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Genetic divergence studies for quantitative traits in linseed (*Linum usitatissimum* L.)

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Abstract
The present investigation entitled "Divergence studies in linseed (*Linum usitatissimum* L.)" was conducted at Agriculture Botany field of College of Agriculture, Latur (Maharashtra) during *Rabi* 2021-2022. The experimental material constituted 31 genotypes which were sown in RBD Design at 30 cm x 5 cm spacing. The observations were recorded on ten quantitative characters namely days to 50% flowering, days to maturity, plant height (cm), 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 (g), oil content (%) and seed yield per plant. The data recorded on these characters was utilized for estimation of mean, variability genetic advance, and genetic diversity by D^2 method. Thirty-one genotypes were grouped into fourteen clusters by Tocher's method. Cluster I was with the highest number of genotypes (13) followed by cluster VI (5), clusters II (02) and remaining 11 clusters include 1 genotype in each cluster. The intra cluster distance (D^2) range from 5.89 to 10.69, whereas inter cluster distance D^2 ranges from 6.80 to 36.94. The maximum inter cluster distance (D^2 = 36.95) was observed between cluster II and cluster V, followed by cluster II and IX (D^2 =3.54), cluster I and cluster II (D^2 = 29), cluster II and cluster IV (D^2 = 28.10). The minimum inter cluster distance (D^2 = 6.80) was between clusters III and IV. All the fourteen clusters in divergence analysis contained genotypes of heterogeneous origin thereby indicating non-parallelism between genetic and geographic diversity. Therefore, crosses between members of cluster separated by high inter-cluster distance are likely to throw desirable segregates.

Keywords: Linseed, genetic diversity, genetic advance, variability, heritability

Introduction
Linseed is an important oilseed crop and its seed contains good percentage of oil varying from 32 per cent to 45 per cent. It's medicinal and nutritional properties have paved the way for its diversified uses and value addition in various forms. Its seed comprises 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 neuron-biology have established that it is best herbal source of Omega-3 and Omega-6 fatty acids which helps in regulating the nervous system.

The area under linseed in Maharashtra is 44 thousand ha with an annual production of 15 thousand tones and average productivity is 316 kg /ha. The area under linseed in Marathwada is 17 thousand ha with an annual production of 8 thousand tones and average productivity is 257 kg/ ha area and 32.36 thousand metric tons production.

All India linseed production is about 1.12 lakh tonnes oilseeds and 0.28 lakh tonnes oils (Anonymous 2021) [3]. India is the second largest producer of linseed, followed by Canada, China and USA; while in production stands at third position. India has 18.8 per cent of world production. The acreage of linseed in India is about 3.22 lakh hectares with production of 1.52 lakh tonnes and national state wise production is as Rajasthan (1056 kg/ha) followed by Bihar (848 kg/ha), MP (726 kg/ha), Jharkhand (617 kg/ha), Karnataka (499 kg/ha) and Maharashtra (318 kg/ha). Linseed accounted for only 0.7% and 0.03% of the oil seed acreage and production, respectively during 2019-2020. MP was the leading linseed growing state with 27.7% and 22.7% area share in acreage production, Anonymous, (2021) [3].

In Maharashtra, farmers are traditionally linseed growing since ancient time and maintained the same seed generation after generation without any scientific approach in most of the areas. With the popularization of improved varieties of linseed, traditionally growing genotypes getting vanished day by day, even though they have maintained genetically important diverse traits. The major cause behind the low productivity is cultivation of linseed in *utera* system, dry/land moisture stress situation and input starved conditions.

Thus there is need to collect and maintain such genotypes with specific traits-approach, so as to avoid loss of valuable genetically diverse population. Keeping these aspects in view, the present investigation is based on diagnostic morphological traits of such germplasm and to study the genetic variability parameters present among them.

Materials and Methods

The experiment material comprised of 31 germplasm lines of linseed collected from P.C. unit Kanpur (Uttar Pradesh), AICRP Linseed PDKV, Nagpur (Maharashtra) and ORS (Latur) were used to study genetic diversity, genetic advance, variability and heritability among the genotypes for quantitative characters. The details of the experimental materials used are given in Table 1.

The field experiment was conducted on the field of Department of Agriculture Botany, College of Agriculture, Latur. Experimental materials comprising 31 germplasm lines (including check) with wider variability for different characters which were sown in RBD design with 30 cm x 5 cm row to row and plant to plant spacing.

Table 1: List of germplasm lines and their sources

	Genotypes	Source
1.	GS-119	P.C. unit Kanpur.
2.	GS-53	P.C. unit Kanpur.
3.	GS-111	P.C. unit Kanpur.
4.	GS-121	P.C. unit Kanpur.
5.	Faithpur	P.C. unit Kanpur.
6.	GA-85	P.C. unit Kanpur.
7.	GEWARGI 1-2	P.C. unit Kanpur.
8.	GS-27	P.C. unit Kanpur.
9.	ES-1534	P.C. unit Kanpur.
10	FR-11	P.C. unit Kanpur.
11	LSL-01	P.C. unit Kanpur.
12	FRW-9	P.C. unit Kanpur.
13	EX-6-3	P.C. unit Kanpur.
14	GS-143	P.C. unit Kanpur.
15	EC-704	P.C. unit Kanpur.
16	ES-1531	AICRP Linseed PDKV, Nagpur.
17	EC-1386	AICRP Linseed PDKV, Nagpur.
18	EC-1474	AICRP Linseed PDKV, Nagpur.
19	Neelum	AICRP Linseed PDKV, Nagpur.
20	Flex-16	AICRP Linseed PDKV, Nagpur.
21	Nagarkot	AICRP Linseed PDKV, Nagpur.
22	Padmini	AICRP Linseed PDKV, Nagpur.
23	Meera	AICRP Linseed PDKV, Nagpur.
24	Mutant-2	AICRP Linseed PDKV, Nagpur.
25	Divya	AICRP Linseed PDKV, Nagpur.
26	A-429	AICRP Linseed PDKV, Nagpur.
27	CI-2260	AICRP Linseed PDKV, Nagpur.
28	ES-1444	AICRP Linseed PDKV, Nagpur.
29	RAC-6	AICRP Linseed PDKV, Nagpur.
30	T-397	AICRP Linseed PDKV, Nagpur.
31	LSL-93(Check)	ORS, Latur

Results and Discussion

The variation among genotypes were highly significant for day to 50% flowering, days to maturity, plant height (cm), 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 (g), oil content (%) and seed yield per plant (g). Analysis of variance for these ten quantitative characters as presented in Table 2.

The results revealed that mean sum of squares of genotypes were significant for all the characters under study, which indicated the existence of adequate amount of variability among the genotypes as given in Table 2, similar results were reported by Akbar *et al.* (2003) [2] and Choudhary *et al.* (2017) [6].

The estimates of heritability, genetic advance and genetic advance as percent mean is given in Table 3, in which maximum heritability was observed for oil per-cent (98.3%), Similar results were reported by Akbar *et al*. (2003) [2] and Kumar *et al*. (2018) [8].

The estimates of genetic advance ranged from 0.82 per-cent to 20.5 per-cent at (5%) level of significance and 1.06 per-cent to 26.2 per-cent at (1%) level of significance with the highest estimates in case of number of capsules per plant (20.5%). The estimates of genetic advance as per cent of mean ranged from 9.63 per-cent to 51.2 per-cent at 5 (%) level of significance and 1.3 (%) to 65.6 per-cent at 1 (%) level of significance with the highest estimates in case of seed yield per plant (51.2%), Similar findings were reported by Akbar *et al*. (2003) [2], Kumar *et al*. (2018) [8] and Choudhary *et al*. (2017) [6].

The average intra and inter cluster D^2 values are presented table 4. The intra cluster distance (D^2) range from 5.89 to 10.69, whereas inter cluster distance D^2 ranges from 6.80 to 36.94. Maximum inter cluster distance (D^2 = 36.95) was observed between cluster II and cluster V, followed by cluster II and IX (D^2 =3.54), cluster I and cluster II (D^2 = 29), cluster II and cluster IV (D^2 = 28.10). The minimum inter cluster distance (D^2 = 6.80) was between clusters III and IV.

Indicating that the genotypes falling in the clusters II and V were highly divergent from each other implying a large amount of diversity within and between groups, which could be exploited in breeding programme. The minimum inter cluster distance (D^2 = 6.80) was between clusters III and IV indicating that this cluster is less divergent.

The cluster means for the ten characters are presented in table 5. A considerable inter-cluster variation was observed among the cluster means for the characters studied viz., days to 50 per-cent flowering, days to maturity, plant height, primary branches per plant, secondary branches per plant, number of capsules per plant, seeds per capsule, 1000 seed weight (g), oil content per cent and seed yield per plant. The cluster mean for days to 50 per cent flowering varied from 38.70 (II) to 60.20 (V), the cluster mean for days to maturity ranged between 85.50 (II) to 111.10 (VI), the cluster mean for plant height was from 32.15 (II) to 70.10 (V), the cluster mean for primary branches ranged from 2.40 (XIII) to 4.20 (VI), the cluster mean for secondary branches ranged from 11.40 (XIII) to 18.50 (VI), the cluster mean for capsules per plant varied from 31 (IX) to 69.20 (VI), the cluster mean for seeds per capsule varied from 7.90 (IX) to 9.00 (IV), the cluster mean for 1000 seed weight (g) ranged from 5.15 (X) to 8.74 (II), the cluster mean for oil content ranged from 33.23 (V) to 37.41 (XIV) and the cluster mean for yield per plant ranged from 1.73 (XIII) to 4.05 (VI). It was observed that oil content (32.47%) contributed highest for divergence, followed by plant height (18.06%), days to maturity (17.20%), number of capsules per plant (12.90%), yield per plant (g) (9.46%), 1000 seed weight (7.74%), days to 50% flowering (0.86), number of seeds per capsule (0.65%) and primary branches per plant (0.65%).

Table 2: Analysis of variance (ANOVA) for different characters in Linseed

Sources of Variation	d. f.	Mean sum of squares									
		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of capsules per plant	Number of seeds per capsule	Test weight (g)	Oil content (%)	Yield per plant (g)
Replications	1	1.84	7.11	0.20	0.10	2.32	1.74	0.05	0.02	0.01	0.06
Genotypes	30	112.25**	163.05**	105.77**	0.82**	9.92**	217.36**	0.52**	2.04**	5.36**	1.32**
Error	30	7.22	1.97	1.05	0.07	1.08	6.68	0.08	0.04	0.04	0.06

*and **, indicates significance at 5% and 1% respectively.

Table 3: Estimates of variability parameters for ten quantitative characters in linseed

Sr. No.	Name of the characters	Range	σ^2g	σ^2p	GCV (%)	PCV (%)	h^2 (b.s) (%)	G.A. % (5%)	G.A. % (1%)	G.A. as % of mean (5%)	G.A. as % of mean (1%)
1.	Days to 50% flowering	38.40-62.30	52.50	59.70	14.06	15.00	87.90	13.90	17.90	27.10	34.80
2.	Days to maturity	85.00-116.00	80.50	82.5	8.70	8.80	97.60	18.20	23.40	17.70	22.70
3.	Plant height (cm)	29.90-70.10	52.30	53.4	13.03	13.10	98.00	14.70	18.90	26.50	34.00
4.	Number of primary branches per plant	2.40-5.10	0.37	0.45	17.70	19.30	83.80	1.15	1.48	33.40	42.80
5.	Number of secondary branches per plant	11.40-19.30	4.40	5.5	13.20	14.70	80.40	3.88	4.90	24.40	1.30
6.	Number of capsules per plant	31.00-75.00	105.30	112	18.80	19.40	94.00	20.50	26.20	37.60	48.20
7.	Number of seeds per capsule	7.20-9.10	0.22	0.30	5.70	6.70	72.60	0.82	1.06	10.00	12.83
8.	Test weight (g)	4.88-8.99	1.00	1.04	15.70	16.12	95.80	2.01	2.50	31.80	40.70
9.	Oil content (%)	32.34-37.46	2.65	2.7	4.70	4.75	98.30	3.33	4.26	9.63	12.30
10.	Seed yield per plant (g)	1.71-4.60	0.62	0.69	26.10	27.50	90.40	1.55	1.99	51.20	65.60

Table 4: Average intra and inter cluster distance D^2 values in linseed

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
I	8.94	29.08	11.46	13.27	12.66	14.38	16.41	18.29	12.02	14.26	15.83	20.37	13.20	18.99
II		5.89	24.31	21.48	36.95	28.10	24.51	21.25	30.54	26.38	20.99	21.27	25.86	21.78
III			0.00	6.80	14.11	15.23	9.74	9.47	12.63	11.77	9.10	14.20	12.58	15.79
IV				0.00	16.79	13.59	7.28	9.53	14.16	10.16	11.69	12.48	12.21	10.18
V					0.00	16.69	17.37	20.82	13.90	16.00	21.13	24.06	18.07	22.17
VI						10.69	17.18	18.85	19.96	13.93	21.59	23.38	19.06	16.17
VII							0.00	7.56	15.02	8.48	12.84	9.61	11.56	10.94
VIII								0.00	18.94	11.36	10.88	10.81	14.66	14.62
IX									0.00	16.51	13.83	17.48	11.11	19.82
X										0.00	15.53	14.51	10.76	12.87
XI											0.00	11.02	11.57	18.72
XII												0.00	11.35	13.33
XIII													0.00	15.43
XIV														0.00

Table 5: Cluster means of different characters to genetic diversity in linseed

Clusters	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of capsules per plant	Number of seeds per capsule	Test weight (g)	Oil content (%)	Seed yield per plant (g)
I	54.59	107.35	56.35	3.37	15.33	51.45	8.06	5.89	33.32	2.57
II	38.70	85.50	32.15	3.45	17.00	53.50	8.50	8.74	37.12	4.04
III	41.60	92.00	59.00	3.40	16.00	61.70	8.70	6.74	34.19	3.50
IV	41.10	96.00	57.20	3.90	16.50	55.00	9.00	7.30	35.50	4.01
V	60.20	109.00	70.10	3.90	17.70	58.00	8.70	5.24	33.23	2.69
VI	55.06	111.10	56.60	4.20	18.50	69.20	8.12	6.30	34.76	4.05
VII	46.60	95.00	61.60	3.60	16.70	55.10	8.40	6.49	36.62	3.17
VIII	39.90	87.00	57.70	2.70	18.40	66.40	8.60	6.43	36.30	3.67
IX	59.05	102.50	58.70	3.60	11.70	31.00	7.90	5.80	33.37	2.26
X	49.00	103.50	58.40	3.50	14.30	64.30	8.40	5.15	36.65	2.74
XI	40.20	86.00	51.30	2.60	12.10	49.10	8.80	6.43	34.52	2.86
XII	47.70	92.00	55.70	2.40	13.00	41.60	8.70	7.30	37.05	2.26
XIII	49.70	103.50	55.00	2.40	11.40	37.70	8.00	5.83	35.51	1.73
XIV	59.60	108.00	56.40	3.60	17.80	47.60	8.70	8.04	37.41	3.36

Conclusions

The variability among genotypes was highly significant for all the characters. The estimate of heritability revealed that it was most for oil per cent (98.3%), whereas estimate of genetic advance was highest for number of capsules per plant followed by days to maturity. The cluster means for different characters showed considerable differences among the clusters for all the characters. A considerable inter-cluster variation was observed among the cluster means for the characters studied viz., days to 50 per-cent flowering, days to maturity, plant height, primary branches per plant, secondary branches per plant, number of capsules per plant, seeds per capsule, 1000 seed weight (g), oil content per-cent, yield/p lant. So the parents selected for hybridization should be from the clusters having maximum distance.

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