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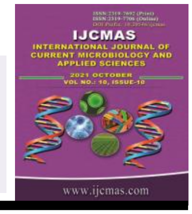

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Stability Analysis for Yield and it's Related Characters in Linseed (*Linum usitatissimum* L.)

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ABSTRACT

Thirty-six genotypes including eight parents and their 28 crosses developed in diallel fashion excluding reciprocals were used to studied their stability performance over six contrasting environments viz., early, normal and late sown under rainfed and irrigated conditions for seed yield and its contributing characters. Genotype x Environment interaction and Linear component of G x E interaction were showed significant for all the characters except plant height, secondary branches per plant and biological yield per plant under study. The parents Meera and PA2 showed stable performance for two characters and rest of the genotypes showed stable performance for one character over a range of environments under study. The cross Meera x RL13161 and RL15583 x KBA3 showed stable performance for seed yield and two crosses RL13161 x KBA3 and RL15583 x KBA3 showed stable performance for oil content and rest of four crosses showed stable performance for other characters.

Introduction

Linseed is one of the oldest and multipurpose crops used for oil, fiber and ingredient of different industrial products and medicines for curing of various diseases of human being and animals. In India linseed is mainly cultivated for its seed and oil. The low yield of linseed is characterized mainly due to lack of high yielding varieties and further irresponsiveness to better conditions and the instability in yield of linseed due to challenging environments are also great concern.

Stability performance is most desirable character of a genotype to be released as a variety for wider adoption for guaranteed return. Yield is a complex trait and is greatly influenced by environmental fluctuation; hence the selection for superior genotype based on yield *per se* at a single location in a year may not be very effective. Thus, varietal stability of paramount importance for stabilizing the production over regions and seasons. Stability has been used by various researchers (Eberhart & Russell 1966, Finley & Wilkinson 1967) to decide whether the performance of a genotype was satisfactory.

There are many methods that can be utilized for stability studied by various workers earlier. However, this information is lacking in linseed, hence the present investigation was undertaken to determine the environmental response and stability analysis of 28 crosses (F_1's) along with their parents.

Materials and Methods

The present investigation was carried-out during *rabi* season of 2019-20 at Agricultural Research Station, Ummedganj, Kota (Raj.). The experimental material comprised 36 genotypes of linseed (8 parents along with their 28 crosses) which were grown in six environmental conditions viz., early, normal and late sown under rainfed and irrigated situation, respectively.

The experiment was raised in a randomized complete block design with three replications at each environment with 4 m row length of each genotype in each plot. Recommended package of practices were followed for raising good and healthy crop.

The observations were recorded on days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight, biological yield per plant, seed yield per plant and harvest index. The statistical analysis of variance was done as per formula suggested by Panse and Sukhatme (1976). For stability analysis data were analyzed as per formula suggested by Eberhart and Russell (1966).

Results and Discussion

Results, showed highly significant variances (mean sum of squares) due to genotypes and environments for almost all the characters except harvest index (Table 1). It indicated the considerable variation present amongst genotypes as well as environments. Genotype x Environment interaction was also showing significant for all the characters except plant height, secondary branches per plant and biological yield per plant, indicating the genotypes interact strongly with the environments for all the twelve characters studied. E + (G x E) was significant for all the characters except biological yield per plant. It revealed that the varied response of genotypes to changing environments. The mean sum of squares due to environment (linear) showed significant for all the characters, revealed that the real differences in the genotypes for regression over environmental means.

Significant differences for G x E (linear) were observed for all the characters except plant height, number of secondary branches per plant and biological yield per plant, revealed that the presence of responsiveness of genotypes for the characters. The mean sum of squares due to linear component of G x E was higher than the non-linear component of G x E, indicating that the performance of genotypes for seed yield could be produced across the environments. Similar results were reported by Rai *et al.,* (1989), Kavani *et al.,* (1999), Patil *et al.,* (2000), Kumari *et al.,* (2003) and vishnuverdhan and Rao (2014).

Eberhart and Russel (1966) discussed, the stability of a genotype depends on three parameters namely, genotypic mean (X), regression or linear response (bi) and deviation from the linearity (S^2di).

Table.1 Pooled analysis of variance of stability for different characters over six environments in linseed

Source	D.F.	Mean sum of squares											
		DF	**DM**	**PH**	**PBPP**	**SBPP**	**CPP**	**SPC**	**TW**	**OC**	**BYPP**	**SYPP**	**HI**
Genotype	35	44.10**	53.55**	99.88**	1.19**	56.53**	1940.48**	1.83**	1.81**	12.09**	100.42**	5.33**	47.56**
Env.	5	784.57**	378.47**	760.11**	3.37**	325.28**	270.34*	1.56**	2.78**	3.07**	75.26**	2.05**	**26.96**
GxE	175	11.20**	14.92**	**9.46**	0.26**	**9.90**	238.47**	0.67**	1.50**	1.50**	**10.62**	0.99**	24.02**
E+(G x E)	180	10.89**	8.34**	10.10**	0.12**	6.22**	79.78**	0.23**	0.51**	0.52**	**4.14**	0.34**	8.04**
E (L)	1	1307.62**	630.78**	1266.84**	5.61**	542.15**	450.34**	2.60**	4.63**	5.10**	125.42**	3.42**	44.94**
G x E (L)	35	5.63**	6.34**	**3.92**	0.16**	**5.52**	69.67**	0.30**	0.52**	**0.37**	**3.84**	0.33**	7.05**
Pooled deviation	144	3.17**	4.50**	**2.88**	0.07**	**2.67**	79.67**	.20**	0.48**	0.52**	**3.37**	0.32**	8.02**
Pooled Error	420	1.100	1.03	2.93	0.05	4.27	34.45	0.05	0.02	0.28	3.99	0.09	4.15

** Significant at P= 0.01, *Significant at P=0.05

DF = Days to 50% flowering
DM = Days to Maturity
PH = Plant height
PBPP= Number of primary branches per plant
SBPP = Number of secondary branches per plant
CPP = Number of capsules per plant
SPC = Number of seeds per capsule
TW =Test weight
OC= Oil content
BYPP = Biological yield per plant
SYPP = Seed yield per plant
HI= Harvest index

Table.2 Estimates of stability parameters for different characters over six environments in linseed.

Genotype	Days to 50% flowering			Days to Maturity			No. Primary branches per plant			No capsules per plant			Number of seeds per capsule		
	Mean	bi	S^2d_i	Mean	bi	S^2d_i	Mean	bi	S^2d_i	Mean	bi	S^2d_i	Mean	bi	S^2d_i
PA 2	66.00	1.00*	4.57**	130.11	1.68*	0.64	5.42	0.75	-0.00	94.53	-0.18	-32.83	7.90	2.58	0.09*
KBA 3	58.33	1.04*	-0.22	122.61	1.28	-0.29	4.44	0.69	-0.03	72.45	-0.27	24.29	7.80	-1.40	0.17**
KBA 4	61.44	0.70	-0.50	122.50	0.64	1.22	4.46	0.77	-0.02	107.01	-0.40	-16.19	7.03	3.34	0.14**
RL13161	60.11	0.79	0.56	123.89	0.46	11.07**	4.39	0.84	-0.03	71.28	2.43	22.94	7.58	0.05	-0.02
Padmani	54.11	0.96*	-0.36	120.44	0.80	-0.32	3.61	0.59	0.01	92.85	1.72	-30.99	7.65	0.64	0.12*
RL15582	56.50	1.21*	-0.75	122.06	0.65	0.21	4.53	0.51	-0.04	85.37	0.51	5.43	7.52	4.95*	0.12*
RL15583	59.61	1.31*	1.42	123.00	1.10	0.42	4.33	-0.03	-0.03	100.11	2.80	78.23**	8.92	2.02	0.01
Meera	62.11	0.67	-0.11	132.61	1.29	2.48**	4.70	0.36	0.12**	113.06	1.19	-13.55	7.72	0.80	0.34**
KBA 3 x PA 2	60.33	1.17*	-0.54	126.00	1.91*	7.69**	5.12	2.70*	0.00	107.10	0.50	83.33**	8.42	1.52	-0.04
KBA 4 x P A 2	60.17	1.49**	4.69**	121.83	1.52*	10.47**	5.01	2.47*	-0.02	117.14	0.50	-0.39	8.14	0.03	0.08*
RL13161 x P A 2	60.89	1.42**	0.31	123.39	1.79*	3.14**	5.01	2.92*	0.06	103.03	0.61	44.53**	8.19	2.33	0.08*
Padmani x P A 2	58.11	1.37**	3.93**	122.22	1.68*	3.20**	4.64	0.33	-0.01	106.88	0.63	21.74	7.34	1.83	0.01
RL15582 x P A 2	60.72	1.02*	1.56*	125.00	1.81*	2.22*	4.92	3.58**	0.22**	121.04	-1.77	8.78	6.93	3.35	0.10*
RL15583 x P A 2	62.17	1.18*	0.49	124.50	1.63*	4.69**	5.44	0.48	-0.02	110.58	2.17	18.11	7.37	1.48	0.05
Meera x P A 2	63.83	0.84*	1.34	128.56	1.42*	0.23	5.61	-0.82	0.04	111.99	0.14	-10.36	7.67	0.03	-0.02
KBA 4 x KBA 3	59.61	0.96*	2.88**	120.50	0.82	1.33	5.00	1.23	0.08*	113.72	5.90	-4.30	7.62	-0.95	0.16**
RL13161 x KBA 3	57.72	0.33	0.19	123.72	1.89*	20.94**	5.30	0.11	0.04	121.11	5.18	51.14*	7.90	3.40	0.09*
Padmani x KBA 3	55.56	0.78	2.15*	119.33	0.61	2.42*	4.23	0.30	-0.02	126.02	-0.56	-32.04	7.41	1.02	0.08*
RL15582 x KBA 3	56.67	1.00*	0.48	121.00	0.31	-0.61	4.71	2.10*	0.03	94.29	0.31	-12.93	7.62	-1.61	-0.01
RL15583 x KBA 3	59.78	1.81**	4.57**	121.56	0.77	5.72**	4.82	2.25*	0.14**	137.62	0.78	56.13*	6.46	-0.25	0.31**
Meera x KBA 3	58.89	1.33*	2.63**	126.28	1.61*	3.47**	4.84	1.75	-0.02	127.39	-1.26	-19.41	7.38	-0.03	0.06
RL13161 x KBA 4	59.94	1.05*	1.32	122.11	0.13	9.49**	5.09	-0.21	0.16**	126.13	-0.99	88.84**	7.18	1.25	0.44**
Padmani x KBA 4	56.06	0.93*	1.62*	119.94	0.73	-0.75	5.36	0.04	-0.00	115.31	-0.48	39.54	7.14	1.60	0.12*
RL15582 x KBA 4	57.00	1.43**	-0.68	120.89	0.09	-0.47	4.71	1.72	-0.01	145.31	0.78	-23.34	7.56	3.08	0.04
RL15583 x KBA 4	59.56	1.26*	-0.65	122.28	0.05	2.92**	5.53	0.64	-0.03	155.04	0.66	-28.38	6.99	2.31	0.06
Meera x KBA 4	58.50	0.21	7.05**	124.56	0.33	0.68	5.01	1.10	0.02	125.39	0.20	-27.95	7.38	1.64	0.03
Padmani x RL13161	55.33	1.11*	0.00	120.28	0.04	2.54**	4.55	1.07	-0.04	124.89	3.09	-25.44	7.03	-0.10	0.07
RL15582 x RL13161	57.72	1.14*	1.08	122.72	0.57	7.62**	4.51	1.74	0.06	128.10	-0.56	30.01	7.20	0.20	0.47**
RL15583 x RL13161	58.83	0.91*	0.20	122.61	0.77	1.81*	5.44	0.72	-0.03	130.37	0.42	52.88*	7.88	0.81	0.57**
Meera x RL13161	57.78	0.16+	9.08**	125.94	0.91	1.42	4.98	1.24	-0.03	118.72	-1.09	33.68	7.67	-0.33	0.03

RL15582 x Padmani	53.83	0.94*	0.71	119.89	0.38	0.54	5.46	1.38	0.04	111.98	-2.91	46.42**	7.79	5.50*	0.73**
RL15583 x Padmani	55.89	1.98**	-0.00	120.83	1.44*	4.39**	4.48	0.84	-0.03	103.26	6.07	-1.61	8.47	0.17	-0.02
Meera x Padmani	55.78	0.64	4.98**	123.94	1.59*	1.20	4.58	0.35	0.04	126.61	-0.38	19.73**	7.52	-1.82	-0.01
RL15583 x RL15582	58.83	0.66	12.22**	120.89	0.51	0.42	5.49	1.32	0.04	126.49	8.21	29.35	9.01	1.73	0.07
Meera x RL15582	54.28	0.64	7.42**	126.56	1.89*	8.09**	4.84	-1.09+	0.04	118.61	3.30	64.40**	7.54	0.63	-0.01
Meera x RL15583	57.33	0.58	0.77	126.78	0.90	4.64**	5.10	1.27	-0.01	130.33	-1.24	-12.10	6.62	-5.80*	0.63**
Population mean	58.59	1.00	0.30	123.37	1.00	0.51	4.88	1.00	0.66	114.47	1.00	2.52	7.60	1.00	1.65

** Significant at P= 0.01, *Significant at P=0.05

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Table.2 Estimates of stability parameters for different characters over six environments in linseed.

Genotype	Test weight (g)			Seed yield per plant (g)			Harvest index (%)			Oil content (%)		
	Mean	bi	S^2d_i	Mean	bi	S^2d_i	Mean	bi	S^2d_i	Mean	bi	S^2d_i
PA 2	8.12	0.74	0.15**	6.73	0.86	-0.07	26.56	0.97	-3.51	38.74	-0.91	0.07
KBA 3	7.18	1.63	0.12**	5.66	3.89	-0.04	22.41	1.14	1.24	40.04	1.43	0.23
KBA 4	6.55	-1.08	0.02	5.93	1.23	0.00	24.91	-0.36	-1.12	42.57	0.28	0.04
RL13161	6.93	1.44	0.13**	5.38	1.29	0.08	22.75	1.69	5.94*	41.81	1.03	1.12**
Padmani	7.00	1.10	0.19**	5.41	0.12	-0.07	24.14	-0.04	-3.51	41.67	2.61	0.32
RL15582	6.62	2.09	0.13**	5.57	1.12	0.37**	25.41	-0.33	5.24	38.49	1.66	0.36
RL15583	7.19	2.31	0.81**	6.63	0.83	0.20*	29.88	3.32	-0.76	41.06	-0.32	-0.14
Meera	7.31	1.37	0.22**	6.84	2.01	0.19*	28.13	0.93	0.74	38.18	-0.13	-0.07
KBA 3 x PA 2	7.95	-3.08	0.62**	7.64	-1.99	0.39**	26.40	6.74	5.31	41.38	0.74	-0.15
KBA 4 x P A 2	8.02	-2.12	1.06**	7.63	0.64	0.04	23.65	-0.66	-3.25	39.49	0.22	0.47*
RL13161 x P A 2	8.01	-2.34	0.61**	7.96	1.86	-0.07	25.66	-0.03	-2.94	41.14	0.67	0.96**
Padmani x P A 2	8.69	3.08	0.43**	7.87	3.71	0.26**	24.06	-2.75	-3.35	41.54	-0.35	0.23
RL15582 x P A 2	7.99	2.06	0.20**	8.55	1.42	-0.02	26.46	0.88	-1.48	38.93	-1.57	0.25
RL15583 x P A 2	8.17	-0.43	2.47**	7.84	6.64*+	1.83**	23.47	0.48	24.14**	40.84	0.14	0.23
Meera x P A 2	7.89	-0.57	0.06**	8.16	1.39	-0.05	30.65	-0.90	18.67**	39.94	-2.43	0.05
KBA 4 x KBA 3	8.17	-0.41	0.06**	7.68	2.04	0.02	22.91	-0.05	-1.72	43.83	0.04	0.16
RL13161 x KBA 3	7.43	-0.27	0.01	8.02	-0.28	0.06	19.87	0.73	-3.38	41.28	0.93	0.01
Padmani x KBA 3	7.51	-0.62	0.04*	7.69	0.26	0.18*	24.95	2.19	-1.07	41.10	4.01	0.33

RL15582 x KBA 3	6.66	0.93	0.11**	6.13	0.61	-0.05	19.85	1.39	-1.80	41.80	0.61	-0.23
RL15583 x KBA 3	8.54	4.55	0.53**	8.86	-1.04	0.69**	28.63	0.67	10.08**	40.67	0.92	0.13
Meera x KBA 3	8.08	0.92	0.06**	6.95	-2.65	1.39**	26.69	6.55	13.21**	40.77	1.21	-0.24
RL13161 x KBA 4	7.67	5.42*	1.08**	8.22	2.60	0.05	27.17	2.95	8.48*	42.77	1.36	-0.13
Padmani x KBA 4	7.54	0.45	0.07**	6.76	0.36	-0.09	19.79	-0.14	-3.90	43.74	0.97	-0.21
RL15582 x KBA 4	6.58	2.00	1.45**	8.36	0.22	0.40**	24.26	-1.16	2.97	42.65	0.63	-0.20
RL15583 x KBA 4	7.41	3.22	1.58**	8.59	-0.48	-0.04	29.18	2.12	6.65*	41.38	-0.22	-0.04
Meera x KBA 4	7.77	-0.29	0.28**	7.37	2.70	0.50**	24.94	4.82	16.33**	39.39	0.06	0.28
Padmani x RL13161	7.80	0.80	0.28**	7.12	4.05	0.76**	23.97	1.85	12.83**	41.09	2.85	0.74**
RL15582 x RL13161	7.13	4.84	1.35**	7.66	2.46	0.16*	26.54	3.26	-0.23	41.04	0.67	0.08
RL15583 x RL13161	8.13	0.77	0.22**	8.25	0.21	0.11	28.23	0.03	8.91*	37.59	-0.04	0.19
Meera x RL13161	7.62	1.06	0.11**	7.98	-0.91	-0.06	27.57	5.88	4.93	41.10	0.15	0.15
RL15582 x Padmani	7.47	0.85	0.07**	7.29	-1.67	0.21*	22.47	0.39	-1.34	41.42	3.05	1.54**
RL15583 x Padmani	8.25	4.21	0.44**	6.69	-1.18	-0.01	20.52	-0.68	-0.28	41.04	2.11	-0.18
Meera x Padmani	7.68	1.16	0.13**	7.36	-0.10	-0.05	25.44	-3.76	7.77*	40.08	5.08	-0.01
RL15583 x RL15582	7.96	2.22	0.79**	8.30	2.49	0.58**	27.76	-0.31	16.56**	41.78	1.93	-0.01
Meera x RL15582	7.68	0.44	0.11**	7.69	0.42	0.01	22.98	1.07	-2.21	40.29	1.27	0.15
Meera x RL15583	8.12	-2.44	0.50**	7.51	0.86	0.32**	27.46	-2.87	5.20	40.36	5.34*	2.04**
Population mean	7.63	1.00	1.93	7.34	1.00	1.84	25.16	1.00	2.53	40.86	1.00	1.91

** Significant at P= 0.01, *Significant at P=0.05

Table.3 Interpretation of suitability of different genotypes based on stability parameters.

Regression coefficient (b_i)	Mean value	Stability	Remarks
$b_i = 1$	High	Average	Well adapted to all environments
$b_i = 1$	Low	Average	Poorly adapted to all environments
$b_i > 1$	High	Below average	Specifically adapted to favorable environments
$b_i < 1$	High	Above average	Specifically adapted to unfavorable environments

According to this model an ideally stable genotype is one that conforms high mean value (>gi), unit regression or linear response (bi=1) and no deviation from the linearity (S^2di = 0). The estimates of mean performance (x), regression coefficient (bi) and deviation from regression ((S^2di) are presented in Table-2.

Considering the stability of a genotype, the three parameters *viz*, grand mean over the environments(x), unit regression coefficient (bi=1) and squared deviation from the regression (S^2di = 0) were considered stable in performance.

Based on these parameters the thirty-six genotypes have been classified into four categories excluding the significant bi and mean square deviation values for all genotypes under study (Table-3). None of the genotypes showed stable performance for all the characters under study. Among the eight parents, Meera and PA2for harvest index, crosses Meera x RL13161 for days to maturity, Meera x KBA4for number of primary branches per plant, Meera x RL13161for number of capsules per plant and seed yield per plant and RL 13161 x KBA3 for oil content showed regression coefficient near unity, high mean than population mean and non-significant regression deviation(S^2di). These genotypes indicating average in stability and well adapted to all the environments.

The parents RL15583 for days to maturity, Meera for number of capsules per plant KBA4 for test weight, PA2 for oil content and KBA3 for harvest index showed regression coefficient near unity, low mean than population mean and non-significant regression deviation (S^2di).These genotypes were showing average stability and poorly adapted to all over the six environments and also used for commercial consumption.

Meera x RL13161, RL15582 x Padmani, RL15583 x RL15582 and Meera x RL15583 for number of primary branches per plant, RL15583, KBA3 x PA2 and RL15583 x RL15582 for number of seed per capsule, Padmani, RL13161 x KBA4, RL15583 x Padmani and RL15583 x RL15582 for oil content, RL13161 x PA2, RL15582 x PA2, Meera x PA2, KBA4 x KBA3 and RL13161 x KBA4 showed high mean, bi>1 and non-significant s^2di. These genotypes indicated below average stability and hence, recommended to be adaptable especially for favorable environments for further improvement in respective character.

In the present Study, six genotypes for seed yield per plant, ten genotypes for oil content and number of capsules per plant, seven genotypes for number of primary branches per plant, four genotypes for number of seeds per capsule and one genotype for each of days to maturity and harvest index showed high mean, bi<1 and non-significants^2di. Theses genotypes showed above average stability and recommended especially for unfavorable environments for further utilization. The rest of genotypes which are showing low mean value and bi > 1 and low mean value with bi < 1 are poor for all the environmental conditions and further improvement of these characters are difficult. Similar results were confined by vishnuverdhan and Rao (2014).

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