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GENETIC VARIABILITY AND ASSOCIATION STUDIES IN LINSEED (*LINUM USITATISSIMUM* L.)

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ABSTRACT

Genetic variability and association studies in linseed (*Linum usitatissimum* L.) was undertaken to assess the nature and magnitude of genetic variability and associations among various traits including their direct and indirect effects on seed yield. Analysis of variance revealed presence of sufficient amount of genetic variability for all the traits amongst the germplasm lines evaluated. Correlation studies indicated the higher magnitude of genotypic correlations than their corresponding phenotypic correlations for most of the characters indicating the inherent association among the various characters. Seed yield per plant exhibited positive associations with aerial biomass (0.839), straw yield (0.632), retted straw yield (0.603), fibre yield (0.602), 1000-seed weight (0.411), oil content (0.329), harvest index (0.305), secondary branches per plant (0.220) and days to maturity (0.218). Path analysis indicated that aerial biomass exhibited high positive direct effect (1.074) and indirect effect through straw yield (0.999), retted straw yield (0.934), fibre yield (0.709), 1000-seed weight (0.293), plant height (0.284), primary branches (0.257), days to maturity (0.251), oil content (0.232) and secondary branches per plant (0.219) towards seed yield per plant. Hence, aerial biomass would be the best selection index for increasing seed yield per plant due to its high direct and indirect contribution(s).

INTRODUCTION

Linseed or flax (*Linum usitatissimum* L.) [n = 15] also known as 'Alsi' is one of the most important oilseed crop ranking next to rapeseed and mustard in area as well as production. According to Vavilov (1951) linseed/flax has two centres of origin *viz;* the oil type originated in south west Asia and fibre type originated in Mediterranean region. Linseed being an important oilseed crop has a very low average productivity in India as well as in Himachal Pradesh due to narrow genetic base of the present varieties, common heritage, cultivation in marginal lands and due to biotic and abiotic stresses.

Most of the characters of economic importance in any crop, including yield, are polygenically controlled, metric in nature and are highly influenced by the environmental factors (Copur *et al*., 2006). Breeding for such characters is influenced by the magnitude and nature of interactions between their genotypic and phenotypic variability under varied agro-climatic conditions. The success of breeding programme mostly depends upon the presence of genetic variability in the breeding material. Higher the genetic variability more will be the opportunities to expect improvement through appropriate selection procedure(s) (Muhammad *et al*., 2003). Moreover, selection for yield has to be made for the component characters contributing towards it based on correlation and association studies. Correlation studies are often misleading as they provide the degree but not the cause of associations (Bhatt, 1972). Whereas, path coefficient analysis developed by Wright (1921) permits critical examination of special forces produced through its components, relative importance of various traits towards yield along with the estimation of direct and indirect effects (Dewey and Lu, 1959). Not only this, but it also helps to access the relative contribution and the magnitude of each component character towards yield; helpful in formulating selection strategies for the development of high yielding genotypes.

Therefore, the present study was undertaken to determine the extent of genetic variability and access the relative contribution and magnitude of each component character towards seed yield in order to formulate selection strategies for the development of ideal genotypes.

MATERIALS AND METHODS

Sixty four genotypes of linseed involving exotic collections (25), lines from project coordinating unit Kanpur (5) and from CSKHPKV, Palampur (34) (Table 1) were grown in 8 x 8 simple lattice design with two replications having 25 x 5cm row to row and plant to plant spacing at Experimental Farm of the Department of Crop Improvement, CSKHPKV, Palampur. The data was recorded on five randomly selected competitive plants for primary branches per plant, secondary branches per plant, plant height (cm), capsules per plant, seeds per capsule, aerial biomass (g), seed yield per plant (g), harvest index (%), technical height, straw yield, retted straw yield and fibre yield (g) whereas days to 50% flowering, days to maturity, 1000- seed weight (g) and percent oil content (%) were recorded on plot basis. The data was analyzed as per standard statistical procedure by Federer (1963) and Panse & Sukhatme (1984). The genotypic and phenotypic coefficients of correlations were worked out as per Al-Jibouri *et al*. (1958) and path analysis as suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance revealed sufficient variability due to genotypes for all the traits (Table 2) indicating the presence of wide range of genetic variability and scope for selection. Similar results were also observed by Khorgade and Pillai (1994) for capsules per plant and Mirza *et al*. (1996) for all the traits except primary branches per plant and 1000-seed weight. Paradhan *et al*. (1999) and Payasi *et al*. (2000) also observed sufficient variability due to genotypes for yield related traits; Savita (2006) for days to 50 per cent flowering, days to maturity, plant height, primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, 1000-seed weight, oil content, harvest index and seed yield per plant.

Diederichsen and Fu (2008) and Rajanna *et al*. (2014) also found a wide range of genetic variability of economically relevant traits which are in confirmation with the results of the present study.

Estimates for genotypic correlation were found to be higher than their corresponding phenotypic ones (Table 3), indicating the inherent association among the various traits studied (Nagaraja *et al.,* 2009). Significant positive correlation of seed yield per plant was observed for days to maturity (0.218), secondary branches per plant (0.220), aerial biomass (0.839), harvest index (0.305), straw yield (0.632), retted straw yield (0.603), fibre yield (0.602), 1000-seed weight (0.411) and oil content (0.329). Whereas, seed yield per plant showed negative correlation with seeds per capsule (-0.320); an undesirable correlation. Hence, it should be broken through hybridization or by selecting desirable genotypes. Satapathi *et al*. (1987) reported positive correlation between seed yield per plant and 1000-seed weight whereas Rashid *et al*. (1998) reported positive correlation between seed yield per plant and oil content which are in accordance with the present results. 1000-seed weight was found to be positively correlated with

Table 1: List of germplasm accessions evaluated

Sr. No.	Genotype	Sr.No.	Genotype	Sr. No.	Genotype	Sr. No.	Genotype
1	Hearmies(E)	17	Polf-16(E)	33	RL-2206(P)	49	KL-235(L)
2	Nataja(E)	18	Polf-24(E)	34	Kangra Local-2(L)	50	KL-236(L)
3	Viking(E)	19	Polf-25(E)	35	02 KLC-1(L)	51	KL-237(L)
4	Rajeena(E)	20	EC-537911(E)	36	02 KLC-4(L)	52	KL-238(L)
5	Mariena(E)	21	EC-541716(E)	37	02 KLC-5(L)	53	KL-239(L)
6	Ariane(E)	22	EC-541206(E)	38	02 KLC-6(L)	54	KL-240(L)
7	Lauro(E)	23	EC-541207(E)	39	02 KLC-7(L)	55	KL-243(L)
8	Belinka(E)	24	EC-541208(E)	40	02 KLC-8(L)	56	Nagarkot(L)
9	Giza-5(E)	25	EC-541210(E)	41	02 KLC-9(L)	57	Jeewan(L)
10	Giza-6(E)	26	JRF-5(P)	42	02 KLC-10(L)	58	Janaki(L)
11	Giza-7(E)	27	DPL-13(L)	43	02 KLC-12(L)	59	Him Alsi-1(L)
12	Giza-8(E)	28	DPL-19(L)	44	02 KLC-13(L)	60	Binwa(L)
13	Faiking(E)	29	DPL-32(L)	45	KL-225(L)	61	Himani(L)
14	Belinka 60(E)	30	Garima(P)	46	KL-226(L)	62	Him Alsi-2 (L)
15	Canada(E)	31	LCK-9936(P)	47	KL-233(L)	63	Baner (L)
16	Flak-1(E)	32	RLC-85(P)	48	KL-234(L)	64	Bhagsu (L)

Checks: Him Alsi-2, Baner, Bhagsu;(E): Exotic collection, (P): Lines from project coordinating unit, Kanpur, (L): Lines from CSKHPKV, Palampur

Table 2: Analysis of variance of linseed for different traits

Traits	Source	Mean sum of square		
	Replication	Genotypes (unadjusted)	Block effect within replication (adjusted)	Intra block error
d.f.	1	63	14	49
Days to 50% flowering	175.78	576.41**	5.02	4.41
Days to maturity	153.12	48.03**	6.28	6.26
Primary branches/plant	0.30	0.31**	0.06	0.06
Secondary branches/ plant	0.46	0.52**	0.07	0.08
Plant height (cm)	18.50	140.92**	5.58	4.44
Capsules/plant	0.75	12.34**	9.91	4.90
Seeds/capsule	0.12	1.27**	0.04	0.04
Aerial biomass (g)	0.16	3.85**	0.16	0.08
Seed yield/plant (g)	0.33	0.45**	0.02	0.03
Harvest index (%)	75.08	56.11**	15.44	14.38
Technical height (cm)	0.46	118.14**	4.90	6.10
Straw yield (g)	0.04	1.62**	0.07	0.05
Retted straw yield (g)	0.01	0.95**	0.05	0.04
Fibre yield (g)	0.05	0.30**	0.01	0.01
1000-seed weight (g)	0.16	6.76**	0.09	0.03
Oil content (%)	9.07	4.31**	0.65	0.20

**Significant at 1 per cent level

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

Traits		Days to 50% fowering	Days to maturity	Primary branches /plant	Secondary branches/ plant	Plant height (cm)	Capsules / plant	Seeds/ capsule	Aerial biomass (g)	Harvest index (%)	Technical height (cm)	Straw yield (g)	Retted straw yield (g)	Fibre yield (g)	1000 seed weight (g)	Oil content content (%)
Seed yield/ plant	P	-0.110	0.218*	0.146	0.220*	0.058	0.140	-0.320**	0.839**	0.305**	-0.086	0.632**	0.603**	0.602**	0.411**	0.329**
	G	-0.123	0.260	0.192	0.247	0.058	0.155	-0.366	0.882	0.166	-0.119	0.688	0.665	0.664	0.435	0.386
Days to 50% flowering	P		0.192*	0.205*	-0.164	0.561**	-0.045	0.492**	0.051	-0.332**	0.621**	0.112	0.072	0.211*	-0.376**	-0.249**
	G		0.231	0.243	-0.186	0.584	-0.068	0.509	0.057	-0.457	0.661	0.120	0.081	0.219	-0.378	-0.260
Days to maturity	P			0.165	0.119	0.106	0.005	-0.226*	0.233**	-0.015	0.098	0.210*	0.211*	0.226*	0.387**	0.377**
	G			0.291	0.215	0.131	0.046	-0.250	0.272	-0.046	0.122	0.275	0.302	0.276	0.426	0.427
Primary branches/ plant	P				0.225*	0.225*	0.254**	-0.087	0.239**	-0.138	0.163	0.207*	0.252**	0.116	0.098	0.146
	G				0.265	0.287	0.432	-0.067	0.321	-0.274	0.219	0.275	0.281	0.131	0.134	0.187
Secondary branches/ plant	P					-0.223*	0.400**	-0.119	0.203*	0.037	-0.292**	0.176*	0.240**	-0.039	0.160	0.294**
	G					-0.267	0.545	-0.184	0.235	0.023	-0.379	0.197	0.257	-0.039	0.175	0.342
Plant height (cm)	P						-0.172	0.409**	0.265**	-0.394**	0.904**	0.341**	0.339**	0.517**	-0.157	-0.280**
	G						-0.365	0.440	0.270	-0.504	0.950	0.349	0.363	0.550	-0.166	-0.312
Capsules/ plant	P							-0.040	0.095	0.047	-0.218*	0.013	0.078	-0.104	-0.087	-0.042
	G							-0.095	0.055	0.113	-0.489	-0.024	0.091	-0.182	-0.192	0.016
Seeds/ capsule	P								-0.205*	-0.224*	0.489**	-0.133	-0.157	-0.124	-0.605**	-0.434**
	G								-0.225	-0.307	0.520	-0.133	-0.170	-0.132	-0.624	-0.469
Aerial biomass (g)	P									-0.238**	0.114	0.931**	0.870**	0.660**	0.273**	0.216*
	G									-0.302	0.105	0.947	0.903	0.695	0.273	0.239
Harvest index (%)	P										-0.384**	-0.472**	-0.429**	-0.155	0.260**	0.212*
	G										-0.543	-0.565	-0.524	-0.200	0.336	0.307
Technical height (cm)	P											0.190*	0.180*	0.429**	-0.253**	-0.346**
	G											0.204	0.210	0.467	-0.276	-0.398
Straw yield (g)	P												0.934**	0.612**	0.161	0.139
	G												0.965	0.640	0.162	0.142
Retted straw yield (g)	P													0.643**	0.195*	0.168
	G													0.648	0.207	0.177
Fibre yield (g)	P														0.225*	0.018
	G														0.235	0.016
1000-seed weight (g)	P															0.695**
	G															0.749
Oil content (%)	P															-
	G															

*significant at 5 per cent level;**Significant at 1 per cent level

Table 4: Estimates of direct and indirect phenotypic (P) and genotypic (G) effects of different traits on seed yield

Traits		Days to 50% flowering	Days to maturity	Primary branches / plant	Secondary branches/ plant	Plant height (cm)	Capsules / plant	Seeds /capsule (g)	Aerial biomass (%)	Harvest index (cm)	Technical height (g)	Straw yield (g)	Retted straw yield	Fibre yield (g)	1000 seed weight (g)	Oil content (%)	Correlation with seed yield
Days to 50% flowering	P	0.022	0.004	0.005	-0.004	0.012	-0.001	0.011	0.001	-0.007	0.014	0.003	0.002	0.005	-0.008	-0.006	-0.110
	G	7.129	1.648	1.733	-1.324	4.164	-0.481	3.628	0.409	-3.256	4.709	0.853	0.577	1.559	-2.696	-1.852	-0.123
Days to maturity	P	-0.003	-0.016	-0.003	-0.002	-0.002	0.000	0.004	-0.004	0.000	-0.002	-0.003	-0.003	-0.004	-0.006	-0.006	0.218*
	G	-0.793	-3.430	-0.999	-0.736	-0.450	-0.158	0.856	-0.931	0.159	-0.420	-0.943	-1.037	0.095	-1.462	-1.466	0.260
Primary branches/ plant	P	-0.006	-0.005	-0.030	-0.007	-0.007	-0.008	0.003	-0.007	0.004	-0.005	-0.006	-0.008	-0.004	-0.003	-0.004	0.146
	G	3.456	4.142	14.220	3.766	4.086	6.142	-0.957	4.571	-3.890	3.118	3.903	3.994	1.862	1.898	2.658	0.192
Secondary branches/ plant	P	-0.002	0.001	0.003	0.011	-0.003	0.005	-0.001	0.002	0.000	-0.003	0.002	0.003	0.000	0.002	0.003	0.220*
	G	-0.420	0.485	0.599	2.262	-0.603	1.233	-0.416	0.531	0.052	-0.858	0.446	0.582	-0.089	0.396	0.774	0.247
Plant height (cm)	P	0.024	0.005	0.010	-0.010	0.043	-0.008	0.018	0.012	-0.017	0.039	0.015	0.015	0.022	-0.007	-0.012	0.058
	G	-3.200	-0.718	-1.575	1.461	-5.480	1.997	-2.411	-1.478	2.762	-5.207	-1.911	-1.987	-3.015	0.907	1.711	0.058
Capsules/ plant	P	-0.002	0.000	0.008	0.013	-0.006	0.033	-0.001	0.003	0.002	-0.007	0.000	0.003	-0.003	-0.003	-0.001	0.140
	G	0.697	-0.476	-4.459	-5.628	3.762	-10.323	0.981	-0.563	-1.165	5.049	0.245	-0.942	1.877	1.985	-0.166	0.155
Seeds/ capsule	P	-0.003	0.001	0.001	0.001	-0.002	0.000	-0.006	0.001	0.001	-0.003	0.001	0.001	0.001	0.004	0.003	-0.320**
	G	1.244	-0.610	-0.164	-0.449	1.075	-0.232	2.444	-0.549	-0.751	1.272	-0.324	-0.417	-0.323	-1.525	-1.145	-0.366
Aerial biomass (g)	P	0.055	0.251	0.257	0.219	0.284	0.102	-0.220	1.074	-0.255	0.122	0.999	0.934	0.709	0.293	0.232	0.839**
	G	-3.214	-15.230	-18.029	-13.181	-15.158	-3.061	12.601	-56.092	16.921	-5.879	-53.092	-50.652	-38.973	-15.329	-13.412	0.882
Harvest index (%)	P	-0.153	-0.007	-0.064	0.017	-0.181	0.022	-0.103	-0.109	0.460	-0.177	-0.217	-0.197	-0.071	0.120	0.097	0.305**
	G	-11.653	-1.180	-6.978	0.582	-12.859	2.879	-7.842	-7.696	25.510	-13.855	-14.424	-13.371	-5.100	8.578	7.824	0.166
Technical height (cm)	P	-0.038	-0.006	-0.010	0.018	-0.055	0.013	-0.030	-0.007	0.023	-0.060	-0.012	-0.011	-0.026	0.015	0.021	-0.086
	G	-4.626	-0.857	-1.536	2.658	-6.656	3.426	-3.645	-0.734	3.804	-7.005	-1.431	-1.471	-3.273	1.932	2.789	-0.119
Straw yield (g)	P	-0.022	-0.041	-0.040	-0.034	-0.066	-0.003	0.026	-0.180	0.091	-0.037	-0.194	-0.181	-0.119	-0.031	-0.027	0.632**
	G	6.814	15.647	15.630	11.194	19.855	-1.349	-7.553	53.894	-32.195	11.636	56.938	54.939	36.424	9.227	8.061	0.688
Retted straw yield (g)	P	-0.002	-0.007	-0.009	-0.008	-0.012	-0.003	0.005	-0.029	0.015	-0.006	-0.032	-0.034	-0.022	-0.007	-0.006	0.603**
	G	0.621	2.318	2.154	1.972	2.781	0.700	-1.307	6.925	-4.020	1.610	7.400	7.669	4.970	1.586	1.356	0.665
Fibre yield (g)	P	0.025	0.026	0.013	-0.005	0.060	-0.012	-0.015	0.077	-0.018	0.050	0.071	0.075	0.117	0.026	0.002	0.602**
	G	1.431	1.803	0.857	-0.256	3.601	-1.190	-0.866	4.547	-1.308	3.058	4.186	4.241	6.544	1.536	0.106	0.664
1000-seed weight (g)	P	0.005	-0.005	-0.001	-0.002	0.002	0.001	0.008	-0.003	-0.003	0.003	-0.002	-0.002	-0.003	-0.012	-0.009	0.411**
	G	1.261	-1.421	-0.445	-0.584	0.552	0.641	2.080	-0.911	-1.121	0.919	-0.540	-0.689	-0.782	-3.333	-2.497	0.435
Oil content (%)	P	-0.010	0.016	0.006	0.012	-0.012	-0.002	-0.018	0.009	0.009	-0.015	0.006	0.007	0.001	0.029	0.042	0.329**
	G	1.131	-1.861	-0.814	-1.490	1.359	-0.070	2.041	-1.041	-1.336	1.734	-0.617	-0.770	-0.071	-3.263	-4.355	0.386

Residual effect (P) = 0.1278 , (G) = 1.0941;Bold values indicate direct effects seed yield per plant while negative correlation with seed yield per plant was reported by Kumar and Singh (1970), Patil *et al.* (1980) and Muduli and Patnaik (1994). Muhammad *et al.* (2001) found that seed yield per plant was positively associated with all traits with high significant correlations with number of seeds per capsule and number of capsules per plant. Whereas, in the present study negative correlation was observed between seed yield per plant and seeds per capsule and absence of correlation between seed yield per plant and capsules per plant.

Path analysis at phenotypic and genotypic levels (Table 4) revealed high positive direct effects of aerial biomass (1.074) on seed yield per plant. On partitioning the components for correlation of seed yield per plant with traits showing positive correlation; direct effects were found to be low indicating that on selection of traits like straw yield, retted straw yield, fibre yield, 1000-seed weight, plant height, primary branches, days to maturity, oil content and secondary branches per plant; seed yield per plant cannot be improved. Whereas, their indirect effects through aerial biomass were found to be high for straw yield (0.999), retted straw yield (0.934), fibre yield (0.709), 1000-seed weight (0.293), plant height (0.284), primary branches (0.257), days to maturity (0.251), oil content (0.232) and secondary branches per plant (0.219). Similar studies on path coefficient analysis were done by Chandra (1978), Muduli and Patnaik (1994) and Chimurkar *et al.* (2001). They observed direct effect of capsules per plant and 1000-seed weight on seed yield per plant. Muhammad *et al.* (2003) in a similar study on path coefficient analysis revealed that the number of capsules per plant had highest direct effect followed by plant height, 1000-seed weight and number of branches per plant on seed yield per plant. Whereas results of present findings showed that only aerial biomass contributed directly towards seed yield. Thus, revealing the importance of aerial biomass rather than number of capsules per plant as suggested by previous workers (Chandra, 1978; Muduli and Patnaik, 1994; Chimurkar *et al.*, 2001; Muhammad *et al.*, 2003, Arsul *et al.,* 2013, Reddy *et al.*, 2013 and Rajanna *et al.*, 2014) for increasing the seed yield per plant through direct selection.

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AND ITS OFFICIAL ORGAN

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