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Genetic variation and characterization of different linseed genotypes (*Linum usitatissimum* L.) for agro-morphological traits

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Abstract: Forty five linseed genotypes (local collection) were subjected to study the genetic variability at the Experimental Farm of the Department of Crop Improvement, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* 2015-2016. Analysis of variance revealed that the differences among all the genotypes were significant for all the traits. Mean performance of genotype KLSA-15 for seed yield recorded highest contribution of 3.69 grams. The PCV values were greater than the GCV values for all the traits studied indicating that the apparent variation is not only due to genotypes but, also due to the influence of environment. The highest PCV (64.17) and GCV (64.09) were found for biological yield per plant. Higher estimates of PCV and GCV were obtained for primary branches per plant, secondary branches per plant, capsules per plant, biological yield per plant, harvest index (45.94 and 44.60) and seed yield per plant (52.39 and 50.94). All the characters studied in the present investigation expressed high heritability estimates ranging from 62.95 to 99.77 percent for technical height and biological yield per plant respectively. It was revealed that most of the traits under study showed low genetic advance, high heritability (94.23) and high genetic advance (31.06) was recorded for harvest index indicating predominance of additive gene action for this character. Simple selection based on phenotypic performance of this character would be more effective. The cluster analysis showed that the genotypes were placed into four clusters, showing inter-cluster divergence, which is important for future hybridization programme.

Keywords: Characterization,Genetic advance,Genetic variability, Heritability, *Linum usitatissimum* L.

INTRODUCTION

Linseed (*Linum usitatissimum* L.: n=15) belongs to the genus *Linum* of the family Linaceae having 14 genera. *Linum usitatissimum* is the only cultivated species of genus *Linum.* India is considered as centre of origin of linseed, from where it spreaded to other parts of the world including Ethiopia. (Wakjira *et al.,* 2004). Two morphologically distinct cultivated species of linseed are recognised, namely Flax and Linseed. The flax types are commercially grown for the extraction of fibres, whereas the linseed is meant for the extraction of oil from seeds. The oil content of the seed generally varies from 33 to 45 per cent. About 20 per cent of the total linseed oil is used for edible and domestic purposes and 80 per cent goes for industrial utilization. The oil is also utilized for manufacturing paints, varnishes, oilcloth, linoleum, pad-ink, printers ink, soap etc. Across the globe it covers 2270.35 thousand hectare area with production of 2238.94 thousand tons having productivity of 986.16 kg per hectare, where as in India its area is limited to 338 thousand hectares and production 147 thousand tons with the productivity of 434.91 kg per hectare, (Anonymous 2013). Being an important oilseed crop, its average productivity in India is very low, because of various factors viz., narrow genetic base, raising of crop by the resource poor farmers in marginal and sub-marginal areas, non-availability of high yielding varieties and resistance to biotic and abiotic stresses, etc., There is an urgent need to increase the productivity by breaking the present yield barrier and developing high yielding varieties. Success of any breeding program depends upon the presence of substantial amount of genetic variability and heritability (Sidra *et al*., 2014; Laila *et al*., 2014) because the ultimate goal is to develop hybrid cultivars that can potentially use the total amount of heterosis available. Development of high yielding varieties requires the knowledge of existing genetic variability. The measurement of genetic variation and mode of inheritance of quantitative and qualitative traits are of prime importance in planning the breeding programme efficiently and effectively (Shah *et al*., 2015). Heritability of any trait depends upon genetic properties of breeding material and environmental conditions in which experiments are carried out (Falconer & Mackay, 1996). A character which has higher range of genetic variability, high heritability and high genetic advance would be an effective tool to improve economic yield (Aytac and Kinaci, 2009). Morphological traits have been used to

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assess the genetic variation and relationships among populations of different oilseed species, for example, Linseed, Brassica and soybean (Iqbal *et al*., 2008; Rabbani *et al*., 1998 & 1999; Kop *et al*., 2003) etc. However, the ariation patterns in these traits are considered to be the result of both genetic and environmental attributes (Rohlf*et al*., 1990). Genetic improvement of seed quality can make oilseed as a source for high quality edible oil for human consumption and high quality protein meal for feeding animals, non-edible industrial products, such as detergents, lubricants, cosmetics, hydraulic oils, biodiesel and bio energy (Ofori & Becker, 2008; Kimber & McGregor, 1995).

With the above background information, the present investigation was undertaken to study the genetic parameters among the seventeen linseed genotypes.

MATERIALS AND METHODS

Genetic variability for various traits was studied in 45local collection including five standard checks viz., T-397, Baner, Nagarkot, Him Alsi-2 and Himani (Table 1) of linseed during *rabi* 2015-16 at Experimental Farm of the Department of Crop Improvement, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India (32°8′ N, 76°3′ E) represents humid sub-temperate climate zone with annual rainfall of 2500 mm and acidic soil with pH of 5.0 to 5.6. The experiment was conducted using randomized complete block design with three replications. Each replication consisted of three rows of each genotype. Row to row distance was 30 cm with row length of 3 meter and plant to plant distance was 10 cm. Normal cultural practices were carried out as recommended for linseed. Data was recorded on five randomly selected plants in each replication. For plant height data was recorded by measuring the distance from the soil to the tip of the plant, at a stage when crop reached physiological maturity, technical height recorded from the ground surface to the point from where the primary branches start at the stage of physiological maturity, primary branches per plant is the numbers of branches emerging from the main stem were counted for each plant at maturity and then averaged, secondary branches per plant was counted of branches arising from primary branches in selected plants of each genotype were recorded and mean value was obtained, capsules per plant were counted total numbers of capsules in the plant and mean value was obtained, biological yield was recorded by weighing five selected plant before threshing and then averaged seeds per capsule were counted in ten randomly selected capsules and then averaged, seed yield per plant was recorded by weighing seed of five selected plant and averaged (Patial, 2014). Harvest index was calculated as:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield per plant}}{\text{Aerial biomass per plant}} \times 100$$

Statistical analysis: The recorded data was subjected to analysis of variance (Panse and Sukhatme 1985).

Genetic variability: Genotypic and phenotypic variances, genotypic (GCV), phenotypic coefficients of variance (PCV) and heritability (broad sense) were computed according to Burton & Devane (1953), Johnson *et al.* (1955) and Singh & Chaudhary (1985):

Environmental variance (Ve) = Error mean squares (EMS)

$$\text{Genetic variance (Vg)} = \frac{\text{Genotypes mean squres (GMS)} - \text{Error mean squares (EMS)}}{\text{No. of replications (r)}}$$

Phenotypic variance (Vp) = Vg + Ve

Heritability broad sense (H^2) on plots mean basis was calculated as:

$$H^2 = \frac{Vg}{Vp}$$

Genotypic coefficient of variation = $\sqrt{V_g}$/GM × 100

Phenotypic coefficient of variation = $\sqrt{V_P}$ /GM × 100

Where:

V_g = Genotypic variance

V_P = Phenotypic variance

GM = Grand mean of the trait

H^2 = Broad sense heritability for a trait.

Cluster analysis: Cluster analysis was carried out through SPSS 16.0 using wards method.

RESULTS AND DISCUSSION

Greater variability in the initial breeding material ensures better chances of producing desired forms of a crop plant. Thus, the primary objective of germplasm conservation is to collect and preserve the genetic variability in indigenous collection of crop species to make it available to present and future generations.

The analysis of variance (Table 2) revealed that highly significant differences among the genotypes for all the characters indicating sufficient variability existed in the present material selected for the study and indicating the scope for selection of suitable initial breeding material for crop improvement. However, the absolute variability in different characters does not permit identification of the characters showing the highest degree of variability.

A thorough probe into mean data (Table 3) revealed that plant height ranged from 59.97 to 89.90 cm with maximum contribution from KLSA-5 while minimum contribution by T-397. Technical height was ranged from 19.13 cm (T-397) to 59.80 cm (KLSA-5). Maximum number of primary branches per plant was produced by KLSA-5 (13.00) followed by KLSA-4 (11.67), KLSA-2 (11.33), KLSA-3 (11.33), and KLSA -1(11.33), where as minimum value was observed for KLC-13 (4.00). Similar observations in primary branches per plant were recorded in case of secondary branches per plant. The capsules per plant ranged from 26.00 (KLC-13) to 75.67 (KLSB-1). Biological yield

Table 1. Details of material (local collection of linseed) used in present study.

S. No.	Collection No.	Crop Name	Botanical Name	Site of collection		State
				Village	**Disst.**	
1	KLSA-1	Linseed	*Linum usitatissimum*	Utrala	Kangra	H.P.
2	KLSA-2	Linseed	*Linum usitatissimum*	HarerBaijnath	Kangra	H.P.
3	KLSA-3	Linseed	*Linum usitatissimum*	DrughNalaBaijnath	-	H.P.
4	KLSA-4	Linseed	*Linum usitatissimum*	HarerBaijnath	Kangra	H.P.
5	KLSA-5	Linseed	*Linum usitatissimum*	BalhHarerBaijnath	Kangra	H.P.
6	KLSA-6	Linseed	*Linum usitatissimum*	BalhHarerBaijnath	Kangra	H.P.
7	KLSA-7	Linseed	*Linum usitatissimum*	DramluHarerBaijnath	Kangra	H.P.
8	KLSA-8	Linseed	*Linum usitatissimum*	DramluHarerBaijnath	Kangra	H.P.
9	KLSA-9	Linseed	*Linum usitatissimum*	KholiDeolBaijnath	Kangra	H.P.
10	KLSA-10	Linseed	*Linum usitatissimum*	Phatar	Kangra	H.P.
11	KLSA-11	Linseed	*Linum usitatissimum*	Bhattu	-	H.P.
12	KLSA-12	Linseed	*Linum usitatissimum*	Tramal	-	H.P.
13	KLSA-13	Linseed	*Linum usitatissimum*	DakBangraChauntra	Mandi	H.P.
14	KLSA-14	Linseed	*Linum usitatissimum*	ChauntraJoginder Nagar	Mandi	H.P.
15	KLSA-15	Linseed	*Linum usitatissimum*	Hara Bagh Joginder Nagar	Mandi	H.P.
16	KLSA-16	Linseed	*Linum usitatissimum*	Hara Bagh Joginder Nagar	Mandi	H.P.
17	KLSB-1	Linseed	*Linum usitatissimum*	Jia	Kangra	H.P.
18	KLSB-2	Linseed	*Linum usitatissimum*	Jia	Kangra	H.P.
19	KLSB-3	Linseed	*Linum usitatissimum*	Jia	Kangra	H.P.
20	KLSB-4	Linseed	*Linum usitatissimum*	Jagehar	Kangra	H.P.
21	KLSB-5	Linseed	*Linum usitatissimum*	Chamotu Jia	Kangra	H.P.
22	KLSB-6	Linseed	*Linum usitatissimum*	Chamotu Jia	Kangra	H.P.
23	KLSB-7	Linseed	*Linum usitatissimum*	Chamotu Jia	Kangra	H.P.
24	KLC-3	Linseed	*Linum usitatissimum*	Nagehar	-	H.P.
25	KLC-4	Linseed	*Linum usitatissimum*	Nagehar	-	H.P.
26	KLC-9	Linseed	*Linum usitatissimum*	Baijnath	Kangra	H.P.
27	KLC-10	Linseed	*Linum usitatissimum*	Arki	Solan	H.P.
28	KLC-11	Linseed	*Linum usitatissimum*	AhjuBaijnath	Kangra	H.P.
29	KLC-12	Linseed	*Linum usitatissimum*	Kandi ,Palampur	Kangra	H.P.
30	KLC-13	Linseed	*Linum usitatissimum*	Trehal ,Baijnath	Kangra	H.P.
31	KLC-14	Linseed	*Linum usitatissimum*	UtralaBaijnath	Kangra	H.P.
32	KLD-1	Linseed	*Linum usitatissimum*	Patti Panchrukhi	Kangra	H.P.
33	KLD-2	Linseed	*Linum usitatissimum*	Patti Panchrukhi	Kangra	H.P.
34	KLD-3	Linseed	*Linum usitatissimum*	Chandropa Patti Panchrukhi	Kangra	H.P.
35	KLD-4	Linseed	*Linum usitatissimum*	Palah Patti Panchrukhi	Kangra	H.P.
36	KLD-5	Linseed	*Linum usitatissimum*	Patti Panchrukhi	Kangra	H.P.
37	KLD-6	Linseed	*Linum usitatissimum*	Chandropa Patti Panchrukhi	Kangra	H.P.
38	KLD-7	Linseed	*Linum usitatissimum*	Palah Patti Panchrukhi	Kangra	H.P.
39	KLD-8	Linseed	*Linum usitatissimum*	Palah Patti Panchrukhi	Kangra	H.P.
40	KLD-10	Linseed	*Linum usitatissimum*	Chandropa Patti Panchrukhi	Kangra	H.P.

Contd.

Table 1. Contd.

41	T-397	Linseed	*Linum usitatissimum*
42	Baner	Linseed	*Linum usitatissimum*
43	Nagarkot	Linseed	*Linum usitatissimum*
44	Him Alsi-2	Linseed	*Linum usitatissimum*
45	Himani	Linseed	*Linum usitatissimum*

Table 2. Analysis of variance for various traits in linseed (*Linum usitatissimum* L.)

S. No.	Traits	Replication df = 2	Genotypes df = 44	Error df = 88	CV(%)
1	Plant height (cm)	21.1	127.96**	11.32	4.5
2	Technical height (cm)	3.57	132.87**	21.79	10.75
3	Primary branches per plant	3.27	12.82**	0.8	12.61
4	Secondary branches per plant	2.36	8.63**	0.69	15.75
5	Capsules per plant	6.9	487.04**	7.41	5.61
6	Biological yield per plant (gm)	1.05	12.53**	0.01	3.06
7	Seeds per capsule	1.79	2.85**	1.35	15.03
8	Harvest index (%)	1187.23	738.63**	14.78	11.04
9	Seed yield per plant (gm)	0.39	0.8**	0.02	12.26

* $P \leq 0.005$and ** $P \leq 0.001$

per plant varied from 0.78 (KLSA-13) to 9.26 (KLSA-16). Maximum number of seeds per capsule was recorded as 10 by KLD-5 and minimum by T-397 (5). Harvest index was ranged from 12.64 to 72.29 and the maximum contribution by KLSB-7. Contemplation of mean values for seed yield per plant demonstrated that cultivars KLC-9 (0.18) was found poor with lowest contribution and KLSA-15 recorded highest contribution of 3.69 grams (Table 3 and Fig. 1).

Range of genotypes studied are given in Table 4. Range values expressed great variation for all the traits indicating presence of variability in material. Estimation of genetic parameters are presented in Table 4. Comparison of variability between two traits is possible with coefficient of variation as it is free of units. The PCV values were greater than the GCV values for all the traits studied (Table 3). The similar results on linseed were also reported by Kumar *et al.* (2015); Kumar and Paul (2016), indicating that the apparent variation is not only due to genotypes but, also due to the influence of environment. Therefore, caution has to be exercised in making selection for these characters on the basis of phenotype alone as environmental variation is unpredictable in nature. These investigations were supported by the previous workers (Akbar *et al.,* 2003; Khan *et al.* 2007; Kumar *et al.,* 2012; Manggoel *et al.,* 2012; Kumar *et al.,* 2015).

The highest PCV (64.17) and GCV (64.09) for biological yield per plant followed by seed yield per plant PCV (52.39) and GCV (50.94) values were found particularly

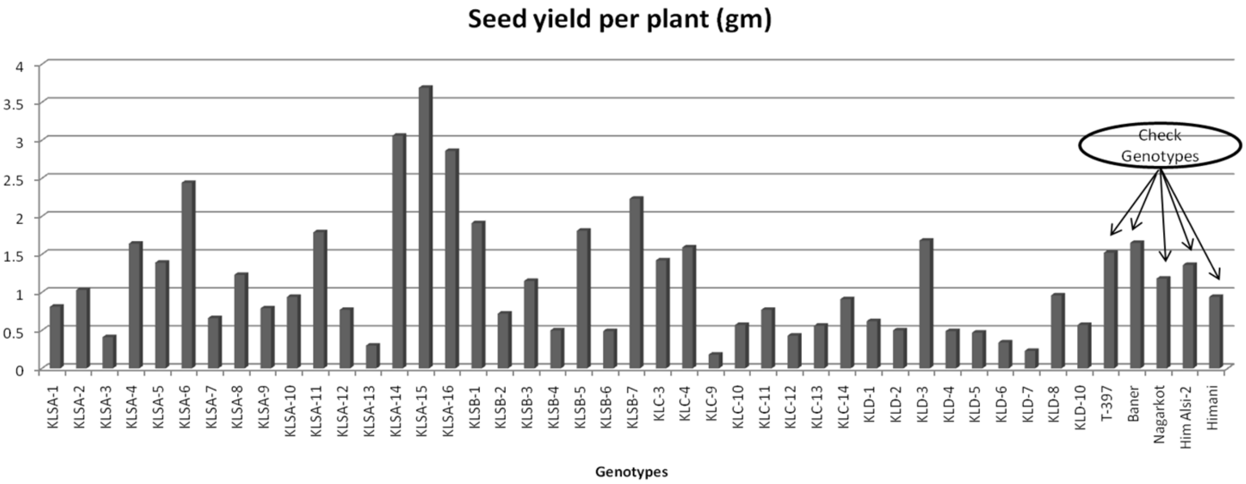

Fig. 1. *Genotypes and mean of seed yield studied with the control cultivars.*

Table 3. Mean values for yield and its components in linseed (*Linumusitatissimum*L.)

	Plant Height (cm)	Technical height (cm)	Primary branches per plant	Secondary branches per plant	Capsules per plant	Biological yield per plant (gm)	Seeds per capsule	Harvest index (%)	Seed yieldper plant (gm)
KLSA-1	72.17	44.40	11.33	7.00	58.67	2.97	8.33	27.58	0.81
KLSA-2	75.13	41.60	11.33	8.67	50.67	2.80	8.00	37.12	1.03
KLSA-3	70.80	40.40	11.33	7.67	71.00	2.16	9.00	19.08	0.41
KLSA-4	67.43	33.60	11.67	10.00	70.33	4.06	9.00	40.53	1.64
KLSA-5	89.90	59.80	13.00	10.67	69.00	3.07	9.67	45.44	1.39
KLSA-6	76.43	41.13	7.33	5.00	68.00	9.18	7.00	26.69	2.44
KLSA-7	60.50	35.50	6.00	4.17	47.33	2.94	8.00	22.49	0.66
KLSA-8	74.90	50.53	6.33	4.67	56.67	3.30	6.33	37.37	1.23
KLSA-9	73.43	39.27	6.00	4.00	42.00	1.68	8.00	47.15	0.79
KLSA-10	75.47	40.67	7.67	7.00	41.33	4.06	8.00	23.14	0.94
KLSA-11	73.27	39.68	7.00	5.67	67.33	3.95	7.33	45.43	1.79
KLSA-12	71.27	41.53	6.00	5.00	39.67	3.65	7.33	21.04	0.77
KLSA-13	75.13	47.27	6.33	5.33	45.67	0.78	7.67	39.43	0.30
KLSA-14	80.90	43.63	6.33	4.67	43.67	9.18	7.33	33.50	3.06
KLSA-15	81.33	41.60	8.67	7.33	54.67	7.77	7.67	47.77	3.69
KLSA-16	76.67	45.00	7.33	5.00	48.00	9.26	7.33	31.06	2.86
KLSB-1	78.97	39.00	7.67	5.33	75.67	3.48	7.00	55.00	1.91
KLSB-2	75.27	43.37	8.00	7.00	72.67	1.90	9.00	38.13	0.72
KLSB-3	66.27	42.07	5.67	4.00	39.00	3.14	8.67	36.88	1.15
KLSB-4	65.63	40.03	4.67	3.33	31.67	1.28	6.67	39.53	0.50
KLSB-5	65.27	55.37	6.33	5.00	44.33	4.50	8.33	40.46	1.81
KLSB-6	74.80	40.53	8.00	6.00	51.33	2.87	7.00	17.09	0.49
KLSB-7	73.93	37.53	6.67	5.00	64.33	3.10	6.33	72.29	2.23
KLC-3	79.47	45.07	5.33	3.67	41.67	2.93	8.00	48.78	1.42
KLC-4	73.87	40.00	7.33	6.00	47.67	3.94	9.00	40.64	1.59
KLC-9	71.23	44.53	5.00	3.67	44.33	1.09	7.00	16.29	0.18
KLC-10	82.10	48.73	4.67	3.67	45.67	1.94	7.33	29.42	0.57
KLC-11	86.50	54.37	6.33	4.67	34.67	1.76	8.00	43.77	0.77
KLC-12	75.37	43.40	7.00	4.67	34.00	1.05	8.67	41.34	0.43
KLC-13	79.60	47.60	4.00	2.67	26.00	1.34	6.33	42.13	0.56
KLC-14	64.53	38.03	5.33	3.67	33.00	3.86	6.67	23.79	0.91
KLD-1	70.23	53.53	6.67	5.00	34.67	2.03	8.00	30.50	0.62
KLD-2	66.53	36.37	4.67	3.67	34.67	2.78	8.33	18.21	0.50
KLD-3	82.07	51.43	6.00	4.33	40.00	3.36	7.00	50.29	1.68
KLD-4	81.87	48.67	5.33	4.00	36.67	1.83	7.33	26.79	0.49
KLD-5	76.50	42.63	8.33	5.00	53.00	1.74	10.00	26.96	0.47
KLD-6	77.80	40.53	8.33	5.00	54.67	1.05	8.33	32.42	0.34
KLD-7	76.07	42.47	6.67	4.67	50.33	1.86	8.33	12.64	0.23
KLD-8	78.70	46.40	10.33	7.67	62.67	2.42	6.67	39.94	0.96

Contd.

Table 3. Contd.

KLD-10	69.60	44.23	7.33	5.67	57.33	1.94	7.33	29.42	0.57
T-397	59.97	19.13	5.67	4.00	42.00	3.24	5.00	47.30	1.52
Baner	72.33	43.70	4.67	3.67	32.67	3.33	8.00	49.75	1.65
Nagarkot	82.83	49.92	7.00	5.67	41.00	2.18	7.67	54.58	1.18
Him Alsi-2	83.43	50.73	7.00	5.00	44.00	2.44	7.33	55.98	1.36
Himani	80.30	40.03	6.33	4.67	39.00	3.24	9.00	29.01	0.94
GM	74.79	43.45	7.11	5.29	48.50	3.17	7.74	36.32	1.15
SE	0.97	0.99	0.31	0.25	1.90	0.30	0.15	1.87	0.12
C.D @ 5%	5.45	7.57	1.45	1.35	4.41	0.15	1.88	3.96	0.19
C.V	4.50	10.75	12.61	15.75	5.61	3.08	15.03	6.73	10.70

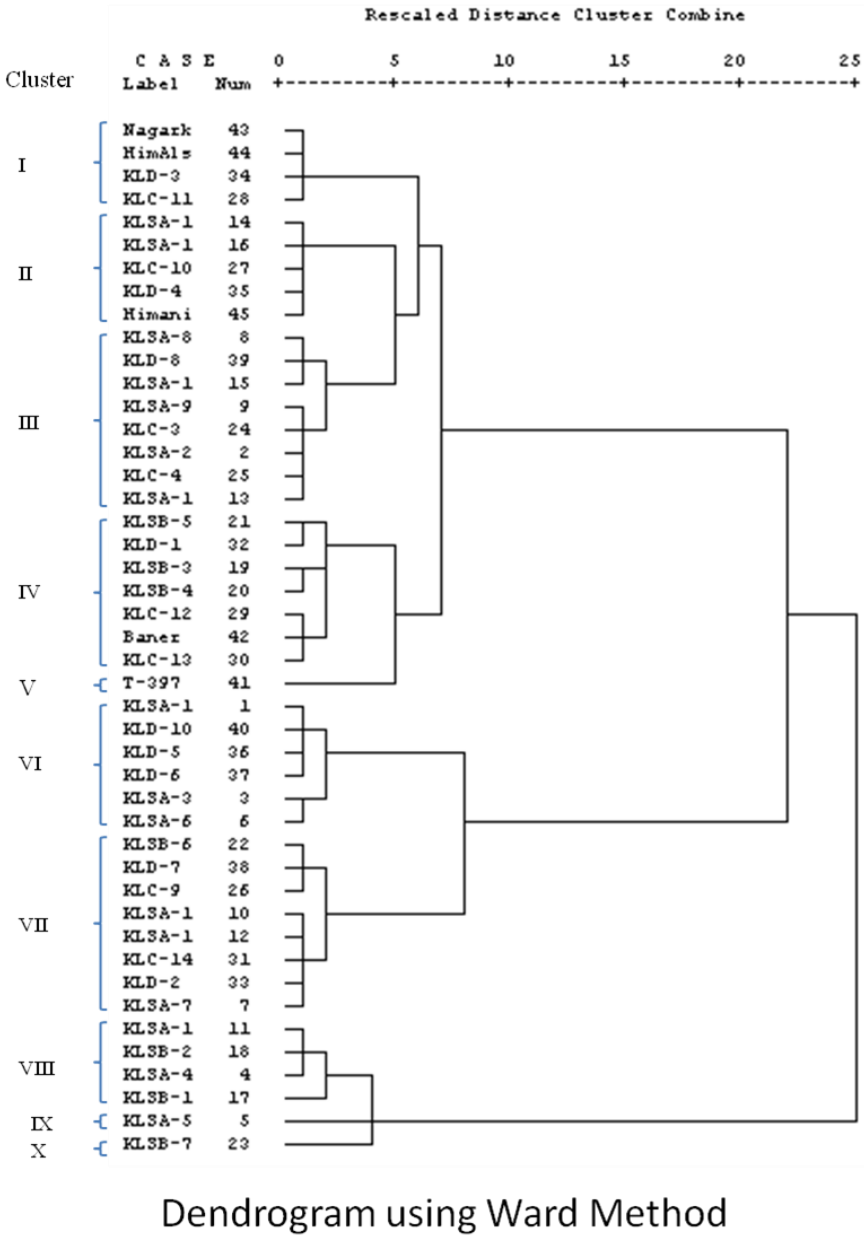

Fig. 2. *Relationship among 45 linseed genotypes revealed by cluster analysis based on 9 traits.*

Table 4. Genetic parameters of variability for different agro-morphological traits of linseed (*Linum usitatissimum* L.)

	Mean ± S.E. (m)	Range	PCV	GCV	Heritability	Genetic Advance
Plant height (cm)	74.79±0.97	59.97-89.90	9.47	8.34	77.47	11.31
Technical height (cm)	43.45±0.99	19.13-59.80	17.65	14.01	62.95	9.95
Primary branches per plant	7.11±0.31	4.00-13.00	30.84	28.14	83.27	3.76
Secondary branches per plant	5.29±0.25	2.67-10.67	34.53	30.74	79.21	2.98
Capsules per plant	48.50±1.9	26.00-75.67	26.67	26.07	95.57	25.46
Biological yield per plant (gm)	3.19±0.3	0.78-9.26	64.17	64.09	99.77	4.20
Seeds per capsule	7.74±0.15	5.00-10.00	17.58	9.11	26.89	0.75
Harvest index (%)	34.83±1.87	12.64-72.29	45.94	44.60	94.23	31.06
Seed yield per plant (gm)	1.01±0.12	0.18-3.69	52.39	50.94	94.53	1.03

Table 5. Clustering pattern of 45 linseed (*Linumusitatissimum*L.) genotypes.

Sr. No.	Clusters	No. of Genotypes	Genotypes
1	I	4	Nagarkot, Him Alsi-2, KLD-3, KLC-11
2	II	5	KLSA-14, KLSA-16, KLC-10, KLD-4, Himani
3	III	8	KLSA-8, KLD-8, KLSA-15, KLSA-9, KLC-3, KLSA-2, KLC-4, KLSA-13
4	IV	7	KLSB-5, KLD-1, KLSB-3, KLSB-4, KLC-12, Baner, KLC-13
5	V	1	T-397
6	VI	6	KLSA-1, KLD-10, KLD-5, KLD-6, KLSA-3,KLSA-6
7	VII	8	KLSB-6, KLD-7, KLC-9, KLSA-10, KLSA-12, KLC-14, KLD-2, KLSA-7
8	VIII	4	KLSA-11, KLSB-2, KLSA-4, KLSB-1
9	IX	1	KLSA-5
10	X	1	KLSB-4

due to very high variability available in these traits. Higher estimates of PCV and GCV (>25 %) are obtained for primary branches per plant, secondary branches per plant, capsules per plant, biological yield per plant, harvest index and seed yield per plant. Moderate PCV and low GCV values were recorded for technical height and seeds per capsule. Whereas, low PCV and GCV (<15) were recorded for plant height suggesting less variability existed in this character. This moderate to low variability indicates the need for improvement of base population through intercrossing in F_2 generation followed by recurrent selection to increase the gene flow and to fix favourable alleles.

The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic value. Heritability is a good index of transmission of characters from parents to its progeny. The estimates of heritability help the plant breeder in selection of elite genotypes from diverse genetic population. Therefore, high heritability helps in effective selection for a particular character. Heritability is classified as low (below 30 %), medium (30-60 %) and high above (60 %). All the characters studied in the present investigation expressed high heritability estimates ranging from 62.95 to 99.77 percent for technical height and biological yield per plant respectively. High heritability values indicate that the characters under study are less influenced by environment in their expression. The plant breeder, therefore, may make his selection safely on the basis of phenotypic expression of these characters in the individual plant by adopting simple selection methods. High heritability indicates the scope of genetic improvement of these characters through selection. Similar results on linseed have been reported by Rama Kant *et al.* (2005).

The genetic advance is a useful indicator of the progress that can be expected as result of exercising selection on the pertinent population. Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al*., 1955). Present study revealed that most of the traits under study showed low genetic advance (<15). High heritability coupled with high genetic advance were more useful than heritability alone in predicting the resultant effect during selection of best individual genotype. Genetic advance is the measure of genetic gain under selection and expression in percentage of mean (Johnson *et al*., 1955). In the present experiment high heritability and high genetic advance was recorded for harvest index indicating predominance of additive gene action for this character. Simple selection based on phenotypic performance of this character would be more effective.

Cluster analysis: The cluster analysis showed that the genotypes were placed into ten clusters (Table 5), of which the III and VII encompasses the largest number of genotypes (8), while the V, IX and X contains one genotype (Fig. 2), showing wide divergence i.e. inter-cluster divergence, which is desirable for future hybridization programme for getting desirable transgressive segregants. Different clustering pattern were also reported on linseed by some earlier workers (Srivastava *et al.,* 2009, Kandil *et al.,* 2011, Kant *et al.,* 2011).

Conclusion

Present investigation signified that seed yield per plant expressed high GCV (50.94) and PCV (52.39), high heritability (94.53) which indicated the presence of sufficient variability a pre requisite for any successful breeding programme. Hence, the breeder should adopt suitable breeding methodology to utilize both additive and non additive gene effects simultaneously, since varietal and hybrid development will go a long way in the breeding programmes especially in case of linseed. Cluster analysis indicating wide divergence, which is desirable for future hybridization programme for getting desirable transgressive segregants.

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