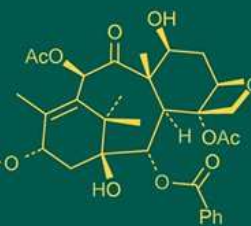
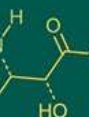
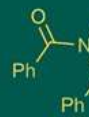
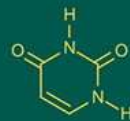
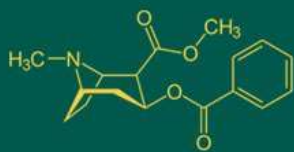


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Stability analysis in Indian mustard

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Abstract

An investigation was carried out to estimate the stability parameters for seed yield and its component characters and to identify stable genotypes among a set of Indian mustard genotypes timely sown at four locations, namely Nagpur, Sindewahi, Amravati and Sakoli, during Rabi season 2025. Ten genotypes, including three check varieties, were evaluated in a Randomized Block Design with three replications at each location. Data were recorded for days to 50% flowering (on plot basis), days to maturity (on plot basis), plant height(cm), number of branches plant⁻¹, number of siliquae plant⁻¹, siliqua density on the main branch, 1000 seed weight (g) and seed yield plant⁻¹(g). Pooled analysis of variance revealed significant differences among locations, among genotypes and for the genotype by location interaction for all eight characters, indicating that the genotypes responded differently across the four locations. Stability analysis following the regression model of Eberhart and Russell showed the linear component of the environmental effect to be significant for seven of the eight characters, while the genotype by environment linear component was significant only for days to maturity and 1000 seed weight (g). Estimation of stability parameters, namely mean performance, regression coefficient and deviation from regression, showed that genotype ACN-237 combined a favourable mean, a regression coefficient close to unity and a deviation from regression close to zero for five of the eight characters studied. Genotypes ACN-226, ACN-250, DRMRJ-150-35 and NRCHB 101 each met the stability criteria for three characters, and ACN-308, Radhika and TAM 108-1 for two characters each. On the basis of these results, ACN-237 is recommended as the most stable genotype for cultivation across the Vidarbha region of Maharashtra under timely sown condition.

Keywords: Indian mustard, genotype × environment interaction, stability analysis, regression coefficient, Eberhart and Russell model

Introduction

Indian mustard (*Brassica juncea* L. Czern and Coss) is one of the most important oilseed crops of the Indian subcontinent, grown across a wide range of agro-climatic conditions during the *rabi* season. Because of this wide cultivation, the expression of seed yield and its component characters in a given genotype is governed not only by its genetic constitution but also by the environment in which it is grown, and by the interaction between the two. This genotype × environment interaction complicates the selection of genotypes for release, since a genotype performing well in one environment may not perform as well in another. Eberhart and Russell ^[1] proposed a regression-based model of phenotypic stability in which the regression coefficient (*b_i*), obtained by regressing a genotype's performance in each environment on an environmental index, and the deviation from regression (*S²_{di}*) are used together with the mean performance to characterise a genotype's stability. A genotype is considered stable under this model if it combines a high mean, a regression coefficient not differing significantly from unity, and a deviation from regression not differing significantly from zero.

Genotype × environment interaction and stability of yield and its component characters in Indian mustard have been examined by several workers under diverse growing conditions (2 to 12), who have consistently reported significant interaction and identified genotypes with wider or specific adaptability.

The present investigation was carried out to estimate the stability parameters for seed yield and its component characters and to identify stable genotypes among a set of Indian mustard genotypes evaluated at four locations under the first date of sowing.

Materials and Methods

The experimental material comprised ten genotypes of Indian mustard, seven test entries (ACN-226, ACN-237, ACN-250, ACN-308, PM-26, Radhika and DRMRJ-150-35) along with three check varieties (NRCHB 101, Kranti and TAM 108-1). The genotypes were evaluated at four locations, namely Nagpur, Sindewahi, Amravati and Sakoli, under the timely sown conditions, during Rabi 2025. At each location the trial was laid out in a Randomized Block Design with three replications. Data were recorded on 5 randomly selected plants in each replication for plant height(cm), number of branches plant⁻¹, number of siliquae plant⁻¹, siliqua density on the main branch and seed yield plant⁻¹(g), and on a plot basis for days to 50% flowering, days to maturity and 1000 seed weight(g).

Analysis of variance was carried out separately for each location following the standard procedure for a Randomized Block Design. Pooled analysis of variance over the four locations partitioned the total variation into components due to locations, genotypes, genotype $\times$ location interaction and pooled error. Stability analysis was carried out following the regression model of Eberhart and Russell^[1], in which the mean performance, the regression coefficient (bi) of each genotype on an environmental index, and the deviation from regression (S²di) were estimated for every genotype and character. A genotype was considered stable if its mean was favourable, its regression coefficient did not differ significantly from unity, and its deviation from regression did not differ significantly from zero. Significance of the mean squares was tested against the pooled error by the F test at the 5% and 1% levels of probability, and significance of the regression coefficient against unity was tested by the t test.

Results and Discussion

Pooled analysis of variance (Table 1) revealed significant differences among locations for all eight characters, at the 1% level for seven characters and at the 5% level for days to maturity. Differences among genotypes were highly significant for all eight characters, confirming adequate genetic variability in the material evaluated. The genotype $\times$ location interaction was significant for all eight characters, highly significant for six and significant at the 5% level for plant height and number of siliquae plant⁻¹, indicating that the relative performance of the genotypes changed across the four locations. Significant genotype $\times$ environment interaction for yield and its component characters in Indian mustard has been reported earlier^[2, 3, 5, 6, 8, 9].

Since genotype $\times$ location interaction was significant for all characters studied, the data were further analysed for stability following the regression model of Eberhart and Russell^[1], the results are presented in Table 2. The

environment + genotype $\times$ environment component, when partitioned into linear and non-linear parts, showed the linear component of the environmental effect to be significant for seven of the eight characters, all except days to maturity, indicating that variation among the four locations followed a largely predictable, ordered pattern for these traits. The genotype $\times$ environment linear component was significant for two characters, days to maturity and thousand seed weight, showing that genotypes differed genuinely in their regression response to the environmental index for these two traits; for the remaining six characters this component was non-significant. The non-linear component, measured as the pooled deviation, was significant for two characters, days to 50% flowering and number of branches plant⁻¹, pointing to an unpredictable genotype response to the changing locations for these two traits, while it remained non-significant for the other six characters. For most characters the magnitude of the linear components was considerably larger than the non-linear pooled deviation, supporting the use of the regression model for predicting stability in this material, a pattern also noted in Indian mustard by Kalpande *et al.*^[12].

Estimates of the stability parameters, mean performance, regression coefficient (bi) and deviation from regression (S²di), are presented in Tables 3 and 4, and genotypes meeting the stability criteria for each character are summarised in Table 5. Applying the criteria described above, genotype ACN-237 was identified as stable for five of the eight characters studied, namely number of branches plant⁻¹, number of siliquae plant⁻¹, siliqua density on the main branch, 1000 seed weight and seed yield plant⁻¹, the largest number recorded among the genotypes evaluated. ACN-226, ACN-250, DRMRJ-150-35 and NRCHB 101 each met the stability criteria for three characters, and ACN-308, Radhika and TAM 108-1 for two characters each; PM-26 and Kranti did not meet the criteria for any of the eight characters. Similar identification of genotypes combining favourable mean performance with a stable regression response has been reported in Indian mustard^[2, 3, 6, 9, 10, 11, 12]. For seed yield plant⁻¹, the character of greatest direct economic value, ACN-237 recorded a mean of 8.75 g plant⁻¹ along with a regression coefficient not differing significantly from unity and a non-significant deviation from regression, confirming its stable performance across the four locations under the timely sown conditions. Identification of genotypes combining high seed yield with a stable regression response has similarly been reported in Indian mustard, including the recent report of Kalpande *et al.*^[12], who identified stable genotypes for seed yield among Indian mustard genotypes using the same Eberhart and Russell model.

Table 1: Pooled analysis of variance for eight characters in Indian mustard under timely sown conditions across four locations (Mean Sum of Squares)

Source	df	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Number of Branches Plant ⁻¹	Number of Siliquae Plant ⁻¹	Siliqua Density on Main Branch	1000 Seed Weight (g)	Seed Yield Plant ⁻¹ (g)
Locations	3	50.67**	64.36*	3462.83**	24.55**	160211.70**	0.1687**	15.69**	738.45**
Genotypes	9	69.19**	251.61**	862.16**	1.75**	1317.49**	0.0138**	2.82**	12.27**
Genotype x Location	27	23.75**	81.60**	156.76*	0.89**	163.65*	0.0032**	1.99**	3.89**
Pooled Error	72	4.25	22.84	85.38	0.19	93.31	0.0012	0.14	0.84

* and ** = Significant at 5% and 1% level, respectively.

Table 2: Analysis of variance for stability (Eberhart and Russell model) for eight characters in Indian mustard under timely sown conditions across four locations (Mean Sum of Squares)

Source	df	Days to 50% Flowering	Days to Maturity	Plant Height (cm)	Number of Branches Plant ⁻¹	Number of Siliquae Plant ⁻¹	Siliqua Density on Main Branch	1000 Seed Weight (g)	Seed Yield Plant ⁻¹ (g)
Environment + (G x E)	30	8.81**	26.63	162.46*	1.08**	5389.48**	0.0066**	1.12**	25.78**
Environment (Linear)	1	50.67**	64.36	3462.83**	24.55**	160211.70**	0.1687**	15.69**	738.45**
G x E (Linear)	9	5.04	51.99*	35.37	0.06	113.05	0.0007	1.70**	1.53
Pooled Deviation	20	8.42*	13.33	54.63	0.37*	22.77	0.0011	0.13	1.06
ACN-226	2	27.43**	14.40	89.16	0.13	55.45	0.0015	0.00	0.18
ACN-237	2	8.62	55.15	28.82	0.51	4.28	0.0003	0.07	0.86
ACN-250	2	4.55	7.75	19.77	0.07	4.70	0.0013	0.14	3.83*
ACN-308	2	2.90	0.75	157.40	1.73**	18.60	0.0009	0.34	0.11
PM-26	2	22.00**	18.73	14.80	0.21	21.11	0.0012	0.03	0.17
Radhika	2	5.99	2.55	22.66	0.27	55.25	0.0026	0.06	0.30
DRMRJ-150-35	2	1.41	7.09	12.57	0.21	2.93	0.0013	0.26	2.67*
NRCHB 101	2	4.10	4.25	20.14	0.01	15.71	0.0002	0.09	0.41
Kranti	2	6.97	17.03	7.57	0.38	28.72	0.0017	0.09	0.51
TAM 108-1	2	0.21	5.58	173.39	0.17	20.93	0.0003	0.25	1.60
Pooled Error	72	4.25	22.84	85.38	0.19	93.31	0.0012	0.14	0.84

* and ** = Significant at 5% and 1% level, respectively.

Table 3: Estimates of stability parameters (Mean, bi, S²di) for days to 50% flowering, days to maturity, plant height and number of branches plant⁻¹ in Indian mustard under timely sown conditions across four locations

Genotype	Days to 50% Flowering			Days to Maturity			Plant Height (cm)			Number of Branches Plant ⁻¹		
	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di
ACN-226	48.00	0.47	26.01**	108.83	2.91	6.79	171.29	1.13	60.69	4.78	0.97	0.07
ACN-237	44.33	1.91	7.21	100.83	5.93	47.54	159.57	0.21	0.35	5.41	1.21	0.45
ACN-250	49.58	0.14	3.13	115.25	1.39	0.14	190.87	0.75	-8.69	5.57	1.15	0.01
ACN-308	47.17	1.04	1.48	111.17	0.94	-6.87	177.11	1.07	128.94	5.13	0.70	1.67**
PM-26	45.17	2.92	20.58**	114.33	-2.04	11.12	169.00	1.21	-13.66	4.57	1.00	0.15
Radhika	49.00	-0.05	4.57	115.33	-2.94*	-5.06	167.36	1.13	-5.80	5.29	0.90	0.21
DRMRJ-150-35	44.67	1.39	-0.01	109.92	2.04	-0.52	175.28	1.24	-15.90	5.76	1.22	0.15
NRCHB 101	43.75	1.86	2.68	110.67	-0.96	-3.37	180.27	1.28	-8.32	5.15	0.98	-0.05
Kranti	50.67	0.11	5.55	115.25	-1.34	9.41	171.94	1.06	-20.89	4.88	0.84	0.31
TAM 108-1	46.33	0.22	-1.21	107.33	4.07	-2.03	168.49	0.93	144.93	4.78	1.03	0.11
Population Mean	46.87			110.89			173.12			5.13		

* and ** = Significant at 5% and 1% level, respectively.

Table 4: Estimates of stability parameters (Mean, bi, S²di) for number of siliquae plant⁻¹, siliqua density on main branch, 1000 seed weight and seed yield plant⁻¹ in Indian mustard under timely sown conditions across four locations

Genotype	Number of Siliquae Plant ⁻¹			Siliqua Density on Main Branch			1000 Seed Weight (g)			Seed Yield Plant ⁻¹ (g)		
	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di
ACN-226	150.22	0.89	24.35	0.6600	1.32	0.0011	5.55	0.84*	-0.04	9.02	0.98	-0.10
ACN-237	164.62	1.02	-26.82	0.7017	0.77	-0.0001	5.45	1.01	0.02	8.75	1.17	0.58
ACN-250	145.79	0.87*	-26.40	0.7058	1.16	0.0010	5.14	0.14	0.10	8.44	0.88	3.55*
ACN-308	176.29	1.11	-12.51	0.6358	1.10	0.0005	5.93	2.09	0.29	9.29	1.12	-0.17
PM-26	139.51	0.98	-9.99	0.6417	0.69	0.0008	4.57	0.82	-0.02	6.57	0.68*	-0.11
Radhika	151.93	1.10	24.15	0.6775	0.82	0.0022	5.06	0.59	0.02	7.27	1.06	0.03
DRMRJ-150-35	146.68	0.95	-28.17	0.6075	1.17	0.0009	4.47	-0.81*	0.21	6.41	1.05	2.39*
NRCHB 101	152.62	1.07	-15.40	0.6408	0.88	-0.0002	5.00	0.54	0.05	7.16	1.09	0.13
Kranti	147.73	1.04	-2.39	0.6125	1.12	0.0013	5.42	2.01	0.04	7.79	1.06	0.23
TAM 108-1	152.78	0.95	-10.18	0.6708	0.97	-0.0001	5.81	2.76*	0.20	8.16	0.92	1.33
Population Mean	152.82			0.6554			5.24			7.89		

* and ** = Significant at 5% and 1% level, respectively.

Table 5: Genotypes showing average, below-average and above-average stability for different characters under timely sown conditions across four locations

Sr. No.	Character	Average stability (suitable for all environments)	Below average stability (bi>1) (suitable for rich environment)	Above average stability (bi<1) (suitable for poor environment)
1	Days to 50% flowering	DRMRJ-150-35	—	TAM 108-1
2	Days to maturity	—	—	NRCHB 101
3	Plant height (cm)	ACN-250, DRMRJ-150-35, NRCHB 101	—	—
4	Number of branches plant ⁻¹	ACN-237, ACN-250, Radhika, DRMRJ-150-35, NRCHB 101	—	—
5	Number of siliquae plant ⁻¹	ACN-237, ACN-308	—	—
6	Siliqua density on main branch	ACN-226, ACN-237, ACN-250, Radhika, TAM 108-1	—	—
7	1000 seed weight (g)	ACN-226, ACN-237	—	—
8	Seed yield plant ⁻¹ (g)	ACN-226, ACN-237, ACN-308	—	—

PM-26 and Kranti did not meet the stability criteria for any of the eight characters studied.

Conclusion

Under the timely sown conditions across the four locations, seed yield and its component characters in Indian mustard were significantly influenced by location, by genotype and by their interaction. Genotype ACN-237 combined a favourable mean, a regression coefficient close to unity and a deviation from regression close to zero for five of the eight characters studied and is recommended as the most stable genotype among the material evaluated for cultivation across the locations represented in this study. Genotypes ACN-226, ACN-250, DRMRJ-150-35 and NRCHB 101, each stable for three characters, and ACN-308, Radhika and TAM 108-1, each stable for two characters, may also be considered for further evaluation and multi-location testing.

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