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Stability analysis in Indian mustard (*Brassica juncea*) varieties

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ABSTRACT

A study was conducted during winter season (*rabi*) 2006–07 and 2007–08 under irrigated and rainfed environments to test the stability of improved and high-yielding varieties of Indian mustard (*Brassica juncea* L. Czerns & coss.). Analysis of variance on 14 characters was carried out individually as well as pooled over the years and locations. Irrigated environment was relatively better for the expression of wider range and higher mean for all characters except 1000-seed weight. Genotype × environment interaction was significant for days to maturity, plant height, point to first branch, primary branches/plant, secondary branches/plant, point to first siliqua and 1000-seed weight along with seed yield/plant. G × E (linear) was also significant for all these 8 traits and days to 50% flowering, indicating substantial amount of predictable G × E interaction. All 30 genotypes were tested for 3 stability parameters, viz mean, bi and $\check{S}^2_{di.}$ Out of all the genotypes, the genotypes 'RGN 13', 'NRCDR 02', 'Vasundhra' and 'Pusa Jagannath' were identified to be high yielding and stable. 'Laxmi' and 'CS 54' were having superior performance for seed yield/plant but were found to be suitable for cultivation under rainfed (poor) environments. 'Pusa Jaikisan' was superior to the population mean for seed yield/plant and was found to be suitable for cultivation under irrigated (favourable) environment. Genotypes, viz 'RGN 13', 'NRCDR 02', 'Vasundhra' and 'Pusa Jagannath' may be included in any breeding programme to develop high-yielding stable genotypes over the environments. Direct selection in the segregating generations of such parents for 1000-seed weight, point to first branch along with simultaneous selection for secondary branches/plant, siliqua length and total number of siliquae/plant will be responsive for improvement of seed yield/plant.

Key words: *Brassica juncea*, G × E interaction, Selection, Stability, Varieties, Yield

Rapeseed and mustard (*Brassica* spp) is the second important oilseed crop of the country after soybean and plays a significant role in the Indian oil economy by contributing about 27% to the total oilseed production. Six *Brassica* species commonly grown in India include 3 diploids, viz *Brassica rapa* (AA, n=10), *Brassica oleracea* (CC, n=9) and *Brassica nigra* (BB, n=8); and 3 amphidiploids, viz *Brassica juncea* (AABB, n=18), *Brassica napus* (AACC, n=19) and *Brassica carinata* (BBCC, n=17) of which 4 species, viz *B. juncea*, *B. napus*, *B. carinata* and *B. rapa* cvs. toria, yellow sarson and brown sarson are grown as oilseed crops. Among these 4, *B. juncea* known as Indian mustard or *raya* or *laha* is covering more than 80% of the total rapeseed and mustard area and contributes to production in the same proportion. It is because of its wider adaptability and comparative tolerance to biotic and abiotic stresses as compared to other *Brassica* species grown as oilseeds.

The area, production and productivity of this crop during 2008–09 was 6.18 million ha, 7.36 million tonnes and 1 190 kg/ha, respectively (AICRP-RM 2009). Though this crop is grown all over the country, however, Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Punjab, Haryana, Bihar, Orissa, Himachal Pradesh and West Bengal are the major rapeseed growing states. In terms of area, Rajasthan is the leading state and occupies nearly 45% of the total area and contributes in the same proportion towards the production to the national oilseed pool. A large number of high-yielding area specific varieties have been developed in Indian mustard but unfortunately, in spite of having the varieties with the yield potential of 2.0–2.5 tonnes/ha, our national average is revolving around 1.0 tonne/ha. Moreover, yield levels are also not sustainable and fluctuate year after year leading to

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fluctuation in production. This fluctuation is because of many factors like growing of this crop on marginal lands either rainfed or with limited irrigation facilities, non-availability of resistant/tolerant varieties for biotic and abiotic stresses for different sowing conditions etc.

Under such a situation, it becomes imperative to identify some already released and notified varieties which can show a steady performance over the years under rainfed and irrigated situations. Keeping this fact in view, the present investigation was carried out for 2 consecutive years under 2 environments and 30 popular varieties developed by the ICAR/State Agricultural Universities system from 6 states were studied to test the stability of the improved varieties over the environments through genotype-environment interaction and to identify high-yielding and stable varieties for stable production in Indian mustard.

MATERIALS AND METHODS

The experiments were conducted at the experimental farm of the Institute during winter (*rabi*) season 2006–07 and 2007–08 under rainfed and irrigated situations. The material for present study consisted of 30 popular varieties of *B. juncea* with wider adaptability in areas of their recommendation from 6 states, viz Rajasthan (‘RN 393’, ‘RGN 13’, ‘RGN 48’, ‘RGN 73’, ‘NRCDR 02’); Punjab (‘RLM 619’, ‘PBR 91’, ‘PBR 97’, ‘PBR 210’); Haryana (‘Laxmi’, ‘RH 30’, ‘RH 819’, ‘RH 781’, ‘Geeta’, ‘Swarnjyoti’, ‘Vasundhra’, ‘PCR 7’, ‘CS 52’, ‘CS 54’); Uttar Pradesh (‘Kranti’, ‘Varuna’, ‘Vardan’, ‘Rohini’); Delhi (‘Pusa Bold’, ‘Pusa Jagannath’, ‘Pusa Karishma’, ‘Pusa Jaikisan’, ‘PR 45’) and Gujarat (‘GM 1’, ‘GM 2’).

During both the years, trials were laid out in randomized block design with 3 replications with plot size of 5.0 m × 1.5 m. Row-to-row and plant-to-plant distance was kept at 30 cm×10 cm. The data was recorded on 14 characters, viz days to 50% flowering, days to maturity, plant height (cm), point to the first branch (cm), number of primary branches/ plant, number of secondary branches/plant, length of main shoot (cm), number of siliquae on main shoot, point to first siliqua on main shoot (cm), siliquae length (cm), number of seeds/siliqua, 1000-seed weight (g), total number of siliquae/ plant and seed yield/plant (g). Except days to 50% flowering and days to maturity, where data was recorded on plot basis, the data for rest of the morphological traits was recorded on randomly selected 10 competitive plants in the middle 3 rows of each plot in all 3 replications. The recommended package of practices was followed to raise a good crop.

The mean values of 10 samples, except for characters recorded on whole plot basis, were used for detailed statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989). Genotype-environment interactions were found to be significant in respect of all the characters studied, hence the data were subjected to stability analysis (Eberhart and Russel 1966) to assess the stability of different genotypes. A genotype with regression coefficient of unity (bi =1) and the deviation not significantly different from zero ($\check{S}^2_{di} = 0$) was taken to be a stable genotype with unity response.

RESULTS AND DISCUSSION

For each environment analysis of variance on 14 characters was carried out individually as well as pooled over the years and locations. Analysis of variance revealed significant differences amongst genotypes for all the observed characters in each of the 4 environments. Pooled analysis of variance over the 4 environments was also carried out in

Table 1 Character-wise pooled mean sum of squares for genotypes under 4 environments

Source of variance	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Point to first branch (cm)	Primary branches/plant	Secondary branches/plant	Length of main shoot (cm)
Location (L)	3	315.875**	3076.333**	10301.000**	9852.417**	29.836**	778.628**	173.542**
Replication (R)	2	2.156	2.750	57.500	18.031	0.592	0.129	6.125
L × R	6	2.396	0.667	18.667	3.813	0.253	4.069	1.271
Genotype (G)	29	112.024**	143.632**	987.747**	1316.570**	3.048**	54.569**	583.006**
L × G	87	24.180**	23.383**	274.418**	154.887**	0.908**	14.635**	26.296**
Error	232	1.532	1.392	13.431	13.27	0.210	2.956	9.337

Source of variance	df	Siliquae on main shoot	Point to first siliqua (cm)	Siliqua length (cm)	Number of seeds/siliqua	1000–seed weight (g)	Total number of siliquae/plant	Seed yield/ plant (g)
Location (L)	3	362.563**	18.476**	0.620**	1.729**	0.790	19102.000**	2697.948**
Replication (R)	2	2.735	0.140	0.019	0.035	0.052	106.000	1.633
L × R	6	7.500	0.456	0.022	0.021	0.267	124.667	11.557
Genotype (G)	29	113.973**	22.573**	1.554**	11.110**	8.598**	4589.494**	235.551**
L × G	87	17.764**	2.644**	0.054**	0.933**	0.256**	459.763	42.302**
Error	232	5.004	0.669	0.016	0.148	0.025	450.920	5.247

**P*=0.05, ***P*=0.01

order to verify presence of G × E interactions (Table 1). G × E interaction variance was significant for all the observed characters, except total number of siliquae/plant. Variance due to genotype was also significant for all the observed characters. Variance due to environment was also significant for all the observed characters, except 1000-seed weight. These results indicated presence of substantial amount of genotype×environment interaction. Stability analysis was carried out as per Eberhart and Russell (1966) model for all the observed characters in order to verify presence of variance due to components of G×E interaction (Table 2).

The genotype × environment interaction was present and it was highly significant for all the characters studied, except for total number of siliquae/plant. Similar findings have been reported by Brar *et al.* (2007). As the environments selected in the present study were diverse (two irrigated and two rainfed), the presence of significant G × E for the observed characters indicates the relevance of stability analysis. The mean values over genotypes were generally lower under rainfed environment as compared to irrigated environments for the characters, viz days to maturity, days to 50% flowering, plant height, point to first branch, primary branches/plant, secondary branches/plant, length of main shoot, siliquae on main shoot, point to first siliqua, siliqua length, number of seeds/siliqua, total number of siliquae/plant and seed yield/plant, whereas reverse trend was observed for 1000-seed weight. Similarly, range was wider under irrigated environments in comparison to rainfed environments for the above characters and reverse trend in range was observed for 1000-seed weight. The results indicated that the irrigated environment was relatively better for the expression of wider range and higher mean for the characters, viz days to maturity, days to 50% flowering, plant height, point to first branch, primary branches/plant, secondary branches/plant, length of main shoot, siliquae on main shoot, point to first siliqua, siliqua length, number of seeds/siliqua, total number of siliquae/plant and seed yield/plant, while rainfed environment was better suited for expression of 1000-seed weight.

Analysis of variance for stability indicated significant differences among the genotypes for all 14 characters observed, indicating the diversity in the selected genotypes. Significant differences were observed among the environments too, hence significant effect of environment was there in the expression of the traits. Genotype × environment interaction was significant for days to maturity, plant height, point to first branch, primary branches/plant, secondary branches/plant, point to first siliqua and 1000-seed weight along with seed yield/plant indicating that the genotypes are varying over the environments due to G × E. The significant G × E interaction has been reported for various traits by Dhillon *et al.* (2001) and Brar *et al.* (2007) which confirm the findings of present investigation. G × E (linear) was also significant for all these 8 traits and days to 50%

Table 2 Analysis of variance (mean sum of squares) for genotype × environment interactions

Source	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Point to first branch (cm)	Primary branches/ plant	Secondary branches/ plant	Length of main shoot (cm)	Siliquae on main shoot	Point to first siliqua (cm)	Siliqua length (cm)	Seeds/ siliqua	1000–seed weight (g)	Total number of siliquae/ plant	Seed yield/ plant (g)
Genotypes (G)	29	37.34**	47.89**	329.26**	438.86**	1.016**	18.19**	194.34**	37.99**	7.524**	0.518**	3.704**	2.866**	1529.74**	78.52**
Environments (E)	3	105.30**	125.47**	3433.68**	3284.15**	9.946**	259.84**	57.82**	120.84**	6.249**	0.207**	2.434**	0.263**	6367.06**	899.33**
G×E	87	8.06	7.80**	91.51**	51.63**	0.303*	4.88**	8.77	5.92	0.881*	0.018	0.311	0.085*	153.29	14.10**
E + (GxE)	90	11.30**	41.72**	202.92**	159.38**	0.624**	13.37**	10.40	9.75**	1.060**	0.024**	0.312	0.091*	360.42	43.61**
Environment (linear)	1	315.87**	3076.36**	10300.83**	9852.41**	29.835**	778.63**	173.52**	362.57**	18.747**	0.620**	7.293**	0.790**	19102.19**	2697.95**
G×E (linear)	29	10.87*	14.61**	198.05**	105.09**	0.502**	6.70**	9.72	7.53	1.042*	0.012	0.328	0.143**	259.20	27.14**
Pooled deviation	60	6.44**	4.25**	36.97**	24.07**	0.196	3.83	8.01	4.95	0.775	0.021	0.292**	0.055**	96.97	7.33**
Pooled error	232	1.53	1.38	13.38	13.28	0.210	2.96	9.34	5.00	0.669	0.016	0.148	0.025	450.90	5.25
Total	119														

$^*P$=0.05, $^{**}P$=0.01

Table 3 Genotypes showing stability for various characters (Eberhart and Russell 1966)

Genotype	Traits for which genotypes showed superiority and stability on the basis of 3 parameters of stability
'RGN 73'	Primary branches/plant, siliquae on main shoot, point to first siliqua (cm), siliqua length (cm), total number of siliquae/plant
'RN 393' ('Aravali')	Siliquae on main shoot
'RLM 619'	Seed yield/plant (g)
'Geeta' ('RB 24')	Length of main shoot (cm), number of seeds/ siliqua
'CS 52'	Length of main shoot (cm), siliquae on main shoot, siliqua length (cm), total number of siliquae/plant
'Kranti'	Days to maturity, length of main shoot (cm)
'Varuna'	Days to maturity
'RGN 13'	Days to maturity, total number of siliquae/ plant, seed yield/plant (g)
'Pusa Bold'	1000-seed weight (g)
'Pusa Karishma'	Point to first siliqua (cm), number of seeds/ siliqua, total number of siliquae/plant
'Pusa Jaikisan'	Length of main shoot (cm), 1000-seed weight (g), seed yield/plant (g)
'SwarnJyoti'	
'Vardan'	Days to maturity, primary branches/plant, length of main shoot (cm), siliqua length (cm)
'RH 819'	Length of main shoot (cm)
'RH 30'	Length of main shoot (cm), 1000-seed weight (g)
'RH 781'	
'NRCDR 02'	Point to first branch (cm), number of seeds/ siliqua, 1000-seed weight (g), total number of siliquae/plant, seed yield/plant (g)
'Rohini'	
'GM 2'	
'Vasundhra'	Secondary branches/plant, point to first siliqua (cm), 1000-seed weight (g), seed yield/plant (g)
'PR 45'	Plant height (cm), point to first branch (cm), length of main shoot (cm), siliquae on main shoot, number of seeds/siliqua
'Laxmi'	Secondary branches/plant, length of main shoot (cm), point to first siliqua (cm), number of seeds/siliqua, 1000-seed weight (g), total number of siliquae/plant, seed yield/plant (g)
'PBR 97'	Point to first branch (cm), 1000-seed weight (g)
'PCR 7'	Number of seeds/siliqua
'GM 1'	Point to first branch (cm)
'PBR 91'	Secondary branches/plant
'RGN 48'	Days to maturity, point to first branch (cm), primary branches/plant, siliqua length (cm), number of seeds/siliqua, total number of siliquae/plant
'PBR 210'	Length of main shoot (cm)
'Pusa Jagannath'	Point to first branch (cm), 1000-seed weight (g), seed yield/plant (g)
'CS 54'	Length of main shoot (cm), 1000-seed weight (g), seed yield/plant (g)

flowering, indicating substantial amount of predictable G × E interaction. Hence, we can predict the performance of genotypes over wide range of environments for these traits. Significant G × E (linear) for different traits has been reported by Chaudhary *et al.* (2004) and Brar *et al.* (2007). Among the above traits, high G × E was observed for days to maturity, plant height, point to first branch, primary branches/plant, secondary branches/plant, 1000-seed weight and seed yield/ plant. Seven traits, viz days to 50% flowering, days to maturity, plant height, point to first branch, number of seeds/ siliqua, 1000-seed weight and seed yield/plant were having high significant pooled deviation which indicated that some portion of G × E was unpredictable. Significant deviations from regression have been reported earlier also by Henry and Dauly (1988) and Brar *et al.* (2007).

G × E (L) component was not significant for length of main shoot, siliquae on main shoot, siliqua length, seeds/ siliqua and total number of siliquae/plant. However, in the present study genotypes were tested for 3 parameters of stability for all the observed characters. In order to classify the genotypes into various categories with respect to stability and suitability for particular environments, all 30 genotypes were tested for 3 stability parameters, viz mean, bi and $\check{S}^2_{di}$. The genotypes showing superiority and stability for different traits have been summarized in Table 3. Out of all the genotypes, the genotypes 'RGN 13', 'NRCDR 02', 'Vasundhra' and 'Pusa Jagannath' were identified to be high yielding and stable genotypes. Thus, these 4 genotypes were suitable for rainfed as well as irrigated conditions. Stability of the genotypes for various traits on the basis of 3 parameters has earlier been reported by Dhillon *et al.* (2001) and Brar *et al.* (2007) which confirm the present findings where various genotypes are showing stability for 1 or more characters.

Genotype 'RGN 13', besides having stable and high performance for yield was also having superior performance for days to maturity and total number of siliquae/plant. Likewise, 'NRCDR 02' also had stable and superior performance for point to first branch, number of seeds/siliqua, 1000-seed weight, total number of siliquae/plant in addition to seed yield/plant. Genotype 'Vasundhra' also had stable and high performance for secondary branches/plant, point to first siliqua and 1000-seed weight along with seed yield/ plant. In addition to superiority and stability for seed yield/ plant, 'Pusa Jagannath' also showed stability for point to first branch and 1000-seed weight. Similarly 'Laxmi' and 'CS 54' were having superior performance for seed yield/plant but were found to be suitable for cultivation under rainfed (poor) environments. Gunasekera *et al.* (2006) also reported wider adaptability and stability of Indian mustard genotypes in comparison to *B. napus*. Genotype 'Laxmi' showed the stability and superiority for maximum number of traits, viz secondary branches/plant, length of main shoot, point to first siliqua, number of seeds/siliqua, 1000-seed weight and total number of siliquae/plant.

Genotype, 'Pusa Jaikisan' was having superior mean than the population mean for seed yield/plant and was found to be suitable for cultivation under irrigated (favourable) environment. Muralia *et al.* (2002) has also reported the stability of 'Pusa Jaikisan' under varying environments. Four genotypes, viz 'RGN 13', 'NRCDR 02', 'Vasundhra' and 'Pusa Jagannath' should be included in any breeding programme where objective is really to develop high-yielding stable genotypes over the environments. Moreover, based on the results of present study, it is revealed that in segregating generations of such crosses including these parents, direct selection for 1000-seed weight, point to first branch along with simultaneous selection for secondary branches/plant, siliqua length and total number of siliquae/plant will be responsive for improvement of seed yield/plant. Dhillon *et al.* (2001) and Brar *et al.* (2007) have also reported that the genotypes stable over environments can be used successfully for developing stable strains having wider adaptability in the future breeding programme.

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