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Stability Analysis for Yield and Related Attributes in *Brassica juncea* under Divergent Environmental Conditions

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ABSTRACT

The experiment involving 125 F1s, 25 parent genotypes (25 lines and 5 testers) and one check were analyzed at two locations, Bikaner and Sriganganagar. For the study, a total of four environments were created, each location had two environments, timely sown and late sown, respectively. Analysis of variance for stability found genotypes to be significant for all the characters indicating the presence of variability in all the genotypes under study. Genotype × Environment interaction was found to be significant for most of the characters except for plant height, number of primary branches per plant, siliqua length and harvest index which indicates that environment has considerable impact upon the expression of genotypes. Based on the study for stability analysis, it was revealed that some of the crosses viz., Vardan x RGN-145, Vardan × RL-1359, RH-749 × RB-50 and RGN-73 × Kranti showed stable and predictable genotype × environment interactions over the environments. These specific crosses reported stable performances not only for seed yield but also for the yield contributing traits. Many of the stable crosses involved Kranti and RB-50 as one of the male parents, which indicates if these male parents are optimally utilized with the genotypes like Vardan, RGN-73 and RH-749 then crosses generating from them can ensure direct selection for many of the yield contributing characters which in turn will be responsible for improvement of seed yield per plant.

Keywords Environment, Stability, Genotypes, Crosses, Seed yield.

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INTRODUCTION

The oilseeds occupy significant place in Indian economy next to food grain. India is the third largest producer of oilseeds in the world. Oilseed *Brassicas* are the second most important oilseed crops of the world after Soybean (Anonymous 2015). India, China, Canada, Japan and European Union are the major *Brassica* growing regions of the world (Anonymous 2016).

The mustard is grown not only as oilseed crop but also as condiments and for medicinal use. The oil content in mustard seed ranges from 30-42%. Its leaves and tender stem form the most popular winter greens in some Indian states. Mustard oil has peculiar pungency due to the presence of sulfur compound, thus making it suitable for condiments and for preparation of pickles, curries and vegetables. Its leaves are rich in protein, minerals and vitamin A and C. After extraction of oil from seeds, the remnant is used as food for milching cattle. The mustard is cultivated during the *rabi* season in India and requires relatively cool temperature,a fair supply of soil moisture during the growing period and a dry weather during the harvest period.

The plant can tolerant wide range of soil pH and can be successfully grown in light sandy to marginal soils, though light loam to heavy loam soils is the best suited. This crop is grown both under rainfed as well as irrigated conditions either as a pure crop or as a mixed crop.

To cope up with the increasing population and demand of oilseeds, various strategies have been evolved to improve the yield levels in the country that are far below the world levels. The systematic genetic improvement efforts have resulted into release of several varieties. Further, taking the advantage of recently available CMS system in addition to barnasebarstar system various hybrids have also been developed. However, yield realization falls much behind the world average and need genetic interventions to further improve the potential of the varieties and hybrids. In this background the present study is justify able and necessary timely effort. Considering all these aspects, the present investigation was undertaken with following objectives:

I. To find out stability parameters of parents and hybrids.
II. Prediction of performance of the genotypes in different environments.

MATERIALS AND METHODS

The present investigation was carried out at Research farm of College of Agriculture, Beechwal, Bikaner (Zone Ic) and at ARS, Sri Ganganagar (Zone Ib) during 2015-16 *rabi* season.The experimental material consisted of 25 lines, 5 testers, their 125 cross combinations and one check. The crosses for the study were developed at ARS, Sri Ganganagar during 2014-15 *rabi* season through Line × Tester mating design. During 2015-16 *rabi* season all the genotypes (crosses, parents and check) were sown in each of the four environments in Randomized Block Design with three replications. Each genotype was sown in single row plot of 3 m row length. Row to row and plant to plant distances were maintained at 45 cm and 15 cm respectively, in each replication. For stability analysis Eberhart and Russell (1966) model was used. Recommended package of practices was adopted to raise a good crop.

The characters studied were: Days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of siliqua per plant, siliqua length, number of seeds per siliqua, 100-seed weight, stover yield per plant, seed yield per plant, harvest index and oil content.

Table 1. The four environments created for the study (on the basis of date of sowing).

Environment- I	Timely sown, Bikaner (27- Oct- 2015)
Environment- II	Timely sown, Sri Ganganagar (20- Oct- 2015)
Environment- III	Late sown, Bikaner (28- Nov – 2015)
Environment- IV	Late sown, Sri Ganganagar (18- Nov – 2015)

Table 2. Details of parent material used.

Lines	RGN-13, RGN-73, RGN-48, RGN-229, RGN-298, RGN-303, BIO-902, RGN-236, ROHINI, GM-3, RN-393, CS-52, PUSABOLD, LAXMI, RH-749, NPJ-113, PBR-357, NRCDR-2, PBR-378, KDM-10-49,RLM-619,VARDAN, PCR-7, JMWR-08-3, RH-30
Testers	RGN-145, Kranti, RL-1359, Geeta, RB-50

RESULTS AND DISCUSSION

Analysis of variance for stability found genotypes to be significant for all the characters indicating towards the presence of variability in all the genotypes under study. Environment (linear) has also reported significant effects for all the characters depicting the predictability of genotypic performances for various characters. Likewise, interaction of genotype with environment i.e. genotype × environment (linear) was found to be significant for most of the characters except for plant height, number of primary branches per plant, siliqua length, harvest index and oil content which indicated that environment had considerable impact upon the expression of genotypes. Pooled deviation also showed significance for all the characters. It has been stated by Dabholkar (1998) that when the mean square for pooled deviation is significant but mean square for genotype × environment (linear) is non-significant, variation in the performance of genotypes is entirely unpredictable. On the other hand, significance of mean square for pooled deviations, when mean square for genotypes × environment (linear) is also significant, implies that part of the variability is unpredictable in nature. Similar findings have been reported by Brar *et al.* (2007), Gupta and Pratap (2007), Gazal *et al*. (2013) Singh and Mishra (2003).

The best stable crosses for different environments have been mentioned in Tables 1-4. In case of days to 50% flowering, RN-393 × Geeta was found to be the best performer in better environment. On the contrary RGN-229 × Kranti reported best stable performances for poor environment.

Hybrids RGN-236 × RL-1359, JMWR-08-3 x RGN-145 and JMWR-08-3 × RL-1359 along with seven others turned out to be good performers if an average environment is provided. All these hybrids if utilized properly, they can give good early flowering performances across a wide range of environments. Similar stability results for days to 50% flowering have also been reported by Jakhar and Yadav (2010).

Table 3. ANOVA for phenotypic stability with regard to different traits in Indian Mustard (Mean Squares). *, ** Significant at 5% and 1% level of significance, respectively.

Source of Variation	df	Days to 50%	Days to maturity	Plant height	No. of Primary branches per plant	No. of siliqua per plant	Siliqua length
Rep. within Env	8	0.32	0.37	49.65	0.205	5283.28	0.03
Genotypes	154	12.87**	19.69**	308.94**	1.16**	56355.79**	0.34**
Env + (Gen x Env)	465	53.59**	48.03**	1669.25**	1.63**	115142.80**	0.48**
Environments	3	7797.64**	6628.73**	229497.10**	163.45**	13245540.00**	49.23**
Gen × Env	462	3.30**	5.29*	189.85	0.58	29880.49**	0.17
Env. (Linear)	1	23392.92**	19886.18**	688491.30**	490.34**	39736620.00**	147.68**
Gen x Env (Linear)	154	7.23**	7.06**	184.76	0.65	59574.00**	0.09
Pooled Deviation	310	1.33**	4.38**	191.15**	0.55**	14936.75**	0.20**
Pooled Error	1232	0.10	0.16	31.64	0.10	1751.33	0.02
Total	619	43.45	40.98	1330.82	1.52	100517.30	0.45

Table 3. Continued.

Source of Variation	df	No. of seed per	100-seed weight	Stover yield per plant	Seed yield per plant	Harvest index	Oil Content
Rep. within Env.	8	0.57	0.0003	236.41	9.93	4.21	0.30
Genotypes	154	5.04**	0.007**	1325.22**	169.014**	7.49	5.31**
Env.+(Gen.xEnv.)	465	5.44**	0.005**	1768.22**	153.41**	6.85	2.42**
Environments	3	393.49**	0.404**	215572.10**	17443.53**	98.26**	124.27**
Gen. x Env.	462	2.99*	0.003**	379.881**	41.14**	6.26	1.63*
Env. (Linear)	1	1180.45**	1.213**	646716.30**	52330.58**	294.78**	372.81**
Gen.xEnv(Linear)	154	4.06**	0.005**	782.50**	89.21**	4.86	2.17
Pooled Deviation	310	2.34**	0.002**	177.42**	16.99**	6.91**	1.35**
Pooled Error	1232	0.23	0.0001	81.35	5.93	2.36	0.16
Total	619	5.34	0.006	1658.004	157.29	7.01	3.14

Table 4. Best stable crosses for different environments (ranked on mean values). Good environment (Below average stability): mean >μ, bi > 1 and S^2di = 0, Poor environment (Above average stability): mean >μ, bi < 1 and S^2di = 0, Average environment (Average stability): mean >μ, bi = 1 and S^2di = 0.

Sl.No.	Characters	Good environment	Poor environment	Average environment
1.	Days to 50% flowering	1. RN 393 × Geeta	1. RGN 229 × Kranti	1. RGN 236 × RL-1359 2. JMWR-08-3 × RGN145 3. JMWR-08-3XRL-1359
2.	Days to maturity	1. RN 393 × RL-1359	-	1. RGN 236 x RGN145 2. RH 749 x RB-50 3. CS 52 x Kranti
3.	Plant height	1. RGN 303 × Kranti	1. Vardan × RGN145 2. Vardan × RB-50	1. Vardan x RL-1359 2. Vardan x Kranti 3. RGN73 x Kranti
4.	Number of primary branches per plant	1. Vardan × Kranti 2. RH 749 x RB-50	-	1. Vardan x RGN145 2. Vardan x Geeta 3. Vardan x RL-1359
5.	Number of siliqua per plant	1. RN 393 x RB-50 2. RGN 229 x Kranti	1. Vardan x Kranti 2. RGN 236 x RB-50	1. RH 749 x RB-50 2. RGN73 x Kranti 3. RN 393 x RB-50
6.	Siliqua length	-	1. GM 3 x Kranti 2. Rohini x RB-50	1. RGN73 x Kranti 2. RN 393 x RL-1359 3. NPJ 113 x RB-50
7.	Number of seeds per siliqua	1. RGN 303 x Geeta 2. CS 52 x Geeta	1. Bio 902 x Geeta	1. Vardan x RGN145 2 .GM 3 x RGN145 3. RGN 303 x Kranti
8.	100-seed weight	1. GM 3 x RB-50 2. KDM-10-49x Kranti	-	1. Vardan x RGN145 2. RH 749 x RB-50 3. RGN 229 x RL-1359
9.	Stover yield per plant	1. RGN 298 x RGN145 2. RGN 298 x Kranti 3. RGN 298 x RB-50	1. RH 749 x RGN145 2. RGN 236 x Kranti 3. RGN73 x RB-50	1. Vardan x RGN145 2. RH 749 x RB-50 3. RGN73 x Kranti
10.	Seed yield per plant	1. Vardan x RL-1359 2. Vardan x Geeta 3. Bio 902 x Kranti	1. RGN 236 x Kranti	1. RGN73 x Kranti 2. PBR 357 x Kranti 3. RGN 303 x Kranti
11.	Harvest index	1. RGN 229 x RGN145 2. KDM-10-49 x RGN145 3. NRCDR 2 x Kranti	1. PBR 357 x RGN145	1. RGN 298 x RL1359 2. RGN13 x RL-1359 3. RH 749 x RB-50
12.	Oil content	1. RGN 298 x RB-50	-	1. RGN 303 x RL-1359 2. NRCDR 2 x RL-1359 3. RN 393 x RB-50

For early maturity, RN-393 x RL-1359 as a hybrid can be utilized in good environment. Performances for average environment can be best harnessed by utilizing crosses like RGN-236 × RGN-145, RH-749 × RB-50 and CS-52 × Kranti. The use of these suitable varieties in a suitable environment can ensure good early maturing performances which is a desirable feature in Brassica cultivars. Gupta and Pratap (2007) also reported stablity for maturity in his findings.

Plant having tall height is one of the important features in order to get good biomass yield. In this study, RGN-303 × Kranti turned out to be stable performer for good environments; Vardan × RGN-145 and Vardan × RB-50 crosses can be considered for poor environment and fifteen crosses led by Vardan × RL-1359, Vardan × Kranti and RGN-73 × Kranti could be considered for average environments. Stable performances for plant height have also been reported by Jakhar and Yadav (2010).

In Indian mustard; number of primary branches per plant, number of siliqua per plant, siliqua length and number of seeds per siliqua are considered as important yield contributing characters. Stable and good performances of these characters for varying environments can ensure better yield results. For good environments; Vardan × Kranti and RH-749 × RB-50 for number of primary branches per plant, RN-393 × RB-50 and RGN-229 × Kranti for number of siliqua per plant and RGN-303 × Geeta for number of seeds per siliqua can be utilized. Similarly, for poor environments; Vardan × Kranti and RGN 236 × RB-50 for number of siliqua per plant, GM 3 × Kranti, Rohini × RB-50 and NRCDR 2 × RB-50 for siliqua length and Bio-902 × Geeta for number of seeds per siliqua can be utilized. Stable performances for yield contributing traits by various crosses ultimately contributing to the performance for seed yield have also been highlighted by Mahto and Haider (2000), Acharya and Sathpathy (2002) and Brar *et al.* (2007).

Better stover yield is a desirable feature along with seed yield in order to get good forage yields for cattle rearing. In the present investigation, RGN-298 × RGN-145 can ensure good performances in better environment; whereas RH-749 × RGN-145, RGN-236 × Kranti and RGN-73 × RB-50 can ensure good performances even in poor environments. Vardan x RGN-145, RH-749 × RB-50 and RGN-73 × Kranti were the leading crosses which can ensure highly stable performances if utilized in average environments.

In the present investigation, prime focus was on getting good seed yield results. Crosses giving good seed yield can be ensured through SCA and heterosis results but they do not generate stable performances across the environments. Through stability estimates we have been able to extract some of the crosses which are not only good in yield performances but also ensured stable performances. Vardan X RL-1359 and Vardan × Geeta turned out to be good crosses for better environments; RGN-73 × RGN-145, Vardan × RL-1359 and Vardan X Geeta ensured good performances for average environments. None of the crosses reported performances stable enough for poor environments. Results similar to above discussed findings have also been mentioned by Mahto (2000), Brar *et al.* (2007) in which they have reported stable performances for various crosses over the environments.

For harvest index, RGN-229 × RGN-145, KDM-10-49 × RGN-145 and NRCDR-2 × Kranti were best performers for stability in good environments, PBR-357 × RGN-145 was found to be the only cross showing good performances for poor environments and RGN-298 × RL-1359, RGN-13 × RL-1359 and RH-749 × RB-50 for average environments.

Oil content is an important quality aspect in Indian mustard, along with the seed yield. Genotypes providing good performance for oil content are highly sought after. Stable performances of varieties for this trait can not only ensure their wider adaptability but also ensure their wide acceptability. From the present study, RGN 298 × RB-50 proved to be the stable performer in good environments and RGN 303 × RL-1359, NRCDR 2 × RL-1359 and RN 393 × RB-50 were found to be suitable for poor environments. None of the crosses reported stable performances for oil content in poor environment. Mahto (2000) and Gazal *et al*. (2013) expressed similar findings for stability performances of genotypes for oil content.

Based on the present study for stability analysis, it is revealed that some of the crosses viz. Vardan x RGN-145, Vardan × RL-1359, RH-749 × RB-50 and RGN-73 × Kranti have shown stable and predictable genotype × environment interactions over the environments. These specific crosses reported stable performances not only for seed yield but also for the yield contributing traits, emphasizing upon the individual buffering capacity of these crosses. Many of the stable crosses involved Kranti and RB-50 as one of the male parents which indicates if these male parents are optimally utilized with the likes of Vardan, RGN-73 and RH-749 then crosses generating from them can ensure direct selection for many of the yield contributing characters which in turn will be responsive for improvement of seed yield per plant. Similar suggestions regarding utilization of various genotypes for seed yield and its contributing traits have also been made by Rashid *et al.* (2002), Gunasekara *et al*. (2006), Yadava *et al*. (2010), Sah *et al*. (2015).

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