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GENERATION MEAN ANALYSIS OF WATER STRESS TOLERANCE PARAMETERS IN INDIAN MUSTARD [*Brassica juncea* (L.) Czern & Coss] CROSSES

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SUMMARY

Little information is available on the genetics of physiological traits for drought tolerance in Indian mustard. Generation mean analysis was performed using two crosses (Maya x BPR-543-2) and (BPR-543-2 x BPR-2) to study the nature and magnitude of gene effects on seed yield and physiological characters in Indian mustard. The F_1, F_2, BC_1 and BC_2 of these crosses, along with P_1 and P_2, were studied for eight physiological traits. As to the water use efficiency, the dominance *(h)* and dominance x dominance *(l)* non-allelic interactions were found to be the most important in BPR-543-2 x BPR-2 cross. In Maya x BPR-543-2, negative significant values of *h* and *l* were observed. Water use efficiency also showed duplicate-type epistasis in both crosses; indicating that *l* gene interaction effect or other types of digenic complementary gene interaction could be exploited effectively by selection for improvement of this character. The seed yield per plant in the cross Maya x BPR-543-2 showed *d*, *h,* and additive x additive (*i*) types of gene interaction, which means that this trait is under the control of fixable and non-fixable gene effects. The *i* gene interaction and duplicate epistasis seen in this trait suggest possibilities of obtaining transgressive segregants in later generations.

Keywords: *Brassica juncea,* gene effect, physiological characters, moisture stress, bi-parental mating

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INTRODUCTION

In India, rapeseed-mustard constitutes an important group of oilseed crops. Of these, Indian mustard (*Brassica juncea* L.) is the predominantly grown species, accounting for about 80% of cultivated area (Ram *et al*., 2012). As *B. juncea* is mostly grown in India on light-textured soils using water conserved from monsoon rains, it inevitably suffers from drought stress during its reproductive stage, when stored water becomes depleted (Kumar and Singh, 1998). This calls for the development of highly water use efficient genotypes.

Among the various abiotic stresses that affect field crops across the world, moisture stress assumes great importance, particularly under a changing climate scenario (Araus *et al*., 2002). Being native to India, *B. juncea* possesses vast genetic variability in seed and drought tolerance characteristics. In spite of this fact, limited efforts have been made towards to improvement of this crop's drought tolerance. Finding a suitable breeding method and identifying a selection strategy for trait improvement would depend on the knowledge of gene effects operating in the breeding population. Generation mean analysis, a concept developed by Hayman (1958) and Jinks and Jones (1958), is an efficient tool to gain an understanding of the nature of gene effects involved in the expression of a character. Generation mean analysis utilizes 6 different generations of a cross, parents P_1, P_2, F_1, F_2, BC_1 and BC_2 to estimate gene effects and components of genetic variation in interacting and non-interacting crosses. Although this tool has been extensively used to understand gene effects in different crops, very few reports are made available on the use of this technique in Indian mustard. In view of this fact, present study was undertaken to estimate the kinds of gene effects that play an important role in the inheritance of seed yield and its physiological traits.

MATERIALS AND METHODS

Three Indian mustard genotypes Maya, BPR-543-2 and BPR-2 were used for carried out the present study. This resulted in six generations: P_1, P_2 (parent cultivars), F_1, F_2 (first and second filial generations), BC_1 and BC_2 (first and second back crosses) of the cross combinations, Maya x BPR-543-2 and BPR-543-2 x BPR-2. The parents of the respective crosses were used as P_1 and P_2 and the F_1 of the particular cross was used as the female parent and back-crossed to P_1 to produce BC_1. F_1 was again backcrossed to P_2 to produce BC_2 and the F_1 hybrids were selfed to obtain the F_2 seeds. All 6 generations were produced during 2 consecutive cropping seasons i.e., 2008-09 and 2009-10 and were evaluated in randomized block design with two replications during 2010-11 at the research farm of the Directorate of Rapeseed-Mustard Research, Bharatpur, India. All the genotypes were grown in rows of 3 meter length. However, the number of rows varied for different generations-3 rows, for the non-segregating generation P_1, P_2, and F_1; 20 rows for the F_2; and 15 rows for the BC_1 and BC_2. Since the non-segregating generations represent the homogeneous population and the segregating generations represent the heterogeneous population, the samples (number of plants analyzed) varied as follows: 10 plants for the P_1, P_2, and F_1; 40 plants for the F_2; and 30 plants for each of the BC_1 and BC_2. The traits assessed were transpiration (mmol/m^2/s), stomatal conductance (mmol^s/m^2/s), photosynthesis (µmole/cm^2/s), SPAD value, water potential, total dry matter (g /plant), water use efficiency (µmol/ mmol) and seed yield (g/plant).

Determination of growth and physiological parameters

Data on physiological characters such as SPAD (soil plant analysis development) reading at flowering and seed formation stages and, transpiration at flowering and seed filling were recorded to quantify physiological efficiency. The unit less measurement obtained from the SPAD chlorophyll meter (SPAD-502, Minolta Corp., Ramsey, NJ) is based on the differences between light attenuation at 430 nm (peak wavelength for chlorophyll a and b) and that at 750 nm (near-infrared) with no transmittance. Thus, the SPAD chlorophyll meter reading (SCMR) represents the chlorophyll concentration in the leaf. The SCMRs were made during full flowering and seed filling stages. The leaves were sampled from the nodal positions of 3 and four below the apex on the main axis from randomly selected plants from each generation. Photosynthesis, transpiration, and stomatal conductance were recorded on the 3rd and 4th fully expanded leaf from the top of randomly chosen plants in each replication using a portable photosynthesis system (CIRAS-2) 80-85 days after sowing (pod formation stage). Water potential was estimated with the help of a pressure chamber (model: ARIMAD 3000). Water use efficiency was computed as the ratio of photosynthesis to transpiration and expressed inµmol/ mmol. All the mature siliquae obtained from the randomly selected plants were threshed and the weight of grains of individually selected plants was recorded on a top pan electric balance. Average weight was taken to determine seed yield per plant. The selected plants were harvested and sun-dried. Whole plants (including siliquae) were weighed to work out total dry weight.

Statistical analysis

The mean values, standard errors, and variances of all the generations were subjected to weighed least-squares analysis using the scaling and joint scaling tests to estimate gene effects. The genetic effects were estimated as per the models of Mather and Jinks (1971) and Jinks and Jones (1958) using indostat software. The significance of the scales and gene effects were tested by using the t-test (Singh and Chaudhary, 1985).Scaling tests A, B, C, and D of Mather (1949) were performed for all characters under study to judge the adequacy of the additive – dominance model.

RESULTS AND DISCUSSION

The results of the joint scaling tests and their interaction effects for 6 generations are presented in Table 1. The additive, dominance, and epistatic types of gene interaction in each cross for different traits were found to differ from each other. In most of the *l* interaction was larger than the *i* and additive x dominance (*j*) effects put together, whereas for the main effect, the dominance component (*h*) was greater than the additive (*d*) component. The dominance (*h*) and dominance x dominance (*l*) effects were in opposite direction, suggesting the occurrence of duplicate type epistasis in most cases and the presence of predominantly dispersed alleles at the interacting loci (Jinks and Jones, 1958). Dominance gene effects were found to be relatively more important, as indicated by the fact that, in most cases, the *h* values were higher than the *d* values.

In the case of transpiration, all gene interaction effects were non-significant in both the crosses and complementary epistasis was observed for this trait. With respect to stomatal conductance, the *h* and (*l)* non-allelic interactions were significant in BPR–543-2 x BPR–2, while the *h* gene interaction effect was significant in Maya x BPR–543-2. The Maya x BPR-543-2 cross had non-significant *l* non-allelic gene interaction effect. Maya x BPR 543-2 showed duplicate type epistasis, while BPR–543-2 x BPR–2 cross had complementary type epistasis for this trait. In the case of photosynthesis, all the gene interaction effects were non-significant, except the *I* effect for BPR-543-2 x BPR-2. These results indicate that photosynthesis is predominantly controlled by additive x additive type gene interaction with duplicate epistasis for this trait.

As to SPAD value, all gene interaction effects were non-significant, except for the *h* effect for the Maya x BPR–543-2 cross, an indication that the SPAD value is predominantly controlled by dominance-type interaction effects. Complementary-type epistasis was observed in Maya x BPR-543-2, while duplicate-type epistasis was observed in BPR-543-2 x BPR-2 for this trait. In the case of water potential trait, the *i* gene effect was significant in the Maya x BPR-543-2 cross, whereas the *j* gene effect was negatively significant in BPR-543-2 x BPR-2. Maya x BPR-543-2 showed complementary-type epistasis, BPR-543-2 x BPR 2 showed duplicate epistasis. Naveed *et al.* (2009) reported that additive variance contributed the highest to variance for leaf water potential and pointed to, the preponderance of additive x dominance effects under non-stress condition of the cross Sanam x ArkaAnamika and Sabazpari x Indian spineless okra. The other 2 crosses, Chinese Red x Ikra 1 and Superstar x P-1999-31, showed the highest h under both conditions. In Sabazpari x Indian spineless, *i* was highest under drought stress for leaf water potential in okra.

For total dry matter, the *d* and *h* effects were significant in Maya x BPR-543-2, while *l* non-allelic interaction was significant in BPR-543-2 x BPR-2. Duplicate epistasis was observed in both crosses for this trait.These findings are in good agreement with those of Yadav *et al.* (2011) and Singh *et al.* (2012).

As to water use efficiency trait, *h* and *l* non-allelic interaction were found to be the most important in BPR-543-2 x BPR 2. Negative *h* gene effect and *l* non-allelic interaction gene effect were noted in Maya x BPR-543-2 for this trait. Also shown were duplicate-type epistases in both crosses. These findings confirm the results found by Ashraf and Ahmed (1998), Wan *et al.* (2009), Naveed *et al.*(2009), and Yadav *et al.* (2011).

Seed yield per plant in Maya x BPR-543-2 showed *d*, *h,* and *i* gene interactions, implying that this trait is under the control of fixable and non-fixable gene effects. The *i* type gene interaction and duplicate epistasis seen in this trait suggest possibilities of obtaining transgressive segregants in later generations.

The additive and dominance x dominance (*l*) gene interaction effects or other types of digenic complementary gene interaction could be exploited effectively by selection for the improvement of the characters. The use of reciprocal recurrent selection or bi- parental mating suggests improvement of characters when additive and non- additive gene effects are involved in the expression of these traits. The presence of non-additive genes for stomatal conductance, water potential, water use efficiency, and seed yield per plant indicates that conventional selection may not be effective enough to improve seed yield and drought tolerance. Therefore, postponing selection in later generation or intermating among selected segregants, followed by one or two generations of selfing, could be suggested to break the undesirable linkage and allow the accumulation of favorable alleles for the improvement of these traits.

The different types of gene effects estimated provide a test for gene action and are useful for analyzing the genetic architecture of a crop in order to further improve desirable traits. The estimates obtained from each cross may be unique to that cross and may not be applicable to the parental population. Additive genetic variance formed the major part of genetic variance for the important yield component dry matter per plant. Therefore, genetic improvement in seed yield per plant would be easier through indirect selection for a component trait, such as dry matter per plant, rather than through direct selection for seed yield itself.

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Table 1. Estimates of components of generation means for different physiological characters under moisture stress condition in Indian mustard.

		Gene effects						Type of Epistasis
Character	Cross	[*m*]	[*d*]	[*h*]	[*i*]	[*j*]	**[*l*]**	
Seed yield/ plant (g)	Maya x BPR-543-2	22.83**	-2.75*	44.55**	16.3**	41.74**	-16.28**	D
	BPR-543-2 x BPR-2	47.72**	-2.11	24.13**	28.36**	30.48**	-9.54**	D
Transpiration (mmol/m^2/s)	Maya x BPR-543-2	3.54*	-0.50	-0.11	0.01	0.01	0.02	C
	BPR-543-2 x BPR-2	55.13**	-0.81	0.18	0.04	0.03	0.01	C
Stomatal conductance (mmol^s/m^2/s)	Maya x BPR-543-2	196.53**	-24**	11.04**	0.02	0.01	-36.34**	D
	BPR-543-2 x BPR-2	142.16**	-13.45**	18.13**	0.01	0.02	19.58**	C
Photosynthesis (µmole/cm^2/s)	Maya x BPR-543-2	11.13**	-2.75*	-1.78	-0.02	0.01	0.04	D
	BPR-543-2 x BPR-2	16.31**	5.37**	-1.26	3.11*	2.31	0.01	D
SPAD value	Maya x BPR-543-2	34.21**	-0.99*	2.1	-0.01	0.01	0.02	C
	BPR-543-2 x BPR-2	22.64**	1.51	-1.66	-1.26	0.02	0.05	D
Water potential	Maya x BPR-543-2	8.2**	0.38	2.43	0.01	17.16**	0.02	C
	BPR-543-2 x BPR-2	44.12**	2.31	2.46	1.12	-11.05**	-1.02	D
Total dry matter/plant (g)	Maya x BPR-543-2	45.51**	8.29**	5.53**	0.02	0.01	-0.03	D
	BPR-543-2 x BPR-2	68.25**	24.21**	-4.29**	0.05	0.05	3.56*	D
Water use efficiency (µmolmmol)	Maya x BPR-543-2	16.10**	-0.10	-6.14**	-1.5	-0.05	4.35*	D
	BPR-543-2 x BPR-2	14.78**	-0.21	3.45*	-0.5	1.50	9.16**	D

M= mid-point, *d* = additive, *h* = dominance, *i* = additive x additive, j = additive x dominance, *l* = dominance x dominance. *, ** significant at 5 % and 1 % respectively.