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CORRELATION AND PATH COEFFICIENT ANALYSIS OF SEED YIELD AND YIELD RELATED TRAITS OF LINSEED (*LINUM USITATISSIMUM* L.) IN MID-HILLS OF NORTH-WEST HIMALAYAS

DEVENDER SHARMA*, SATISH PAUL AND RANJANA PATIAL
Department of Crop Improvement,
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur 176062
e-mail : devenderyspuhf@gmail.com

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***Corresponding author**

ABSTRACT
The present study on correlation and path coefficient analysis for yield and yield contributing characters in 30 genotypes of linseed to ascertain the genetic and phenotypic correlation and contribution of these traits towards the yield directly and indirectly in linseed. The results indicated that seed yield had significant positive correlation with secondary branches per plant (0.416), aerial biomass (0.760), seeds per capsule (0.306), capsules per plant (0.312), harvest index (0.572), 1000 seed weight (0.318) and oil content (0.312). The results obtained in the present investigation clearly indicated that improvements of seed yield are simultaneously possible through indirect selection for aerial biomass (2.122) followed by plant height (0.0051) which is highly correlated with seed yield. The path analysis also indicates that aerial biomass and plant height are the most important traits in influencing seed yield. The inter-relationship among the characters identified above used in the breeding programme to exploit the yield potential and to develop high yielding improved varieties with ease and target oriented research.

INTRODUCTION

Linseed (*Linum usitatissimum* L.) commonly known as Alsi, a multipurpose *rabi* oilseed crop, cultivated for oil and fibre, which belongs to the family Linaceae having 14 genera. *Linum* has over 200 species with *Linum angustifolium* Huds (n = 15) being its probable progenitor, native to Mediterranean region and Southwest Asia. *Linum usitatissimum* is the only economically significant species of the family with semi-dehiscent and non-dehiscent capsules type (Savita, 2011). Two morphologically distinct cultivated species of linseed are recognized, namely Flax and Linseed. The flax type is commercially grown for the extraction of fibre, whereas the linseed is meant for the extraction of oil from seeds and cake, as a by-product.

Linseed contains about 36 to 48% oil content which is high in unsaturated fatty acids, especially alpha linolenic acid (ALA), an essential Omega-3 fatty acid and lignin oligomers which constitute about 57 % of total fatty acids in linseed (Reddy *et al.,* 2013). It has drying and hardening properties which is emanated from its high linolenic acid content, thus is mostly used for industrial purposes such as manufacturing of paints, varnishes, soaps and printing inks. About 20% of the total linseed oil produced in India is used by the farmers and the rest about 80% goes to industries for the manufacture of paints, varnish, oil-cloth, linoleum and printing ink. Being an important oilseed crop, its average productivity in India as well as in Himachal Pradesh is very low, because of various factors (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, *etc).*

The effectiveness of any breeding or selection programme depends upon the nature and association between seed yield and other component characters, as more directly and positively a character is associated with seed yield. Since yield is a complex character and its appearance mainly depends upon the interaction of numerous traits. Seed yield is a complex polygenic trait and highly influenced by various genetic and environmental factors. So, direct selection for yield as such could be misleading. A successful selection depends upon the information on the association of morpho-agronomic traits that acts directly or indirectly on seed yield (Kumar *et al.,* 2013).

The inter-relationship between important yield components with yield is best estimated by correlation coupled with path coefficient analysis. These techniques used in the crop improvement programmes to exploit the yield potential for enhancing the productivity of the linseed and to develop high yielding improved varieties. Correlation coefficient estimates degree of association of different component characters of yield among themselves and with the yield. When there is positive correlation between major yield components, breeding strategies would be very effective but on the reverse, selection becomes very difficult. (Paul *et al.,* 2016) reported that secondary branches per plant, number of capsule per plant, number of seed per pod, aerial biomass and harvest index were positive and significant correlated with seed yield.

The correlation coefficients estimates alone may be often not accurate due to mutual cancellation of yield component characters. So, study of correlation coupled with a path analysis is more effective tool in the study of yield contributing characters (Naik *et al.,* 2016).

Path analysis measures direct and indirect contribution of individual attributes towards seed yield. Path coefficient analysis partitions the correlation coefficient into direct and indirect effect of the one component on the complex component. Chaudhary *et al.,* (2016) reported harvest index and biological yield per plant exerted high positive direct effects on seed yield.

A clear picture of contribution of each component in final expression of complex character would emerge through the study of correlations and path coefficient analysis revealing different ways in which component attributes influence the complex trait. Keeping this in view, the aim of present investigation was to develop a variety with high in yield and quality through correlation and path analysis studies.

MATERIALS AND METHODS

An experiment was conducted with 30 genotypes (Table 1) of linseed along with three checks *viz*., Nagarkot, Him Alsi-2 and Himani, during *rabi* crop season 2013-14 at Experimental Farm of the Department of Crop Improvement, CSK HPKV, Palampur. The trail was laid out in Randomized Block Design with three replications having 25cm × 5cm spacing from row to row and plant to plant. The parameters taken at plant basis are primary branches per plant, secondary branches per plant, plant height (cm), capsules per plant, seeds per capsule, seed yield per plant (g), aerial biomass (g) and harvest index (%). Whereas, days to flowering, 1000-seed weight and oil content (%) were taken on plot basis. The data on these traits is then subjected to statistical analysis. Statistical analysis of the data was subjected to analysis of variance (ANOVA). Calculations of ANOVA can be characterized as computing a number of means and variances, dividing two variances and comparing the ratio to a handbook value to determine statistical significance. Differences within and between treatments and their significance is best explained in the procedure suggested by Panse and Sukhatme (1984). Phenotypic and genotypic coefficients of correlation were worked out by the procedure of Al- Jibouri *et al.* (1958) and Dewey and Lu (1959). 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) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance (Table 2) revealed significant differences among the genotypes studied for all the characters studied *viz*., namely days to 50% flowering, primary branches per plant, secondary branches per plant, plant height (cm), capsules per plant, seeds per capsule, seed yield per plant (g), aerial biomass (g), harvest index (%), 1000-seed weight and oil content (%). High amount of genetic variability for many of these characters has also been reported by some other workers *viz*., Bibi *et al*. (2013), Yadav *et al*. (2014), Sharma and Paul (2016) and Paul *et al*. (2016) observed highly significant differences for plant height, number of branches per plant, number of capsules per plant, 1000-seed weight and harvest index, which were in conformity with the present findings.

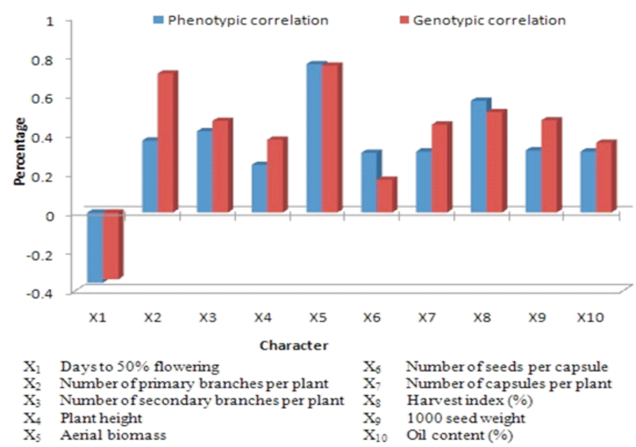

Figure. 1: Genotypic and phenotypic correlation of seed yield per plant with 10 characters in linseed

Table 1: List of 30 germplasm accessions.

S. No.	Genotype	Source/Pedigree	S. No.	Genotype	Source/Pedigree
1	Himalini	K2 × Kangra Local	16	Mariena	Exotic collection
2	Janaki	Palampur	17	Ariane	Exotic collection
3	Jeewan	Sumit × LC-216	18	Giza-5	Exotic collection
4	Surbhi	LC-216 × LC-185	19	Giza-6	Exotic collection
5	Him Alsi-1	K2 × TLP-1	20	Giza-7	Exotic collection
6	Binwa	Flak-1 × SPS 47/7-10-3	21	Giza-8	Exotic collection
7	Baner	EC-21741 × LC-214	22	Faking	Exotic collection
8	Bhagsu	RL-50-3 × Surbhi	23	Aoyagi	Exotic collection
9	KL-241	Giza-7 × KLS-1	24	Flak-1	Exotic collection
10	KL-257	LC-2323 × KLS-1	25	Canada	Exotic collection
11	KL-263	KL-223 × KL-224	26	B-509	Exotic collection
12	Hearmies	Exotic collection	27	Belinka-60	Exotic collection
13	Nataja	Exotic collection	28	Nagarkot	New River × LC-216
14	Viking	Exotic collection	29	Him Alsi-2	EC-21741 × LC-216
15	Rejeena	Exotic collection	30	Himani	DPL-20 × KLS-1

Table 2: Analysis of variance for different characters

Sr.No.	Characters	Mean Sum Of Squares		
	Source	Replication	Genotypes	Error
	df	2	29	59
1	Days to 50% flowering	2.13	165.38*	1.62
2	Primary branches/plant	0.06	1.02*	0.12
3	Secondary branches/plant	0.14	1.63*	0.05
4	Plant height (cm)	10.70	210.96*	11.72
5	Aerial biomass/plant (g)	0.15	0.46*	0.08
6	Seeds/capsule	0.05	0.76*	0.04
7	Capsules/plant	0.78	18.75*	7.74
8	Seed yield/plant (g)	0.02	0.14*	0.03
9	Harvest index (%)	1.02	38.37*	8.20
10	1000-seed weight (g)	0.04	4.57*	0.03
11	Oil content (%)	0.31	14.96*	0.27

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

Characters		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Correlation with SYP
X_1	P	1	-0.132	-0.062	0.112	-0.153*	-0.061	-0.214**	-0.089	-0.201	-0.365**	-0.361**
	G	1	-0.564**	-0.417**	0.712**	-0.269**	0.182*	-0.398**	-0.023	-0.269**	-0.786**	-0.342**
X_2	P		1	0.680**	-0.109*	0.316**	0.047	0.387**	0.174	0.312**	0.304*	0.368**
	G		1	0.614**	-0.172	0.672**	0.098	0.982**	0.365**	0.672**	0.259*	0.712**
X_3	P			1	-0.061	0.204**	0.046	0.541**	0.004	0.112	0.004	0.416**
	G			1	0.041	0.412**	0.046	0.711**	0.064	0.131	-0.021	0.469**
X_4	P				1	0.234**	0.132	0.056	-0.131	0.125	-0.245*	0.244*
	G				1	0.564**	0.116	-0.212*	-0.192	0.159	-0.347**	0.373**
X_5	P					1	-0.023	0.456**	-0.119	0.178	-0.102	0.760**
	G					1	-0.056	0.562**	-0.187	0.185	-0.092	0.752**
X_6	P						1	0.087	0.367**	0.103	0.096	0.306*
	G						1	0.212	0.453**	0.084	0.152	0.168*
X_7	P							1	0.042	0.021	-0.021	0.312**
	G							1	-0.112	0.008	0.017	0.450**
X_8	P								1	0.365**	0.465**	0.572**
	G								1	0.428**	0.712**	0.514**
X_9	P									1	0.361**	0.318**
	G									1	0.378**	0.472**
X_{10}	P										1	0.312*
	G										1	0.357**

X_1	Days to 50% flowering	X_6	Seeds per capsule
X_2	Primary branches per plant	X_7	Capsules per plant
X_3	Secondary branches per plant	X_8	Harvest index (%)
X_4	Plant height (cm)	X_9	1000 Seed weight
X_5	Aerial biomass	X_{10}	Oil content (%)

*Significant at 5 per cent level; **Significant at 1 per cent level, SYP-Seed yield per plant.

Correlation coefficient analysis

Correlation coefficient estimates degree of association of different component characters of yield among themselves and with the yield. The correlation studies between various yield attributes with yield, provides a basis for further breeding programmes. The results of experiment revealed that, genotypic and phenotypic correlation coefficient was similar in directions, while in magnitude, genotypic correlations were mostly higher than corresponding phenotypic correlations. Similarly, Nagaraja *et al.* (2009) also reported that genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients for most of the characters. Thus the low phenotypic correlation could results due to the masking and modifying effect of environment on the association of characters at genotypic level. At phenotypic level, seed yield per plant had significant positive associations with primary branches per plant, secondary branches per plant, plant height, seeds per capsule, capsules per plant, aerial biomass, harvest index, 1000-seed weight and oil content, whereas seed yield per plant showed negative correlation with days to 50 per cent flowering (Table 3 and Fig. 1).

On the basis of association analysis studies, seed yield per plant showed highly significant and positive association with aerial biomass (g) (r=0.760**), harvest index (%) (r=0.572**), capsules per plant (r=0.312**). The similar agreements was reported by Savita *et al.* (2011), Meena and Baha (2013) and Muhammad *et al.* (2014). Seeds per capsule (r=0.306**), 1000 seed weight (r=0.318**) and secondary branches per plant (r=0.416**) can provide better result for improvement of seed yield in linseed. The available literature has also identified the above characters have important association with seed yield in linseed. Almost similar findings have been

Table 4: Estimates of direct and indirect phenotypic and genotypic effects of different characters on seed yield

Traits		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Correlation with seed yield
X_1	P	**0.0038**	-0.0006	-0.0003	0.0003	-0.0008	-0.0001	-0.0008	-0.0003	-0.0006	-0.0008	-0.361**
	G	**0.004**	-0.0022	-0.0007	0.0022	-0.0007	0.0007	-0.0012	0	-0.0009	-0.0024	-0.342**
X_2	P	0.0004	**-0.0011**	-0.0004	0.0004	-0.0005	0	-0.0006	-0.0003	-0.0008	-0.0004	0.368**
	G	-0.0112	**0.0131**	0.0092	-0.0021	0.0062	0.0013	0.0121	0.0062	0.0082	0.0042	0.712**
X_3	P	-0.0003	0.0016	**0.0032**	-0.0004	0.0007	0.0001	0.0008	0	0.0004	0	0.416**
	G	-0.0015	0.0025	**0.0041**	0.0004	0.0014	0.0001	0.0012	0.0002	0.0005	-0.0002	0.469**
X_4	P	0.0004	-0.0022	-0.0002	**0.0051**	0.0022	0.0006	0.0003	-0.0007	0.0008	-0.0021	0.244*
	G	0.0162	-0.0042	0.0007	**0.0128**	0.0114	0.0032	-0.0057	-0.0042	0.0038	-0.0082	0.373**
X_5	P	-0.6214	0.8114	1.0147	1.0746	**2.1221**	-0.0421	1.0214	-0.2471	0.4821	-0.2412	0.760**
	G	-0.8612	1.432	1.3204	1.5069	**2.7618**	-0.22237	1.7075	-0.3988	0.5214	-0.2521	0.752**
X_6	P	0.0007	0	-0.0004	-0.0001	0	**-0.0012**	-0.0003	-0.0004	-0.0002	-0.0003	0.306*
	G	0.0017	0.0001	0.0004	0.0004	-0.0007	**0.0061**	0.0007	0.0031	0.0004	0.0006	0.168*
X_7	P	0.0003	-0.0002	-0.0004	0	-0.0001	-0.0002	**-0.0007**	0	0	0	0.312**
	G	0.0081	-0.0132	-0.0132	0.0031	-0.0032	-0.0012	**-0.0158**	0.0014	-0.0002	-0.0001	0.450**
X_8	P	-0.0007	0.0002	0	-0.0003	-0.0002	0.0008	0.0002	**0.0037**	0.0007	0.001	0.572**
	G	0.0023	-0.0312	-0.0047	0.0124	0.0151	-0.0412	0.0089	**-0.1121**	-0.0542	-0.0521	0.514**
X_9	P	0.0001	-0.0002	-0.0002	-0.0003	-0.0006	-0.0001	0	-0.0003	**-0.0021**	-0.0003	0.318**
	G	0.001	-0.0021	-0.0004	-0.0004	-0.0004	-0.0003	0	-0.0017	**-0.0047**	-0.0014	0.472**
X_{10}	P	-0.0004	0.0001	0	-0.0002	-0.0001	0.0003	0.0001	0.0007	0.0006	**0.0021**	0.312*
	G	-0.0021	0.0004	-0.0002	-0.0012	-0.0002	0.0003	0	0.0017	0.0014	**0.0037**	0.357**

Residual effects (P) = 0.019; (G) = 0.008 ; Bold values indicates direct effects; *Significant at 5 per cent level ; Significant at 1 per cent level

reported by most of the workers in linseed *viz.*, Mehandi *et al.* (2013), Vikas and Nandan (2013), Tariq *et al.* (2014) and Dash *et al.* (2016). But seed yield per plant had non significant and positive correlation with days to 50% flowering (0.361). Paul *et al.* (2015) reported similar finding that day to 50% flowering is negatively correlated with seed yield.

Primary branches per plant (r=0.368), plant height (r=0.244), oil content (r=0.312). More or less observations were observed by Muhammad *et al.* (2014), Paul *et al.* (2015) and Chaudhary *et al.* (2016).

Correlation does not provide the clear picture of contribution of each component traits. Under such situation, path coefficient analysis permits separation of correlation coefficients into components of direct and indirect effects. Partitioning of total correlation into direct and indirect effects provides actual information on contribution of characters and thus forms the basis for selection to improve the yield.

Path coefficient analysis

Path coefficient analysis measures direct and indirect contribution of individual attributes towards seed yield. In order to find out the direct and the indirect contribution of different characters towards seed yield per plant, the path coefficient analysis was done (Table 4). Although eleven traits *viz.*, primary branches per plant, secondary branches per plant, plant height, capsules per plant, seeds per capsule aerial biomass, harvest index, 1000 seed weight and oil content and showed positive correlation with the seed yield per plant and one trait *viz.*, days to 50 per cent flowering and showed negative correlation.

On partitioning the components for correlation of seed yield with characters showing positive correlation, direct effect were found to be low indicating that while selecting these characters seed yield per plant can't be improved through these characters. Their indirect effects through aerial biomass (0.0038) were high; therefore harvest index (0.0037), secondary branches per plant (-0.0011), primary branches per plant (-0.0011), 1000 seed weight (-0.0021), capsules per plant (-0.0007), oil content (0.0021) and seeds per capsule (-0.0012) contributed indirectly through aerial biomass. Similar results were observed by Paul *et al.* (2015) and Dash *et al.* (2016) for harvest index and aerial biomass. Chaudhary *et al.* (2014) also reported that aerial biomass was the main determinant of seed yield per plant. The results of the present study suggest that for improving yield selection should be made for aerial biomass.

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