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Genetic variability and character association for seed yield in linseed (*Linum usitatissimum* L.) under rainfed conditions

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Abstract
The present investigation was conducted to estimate the genetic variability and character association existing among 21 linseed genotypes including one national check which were evaluated during *Rabi* 2016-17 under randomised block design having three replications. The data was recorded for days to 50% flowering, number of primary branches per plant, plant height, technical plant height, plant stand per net plot, number of seeds per capsules, number of capsules per plant, days to maturity, harvest index, seed index and seed yield per hectare. Analysis of variance revealed significant differences among the genotypes for the all characters studied except number of seeds per capsule and number of primary branches per plant. Technical plant height, number of capsules per plant, harvest index, test weight and number of primary branches per plant exhibited high genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) heritability (bs) as well as genetic advance and genetic advance as percent of mean. Correlation coefficient analysis revealed that seed yield per hectare exhibited significant and positive correlation both at genotypic and phenotypic level with plant stand per net plot at harvest, number of capsules per plant, test weight and harvest index. Hence, these characters may serve as effective selection criterion for yield improvement.

Keywords: Linseed (*Linum usitatissimum* L.), Genetic variability, heritability (broad sense), genetic advance, character association, correlation, technical plant height.

1. Introduction
Linseed (*Linum usitatissimum* L.) is one of the most important *Rabi* oilseeds after rapeseed mustard. The plant originated from the Mediterranean and Southwest Asian regions. Linseed (*Linum usitatissimum* L.) 2x=2n=30 is an annual self-pollinated crop. It belongs to the order Malpighiales, genus *Linum* and family Linaceae. The botanical name, *Linum usitatissimum* was given by Linnaeus in his book “Species Plantarum”. It is an annual herbaceous plant with shallow root system. The Latin species name *usitatissimum* means "most useful. (Linnaeus, 1857) [6]

Linseed is an important oilseed and fiber crop; the seed contains good percentage of oil varying from 33-45 and 24% crude protein in different varieties. It’s medicinal and nutraceutical properties have paved the way for its diversified uses and value addition in various forms. Its seed is comprising complete protein (rich in eight essential amino acids), higher order linolenic acid (an essential poly unsaturated Omega-3 fatty acid) highest in plant kingdom. Recent advances in neuro-biology have established that it is best herbal source of Omega-3 and Omega-6 fatty acids which helps in regulating the nervous system.

Linseed is grown mainly for seed used for extracting oil in rainfed conditions. The utilization of flax for various purposes including industry, nutraceutical, bio- pharmaceutical, fiber, animal feed and human food is continuing to develop.

India ranks first in terms of area under linseed cultivation and third in production in the world. In technical oil production, it ranks first in the country. The area under cultivation is approximately 3.4 Lakh ha in India. Average yield of linseed in India 498 kg/ha which is comparably very low in comparison with world average yield that is 943 kg/ha. Annual production of linseed is 1.43 Lakh tonnes in India. In U.P linseed productivity is 560kg/ha and highest productivity is in Rajasthan (1285 kg/ha) Agricultural Statistics at a Glance (2015) [1].

Genetic variability studies help in development of high yielding varieties. Genetic variability among genotype offers better scope for selection. The magnitude of heritable variation in the traits studied has immense value in understanding the potential of the genotype for further breeding programme. Assessment of variability for yield and its component characters becomes absolutely essential before planning for an appropriate breeding strategy for genetic improvement.

Genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are useful in detecting the amount of variability present in the germplasm.

Phenotypic and genotypic correlation coefficients between yield and the yield components provide information on their relative importance in determining the yield. Correlation coefficient estimates degree of association of different component characters of yield among themselves and with the yield. For further the correlation studies between various yield attributes with yield, provides a basis breeding programmes. More production under diversified environment conditions is a big challenge for plant breeders. Hence, there is need to identify and improve crop traits that are directly correlated with seed yield. In view of above facts the present investigation was undertaken to estimate the genetic variability and association between seed yield and its component characters in linseed.

2. Materials and Methods

The experiment was conducted during 2016-17 at the Field Experimentation Centre of the Department of genetics and plant breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, (U.P.). The Allahabad is situated at 25.57^{0}N latitude and 81.25^{0}E longitude. This region has a subtropical climate prevailing in the southern at U.P. Allahabad fall under agro-climatic zone, which is named as "North Eastern plain zone". In cold winters, the temperature sometimes goes as low as 1-2^{0}C in the month of December – January up to 45-47^{0}C in the month of May – June. In *Rabi* season, the temperature up to 25-35^{0}C, the average rainfall is around 1013.4 mm. Experimental materials for the present study consist of 21 genotypes of linseed which were obtained from Initial Varietal Trial (Rainfed) of All India Co-Ordinated Research Project on Linseed, Kanpur. The experiment was conducted in Randomized Block Design (RBD) with 21 treatments. The treatments were replicated three times with 30×5 cm inter and intra row spacing. Treatments were randomly arranged in each replication divided into 63 plots. The recommended done of fertilizer @ 80:30 (N: P kg/ha) were applied in the form of urea, single super phosphate, respectively as basal dose at the time of sowing. Recommended agronomic practices were followed to raise a competent crop. Observations on days to 50% flowering, days to maturity and seed index were recorded on plot basis, whereas for characters like number of primary branches per plant, plant height, technical plant height, plant stand per net plot, number of capsules per plant, number of seeds per capsule, harvest index, test weight and seed yield per ha. Were recorded on five randomly selected plants. The mean characters were subjected to analysis of variance to test the level of significance among the genotypes for different characters according to the method suggested by Panse and Sukhatme, (1967) [9]. The mean data over replications was used for calculating the genetic parameters according to Burton and Devane (1953) [4] and Johnson *et al.* (1955) [5]. The genotypic and phenotypic correlation coefficients were calculated according to the method suggested by Al-Jibouri *et al.* (1958) [3].

3. Results and Discussion

The grain yield is a highly variable and complex character and is a cumulative effect of its component characters. The analysis of variance revealed that the mean sum of square due to treatments (genotypes) for all the characters studied is found to significant except number of seeds per capsule and number of primary branches per plant. This suggested that the genotypes selected for research were quite variable and considerable amount of variability existed among them. Hence, it provides ample scope for selection of different quantitative and qualitative characters for yield improvement in linseed (Table 1). Similar results were reported by Akbar *et al.* (2003) [2]. An estimate of GCV and PCV for all characters studied revealed that the phenotypic coefficient of variation (PCV) was higher than their corresponding genotypic coefficient of variation (GCV), indicating the influence of environment on the expression of these characters. Higher magnitude of GCV and PCV were recorded for technical plant height followed by number of capsules per plant, harvest index and test weight, suggesting sufficient amount of variability and thus offer better scope for genetic improvement through selection of these traits. Similar results were reported by Pali and Mehta (2013) [8]. Estimates of higher heritability (bs) coupled with high genetic advance as percent of mean were observed for technical plant height followed by number of capsules per plant, harvest index, test weight and number of primary branches per plant indicating to the preponderance of additive gene action and selection pressure could profitability be applied on these characters for yield improvement (Table 2). Similar results were reported by Akbar *et al.* (2003) [2] and Narayan & Murugan (2013) [7]. Correlation coefficient analysis revealed that seed yield per ha. exhibited significant and positive correlation both at genotypic and phenotypic level with plant stand per net plot, number of capsules per plant, test weight, harvest index and number of primary branches per plant. Hence, direct selection for these traits would therefore be most effective in the improvement of linseed genotypes (Table 3). Similar results were reported by Vardhan and Rao (2006) [10].

Table 1: Analysis of variance for different quantitative characters in linseed.

S.N.	Traits	Mean sum of squares		
		Replications	Treatments	Error
		d.f.= 2	d.f.= 20	d.f.= 40
1.	Days to 50% flowering	6.397	185.063**	3.680
2.	Number of primary branches per plant	0.093	1.114	0.097
3.	Plant height	13.944	346.694**	6.560
4.	Technical plant height	2.289	307.444**	3.256
5.	Plant stand per net plot at harvest	520.0476	45921.55**	271.3643
6.	Number of capsules per plant	11.9862	593.000**	12.8287
7.	Number of seeds per capsule	0.125	0.963	0.181
8.	Days to maturity	21.778	147.754**	10.461
9.	Harvest index	1.222	60.485**	2.987
10.	Test weight	0.033	5.174**	0.129
11.	Seed yield per ha	573.5977	28390.682**	455.5993

**Significant at 1% level of significance. d.f.= degree of freedom.

Table 2: Estimation of genetic parameters for eleven quantitative characters in linseed genotypes.
Vg= genotypic variance, Vp= phenotypic variance, h2(bs)= heritability (broad sense) and GA= genetic advance.

Parameters Traits	Vg	Vp	Coefficient of variation		h^2 (bs)%	GA	GA as % mean
			Genotypic	Phenotypic			
Days to 50% flowering	60.46	64.14	10.29	10.60	94.26	15.55	20.57
Number of primary branches per plant	0.34	0.44	16.03	18.19	77.66	1.06	29.10
Plant height	113.38	119.94	13.21	13.59	94.53	21.33	26.46
Technical plant height	101.40	104.65	21.16	21.50	96.89	20.42	42.90
Plant stand per net plot at harvest	15216.73	15488.09	10.52	10.62	98.97	251.88	21.49
Number of capsules per plant	193.39	206.22	20.91	21.59	94.38	27.74	41.71
Number of seeds per capsule	0.26	0.44	5.90	7.68	59.06	0.81	9.34
Days to maturity	45.76	56.23	5.38	5.96	81.39	12.57	9.99
Harvest index	19.17	22.15	18.20	19.56	86.52	8.39	34.87
Test weight	1.68	1.81	16.91	17.55	92.90	2.57	33.58
Seed yield per ha	9311.69	9767.29	12.91	13.13	95.27	194.09	25.79

Table 3: Estimation of genotypic and phenotypic correlation among quantitative characters with seed yield linseed.

Traits		Days to 50% flowering	Number of primary branches per plant	Plant height	Technical plant height	Plant stand per net plot at harvest	Number of capsules per plant	Number of seeds per capsule	Days to maturity	Harvest index	Test weight	Seed yield
Days to 50% flowering	G	1.00	0.022	0.629**	0.647**	-0.457**	-0.544**	0.328**	0.716**	-0.603**	-0.234	-0.502**
	P	1.00	-0.019	0.590**	0.612**	-0.427**	-0.518**	0.255*	0.604**	-0.552**	-0.205	-0.480**
Number of primary branches per plant	G		1.00	0.076	0.018	-0.049	0.096	-0.063	-0.149	-0.475**	-0.060	0.021
	P		1.00	0.069	0.017	-0.041	0.080	-0.033	-0.124	-0.406**	-0.078	0.011
Plant height	G			1.00	0.931**	-0.422**	-0.539**	0.575**	0.824**	-0.757**	-0.093	-0.536**
	P			1.00	0.887**	-0.406**	-0.505**	0.413**	0.730**	-0.686**	-0.079	-0.517**
Technical plant height	G				1.00	-0.390**	-0.511**	0.524**	0.800**	-0.715**	0.0129	-0.474**
	P				1.00	-0.382**	-0.481**	0.425**	0.722**	-0.645**	0.024	-0.467**
Plant stand per net plot at harvest	G					1.00	0.904**	-0.529**	-0.400**	0.381**	0.552**	0.967**
	P					1.00	0.868**	-0.385**	-0.362**	0.341**	0.528**	0.953**
Number of capsules per plant	G						1.00	-0.549**	-0.561**	0.308**	-0.340**	0.967**
	P						1.00	-0.403	-0.473**	0.248*	0.332**	0.613**
Number of seeds per capsule	G							1.00	0.436**	-0.257*	-0.359**	-0.550**
	P							1.00	0.265*	-0.209	-0.208	-0.409**
Days to maturity	G								1.00	-0.616**	0.035	-0.516**
	P								1.00	-0.535**	0.016	-0.450**
Harvest index	G									1.00	0.152	0.409**
	P									1.00	0.115	0.376**
Test weight	G										1.00	0.425**
	P										1.00	0.397**
Seed yield	G											1.00
	P											1.00

*and ** indicate significance at 5% and 1% level, respectively. G= Genotypic, P= Phenotypic.

4. Conclusion

From the results from the present investigation, it can be concluded that the genotypes DLV-1 (925.18) followed by NL-294 (874.07), SLS-108 (867.03), LCK-1625 (867.03) and BRLS-108-1 (858.88) were identify as top five high yielding and better genotypes compared to T-397 (check) for this agro-climatic region. These genotypes have potential for promotion and development as new pureline variety of linseed. The characters like technical plant height, number of capsules per plant, harvest index and seed index exhibited high genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad-sense), genetic advance and genetic advance as percent of mean. Plant stand per net plot at harvest, number of capsules per plant, test weight and harvest index showed positive and significant correlation with seed yield per hectare. Hence, these characters may be subjected to mass or progeny or family selection or any selection scheme, aimed at exploiting additive (fixable) genetic variance, a widely adapted genotype could be developed, possessing good quality and productivity and direct selection for these traits would be most effective and should be taken into consideration for the improvement of seed yield in linseed.

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