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STABILITY ANALYSIS IN INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN & COSS.) OVER NORMAL AND TERMINAL HEAT STRESS ENVIRONMENTS

Ayushi Srivastava* and K. Srivastava

Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221005 (U.P.), India

Aabstract

An experimentation was conducted involving 39 genotypes of Indian mustard (*Brassica juncea* L. Czern & Coss.) comprising of 9 thermo-tolerant lines, 3 high yielding testers and their 27 F_1 hybrids by sowing them at two locations (Varanasi and Mirzapur) and three dates of sowing (*i.e.* timely, late and very late sown) to identify genotypes which are stable and high yielding in overall and especially in poor (terminal heat stress) environment. The evaluation trials were laid out in randomized block design with 3 replications at each date of sowing at both the locations. All the genotypes were tested for 3 stability parameters *i.e.* mean, b_i and S^2d_i. The analysis of variance (ANOVA) was conducted on eight characters (plant height, primary branches/plant, siliqua/plant, seeds/siliqua, test weight, seed yield/plant, oil content percent and oil yield tons/ha) for 6 environments individually as well as pooled over the environments. The pooled ANOVA revealed significant GxE interactions for seed yield and oil yield. The hybrid PM-28 × NRCHB-101 was revealed to be stable genotype for most of the characters including plant height, siliqua per plant, test weight and seed yield per plant. Among the parents, PM-26 was found stable for primary branches and test weight, RH-406 for test weight, RGN-236 for seed per siliqua, JD-6 for plant height and Giriraj for oil yield. These parental genotypes can be included in further breeding programs as they exhibited stable performance over the environments. The parents PM-26, PM-28, RH-406, RGN-229 and BPR-541-4 which were found stable for seed yield in the 'poor' (heat stress) environment (b_i<1, S^2_d) could be exploited further in stress breeding programs or can be recommended for cultivation in late sown conditions where the crop faces heat stress in the terminal stage due to delay in sowing time. On the other hand, the hybrids such as PM-28 × NRCHB-101, JD-6 ×NRCHB-101, PM-28 × Vardan, RH-406 × NRCHB-101, RH-749 × Vardan and RGN-236 × NRCHB-101, which were found stable for more than a single character simultaneously, could be subjected to generation advancement for developing stable varieties across the environments.

***Key words**:* terminal heat stress, environment, stable, late sown, seed yield.

Introduction

Indian mustard *i.e. Brassica juncea* L. Czern & Coss., commonly known as brown mustard, *rai, sarson, raya, laha,* constitutes the major proportion of oilseeds cultivated in the Indian sub-continent (next to soybean & groundnut). It is an amphidiploid belonging to family Brassicaceae which includes other important oilseed crops of the group 'rapeseed-mustard' comprising of *B. napus, B. carinata* and *B. rapa cv toria*. India ranks third, both in area and production of rapeseed-mustard, standing next to Canada and China (production of 8.00 million metric tons from 7.20 million hectare area: USDA 2018-19). In spite of this, our country lags behind all the major rapeseed-mustard growing countries such as Canada, China, EU, Russia, in terms of productivity : 1.11 metric tons/ha against world's average of 1.97 metric tons/ha, USDA 2018-19). This is mainly because most of the mustard is grown in marginal lands with poor agronomic practices such as lack of irrigation, improper disease-pest control, etc., one of the most prominent reasons being the delay in the optimum sowing time of mustard due to late harvest of paddy. Consequently, the crop faces high temperature during flowering and pod filling stage. High temperature stress is one of the most important abiotic stresses affecting plant productivity around the world (Hall, 1992). Though mustard is a hardy crop which has an has inbuilt abiotic stress tolerance making it easy to

***Author for correspondence :** E-mail: srivastavaayushi7@gmail.com

cultivate under rainfed conditions (Yadav *et al.*, 2010), moreover terminal heat stress effects seed set and grain filling thereby reducing yield (up to 53.10% reduction in yield and 6.97% reduction in oil content, Sharma & Sardana, 2013). Yield maximization has always been the prime focus of any breeding program. Many high yielding varieties (including hybrids) have been released in mustard (Giriraj, Vardan, Kranti, RH-406, RH-749, NRCHB-101, NRCHB-506 etc.) but they fail to express their full yield potential due to neglect in the optimum sowing time thereby subjecting the crop to unfavourable growth environment. Therefore, it becomes necessary to identify some genotypes including released varieties and potential hybrids which can exhibit stable performance over different environments created by alterations in sowing dates. With the above view in mind, an experimentation was conducted using 39 genotypes of Indian mustard comprising of 9 lines, 3 testers and their 27 F_1 hybrids. Stability analysis was carried out at two locations (Varanasi and Mirzapur) and three dates of sowing *i.e.* timely, late and very late sown conditions, creating six environments in total, to identify genotypes which are stable and high yielding in overall and especially in poor (terminal heat stress) environment.

Materials and methods

The experiment was conducted at two locations: (i) Agriculture research farm, B.H.U., Varanasi and (ii) Agriculture farm, R.G.S.C., Barkachha, Mirzapur during winter (*rabi*) season of 2017-18. Three environments were created at each location by alteration in the sowing dates so as to expose the crop to terminal heat stress *viz*. (i) timely sown (October 30th, 2017 at Varanasi & November 1st, 2017 at Mirzapur), (ii) late sown (November 15th, 2017 at Varanasi & November 16th, 2017 at Mirzapur) and (iii) very late sown (November 29th, 2017 at Varanasi & November 30th, 2017 at Mirzapur). The experiment material comprised of 39 genotypes of *B. juncea* including 9 thermo-tolerant lines (Pusa Mustard-26, Pusa Mustard-28, RH-406, RH-749, RGN-229, RGN-236, BPR-541-4, NRCDR-02 & JD-6), 3 high yielding, broad base testers (Giriraj, NRCHB-101, Vardan) and their 27 F_1s generated by crossing the above in Line × Tester manner. The evaluation trials were laid out in randomized block design (RBD) with 3 replications at each date of sowing at both the locations. The row to row distance was maintained at 30cm between the rows of same genotype and 60 cm between rows of different genotypes while the plant to plant distance was maintained at 10 cm. All the recommended agronomic package of practices were adopted to raise a good crop. The data used for statistical analysis was recorded as a mean value of 10 randomly selected plants for 8 yield attributing characters *viz*. plant height, primary branches/ plant, siliqua/plant, seeds/siliqua, test weight, seed yield/ plant, oil content percent and oil yield tons/ha. This data was subjected to analysis of variance as per the method of Panse & Sukhatme (1978). Since significant variation was found in the data of each environment, therefore stability analysis was carried out as per the procedure suggested by Eberhart & Russel (1969). According to this model, a stable genotype is one with high mean (X), unit regression coefficient (bi =1) and not significant deviatio n from regression (S^2_d=0). The genotypes can be further categorized as suited for rich, poor, overall and average environment. Rich environment: bi >1, S^2_d, Overall environment: bi >1, S^2_d, Poor environment: bi <1, S^2_d and Average environment: bi <1, S^2_d (Fig 1).

Result and discussion

The analysis of variance (ANOVA) was conducted on eight characters for 6 environments individually as well as pooled over the environments. The pooled

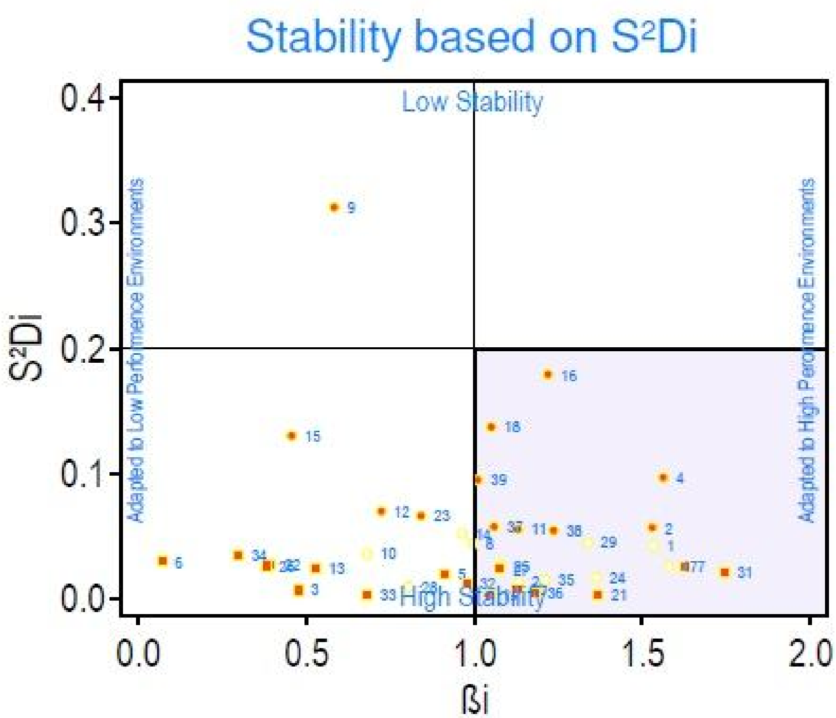

Fig 1 : Classification of genotypes based on bi and S^2_d

ANOVA revealed significant G×E interactions for seed yield and oil yield (Table 1). Similar findings have been reported by Yadav *et al.,* (2010) where they obtained significant GxE interaction for seed yield per plant. Significant differences were observed among the 39 genotypes (G) for all characters except for primary branches, siliqua per plant and seeds per siliqua. Also, significant differences observed among the environments (E) for all the eight characters indicated the profound effect of environment in expression of such characters. Similar findings by Brar *et al.,* (2007) and Dhillon *et al.,* (2001) confirms the findings of the present experimentation. The G×E (Linear) component was found significant for important traits such as seed yield per plant and oil yield. The E (Linear) as well as E + (G×E) (Linear) was found significant for all eight characters *i.e.* plant height, primary branches, siliqua per plant, seeds per siliqua, test weight, seed yield per plant, oil contet and oil yield. Since the linear component indicates predictable performance, therefore the performance of genotypes for the above traits could be predicted over the environments. Similar findings by Priyamedha *et al.,* (2017), Yadav *et al.,* (2010), Brar *et al.,* (2007) and Choudhary *et al.,* (2004) with linear components support our investigation.

Based on the Eberhat and Russel model, all the 39 genotypes were subjected to stability analysis and were classified as 'stable' genotypes based on three parameters *viz*. mean, bi and S^2_{di}. Character wise summary of these genotypes for 8 characters has been summarized in (Table 2). Since the present investigation also emphasizes upon the identification of genotypes tolerant to terminal heat stress, therefore, the genotypes suited for poor environment (*i.e.* heat stress) are of prime importance as they can be further exploited in stress breeding programs. These genotypes include the parents: PM-26, PM-28, RH-406, RGN-229 and BPR-541-4 which were found stable for seed yield in the 'poor' environment (b_i<1). The genotypes PM-26 and PM-28 were found stable also for siliqua per plant and oil yield in the poor environment. Thus, these genotypes can be recommended for cultivation in late sown conditions where the crop faces heat stress in the terminal stage due to delay in sowing time.

The hybrid PM-28 × NRCHB-101 was revealed to be stable genotype for most of the characters including plant height, siliqua per plant, test weight and seed yield per plant. A stable genotype is one with high mean, unit regression coefficient and zero deviation from regression (Eberhart & Russel, 1966). Among the parents, PM-26 was found stable for primary branches and test weight, RH-406 for test weight, RGN-236 for seed per siliqua, JD-6 for plant height and Giriraj for oil yield. These parental genotypes can be included in further breeding

Table 1: Pooled analysis of variance table showing genotype×environment interaction for eight characters.

Source of variation	DF	Plant Ht	Primary branches	Siliqua/ plant	Seeds/ siliqua	Test Wt.	Seed Yield/ Plant	Oil Content %	Oil yield tonnes/ha
Genotypes G	38	152.518*	0.374	904.073	1.271	0.239**	4.608**	5.034**	0.940**
Environments E	5	48810.746**	5.803**	385126**	115.872**	3.38**	920.796**	65.689**	270.274**
G×E	190	83.015	0.338	954.913	1.099	0.074	2.087**	1.990	0.406**
E+(G×E)	195	1332.444**	0.478*	10805.455**	4.042**	0.159**	25.644**	3.624**	7.326**
Environment (Linear)	1	244053.734**	29.013**	1925630**	579.358**	16.899**	4603.979**	328.447**	1351.374**
G×E (Linear)	38	109.669	0.387	694.973	0.969	0.071	7.042**	1.680	1.188**
Pooled deviation	156	74.394**	0.317**	993.747**	1.102**	0.073**	0.827	2.015**	0.205**
Pooled error	456	44.226	0.102	201.464	0.335	0.038	0.711	0.116	0.128
Total	233	1140.010	0.461	9190.637	3.590	0.172	22.213	3.854	6.284

*P=0.05, **P=0.01

Table 2: Character wise summary of thirty-nine genotypes for eight characters.

Character	Stable genotypes
Plant Height	RGN-229 × Giriraj, JD-6, PM-28 ×NRCHB-101
Primary branches	RH-406×Vardan, PM-26
Siliqua/ plant	PM-28 ×NRCHB-101, PM-28×Giriraj, RGN-236 xVardan
Seeds/siliqua	RH-749×Vardan, BPR-541-4×NRCHB-101, JD-6×NRCHB-101, RGN-236, RH-749×NRCHB-101
Test weight	PM-28 ×NRCHB-101, RH-406×NRCHB-101, JD-6×Giriraj, PM-26, RH-406
Seed Yield/ Plant	PM-28 ×NRCHB-101, RGN-229×Vardan, PM-26×Giriraj, PM-26×NRCHB-101, RH-749×Vardan
Oil Content %	RGN-236×NRCHB-101, JD-6×NRCHB-101, RH-406×NRCHB-101, PM-28×Vardan, NRCDR-02×Vardan
Oil yield tons/ha	JD-6 ×NRCHB-101, BPR-541-4 ×Giriraj, Giriraj, PM-28×Vardan, RGN-236×NRCHB-101

programs as they exhibited stable performance over the environments. Yadav *et al.*, (2010) reported similar findings where they classified several released varieties of Indian mustard as stable over four environments for yield and yield attributing characters thus supporting our investigation. Considering the hybrids (F_1s), only a few among the 27 hybrids exhibited stable performance for more than one character under study. These hybrids comprised of JD-6 × NRCHB-101 for seeds per siliqua, oil content and oil yield; PM-28 × Vardan for oil content and oil yield; RH-406 × NRCHB-101 for test weight and oil content; RH-749 × Vardan for seeds per siliqua and seed yield per plant and RGN-236 × NRCHB-101 for oil content and oil yield. These findings are in accordance with that of Priyamedha *et al.,* (2017), Mahto and Haider (2012) where they reported hybrids showing stable performance for more than one character. These hybrids can be further exploited in breeding programs through generation advancement with a view of isolating desirable genotypes that can exhibit stable performance over a wide range of sowing dates.

Based on the results, it can be observed that none of the 39 genotypes could be found stable across the environments for all the eight characters. This finding is supported by findings of Jambhulkar *et al.,* (2019) where they didn't obtain a single genotype stable simultaneously for all the characters over four years. Thus, it can be stated that some important yield attributing characters should be considered while discerning the stability of a genotype. In the present investigation, the genotypes RGN-229 × Giriraj, PM-28 × NRCHB-101 and JD-6 were found to be stable for plant height with their mean height lower than the population mean. For primary branches per plant, only two genotypes *i.e.* PM-26 and RH-406 × Vardan showed stable performance across the environments. Considering siliqua per plant, which is an important trait since the seed yield is positively associated with it (Jakhar & Yadav, 2010), three hybrids *viz.* PM-28 × NRCHB-101, PM-28 × Giriraj and RGN-236 × Vardan were found stable. For seeds per siliqua, the parental genotype RGN-236 as well as the hybrids RH-749 × Vardan, BPR-541-4 × NRCHB-101, JD-6 × NRCHB-101 and RH-749 × NRCHB-101 were found to be stable across environments. Test weight is a very important yield attributing trait which is directly affected by heat stress (Sharma & Sardana, 2013, Bhagirath Ram *et al.*, 2014). The parents PM-26, RH-406 and the F_1s PM-28 × NRCHB-101, RH-406 × NRCHB-101 and JD-6 × Giriraj were found stable for the same. The hybrids PM-28 × NRCHB-101, RGN-229 × Vardan, PM-26 × Giriraj, PM-26 × NRCHB-101 and RH-749 × Vardan were revealed stable across the environments for seed yield per plant. Considering oil content, the hybrids RGN-236 × NRCHB-101, JD-6 × NRCHB-101, RH-406 × NRCHB-101, PM-28 × Vardan and NRCDR-02 × Vardan exhibited stable and superior performance over the population mean. Lastly, looking into oil yield, the parent Giriraj and the F_1s JD-6 × NRCHB-101, BPR-541-4 × Giriraj, PM-28 × Vardan and RGN-236 × NRCHB-101 emerged out to be stable genotypes for all the 6 environments. Since increasing oil yield is the ultimate aim of any rapeseed-mustard breeding program, these genotypes can be suggested for the same. Several researchers have conducted stability analysis in rapeseed-mustard group of crops and similar findings have been reported by Z.A. Dar *et al.,* (2013) in brown sarson; Kumari *et al.,* (2010) in Eithopian mustard; Priyamedha *et al.,* (2017), Bibi *et al.,* (2016), Muralia *et al.,* (2013), Chauhan *et al.,* (2010) and Yadav *et al.,* (2010) in Indian mustard.

Conclusion

From the present investigation, it can be concluded that the genotypes JD-6, PM-26, RGN-236, RH-406 and Giriraj, which were found stable for plant height, primary branches & test weight, seeds per siliqua, test weight and oil yield respectively, could be further utilized as parental genotypes in hybrid breeding programs and to breed high yielding genotypes adapted to/tolerant to terminal heat stress. On the other hand, the hybrids such as PM-28 × NRCHB-101, JD-6 × NRCHB-101, PM-28 × Vardan, RH-406 × NRCHB-101, RH-749 × Vardan and RGN-236 × NRCHB-101, which were found stable for more than a single character simultaneously, could be subjected to generation advancement for developing stable varieties across the environments.

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