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Stability analysis in linseed (*Linum usitatissimum*) varieties

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ABSTRACT

A study was conducted during winter season (*rabi*) 2010-2011 and 2011-2012 under different agro climatic conditions to test the stability of improved and high yielding varieties of linseed (*Linum usitatissimum* L.). Analysis of variance on 13 characters was carried out individually as well as pooled over the years and locations. Kanpur location was relatively better for wider range and higher mean for all the characters except 1000-seed weight. Genotype × environment interaction was significant for plant height, number of tillers/plant, number of branches/plant, days to maturity, number of seeds/capsule, 1000-seed weight, harvest index, iodine value along with seed yield/plant. G × E (linear) was also significant for all these 7 traits and early growth vigour indicating substantial amount of predictable G × E interaction. All 10 genotypes tested for 3 stability parameters, viz. mean, bi and S^2di. Out of all the genotypes, the genotypes Garima, Neelum, Gaurav, Laxmi 27 and T 397 were identified to be high yielding and stable. Genotypes, viz. Garima, Neelum, Gaurav, Laxmi 27 and T 397 may be included in any breeding programme to develop high yielding stable genotypes over the environments. Direct selection in the segregating generations of such parents for 1000-seed weight, number of tillers per plant along with simultaneous selection for number of branches per plant will be responsive for improvement of seed yield/plant.

Key words: *Linum usitatissimum*, G × E interaction, Selection, Stability, Varieties, Yield

Linseed (*Linum usitatissimum* L.) is an important oil seed crop in India. Every part of the plant is utilized commercially either directly or after processing. The oil primarily goes to industries for the manufacturing of paints, varnish, oil-cloth, linoleum, pad-ink and printing-ink. Oil-cake is a good feed for milch cattle. The stem yields fibre of good quality having high strength and durability. The woody matter and short fibers are used as row pulp for making of quality.

Breeding cultivars that adapted reasonably larger geographical area with some degree of stability from year to year, has been a major problem confronting plant breeder. The only effective control might be to reduce environments by grouping them on the basis of their similar responses and subsequently evaluating genotypes in representative environments from each group. This would facilitate the development of widely adapted genotypes in the selected environments with a high degree of diversity (Compbell and Lafever 1977).

Moreover, yield level are also not sustainable and fluctuation year after year leading to fluctuation in production. This fluctuation is because of many factors like growing of this crop on marginal lands, non-availability of resistant/tolerant varieties for biotic and abiotic stresses for different ecological conditions. Under such a situation, it becomes, imperative to identify some already released varieties which can show a steady performance under different agro climatic conditions. Keeping, this in view, the present investigation was carried out for two consecutive years under 6 environments and 10 genotypes were studied to test the stability of the improved varieties over the environments through genotype – environment interaction and to identify high yielding and stable varieties for stable production in linseed.

MATERIALS AND METHODS

The experiments were conducted at Kanpur (central zone), Aligarh (semi- arid zone) and Jhansi (Bundelkhand zone) in Uttar Pradesh during *rabi* 2010-11 and 2011-12 under different agro climatic conditions. The material for present study consisted of 10 varieties of linseed, viz. Garima, Neelum, Gaurav, Laxmi 27, T 397, Padmani, Shekhar, Sweta, Parvati and Shubhra was evaluated.

During both the years and 3 different locations namely, Kanpur, Aligarh and Jhansi were laid out in randomized block design with 3 replications with plot size of 5 m × 1.5 m. Row to row and plant to plant distance was kept at 30 m × 10 m. The data were recorded on 13 characters, viz. early growth vigour, plant height, number of tillers per plant,

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number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight, seed yield per plant, oil content, harvest index and iodine value except days to 50% flowering and days to maturity, where data was recorded on plot basis, the data for rest of the morphological traits were recorded on randomly selected 10 competitive plants in the middle 3 rows of each plot in all 3 replications. The recommended package of practices was followed to raise a good crop.

The mean values of 10 sampled plants for all characters, except for characters data recorded on whole plot basis, were used for detailed statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989). Genotype – environment interaction were found to be significant in respect of all the characters studies, hence the data were subjected to stability analysis (Eberhart and Russell 1966) to asses the stability of different genotypes. A genotype with regression coefficient of unity (bi=1) and the deviation not significantly different from zero ($s^2di=0$) was taken to be stable genotype with high mean response. Biochemical analysis was done using NMR for oil content according to Tiwari *et al.* (1974) and iodine value according to AOAC procedure.

RESULTS AND DISCUSSION

For each environment analysis of variance on 13 characters was carried out individually as well as pooled over the years and locations. Analysis of variance revealed significant differences amongst genotypes for all the observed characters in each of 6 environments. Pooled analysis of variance over 6 environments was also carried out in order to verify presence of G × E interaction (Table 1). G × E interaction variance was significant for all the observed characters. Variance due to genotypes was also significant for all observed characters. Variance due to environment was also significant for all the observed characters. These results indicated presence of substantial amount of genotype × environment interaction. Stability analysis was carried out as per Eberhart and Russell (1966) model for all the observed characters in order to verify presence of variance due to components of G × E interaction (Table 2). The genotype × environment interaction was present and it was highly significant for all the characters studied except for early growth vigour, days to 50% flowering. Similar finding have been reported by Yadav *et al.* (2000) and Rai *et al.* (1989). As the environment selected in the present study were different agro climatic conditions (Kanpur, Ailgarh and Jhansi at two consecutive years), the presence of significant G × E for the observed characters indicates the relevance of stability analysis. The mean values over genotypes were generally lower at Aligarh and Jhansi location as compared to Kanpur location for the characters, early growth vigour, plant height, number of tillers per plant, number of branches per plant, number of seeds per capsule, number of capsules per plant, seed yield per plant, oil content, harvest index and iodine value, whereas reverse

Table 1 Character-wise pooled mean sum of squares for genotypes under 6 environments

Source	df	Early growth vigour	Days to 50% flowering	Plant height	Number of tillers/ plant	Number of branches/ plant	Days to maturity	Number of capsules/ plant	Number of seeds/ capsule	1000-seed weight	Seed yield/ plant	Oil content	Harvest index	Iodine value
Location (L)	5	40.88**	8204.34**	1025.4**	67.70**	87.5**	5920.86**	25269.02**	61.2**	49.78**	358.52**	103.56**	2318.54**	559.66**
Replication (R)	2	0.02	0.82	3.18	0.74	3.48	2.18	22.5	0.1	0.1	o,016	0.3	0.46	5.5
L × R	10	1.42	1.88	3.6	0.14	0.24	0.02	86.5	0.44	0.1	o.02	0.22	5.44	3.16
Genotypes (G)	9	16.24**	137.02**	301.0**	6.8	11.3**	106.58**	7310.24**	2.68**	9.04**	16.50**	20.58**	165.84**	173.18**
L × G	45	8.99**	40.52**	65.26**	6.64	9.54**	20.16**	2644.30**	1.72**	2.52**	7.18**	10.62**	131.34**	135.54**
Error	108	1.14	3.68	6.42	0.52	1.44	3.68	177.9	0.2	0.3	4.68	2.36	3.8	11.32

*P =0.05, **P =0.01

trend was found for 1000-seed weight. Similarly, range was wider at Aligarh location in comparison to Jhansi location for the above characters and reverse trend in range was observed for 1000-seed weight. The results indicate that the Kanpur location was relatively better suited for the characters, viz early growth vigour, plant height, number of tillers per plant, number of branches per plant, number of seeds per capsule, number of capsules per plant, seed yield per plant, oil content, harvest index and iodine value while Jhansi location was better suited for expression of 1000-seed weight.

Analysis of variance for stability indicated significant differences among the genotypes for all 13 characters observed, indicating the diversity in the selected genotypes. Significantly differences was observed among the environments too, hence significant effect of environment was there in the expression of the traits. Genotype × environment interaction was significant for plant height, number of tillers per plant, number of branches per plant, number of seeds per capsule, number of capsules per plant, oil content, harvest index and iodine value along with seed yield per plant, indicating that the genotypes are varying over the environments due to G × E. The significant G × E interaction has been reported for various traits by Mishra and Rai (1993) which confirm the finding of present investigation. G × E (linear) is also significant for 7 traits. Early growth vigour and days to maturity show substantial amount of predictable G × E interaction. Hence, we can predict the performance of genotypes over wide range of environments for these traits. Significant G × E (linear) for different traits has been reported by Yadav *et al.* (2000).

Among the above traits high G × E was observed for plant height, number of tillers/plant, number of branches/plant, number of seeds/capsule, number of capsules/plant, seed yield/plant, oil content, harvest index and iodine value. Seven traits, viz. days to 50% flowering, days to maturity, number of capsules/plant, 1000-seed weight, seed yield per plant, oil content, harvest index and iodine value were having high significant pooled deviation which indicated that some portion of G × E was unpredictable. Significant deviation from regression have been reported earlier also by Yadav and Ram Krishna (2000).

(G × E) +E component was not significant for oil content. However, in the present study genotypes were tested for 3 parameters of stability for all the observed characters. In order to classify the genotypes into various categories with respect to stability and suitability for particular environment, all 10 varieties were tested for 3 stability parameters, viz. mean, bi, and s^2di. The genotype showing superiority and stability for different traits have been summarized in Table 3. Out of 10 genotypes, the genotypes Garima, Neelum, Gaurabh, Laxmi 27 and T 397 were identified to be high yielding and stable genotypes. Thus, these 5 genotypes were suitable for all the 3 locations, viz. Kanpur, Aligarh and Jhansi of different agro climatic situation of Uttar Pradesh. Stability of the genotypes for various traits on the basis of 3 parameters has earlier been

Table 2 Analysis of variance (Mean sum of square) for genotype × environments

Source	df	Early growth vigour	Days to 50% flowering	Plant height	Number of tillers/ plant	Number of branches/ plant	Days to maturity	Number of capsules/ plant	Number of seeds/ capsule	1000-seed weight	Seed yield/ plant	Oil content	Harvest index	Iodine value
Genotype (G)	9	8.12**	59.16**	113.74**	3.7**	6.84**	49.68**	2562.74**	o.78**	4.78**	8.50**	13.02**	86.30**	52.22**
Environment (E)	5	37.88**	5777.90**	723.84**	47.18**	14.78**	4237.82**	141132.16**	22.74**	16.54**	282.44**	14.12**	510.74**	530.16**
G × E	45	1.78	1.08	15.44**	1.82**	2.9**	6.14**	32.56	0.62**	0.34**	12.16**	1.86	31.54**	58.24**
E+(G × E)	50	3.12	64.78**	17.58	2.46**	3.02**	48.44**	282264.94**	0.84**	0.6**	8.10**	1.98	36.34**	64.54**
Environment (linear)	1	73.80**	11555.16**	11450.84**	94.24**	29.53**	8467.96**	1108.72**	48.52**	33.10**	564.86**	27.92**	1021.28**	1071.46**
G × E linear	9	2.48	6.28*	10.6	2.86**	4.44	6.70**	867.62**	0.19	0.34**	6.36**	1.54	49.28**	62.30**
Pooled deviation	40	3.06	7.80**	10.16	0.54	1.34	5.58**	867.67**	0.18	0.34**	4.26**	2.16**	13.68**	53.52**
Pooled error	108	1.36	1.68	6.74	0.32	0.34	1.82	34.66	0.16	0.12	2.9	1.54	1.04	3.78

*P =0.05, **P =0.01

Table 3 Genotype showing stability for various characters (Eberhart and Russell 1966)

Genotype	Trait for which genotypes showed superiority and stability on the basis of 3 parameters of stability
Garima	Days to 50% flowering (X=72.12, bi=1.52, S^2di=0.10), number of branches per plant (X=6.98, bi=0.96, S^2di=0.26), days to maturity X=133.05, bi=1.04, S^2di=-2.47), seed yield per plant (X= 4.92, bi= 0.75, S2di= 0.05) and harvest index(X=31.00, bi=1..25, S^2di=0.90)
Neelum	Early growth vigour (X=1.83, bi=o.82, S^2di=-0.11), number of capsules per plant (X=105.54, bi=1.32, S^2di=-1.57), 1000-seed weight (X=11.22, bi=1.08, S^2di=0.03) and seed yield per plant (X=6.90, bi=1.07, S^2di=0.08)
Gaurav	Seed yield per plant (X=5.29, bi=1.04, S^2di=0.02,and oil content (X=42.52, bi=1.22, S^2di=0.18)
Laxmi 27	Early growth vigour (X=2.42, bi=1.93, S^2di=0.17),, 1000-seed weight (X=10.83, bi=0.99, S^2di=0.00), seed yield per plant (X=4.81, bi=0.76, S^2di=0.04),and 0il content (X=44.52, bi=0.96, S^2di=-0.14)
T 397	Number of tillers per plant (X=4.8, bi=1.18, S^2di=0.41), number of capsules per plant (X=99.19, bi=1.72, S^2di=-0.80), seed yield per plant (X=5.24, bi=1.17, S^2di=0.01), oil content (X=43.39, bi=1.06, S^2di=-0.12)
Padmani	Plant height (X=71.41, bi=0.97, S^2di=0.37)
Shekhar	Plant height (X=71.19, bi=0.94, S^2di=0.09), days to maturity (X=132.25, bi=0.89, S^2di=-0.39), and harvest index (X=31.8, bi=1.02, S^2di=0.01)
Sweta	Early growth vigour (X=3.29, bi=1.16, S^2di= -0.31), days to 50% flowering (X=73.16, bi=1.02, S^2di=-0.66), days to maturity (X=130.28, bi=0.84, S^2di=0.19),, harvest index (X=29.18, bi=1.11, S^2di=0.12)
Parvati	Iodine value (X=183.00, bi=1.06, S^2di= -0.33)
Shubhra	Oil content (X=42.09, bi=1.46, S^2di= -0.99) and seed yield per plant (X=4.65, bi=0.92, S^2di= -0.72)

reported by Yadav *et al.* (2000) which confirm the present findings where various genotypes are showing stability for 1 or more characters.

Genotype Garima besides having stable and high performance for seed yield per plant, also having superior performance for days to 50% flowering, number of branches/ plant, days to maturity and harvest index. Likewise, Neelum also stable and superior performance for early growth vigour, number of capsules/plant and 1000-seed weight in addition to seed yield/plant. Genotype Laxmi 27 also had stable and high performance for early growth vigour, 1000-seed weight and oil content along with seed yield/plant. In addition to superiority and stability for seed yield/plant, T 397 also showed stability for number of tillers/plant, number of capsules/plant and oil content. Similarly Gaurav was having superior performance for seed yield/plant.

Genotype, Garima was having superior mean than the population mean for seed yield/plant for seed yield/plant was found to be suitable for cultivation under different agro climatic conditions. Yadav *et al.* (2000) has also reported the stability of Garima under varying environments. Four genotypes, viz. Neelum, Laxmi 27, T 397 and Gaurav should be included in any breeding programme where objective is really to develop high yielding stable genotypes over environments.

Moreover, based on the results of present study, it is revealed that in segregating generation of such crosses including these parents, direct selection for 1000-seed weight, number of tillers/plant, along with simultaneous selection for number of branches/plant, number of capsules/ plant will be responsive for improvement of seed yield/ plant. Yadav and Ram Krishna (2000) and Rai *et al.* (1989) have also reported that the genotype stable over environments can be used successfully for developing stable strains having wider adaptability in the future breeding programme.

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