Indian J. Plant Genet. Resour. 28(3): 329-334 (2015)
DOI 10.5958/0976-1926.2015.00044.3

Genetic Variability and Correlation Analysis in Indian Mustard [*Brassica juncea* (L.) Czern & Coss.] under Drought Stress

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(Received: 07 July, 2014; Revised: 16 October, 2015; Accepted: 17 October 2015)

Genetic variation study in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] revealed low phenotypic and genotypic variability for days to maturity and oil content but substantial for secondary branches/plant, biological yield/plant, seed yield/plant, plant height, primary branches/plant and siliquae on main shoot. The seed weight had high heritability with high genetic advance implying that additive gene effects were mainly responsible for the expression of the character. Seed yield/plant was positively and significantly correlated at both phenotypic and genotypic levels with days to maturity, plant height, primary branches/plant, secondary branches/plant, siliquae on main shoot and biological yield/plant. Selection for higher 1000-seed weight would bring forth positive correlated response in oil content owing to its positive genetic correlation with oil content. Indirect selection for high oil content through seed size might reduce siliquae on main shoot due to its negative genetic correlation of moderate magnitude with oil content. Positive association of days to maturity and plant height with seed yield is undesirable; therefore, efforts should be made to break this linkage by resorting to bi-parental mating to breed for varieties having earliness, short plant stature and high oil content in *Brassica juncea*.

Key Words: ***B. juncea*, Drought stress, Genetic advance, Genetic variability, Genotypic correlations, Indian mustard, Seed yield**

Introduction

Rapeseed-mustard group of crops require low water (80-240 mm) and thus fits well in the rainfed cropping system, which accounts for 30% of the total cropped area in the country under these crops. Seed yield is a complex character and *per se* doesn't have major genes and largely influenced by components characters (Meena *et al*., 2006; Singh *et al*., 2006; Brar *et al*., 2007; Misra *et al*., 2007b). Yield improvement in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is primarily dependent on nature and magnitude of genetic variability for component characters. The genetic variability coupled with heritability helps in the identification of the characters that offer scope for improvement through selection and predict the expected gain. Information on interrelationship among the yield components enables choosing appropriate selection criteria for yield improvement. Pleiotropic action of genes and/or linkage determines the inherent association between any two variables (Falconer, 1989). Studies on these aspects under drought stress is limited in Indian mustard (Mondal and Khajura, 2000; Tyagi and Chauhan, 2003). The present study was under taken to assess extent and nature of variability for seed yield and its components, their *inter se* associations to identify appropriate selection criteria for yield enhancement under drought stress in *B. juncea*.

Materials and Methods

The materials for the present investigation comprised of 16 advanced breeding lines and 6 varieties of Indian mustard grown in a randomized complete block design with three replications under rainfed conditions during *rabi s*eason of 2007-08. There were 4 rows of 4 m length for each genotype in a block. The row spacing was 30 cm and plant spacing within a row was maintained at 10 cm by thinning. A fertilizer dose of 40:20:20 kg/ha ($N:P_2O_5:K_2O$) was applied at the time of sowing. Soil moisture content was recorded from the time of sowing till maturity at an interval of 15 days at 3 depths (15, 30 and 60 cm) using gravimetric method. The soil samples were dried in an oven at $75 \pm 2^{\circ}C$ for at least 72 hrs till constant weight was achieved. The soil moisture content was expressed in percentage on wet basis. Days to maturity was recorded on plot basis. At the time of harvest, 10 random competitive plants were taken from the middle row to record plant height (cm), primary branches/plant (no.), secondary branches/plant (no.), main shoot length

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(cm), siliquae on main shoot (no.), siliqua length (cm), seeds/siliqua (no.), 1000-seed weight (g) and seed yield/plant (g). Oil and protein content were recorded on a composite sample of 10 plants taken for recording seed yield using Near Infrared Reflectance Spectroscopy (Kumar *et al*., 2003).

The data were subjected to analysis of variance according to the procedure outlined by Panse and Sukhatme (1967). Phenotypic and genotypic coefficients of variation were calculated following the method of Burton (1952). Heritability in broad sense (h^2_b) and expected genetic advance at 5% selection intensity were calculated following the methods of Hanson (1963) and Johnson *et al.* (1955), respectively. The correlation coefficients at phenotypic (r_{pxy}) and genotypic (r_{gxy}) level among different characters were computed according to the methods suggested by Searle (1971).

Results and Discussion

Soil Moisture Content

There was steady and rapid decline in soil moisture content at all the three soil depths up to 65 days after sowing (DAS) coinciding with 50% flowering in majority of the genotypes. The soil moisture content at this time reached 4.6%, 5.6 % and 7.4% at 15, 30 and 60 cm, respectively. Thereafter, the moisture content stabilized and showed gradual decline. The reduction in soil moisture content from 65 DAS till the time of harvest was only 1.6% at 15 cm, 0.6% at 30 cm and 1.4% at 60 cm.

Analysis of Variance

Analysis of variance revealed highly significant genotypic differences for days to maturity, plant height, and siliquae on main shoot, siliqua length, 1000-seed weight, seed yield/plant and oil content. The genotypic differences were significant for primary branches/plant, secondary branches/plant, seeds/siliqua and biological yield/plant (Table 1). Non-significant genotypic differences were recorded for main shoot length, harvest index, protein content and seed:husk ratio. Hence these characters were excluded from further discussion.

Range and Variability

The oil content and secondary branches/plant, respectively, showed lowest and highest PCV and GCV (Table 2). The PCV >35%, 25-35% and < 25% were classified as high, moderate and low, respectively and GCV > 20%,10-20% and < 10% were categorized as high, moderate and low, respectively. The genotype BPR-542-6 was the earliest to mature (125 days) and BPR-549-9 being the latest maturing genotype (139.7 days). The PCV and GCV were low for days to maturity. The genotype RH-819 had the tallest plants whereas; Rohini showed the shortest plant stature among the genotypes. The PCV and GCV were 19.0% and 11.1%, respectively. Primary branches/plant ranged from 3.7 (BPR-542-6) to 5.7 (BPR-543-2) and showed low PCV and GCV (Table 2). The minimum (1.3) and the maximum secondary branches/plant (5.9) were recorded for the genotype BPR-542-6 and RCC-4, respectively. The PCV and GCV were the highest among

Table 1. Analysis of variance for seed yield and other agro-morphological characters in Indian mustard under drought stress

Character/degree of freedom	Source of variation (Mean sum of squares)			SEM (±)	CD (5%)
	Replication	Genotype	Error		
	2	21	42		
Days to maturity	35.64	108.96**	13.14	2.05	5.97
Plant height	1837.81*	1041.59**	405.46	11.36	33.18
Primary branches/plant	0.53	0.60*	0.32	0.32	0.93
Secondary branches/plant	5.37	5.00*	2.30	0.86	2.50
Siliquae on main shoot	69.37*	37.96**	15.14	2.19	6.41
Siliqua length	0.13*	0.15**	0.03	0.10	0.30
Seeds/siliqua	1.91	1.36*	0.64	0.46	1.32
1000-seed weight	0.02	0.62**	0.04	0.12	0.34
Biological yield/plant	214.36**	84.12*	40.47	3.59	10.48
Seed yield/plant	14.84*	7.54**	2.98	0.97	2.84
Oil content	0.03	0.91**	0.35	0.34	0.98

*, **: Significant at 5% and 1% probability level, respectively.

Table 2. Range, mean, phenotypic (PCV) and genotypic coefficient of variability (GCV), heritability and genetic advance for seed yield and other agro-morphological characters in Indian mustard under drought stress

Character	Range	Mean ± SEM	PCV (%)	GCV (%)	Heritability (%)	Genetic advance	Genetic advance as % of mean
Days to maturity	125.0 -139.7	131.8 ± 2.1	5.1	4.3	70.9	980.0	7.4
Plant height (cm)	97.3 - 161.0	131.0 ± 11.6	19.0	11.1	34.3	1757.8	13.4
Primary branches/plant (no.)	3.7 - 5.7	4.4 ± 0.3	14.7	7.0	22.7	300.9	6.9
Secondary branches/plant (no.)	1.3 - 5.9	3.2 ± 0.9	55.8	29.6	28.1	103.5	32.3
Siliquae on main shoot (no.)	25.5 - 40.5	33.4 ± 2.2	14.3	8.2	33.5	328.6	9.8
Siliqua length (cm)	3.4 - 4.1	3.8 ± 0.1	7.0	5.2	54.7	30.8	7.9
Seeds/siliqua (no)	12.9 -15.9	13.9 ± 0.1	6.8	3.5	27.2	52.6	3.8
1000-seed weight (g)	3.8 - 5.2	4.6 ± 0.1	10.6	9.6	82.0	82.1	17.9
Biological yield/plant (g)	9.9 - 29.2	18.9 ± 3.7	39.3	20.2	26.4	404.0	21.4
Seed yield/plant (g)	3.1 - 9.1	6.0 ± 1.0	35.6	20.7	33.8	147.8	24.8
Oil content (%)	42.4 - 43.9	43.1 ± 0.5	1.7	1.0	34.1	50.9	11.8

the characters studied. Siliquae on main shoot showed low phenotypic and genotypic variations. Rohini and BPR-538-12 had the lowest and the highest siliquae on main shoot, respectively. The GCV (3.5%) and PCV (6.8%) were the lowest for seeds/siliqua except for days to maturity and oil content. The genotype BPR-541-2 (12.9) and BPR-543-2 (15.9) had the minimum and maximum seeds/siliqua. The 1000-seed weight ranged from 3.8 (BPR-542-14)-5.2 g (BPR-549-2) with low phenotypic and genotypic variability.

The biological yield/plant had relatively high PCV and GCV. The genotype BPR-349-9 had the highest seed yield/plant (9.1g) whereas, the genotype BPR-542-6 showed the lowest (3.1g) with an overall mean of 6.0 ± 1.0 g. It had high phenotypic and genotypic variability (Table 2).The minimum (42.4%) and maximum (43.9%) oil content was recorded in the genotype BPR-538-12 and BPR-125-1, respectively and the character had the least variability. Seed yield, being a complex character and influenced by several quantitatively inherited characters, hence direct selection for seed yield is not usually very effective. Chauhan *et al.* (2000) also reported considerable variability for seed yield/plant, secondary branches/plant and siliquae on main shoot under rainfed conditions. Grafius (1964) suggested component(s) selection to improve seed yield. Appreciable variability was present for seed yield, secondary branches/plant, biological yield/plant, plant height, primary branches and siliquae on main shoot. Moderate to high variability available in the present materials could be quite useful for selection. The results of the present investigation concerning low variability for oil content and days to maturity were in agreement with the earlier reports (Chauhan *et al.*, 2000; Meena *et al.*, 2006). Therefore, these characters had limited scope of improvement through selection due to lack of enough variability in the experimental materials.

Heritability and Genetic Advance

The heritability estimates ranged from 22.7% for primary branches/plant to 82.1% for 1000-seed weight. The expected genetic advance varied from 3.8% (seeds/siliqua) to 32.3% (secondary branches/plant). The heritability >70%, 50-70% and <50% were classified as high, moderate and low, respectively and the genetic advance was categorized as high (>20%), moderate (10-20 %) and low (<10%). Although days to maturity had high heritability but the genetic advance was low. Plant height exhibited low heritability accompanied by moderate genetic advance. The estimates for both heritability and genetic advance were low for primary branches/plant. Secondary branches/plant had low heritability with highest genetic advance (Table 2). Low heritability coupled with low genetic advance was recorded for siliquae on main shoot. Siliqua length had moderate heritability but low genetic advance. Both heritability and genetic advance were low for seeds/siliqua. The highest heritability for 1000-seed weight was associated with moderate genetic advance. High genetic advance was accompanied by low heritability for biological yield/plant and seed yield/plant. Oil content had low heritability as well as low genetic advance.

Success of selection in improving a character depends on both extent of variability and heritability estimate. The seed weight had high heritability and high genetic advance implying that additive gene effects were mainly

Table 3. Phenotypic and genotypic correlation coefficients of seed yield and other agro-morphological characters in Indian mustard under drought stress

Character	PH	PB	SB	SMS	SL	SS	SW	BY	SY	OC
DM	0.595**	0.160	0.174	0.461*	0.161	-0.024	0. 307	0.538**	0.539**	-0.059
	0.661	**0.587**	**0.439**	**0.449**	**0.183**	**- 0.274**	**0. 354**	**0.863**	**0.816**	**-0. 313**
PH		0.336	0.386	0.841**	0.263	0.052	0.184	0.795**	0.751**	0. 033
		1. 347	**1.054**	**0.894**	**0.041**	**-0.451**	**0.147**	**0.971**	**0.956**	**-0. 399**
PB			0.631**	0.374	0.113	0.268	0.050	0.533*	0.588**	-0.194
			0.456	**0.914**	**0.174**	**0.241**	**0.125**	**0.886**	**0.963**	**-0. 066**
SB				0.596**	0.074	0.148	0.064	0.688**	0.717**	-0.084
				1.048	**0.066**	**-0.127**	**-0.158**	**0.875**	**0.799**	**-0. 078**
SMS					0.063	0.108	0.085	0.786**	0.762**	-0.074
					-0.096	**-0.672**	**-0.057**	**0.738**	**0.751**	**-0.455**
SL						0.216	0.386	0.269	0.240	0.059
						0.313	**0.594**	**0.351**	**0.274**	**- 0.339**
SS							0.272	0.171	0.198	-0.040
							0.294	**-0.251**	**-0.132**	**-0. 285**
SW								0.238	0.226	-0.353
								0.256	**0.228**	**0.562**
BY									0.955**	-0.075
									0.998	**- 0.348**
SY										-0.123
										-0.335

*, **: Significant at 5% and 1% probability level, respectively. Values in light and bold face are correlation coefficients at phenotypic and genotypic level, respectively. DM: Days to maturity; PH: Plant height; PB: Primary branches/plant ;SB: Secondary branches/plant; SMS: Siliquae on main shoot; SL: Siliqua length; SW: 1000-seed weight; BY: Biological yield/plant; SY: Seed yield/plant and OC: Oil content

responsible for the expression of these characters. Low heritability with low, moderate and high genetic advance or *vice versa* for days to maturity, plant height, primary branches/plant, secondary branches/plant, siliquae on main shoot, siliqua length, seeds/siliqua, biological yield/plant and oil content were indicative of predominant role of non-additive gene action in their inheritance and thus simple selection for improvement may not be effective. Moderate to high heritability and genetic advance for 1000-seed weight was also reported by Meena *et al.* (2006) whereas, Brar *et al.* (2007) observed high heritability coupled with low genetic advance.

Correlation Coefficients

Genotypic correlations for seed yield and other characters were invariably higher than phenotypic correlations (Table 3). The high magnitude of genotypic correlation coefficients form sound base for their practical implications. The results of the present study are in agreement with earlier studies (Kumar *et al.,* 1999). Both correlations were in the same direction except for seeds/siliqua with plant height and siliqua length where genetic correlations were high and negative but phenotypic correlations were non-significant. Similarly, oil content had low/moderate negative genotypic correlations with plant height, siliquae on main shoot and seeds/siliqua but no correlation at phenotypic level. It also had positive correlation of moderate magnitude with biological yield at genotypic level.

Phenotypic Correlations

Days to maturity and plant height were positively and significantly interrelated with each other. Biological yield/plant (r_{pxy} = 0.538**) and siliquae on main shoot (r_{pxy} = 0.461*) also had significant association with days to maturity. Positive and highly significant association of plant height with siliquae on main shoot and biological yield/plant was recorded. The relationship of primary branches/plant with secondary branches/plant and biological yield/plant was positive. However, the interrelationship of secondary branches/plant with siliquae on main shoot and biological yield/plant was positive and significant (Table 3). Positive and significant phenotypic correlation (r_{pxy} = 0.786**) was also recorded between siliquae on main shoot and biological yield. Seed yield/plant was positively and significantly correlated with days to maturity, plant height, primary and secondary branches/plant, siliquae on main shoot and biological yield/plant (Table 3).

Genotypic Correlations

The genotypic correlations were categorized as low ($r < 0.400$) moderate ($r = 0.400$-0.680) and high ($r > 0.680$). Seed yield/plant had high positive correlation with days to maturity, plant height, primary branches/plant, secondary branches/plant, siliquae on main shoot and biological yield/plant. The relationship between seed yield and oil content was negative (Table 3). Days to maturity and plant height were also correlated positively with each other, similarly days to maturity had high association with biological yield/plant and primary branches/plant. The association of days to maturity with other characters was positive and moderate except with oil content ($r_{gxy} = -0.313$) and seeds/siliqua ($r_{gxy} = -0.274$) where the correlations coefficient were negative. Plant height had high and positive correlation coefficients with siliquae on main shoot and biological yield/plant. The negative and moderate association of oil content and seeds/siliqua with plant height was also observed.

Primary branches and secondary branches/plant had high positive correlation with plant height, the correlation coefficient being 1.347 and 1.054, respectively. The relationship of primary branches/plant was positive and moderate with secondary branches/plant. The association of primary branches/plant with biological yield and siliquae on main shoot were positive and high (Table 3). A high and positive relationship of secondary branches/plant was also observed with siliquae on main shoot ($r_{gxy} = 1.048$), biological yield/plant ($r_{gxy} = 0.875$) and seed yield/plant ($r_{gxy} = 0.799$).The genetic correlation between siliquae on main shoot and biological yield/plant was high and positive whereas such correlation between oil content and siliquae on main shoot was negative and moderate ($r_{gxy} = -0.455$). Siliqua length had positive association of low to moderate ($r_{gxy} = 0.274$-0.594) strength with seeds/siliqua, 1000- seed weight, seed yield/plant and biological yield/plant but its association with oil content was negative and moderate ($r_{gxy} = -0.339$). Seeds/siliqua had low and negative genetic correlation with oil content and biological yield/plant but low and positive association was observed with 1000-seed weight ($r_{gxy} = 0.294$). Positive genetic correlation of moderate strength was recorded between 1000-seed weight and oil content. Further, 1000-seed weight had low positive association with biological yield/plant and seed yield/plant. Seed yield/plant was positively and significantly correlated at both phenotypic and genotypic levels with days to maturity, plant height, primary branches/plant, secondary branches/plant, siliquae on main shoot and biological yield/plant. Biological yield/plant showed positive and significant correlations with days to maturity, plant height, primary and secondary branches/plant and siliquae on main shoot. The results are in agreement with earlier reports (Kardam and Singh, 2005; Singh *et al*., 2006; Misra *et al*., 2007a; Patel *et al*., 2003). Singh *et al.* (1987) observed that oil content and seed weight were positively and significantly correlated. But all these studies were carried out under irrigated conditions.

The studies revealed that selection for higher 1000-seed weight would bring forth positive correlated response in oil content owing to their positive genetic correlations. Nevertheless, it might also result in reduction in siliquae on main shoot due to its negative genetic correlation of moderate magnitude with siliquae on main shoot, but this effect could be offset by selection for more branches/plant. Hence the number of siliquae/plant should be emphasized in selection programme rather than siliquae on main shoot. Considering the results of the present investigation it is concluded that donors with multiple determinants of seed yield like days to maturity, plant height, more primary and secondary branches/plant and high biological yield/plant should be used in the breeding programme for genetic enhancement of seed yield. However, a balance has to be struck between plant height, days to maturity and seed yield because of their positive associations suggesting that late maturing and very tall genotypes would have high seed yield while early maturity is a desirable character under drought stress. Therefore, efforts should be made to break these undesirable linkages by resorting to bi-parental mating.

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