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Research Note

Association studies in linseed (*Linum usitatissimum* L.) under different production systems over locations

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Abstract
The present experiment was conducted to determine the important yield components and their association with one another and with yield. The experiment was laid out under two production systems over four different locations in the mid-hills of the North-western Himalayas. Correlation studies indicated a strong positive correlation for seed yield with harvest index (EI 0.668**; EII 0.472**) and biological yield (EI 0.362; EII 0.532) in both the production systems. Whereas, a non-significant positive correlation was observed for the number of primary branches (EI 0.103; EII 0.122) and the number of secondary branches (EI 0.033; EII 0.160) in both production systems. Whereas, among other traits highly significant correlation was observed for days to 50% flowering with days to 75% maturity in both production systems (EI 0.837**; EII 0.781**) followed by plant height (EI- 0.626**; EII- 0.562**) and technical plant height (EI 0.617**; EII 0.598**). Path coefficient analysis indicated that only biological yield (EI 0.70348; EII 0.60597) and harvest index (EI 0.90210; EII 0.53283) showed a highly significant direct effect with seed yield in both production systems. This showed that selection for biological yield and harvest index would have a direct positive effect in the improvement of grain yield and are the most important determinants of yield in linseed. However, traits such as number of primary branches, number of secondary branches and 1000 seed weight should also be given significant importance since these traits also showed a positive correlation with seed yield but with indirect effects *via* biological yield and harvest index in EI and EII, respectively.

Keywords: Linseed, correlation, path analysis, seed yield

Linseed is an annual field crop that is largely grown in temperate areas of the world. It is a multipurpose crop valued for its seed, fibre and nutraceutical properties with a wide range of adaptability to different environments (Kaur *et al.*, 2017). Linseed requires a cool temperature ranging from 10 to 30°C although the crop grows best within 21 and 22°C during its growing period to produce a good yield. The cultivation of linseed is restricted mostly to marginal and submarginal lands under a limited supply of fertilizer and irrigation, resulting in low crop yield. In India, it is mainly grown for seed and oil for the non-edible purpose.

The principle goal of linseed breeding is to develop new varieties that outperform the existing ones in relation to many traits out of which seed yield is considered to be the most important. Also, selection of the most valuable genotype in any breeding programme defines the success and efficiency of that programme. Seed yield is a complex trait and is dependent upon many other different factors. It is majorly affected by the environment and also shows low heritability (Mubai *et al.*, 2020). Therefore, it is important to recognize the interdependence between seed yield and its contributing traits with a view to outline different selection indices to improve grain yield

(Aman *et al.*, 2020). This association can be assessed by correlation and path analysis. Correlation analysis helps in determining the magnitude of strength and direction of an association of different yield contributing traits among themselves and with seed yield. It shows the degree to which two or more traits are associated with one another (Gomez and Gomez, 1984) and in which direction do they change together. However, path coefficient analysis helps in determining the direct and indirect effects of those characters with grain yield which further helps in better understating of interdependence of different traits on yield. Ultimately, this kind of analysis could help the breeder to design his selection strategies to improve grain yield. Considering the above scenario present investigation was carried out for studying the character associations in linseed genotypes for seed yield grown over two different production systems.

The experiment was laid during *rabi,* 2019-20 over four different locations covering three different districts of Himachal Pradesh with varying altitudes. The locations included 1. Linseed experimental farm, CSKHPKV Palampur (1290 m MSL), 2. Shivalik Agricultural Research and Extension Centre, Kangra (700 m MSL) and 3. Hill Agricultural Research and Extension Centre, Dhaulakuan (468 m MSL) and 4. Hill Agricultural Research and Extension Centre, Bajaura (1090 m MSL). Each location comprised of two production systems i.e. conventional and zero budget natural farming (ZBNF) under which each experiment was laid. Hence, total of eight experiments were conducted (4 conventional, 4 ZBNF) each comprising 30 genotypes (**Table 1**) sown with randomized block design over three replications. Data belonging to each production system was pooled over four locations thus overall comprising of two environments

Table 1. List of 30 linseed accessions

S.No.	Genotypes	Parentage
1	KL-236	Jeevan ×Janki
2	KL-241	Giza-7 ×KLS-1
3	KL-244	(RLC 29 × Jeevan) × RLC-29
4	KL-257	LC-2323 × KLS-1
5	KL-263	KL-223 × KL-224
6	KL-269	EC-21741 × LC-216
7	KL-278	Giza-5 × Aayogi
8	KL-279	Mariena × Giza-5
9	KL-280	Giza-7 × Belinka
10	KL-284	Rjeena × Him Alsi-2
11	KL-285	Binwa × Him Alsi-2
12	KL-309	Canada × Nagarkot
13	KL-311	Giza-6 × Nagarkot
14	KL-314	Belinka 60 × Nagarkot
15	KL-315	TL-27 × Flak-1
16	KL-317	Him Alsi-1 × Binwa
17	Him Alsi-2	EC-21741 × LC-216
18	Nagarkot	New River × LC – 216
19	Himani	DPL-20 × KLS-1
20	Jeewan	Sumit × LC-216
21	Baner	EC-21741 × LC-214
22	Bhagsu	RL-50-3 × Surbhi
23	Himalini	K2 × Kangra Local
24	Him Alsi-1	K2 × TLP-1
25	Janki	Palampur
26	Surbhi	LC-216 × LC-185
27	Canada	Exotic collection
28	Binwa	Flak-1 × SPS 47/7-10-3
29	Giza-7	Exotic collection
30	Giza-8	Exotic collection

i.e. E1 – conventional (pooled over locations), E2- ZBNF (pooled over locations). Pooled analysis of variance was carried out for the two environments as per the standard statistical methods. Pooled analysis revealed highly significant differences ($P \leq 0.01$) for traits *viz.*, the number of primary branches, the number of secondary branches, biological yield, seed yield and 1000 seed weight indicating that relative genotypic values of these traits changed significantly over the environments (**Table 2**). 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 the correlation coefficient of various traits as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

Genotypic and phenotypic correlations are of value to indicate the degree to which various morpho-physiological characters are associated with economic productivity (Baye *et al.*, 2020). However, it does not provide the information on direct and indirect effects of these components. In the present investigation, phenotypic and genotypic correlation coefficients were estimated to know the degree of association between 12 traits. However, genotypic correlation coefficients were greater than its corresponding phenotypic correlation coefficients for most of the traits which indicated a strong inherent association between the characters which might be due to masking or modifying effects of the environment. Phenotypic correlation is the net result of genetic and environmental correlation (Anwar *et al.*, 2009) because phenotype is the result of both genotype and environment. The environment can affect both correlations in either same direction or opposite. Difference in the magnitudes of phenotypic and genotypic correlations in linseed was also observed by Reddy *et al.* (2013), Akbar *et al.* (2001) and Sharma *et al.* (2016) in linseed. The results (**Table 3**) showed a strong significant positive correlation for seed yield with two independent variables i.e., harvest index (EI 0.668**; EII 0.472**) and biological yield (EI0.362; EII0.532) in both the environments. This was in accordance to the findings of Ankit *et al.* (2019), Dogra *et al.* (2020), Tadesse *et al.* (2009), Sharma *et al.* (2016), Patial *et al.* (2018), Savita *et al.* (2011) Kanwar *et al.* (2013) and Paul *et al.* (2015) who also observed aerial biomass and harvest index as one of the independent variables having positive significant association with seed yield in linseed. A significant positive correlation was also observed for 1000 seed weight with seed yield in EI (0.232**) which are in accordance to the findings of Akbar *et al.* (2003), Bindra and Paul (2016), Gudmewad *et al.* (2016) and Sonwane *et al.* (2015). Whereas, a non-significant positive correlation was observed for the number of primary branches (EI 0.103; EII 0.122) and the number of secondary branches (EI 0.033; EII 0.160) in both the environments, for seed per capsule in EI (0.080) and for capsules per plant in EII (0.184). Significant and positive association of primary branches, secondary branches, seeds per capsule and capsule per plant were stated by Iqbal *et al.* (2013) and Gudmewad *et al.* (2016). These observations indicate that seed yield cannot be increased by simply selecting for traits with increased number of primary branches, the number of secondary branches, seed per capsule and capsules per plant as their effect is non-significant on seed yield. A negative significant correlation was observed for plant height (-0.351**), technical plant height (-0.319**) and days to 50% flowering (-0.272**) with seed yield in EI as also observed by Iqbal *et al.* (2013) and

Table 2. Pooled ANOVA for different traits

	Characters	EI		EII		Pooled over environments			
		Mean squares							
	Source	Genotypes	Error	Genotypes	Error	Genotypes	Environment	Genotype x Environment	Pooled Error
	df	**29**	**58**	**29**	**58**	**29**	**1**	**29**	**116**
1.	Days to 50 % flowering	**56.863**	3.093	47.902	2.626	102.345	9.339	2.419	2.860
2.	Days to 75 % maturity	43.272	2.341	41.101	3.011	80.427	11.250	3.946	2.676
3.	Plant Height	214.219	12.684	189.655	16.984	391.726	402.023	12.148	14.834
4	Technical plant height	155.505	12.420	144.779	6.200	295.557	247.236	4.727	9.310
5	Number of primary branches	0.709	0.162	1.079	0.210	1.312	80.719	0.476**	0.186
6	Number of secondary branches	22.686	7.135	16.760	4.853	24.891	1,732.609	14.554**	5.994
7	Capsules per plant	239.787	187.567	266.144	94.171	348.896	41,733.850	157.034	140.869
8	Seeds per capsule	0.250	0.160	0.198	0.065	0.300	0.016	0.148	0.112
9	Biological yield	33.320	10.436	2.322	13.716	27.373	29,916.784	19.662**	5.712
10	Seed yield	7.041	2.047	1.387	0.503	5.454	1,225.915	2.974**	1.275
11	1000 seed weight	0.300	0.031	0.363	0.022	0.569	3.087	0.095**	0.027
12	Harvest index	24.635	7.829	14.203	8.985	26.605	151.507	12.234	8.407

Table 3. Genotypic and Phenotypic correlation coefficients

Characters			X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	EI	P	1	0.837**	0.626**	0.617**	-0.015	0.033	0.042	0.120	0.176	-0.121	-0.378**	-0.272**
		G	1	0.990**	0.730**	0.753**	-0.021	-0.093	0.073	0.301**	0.313**	-0.203	-0.641**	-0.400**
	EII	P	1	0.781**	0.562**	0.598**	0.312**	0.333**	0.292**	0.123	0.086	0.005	-0.049	0.058
		G	1	0.936**	0.628**	0.682**	0.375**	0.483**	0.355**	0.197	0.135	-0.001	-0.080	0.137
X2	EI	P		1	0.618**	0.615**	-0.080	-0.013	0.029	0.178	0.093	-0.122	-0.279**	-0.228*
		G		1	0.752**	0.757**	-0.121	-0.122	-0.014	0.403**	0.215*	-0.238*	-0.593**	-0.439**
	EII	P		1	0.643**	0.703**	0.142	0.210*	0.137	0.110	0.162	-0.137	-0.138	0.065
		G		1	0.753**	0.795**	0.230*	0.356**	0.210*	0.208*	0.201	-0.136	-0.383**	0.048
X3	EI	P			1	0.924**	-0.288**	-0.162	-0.043	0.087	0.042	-0.168	-0.436**	-0.351**
		G			1	0.980**	-0.433**	-0.317**	-0.428**	0.237*	0.112	-0.223*	-0.594**	-0.392**
	EII	P			1	0.881**	0.035	-0.034	-0.066	0.077	0.124	-0.111	-0.238*	-0.033
		G			1	0.988**	0.040	0.019	-0.111	0.059	0.202	-0.092	-0.661**	-0.036
X4	EI	P				1	-0.216*	-0.142	-0.109	0.071	0.041	-0.180	-0.385**	-0.319**
		G				1	-0.368**	-0.285**	-0.438**	0.169	0.123	-0.236*	-0.614**	-0.430**
	EII	P				1	-0.010	-0.006	-0.059	0.115	0.188	-0.153	-0.268*	-0.001
		G				1	-0.005	0.018	-0.041	0.156	0.239*	-0.178	-0.709**	-0.013
X5	EI	P					1	0.641**	0.453**	0.190	0.298**	0.371**	-0.044	0.103
		G					1	0.959**	0.967**	0.187	0.504**	0.669**	-0.132	0.084
	EII	P					1	0.741**	0.571**	0.098	-0.155	0.300**	0.137	0.122
		G					1	0.798**	0.666**	0.033	-0.223*	0.327**	0.569**	0.156
X6	EI	P						1	0.470**	0.229*	0.143	0.287**	-0.035	0.033
		G						1	0.922**	0.187	0.299**	0.491**	-0.069	0.048
	EII	P						1	0.740**	0.197	-0.124	0.306**	0.100	0.160
		G						1	0.865**	0.138	-0.183	0.371**	0.541**	0.179
X7	EI	P							1	0.157	0.126	0.236*	-0.077	-0.044
		G							1	0.347**	0.311**	0.929**	-0.307**	-0.315**
	EII	P							1	0.073	-0.125	0.303**	0.120	0.184
		G							1	-0.084	-0.185	0.435**	0.430**	0.191
X8	EI	P								1	0.053	0.042	0.067	0.080
		G								1	0.029	0.241*	0.177	0.052
	EII	P								1	-0.037	0.132	0.031	-0.051
		G								1	0.039	0.164	0.399**	0.310**
X9	EI	P									1	0.278**	-0.323**	0.362**
		G									1	0.601**	-0.106	0.403**
	EII	P									1	-0.209*	-0.104	0.532**
		G									1	-0.218*	-0.374**	0.701**
	EI	P										1	0.166	0.232**
X10		G										1	0.180	0.360**
	EII	P										1	0.208*	0.026
		G										1	0.546**	0.104
	EI	P											1	0.668**
X11		G											1	0.848**
	EII	P											1	0.472**
		G											1	0.379**

X1	:	Days to 50 % flowering	X7	:	Capsules/plant
X2	:	Days to 75% maturity	X8	:	Seeds/capsule
X3	:	Plant height	X9	:	Biological yield/plant
X4	:	Technical plant height	X10	:	1000 seed weight
X5	:	Number of primary branches	X11	:	Harvest index
X6	:	Number of secondary branches	X12	:	Seed yield

Table 4. Direct and Indirect effects

Charac-ters			X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	Correla-tion values for seed yield
X1	EI	P	-0.09658	-0.00358	0.09450	-0.06096	0.00005	0.00131	-0.00218	-0.00083	0.12380	0.01400	-0.34127	-0.272**
		G	0.00374	-0.52425	0.08971	-0.17230	-0.03712	-0.04209	0.16168	-0.29138	-1.17898	0.37569	-0.78440	-0.400**
	EII	P	-0.13237	0.02483	0.00541	0.05488	0.00725	0.03694	0.04408	-0.00947	0.05200	-0.00007	-0.02590	0.058
		G	1.64121	-1.89822	-1.46253	1.29340	0.19691	0.48068	-0.35068	0.05678	0.10185	-0.00031	0.07790	0.137
X2	EI	P	-0.08086	-0.00428	0.09333	-0.06080	0.00028	-0.00050	-0.00153	-0.00124	0.06576	0.01417	-0.25210	-0.228*
		G	0.62055	-0.89597	0.56370	-0.23990	-0.21313	-0.05489	-0.03112	-0.38988	-0.80811	0.44051	-0.43104	-0.439**
	EII	P	-0.10334	0.03180	0.00619	0.06453	0.00330	0.02327	0.02070	-0.00848	0.09842	0.00191	-0.07333	0.065
		G	1.53678	-2.02721	-1.75441	1.50802	0.12082	0.35393	-0.20764	0.05981	0.15141	-0.06674	0.37277	0.048
X3	EI	P	-0.06042	-0.00264	0.15106	-0.09136	0.00100	-0.00634	0.00225	-0.00061	0.02972	0.01949	-0.39325	-0.351**
		G	0.99578	-0.01021	0.68382	-0.53636	-0.76543	-0.14262	-0.94248	-0.22913	-0.42302	0.41280	-0.43555	-0.392**
	EII	P	-0.07441	0.02046	0.00963	0.08090	0.00080	-0.00378	-0.01001	-0.00593	0.07502	0.00155	-0.12674	0.048
		G	1.03019	-1.52644	-2.32996	1.87461	0.02098	0.01857	0.10951	0.01693	0.15203	-0.04546	0.64272	-0.036
X4	EI	P	-0.05955	-0.00263	0.13959	-0.09887	0.00075	-0.00557	0.00567	-0.00050	0.02895	0.02082	-0.34769	-0.319**
		G	0.85794	-0.18748	0.26036	-0.84018	-0.64989	-0.12830	-0.96473	-0.16318	-0.46282	0.43565	-0.58731	-0.430**
	EII	P	-0.07912	0.02235	0.00848	0.09182	-0.00022	-0.00063	-0.00890	-0.00885	0.11407	0.00214	-0.14254	-0.001
		G	1.11855	-1.61088	-2.30153	1.89776	-0.00236	0.01827	0.04019	0.04507	0.17952	-0.08774	0.69007	-0.013
X5	EI	P	0.00147	0.00034	-0.04358	0.02132	-0.00348	0.02512	-0.02358	-0.00132	0.20938	-0.04302	-0.03992	0.103
		G	-0.77709	0.32857	-0.95774	0.45689	0.76741	0.43174	0.13049	-0.18107	-1.89530	-1.23700	-0.98301	0.084
	EII	P	-0.04133	0.00452	0.00033	-0.00088	0.02321	0.08210	0.08630	-0.00752	-0.09378	-0.00418	0.07286	0.122
		G	0.61608	-0.46692	-0.09321	-0.00855	0.52457	0.79335	-0.65808	0.00943	-0.16801	0.16085	-0.55338	0.156
X6	EI	P	-0.00323	0.00005	-0.02444	0.01404	-0.00223	0.03919	-0.02446	-0.00160	0.10037	-0.03327	-0.03173	0.033
		G	-0.45797	0.37489	-0.54944	0.22722	1.69417	0.45040	0.03200	-0.18074	-1.12364	-0.90699	-0.51218	0.048
	EII	P	-0.04414	0.00668	-0.00033	-0.00052	0.01720	0.11076	0.11177	-0.01518	-0.07493	-0.00426	0.05321	0.160
		G	0.79329	-0.72149	-0.04350	0.03487	0.41848	0.99447	-0.85516	0.03991	-0.13734	0.18222	-0.52660	0.179
X7	EI	P	-0.00406	-0.00013	-0.00653	0.01077	-0.00158	0.01843	-0.05201	-0.00109	0.08871	-0.02731	-0.06952	-0.044
		G	0.71451	0.50692	-0.84503	0.49592	1.70848	0.41526	0.20396	-0.33524	-1.17131	-1.71839	-0.29019	-0.315**
	EII	P	-0.03861	0.00436	-0.00064	-0.00541	0.01325	0.08193	0.15109	-0.00562	-0.07560	-0.00422	0.06370	0.184
		G	0.58232	-0.42590	0.25815	-0.07718	0.34927	0.86045	-0.98835	-0.02412	-0.13889	0.21400	-0.41837	0.191
X8	EI	P	-0.01157	-0.00076	0.01319	-0.00703	-0.00066	0.00899	-0.00815	-0.00697	0.03732	-0.00489	0.06011	0.080
		G	0.14443	-0.46551	0.89848	-0.50301	0.33077	0.08414	0.76368	-0.96749	-0.10917	-0.44565	1.32121	0.052
	EII	P	-0.01629	0.00351	0.00074	0.01056	0.00227	0.02186	0.01103	-0.07693	-0.02253	-0.00184	0.01632	-0.051
		G	0.32333	-0.42068	-0.13690	0.29674	0.01716	0.13771	0.08272	0.28822	0.02956	0.08065	-0.38840	0.310**
X9	EI	P	-0.01700	-0.00040	0.00638	-0.00407	-0.00104	0.00559	-0.00656	-0.00037	0.70348	-0.03222	-0.29150	0.362**
		G	0.59658	-0.71071	0.32579	-1.82572	0.89042	0.13453	0.68620	-0.02808	-3.76203	-1.11186	-0.79262	0.403**
	EII	P	-0.01136	0.00517	0.00119	0.01728	-0.00359	-0.01370	-0.01885	0.00286	0.60597	0.00292	-0.05546	0.532**
		G	0.22215	-0.40791	-0.47075	0.45275	-0.11712	-0.18150	0.18243	0.01132	0.75248	-0.10716	0.36435	0.701**
X10	EI	P	0.01167	0.00052	-0.02539	0.01775	-0.00129	0.01125	-0.01225	-0.00029	0.19553	-0.11593	0.15006	0.232*
		G	-0.51877	0.55211	-0.61792	0.49664	1.18245	0.22094	0.04835	-0.23319	-0.26230	-1.84894	1.34090	0.360**
	EII	P	-0.00068	-0.00435	-0.00107	-0.01408	0.00696	0.03386	0.04575	-0.01016	-0.12668	-0.01395	0.11076	0.026
		G	-0.00103	0.27517	0.21542	-0.33864	0.17160	0.36854	-0.43015	0.04727	-0.16399	0.49170	-0.53148	0.104
X11	EI	P	0.03654	0.00120	-0.06585	0.03811	0.00015	-0.00138	0.00401	-0.00046	-0.22732	-0.01928	0.90210	0.668**
		G	-0.70624	0.29810	-0.28479	0.11563	-0.23264	-0.03089	-0.67587	-0.17116	0.39928	-0.33198	0.46810	0.848**
	EII	P	0.00643	-0.00438	-0.00229	-0.02457	0.00317	0.01106	0.01806	-0.00236	-0.06308	-0.00290	0.53283	0.472**
		G	-0.13140	0.77664	1.53902	-1.34588	0.29833	0.53820	-0.42496	0.11505	-0.28177	0.26857	-0.97303	0.379**

X1 : Days to 50 % flowering
X2 : Days to 75% maturity
X3 : Plant height
X4 : Technical plant height
X5 : Number of primary branches
X6 : Number of secondary branches
X7 : Capsules/plant
X8 : Seeds/capsule
X9 : Biological yield/plant
X10 : 1000 seed weight
X11 : Harvest index

Dogra *et al.* (2020). A negative association of plant height with seed yield is also confirmed by Awasthi and Rao (2005). A negative significant correlation between days to 50% flowering specifies that selection for early genotypes could have a positive impact on seed yield also reported by Gudmewad *et al.* (2016).

Among other characters highly significant correlation was observed for days to 50% flowering with days to 75% maturity in both environments (EI 0.837**; EII 0.781**) followed by plant height (EI 0.626**; EII 0.562**) and technical plant height (EI 0.617**; EII 0.598**) similar to the study of Khandagale *et al.* (2016). Days to 75% maturity also showed a highly significant positive correlation with plant height (EI 0.618**; EII 0.643**) and technical plant height (EI 0.615**; EII 0.703**). This showed that late maturing plants are taller than early maturing. This was in agreement with Nagaraja *et al.* (2009) and Gudmewad *et al.* (2016). A highly positive significant correlation was also observed for plant height with technical plant height for both environments (EI 0.924**; EII 0.881**). The number of primary branches alone showed a highly positive significant correlation with the number of secondary branches (EI 0.641**; EII 0.741**), whereas the number of primary branches and the number of secondary branches both revealed a positive significant correlation with capsules per plant (EI0.453**; EII 0.571**); (EI 0.470**; EII 0.470**), respectively which were in accordance to the findings made by Akbar *et al.* (2001), Nagaraja *et al.* (2009) and Reddy *et al.* (2013). A significant positive correlation was observed for the number of primary branches, the number of secondary branches and capsules per plant with 1000 seed weight (EI 0.371**; EII 0.300**); (EI 0.287**; EII 0.306**); (EI 0.236**; EII 0.303**), respectively similar to the reports of Nagaraja *et al.* (2009) in linseed.

Path analysis is more reliable in determining the cause and effect of yield related components. According to this method, the correlation coefficient between two traits is separated into the components that measure the direct and indirect effects. Path coefficient is essentially a standardised partial regression coefficient that quantifies the direct influence of one variable on another and allows the correlation coefficient to be separated into direct and indirect effects (Goswami *et al.,* 2020). It gives a clear stipulation of interrelationship of the traits, which trait has a direct influence on the yield and which trait shows an indirect effect via some another pathway Oladosu *et al.* (2018) which even allows for an indirect selection. The positive correlation with seed yield was observed for characters biological yield, harvest index, the number of primary branches, the number of secondary branches, capsules per plant and 1000 seed weight (**Table 4**). Among these traits, only biological yield (EI 0.70348; EII 0.60597)and harvest index (EI 0.90210; EII 0.53283) showed a highly significant direct effect with seed yield in both the environments which were in compliance with Kanwar *et al.* (2013), Paul *et al.* (2015), Ankit *et al.* (2019), Tadesse *et al.* (2009) and Kumar *et al.* (2018) whereas, the number of primary branches in EII(0.02321) and the number of secondary branches in EI (0.03919) and EII (0.11076) showed a low direct effect with seed yield. High direct effect of biological yield with seed yield was also observed by Bindra and Paul (2016). Capsules per plant showed a non-significant positive correlation with seed yield in EII with a low direct effect of 0.15109. This showed that the selection for biological yield and harvest index would have a direct positive effect in the improvement of grain yield and are the most important determinants of yield also suggested by Tadesse *et al.* (2009). As suggested earlier, studies by Sharma *et al.* (2016) and Patial *et al.* (2018) have indicated the importance of biological yield for improvement of seed yield. However, positive correlation of the number of primary branches and the number of secondary branches with seed yield was due to indirect effect via biological yield in EI (0.20938; 0.10037, respectively) and *via* harvest index in EII (0.07286; 0.05321, respectively). A positive indirect effect of the number of secondary branches with seed yield *via* harvest index and its positive non-significant association with seed yield was also observed by Tadesse *et al.* (2009) and Awasthi and Rao (2005). 1000 seed weight also showed an indirect effect on seed yield via biological yield in EI (0.19553) and harvest index in EI (0.15006) and EII (0.11076). This suggests that in the course of selection traits such as the number of primary branches, the number of secondary branches and 1000 seed weight should also be considered important in the advancement of grain yield in linseed also outlined by Ibrar *et al.* (2016). Other characters had negligible or very low direct and indirect effects on seed yield. A low residual effect was observed (0.16114) indicating that the causal factors account for the variability of the dependent factor i.e. seed yield in the present case.

It could be concluded from the present experiment that biological yield and harvest index are the most imperative traits while considering the improvement in seed yield in linseed and selection for these traits should be prioritized as they showed high positive significant correlation accompanied with high direct effects with seed yield. However, traits such as the number of primary branches, the number of secondary branches and 1000 seed weight should also be given importance while viewing linseed breeding programmes.

REFERENCES

Akbar, M., Khan, N.U.I. and Sabir, K.M. 2001. Correlation and path coefficient studies in linseed. *Online Journal of Biological Sciences*, **1**(6): 446-447. [Cross Ref]

Akbar, M., Mahmood, T., Anwar, M., Ali, M., Shafiq, M. and Salim, J. 2003. Linseed improvement through genetic variability, correlation and path coefficient analysis. *International. Journal of Agricultural. Biology*, **5**(3): 303-305.

Aman, J., Bantte, K., Alamerew, S. and Sbhatu, D.B. 2020. Correlation and path coefficient analysis of yield and yield components of quality protein maize (*Zea mays* L.) hybrids at Jimma, western Ethiopia. *International Journal of Agronomy*, **2020***:* 9651537. [Cross Ref]

Ankit, S.A., Singh, S.P., Singh, V.K., Tiwari, A. and Singh, A. 2019. Estimation of genetic variability, heritability and genetic advance among the genotypes/lines for seed yield and other economic traits in linseed *Linum usitatissimum* L. *Journal of Pharmacognosy and Phytochemistry*, **8**(2): 390-394.

Anwar, J., Ali, M.A., Hussain, M., Sabir, W., Khan, M.A., Zulkiffal, M. and Abdullah, M. 2009. Assessment of yield criteria in bread wheat through correlation and path analysis. *Journal of Animal and Plant Sciences*, **19**(4): 185-188.

Awasthi, S. K. and Rao, S. S. 2005. Selection parameters for yield and it's components in linseed (*Linum usitatissimum* L.). *Indian Journal of Genetics and Plant Breeding*, **65**(04): 323-324.

Baye, A., Berihun, B., Bantayehu, M. and Derebe, B. 2020. Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food & Agriculture,* **6** (1)**:** 1752603. [Cross Ref]

Bindra, S. and Paul, S. 2016. Genetic variability and association studies in linseed (*Linum usitatissimum* L.). *The Bioscan*, **11**(3): 1855-1859.

Burton, G. W. and Devane, D. E. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy journal*, **45**(10): 478-481. [Cross Ref]

Dewey, D. R. and Lu, K. 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed production 1. *Agronomy Journal*, **51**(9): 515-518. [Cross Ref]

Dogra, R., Paul, S. and Satasiya, P. 2020. Assessment of genetic variability, correlation and path analysis for yield and it's components in Linseed (*Linum usitatissimum* L.). *Journal of Pharmacognosy and Phytochemistry,* **9 (5)**: 2384-2389.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research, John Wiley & Sons, New York.

Gudmewad, R., Misal, A., Dhutmal, R. and Pole, S. 2016. Correlation and path analysis studies in linseed. *Annals of Plant and Soil Research,* **18** (2):123-126.

Ibrar, D., Ahmad, R., Mirza, M.Y., Mahmood, T., Khan, M.A. and Iqbal, M. S. 2016. Correlation and path analysis for yield and yield components in linseed (*Linum usitatissimum* L.). *Journal of Agricultural Research*, **54**(2): 153-159.

Iqbal, J., Hussain, F., Ali, M., Iqbal, M.S. and Hussain, K. 2013. Trait association of yield and yield components of linseed (*Linum usitatissimum* L). *International Journal of Modern Agriculture*, **2**(3): 114-117.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybeans 1. *Agronomy journal*, **47**(7): 314-318. [Cross Ref]

Kanwar, R.R., Saxena, R.R. and Ekka, R.E. 2013. Correlation and path co-efficient analysis of some quantitative traits in linseed (*Linum usitatissimum* L.). *International Journal of Plant Sciences*, **8**(2): 395-397.

Kaur, V., Yadav, R. and Wankhede, D.P. 2017. Linseed (*Linum usitatissimum* L.) genetic resources for climate change intervention and its future breeding. *Journal of Applied and Natural Science*, **9**(2): 1112-1118. [Cross Ref]

Khandagale, S. G., Gudmewad, R. B. and Swamy, K. 2016. Correlation and path coefficient analysis of economically important traits in linseed (*Linum usitatissimum* L.) germplasm. *Electronic Journal of Plant Breeding*, **7**(2):.427-433. [Cross Ref]

Kumar, S., Sharma, A., Choudhary, A., Purushottam, M. and Chauhan, M.P. 2018. Applying correlation and path coefficient to study genetic variability in linseed (*Linum usitatissimum* L.). *Journal of Pharmacognosy and Phytochemistry*, **7**(2): 2593-2595.

Mubai, N., Sibiya, J., Mwololo, J., Musvosvi, C., Charlie, H., Munthali, W., Kachulu, L. and Okori, P. 2020. Phenotypic correlation, path coefficient and multivariate analysis for yield and yield-associated traits in groundnut accessions. *Cogent Food & Agriculture*, **6**(1): 1-22. [Cross Ref]

Nagaraja, T. E., Ajit, K. R. and Golasangi, B.S. 2009. Genetic variability, correlation and path analysis in linseed. *Journal of Maharashtra Agricultural University*, **34**: 282-285.

Oladosu, Y., Rafii, M. Y., Magaji, U., Abdullah, N., Miah, G., Chukwu, S. C. and Kareem, I. 2018. Genotypic and phenotypic relationship among yield components in rice under tropical conditions. *BioMed Research International,* 2018**.** [Cross Ref]

Patial, R., Paul, S. and Sharma, D. 2018. Correlation and path coefficient analysis for improvement of seed yield in linseed (*Linum usitatissimum* L.). *International*

Journal of Current Microbiology and Applied Sciences, **7**(3): 1853-1860. [Cross Ref]

Paul, S., Bhateria, S. and Kumari, A. 2015. Genetic variability and interrelationships of seed yield and yield components in linseed (*Linum usitatissimum* L.). *SABRAO Journal of Breeding & Genetics*, **47**(4).

Reddy, M.P., Rajasekhar Reddy, B., Arsul, B. T. and Maheshwari, J. J. 2013. Character association and path coefficient studies in linseed. *International Journal of Current Microbiology and Applied Sciences,* **2** (9): 250-254.

Savita, S. G., Kenchanagoudar, P. V., Parameshwarappa, K. G. and Rudranaik, V. 2011. Correlation and path coefficient analysis for yield and yield components in linseed (*Linum usitatissimum* L.) germplasm. *Karnataka Journal of Agricultural Sciences*, **24**(3): 382-386.

Sharma, D., Paul, S. and Patial, R. 2016. Correlation and path coefficient analysis of seed yield and yield related traits of linseed (*Linum usitatissimum* L.) in mid-hills of North-West Himalayas. *The Bioscan,* **11** (4): 3049-3053.

Sonwane, A.G., Kathale, M.N., Ghodke, M.K. and Ingle, A.U. 2015. Correlation and path analysis studies for yield and yield contributing characters in linseed (*Linum usitatissimum*). *Trends in Biosciences*, **8**(14): 3655-3659.

Tadesse, T., Singh, H.A.R.J.I.T. and Weyessa, B. 2009. Correlation and path coefficient analysis among seed yield traits and oil content in Ethiopian linseed germplasm. *International Journal of Sustainable Crop Production*, **4**(4): 8-16.

Wright, S. 1921. Correlation and causation. *Journal of Agriculture Research,* **20:** 557–585.