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Studies on Correlation and Path Analysis in Linseed (*Linum usitatissimum* L.) Over Locations in Mid-hills of North-Western Himalayas

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ABSTRACT

Background: Seed yield is a very important trait for selection but shows low heritability and hence is difficult to improve. Since the productivity of linseed (*Linum usitatissimum* L.) in India as well as Himachal Pradesh is low in comparison to other major linseed growing countries and states, improvement in cultivars for grain yield is a must. Therefore, the present study was aimed for studying the character associations in linseed genotypes for seed yield over locations.

Method: The experiment was conducted during *rabi* 2019-2020. The experimental material for the present investigation comprised of 52 linseed genotypes grown over three locations in Himachal Pradesh *i.e.* Linseed Experimental Farm, CSK HPKV, Palampur (1290 m amsl), Shivalik Agricultural Research and Extension Centre, Kangra (700 m amsl) and Hill Agricultural Research and Extension Centre, Dhaulakuan (468 m amsl). Randomized block design with three replications was used. Phenotypic and genotypic correlation coefficients were worked out as per the procedure outlined by Burton and De Vane (1953) and Johnson *et al.* (1955). Direct and indirect effects of component traits on grain yield were worked out using correlation coefficient of various traits as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

Result: Correlation studies indicated highly significant positive correlation for seed yield with 1000 seed weight (0.965**) followed by harvest index (0.801**), secondary branches (0.585**) and a significant correlation with biological yield (0.269**). Seed yield exhibited a non-significant positive correlation with seeds per capsule. However, a negative significant correlation was observed for seed yield with days to 50 per cent flowering and number of primary branches. The path coefficient analysis indicated that 1000 seed weight exhibited maximum positive direct effect with seed yield (0.741) while others had a low direct effect. The significant positive correlation of number of secondary branches and harvest index with seed yield was mainly due to indirect effect *via* 1000 seed weight indicating that 1000 seed weight is the most important trait for the improvement of grain yield in linseed as per the present study.

Key words: Correlation coefficients, Linseed, Path coefficients, Seed yield.

INTRODUCTION

Linum usitatissimum L. is an important fibre (flax) and oilseed (linseed) plant (Milliam *et al*., 2005) belonging to the genus *Linum* and family linaceae. *Linum usitatissimum* is the only agriculturally important species belonging to the genus *Linum.* Every part of the plant has some economic use. Seeds give oil which can be used for both edible as well as non-edible purposes and stems give fibre used for making of fabric "linen". Linseed is a cool season crop but is sensitive to frost. A temperature range of 20-25°C is optimum for its good yield and quality. The linseed crop is suitable for low rainfall area and is generally raised where the average annual rainfall ranges from 45 to 75 cm. In India, it is among the important non-edible oilseed crops (Bhateria *et al*., 2006) with major role in industrial purposes such as paints and varnishes. Despite of the wide range of benefits provided by the crop, it's productivity in India is very low (573.62 kg/ha) in comparison to the world average of 951.83kg/ha (FAOSTAT 2019) because it is normally grown under rainfed situation by resource poor farmers and also, non-availability of high potential cultivars have lowered down the productivity of this oilseed.In Himachal Pradesh, linseed has a productivity of 375kg/ha (Statistical Year Book of Himachal Pradesh 2018) and is mostly grown for domestic use which is either sown on poor marginal land or is broadcasted in standing paddy crop, 15 -20 days before its harvest.

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Major basis for low productivity in India would be non-availability of high yielding linseed varieties. This may be due to the fact that yield is a complex trait, controlled by many genes with small additive effects in self-pollinated crops. Therefore, yield shows low heritability and is a difficult trait to improve (Slinkard 2000). Hence, direct selection for high yield is non-effective. Since seed yield is an outcome of several traits interacting with one another, indirectselection through various yield components has proven more effective. This selection criterion takes into account the information on interrelationship among agronomic characters, their relationship with grain yield as well as their direct influence on grain yield (Tadesse *et al*. 2009). This analysis can be brought about by correlation and path studies.

Correlation and path analysis estimates the extent of association of different yield components among themselves and with the yield and also measures direct and indirect contribution of individual attributes towards seed yield (Rajanna *et al*. 2014). This kind of analysis further helps the breeder in outlining his selection strategies to improve grain yield. In the light of above scenario present investigation was carried out for studying the character associations in linseed genotypes for seed yield grown over locations.

MATERIAL AND METHODS

The experiment was conducted in *rabi* 2019-20 at three locations *i.e.,* Linseed experimental farm, CSKHPKV Palampur (1290 m amsl), Shivalik Agricultural Research and Extension Centre, Kangra (700 m amsl) and Hill Agricultural Research and Extension Centre, Dhaulakuan (468 m amsl). The experimental material comprised of 52 genotypes (Table 1) sown in randomized block design with three replications at each location. Pooled analysis of variance was carried out as per the standard statistical methods. Phenotypic and genotypic correlation coefficients were worked out as per the procedure outlined by Burton and De Vane (1953) and Johnson *et al*. (1955). Direct and indirect effects of component traits on grain yield were worked out using correlation coefficient of various traits as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

$$PCV = \sqrt{VP}/\bar{X} \times 100$$

$$GCV = \sqrt{VG}/\bar{X} \times 100$$

Where;

VP = Phenotypic variance

VG = Genotypic variance

X = Mean of the sample

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

RESULTS AND DISCUSSION

Genetic parameters of variability

Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and heritability in broad sense (h2bs) were estimated for characters studied and are presented in (Table 2). PCV was found highest (>20%) for

Table 1: List of 52 linseed accessions.

Genotypes	Parentage
KL-236	Jeevan ×Janki
KL-241	Giza-7 ×KLS-1
KL-244	(RLC 29 × Jeevan) × RLC-29
KL-257	LC-2323 × KLS-1
KL-263	KL-223 × KL-224
KL-269	EC-21741 × LC-216
KL-278	Giza-5 × Aayogi
KL-279	Mariena × Giza-5
KL-280	Giza-7 × Belinka
KL-284	Rjeena × Him Alsi-2
KL-285	Binwa × Him Alsi-2
KL-305	TL-27 × Nagarkot
KL-306	Nagarkot × T-397
KL-307	Him Alsi-2 × Nagarkot
KL-308	TL-397 × Nagarkot
KL-309	Canada × Nagarkot
KL-310	Giza-8 × Nagarkot
KL-311	Giza-6 × Nagarkot
KL-312	Giza -7 × Nagarkot
KL-313	Faiking × Nagarkot
KL-314	Belinka 60 × Nagarkot
KL-315	TL-27 × Flak-1
KL-316	Him Alsi-2 × Binwa
KL-317	Him Alsi-1 × Binwa
KL-318	Him Alsi-2 × TL-11
KL-319	(KL-243× Janki)× KL-243
KL-320	(Gaurav × Nagarkot) × Nagarkot
KL-321	TL-43 × Binwa
KL-322	(TL-43× Binwa)× TL-43
KL-323	(KL-178× Ariane) × KL-178
KL-324	TL-11 × Him Alsi-2
KL-325	TL-37-2 × Him Alsi-2
KL-326	Binwa × Him Alsi-2
KL-327	(Janki × TL- 43) × Janki
Him Alsi-2	EC-21741 × LC-216
Nagarkot	New River × LC – 216
Himani	DPL-20 × KLS-1
Jeewan	Sumit × LC-216
Baner	EC-21741 × LC-214
Bhagsu	RL-50-3 × Surbhi
Himalini	K2 × Kangra Local
Him Alsi-1	K2 × TLP-1
Janki	Palampur
Surbhi	LC-216 × LC-185
Canada	Exotic collection
Binwa	Flak-1 × SPS 47/7-10-3
Giza-7	Exotic collection
Giza-8	Exotic collection
Belinka	Exotic collection
K-1 Raja	CSIRO, Canberra, Australia
JRF-4	CRIJAF, Barrackpore
Ayogi	Exotic collection

seed yield (60.91%), followed by harvest index (58.21%) and number of primary branches (23.58%) and secondary branches (23.52%) in accordance with the results of Dabola *et al*., 2020. The lowest PCV (<10%) was observed for days to 50 per cent flowering (3.83%) followed by seeds per capsule (5.40%) and days to 75 per cent maturity (5.587). Lowest PCV for seeds/capsule was also observed by Terfa and Gurmu 2020. GCV was observed highest for seed yield per plant (58.77%) followed by harvest index (56.75%). The least GCV was observed for seed per capsule (2.13%) followed by days to 50 per cent flowering (3.46%) confirmed by Singh *et al.,* 2015 and days to 75 per cent maturity (5.47%). Heritability in broad sense was also estimated and it ranged from 15.66% in seeds per capsule to 95.95% in days to 75 per cent maturity. Heritability was observed high (>60%) for most of the traits with highest for days to 75 per cent maturity (95.95%) followed by harvest index, seed yield, 1000 seed weight, numberof secondary branches, plant height, biological yield, days to 50 per cent flowering and technical height. Genetic advance as percent of mean was observed highest for seed yield (96.383%) followed by harvest index (94.521%).

Correlation coefficient analysis

Phenotypic and genotypic correlation coefficients were estimated to know the degree of association among the 12 traits. In the present investigation correlation coefficient analysis depicted that genotypic and phenotypic correlation coefficient differed in their magnitude for few characters yet both phenotypic and genotypic correlation coefficients were in the same direction. However, genotypic correlation coefficients were greater than its corresponding phenotypic correlation coefficients for most of the traits. Similar results were observed by Reddy *et al.,* 2013, Akbar *et al.,* 2001, Sharma *et al.,* 2016. The difference in magnitude between the genotypic and phenotypic correlation is a result of the effect of environment on the phenotype. The environmental effect may be in the same direction as the genetic effects and hence result in similarity between genotypic and phenotypic correlation (Cheverud 1984) or instead have an effect opposite to the genetic effects which results in different genotypic and phenotypic correlations.

Since genotypic correlations require large sample sizes for its appropriate estimation, phenotypic correlation coefficient can be the representative of genotypic correlation coefficient (Sodini *et al.,* 2018). Therefore the use of phenotypic correlation as a reflection of genotypic correlation is considered appropriate in evolutionary biology. Results indicated highly significant positive correlation for seed yield with 1000 seed weight (0.965**) followed by harvest index (0.801**), secondary branches (0.585**) and a significant correlation with biological yield (0.269**) (Table 3) which were in accordance to the findings of Kumar and Paul 2016 and Ankit *et al.*2019. Positive association of 1000 seed weight with seed yield is reported earlier by Gudmewad *et al.* 2016, Tariq *et al.* 2014, Ibrar *et al.* 2016. It suggested that improvement for these traits can lead to improvement in grain yield under selection.

Whereas, a non-significant positive correlation was observed for seed yield with seeds per capsule which were in conformity with the findings of Kumar and Paul 2016. A negative significant association was also observed for seed yield with days to 50 per cent flowering and number of primary branches which was similar to findings of Tadesse *et al.* 2009. Conversely, among the other traits days to 50% flowering showed a highly positive significant correlation with plant height (r_p = 0.513**) and technical plant height (0.475**). Plant height was positively and highly significantly correlated with technical plant height (r_p = 0.883**). Significant positive correlation was also observed between technical plant height and number of primary branches (r_p = 0.195*). Plant height and number of primary branches revealed positive significant association with biological yield (r_p=0.209**, r_p = 0.247** respectively). Highly significant positive correlation was also observed for harvest index with number of secondary branches (r_p = 0.597**), biological yield (r_p = 0.354**) and 1000 seed weight (r_p = 0.797**). Positive significant correlation of harvest index with 1000 seed weight was also observed by Patial *et al.* 2018. Positive correlation arises due the coupling phase of linkage of genes controlling

Table 2: Genetic parameters of variability for different yield and related traits in linseed pooled over locations.

Character	Mean ± S.E. (m)	range	PCV	GCV	h^2bs	GA
Days to 50% flowering	122.678 ± 1.651	107-135	3.836	3.464	81.532	6.444
Days to 75% maturity	171.058 ± 1.569	153-183	5.587	5.473	95.957	11.045
Plant height	89.751 ± 2.528	84.127-112.820	9.157	8.483	85.810	16.187
Technical Plant height	63.764 ± 2.666	50.303-76.247	11.639	10.451	80.635	19.333
No. of primary branches	6.504 ± 0.399	4.390 – 9.240	23.589	22.358	89.831	43.652
No. of secondary branches	19.240 ± 2.332	13.673 – 30.150	23.529	18.254	60.188	29.173
Capsule/plant	77.634 ± 10.623	56.750 – 100.863	19.277	9.526	24.418	9.697
Seeds/capsule	7.865 ± 0.319	7.343- 8.573	5.405	2.139	15.661	1.744
Biological yield/plant	55.000 ± 2.529	74.600 – 40.577	14.548	13.414	85.019	25.479
1000 seed weight	6.650 ± 0.263	5.150 – 7.927	14.805	13.993	89.331	27.244
Harvest index	18.009 ± 1.908	5.360 – 34.753	58.214	56.751	95.034	94.521
Seed yield/plant	9.192 ± 1.202	2.757- 17.223	60.917	58.775	93.090	96.383

Table 3: Estimates of genotypic and phenotypic correlation coefficients.

Characters		Days to 50% flowering	Days to 75% maturity	Plant height	Technical plant height	Number of primary branches	Number of secondary branches	Capsules/ plant	Seeds/ capsule	Biological yield/ plant	1000 seed sweight	Harvest index	Seed yield
Days to 50% flowering	P	1	0.369**	0.513**	0.475**	0.070^{NS}	0.038^{NS}	0.091^{NS}	0.043^{NS}	0.043^{NS}	-0.166*	-0.132^{NS}	-0.185*
	G	1	0.379**	0.603**	0.566**	0.078^{NS}	-0.009^{NS}	0.191*	0.058^{NS}	0.082^{NS}	-0.183*	-0.151^{NS}	-0.205*
Days to 75% maturity	P		1	0.266**	0.381**	0.788**	-0.557**	0.132^{NS}	0.000^{NS}	-0.355**	-0.897**	-0.800**	-0.910**
	G		1	0.289**	0.422**	0.835**	-0.782**	0.210**	-0.080^{NS}	-0.387**	-0.954**	-0.851**	-0.955**
Plant height	P			1	0.883**	0.061^{NS}	-0.060^{NS}	0.077^{NS}	0.039^{NS}	0.209**	-0.170*	-0.109^{NS}	-0.195*
	G			1	0.939**	0.050^{NS}	-0.082^{NS}	0.104^{NS}	0.046^{NS}	0.279**	-0.154^{NS}	-0.123^{NS}	-0.202*
Technical plant height)	P				1	0.195*	-0.104^{NS}	0.054^{NS}	-0.026^{NS}	0.185*	-0.268**	-0.190*	-0.292**
	G				1	0.208**	-0.140^{NS}	0.113^{NS}	-0.087^{NS}	0.247**	-0.296**	-0.224**	-0.340**
Number of primary branches	P					1	-0.331**	0.337**	0.044^{NS}	-0.246**	-0.802**	-0.647**	-0.830**
	G					1	-0.602**	0.472**	-0.019^{NS}	-0.275**	-0.881**	-0.712**	-0.901**
Number of secondary branches	P						1	0.357**	0.158*	0.298**	0.582**	0.597**	0.585**
	G						1	0.189*	0.124^{NS}	0.404**	0.773**	0.845**	0.771**
Capsules/plant	P							1	0.185*	0.052^{NS}	-0.121^{NS}	-0.018^{NS}	-0.135^{NS}
	G							1	0.167*	0.110^{NS}	-0.273**	-0.031^{NS}	-0.298**
Seeds /capsule	P								1	0.050^{NS}	0.089^{NS}	0.010^{NS}	0.072^{NS}
	G								1	0.022^{NS}	0.130^{NS}	0.237**	0.137^{NS}
Biological Yield	P									1	0.423**	0.354**	0.269**
	G									1	0.438**	0.401**	0.327**
1000 seed weight	P										1	0.797**	0.965**
	G										1	0.877**	0.988**
X11 (harvest index)	P											1	0.801**
	G											1	0.868**
Seed yield	P												
	G												

Table 4: Estimates of direct and indirect effects.

Characters		Days to 50% flowering	Days to 75% maturity	Plant height	Technical plant height	Number of primary branches	Number of secondary branches	Capsules /plant	Seeds/ capsule	Biological yield/ plant	1000 seed weight	Harvest index	Seed yield
Days to 50 % flowering	P	**0.017**	-0.07851	-0.02218	0.03681	-0.00666	0.00141	0.00058	0.00062	-0.00739	-0.12286	-0.00380	-0.185*
	G	**0.031**	-0.02785	0.07056	-0.06586	0.00896	0.00036	-0.00689	-0.00156	0.01000	-0.01003	-0.19176	-0.205*
Days to 75% maturity	P	0.00637	**-0.213**	-0.01152	0.02953	-0.07516	-0.02077	0.00083	0.00001	0.06086	-0.66471	-0.02310	-0.910**
	G	0.01180	**-0.073**	0.03378	-0.04912	0.09553	0.03135	-0.00760	0.00217	-0.04724	-0.05643	-0.89524	-0.955**
Plant height	P	0.00886	-0.05669	**-0.043**	0.06834	-0.00581	-0.00223	0.00049	0.00056	-0.03582	-0.12622	-0.00314	-0.195*
	G	0.01878	-0.02122	**0.117**	-0.10925	0.00573	0.00330	-0.00377	-0.00124	0.03409	-0.00818	-0.18947	-0.202*
Technical plant height)	P	0.00821	-0.08111	-0.03817	**0.077**	-0.01865	-0.00390	0.00034	-0.00037	-0.03171	-0.19856	-0.00549	-0.292**
	G	0.01760	-0.03099	0.10974	**-0.116**	0.02381	0.00561	-0.00407	0.00235	0.03020	-0.01487	-0.31918	-0.340**
Number of primary branches	P	0.00121	-0.16757	-0.00263	0.01514	**-0.095**	-0.01236	0.00213	0.00062	0.04220	-0.59419	-0.01869	-0.830**
	G	0.00244	-0.06134	0.00586	-0.02424	**0.114**	0.02416	-0.01705	0.00052	-0.03351	-0.04723	-0.84455	-0.901**
Number of secondary branches	P	0.00065	0.11845	0.00259	-0.00809	0.03160	**0.037**	0.00226	0.00226	-0.05098	0.43144	0.01726	0.585**
	G	-0.00028	0.05740	-0.00961	0.01629	-0.06891	**-0.040**	-0.00684	-0.00336	0.04929	0.05600	0.72266	0.771**
Capsules/plant	P	0.00157	-0.02803	-0.00334	0.00415	-0.03214	0.01331	**0.006**	0.00264	-0.00889	-0.09001	-0.00053	-0.135NS
	G	0.00593	-0.01546	0.01222	-0.01310	0.05398	-0.00759	**-0.036**	-0.00453	0.01338	-0.00204	-0.27924	-0.298**
Seeds /capsule	P	0.00075	-0.00010	-0.00168	-0.00202	-0.00417	0.00590	0.00117	**0.014**	-0.00856	0.06608	0.00028	0.072^{NS}
	G	0.00179	0.00587	0.00534	0.01007	-0.00219	-0.00496	-0.00603	**-0.027**	0.00266	0.01568	0.12881	0.137^{NS}
Biological Yield	P	0.00074	0.07559	-0.00904	0.01434	0.02350	0.01110	0.00033	0.00071	**-0.171**	0.31323	0.01023	0.269**
	G	0.00255	0.02842	0.03265	-0.02880	-0.03140	-0.01620	-0.00396	-0.00059	**0.12206**	0.02659	0.30654	0.327**
1000 seed weight	P	-0.00286	0.19075	0.00736	-0.02074	0.07647	0.02171	-0.00077	0.00127	-0.07237	**0.741**	0.02303	0.965**
	G	-0.00471	0.06250	-0.01443	0.02612	-0.08147	-0.03388	0.00111	-0.00642	0.04896	**0.066**	0.81338	0.988**
X11 (harvest index)	P	-0.00227	0.17007	0.00470	-0.01472	0.06172	0.02228	-0.00012	0.00014	-0.06064	0.59103	**0.029**	0.801**
	G	-0.00636	0.07013	-0.02363	0.03963	-0.10303	-0.03092	0.01076	-0.00373	0.03991	0.05752	**0.938**	0.868**
Seed yield	P												
	G												

Residual effect= 0.03015.

two characters. Significant positive correlation between the two traits may also be due to pleiotropic effects *i.e.*, a single gene governs the expression of two traits. Hence, increase in the value of one will also increase the value of other.

Path coefficient analysis

Path analysis differs from simple correlation in that it points out the causes and their relative importance, whereas latter simply measures the mutual association ignoring the causation. Therefore characters association were partitioned into direct and indirect effects as given in (Table 4). The positive correlation with seed yield was observed for characters 1000 seed weight, harvest index, secondary branches and biological yield. The path coefficient analysis on phenotypic level revealed that 1000 seed weight exhibited maximum positive direct effect with seed yield (0.741) while others had a low direct effect indicating that seed yield can't be improved by selecting these characters. However, the significant positive correlation of number of secondary branches and harvest index with seed yield was mainly due to indirect effect *via* 1000 seed weight This specifies that 1000 seed weight is the most imperative trait for the improvement of grain yield whereas, selection for number of secondary branches and harvest index would also have a positive indirect effect on seed yield. Therefore, these characters could be considered important during selection for advancement of grain yield. Other characters had negligible or very low direct and indirect effects on seed yield. The present investigation is in agreement with Badwa, *et al.* (1970), Ahmad (2017), Gudmewad *et al.*(2018) who also reported that 1000 seed weight is one of the major factors which directly contribute to seed yield. The residual effect was found to be low (0.03015) indicating that the causal factors account for the variability of the dependent factor *i.e.* seed yield in the present case.

CONCLUSION

It is concluded from the results of this experiment that 1000 seed weight could be considered the major yield contributing character because it showed a highly positive significant correlation with seed yield at both phenotypic and genotypic level and also had the maximum positive direct effect on seed yield. While other traits like number of secondary branches and harvest index should also be given importance while designing new breeding programmes for linseed improvement.

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