



Genetic analysis of heat stress tolerance in Indian mustard (*Brassica juncea* L.)

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Abstract

A set of fifty-three Indian mustard [*Brassica juncea* (L.) Czern & Coss.] genotypes were evaluated for genetic variability and correlation for yield and physiological characters during *rabi* 2012-13 and 2013-14 under heat stress (early sown), and normal (optimum time) environmental conditions. The study was undertaken to generate genetic information for seed yield per plant (g), population survival (%) at 10 and 25 days after sowing (DAS), membrane stability index (%), excised-leaf water loss (%), relative water content (%), water retention capacity of leaves (%), 1000-seed weight (g), and oil content (%), and quantification of relationships among these characters. Significant differences were observed for all the characters among the genotypes, except 1000-seed weight, which revealed the presence of sufficient variability for these characters. High estimates of PCV for MSI, seed yield per plant, and population survival (PS) 25DAS indicated the importance of additive genes. High heritability estimates coupled with high to moderate genetic advance as per cent of mean was recorded for PS 25DAS, WRCL, and RWC indicating the role of additive gene action for its inheritance, and could be improved through selection. Oil content had low heritability estimates along with low genetic advance, indicating non-additive gene activity, and this could be improved through hybridization. Character association analysis revealed that seed yield per plant showed positive, and highly significant correlations with RWC ($r=0.407^{**}$) which could be considered as one of the important selection criteria in the improvement of seed yield under heat stress situation.

Key words: Indian mustard, correlation, gene action, physiological character, seed yield

Introduction

Rapeseed-mustard (*Brassica* spp.) constitutes an important group of oilseed crops in India. Among the rapeseed-mustard group of crops, Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is the principal crop. It accounts for about 80% of the total area under rapeseed-mustard cultivation in India (Ram *et al.*, 2014). Rajasthan is among the largest producers, accounting for about 50% of the total rapeseed-mustard production in India. The cultivation of rapeseed-mustard in Rajasthan is largely carried out under rainfed farming systems where sowing commences after south-west monsoon rains. Early rains may cause the farmers to sow the crop early in the season to take advantage of conserved moisture in the soil (Venkateswarlu and Prasad, 2012). However, at the time of early

sowing (second fortnight of September to first fortnight of October), the average surface soil temperature may reach as high as 45 °C. High soil temperature often result in seedling mortality upon initial germination which may eventually lead to a situation where the crop needs to be re-sown before a final successful crop is established (Salisbury and Gurung, 2011). The simulation studies by Indian Institute of Tropical Meteorology (IITM), Pune, has reported that annual mean surface temperature is expected to raise by the end of century, ranges from 3 to 5 °C with warming more pronounced in the northern and north-western parts of India. Therefore, efforts to strengthen resilience by genetic up scaling of thermotolerance at seedling stage by utilizing diverse heat tolerant genotypes in *Brassica* crop improvement programmes would be vital to

stabilize the productivity and to meet the growing demands of edible oil in the country. Since, genetic variability is a prerequisite for the meaningful selection, the heritability in conjunction with expected genetic advance determines its success. Furthermore, correlated response to selection depends primarily on the nature and strength of relationship between characters. Keeping in view the above points, the present investigation was aimed to assess, genetic variability, gene action and pattern of correlations of seed yield with other physiological characters.

Material and Methods

A set of 53 Indian mustard genotypes were collected from ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, India. These genotypes were evaluated under heat stress conditions for two consecutive years (2012-13 and 2013-14) in complete randomized block design with three replications. The experiment was conducted at the experimental farm of the ICAR-DRMR, Bharatpur (77°27' E longitude; 27°12'N latitude and 178.37 m above mean sea level). The soil of the experimental site was sandy loam with EC 1.5 dSm⁻¹, organic carbon (0.25 - 0.30%), available N (125-135 kg/ha), P (20-22 kg/ha), K of 240-260 kg/ha, and pH of 8.1. The crop was raised strictly under conserved moisture conditions.

Two hundred seeds of each genotype, including two checks (BPR-543-2 and RH-30), were sown during the two consecutive *Rabi* seasons of 2012-13 and 2013-14. On the date of seeding (September, 26) of the year 2012-13, the maximum soil temperature at 0 - 10 cm depth was 40.1°C while on the seeding date (September 28) of the year 2013-14, the maximum soil temperature at the same depth was 39.0 °C. The same set of genotypes was also evaluated under timely sown conditions under normal temperature during both the years. During the year 2012-13, the maximum soil temperature on the seeding date (October, 23) at 0- 10 cm depth was 31.0°C while in the year 2013-14 the maximum soil temperature on the seeding date (October, 23) at 0- 10 cm depth was 30.5°C. All genotypes were grown in two rows of five meter length; with row to row and plant to plant spacing of 30 cm and 10 cm, respectively. The recommended package of practices

was followed to raise a good crop. Growth and physiological characters, including, population survival (%) at 10 and 25 days after sowing (DAS), membrane stability index (%), excised-leaf water loss (%), relative water content (%), water retention capacity of leaves (%), seed yield per plant (g), 1000-seed weight (g) and oil content (%) were recorded on five randomly selected plants of each genotype.

Determination of growth and physiological parameters

The estimation procedures of physiological parameters i.e. membrane stability index (MSI), excised- leaf water loss (ELWL), relative water content (RWC), and water retention capacity of leaves (WRCL) were same as described in Ram *et al.* (2015).

The oil content (%) was estimated using nuclear magnetic resonance (NMR), according to the protocol of the AOCS (1980). All mature siliquae from five randomly selected plants were threshed and average seed weight per plant was calculated.

Statistical analysis

Analysis of variance (ANOVA) was performed on the data following Panse and Sukhatme (1978) and critical differences (CD) were calculated at 5 and 1% probability level. Estimation of phenotypic and genotypic coefficient of variation, heritability in broad sense, genetic gain, and correlation coefficient between seed yield per plant and physiological parameters were determined using statistical software Windostat version 8.5 (Windostat Services, Hyderabad, A.P., India)

Results and Discussion

A set of fifty-three genotypes of Indian mustard were included in the study. Analysis of variance over the environments revealed that these genotypes vary significantly for all the growth and heat stress related characters, except 1000-seed weight (Table 1). These results indicated that selection for traits responsible for high yield potential along with heat stress tolerance characters can be made effectively in the breeding material evaluated in the present study. Estimates of mean and range for all the characters exhibited wide range of variation

Table 1: Analysis of variance for different seed yield and physiological characters in Indian mustard

Source of Variation	D.F.	Mean Squares								
		PS 10 DAS	PS 25 DAS	MSI	ELWL	RWC	WRCL	1000 -seed weight (g)	Oil content (%)	Seed yield per plant (g)
Replications	2	44.44	16.56	134.15	19.20	0.79	13.95	0.03	0.18	540.75
Environments	3	27.55	15.74	54.49	9.82	757.25	965.02	0.57	2.44	40.19
Interactions	6	3.95	4.36	5.14	1.99	8.21	1.77	0.01	2.83	5.96
Total	11	17.74	9.68	42.05	7.26	211.14	266.69	0.16	2.24	112.53
Treatments	52	4251.95	5249.37	785.51	154.57	1449.10	1020.47	2.56	4.37	378.30
Error	572	80.27	95.37	111.45	15.59	87.87	52.81	0.50	2.35	40.87

(Table 2). The most pronounced range was obtained for PS 10 DAS (22.02 to 94.86), PS 25 DAS (16.66 to 89.12), RWC (45.23 to 91.26), MSI (8.45 to 43.43), and seed yield per plant (10.80 to 34.38). On other hand, characters like 1000-seed weight and oil content exhibited narrow range of variation. The estimates of genotypic and phenotypic coefficients of variation were considerably high for PS 25 DAS, MSI, PS 10 DAS, WRCL, RWC and seed yield per plant (Table 2). High genotypic coefficient of variation for PS 25 DAS (35.37), MSI (30.30), seed yield per plant (26.96) and WRCL (23.66) provide good opportunity for selecting desirable yield and physiological traits responsible

for heat stress. The phenotypic coefficient of variation (PCV) exhibited higher values than genotypic coefficient of variation (GCV) for all the characters (Table 2), indicating close association between phenotype and genotype. Similar pattern of high genotypic and phenotypic coefficients of variation for PS 25 DAS, MSI and seed yield per plant have also been reported by Cheema and Sadaqat (2005) in Canola, and Ram *et al.* (2012) in Indian mustard. The results suggested that characters showing high value of genotypic and phenotypic coefficients of variation can be improved by careful selection. The estimates of heritability act as a predictive instrument in exercising the

Table 2: Estimates of different genetic parameters of variation over four environments (pooled)

Characters	Mean \pm SEm	Range	CD		PCV (%)	GCV (%)	Heritability h^2 (%)	Genetic advance as % of mean
			(P=0.05)	(P=0.01)				
PS 10 DAS	68.43 \pm 2.58	22.02-94.86	7.18	9.45	30.22	27.24	0.81	64.82
PS 25 DAS	58.59 \pm 2.81	16.66-89.12	7.83	10.30	39.10	35.37	0.82	84.47
MSI	24.72 \pm 3.04	8.45-43.43	7.46	9.13	52.35	30.30	0.53	42.31
ELWL	20.93 \pm 1.13	13.28-28.41	3.16	4.16	24.89	16.25	0.52	33.01
RWC	66.64 \pm 2.70	45.23-91.26	7.51	9.89	21.28	15.98	0.61	31.66
WRCL	37.94 \pm 2.09	21.38-54.05	5.82	7.66	30.44	23.66	0.65	48.56
Seed yield per plant (g)	19.46 \pm 1.84	10.80-34.38	4.45	5.74	42.23	26.96	0.50	45.44
1000-seed weight (g)	5.31 \pm 0.20	4.49-6.25	0.56	0.74	15.44	7.79	0.35	10.40
Oil content (%)	41.61 \pm 0.44	39.60-43.17	1.23	1.61	3.81	1.98	0.16	1.67

reliability of phenotypic value. Therefore, it helps the breeder to make selection for a particular character when heritability is high. In addition to this, the genetic advance is a useful indicator of the progress which can be expected as a result of exercising selection on the pertinent population. In the present study, the estimates of heritability varied substantially from 16% for oil content to 82% for PS 25 DAS. High heritability estimates (broad sense) were observed for PS 25 DAS (82%), PS 10 DAS (81%), WRCL (65%), RWC (61%) and MSI (53%). The results indicated that these characters are less influenced by the environmental factors, and direct selection for these characters would be effective for further improvement. The high genetic advance was observed for PS 25 DAS (84.47%), PS 10 DAS (64.82%), WRCL (48.56%), and for seed yield per plant (45.44%), while the remaining characters showed moderate to low genetic advance.

According to Hanson *et al.* (1956), heritability estimates along with genetic advance are of more value than the former alone, in predicting effect of selection. Further, Panse (1957) has also reported that high genetic advance might be expected when heritability is mainly due to additive gene effect. In the present study, heritability (broad sense) of PS 25 DAS (82%) with maximum genetic advance (84.47%) was observed. This might be due to heritability with additive gene impact, and therefore selection may be effective. These results are in

agreement with the results obtained by Ram *et al.* (2012), and Azharudheen *et al.* (2013) for PS 25 DAS.

High heritability estimates coupled with moderate genetic advance as per cent of mean was recorded for WRCL and RWC indicating the predominance of additive gene action for these characters. On other hand, character like oil content exhibited low heritability estimates along with low genetic advance, indicating non-additive gene activity. Such character can be improved through hybridization breeding.

The genotypic correlations were estimated for yield and heat stress tolerance characters in all possible combinations. The significant coefficient of correlation between seed yield, and heat stress tolerance characters ranged from 0.334* to 0.953** (Table 3). Seed yield per plant showed positive and highly significant correlations with RWC ($r=0.407^{**}$). Thousand-seed weight was positively correlated with MSI ($r=0.334^{*}$) and WRCL ($r=0.395^{*}$). At the same time, WRCL was highly significantly positively correlated with MSI ($r=0.486^{**}$). Positive correlation of RWC with seed yield per plant has also been reported in earlier studies in *B. juncea* by Ram *et al.* (2012, 2014). Hence, selection for this character would also help in improving the seed yield under heat stress situation in this crop. Population survival 25 DAS was significantly positively associated with PS 10 DAS at genotypic level (Table 3). Excised-leaf water loss showed negative

Table 3. Correlation coefficient among seed yield and physiological traits in Indian mustard (pooled)

Characters	PS 10 DAS	PS 25 DAS	MSI	ELWL	RWC	WRCL	1000-seed weight (g)	Oil content (%)	Seed yield per plant (g)
PS 10DAS	1.000	0.953**	-0.271*	-0.136	-0.018	-0.094	-0.182	-0.038	-0.137
PS 25DAS		1.000	-0.349*	-0.025	0.018	-0.094	-0.061	-0.081	-0.177
MSI			1.000	-0.184	-0.120	0.486**	0.334*	-0.099	0.024
ELWL				1.000	0.056	-0.068	-0.021	-0.300*	-0.106
RWC					1.000	0.018	0.090	-0.183	0.407**
WRCL						1.000	0.395*	-0.306*	0.164
1000-seed weight (g)							1.000	-0.368**	0.016
Oil content (%)								1.000	-0.012
Seed yield per plant (g)									1.000

* and ** Significant at 5 and 1 per cent level of significance, respectively

significant correlation with oil content (Table 3). Moreover, 1000-seed weight also showed negative highly significant relationship with oil content ($r=-0.368^{**}$).

Holland (2006) observed that genetic correlations between traits are due to linkage, and/or pleiotropy indicating the magnitude, and direction of correlated response to selection. He also emphasized the relative efficiency of correlations facilitating indirect selection. The present findings indicate that since the traits are highly correlated, selection based on correlations may be a useful breeding strategy for indirect selections for higher seed yield potential (Ojaghi and Akhundova, 2010).

Adequate genetic variability was observed within the genotypes evaluated in the present study. Physiological variability and association analysis conducted on the genotypes indicated that PS 25 DAS, RWC, and WRCL are major physiological parameters which can be exploited for selecting high yielding Indian mustard genotypes under heat stress situation. Therefore, more attention should be paid to improve these characters while selecting high-yielding genotypes or choosing parents for heterosis breeding under heat stress conditions.

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