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Assessment of genetic variability, correlation and path analysis for yield and it's components in Linseed (*Linum usitatissimum* L.)

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Abstract
The present investigation was undertaken with a view to study the magnitude of variation and association for seed yield and to identify promising genotypes. The experimental material comprising of 30 linseed genotypes were evaluated in randomized block design with three replications during rabi 2018-19 and the data were recorded on thirteen morphometric traits. Sufficient genetic variability was observed for all the characters. High PCV and GCV was observed for aerial biomass, primary branches per plant, capsules per plant, and seed yield per plant. For rest of the traits PCV and GCV was moderate to low. High heritability with high genetic advance was observed for aerial biomass, capsules per plant, primary branches per plant, seed yield per plant, secondary branches per plant, technical height and harvest index. Seed yield per plant showed positive and significant correlation with length of flowering period, seeds per capsule, harvest index, primary branches, secondary branches, capsules per plant, aerial biomass and 1000-seed weight while, plant height and technical height showed negative correlation. On the basis of path coefficient analysis, capsules per plant followed by 1000-seed weight exhibited the highest direct effects on seed yield per plant.

Keywords: Linseed, variability, path analysis, GCV, PCV

Introduction
Linseed (*Linum usitatissimum* L.), also called as flax, is an annual winter season self pollinated crop, cultivated for oil and fibre, which belongs to family Linaceae having 14 genera and over 200 species. All the aerial part of linseed is used either directly or indirectly by humans. Its oil is a rich source of polyunsaturated fatty acids such as oleic (C18, 13.44–19.39%), linoleic (C18, 12.25–17.44%), and linolenic acid (C18, 39–60%) and lignans (phytoestrogens) (Singh *et al*. 2011) [30]. Linseed is also a source of linatine, a vitamin B_6 compound having antagonistic properties (Klosterman *et al*. 1967) [13]. It is extensively cultivated throughout the world where India occupies fifth rank in terms of area and production among the linseed-producing countries. In spite of the vast area and varied utility of the crop in India as well as in Himachal Pradesh, the productivity is very low because of various factors such as, narrow genetic base, raising of crop by the resource poor farmers in marginal and sub-marginal areas, non availability of high yielding varieties having resistance to biotic and abiotic stresses, non-adoption of plant protection measures and improved agro-techniques etc. As in linseed, there is low genetic variability so reinforcement of breeding programme through introduction of new germplasm, collection of the local ecotypes and adopting interspecific hybridization is a necessity. Development of high yielding varieties requires the knowledge of existing genetic variability. A quantitative assessment of the variability for the economically important characters is, therefore, one of the basic steps in breeding for high yield. Thus, studies on various parameters of variability, correlation and path analysis studies helps in measuring variation and relative importance of each factor contributing towards seed yield.

Materials and Methods
The experimental material for the present study comprised of 30 linseed (*Linum usitatissimum* L.) genotypes, amongst which JRF-4, Nagarkot and Him Palam Alsi -2 were used as checks. The list of genotypes studied is presented in Table 1. The experiment was carried out in randomized block design with three replications. Each genotype was sown in three rows with the plot size of 1.5m × 1m² with row to row and plant to plant spacing of 25cm and 5cm, respectively. The experimental field was well prepared and recommended doses of fertilizers were applied @ 50kg N, 40kg P_2O_5 and 20kg K_2O per hectare. Half dose of N and full dose of P_2O_5 and K_2O were applied as basal and the remaining half nitrogen was top dressed after 45 days of sowing and regular weeding was done to keep the experimental field weed free.

Observations were recorded on five randomly selected plants for days to 50% flowering, length of flowering period, days to 75% maturity, plant height, technical height, primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, aerial biomass, seed yield per plant, 1000-seed weight and harvest index.

Table 1: List of germplasm accessions

Sr. No.	Genotypes	Pedigree/Source
1	KL-305	TL-27 × Nagarkot
2	KL-306	Nagarkot × T-397
3	KL-307	Him Alsi-2 × Nagarkot
4	KL-308	T-397 × Nagarkot
5	KL-309	Canada × Nagarkot
6	KL-310	Giza-8 × Nagarkot
7	KL-311	Giza-6 × Nagarkot
8	KL-312	Giza-7 × Nagarkot
9	KL-313	Faiking × Nagarkot
10	KL-314	Belinka-60 × Nagarkot
11	KL-315	TL-27 × Flake-1
12	KL-316	Him Alsi-2 × Binwa
13	KL-317	Him Alsi-1 × Binwa
14	KL-318	Him Alsi-2 × TL-11
15	KL-319	(KL-243 × Janki) × KL-243
16	KL-320	(Gaurav × Nagarkot) × Nagarkot
17	KL-321	TL-43 × Binwa
18	KL-322	(TL-43 × Binwa) × TL-43
19	KL-323	(KL-178 × Ariane) × KL-178
20	KL-324	TL-11 × Him Alsi-2
21	KL-325	TL-37-2 × Him Alsi-2
22	KL-326	Binwa × Him Alsi-2
23	KL-327	(Janki × TL-43) × Janki
24	KL-284	Rajeena × Him-Alsi-2
25	Belinka	Exotic collection
26	K1 Raja	Exotic collection
27	Ayogi	Exotic collection
28	JRF-4	CRIJAF, (Barrackpore)
29	Nagarkot	New River × LC-216
30	Him Palam Alsi-2 (KL-263)	Him-Alsi-2 × Baner

Checks: JRF-4, Nagarkot and Him Palam Alsi-2

Data was statistically analyzed as per the procedure given by (Panse and Sukhatme 1984) [20]. The phenotypic, genotypic and environmental coefficients of variation for different characters content were calculated as suggested by Burton and De Vane (1953) [6] and Johnson *et al*. (1955) [12]. Heritability in broad sense (h^2bs) was calculated as a ratio of genotypic variance to the sum of genotypic and environmental variance given by Burton and De Vane (1953) [6] and Johnson *et al*. (1955) [12]. The expected genetic advance for different characters was calculated as per Burton and De Vane (1953) [6] and Johnson *et al*. (1955) [12]. For computing phenotypic, genotypic and environmental correlation coefficients, analysis of co-variance was carried out in all possible pairs of combinations of the characters following the procedure of Al-Jibouri *et al*. (1958) [1] and Dewey and Lu (1959) [9]. Direct and indirect effects of component characters on grain yield were computed using appropriate correlation coefficient of different component characters as suggested by Wright (1921) [34] and elaborated by Dewey and Lu (1959) [9].

Results and Discussion

Persual of the data on analysis of variance (ANOVA) revealed that all the characters studied, indicating the presence of wide range of genetic variability among genotypes for yield and its related traits (Table 2). High amount of genetic variability for many of these characters has also been reported by various other workers viz., Payasi *et al*. (2000) [23], Singh (2001) [29], Savita (2006) [25], Diederichsen and Fu (2008) [10], Bibi *et al*. (2013) [5], Singh *et al*. (2015) [28], Shalini *et al*. (2016) [26], Kumar and Paul (2016) [14], Patial *et al*. (2018) [21, 22], Ankit *et al*. (2019) [2] and Banjare *et al*. (2019) [3].

Table 2: Analysis of variance for different traits of linseed

Sr. No.	Characters	Mean Sum of Squares		
		Replication	Treatments	Error
	d.f.	2	29	58
1	Days to 50%fowering	3.43	45.05**	8.93
2	Length of flowering period	1.01	102.20**	17.97
3	Days to 75% maturity	7.07	14.31**	2.06
4	Primary branches per plant	0.15	13.10**	0.66
5	Secondary branches per plant	1.34	5.26**	0.41
6	Plant height (cm)	25.75	290.67**	16.95
7	Technical height (cm)	2.87	236.61**	10.26

8	Aerial biomass (g)	354.44	747.97**	33.24
9	Seeds per capsule	1.13	0.766**	0.13
10	Capsules per plant	29.63	747.705**	6.56
11	Seed yield per plant (g)	0.06	0.94**	0.09
12	Harvest index (%)	67.50	96.74**	6.30
13	1000 seed weight (g)	0.48	1.81**	0.10

** Significant at 1 per cent level

Table 3: Genetic parameters of variability for different traits of linseed

Sr. No.	Character	Mean±S.E.(m)	Range	PCV (%)	GCV (%)	h²bs (%)	GA% of mean
1	Days to 50% flowering	150.33 ± 1.73	144.33-157.33	3.04	2.30	57.38	3.60
2	Length of flowering period	49.49 ± 2.45	35.67-60.67	13.71	10.70	60.96	17.22
3	Days to 75% maturity	207.99 ± 0.83	205.33-212.00	1.19	0.97	66.38	1.630
4	Plant height (cm)	71.96 ± 2.38	51.15-101.75	14.45	13.27	84.33	25.11
5	Technical height (cm)	39.33 ± 1.85	25.94-63.56	23.54	22.08	88.02	42.68
6	Primary branches/plant	6.37 ± 0.47	4.23-12.13	34.44	31.97	86.14	61.12
7	Secondary branches/plant	5.13 ± 0.37	3.55-8.36	27.74	24.76	79.67	45.54
8	Capsules/plant	48.99 ± 1.48	28.63-94.22	32.50	32.08	97.41	65.23
9	Seeds/capsule	8.07 ± 0.21	7.35-9.35	7.26	5.68	61.24	9.71
10	Aerial biomass (g)	44.21 ± 3.33	27.98-92.09	37.27	34.91	87.75	67.38
11	Seed yield/plant (g)	1.96 ± 0.57	1.20-3.10	31.12	27.30	76.96	49.34
12	1000-seed weight (g)	5.60 ± 0.13	3.79-7.52	14.65	13.52	85.09	25.69
13	Harvest index (%)	27.22 ± 1.45	15.89-40.73	22.17	20.16	82.69	37.78

PCV: Phenotypic Coefficient of variation; GCV: Genotypic Coefficient of variation; h²bs (%): heritability in broad sense

The estimates of parameters of variability, viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h²bs) and expected genetic advance expressed as per cent of mean for the characters studied are presented in table 3. The estimates of phenotypic coefficient of variation for all the traits under investigation were higher than their corresponding genotypic coefficient of variation, indicating the considerable influence of environment on the expression of these characters. PCV was high (>25%) for aerial biomass (37.27%), primary branches per plant, capsules per plant, seed yield per plant and secondary branches per plant. The least PCV (<15%) was observed for days to 75% maturity (1.19%), days to 50% flowering, seeds per capsule, length of flowering period, plant height and 1000-seed weight. GCV was high (>25%) for aerial biomass (34.91%), capsules per plant, primary branches per plant and seed yield per plant. The lowest GCV (<15%) was observed for days to 75% maturity (0.97%), days to 50% flowering, seeds per capsule, length of flowering period, plant height and 1000-seed weight. Similar studies with respect to PCV and GCV were carried out by various workers. Payasi *et al*. (2000) [23] recorded high GCV for fibre length. Savita (2006) [25] also observed high PCV for seed yield per plant. High estimates PCV and GCV for seed yield have been reported by Mirza *et al*. (1996) [17] and Tadesse *et al*. (2010) [31]. Siddiqui *et al*. (2016) [27] revealed high PCV and GCV for plant weight, seed yield and secondary branches per plant. Patial *et al*. (2018) [21, 22] recorded for fibre yield and seed yield per plant and straw yield.

In the present study, the heritability in broad sense (h²bs) ranged from 57.38% in days to 50 per cent flowering to 97.41% in capsules per plant. Heritability was observed high (>60%) for capsules per plant (97.41%), technical height, aerial biomass, primary branches per plant, 1000-seed weight, plant height, harvest index, secondary branches per plant, seed yield per plant, days to 75 per cent maturity, seeds per capsule and length of flowering period. High heritability indicates the dependency of phenotypic expression which reflects the genotypic ability of cultivars to transmit the genes to their off springs. High estimates of heritability were reported earlier for seed weight by different workers viz., Singh *et al*. (2015) [28], Bhushan *et al* (2019) [4] and for all the traits Kumar *et al*. (2015) [15], Tewari and Singh (2018) [32]. Moderate heritability estimates (30-60%) were observed for 50 per cent flowering. Yadav and Gupta (1999) [33] observed that heritability estimates were moderate to high for all characters. The high expected genetic advance (>30%), expressed as percentage of mean were observed for aerial biomass (67.38%), capsules per plant, primary branches per plant, seed yield per plant, secondary branches per plant, technical height and harvest index. Expected genetic advance was moderate (15-30%) for 1000-seed weight (25.69%), plant height and length of flowering period whereas, seeds per capsule (9.71%), days to 50 per cent flowering and days to 75 per cent maturity exhibited low estimates (<15%) for genetic advance. High heritability with moderate genetic advance was observed for 1000-seed weight, plant height and length of flowering period indicating the presence of additive and non-additive gene action and providing scope for improvement through hybridization and selection of these traits. On the contrary, Bibi *et al*. (2013) [5] also reported high heritability with low genetic advance for days to flowering and days to maturity. Similarly, Pali & Mehta (2013) [19] found high heritability with moderate genetic advance for oil content and all fatty acid components. Leelavathi and Mogali (2018) [16] reported high heritability with moderate to high level of genetic advance for all characters.

Table 4: Estimates of correlation coefficients at phenotypic (P) and genotypic (G) levels among different traits of linseed

		Length of flowering period	**Days to 75% maturity**	**Plant height (cm)**	**Technical height (cm)**	**Primary branches**	**Secondary branches**	**Capsules per plant**	**Seeds per capsule**	**Aerial biomass (g)**	**1000 seed weight (g)**	**Harvest index (%)**	**Correlation with seed yield per plant**
Days to 50% flowering	P	-0.486**	0.252*	0.355**	0.396**	0.266*	0.216*	0.061	-0.071	0.116	-0.076	-0.326**	0.013
	G	-0.693**	0.307**	0.464**	0.556**	0.391**	0.366**	0.076	-0.032	0.156	-0.094	-0.481**	0.075
Length of flowering period	P		-0.070	-0.432**	-0.483**	-0.016	0.003	0.224*	0.117	-0.031	0.088	0.390**	0.222*
	G		-0.199	-0.582**	-0.671**	0.019	0.041	0.312**	0.220*	0.013	0.114	0.492**	0.357**
Days to 75% maturity	P			-0.006	-0.043	-0.011	0.058	-0.098	0.178	-0.182	-0.150	-0.069	0.078
	G			-0.003	-0.080	-0.036	0.065	-0.107	0.288**	-0.184	-0.175	-0.161	-0.130
Plant height (cm)	P				0.857**	-0.115	-0.168	-0.234*	0.066	-0.009	-0.250*	-0.501**	-0.228*
	G				0.921**	-0.153	-0.233*	-0.260**	0.121	-0.020	-0.339**	-0.564**	-0.289**
Technical height (cm)	P					-0.145	-0.175	-0.315**	-0.039	0.006	-0.167	-0.560**	-0.252*
	G					-0.168	-0.243*	-0.328**	-0.102	0.008	-0.241*	-0.655**	-0.337**
Primary branches	P						0.887**	0.818**	0.096	0.416**	0.216*	0.042	0.637**
	G						0.962**	0.881**	0.126	0.461**	0.257*	0.064	0.747**
Secondary branches	P							0.772**	0.058	0.415**	0.242*	0.098	0.664**
	G							0.874**	0.070	0.495**	0.311**	0.106	0.808**
Capsules per plant	P								0.151*	0.285**	0.296**	0.136	0.816**
	G								0.198	0.306**	0.338**	0.163	0.933**
Seeds per capsule	P									-0.036	-0.020	0.275**	0.233*
	G									-0.126	0.032	0.335**	0.236*
Aerial biomass (g)	P										0.313**	0.112	0.361**
	G										0.380**	0.158	0.429**
1000 seed weight (g)	P											0.120	0.552**
	G											0.148	0.634**
Harvest index (%)	P												0.213*
	G												0.240*

*significant at 5% level; **significant at 1% level

Table 5: Estimates of direct and indirect phenotypic (P) and genotypic (G) effects of different traits on seed yield in linseed

		Days to 50% flowering	**Length of flowering period**	**Days to 75% maturity**	**Plant height (cm)**	**Technical height (cm)**	**Primary branches**	**Secondary branches**	**Capsules per plant**	**Seeds per capsule**	**Aerial biomass (g)**	**1000 seed weight (g)**	**Harvest index (%)**	**Correlation with seed yield per plant**
Days to 50% flowering	P	0.0146	-0.0161	0.0071	-0.0108	0.0453	-0.0736	0.0463	0.0461	-0.0088	0.0082	-0.0247	-0.0204	0.0130
	G	0.5439	-0.0732	-0.0600	0.0580	-0.1482	-0.5541	0.2173	0.1015	-0.0040	0.0266	-0.0258	-0.0070	0.0750
Length of flowering period	P	-0.0071	0.0330	-0.0020	0.0132	-0.0552	0.0044	0.0007	0.1695	0.0144	-0.0022	0.0286	0.0245	0.222*
	G	-0.3768	0.1056	0.0390	-0.0728	0.1789	-0.0271	0.0245	0.4183	0.0271	0.0022	0.0311	0.0072	0.357**
Days to 75%maturity	P	0.0037	-0.0023	0.0282	0.0002	-0.0049	0.0029	0.0125	-0.0740	0.0219	-0.0129	-0.0487	-0.0044	0.0780
	G	0.1668	-0.0211	-0.1955	-0.0004	0.0214	0.0507	0.0384	-0.1439	0.0355	-0.0313	-0.0480	-0.0024	-0.1300
Plant height (cm)	P	0.0052	-0.0143	-0.0002	-0.0304	0.0980	0.0317	-0.0361	-0.1774	0.0081	-0.0006	-0.0808	-0.0315	-0.228*
	G	0.2521	-0.0615	0.0006	0.1252	-0.2454	0.2163	-0.1387	-0.3486	0.0149	-0.0033	-0.0927	-0.0083	-0.289**
Technical height (cm)	P	0.0058	-0.0160	-0.0012	-0.0261	0.1143	0.0402	-0.0375	-0.2382	-0.0047	0.0004	-0.0540	-0.0352	-0.252*
	G	0.3024	-0.0709	0.0157	0.1152	-0.2665	0.2388	-0.1444	-0.4402	-0.0125	0.0014	-0.0659	-0.0096	-0.337**
Primary branches	P	0.0039	-0.0005	-0.0003	0.0035	-0.0166	-0.2765	0.1904	0.6190	0.0118	0.0295	0.0700	0.0026	0.637**
	G	0.2125	0.0020	0.0070	-0.0191	0.0449	-1.4185	0.5719	1.1808	0.0155	0.0786	0.0703	0.0009	0.747**
Secondary branches	P	0.0032	0.0001	0.0016	0.0051	-0.0200	-0.2453	0.2146	0.5840	0.0072	0.0294	0.0781	0.0061	0.664**
	G	0.1989	0.0044	-0.0126	-0.0292	0.0648	-1.3650	0.5943	1.1725	0.0087	0.0844	0.0849	0.0016	0.808**
Capsules per plant	P	0.0009	0.0074	-0.0028	0.0071	-0.0360	-0.2262	0.1656	0.7568	0.0186	0.0202	0.0956	0.0085	0.816**
	G	0.0412	0.0330	0.0210	-0.0325	0.0875	-1.2491	0.5197	1.3409	0.0244	0.0521	0.0924	0.0023	0.933**
Seeds per capsule	P	-0.0010	0.0039	0.0050	-0.0020	-0.0044	-0.0267	0.0125	0.1145	0.1228	-0.0025	-0.0064	0.0172	0.233*
	G	-0.0176	0.0232	-0.0564	0.0152	0.0271	-0.1789	0.0419	0.2660	0.1232	-0.0214	0.0088	0.0049	0.236*
Aerial biomass (g)	P	0.0017	-0.0010	-0.0051	0.0003	0.0007	-0.1151	0.0890	0.2161	-0.0044	0.0709	0.1012	0.0070	0.361**
	G	0.0851	0.0014	0.0359	-0.0025	-0.0022	-0.6544	0.2944	0.4100	-0.0155	0.1704	0.1038	0.0023	0.429**
1000 seed weight (g)	P	-0.0011	0.0029	-0.0042	0.0076	-0.0191	-0.0598	0.0518	0.2237	-0.0025	0.0222	0.3234	0.0075	0.552**
	G	-0.0514	0.0120	0.0343	-0.0424	0.0643	-0.3646	0.1847	0.4531	0.0040	0.0647	0.2733	0.0022	0.634**
Harvest index (%)	P	-0.0048	0.0129	-0.0020	0.0153	-0.0641	-0.0116	0.0210	0.1029	0.0337	0.0079	0.0389	0.0628	0.213*
	G	-0.2617	0.0520	0.0316	-0.0706	0.1745	-0.0911	0.0630	0.2189	0.0412	0.0269	0.0403	0.0146	0.240*

Residual effect (P)= 0.18657; (G)= 0.10808; Bold values indicates direct effects

The results on correlations at phenotypic and genotypic levels computed for all possible paired combinations are presented in Table 4. At phenotypic level, seed yield per plant showed significant positive correlations with length of flowering period, seeds per capsule, harvest index, primary branches, secondary branches, capsules per plant, aerial biomass and 1000-seed weight, whereas seed yield per plant showed significant negative correlation with plant height and technical height. At genotypic level, the estimates of correlation coefficients were generally similar to those observed at phenotypic level. Keeping seed yield per plant as dependent variable and other traits as independent variables, the following results were obtained (Table 5). The direct and indirect effects of genotypic path coefficient were higher in magnitude than the corresponding phenotypic path coefficients. Similar finding with respect to path coefficients have also been reported by Gauraha and Rao (2011) [11] and Reddy *et al*. (2013) [24]. In the present study, residual effect for path coefficients was (0.186). At phenotypic level, capsules per plant (0.75) followed by 1000-seed weight (0.32) had highest positive direct effect on seed yield. This indicated significant role of accumulation of capsules per plant and its partitioning into seed yield. The significant positive correlation of length of flowering period with seed yield was mainly due to indirect effects via capsules per plant, whereas indirect effects via other traits were low in magnitude. Technical height exhibited the highest direct effect with seed yield per plant. Similar results on path coefficient analysis were also observed by Chandra (1978) [7], Muduli and Patnaik (1993) [18], Chimurkar *et al*. (2001) [8] and Patial *et al*. (2018) [21, 22].

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