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HEAT TOLERANCE IN INDIAN MUSTARD AT SEEDLING AND TERMINAL STAGE

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ABSTRACT

A set of 22 Indian mustard genotypes from different agro climatic conditions were grown in randomized block design with three replications in two environments viz. timely (3rd week of October) and late sown (3rd week of November)during 2005-06 and 2006-07 at Punjab Agricultural University ,Ludhiana. Significant genotypic differences existed for all the characters and environment had a profound impact on morphological traits investigated. Genotypes SKM-9927, NDRS-2001 and NRCDR-2 showed < 30% seedling mortality and were rated as tolerant. Reduction in seed yield (≤ 30%)were recorded in SKM-0149,Varuna,NPJ-92,PR-2002-8,RM-15 and RM101 .Furthermore, average heat susceptible index (HSI) was 0.155 and heat tolerance efficiency(HTE) was 92 % in the resistant genotypes. This study reveals that heat tolerance parameters may be used as screening trait and identified genotypes as suitable donor for crossing programmes to develop heat tolerant mustard genotypes.

Key words: Indian mustard, heat stress, mortality, seed yield, heat susceptible index.

INTRODUCTION

Temperature stress is one of the major limitations to the crop productivity. Identifying suitable screening indices and quantifiable traits would facilitate the crop improvement process for high temperature tolerance. Under the climate change scenario, identification of suitable genotypes and management practices is must to sustain the crop productivity. Various studies demonstrates that variability in temperature affects the grain and seed yield of annual crops (Semenov and Porter, 1995, Kumar *et al.*,2013). *Brassica juncea* is an important winter season oilseed crop of India. Rapeseed-mustard constitutes an important source of edible oil next to soybean and groundnut. This crop inter/mixed cropping with wheat is raised and is affected by high temperature stress during reproductive stages. Sowing of Indian mustard gets delayed to end October to mid November due to late harvesting of cotton also. Plant responses to heat stress depend on its developmental stage. Growth and development of late sown crop is more adversely affected by severe winter, foggy and frost conditions during vegetative stage and high temperature during pod and seed filling stages. Heat stress during the postanthesis/ seed filling negatively influences the movement of photosynthates to the developing sinks and inhibits the synthetic processes, thus causes lower seed weight, seed yield and may alter seed a quality High temperature in Brassica caused flower abortion with appreciable loss in seed yield (Rao *et al*, 1992). Effect of salicylic acid on growth and seed filling under high temperature stress has been reported in Indian mustard by Sharma *et al.*, (2013). Decline in physiological traits along with the seed yield has recently been reported in *B. juncea* by Sharma *et al* (2013).With the climatic vagaries there is ambient need of new varieties which could surpass the adverse effects of heat so that there should be minimum yield losses. There is good chance of finding promising source of heat tolerance in the available germplasm of Indian mustard. The present investigation was aimed at analyzing the genotypic responses in terms of seedling mortality and productivity to the effects of high temperature on seedling and terminal stage.

MATERIAL AND METHODS

Twenty two genotypes of *B. juncea* were screened during 2005-06 and 2006-07 for high temperature under laboratory and field conditions.

Laboratory experiment: Genotypes were grown in the plastic trays filled with 5 kg of soil, which was thoroughly mixed with known volume of water for germination .Seeds of twenty two genotypes were sown in rows with three replications for each genotype in a random order to avoid minor microclimatic variation inside the tray and the seed germinator. Seedlings were initially allowed to grow at $25^0C\pm1^0C$ for 5 days at 70 -80 % RH. Twenty seedlings per genotype per replicate were kept for recording the observations. Known volume of water was sprinkled on the 3rd day of germination. Five day old seedlings were exposed to $40^0C\pm1^0C$ at 30% RH for 4hrs daily with field capacity of 90-95%.The high temperature treatment was given up to 3 days. Experiments were repeated on two separate occasions and seedling mortality was recorded and expressed on percent basis.

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Field experiments: The same set of 22 genotypes were sown in the fields of Oilseeds Section ,Department of Plant Breeding and Genetics at Punjab Agricultural University Ludhiana at two dates of sowing 1st at optimum time (third week of October) and 2nd as late sown(third week of November)during 2005and 2006 to allow high temperature at terminal stage. Each genotype was sown in paired rows with three replications in random block design at two sowing dates. All the recommended agronomic package and protection measures were adopted for raising healthy crop. Yield and yield components were recorded at physiological maturity and data was anal- sized statistically by CPCS (2008) software. Heat susceptibility index (HSI) was calculated by the formula of Fischer and Maurer (1978) and heat tolerance efficiency (HTE) by the equation of Fischer and Wood (1981).

RESULTS AND DISCUSSION

Seedling mortality

Genotypes displayed a wide range of heat tolerance responses in the seedlings to high temperature suggesting wide genetic variability. Seedling succumbs to heat stress referred to as seedling mortality expressed on percent basis. Seedling mortality varied significantly within the genotypes (Table1). Seedling mortality was 18.3% in NDRS-2001 and 63.6% in RM-15.Genotypes SKM-9927, NDRS-2001 and NRCDR-2 had seedling mortality less than 30% and hence was rated as tolerant to heat stress. Six genotypes registered seedling mortality between 30-45% and were moderately tolerant while thirteen genotypes with seedling mortality >45% were categorized as susceptible.

Growth and yield attributes

Main shoot length (MSL) varied significantly with in the genotypes in two dates of sowing (Table1). Main shoot length ranged from 61.0 cm (RM-101) to 89.2 cm (SKM-0125) in timely and 52.0 cm (PCR-7) to 74.0cm (RH-0116) under late sown conditions. Minimum reduction in MSL was recorded in SKM-0125(0.8%) followed by RGN-81(3.6%) and RM-11(4.6%).Overall, decline in MSL was 12.6% over timely sown crop. Siliqua on main shoot (SMS) ranged from 30.2 (Varuna) to 51.0 (RGN-48) in timely sown and 24.2 (Varuna) to 39.2(RGN-81) in late sown crop. Overall reduction in mean SMS was 16.9% in delayed sowing and reduction was less than 5% in cultivars RH-0116, NPJ-93, PBR-97 and PCR-7. Siliqua intensity differed in the cultivars under the two dates of sowing. Siliqua intensity was

Table 1: Effect of terminal heat stress on seedling mortality (%) and growth parameters in *Brassica juncea* genotypes

Sl. No.	Genotypes	Seedling mortality (%)	Main shoot length(cm)			Siliqua on main shoot			Siliqua intensity		
			Timely	Late	% reduction	Timely	Late	% reduction	Timely	Late	% reduction
1	RGN-48	42.5	77.8	66.0	15.2	51	38.2	25.1	0.65	0.58	11.0
2	RGN81	32.2	70.6	68.0	3.7	46.1	39.2	15.0	0.65	0.58	11.7
3	SKM-9927	28	70.8	61.8	12.7	41.8	35.8	14.4	0.59	0.58	1.9
4	SKM-9928	38.4	72.2	53.6	25.8	42.8	31.4	26.6	0.59	0.58	1.2
5	Varuna	35.6	84.6	57.4	32.2	30.2	24.2	19.9	0.42	0.36	14.3
6	RH-0116	47.5	75.8	74.0	2.4	39.8	39.6	0.5	0.54	0.53	1.9
7	RK-02-03	49.1	65.0	64.0	1.5	35.8	31.6	11.7	0.55	0.49	10.4
8	SKM-0125	31.9	89.2	63.0	29.4	46.2	33.6	27.3	0.53	0.52	1.9
9	NPJ-93	51.5	71.0	70.4	0.8	37.8	36.8	2.6	0.53	0.52	1.8
10	SKM-0158	63.3	67.0	64.4	3.9	38.4	30.8	19.8	0.57	0.48	16.6
11	NPJ-92	46.6	64.8	60.0	7.4	40.8	36.4	10.8	0.63	0.61	3.6
12	NDRS-2001	18.3	68.2	64.0	6.2	33.8	30.0	11.2	0.50	0.47	5.4
13	SKM-0149	52.3	67.1	61.0	9.1	38.6	32.0	17.1	0.58	0.52	8.8
14	Kranti	49.2	78.4	64.2	18.1	49.8	36.8	26.1	0.64	0.57	9.8
15	NRCDR-2	19.4	70.8	57.6	18.6	45.0	29.8	33.8	0.64	0.52	18.6
16	PBR-92	49.7	78.4	73.0	6.9	41.0	36.6	10.7	0.52	0.50	4.1
17	PR-2002-8	30	65.6	57.8	11.9	48.2	32.6	32.4	0.73	0.56	23.2
18	PBR97	62.3	71.0	64.2	9.6	39.2	38.0	3.1	0.59	0.55	6.8
19	PCR-7	52.2	69.6	52.0	25.3	40.4	38.6	4.5	0.74	0.58	21.6
20	RM-11	47.5	76.8	73.2	4.7	48.2	35.2	27.0	0.63	0.48	23.4
21	RM-15	63.6	69.8	61.8	11.5	35.8	33.2	7.3	0.54	0.51	5.6
22	RM-101	45.8	61.0	54.8	10.2	39.4	35.4	10.2	0.65	0.65	0.0
MEAN			72.07	63.01		41.37	34.35		0.59	0.53	
CD(P=0.05)		1.57	10.2	3.8		5.1	1.7		0.11	0.15	

least affected by heat stress in genotypes SKM-9927, SKM-9928, RH-0116,SKM-0125 NPJ-93 and was comparable in RM-107 in both late and timely sown crop. Reduction in siliqua intensity was 10.6% in the late sown crop due to shorter reproductive phase. Siliqua length varied in timely sown crop from 4.5cm (NPJ-93) to 6.0 cm (RH-0116) and under late sown conditions from 3.5cm (SKM-0158) to 5.6 cm (RM-15).Minimum reduction in siliqua length (< 5%) was recorded in RGN-81,NPJ-92.PBR-92.PBR-97 and PCR-7.Seeds per siliqua declined significantly under late sown conditions(Table2). In timely sown crop maximum seeds/siliqua were registered in PBR-92 and PBR-97 (18.3) whereas PBR-97(14.1) followed by SKM-0158(13.9) under 2nd date of sowing. Seeds /siliqua were reduced to minimum in genotype PR-202-8 and overall decline was 16.6% under late sown conditions as the crop encountered terminal high temperature hindering availability of assimilates to developing sinks. 1000 seed weight did not vary in RGN-48, RK-02-03, and SKM-0126 cultivars at two sowing dates. Seed weight was 6.9g in Varuna and RK-02-03 and 6.7g in NDRS-2001.Minimum seed weight of 4.8g was recorded in RGN-81 under timely sown conditions. Under late sown crop highest seed weight of 6.9g was in cultivar RK-02-03 followed by 6.3g in SKM-0125 and minimum of 4.3g in SKM-0158, NPJ-92 and Kranti. Overall seed weight declined by 10.3% in delayed sowing. Significant genotypic variations were observed in seed yield at optimum date of sowing which declined significantly under late sown conditions.

Table 2: Influence of terminal heat stress on siliqua length, seeds/siliqua and seed weight in *Brassica juncea* genotypes

Sr. No.	Genotypes	Siliqua length(cm)			Seeds/siliqua			1000seed weight(g)		
		Timely	Late	%reduction	Timely	Late	%reduction	Timely	Late	%reduction
1	RGN-48	4.96	4.5	9.3	12.2	9.6	21.3	5.3	5.3	0.0
2	RGN81	5.5	5.3	3.6	12.8	10.8	15.6	4.8	4.6	4.2
3	SKM-9927	4.6	4.2	8.7	11.9	7.7	35.3	5.2	5.0	3.8
4	SKM-9928	5.5	4.1	25.5	11.6	11.1	4.3	5.6	5.5	1.8
5	Varuna	5.2	4.7	9.6	10.4	9.5	8.7	6.9	6.6	4.3
6	RH-0116	6.0	4.3	28.3	10.5	9.8	6.7	6.0	5.9	1.7
7	RK-02-03	5.2	3.7	28.8	11.8	10.6	10.2	6.9	6.9	0.0
8	SKM-0125	5.1	3.7	27.5	10.0	8.5	15.0	6.3	6.3	0.0
9	NPJ-93	4.5	3.9	13.3	11.0	9.0	18.2	6.6	4.8	27.3
10	SKM-0158	4.6	3.5	23.9	14.9	13.9	6.7	5.3	4.3	18.9
11	NPJ-92	5.6	5.5	1.8	16.5	12.5	24.2	5.6	4.3	23.2
12	NDRS-2001	5.6	4.2	25.0	12.5	11.5	8.0	6.7	5.1	23.9
13	SKM-0149	4.96	4.4	11.3	12.0	11.4	5.0	6.0	5.8	3.3
14	Kranti	4.7	4.4	6.4	14.6	9.0	38.4	4.9	4.3	12.2
15	NRCDR-2	5.1	4.2	17.6	13.8	12.7	8.0	5.1	4.9	3.9
16	PBR-92	5.0	4.9	2.0	18.3	12.1	33.9	5.5	4.7	14.5
17	PR-2002-8	5.2	4.6	11.5	12.2	12	1.6	6.0	5.8	3.3
18	PBR97	5.4	5.2	3.7	18.3	14.1	23.0	5.7	5.0	12.3
19	PCR-7	4.9	4.7	4.1	13.2	12.2	7.6	6.2	4.8	22.6
20	RM-11	4.9	3.7	24.5	16.6	12.1	27.1	5.5	5.0	9.1
21	RM-15	5.9	5.6	5.1	12.7	10.3	18.9	5.6	5.2	7.1
22	RM-101	5.3	4.8	9.4	11.9	11.1	6.7	5.8	5.3	8.6
Mean		5.17	4.46		13.2	11.0		5.8	5.2	
CD(P=0.05)		3.4	1.7		1.2	1.1		1.2	1.0	

In timely sown crop seed yield (g/plant) varied from 9.4g (RM-101) to 40g (Kranti) while the values in the late sown crop were 4.2g (RGN-81) to 16g (Varuna and PBR-97).Mean seed yield declined by 47.5 % in the late sown crop due to heat stress as compared to the timely sown crop. Reduction in seed yield ≤ 30% was reported in SKM-0149, Varuna, NPJ-92, PR-2002-8, RM-15 and RM-101.Seed yield was comparable under both the sowing dates in PR-2002-8.Late sowing reduced the growth phase leading to lower photosynthesis and dry matter accumulation. Heat stress at the terminal stage hampers the mobilization of assimilates to the developing sinks/seeds in the siliqua which significantly affects the seed filling leading to seed abortion or shrived seeds ultimately reducing seed weight and seed yield. Significant differences were recorded in the oil content of the genotypes at two dates of sowing. Over all, delayed sowing reduced oil content by 6.3% over timely sown crop. Cultivar PR-2002-8 also registered minimum decline in oil content. Twelve genotypes showed less than 5% decline in oil content. The present work corroborates with the findings of Ray *et al.* (2005) and Sangha and Sardana (2007). Rise in temperature results in less time available for transport of photosynthates to sink ultimately lowering yields. Further differential metabolic pathways probably depend on enzymes with different sensitivities to excessive heat. Heat stress might uncouple some metabolic pathways and cause accumulation of reactive oxygen species (ROS) leading to down regulation of fatty acid biosynthesis and also triggering secondary responses(Mittler *et al*,2012). Impact of high temperature stress has been studied in various crops and for details references be made to studies in Brassicas (Angadi *et al.* 2000, Kaur *et al* 2011).Heat tolerance efficiency (HTE) value which was one of the heat resistance parameters ranged from 31-99% (Table3).

Table 3: Influence of terminal heat stress on oil content .seed yield and heat tolerance parameters in *B.juncea*

Sr. No	Genotypes	Oil content (%)			Seed yield (g/plant)			Heat tolerance parameters	
		Timely	Late	% reduction	Timely	Late	% reduction	HSI	HTE (%)
1	RGN-48	38.8	35.9	7.5	32	8	75.0	1.56	25
2	RGN81	36.7	35.5	3.3	12	4.2	65.0	1.35	35
3	SKM-9927	39.3	37.4	4.8	28	12	57.1	1.19	43
4	SKM-9928	38.5	36.9	4.2	32	10	68.8	1.43	31
5	Varuna	39.2	35.9	8.4	20	16	20.0	0.42	80
6	RH-0116	37.8	33.5	11.4	12	6	50.0	1.04	50
7	RK-02-03	36.8	33.2	9.8	24	12	50.0	1.04	50
8	SKM-0125	37.3	36.8	1.3	30	14	53.3	1.11	47
9	NPJ-93	35.4	34.9	1.4	18	12	33.3	0.69	67
10	SKM-0158	40.0	35.4	11.5	32	12	62.5	1.30	38
11	NPJ-92	39.1	36.9	5.6	17	12	29.4	0.61	71
12	NDRS-2001	39.5	37.6	4.8	16	8	50.0	1.04	50
13	SKM-0149	37.3	36.8	1.3	20	14	30.0	0.63	70
14	Kranti	38.7	31.8	17.8	40	12	70.0	1.46	30
15	NRCDR-2	37.2	36.2	2.7	26	12	53.8	1.12	46
16	PBR-92	39.4	35.1	10.9	16	10	37.5	0.78	63
17	PR-2002-8	36.4	36.1	0.8	8.6	8	7.0	0.15	93
18	PBR97	40.5	38.9	4.0	22	16	27.3	0.57	73
19	PCR-7	37.0	33.8	8.6	20	14	30.0	0.63	70
20	RM-11	39.8	37.2	6.5	24	12	50.0	1.04	50
21	RM-15	37.7	36.4	3.4	14	13.9	0.7	0.01	99
22	RM-101	37.1	36	3.0	9.4	9	4.3	0.09	96
	Mean	38.2	35.8		21.5	11.2			
	CD(P=0.05)	1.01	0.28		2.1	1.5			

Cultivars RM-15(99%),RM-101(96%),PR-2002-and Varuna (80%) had high tolerance efficiency .Another parameter of temperature tolerance is heat susceptibility index (HSI) and the values ranged from0.01 -1.56.The HSI of the above mentioned genotypes were 0.01,0.09. 0.15 and 0.42 respectively. These genotypes had least HSI and high values of heat tolerance efficiency (HTE).Results of the present study have showed a parallelism with earlier findings (Sharma *et al.* 2011 and 2012). According to these studies minimum yield reduction was realized in the genotypes which had the highest HTE and the lowest HSI.8 genotypes were rated as the most susceptible genotypes with more than 50% yield losses and lowest HTE and also the highest HSI. In parallel most of the findings (Sio-Se *et al.* 2006) showed that genotypes with lowest HSI was most tolerant than the highest HSI. In the same way Sharma *et al.* (2011) have reported that heat susceptible varieties had high values (HSI>1) while resistant varieties had lower values. Furthermore average of HSI value for resistant genotypes (Varuna, PR-2002-8, RM-15 and RM-101) in this study was 0.155 and average HTE was 92% while for susceptible genotypes (RGN 48, RGN-81, SKM-9927, SKM- 9928. RH- 0116, RK-02-03 ,SKM-1025, SKM- 0158, NDRS-2001, Kranti, NRCDR-2) average HSI was 1.22 and HTE 41.3%.Rest of the 6 genotypes were rated as moderately tolerant with average HSI of 0.64 and HTE 69%. Conclusively, heat susceptible index (HSI) and heat tolerance efficiency (HTE) are the most important resistant parameters to evaluate genotypes under high temperature under field conditions. Yield reduction less than 30% is another criteria followed for heat tolerance. These indices can be easily used to find heat tolerant/resistant genotypes in the mustard breeding programmes. Based on these criteria's genotypes Varuna, NPJ-92, PR-2002-8, PBR-97, RM-15 and RM-101 were tolerant to terminal heat stress. Interestingly, PR-2002-8 and RM-101showed moderate thermo tolerance at seedling stage.

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