop cultivars with higher heat tolerance (Jifon et al., 2004).

4. Conclusion

Among the eleven genotypes screened for heat tolerance, only five genotypes namely Pepsi-17-2, DCL- 524, VR-16, MS-12 and S-217621 were identified as highly heat tolerant having HSI<1.0 for fruit set and are most promising to initiate hybrid breeding program for the development of heat tolerant cultivars of chilli.

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