Int.J.Curr.Microbiol.App.Sci (2021) *10*(11): 133-141

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 11 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1011.017

Phenotypic Stability Analysis for Seed Yield and its Associated Traits in Advanced Lines of Indian Mustard (*Brassica juncea* L. Czern and Coss)

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Keywords

Indian mustard, G X E interaction, Phenotypic Stability

Article Info

Received:
05 October 2021
Accepted:
29 October 2021
Available Online:
10 November 2021

ABSTRACT

"Phenotypic Stability Analysis for Seed Yield and its Associated Traits In advanced lines of Indian Mustard (*Brassica juncea* L. Czern and Coss)" was carried out to study the effects of different environments on seed yield and its associated traits, to estimate the magnitude of Genotype x Environment interaction and to find out the most stable and high yielding genotype among the selected lines of Indian mustard under different environments of different topography, soil texture and prevailing climatic conditions of Manipur. Fifteen genotypes were evaluated in 3 different locations (Andro, Iroisemba and Senapati) in RBD with 3 replications over two seasons *viz*; *Rabi* 2018-19 and 2019-20. The environment wise ANOVA revealed highly significant differences among all the genotypes studied for all the 11 characters of seed yield and its associated traits. The pooled ANOVA also indicated significant differences among the environments, genotypes as well as genotype by environment (GXE) interaction for all the traits. Genotype X Location interaction was observed as the main component for GXE interaction. Genotypes performed better in 2019-20 *rabi* season as compared to *rabi* 2018-19. Environment (E-5) i.e. Iroisemba, valley area was the best for expression of most of the characters studied. Stability Analysis using Eberhart and Russell indicated the significance of GXE (linear) for no. of siliqua/plant, no. of seeds/siliqua, siliqua length, no. of primary branches, no. of secondary branches, days to first flowering, days to 50% flowering, days to 80% maturity and 1000 seed weight except for plant height and seed yield per plot which shows the substantial amount of predictable G X E interaction for the expression of these characters in the selected genotypes. All the 15 genotypes were tested for 3 stability parameters, *viz* mean, bi and S^2 di. The genotypes CAURMM-3, CAURMM-4, CAURM- 5, CAURM-4, PM-25, CAURMM-1 and JM-1 were identified to be the high yielding and stable, hence they can be recommended for general cultivation under varied environments of Manipur. CAURM-1 CAURM-2, CAURM-3 had more stable characters although their yield was below the population mean, Therefore, proposed as promising genotypes for general cultivation under intensive input supply as they performed best in favourable environments, while NRCHB 101 found to be suitable for cultivation under poor environments.

Introduction

In Manipur, Rapeseed mustard is one of the leading oil seed crop grown after harvest of rice. However, the production and productivity of this important oil yielding crop in the North-East region, Manipur in particular, is still far below the requirement. Several reasons are responsible for low productivity; the important one is unavailability of high yielding varieties with shorter and better stability and use of semi glutinous longer duration rice varieties that occupies the land up to November end resulting into limited land preparing period for *rabi* crops. Hence there is need for increasing the productivity of this crop through breeding of high yielding and stable varieties preferably with shorter maturity. The enhancement in production and productivity of the crop assumes significance, not only for farmer's viewpoint but also for all closely linked enterprises. Thus, there is compelling need to increase and stabilize the productivity of Indian mustard varieties to meet the growing demands for edible oil.

With these facts in view, the current research work was carried out to study the effects of different environments on seed yield and its associated traits, estimate the magnitude of Genotype x Environment interaction and to find out the most stable high yielding one among the selected lines of Indian mustard under different environments.

Materials and Methods

The experimental material comprising of fifteen genotypes of Indian mustard, they were evaluated in randomised block design with three replications and spacing of 30cm X 10cm during two consecutive *rabi* seasons under six environments namely; 2018-19(Andro, Iroisemba, Senapati), 2019-20(Andro, Iroisemba, Senapati) spread over different agro-climatic zones of Manipur. The sowing was completed during the second week of November at all the locations during each year and all crop management practices were followed to raise the crop.

Observations were recorded on ten randomly selected plants from each genotype in each replication with respect to nine qualitative traits. The stability parameters for different traits were computed using Eberhart and Russell model (1966).

Results and Discussion

The analysis of variance for pooled data indicated significant difference among the genotypes for all the eleven traits studied (Table1) revealing that there was inherent variability among the fifteen genotypes. Significant mean squares due to environments for all the eleven characters revealed that the six environments were variable hence played a significant role in the expression of eleven characters in the selected genotypes. Significant mean squares due to genotype X environment interactions confirmed the differential performance of Indian mustard genotypes across environments for all the eleven characters. Therefore, proved to be the Genotype × Environment (G×E) interaction effects are of special interest for identifying the most suitable genotypes with respect to target environments, representative locations and other specific stresses.

Eberhart and Russell model (1966) reported that both linear and non-linear components are important for determining the differential genotypic response to different environmental conditions. Significant mean square due to environment linear for all the eleven traits studied indicated the presence of predictable differences over six environments. This could be attributed to variation in weather and soil conditions over different locations.

Significant mean square due to genotype X environment (linear) for no. of siliqua/plant, no. of seeds/siliqua, siliqua length, no. of primary branches, no. of secondary branches, days to 80% maturity and 1000 seed weight revealed a predictable differential response of genotypes across environments. While unpredictable response was observed for the characters plant height and seed yield per plot. Similar findings of significance variance for genotype x environment in Indian mustard has also been observed by Chauhan *et al.,* (2010), Yadava *et al.,* (2010), Sagolsem *et al.,* (2013) Singh *et al.,* (2016), Priyamedha *et al.,* (2017) and Kumari *et al.,* (2019). Also by Tadesse *et al.,* (2018) in Ethopian mustard; Rezaizad *et al.,* (2018), Brown *et al.,* (2019) and Puhl *et al.,* (2019) in oil seed rape.

Eberhart and Russell model 1966 suggested that an ideal genotype may be characterised as having high mean performance with unit regression coefficient (b=1) and non-significant deviation from linear regression (s^2di=0).

Accordingly the mean and deviation regression (s^2di=0) are considered as measures of stability and regression coefficient is used for evaluating the genotypic response.

The genotype having regression coefficient (bi) value significantly above 1.0 (b>1) will have below average stability and specifically adapted to favourable environments as they are highly sensitive to changing environments. Regression coefficient significantly below 1.0 (b<1) are genotypes having above average stability and they are well adapted to unfavourable environments.

Based on stability parameters (table 2a and 2b), genotypes CAURM-4, CAURMM-1, CAURMM-3, CAURMM-4, CAURM-5, PM 25, JM-1 and CAURM-2 were having bi value near to unity, S^2di=0 and mean above or at par with population mean for seed yield per plot, hence they are stable and can be recommended for general cultivation in Manipur. However genotypes CAURM-1, CAURMM-2 and CAURM-3 had bi values near unity and mean values significantly lower than the population mean, thus these genotypes can be recommended for wide adaptation and cultivated under intensive input application as they were performing better in favourable environments. While NRCHB 101 had bi value significantly lower than unity and mean value above the population mean hence it was specifically adapted to unfavourable environments.

Based on the results, it appeared that no genotype could be found stable simultaneously for all characters across the environments. Each genotype was stable for one or more traits.

Thus, it is concluded that while selecting for stability in seed yield, various yield associated traits should also be taken into consideration. In the present study, CAURM-4, CAURMM-1, CAURMM-3, CAURMM-4, CAURM-5, PM-25, JM-1, CAURM-2, CAURM-1, CAURMM-2 and CAURM-3 were having average stability with similar mean performance which could be considered as ideal genotypes for seed yield per plot while NRCHB 101 can be considered for unfavourable environments.

Five genotypes *viz*; CAURMM-1, CAURMM-2, PM 25, NRCHB 101 and Kranti were stable for days to 80% maturity. Such genotypes matures within 115 days. Because of their shorter duration, they may be recommended for inclusion in the rice based cropping system in Manipur under wide cultivation. Early maturing genotypes of oilseed and pulses will solve the problems of low output of mustard cultivation facing by the farmers after longer maturity rice varieties.

Table.1 Analysis of Variance (mean sum of squares) for phenotypic stability different characters in 15 Indian mustard genotypes (Eberhart and Russell, 1966).

		Mean Sum of Square								
Source of Variation	**df**	**Days to 80% maturity**	**No. of primary branches**	**No. of Secondary branches**	**Plant height (cm)**	**No. of siliqua/ plant**	**Siliqua length (cm)**	**No.of seeds /siliqua**	**1000 seed weight(g)**	**Yield/plot (kg)**
Genotype(G)	14	88.61**	11.26**	50.60**	753.39**	46507.45**	2.02**	7.34**	4.29**	286555.47**
E+(gxe)	75	41.72**	0.69*	13.31**	223.79**	8491.60**	0.14**	2.33**	0.48**	111467.65**
E (linear)	1	1650.21**	12.88**	444.06**	7540.37**	224195.75**	2.15**	103.09**	15.02**	5736204.74**
g x e (linear)	14	46.48**	0.85*	12.28*	83.67ns	13625.15**	0.23**	1.72**	0.49*	22662.07ns
pooled deviation	60	13.79**	0.45**	6.37**	134.55**	3698.71**	0.09**	0.79ns	0.24ns	38443.33*
Pooled error	168	5.55	0.16	2.08	37.37	897.22	0.04	0.59	0.19	25850.51

Table.2a Stability parameters for seed yield and its associated traits in 15 Indian mustard genotypes

Genotypes	Days to 80% maturity			No. of primary braches per plant			No. of secondary braches per plant			1000 seed weight (g)		
	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di
CAURM-1	116.94	0.98	31.31**	3.44	0.76	0.18	5.24	0.90*	-0.80	3.80	0.35	0.18
CAURM-2	115.33	1.36**+	-4.44	3.60	0.38	0.25*	6.04	0.88	4.41*	4.25	2.56**+	-0.04
CAURM-3	114.44	1.80**+	-1.22	3.70	0.31	-0.01	6.35	0.93	4.93*	4.38	1.55*	0.03
CAURM-4	117.50	0.94	21.98**	3.78	0.38	0.37*	8.09	1.16**	-0.27	4.24	0.70	-0.08
CAURM-5	119.67	-0.28+	9.75*	3.54	0.61	-0.07	5.84	0.75*	-1.14	4.92	0.59	0.08
CAURMM-1	118.44	1.33**	-3.33	5.52	1.92**	-0.01	11.18	1.00	14.07**	2.82	0.83	0.60**
CAURMM-2	118.67	1.03*	0.23	7.69	3.44	3.97**	14.12	1.91	48.80**	2.21	0.32	0.40*
CAURMM-3	105.72	2.07*	44.38**	3.94	0.35	-0.13	7.07	0.70	-0.09	4.39	0.66	-0.09
CAURMM-4	113.06	1.33*	11.53*	3.56	0.18	-0.10	7.02	0.67*	-1.34	4.55	1.77*	0.02
NRCHB-101	114.89	1.74**	3.54	3.32	0.91*	-0.10	5.45	0.74*	-1.26	4.57	1.60**+	-0.14
PM 25	114.44	0.77	5.68	3.42	0.51*+	-0.14	6.84	0.69*	-0.80	3.89	0.84	0.06
Kranti	117.67	0.87**	-4.21	3.75	0.77	-0.04	6.13	0.67*	-1.40	3.80	1.33*	0.02
Basanti	118.61	0.67**++	-5.25	3.69	0.80	-0.07	6.81	0.54*+	-1.38	3.69	1.09**	-0.16
JM-1	119.56	0.10+	3.12	3.53	0.62	-0.09	6.80	0.43+	-1.17	3.25	1.07*	-0.04
CAULC-1	122.11	0.24	10.56*	6.98	2.99*	0.47**	14.02	2.96**++	1.87	2.15	-0.32++	-0.16
Mean	116.47			4.23			7.80			3.79		

*, ** bi and S2di values significantly deviated from 0 at 5% and 1% levels respectively.
+, ++ bi value significantly deviated from unity at 5% and 1% levels respectively.

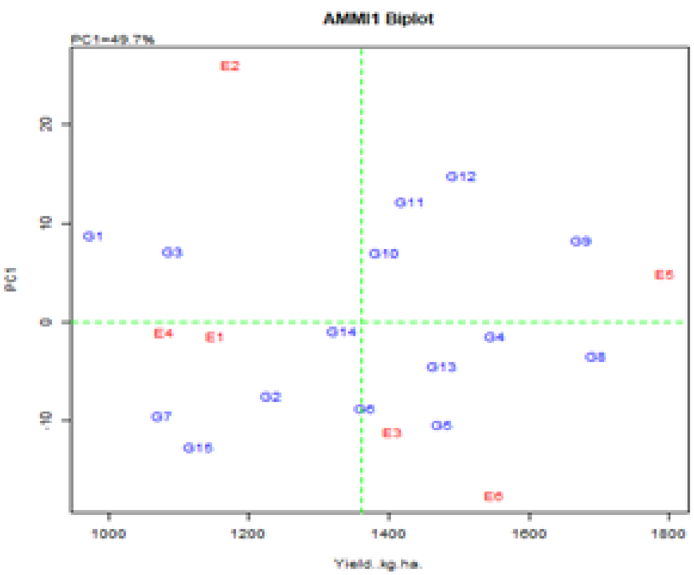
Table.2b Stability parameters for seed yield and its associated traits in 15 Indian mustard genotypes

Genotypes	Plant height (cm)			No. of siliqua per plant			Siliqua length (cm)			No. of seeds per siliqua			Seed yield per plot (kg)		
	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di
CAURM-1	134.96	1.54	645.79**	148.62	0.68	1510.32*	5.23	0.82	-0.02	13.24	0.92*	-0.27	978.66	0.66*	-9227.83
CAURM-2	133.17	1.32**	-2.13	132.85	0.53	-31.90	5.86	1.32**	-0.03	12.69	1.39*	0.12	1231.41	1.20**	-1592.89
CAURM-3	132.84	1.66**	3.625	142.31	0.09	-358.23	5.28	0.38	-0.01	12.77	0.93*	-0.02	1091.93	0.84	16278.26
CAURM-4	134.79	0.89	16.63	170.76	0.63*	-581.52	5.33	0.89*	-0.03	13.33	0.96	1.73**	1551.60	1.15**	-12232.90
CAURM-5	142.01	1.13**	-20.53	150.00	0.57*+	-594.66	5.58	2.46*	0.01	14.15	0.52	-0.21	1474.47	0.99	28191.86
CAURMM-1	147.19	1.39	162.41**	345.42	2.96*	13753.28**	4.62	0.33	0.27**	11.56	0.43	0.70	1364.91	1.37**	-3976.99
CAURMM-2	136.63	0.93*	-6.51	346.63	2.39	15279.65**	4.21	-0.73	0.03	11.46	0.84	0.49	1077.10	1.23*	8175.27
CAURMM-3	121.55	0.78**	-26.58	152.25	0.48*++	-720.91	6.08	4.64	0.55**	14.16	2.03*	1.33*	1694.82	1.22**	-5278.7
CAURMM-4	119.42	1.01	78.71*	154.84	0.46	-126.94	5.65	1.43*	-0.02	14.77	0.39**++	-0.57	1674.21	1.05*	11094.29
NRCHB-101	138.73	0.36	39.68	131.88	0.75**	-515.43	5.72	0.01	-0.02	13.66	1.513**+	-0.42	1393.89	0.51*+	-16617.9
PM 25	124.34	1.40*	56.74*	143.24	0.46*++	-739.71	5.74	1.61**	-0.023	14.77	0.17+	-0.34	1429.00	0.66	14092.94
Kranti	150.48	0.68	104.91**	166.36	0.63*	-506.96	5.35	0.65	0.08*	13.69	1.23*	0.27	1502.25	1.05	53258.38*
Basanti	151.51	0.66	80.53*	187.60	0.54	-313.27	5.16	0.398	-0.02	14.35	1.28*	0.091	1475.24	1.13	65427.55**
JM-1	158.98	0.31	66.98*	163.82	0.76**	-710.51	5.53	0.71*	-0.03	13.19	1.473**	-0.37	1332.36	1.05**	-21171.2
CAULC-1	140.28	0.90	257.25**	393.86	3.03*	16679.32**	4.08	0.04	-0.02	11.60	0.87	0.36	1127.80	0.91	62472.16*
Mean	137.79			195.36			5.29			13.29			1359.98		

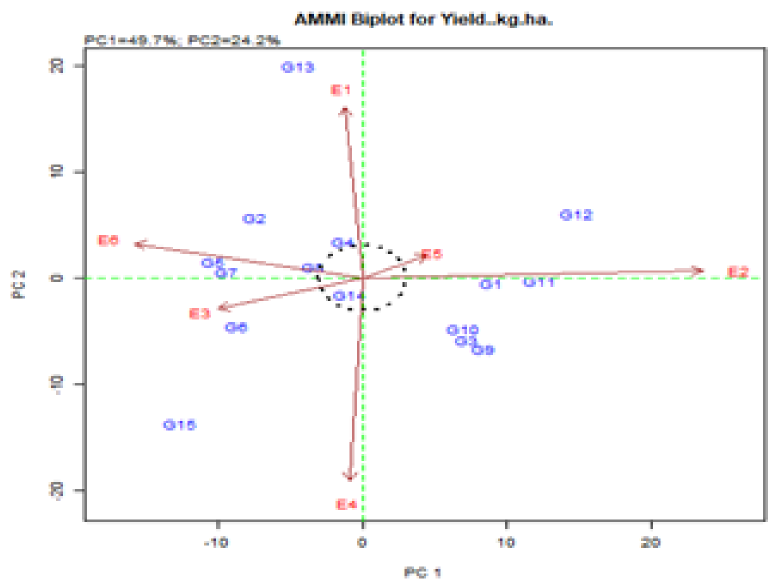
*, ** bi and S2di values significantly deviated from 0 at 5% and 1% levels respectively.
+, ++ bi value significantly deviated from unity at 5% and 1% levels respectively

Fig.1 AMMI biplot for Seed yield per plot in six environments

AMMI 1 Biplot



AMMI 2 Biplot



Genotypes:

						E1- Andro (Rabi2018)	
G1-	CAURM-1	G6-	CAURMM-1	G11-	PM25	E2- Irosemba(Rabi 2018)	
G2-	CAURM-2	G7-	CAURMM-2	G12-	Kranti	E3- Senapati(Rabi 2018)	
G3-	CAURM-3	G8-	CAURMM-3	G13-	Basanti	E4- Andro (Rabi2018)	
G4-	CAURM-4	G9-	CAURMM-4	G14-	JM-1	E5- Irosemba (Rabi 2018)	
G5-	CAURM-5	G10-	NRCHB-101	G15-	CAULC-1	E6- Senapati (Rabi 2018)	

Seven genotypes; CAURM-1, CAURM-3, CAURM-5, CAURMM-3, CAURMM-4, Kranti, Basanti and JM-1 were stable genotypes for no. of primary branches per plant. Eight genotypes; CAURM-4, CAURM-1, CAURM-5, CAURMM-3, CAURMM-4, PM-25, NRCHB 101 were stable genotypes for no. of secondary branches per plant. Seven genotypes *viz*; CAURM-2, CAURM-3, CAURMM-2, CAURM-4, NRCHB 101, CAURM-5, and CAURMM-3 exhibited stability for plant height. Eight genotypes; CAURM–2, CAURM-3, CAURMM-4, Basanti, CAURM-4, NRCHB-101, Kranti and JM-1 were stable for no. of siliqua/plant. Ten genotypes CAURM-2, CAURM-4, CAURM-5, CAURMM-4, NRCHB-101, PM-25, JM-1, CAURM-1, CAURM-3 and Basanti exhibited average performance and stability for siliqua length. Seven genotypes *viz;* CAURM-5, Kranti, Basanti, CAURM-1, CAURM-2, CAURM-3 and JM-1 were stable genotypes for no. of seeds per siliqua. Ten genotypes *viz*; CAURM-1, CAURM-4, CAURM-5, CAURMM-3 and PM-25, CAURM-3, CAURMM-4, Kranti, Basanti and JM-1 were stable characters for 1000 seed weight. Based on the desirability characters, such stable genotypes can be selected and recommended to be involved in breeding programmes to develop high yielding and stable genotypes.

AMMI stability Analysis (Fig. 1)

AMMI Analyisis of Variance has indicated that the proportion of variation due to environment was highest for no. of seeds per siliqua and seed yield per plot indicating highly significant difference among environments for the expression of these traits. AMMI1 biplot and AMMI 2 biplot revealed that the six environments were unstable except E-5 which was stable for seed yield per plot; hence it is a desirable environment for the character seed yield per plot as it was stable and had highest seed yield per plot. Genotypes CAURM-4, CAURMM-3 and JM-1 were the most stable genotypes for seed yield per plot, while all other genotypes were relatively stable except for Kranti, Basanti and CAULC-1 which were unstable as indicated by their scattering away from the point of origin. (Fig. 1)

Environmental Grading on the performance of Genotypes

Grading environments according to their performance revealed that the best environment was E-5. This could be attributed to the climatic conditions such as annual average rainfall of 1469.7mm, cooler temperature, soil type (alluvial to loam black soils) and topography (valley) etc. of the location.

Magnitude of GXE

For seed yield per plot; genotypes Basanti, Kranti and CAULC1 had the highest magnitude of interaction with environments. While genotypes; JM-1, CAURM-4 and CAURMM-3 exhibited the lowest magnitude of interaction with environments, this implicates that these three genotypes viz; Basanti, Kranti and CAULC1 had highest differential performance across environments. EnvironmentsE-4, E2, E-6 and E-1 exhibited higher magnitude of interaction with genotypes. While E-5 and E-3 revealed lowest magnitude of interaction with the selected genotypes.

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How to cite this article:

Danisa Dube, Th. Renuka Devi, Ph. Ranjit Sharma and Singh, N. B. 2021. Phenotypic Stability Analysis for Seed Yield and its Associated Traits in Advanced Lines of Indian Mustard (*Brassica juncea* L. Czern and Coss). *Int.J.Curr.Microbiol.App.Sci.* 10(11): 133-141.
doi: https://doi.org/10.20546/ijcmas.2021.1011.017