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Stability analysis in Indian mustard

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Abstract
An experiment was conducted for estimating the stability parameters for yield and its related traits and identifying the stable genotypes in Indian mustard. Eleven elite genotypes along with 4 checks were evaluated during winter season (*rabi*) 2019-20 and 2020-21 at three different environments in 4 replications. Analysis of variance was estimated individually and pooled over the years for 5 characters *viz*. days to 50% flowering, number of branches plant^{-1}, plant height, number of siliquae plant^{-1} and seed yield plant^{-1}. Estimate of environment wise analysis of variance suggested the significant differences for all the characters in all six environments. Significant mean squares due to environments were also observed for all the traits under study showed that environments selected for study were random and different in agro-climatic conditions. Genotypes x y interactions were significant for all the characters. The genotype ACN-184 ranked second for seed yield and was observed to be ideally stable for seed yield plant^{-1}, number of siliquae plant^{-1} and number of branches plant^{-1} whereas genotype ACN-141 was ranked first for seed yield and stable for number of siliquae plant^{-1} and seed yield plant^{-1}.

Keywords: stable genotype, genotype x environment interaction, Mustard, Stability

Introduction
Rapeseed-Mustard is an important oilseed crop and is being cultivated in 53 countries over the six continents of the world. In Asia, it is particularly cultivated in India, Pakistan, China and Bangladesh. In India, it is the second essential edible oilseed crop and has important share in the India‟s oilseed economy. Rapeseed mustard is being cultivated in Indian states particularly in Uttar Pradesh, Rajasthan, Haryana, Assam, Gujarat, Punjab, West Bengal and Madhya Pradesh. It is major oilseed crop of these states. Mustard seed contain 33 to 40% oil and is mainly used for cooking as well as frying purpose throughout Northern and Eastern India. Mustard oil is nutritional superior than other edible oil due to low level of saturated fatty acid, moderate level of poly unsaturated fatty acid and balance amount of omega-3 and omega-6 fatty acid. Mustard oil is utilized as raw material for various industrial products like paints, soap, lubricant etc. Mustard oil is used in preparation of vanaspati ghee, hair oils and also utilized in bakery, tea industries etc. Oil cake is used row material in biodiesel production and in tanning industries for softening leather. Therefore, it is necessary to increase the mustard production under diverse environmental conditions of India. Number of high yielding varieties has been developed in mustard but none of the variety can give good yield consistently in diverse environmental condition. Hence, it is essential to judge the stable yield performance of genotypes under different environment. The stable genotypes show minimum interaction with environments in which they are sown. Lack of stability of genotypes in production may be the major factor responsible for low productivity than low yield potential of genotype. Several statistical models have been used to estimate the stability of different genotypes over the fluctuating environments. These are the Eberhart and Russell (1966) [2], Perkins and Jinks (1968) and Freeman and Perkins (1971). Eberhart and Russell model is more informative and simple than other model. Therefore, this model is mostly used for asses the stability.
In Maharashtra, mustard is minor oilseed crop and is being grown in Vidarbha, Konkan and Marathwada region of Maharashtra. The most of the farmers of eastern Vidarbha region of Maharashtra grow late or mid late varieties of paddy and harvest up to last week of November. Mustard crop sow at second week of November to first week of December. In western Vidarbha, after harvesting of soybean, mustard crop grow in the first forth night of November. The major constrains in achieving higher yield of mustard in Vidarbha region of Maharashtra is absence of variety suitable to different cropping systems and environments. Hence, it is essential to develop varieties which suit to local conditions of Vidarbha region of Maharashtra.

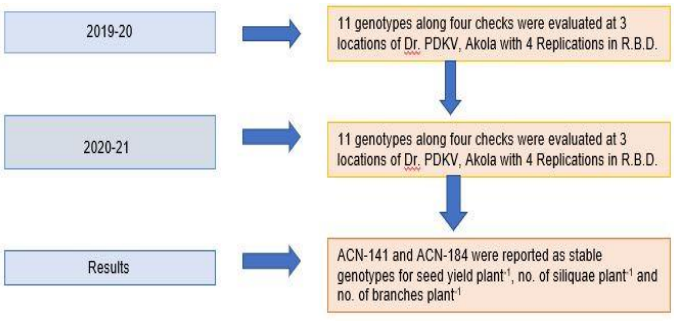
Hence, the present study was designed to assess the genotype x environmental interaction in mustard genotypes which are developed by selection from segregating generation of inter varietal crosses.

Materials and methods

The present research was conducted at three diverse locations viz. Research farm of All India Co-ordinated Research Project on Rapeseed and Mustard, College of Agriculture, Nagpur, Experimental farm of Agricultural Research Station, Washim and Experimental farm of Regional Research Center, Amravati. The material for present study consisted of 11 genotypes (ACN-141, ACN-184, ACN-201, ACN-243, ACN-212, ACN-214, ACNMM-3, ACNMM-15, ACNMM-14, ACNMM-12 and ACNMM-23) along with four checks (Shatabdi, Kranti, BIO-902, TAM-108-1)

Eleven genotypes along with four checks were evaluated in randomized block design in 4 replications during the year 2019-20 and 2020-21 with plot size of 4.5 m × 2.7 m^2. Each genotype was grown by keeping 45 cm distances between two rows and 10 cm between two plants in a plot. The data was reported on 5 seed yield and its contributing characters, *viz* days to 50% flowering, number of branches $plant^{-1}$, plant height (cm), number of siliquae $plant^{-1}$ and seed yield $plant^{-1}$ (g). The data for all the morphological characters was recorded on randomly selected 5 competitive plants in the middle 4 rows of each plot in all 4 replications except days to 50% flowering, where data was recorded on plot basis. The recommended package of practices for raising of mustard crop in Vidarbha region of Maharashtra was followed to raise a healthy crop.

The recorded data after calculating mean were subjected to analysis of variance as per the method prescribed by Panse and Sukhatme (1989). Significant genotype-environment interactions were observed for all the characters under study, hence the data were further subjected for assessing the stability of different genotypes as per the procedure prescribed by Eberhart and Russel 1966 [2]. A genotype was considered to be a stable genotype having regression coefficient of unity (bi =1) and the deviation not significantly different from zero (S^2 di = 0).



Results and Discussion

Analysis of Variance: A genotype can be taken as stable over environments if it gives high mean yield, has unit regression and least deviation around the regression slope (Eberhart and Russell, 1966) [2]. There are although many stability parameters, but Eberhart and Russell (1966) [2] model's parameter S^2di found to be very important for assessing the stability of genotype. Since the variance of S^2di is a function of number of environments therefore numerous environments along with minimum replications per environment are necessary to calculate reliable estimates of S^2di. In the present study, for each environment, analysis of variance for seed yield and its contributing characters was computed individually along with pooled over the years and locations. Analysis of variance showed the significant differences among genotypes for all the characters under study in each of the 6 environments. Pooled analysis of variance for 6 environments was also estimated to verify presence of G × E interactions is presented in Table 1.

Analysis of variance for genotype x environment interactions suggested that all the genotypes exhibited highly significant genetic variability for all the characters *viz.* days to 50% flowering, number of branches $plant^{-1}$, plant height (cm), number of siliquae $plant^{-1}$ and seed yield $plant^{-1}$ (g). Significant mean squares due to environments for seed yield and its contributing characters indicated that selected environments were random and having different agro-climatic conditions. Significant interaction of genotypes with the environment (G x E) were observed for seed yield and its contributing traits, hence genotypes performed differently for all the characters under study at different locations (Table 2). Naazar *et al.* (2002) observed the significant mean squares for genotype and environment interaction when 12 winter type rapeseed varieties of *B. napus* evaluated at 10 locations for estimating stability parameters. Partitioning of environment + (G x E) interaction into Environment (linear), G x E (linear) and pooled deviation showed that significant mean square due to environment (linear) for all characters under study, indicated that significant differences were present between environments and had exhibited the considerable influence on expression of seed yield and its contributing characters. G (genotypes) x E (linear) was significant for the days to 50 per cent flowering, number of branches $plant^{-1}$, plant height (cm) and number of siliquae $plant^{-1}$ while non-significant for seed yield $plant^{-1}$(g) also confirmed divergent linear response to environmental changes. Significant variation due to genotype x environment (linear), genotype (G) and environments (E) were observed for yield and its component characters by Dharmendra and Mishra (2003) [4] and advised that significant G x E interactions (linear) causes differential response of the varieties to changing environments. Yadava *et al.* (2010) [15] evaluated 30 varieties of *B. juncea* under rainfed and irrigated situations for two years and reported significant variance due to genotypes x environments (linear) for seed yield and various yield contributing traits. Significant G x E (liner) for yield and associated characters was observed by Chaudhary *et al.* (2004) [3] and Brar *et al.* (2007) [1] in Indian mustard. The mean squares due to pooled deviation (non-linear) were observed to be significant for seed yield and its component traits, suggesting that the non-liner component was important for characters which contributed to total G x E interaction. Hence, the genotypes showed variations in stability for the studied over the environments. Significant mean squares for pooled deviation (non-linear) was also recorded by Jakhar and Yadav (2010) [5] for seed yield and various yield contributing characters while evaluating 30 genotypes of taramira at three environments to estimate the stability parameters. The significant mean squares due to pooled deviation (non-linear component) was also reported by Sah *et al.* (2015) [9] for the traits under study and observed the non-linear response of genotypes to the changing environment. Similarly, Quddus *et al.* (1991) [7] observed significant linear and nonlinear components of genotype x environment interaction in 10 genotypes of *B. campestris* for 5 yield and its contributing characters when grown over six years.

Stability Parameter

The genotypes having regression coefficient value of unity (bi=1), non-significant deviations from linear regression deviation (S^2di =0) along with higher mean values were considered to be stable for the traits and showed adoptability to variety of environmental conditions was used as criteria for selection of stable genotype in the present study. Similarly, genotypes having regression coefficient near to unity, higher mean value along with non-significant deviations from linear regression were considered as suitable and approachable for favorable environmental conditions. While, the genotypes along with higher mean, regression coefficient less than one or negative and non-significant deviations from linear regression were classified as responsive and fit for poor environmental conditions. According to these criteria, genotypes understudy were grouped into different classes which fit for varied environmental condition.

None of the genotypes having lower mean than population mean, regression coefficient value of unity (bi=1) and non-significant deviations from linear regression deviation (S^2di =0) for days to 50% flowering, while among the checks, only Kranti had lower mean (48.92 days) than population mean (49.81 days) and non-significant deviation from regression (S^2di =0) along with regression coefficient less than unity. Hence, check Kranti found to be fit for favorable environment. In accordance to these result, Shekhawat (2020) [14] also identified stable genotypes for days to 50% flowering in mustard. None of the genotypes possessed regression coefficient less than one (unity) or negative and non-significant deviations from linear regression for plant height. Therefore no genotypes were considered as stable for this trait.

For number of branches plant^{-1} eight genotypes ACN-141 (6.11), ACN-184 (5.36), ACN-201 (5.52), ACN-243 (5.31) ACN-212 (5.46), ACN-214 (5.78), ACNMM-12 (5.33) and ACNMM-23 (5.57) showed higher mean than the population mean (5.28). Among these eight genotypes, non-significant deviation from regression along with regression coefficient about unity observed in three genotypes *viz*., ACN-184 (5.36), ACN-212 (5.46) and ACNMM-12 (5.33). Thus, these genotypes exhibited their fitness for average environment. Similar findings were also reported by Sagolsem *et al.* (2013) [8], Sah *et al.* (2015) [9] and Shekhawat (2020) [14] in mustard and identified stable genotypes for number of branches plant^{-1}.

For the trait, number of siliquae plant^{-1}, ACN-141 (222.85) and ACN-184 (223.63) exhibited non-significant regression co-efficient but closer to unity and non-significant S^2di hence these genotypes were identified as stable genotype. Priyamedha *et al.* (2017) [11], Ram *et al*. (2016) [12], Sagolsem *et al.* (2013) [8] and Yadava *et al.* (2010) [15] also earlier reported stable genotypes for number of siliquae plant^{-1} in mustard.

The mean value for seed yield plant^{-1} ranged from 7.90 g (ACN-141) to 5.93 g (ACNMM-14) respectively with an average of 6.62 g is shown in table 3. The genotypes ACN-141, ACN-184, ACN-201 and ACN-214 exhibited high mean value, non-significant b_i but closer to unity and non-significant S^2di for seed yield plant^{-1} and hence these genotypes can be considered as stable genotype. Rashid *et al*. (2002) and Tahira (2013) identified stable genotype for seed yield plant^{-1} in mustard.

From overall study of stability parameters (Table 3) concluded that not a single genotype was ideally stable for all the five characters under investigation. The stability parameters for seed yield plant^{-1} exhibited that four genotypes *viz.* ACN-141, ACN-184, ACN-201 and ACN-214 were stable over the different locations over years. These genotypes showed higher mean seed yield plant^{-1}, non-significant deviation from regression and regression coefficient not deviating from one.

The genotype ACN-184 was found ideally stable for number of siliquae plant^{-1}, for number of branches plant^{-1} and seed yield plant^{-1} and it was the second ranking in terms of seed yield while the genotype for ACN-141 was found stable for number of siliquae plant^{-1} and seed yield plant^{-1}. Similarly, ACN-201 and ACN-214 genotypes were observed to be stable for seed yield plant^{-1}.

Table 1: Pooled Analysis of variance over two years for five yield contributing characters in mustard

Source of Variations	D.F	Mean sum of squares				
		Days to 50% flowering	Plant height (cm)	Number of branches plant^{-1}	Number of Siliquae Plant^{-1}	Seed Yield Plant^{-1}
Years	1	297.03**	20,827.04**	40.67**	116,234.24**	0.34**
Genotypes	44	321.81**	1,526.78**	27.70**	6,460.58**	26.49**
Genotype x Environments	44	28.52**	936.07**	5.86**	10,668.31**	7.40**
Pooled Error	264	2.74**	65.28**	0.47**	514.52**	0.60**

Note: **Significant at 1% and *Significant at 5%

Table 2: Analysis of variance (mean sum of squares) for genotype x environment interactions.

Sources of Variation	D.f.	Mean sum of squares				
		Days to 50% Flowering	Plant height cm.	No. of branches plant^{-1}	No. of siliquae plant^{-1}	Seed yield plant^{-1}
Variety	14	21.27**	358.90**	0.97**	1,785.82**	2.20**
Environments	5	639.74**	2,862.38**	57.46**	16,388.98**	55.87**
Var. X Envion.	70	6.16**	185.17**	1.12**	1,579.01**	0.90
Env +Var X Env	75	48.40*	363.65*	4.88**	2,566.34*	4.56**
Env (Linear)	1	3,198.71*	14,311.89**	287.31*	81,944.89*	279.34**
Env X Var (Lin)	14	11.78*	184.94**	3.39**	3,467.10**	0.91
Pooled Deviation	60	4.44**	172.88**	0.52**	1,033.18**	0.84**
Pooled Error	252	2.334	60.52	0.46	527.25	0.61

Note: **Significant at 1% and *Significant at 5%

Table 3: Estimates of stability parameters

Sr. No.	Genotypes	Days to 50%Flowering			Plant Height (cm.)			No. of Branches Plant^{-1}			No. of siliquae plant^{-1}			Seed yield plant^{-1}		
		Mean	Bi	S^2di	Mean	Bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	Bi	S^2di
1	ACN-141	51.25	0.84	16.13	171.48	0.77	15.43	6.11	1.63**	0.26	222.86	1.07	-13.17	7.90	1.01	0.54
2	ACN-184	51.33	0.48**	0.41	180.19	0.81	8.70	5.36	1.26	0.18	223.63	1.01	-117.34	7.75	1.27	-0.11
3	ACN-201	48.71	0.89	3.12	164.02	1.35	124.19*	5.52	1.36*	0.03	192.05	2.32**	276.75	6.65	1.07	0.34
4	ACN-243	46.83	0.89	5.07	168.97	1.41	207.52**	5.31	1.30	1.14**	180.89	1.52	2411.05**	6.92	0.84	1.05*
5	ACN-212	53.13	0.77	1.41	188.16	1.19	208.76**	5.46	1.05	-0.02	196.63	1.63	345.71	6.48	0.99	0.56
6	ACN-214	51.67	0.76	4.23	186.05	0.88	210.06**	5.78	1.51**	0.36	210.25	1.21	1213.71**	7.25	1.25	0.20
7	ACNMM-3	48.29	1.25	3.04	183.83	1.91*	69.07	4.97	0.95	0.21	207.99	1.97*	739.75	6.13	1.32	1.03
8	ACNMM-15	50.13	1.06	-0.42	167.10	0.97	124.68*	4.97	0.78	0.14	208.82	1.23	1916.03**	6.75	1.03	2.01**
9	ACNMM-14	49.75	1.17	2.76	170.53	1.28	21.41	4.95	0.85	0.34	169.69	0.27	8.87	5.93	0.90	0.16
10	ACNMM-12	48.25	1.15	4.65	167.34	0.11*	71.57	5.33	1.08	-0.02	204.07	0.45	1816.48**	6.08	1.09	1.26*
11	ACNMM-23	48.17	1.26	2.33	165.65	1.31	154.84*	5.57	1.34*	0.36	189.73	0.87	463.23	6.10	1.21	2.63**
12	Shatabdi	47.92	1.26	1.55	168.00	1.12	33.02	4.40	0.23**	0.46	166.61	0.60	130.54	6.26	0.50*	-0.10
13	Kranti	48.92	0.89	-0.36	170.10	0.77	352.22**	5.11	0.26**	1.73**	202.57	2.23**	4060.47**	6.17	0.93	0.00
14	BIO-902	50.21	1.26	4.89	170.04	0.71	329.95**	5.26	0.63*	0.49	180.71	0.07*	-43.19	6.38	0.70	0.09
15	TAM-108-1	52.75	1.09	9.05	172.71	0.42	434.76**	5.09	0.78	0.39	197.55	0.57	311.67	6.58	0.89	0.62
Population mean		49.81			172.94			5.28			196.93			6.62		

Note: **Significant at 1% and *Significant at 5%

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