

Correlation and path coefficient analysis of linseed (*Linum usitatissimum* L.) genotypes

Saurav Roy, Shamima Akter*, Md. Mazbha Uddin, Md. Kamal Hossain and Nazmul Alam

Department of Botany, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

Abstract

The current experiment was conducted to evaluate correlation and path coefficient analyses for 16 quantitative traits in 10 linseed (*Linum usitatissimum* L.) genotypes at the Botanical Garden of Jahangirnagar University, Savar. Randomized Complete Block Design (RCBD) with three replications was used to evaluate the experiment during the Rabi season 2024-2025. Seed yield per plant showed strong positive correlation with number of capsules per plant (0.988, 0.942) and number of seeds per capsule (0.937, 0.738) at both genotypic and phenotypic levels, respectively while showed negative correlation with plant height (-0.059, -0.076), days to final harvesting (-0.200, -0.191), free fatty acid (-0.752, -0.718) at both genotypic and phenotypic level. Path coefficient analysis revealed that total biomass per plant had a strong positive direct effect on seed yield per plant (0.924, 0.961) at both genotypic and phenotypic levels, followed by harvest index, number of capsules per plant, while a negative direct effect was shown by seed germination percentage, plant height and number of primary branches per plant. The positive correlation and direct effect on seed yield per plant exhibited by number of capsules per plant, number of seeds per capsule, total biomass per plant and harvest index signifying the importance of these traits while selecting for improvement of seed yield of linseed.

Key words: Linseed, Correlation, Path coefficient analysis, Character association.

INTRODUCTION

Linseed (*Linum usitatissimum* L.), which is also worldwide known as ‘Flax’, is an annual diploid (2n=30) crop. Taxonomically, it belongs to the order Malpighiales, family Linaceae and the genus *Linum* (*Linum usitatissimum* L.) remains the only species of significant economic importance within the Linaceae family (Getinet & Nigussie, 1997). Linseed has two primary centers of origin. The oilseed type originated in South West Asia, while the fibre type originated in the Mediterranean region, covering Asia Minor, Egypt, Algeria, Spain, Italy, and Greece (Vavilov, 1926).

Fiber flax is largely cultivated in Northern Europe, Russia, and China, whereas linseed production is concentrated in Canada, the former USSR, Argentina, Pakistan, China, Ethiopia, India, and Australia (Wakjira *et al.*, 2004 and Green *et al.*, 2008). Linseed (*Linum usitatissimum* L.) is a herbaceous crop, generally cultivated during the Rabi season because a temperature range of (21-27) °C is suitable for the vegetative and reproductive phases (Atmaram, 2022).

* Corresponding author. Email: sanupurbotju@juniv.edu

Linseed oil, which is rich in α -linolenic acid- a crucial omega-3 fatty acid beneficial for human health (Diederichsen & Ulrich, 2009). Linseed also plays a crucial role in industries such as paints, varnishes and various other products. Flax fiber is used as a valuable raw material for textiles, threads, and wrapping materials and its straw is used to manufacture different forms of cigarette papers, currency notes, and the wooden component used as a biomass energy source (Rowland, 1998).

The primary cause of limited linseed cultivation is its low yield potential, which occurs due to lack of improved cultivars. Information on the extent and nature of interrelationships among traits aids in formulating efficient multi-trait selection schemes (Tadesse *et al.*, 2010). A thorough understanding of trait associations provides a more reliable selection criterion for achieving high seed yield (Akbar *et al.*, 2001). Understanding the associations between yield and its component traits, particularly at the genotypic level, is of considerable importance in yield-based selection. Likewise, knowledge of the interrelationships among the yield components themselves is essential for selecting an optimal combination of traits to improve overall yield. Simple estimates of correlation coefficients may not be reliable due to the effects of different yield component traits can offset each other. Path coefficient analysis addresses this limitation by partitioning the correlation into direct and indirect effects of each component trait on the complex trait (Naik *et al.*, 2016). Consequently, successful selection programs depend on understanding the relationships among the traits that have direct or indirect effects on seed yield (Kumar *et al.*, 2013). The present research was undertaken to evaluate the interrelationships among different traits and their influence on yield.

MATERIALS AND METHODS

The present investigation was carried out at the Botanical Garden of Jahangirnagar University, Savar, Dhaka, Bangladesh, during the Rabi season (November 2024 to March 2025) on 10 linseed genotypes (Table 1) collected from different sources. The soil of the experimental field was sandy loam in texture and belonged to the 'Shallow Red Brown Terrace' under the Madhupur Tract, with a p^H ranging from 6.2 to 6.8 (Anonymous, 1998; Haider *et al.*, 1991) and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The data was recorded from ten randomly selected plants in each replication at field level and 16 quantitative characters were considered for the experimentation namely Seed germination percentage, Plant height(cm), Number of primary branches per plant, Number of secondary branches per plant, Days to first flowering, Days to 50% flowering, Days to final harvesting, Total biomass per plant (gm), Harvest index (%), Number of capsule per plant, Capsule diameter (mm), Number of seed per capsule, 1000 seed weight (gm), Oil content (%), Free fatty acid (%) and Seed yield per plant (gm). To examine the relationships between the independent variables and yield, and their interrelationships, the correlation coefficients were calculated from the variance and covariance components, as suggested by Pearson & Hartley (1962). The path coefficient analysis was carried out using the formula of Wright (1923) as illustrated by Dewey and Lu (1959). Correlation and path coefficient analyses were performed using Indostat 9.1.

Table 1. List of linseed genotypes with their sources used in the experimen

Codes	Genotypes name	Sources
G ₁	BARI Tishi-1(Neela)	ORC, BARI
G ₂	Narail	Local
G ₃	Faridpur	Siddiq Bazar, Dhaka
G ₄	Thakurgaon	ACI Ltd.
G ₅	Gopalganj	Local
G ₆	Rajshahi	Local
G ₇	Natore	Local
G ₈	Shariatpur	Namabazar, Savar
G ₉	Sirajganj	Local
G ₁₀	Habiganj	Local

*G = Genotype, ORC = Oil Research Centre, BARI = Bangladesh Agricultural Research Institute

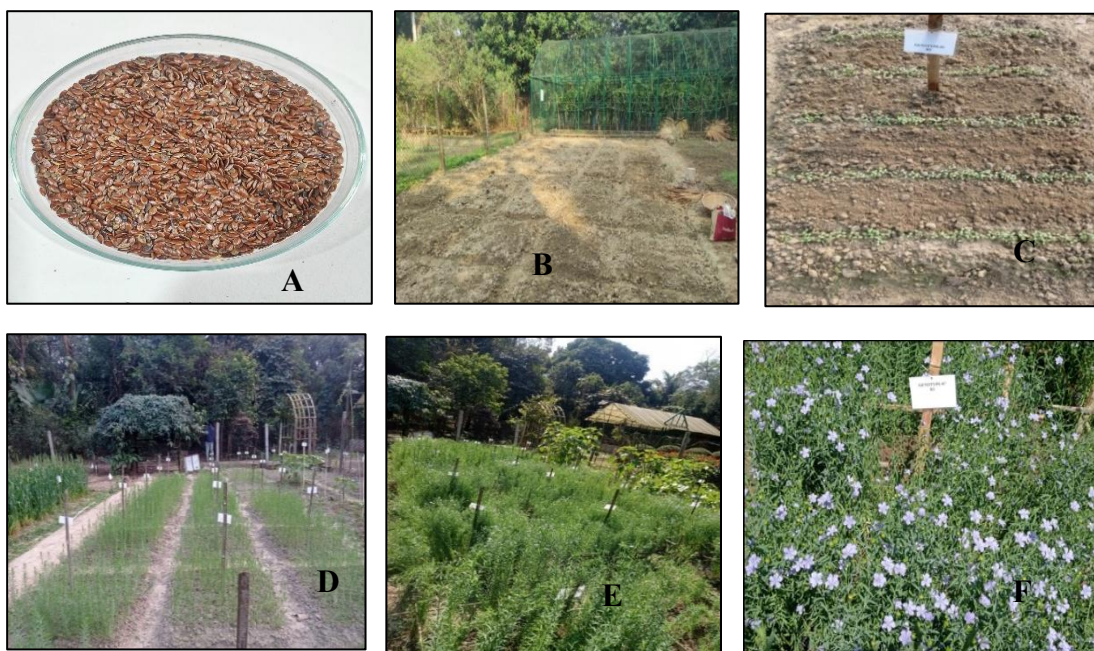


Plate 1. Different stages of linseed genotypes: A- Linseed seeds, B- Experimental field, C- Germination stage, D- Seedling stage, E-Growth stage, F- Flowering stage of linseed

RESULTS AND DISCUSSION

Genotypic and phenotypic correlation coefficients among yield and its component characters are presented in Tables 2 and 3, respectively. Correlation coefficient analysis for seed yield per plant revealed that it had strong positive correlation with number of capsules per plant (0.988, 0.942), number of seeds per capsule (0.937, 0.738) and oil content (0.932,

0.595) at both genotypic and phenotypic levels, respectively (Table 2 and 3), which indicates that the improvement of these characters would be better for the seed yield per plant. Number of primary branches per plant, number of secondary branches per plant, days to first flowering, days to 50% flowering, total biomass per plant, harvest index, capsule diameter and 1000 seed weight also positively correlated with seed yield per plant which indicates that the improvement of these characters would be better for seed yield per plant (Table 2, Table 3). Similarly, positive correlation with number of capsules per plant (0.797, 0.704) reported by Rajanna *et al.* (2014); number of capsules per plant (0.202, 0.196), number of seed per capsule (0.106, 0.132) reported by Patra (2018); number of capsules per plant (0.04, 0.03), number of seeds per capsule (0.07, 0.04) reported by Sahu (2015). Correlation coefficient analysis revealed that seed yield per plant had a negative correlation with plant height (-0.0598, -0.0760), days to final harvesting (-0.200, -0.191) and free fatty acid (-0.752, -0.718) at both genotypic and phenotypic level, respectively which indicates that the improvement of these characters would not be better for seed yield per plant (Table 2 and 3). Similarly, negative correlation with plant height (-0.396, -0.388) was reported by Akbar *et al.* (2003), and days to maturity (-0.406, -0.303) was reported by Meena *et al.* (2020).

Table 2. Genotypic correlation between yield and yield attributing characters in linseed genotypes

Characters	PH (cm)	NPBPP	NSBPP	DFP	D50%F	DFH	TBPP (gm)	HI (%)	NCPP	CD (mm)	NSPC	1000 SW (gm)	OC (%)	FFA (%)	SYPP (gm)
SG%	-0.764*	-0.123	-0.585	-0.527	-0.532	-0.887**	-0.508	.931**	0.535	0.001	0.806**	-0.409	0.509	-0.673**	0.454
PH (cm)		0.544	0.845**	0.741*	0.749	0.820**	0.811**	0.902**	-0.119	-0.119	-0.548	0.506	-0.124	0.484	-0.059
NPBPP			0.832**	0.309	0.364	0.161	0.635*	0.261	0.335	0.248	0.175	0.464	0.313	0.055	0.478
NSBPP				0.500	0.550	0.613	0.721*	0.741*	-0.071	0.012	-0.367	0.462	-0.063	0.374	0.057
DFP					0.999**	0.790**	0.926**	0.664*	0.379	0.288	-0.042	0.589	0.489	-0.119	0.372
D50%F						0.810**	0.944**	0.674*	0.381	0.299	-0.046	0.604	0.506	-0.117	0.388
DFH							0.693*	0.925**	-0.231	0.009	-0.587	0.397	-0.141	0.380	-0.200
TBPP (gm)								0.645*	0.427	0.410	0.036	0.747	0.633*	-0.073	0.485
HI (%)									0.412	0.147	0.792**	-0.401	0.382	-0.545	0.350
NCPP										0.570	0.939**	0.340	0.983**	-0.803**	0.988**
CD (mm)											0.569	0.704	0.967**	-0.527	0.682*
NSPC												0.051	0.987**	-0.816**	0.937**
1000 SW (gm)													0.799**	-0.137	0.441
OC (%)														-0.996**	0.932**
FFA (%)															-0.752*

** = Significance at 1% level of probability, * = Significance at 5% level of probability

SG% = Seed germination percentage, PH = Plant height, NPBPP = Number of primary branches per plant, NSBPP = Number of secondary branches per plant, DFP = Days to first flowering, D50%F = Days to 50% flowering, DFH = Days to final harvesting, TBPP = Total biomass per plant, HI = Harvest index, NCPP = Number of capsules per plant, CD = Capsule diameter, NSPC = Number of seeds per capsule, 1000 SW = 1000 seed weight, OC = Oil content, FFA = Free fatty acid, SYPP = Seed yield per plant

Table 3. Phenotypic correlation between yield and yield attributing characters in linseed genotypes

Characters	PH (cm)	NPBPP	NSBPP	DFF	D50%F	DFH	TBPP (gm)	HI (%)	NCP	CD (mm)	NSPC	1000 SW (gm)	OC (%)	FFA (%)	SYPP (gm)
SG%	-0.728*	-0.109	-0.552	-0.494	-0.502	-0.856**	-0.464	0.869**	0.504	0.001	0.633*	-0.390	0.262	-0.646*	0.427
PH (cm)		0.505	0.810**	0.718*	0.733*	0.805**	0.772**	-0.864**	-0.115	-0.102	-0.429	0.484	-0.076	0.469	-0.076
NPBPP			0.807**	0.284	0.325	0.159	0.607	-0.237	0.335	0.220	0.138	0.444	0.191	0.063	0.465
NSBPP				0.484	0.530	0.602	0.717*	-0.712*	-0.072	0.020	-0.359	0.445	-0.027	0.368	0.072
DFF					0.987**	0.777**	0.889**	-0.637*	0.359	0.291	-0.048	0.566	0.324	-0.127	0.347
D50%F						0.785**	0.892**	-0.639*	0.356	0.310	-0.035	0.575	0.331	-0.125	0.348
DFH							0.673*	-0.889**	-0.226	0.006	-0.499	0.388	-0.089	0.378	-0.191
TBPP (gm)								-0.628	0.405	0.406	-0.033	0.695*	0.291	-0.071	0.493
HI (%)									0.395	0.129	0.687*	-0.374	0.200	-0.517	0.354
NCP										0.548	0.787**	0.323	0.614	-0.788**	0.942**
CD (mm)											0.475	0.663*	0.551	-0.520	0.649*
NSPC												0.029	0.495	-0.692	0.738*
1000 SW (gm)													0.428	-0.127	0.401
OC (%)														-0.605	0.595
FFA (%)															-0.718*

** = Significance at 1% level of probability, * = Significance at 5% level of probability

SG% = Seed germination percentage, PH = Plant height, NPBPP = Number of primary branches per plant, NSBPP = Number of secondary branches per plant, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFH = Days to final harvesting, TBPP = Total biomass per plant, HI = Harvest index, NCP = Number of capsules per plant, CD = Capsule diameter, NSPC = Number of seed per capsule, 1000 SW = 1000 seed weight, OC = Oil content, FFA = Free fatty acid, SYPP = Seed yield per plant

The association of traits, as measured by correlation coefficients, may not provide an exact picture of the relative importance of the direct and indirect influences of each yield component trait on yield. Correlation coefficients were partitioned into direct and indirect effects to provide a clear picture of the interrelationships among yield and other yield-related traits using path analysis. The results of path coefficient analysis for the studied traits are shown in Tables 4 and 5 at the genotypic and phenotypic levels, respectively.

Path analysis results revealed that number of secondary branches per plant (0.824, 0.233), total biomass per plant (0.924, 0.961), harvest index (0.611, 0.694), number of capsules per plant (0.568, 0.363), number of seeds per capsule (0.189, 0.101) and oil content (0.064, 0.022) showed direct positive effect on seed yield per plant at both genotypic and phenotypic level (Table 4 and 5 respectively). So, direct selection of plants based on these traits would be effective to increase seed yield per plant. Rajanna *et al.* (2014) found number of capsule per plant had positive direct effect (0.761) on seed yield per plant followed by days to maturity (0.278), plant height (0.138) at phenotypic level; Meena *et al.* (2020) found number of capsule per plant had positive direct effect (0.486) on seed yield per plant followed by number of seed per capsule (0.166) at genotypic level; Akbar *et al.* (2003) found plant height had positive direct effect (0.525) on seed yield per plant followed by number of branches per plant (0.111) at phenotypic level.

The path coefficient analysis showed that the seed germination (-0.054, -0.078), plant height (-0.277, -0.261), number of primary branches per plant (-0.729, -0.110), days to first flowering (-0.046, -0.007), days to 50% flowering (-0.580, -0.179), days to final harvesting (-0.012, 0.0139), capsule diameter (-0.007, -0.050) and 1000 seed weight (-0.079, -0.005) had negative direct effect on seed yield per plant at both genotypic and phenotypic level (Table 4 and 5). So, direct selection of plants based on these traits reduces the seed yield per plant. Rajanna *et al.* (2014) found days to 50% flowering had direct negative effect (-0.124) followed by technical plant height (-0.095) at phenotypic level; Meena *et al.* (2020) found days to maturity (-0.394), number of primary branches per plant (-0.135) and harvest index (-0.284) had negative direct effect on seed yield per plant at genotypic level.

Table 4. Path coefficients for yield and yield attributing characters in linseed genotypes at genotypic level

Characters	SG%	PH (cm)	NPBPP	NSBPP	DFF	D50%F	DFH	TBPP (gm)	HI (%)	NCPP	CD (mm)	NSPC	1000 SW (gm)	OC (%)	FFA (%)	SYPP (gm)
SG %	-0.054	0.041	0.006	0.031	0.028	0.028	0.048	0.027	-0.050	-0.028	0.010	-0.043	0.022	-0.027	0.036	0.454
PH (cm)	0.212	-0.277	-0.151	-0.234	-0.205	-0.208	-0.227	-0.225	0.250	0.033	0.033	0.152	-0.140	0.034	-0.134	-0.059
NPBPP	0.089	-0.397	-0.729	-0.606	-0.225	-0.265	-0.117	-0.463	0.190	-0.244	-0.181	-0.128	-0.338	-0.228	-0.040	0.478
NSBPP	-0.482	0.696	0.685	0.824	0.412	0.453	0.505	0.594	-0.610	-0.058	0.009	-0.302	0.381	-0.052	0.308	0.057
DFF	0.024	-0.034	-0.014	-0.023	-0.046	-0.046	-0.036	-0.042	0.030	-0.017	-0.013	0.002	-0.027	-0.022	0.005	0.372
D50%F	0.308	-0.434	-0.211	-0.319	-0.580	-0.580	-0.470	-0.547	0.391	-0.221	-0.173	0.027	-0.350	-0.293	0.068	0.388
DFH	0.011	-0.010	-0.002	-0.007	-0.009	-0.010	-0.012	-0.008	0.011	0.002	-0.001	0.007	-0.004	0.001	-0.004	-0.200
TBPP (gm)	-0.673	0.974	0.841	0.956	0.928	0.955	0.918	0.924	-0.855	0.566	0.543	0.048	0.990	0.838	-0.097	0.485
HI (%)	0.569	-0.551	-0.159	-0.452	-0.405	-0.412	-0.565	-0.394	0.611	0.251	0.090	0.484	-0.245	0.233	-0.333	0.350
NCPP	0.304	-0.067	0.191	-0.040	0.215	0.217	-0.131	0.243	0.234	0.568	0.324	0.534	0.193	0.684	-0.457	0.988
CD (mm)	0.001	0.009	-0.001	-0.001	-0.002	-0.002	-0.001	-0.003	-0.001	-0.004	-0.007	-0.004	-0.005	-0.007	0.004	0.682
NSPC	0.153	-0.104	0.033	-0.069	-0.008	-0.008	-0.111	0.006	0.150	0.178	0.108	0.189	0.009	0.187	-0.155	0.937
1000 SW (gm)	0.032	-0.040	-0.036	-0.036	-0.046	-0.047	-0.031	-0.059	0.031	-0.026	-0.055	-0.004	-0.079	-0.063	0.010	0.441
OC (%)	0.032	-0.008	0.020	-0.004	0.031	0.032	-0.009	0.040	0.024	0.077	0.062	0.063	0.051	0.064	-0.070	0.930
FFA (%)	-0.072	0.052	0.006	0.040	-0.012	-0.012	0.041	-0.007	-0.058	-0.086	-0.056	-0.088	-0.014	-0.118	0.107	-0.752

SG% = Seed germination percentage, PH = Plant height, NPBPP = Number of primary branches per plant, NSBPP = Number of secondary branches per plant, DFF = Days to first flowering, D50%F = Days to 50% flowering, DFH = Days to final harvesting, TBPP = Total biomass per plant, HI = Harvest index, NCPP = Number of capsule per plant, CD = Capsule diameter, NSPC = Number of seed per capsule, 1000 SW = 1000 seed weight, OC = Oil content, FFA = Free fatty acid, SYPP = Seed yield per plant

Table 5. Path coefficients for yield and yield attributing characters in linseed genotypes at phenotypic level

Characters	SG%	PH (cm)	NPBPP	NSBPP	DFP	D50%F	DFH	TBPP (gm)	HI (%)	NCPP	CD (mm)	NSPC	1000 SW (gm)	OC (%)	FFA (%)	SYPP (gm)
SG%	-0.078	0.057	0.008	0.043	0.039	0.039	0.067	0.036	-0.068	-0.039	-0.001	-0.049	0.030	-0.020	0.050	0.427
PH (cm)	0.190	-0.261	-0.132	-0.212	-0.187	-0.192	-0.210	-0.202	0.226	0.030	0.026	0.112	-0.126	0.019	-0.122	-0.076
NPBPP	0.012	-0.055	-0.110	-0.088	-0.031	-0.035	-0.017	-0.066	0.026	-0.036	-0.024	-0.015	-0.048	-0.021	-0.007	0.465
NSBPP	-0.129	0.189	0.188	0.233	0.113	0.124	0.140	0.167	-0.166	-0.017	0.004	-0.084	0.104	-0.006	0.086	0.072
DFP	0.003	-0.005	-0.002	-0.003	-0.007	-0.007	-0.006	-0.006	0.004	-0.002	-0.002	0.004	-0.004	-0.002	0.001	0.347
D50%F	0.090	-0.131	-0.058	-0.095	-0.176	-0.179	-0.140	-0.159	0.114	-0.063	-0.055	0.006	-0.103	-0.059	0.022	0.348
DFH	-0.011	0.011	0.002	0.008	0.010	0.010	0.013	0.009	-0.012	-0.003	0.001	-0.006	0.005	-0.001	0.005	-0.191
TBPP	-0.493	0.819	0.644	0.761	0.944	0.946	0.714	0.961	-0.666	0.430	0.431	-0.035	0.738	0.309	-0.075	0.493
HI (%)	0.603	-0.600	-0.164	-0.494	-0.442	-0.444	-0.617	-0.436	0.694	0.274	0.089	0.477	-0.260	0.138	-0.358	0.354
NCPP	0.132	-0.030	0.088	-0.019	0.094	0.093	-0.059	0.106	0.104	0.263	0.144	0.207	0.085	0.161	-0.207	0.942
CD (mm)	-0.001	0.005	-0.011	-0.001	-0.014	-0.015	-0.003	-0.020	-0.006	-0.027	-0.050	-0.023	-0.033	-0.027	0.026	0.649
NSPC	0.064	-0.043	0.014	-0.036	-0.004	-0.003	-0.050	-0.003	0.069	0.079	0.048	0.101	0.003	0.050	-0.070	0.738
1000 SW (gm)	0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.002	-0.003	0.002	-0.001	-0.003	-0.002	-0.005	-0.002	0.007	0.401
OC (%)	0.005	-0.001	0.004	-0.006	0.007	0.007	-0.002	0.006	0.004	0.013	0.012	0.011	0.009	0.022	-0.013	0.595
FFA (%)	0.036	-0.026	-0.003	-0.020	0.007	0.007	-0.021	0.004	0.028	0.043	0.029	0.038	0.007	0.033	-0.055	-0.718

SG% = Seed germination percentage, PH = Plant height, NPBPP = Number of primary branches per plant, NSBPP = Number of secondary branches per plant, DFP = Days to first flowering, D50%F = Days to 50% flowering, DFH = Days to final harvesting, TBPP = Total biomass per plant, HI = Harvest index, NCPP = Number of capsule per plant, CD = Capsule diameter, NSC = Number of seed per capsule, 1000 SW = 1000 seed weight, OC = Oil content, FFA = Free fatty acid, SYPP = Seed yield per plant

Plant height, number of primary branches per plant, days to first flowering, days to 50% flowering, days to final harvesting, capsule diameter, and 1000-seed weight also showed an indirect positive effect on seed yield per plant via other characters. Similarly, the number of secondary branches per plant, total biomass per plant, harvest index, number of capsules per plant, number of seeds per capsule, oil content and free fatty acid also showed indirect negative effects on seed yield per plant (Table 4 and 5).

Based on the experiment's correlation and path coefficients, it is concluded that the number of secondary branches per plant, total biomass per plant, harvest index, number of capsules per plant, number of seeds per capsule, and oil content are important selection parameters for improving seed yield per plant. All these traits are positively correlated with seed yield per plant at both the genotypic and phenotypic levels. Path analysis also indicated that these parameters had a positive direct effect on seed yield per plant, as their correlations were positive.

REFERENCES

- Akbar, M., Khan, N.I. and Sabir, K.M. 2001. Correlation and path coefficient studies in linseed. *Online J. Biol. Sci.*, **1**(6): 446-447.
- Akbar, M., Mahmood, T., Anwar, M., Ali, M., Shafiq, M. and Salim, J. 2003. Linseed improvement through genetic variability, correlation and path coefficient analysis. *Int. J. Agric. Biol.*, **5**(3): 303-305.
- Anonymous, 1998. Year Book of Agricultural Statistics of Bangladesh 1996-97, Bangladesh Bureau of Statistics, Dhaka, p. 890.
- Atmaram, C.S. 2022. Genetic variability, correlation and path analysis studies in linseed. M.Sc. (Ag.) Thesis. College of Agriculture, Vasantao Naik Marathwada Krishi Vidyapeeth, India. p. 1.
- Dewey, D.R., and Lu, K. 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agron. J.*, **51**(9): 515-518.
- Diederichsen, A. and Ulrich, A. 2009. Variability in stem fibre content and its association with other characteristics in 1177 flax (*Linum usitatissimum* L.) gene bank accessions. *Ind. Crops Prod.*, **30**(1): 33-39.
- Getinet, A. and Nigussie, A. 1997. Highland Oil Crops: A three-decade Research Experience in Ethiopia. Research Report No 30. Institute of Agricultural Research, Addis Ababa, Ethiopia.
- Green, A.G., Chen, Y., Singh, S.P. and Dribnenki, 2008. Flax. *In*: Chittaranjan, K., Hall, T.C. (Eds.), Compendium of Transgenic Crop Plants: Transgenic Oilseed Crops. Blackwell Publishing Ltd, Chicester, UK, pp. 200-226.
- Haider, J., Marumoto, T. and Azad, A.K. 1991. Estimation of microbial biomass carbon and nitrogen in Bangladesh soils. *oil Sci. Plant Nutr.*, **37**(4): 591-599.
- Kumar, J, Srivastava, E, Singh, M. 2013. Genetics of early growth vigour in lentil (*Lens culinaris* Medik.). *J. Genet.*, **92**(2): 323.
- Meena, A.K., Kulhari, S., Kumar, M., Koli, N.R., Tak, Y., Meena, D. and Meena, N. 2020. Studies on genetic variability and character association in linseed (*Linum usitatissimum* L.) genotypes. *Int. J. Curr. Microbiol. Appl. Sci.*, **9**(7): 3949-3957.
- Naik, B.S., Janakinath, D. and Mohapatra G.B. 2016. Path-coefficient analysis of seed yield and its components in linseed (*Linum usitatissimum* L.). *Int. J. Adv. Res.*, **4**(1): 799- 811.

- Patra, D. 2018. Morphological and biochemical characterization of elite genotypes of linseed. (Doctoral dissertation), Orissa University of Agriculture and Technology, Orissa, India.
- Pearson, E.S. and Hartley, O.H. 1962. Biometric tables for Statisticians. Cambridge University Press, London. **1&2**: 218.
- Rajanna, B., Biradar, S.A., and Ajith, K. 2014. Correlation and path coefficient analysis in linseed (*Linum usitatissimum* L.). *Int. Q. J. Life Sci.*, **9**(4): 16-25.
- Rowland, G.G. 1998. Growing flax: Production, management and diagnostic guide. Flax Council of Canada and Saskatchewan Flax Development Commission.
- Sahu, D. 2015. Characterization and genetic analysis in germplasm accessions of linseed (*Linum usitatissimum* L.). M.Sc. (Ag.) Thesis. Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), India. p. 19.
- Tadesse, T., Singh, H. and Weyessa, B. 2010. Estimates of variability and heritability in linseed germplasm. *Int. J. Sustain. Crop Prod.*, **5**(3): 8-16.
- Vavilov, N.I. 1926. Studies on the origin of cultivated plants. *Institute of Applied Botany and Plant Breeding*, Leningrad. Bulletin 1.
- Wakjira, A., Maryke, T. and Arno, H. 2004. Variability in oil content and fatty acid composition of Ethiopian and introduced cultivars of Linseed. *J. Sci. Food Agric.*, **84**: 1-8.
- Wright, S. 1923. The theory of path coefficients a reply to Niles criticism. *Genetics*, **8**(3): 239.