

## SELECTION CRITERIA OF LINSEED GENOTYPES FOR SEED YIELD TRAITS THROUGH CORRELATION, PATH COEFFICIENT AND PRINCIPAL COMPONENT ANALYSIS

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### ABSTRACT

Twenty five linseed genotypes were evaluated to determine the selection criteria and interrelationships of seed yield and yield related traits, during *rabi* 2013-14 at the Department of Crop Improvement, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India. Genotypic and phenotypic correlation coefficients obtained between different traits was similar in direction, while in magnitude, the genotypic correlations were higher than the corresponding phenotypic correlations. Seed yield per plant had significant and positive association with biological yield per plant, straw yield per plant, fibre yield and 1000 seed weight. Path analysis demonstrated that biological yield per plant showed higher and positive direct effect on seed yield per plant indicating selection for this character would lead to increase of yield. Straw yield per plant, fibre yield and 1000 seed weight contributed indirectly through biological yield per plant. Conformingly, the principal component analysis (PCA) showed that biological yield per plant, straw yield per plant, fibre yield and 1000 seed weight had the most contributions, interpreting almost all the variation of traits. Indeed, to simultaneously breed of high yielding linseed varieties, biological yield per plant should firstly be considered followed by straw yield per plant, fibre yield and 1000 seed weight.

**Key words:** Linseed, correlation, path coefficient analysis, principal component analysis, yield components.

### INTRODUCTION

Linseed (*Linum usitatissimum* L.) an important oilseed crop belonging to Linaceae family, with 14 genera and over 200 species, and *Linum usitatissimum* L. is the only species in this family with economic and agronomic values (Tadesse *et al.*, 2009). Possibly, this crop species has originated from *Linum angustifolium* Huds. The origin of cultivated linseed is not exactly known, however, it assumed that said crop has been originated from the Indian sub-continent as the greatest genetic diversity of this crop found in this specific area (Genesar and Morris, 2003). It is a self pollinated crop but cross pollination can take place up to 2% (Tadesse *et al.*, 2009). Every part of the linseed plant is utilized either directly or after processing. It is used as food (dietary fibres, micronutrients and omega -3 fatty acids), feed (oil cakes) and contains medicinal properties like antioxidant, phytoestrogen and anti-cancerous (Touré and Xueming, 2010), also have a huge industrial demand for its fibre (flax and linen) and oil (paint, lubricant and varnish). 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).

Selection is a pivotal axis of breeding programmes by which genotypes with high productivity

in a given environment may be developed. The yield of linseed is related to its components as number of plant per unit area, number of capsules per plant and 1000 seed weight and so on. The main target of improvement programmes is achieving varieties having high yield and quality potential. Selection for yield has many complexities because it is end product of various yield contributing characters which are naturally polygenic and majorly influenced by environment. So due to less impression of direct selection for yield, more efforts should be over indirect selection for yield components (changing yield through yield components). Proper understanding of association of different traits, provide more reliable selection criterion to achieve a high seed yield (Akbar *et al.*, 2001). This selection criterion takes into account the information on interrelationships among agronomic characters, their relationship with seed yield as well as their direct influence on seed yield. However, simple correlation coefficients and analysis of variance may not evolve satisfactory findings in uncovering the real interrelationships among the various traits.

Nevertheless, selection for yield via highly correlated characters becomes easy if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey and Lu, 1959). In fact, practically selection criteria will contribute to selection based on direct effects (Yucel, 2004; Copur and Oglakci, 1998). So path coefficient analysis technique is a statistical approach which is based on multiple regression

and is useful for revealing the direct and indirect effects of the variables in a network of factors like agro/morpho/physio/biochemical traits which is able to separate correlation coefficients into their components of direct and indirect effects (Dewey and Lu, 1959; Wright, 1960). However, achieving the interrelationships among characters aids in programming efficient approaches of multiple trait selection. The present study was conducted to study and determine the main possible associations among yield, yield related characters in linseed to determine the best selection criteria to enhance seed yield of linseed.

## MATERIALS AND METHODS

To identify the relationship of grain yield and yield related attributes, 25 linseed genotypes, were evaluated at the Department of Crop Improvement, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India, situated at an elevation of 1300 m. a.m.s.l with 36°6'N latitude and 76°3'E longitude, which represents the mid-hill zone of Himachal Pradesh, during *rabi* 2013-14 (Table 1). The experiment was laid out in a randomized complete block design (RCBD) with two replications. Each genotype was having three rows in each replication. Row to row distance was 30 cm with row length of 3 meter and plant to plant distance was 10 cm which maintained by thinning. The recommended package of practices were followed for raising a good crop. Observations were recorded on five randomly selected plants per entry and per replication for plant height, technical height, primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, biological yield per plant, straw yield per plant, fibre yield, 1000-seed weight, seed yield per plant, whereas phenological traits i.e. days to 50% flowering and days to 75% maturity were recorded on plot basis.

The collected data were subjected to analysis of variance (Panse and Sukhatme, 1985). Genotypic and phenotypic correlation coefficient correlation were worked out following the procedure of Al-Jibouri *et al.* (1958)

$$\text{Genotypic correlation (rg)} = \frac{g(xy)}{(\sqrt{g(X)} \times \sqrt{g(Y)})^{1/2}}$$

$$\text{Phenotypic correlation (rp)} = \frac{p(xy)}{(\sqrt{p(X)} \times \sqrt{p(Y)})^{1/2}}$$

where,

$g(xy)$  = genotypic covariance between two traits 'x' and 'y'

$g(X)$  = genotypic variance of trait 'x'

$g(Y)$  = genotypic variance of trait 'y'

$p(xy)$  = phenotypic covariance between two traits 'x' and 'y'

$p(X)$  = phenotypic variance of trait 'x'

$p(Y)$  = phenotypic variance of trait 'y'

Estimates of correlation coefficients were compared against r-values given in Fisher and Yates (1963) table at (n-2) d.f. at the probability levels of 0.05 and 0.01 to test their significance. Direct and indirect effects of traits on grain yield were calculated using genotypic correlation coefficient of various traits as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Therefore, genotypic correlation coefficient of any attribute with grain yield was divided into direct and indirect effects adopting the standard formula:

$$\text{Path analysis} = r_{ij} = p_{ij} + \sum r_{ik} p_{kj}$$

Where

$r_{ij}$  = Mutual association of independent variable (i) and dependent variable (j)

$p_{ij}$  = Components of direct effects of independent variable (i) on the dependent variable (j) as measured by the path coefficients

$\sum r_{ik} p_{kj}$  = Summation of components of indirect effects of a given independent character (i) on a given dependent character (j) through all other independent characters (k).

Principal component analysis (PCA) analysis was performed using XLSTAT software to determine the best relationships among characters.

## RESULTS AND DISCUSSION

Selection based on the detailed knowledge of magnitude and direction of association between yield and its attributes is very important in identifying the key characters, which can be exploited for crop improvement through suitable breeding programme. Analysis of variance revealed that highly significant differences among the genotypes for all the characters indicating sufficient variability present in the present material selected for the study and indicating the scope for selection of suitable initial breeding material for crop improvement.

**Correlation coefficient analysis:** The possible enhancements of high yield through yield attributes, as primary target of crop improvement, requires understanding the amount of correlations among various yield contributing characters or in fact, yield components. The simple correlation coefficients between various traits are given in Table 3. Results revealed that traits viz., biological yield and straw yield per plant, fibre yield and 1000 seed weight had strong positive association with seed yield per plant at both genotypic and phenotypic levels (Table 3). Whereas, plant height, technical height and capsules per plant showed negative significant correlation with seed yield per plant. Seed yield per plant showed non-significant negative associations with days to 50% flowering, days to 75% maturity, primary branches per plant and secondary branches per plant, however,

nonsignificant positive correlation with seeds per capsule. Genotypic and phenotypic correlation coefficients were similar in directions, while in magnitude, genotypic correlations were mostly higher than corresponding phenotypic correlations. Similar findings were reported by Sohan *et al.* (2004), Joshi (2004), Rajanna *et al.* (2014), Gauraha *et al.* (2011). Thus, low phenotypic correlation could result due to the masking and modifying effect of environment on the association of characters at genotypic level. On the basis of association analysis, it can be concluded that selection criteria based on traits *viz.*, biological yield per plant, straw yield per plant, fibre yield and 1000 seed weight can provide better basis for improvement of seed yield per plant in linseed, as reported by most of the workers in linseed *viz* Pal *et al.* (2000), Yadav (2001), Muhammad *et al.* (2003), Gauraha *et al.* (2011), their research findings elaborated that seed yield per plant had significant positive correlation with number of branches per plant, number of capsules per plant, and 1000 seed weight.

**Path coefficient analysis:** Correlation coefficient measures the mutual association between two variables but does not permit the cause and effect relationship of traits contributing directly or indirectly towards economic yield. Whereas, path coefficient analysis specifies the causes and measures of their relative importance (Shivanna *et al.*, 2007). This kind of analysis is of a more precise manner than simple correlation coefficients by which partitioning the correlations into direct and indirect effects of individual traits (independent) on final dependent trait (seed yield per plant) is achieved. Such an analysis helps the breeders to identify the characters that could be used as selection criteria in linseed breeding programmes.

The direct and indirect effects of genotypic path coefficients were mostly higher in magnitude than corresponding phenotypic path coefficients (Table 4). Similar finding with respect to path coefficients in the case of plant height, number of capsules per plant, branches per plant and 1000 seed weight respectively have been reported by Gauraha and Rao (2011) and Reddy *et al.* (2013). Biological yield per plant showed the higher positive direct effect on seed yield per plant indicating that it had a high association with seed yield per plant and selection for this character will lead to increase in yield. The high magnitude of association of this trait with seed yield per plant is the result of their direct effects on seed yield. On partitioning the components for correlation of seed yield per plant with characters showing positive correlation, direct effects

were found to be low indicating that while selecting these characters seed yield per plant can not be improved through these characters. Their indirect effects through biological yield per plant were high, therefore, straw yield per plant, fibre yield and 1000 seed weight contributed indirectly through biological yield per plant. Path coefficient analysis revealed the importance of biological yield per plant as major yield contributing component in linseed. Similar findings were reported by Naik and Satapathy (2002); Rama Kant, *et al.* (2008), Dash *et al.* (2016), Akbar *et al.* (2003). Hence, direct selection for the biological yield per plant, may ultimately leads to development of high yielding linseed genotypes from segregating population.

**Principal component analysis of seed yield and other traits:** The principal component analysis was performed for various traits (Table 5 and Fig. 2.). The PCA revealed that five most informative principal components with eigen-values of 4.228, 3.148, 1.748, 1.012 and 0.939, respectively were noted which together accounted 85% of the total variance for all the characters (Fig. 1.). Thus, according to principal component 1, characters such as biological yield per plant, straw yield per plant, fibre yield, 1000 seed weight and seed yield per plant had relatively higher contributions to the total morphological variability, a truth which proved by other statistical approaches similar to path coefficients analysis which discussed at earlier parts of this paper. The first two principal components biplot including loadings of the various characters along with the genotypes spread over is given in Fig. 2. This Figure indicates that the PCA showed a clear differentiation between most of the linseed genotypes from each others. The variation (32.52%) is explained by first principal component and in total this biplot explained 56.73% of the variation. Thus, this biplot can interpret the near-real differentiation of the linseed cultivars and morphological characters studied in this experiment. Vromans (2006) examined 110 flax accessions and a wild species from different locations such as Dutch, French and Canada countries to investigate the hereditary basis of important traits such as disease resistance and fiber quality using molecular markers, and achieved a biplot of two first principal components together with 22% of the variation. As Vromans (2006) concluded that PCA indicated a clear differentiation and also high inter-population distance supported the differentiation between the two morphological groups. Thus, the biplot can be used as a vital instrument to categorize, differentiate and address the genetic entities in breeding decisions.

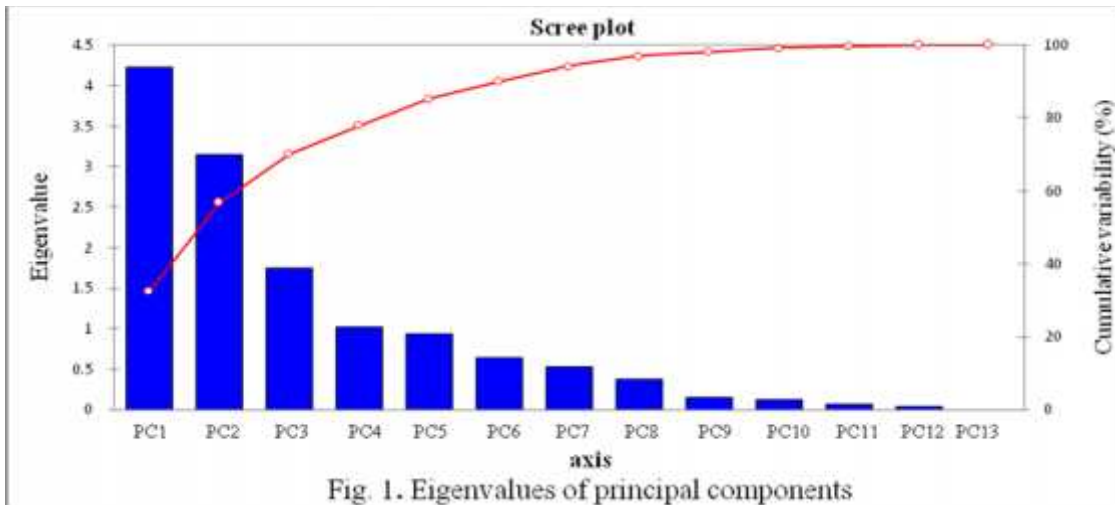


Fig. 1. Eigenvalues of principal components

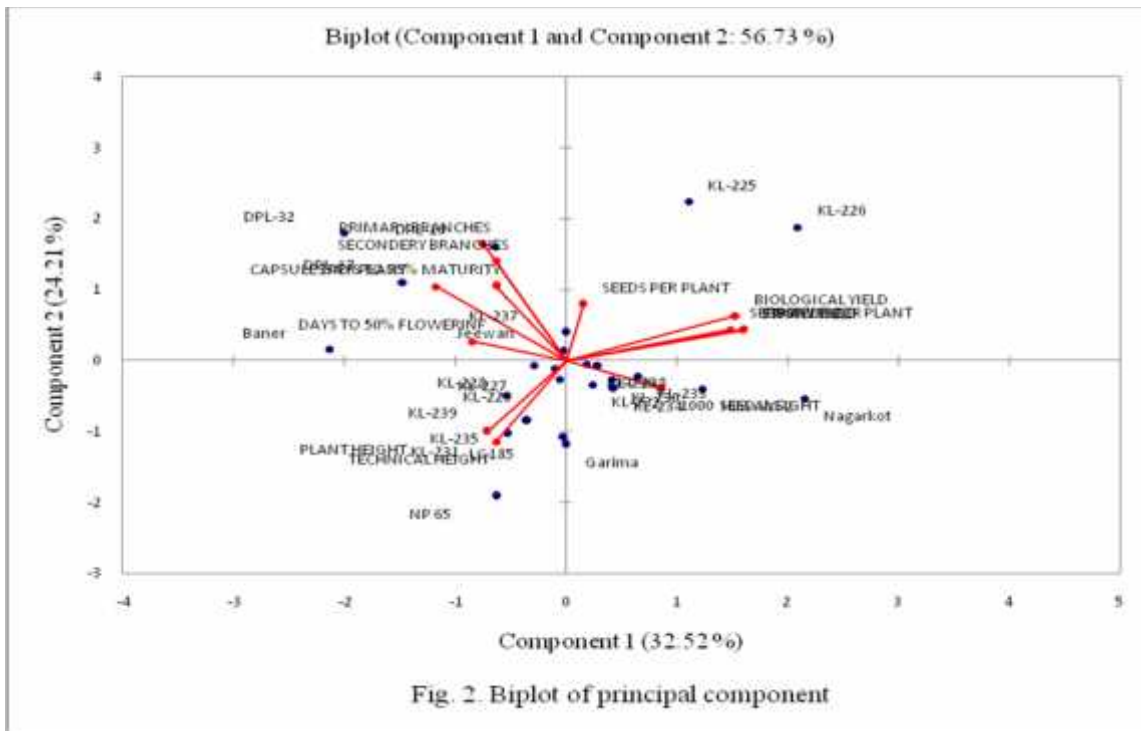


Fig. 2. Biplot of principal component

Table 1. List of linseed accessions/lines and their parentage/source used in the study

S.No.	Genotype	Source/Pedigree
1	KL-225	K2 × EC 23239
2	KL-226	Aoyogi × JRF-2
3	KL-227	Flak-1 × Janaki
4	KL-228	Polf-22 × KL-31
5	KL-229	Palampur
6	KL-230	Aoyogi × RL-33-4
7	KL-231	Polf-16 × KL-1
8	KL-232	Polf-16 × Janki
9	KL-233	Flax purple × Gaurav
10	KL-234	Polf-22 × Jeevan
11	KL-235	Polf-22 × Aoyagi
12	KL-236	Jeevan × Janaki
13	KL-237	Aoyagi × Jeevan

14	KL-238	Aoyogi × Nagarkot
15	KL-239	Polf-27 × RL-33-4
16	Nagarkot	New River × LC-216
17	Jeevan	Summit × LC-216
18	Him Alsi-2	EC-21741 × LC-216
19	DPL-17	EC 21741 × LC.216
20	DPL-19	-
21	DPL-32	-
22	Baner	EC 21741 × LC 216
23	LC 185	NP (RR)-37 × Kangra local
24	NP 65	-
25	Garima	T126 × Neelum

**Table 2. Analysis of variance for thirteen traits in linseed.**

S.No.	Traits	Replication df = 1	Genotypes df = 24	Error df = 24	CV(%)
1	Days to 50% flowering	1.75	14.95**	1.39	0.98
2	Days to 75% maturity	1.72	10.45**	1.55	0.69
3	Plant Height (cm)	2.05	169.17**	1.49	1.82
4	Technical Height (cm)	0.54	107.61**	0.6	2.04
5	Primary branches per plant	0.82	.80**	0.02	2.19
6	Secondary branches per plant	0.63	.63**	0.01	1.75
7	Capsules per plant	1.44	24.52**	0.25	1.48
8	Seeds per Capsule	4.68	.49**	0.01	1.09
9	Biological Yield per plant (g)	1.28	2.54**	0.02	1.56
10	Straw yield per plant (g)	0.98	.67**	0.03	2.55
11	Fibre Yield	0.12	.03**	0.02	5.27
12	1000 Seed Weight (g)	2.13	1.01**	0.01	1.02
13	Seed yield per Plant (g)	0.64	.16**	0.01	1.78

**Table 3. Estimates of correlation coefficients at phenotypic (P) and genotypic (G) levels among different traits of linseed.**

		DTM	PH	TH	PB	SB	CPP	SPC	BY	SY	FY	SW	SYP
DTF	P	.2614	-.0751	-.1265	.2198	-.0159	.2212	-.1027	-.4070**	-.2587	-.3007*	-.3105*	-.2462
	G	.3533*	-.0908	-.1613	.2504	-.0097	.2246	-.1128	-.4447**	-.2834*	-.3542*	-.3439*	-.2661
DTM	P		-.1146	-.1063	.5736**	.3686**	.2596	.3042*	-.0983	-.0883	-.1129	-.1929	-.1779
	G		-.1357	-.1193	.6282**	.4272**	.2990*	.3404*	-.1052	-.115	-.1228	-.2205	-.2098
PH	P			.8536**	-.2778	-.0727	.1441	-.0046	-.3137*	-.3175*	-.3299*	-.0434	-.3057*
	G			.8658**	-.2872*	-.0778	.1417	-.0087	-.3165*	-.3211*	-.3312*	-.0416	-.3098*
TH	P				-.4010**	-.1761	.0383	.0723	-.2922*	-.3547*	-.3365*	.0190	-.2969*
	G				-.4097**	-.1794	.0325	.0736	-.2939*	-.3574*	-.3439*	.0170	-.2978*
PB	P					.7737**	.7584**	.2891*	-.0401	-.1150	-.1153	-.3623**	-.1310
	G					.8004**	.7745**	.2907*	-.0380	-.1227	-.1184	-.3738**	-.1343
SB	P						.7482**	.3149*	.0965	-.1673	-.1613	-.1771	-.0191
	G						.7593**	.3212*	.0966	-.1700	-.1575	-.1782	-.0182
CPP	P							.2657	-.2117	-.3793**	-.3664**	-.3732**	-.3167*
	G							.2710	-.2130	-.3853**	-.3678**	-.3828**	-.3215*
SPC	P								.2236	.1244	.1917	.2651	.1927
	G								.2297	.1304	.1941	.2700	.1976
BY	P									.7160**	.7085**	.3055**	.8823**
	G									.7187**	.7174**	.3101**	.8849**
SY	P										.9859**	.1715	.6040**
	G										1.0000*	.1750	.6048*
FY	P											.1908	.5917**
	G											.1978	.6000**
SW	P												.2847*
	G												.2916*

\* , \*\* Significant at 5 and 1% level of probability.

DTF- Days to 50% flowering; DTM- Days to 75% maturity; PH-Plant height; TH- Technical Height; PB- Primary branch per plant ; SB- Secondary branch per plant; CPP-Capsules per plant; SPC-Seeds per capsule; BY- Biological Yield per plant; SY- Straw yield per plant; FY- Fibre yield; SW- 1000 Seed; SY-Seed yield per Plant

**Table 4. Estimates of direct and indirect phenotypic (P) and genotypic (G) effects of different traits on seed yield in linseed.**

		DTF	DTM	PH	TH	PB	SB	CPP	SPC	BY	SY	FY	SW	SYP
DTF	P	<b>.1973</b>	-.0609	-.0084	.0121	.0381	-.0005	-.0949	-.0197	-.4137	-.0112	.0851	.0306	-.2462
	G	<b>.2348</b>	-.1711	-.0029	-.0139	.1232	-.0008	-.1528	-.0344	-.4410	-.2428	.3964	.0392	-.2661
DTM	P	.0516	<b>-.2329</b>	-.0128	.0101	.0995	.0124	-.1113	.0584	-.1000	-.0038	.0319	.0190	-.1779
	G	.0830	<b>-.4843</b>	-.0043	-.0103	.3090	.0371	-.2034	.1037	-.1044	-.0986	.1374	.0251	-.2098
PH	P	-.0148	.0267	<b>.1121</b>	-.0813	-.0482	-.0024	-.0618	-.0009	-.3189	-.0137	.0934	.0043	-.3057*
	G	-.0213	.0657	<b>.0319</b>	.0746	-.1413	-.0068	-.0964	-.0026	-.3139	-.2750	.3706	.0047	-.3098*
TH	P	-.0250	.0247	.0957	<b>-.0952</b>	-.0695	-.0059	-.0164	.0139	-.2971	-.0153	.0952	-.0019	-.2969*
	G	-.0379	.0578	.0276	<b>.0861</b>	-.2016	-.0156	-.0221	.0224	-.2914	-.3061	.3848	-.0019	-.2978*
PB	P	.0434	-.1336	-.0311	.0382	<b>.1734</b>	.0260	-.3253	.0555	-.0408	-.0050	.0326	.0357	-.1310
	G	.0588	-.3042	-.0092	-.0353	<b>.4920</b>	.0696	-.5270	.0886	-.0377	-.1050	.1325	.0426	-.1343
SB	P	-.0031	-.0858	-.0081	.0168	.1342	<b>.0336</b>	-.3209	.0605	.0981	-.0072	.0456	.0175	-.0191
	G	-.0023	-.2069	-.0025	-.0155	.3938	<b>.0870</b>	-.5166	.0979	.0958	-.1456	.1763	.0203	-.0182
CPP	P	.0436	-.0604	.0161	-.0036	.1315	.0251	<b>-.4289</b>	.0510	-.2152	-.0164	.1037	.0368	-.3167*
	G	.0527	-.1448	.0045	.0028	.3811	.0660	<b>-.6804</b>	.0826	-.2113	-.3300	.4116	.0436	-.3215*
SPC	P	-.0203	-.0708	-.0005	-.0069	.0501	.0106	-.1140	<b>.1921</b>	.2274	.0054	-.0543	-.0261	.1927
	G	-.0265	-.1648	-.0003	.0063	.1430	.0279	-.1844	<b>.3048</b>	.2278	.1117	-.2172	-.0307	.1976
BY	P	-.0803	.0229	-.0352	.0278	-.0070	.0032	.0908	.0429	<b>.9916</b>	.0310	-.2005	-.0301	.8823**
	G	-.1044	.0510	-.0101	-.0253	-.0187	.0084	.1450	.0700	<b>1.0167</b>	.6156	-.8028	-.0353	.8849**
SY	P	-.0510	.0206	-.0356	.0338	-.0199	-.0056	.1627	.0239	.7279	<b>.0433</b>	-.2790	-.0169	.6040**
	G	-.0666	.0557	-.0102	-.0308	-.0603	-.0148	.2622	.0398	.7127	<b>.8565</b>	-.1.1194	-.0199	.6048*
FY	P	-.0593	.0263	-.0370	.0320	-.0200	-.0054	.1572	.0368	.7203	.0427	<b>-.2830</b>	-.0188	.5917**
	G	-.0832	.0594	-.0106	-.0296	-.0583	-.0137	.2502	.0592	.7114	.8567	<b>-1.0091</b>	-.0225	.6000**
SW	P	-.0613	.0449	-.0049	-.0018	-.0628	-.0059	.1601	.0509	.3106	.0074	-.0540	<b>-.0986</b>	.2847*
	G	-.0808	.1068	-.0013	.0015	-.1839	-.0155	.2604	.0823	.3075	.1499	-.2214	<b>-.1139</b>	.2916*

Residual effects (P) = 0.9036; (G) = 0.8818; Bold values indicates direct effects; \*, \*\* Significant at 5 and 1% level of probability

DTF- Days to 50% flowering; DTM- Days to 75% maturity; PH-Plant height; TH- Technical Height; PB- Primary branch per plant ; SB- Secondary branch per plant; CPP- Capsules per plant; SPC-Seeds per capsule; BY- Biological Yield per plant; SY- Straw yield per plant; FY- Fibre yield; SW-1000 Seed; SY-Seed yield per Plant

**Table 5. Eigen-vectors and eigen-values of 5 principal components for 13 characters of 25 linseed genotypes**

	DTF	DTM	PH	TH	PB	SB	CPP	SPC	BY	SY	FY	SW	SYP	Eigen value	Propo-rtion	Cumu-lative
PC1	-0.220	-0.164	-0.186	-0.164	-0.194	-0.164	-0.306	0.040	0.399	0.414	0.417	0.224	0.386	4.228	32.52	32.52
PC2	0.080	0.316	-0.303	-0.346	0.496	0.422	0.315	0.238	0.189	0.129	0.134	-0.118	0.131	3.148	24.21	56.73
PC3	-0.383	0.015	0.439	0.457	0.013	0.262	0.221	0.473	0.186	-0.020	0.017	0.253	0.102	1.748	13.44	70.18
PC4	0.251	0.404	-0.212	-0.072	-0.073	-0.193	-0.268	0.456	-0.154	-0.142	-0.130	0.579	-0.080	1.012	7.78	77.96
PC5	0.354	0.428	0.294	0.280	-0.021	-0.248	-0.094	0.163	-0.035	0.374	0.337	-0.415	-0.050	0.939	7.22	85.19

DTF- Days to 50% flowering; DTM- Days to 75% maturity; PH-Plant height; TH- Technical Height; PB- Primary branch per plant ; SB- Secondary branch per plant; CPP- Capsules per plant; SPC-Seeds per capsule; BY- Biological Yield per plant; SY- Straw yield per plant; FY- Fibre yield; SW-1000 Seed; SY-Seed yield per Plant.

**Conclusion:** Significant differences were observed among the genotypes for various traits indicating the scope for selection from diverse genotypes for various agronomically important traits. Moreover, there were significant positive associations between seed yield per plant and four other characters. Positive associations of such traits indicated especially that such variables can be applied for direct and indirect selection in yield breeding programmes. Additionally, the PCA showed that first two components explained 56.73 percent of the existing variation in genotypes as depicted by biplot. Thus, the present study finds immense applications in linseed improvement programmes.

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