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GENETIC VARIABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS OF LINSEED (*LINUM USITATISSIMUM* L.) IN BIHAR, INDIA

Abhishek Kumar, Rounak Kumar and Ram Balak Prasad Nirala*

Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour - 813 210, Bihar, India.

*Corresponding author E-mail : nrambalak@yahoo.co.in

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ABSTRACT

Farmers often overlook linseed, the second most crucial oilseed after mustard, due to the low productivity of local cultivars. To improve yields, selecting suitable genotypes from germplasm collections is essential for potential crossbreeding programs aimed at developing high-yielding varieties. The present investigation was carried out in *Rabi*, 2021-22 at Bihar Agricultural College farm, BAU, Sabour, Bhagalpur with 28 genotypes and three checks with aim to study estimation of genetic variability, correlation and path coefficient analyses. ANOVA showed significant differences among all the genotypes for twelve quantitative traits under study. Flower diameter, number of primary branches per plant, capsule diameter, number of capsules per plant, number of seeds per capsule, seed length, 1000-seed weight and oil content percentage showed positive and significant correlation with seed yield whereas, days to 50% flowering, plant height and days to 50% maturity showed negative and significant correlation with seed yield. Maximum positive direct effect on seed yield was found to be for capsule diameter followed by seed length and 1000- seed weight, whereas, maximum negative direct effect on seed yield was found to be for plant height followed by days to 50% flowering. Maximum positive indirect effect on seed yield was shown by seed length via capsule diameter. Whereas, maximum negative indirect effect was shown by days to 50 % maturity via capsule diameter. So, for improvement of seed yield the selection criteria should be more capsule diameter, seed length, 1000- seed weight and days to 50% flowering.

Key words : Linseed, Genetic variability, Path coefficient, seed weight.

Introduction

Oilseed crops occupy prestigious place in Indian agriculture due to their resuscitative role in the sustainable economy of the country. Linseed (*Linum usitatissimum* L.) commonly known as flax having 2n = 2x = 30 chromosomes is a self-pollinated crop that belongs to the family *linaceae*. Linseed is primarily grown for its seed oil and high-quality stem fiber, with its oil being the richest source of omega-3 fatty acids, known for their numerous positive health benefits in both humans and animals. It is presumed to be originated in South-west Asia particularly in India (Vavilov, 1935; Richharia, 1962).

Globally, India is the world's sixth largest producer, contributing 13% and 5.5% of worldwide linseed area and production, respectively. In 2020, its world production and productivity was 3.4 million tons and 943 kg/ha, led by Kazakhstan with 31% of the total, followed by Russia (FAOSTAT, 2020). During 2020-21, in India, a total of 1.1 lakh tons of linseed was produced from an area of 1.7 lakh ha with an average productivity of 644 kg/ha (AICRP Report linseed, 2020-21). It is grown mostly under rainfed (63%), utera (25%) and irrigated (17%) situations under input starved conditions in most of the linseed producing states. In Bihar, it occupies 9.65 thousand ha area with 8.19 metric tons production and productivity of 849 kg ha^{-1} (Anonymous, 2018-19).

Yield components are the primary objective under study for crop improvement. Grafius (1978) suggested that there may not be genes for yield *per se* but rather for the various components, the multiplicative interactions

of which, result in the artifact of yield. So, due to less impression for direct selection for yield, more efforts should be over indirect selection for yield components (changing yield through yield components). Proper knowledge of association of different traits, provide more reliable selection criterion to achieve a high seed yield (Akbar *et al*., 2001). This selection criterion provides information about inter- relationships among agronomic characters, their relationship with seed yield as their direct influence on seed yield. Nevertheless, selection for yield via highly correlated characters becomes easy, if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey and Lu 1959). So, path coefficient analysis technique is a statistical approach, which is based on multiple regressions and is useful for revealing the direct and indirect effects of the variables in a network of factors like agronomical, morphological, physiological, biochemical traits which is able to separate correlation coefficient into their components of direct and indirect effects (Paul *et al*., 2017). As average seed yield of linseed in India is very low in comparison with world average, the development of high yielding varieties is needed to compete with other linseed growing countries.

Materials and Methods

The present investigation was carried out at the experimental farm of Bihar Agricultural College, B.A.U., Sabour, Bhagalpur during *rabi*, 2021-22. Bhagalpur is located at an elevation of 52.73 meters above mean sea level, between 25°50' N latitude and 87°19' E longitude, comes under the Middle Gangetic Plain region of agro-climatic zone III B of Bihar. The experiment was carried out in a favorable ecosystem of heavy textured alluvial soil with no field heterogeneity. Seven parents (obtained from the AICRP- Linseed BAC, Sabour), their 21 half diallel crosses, and three checks (Table 1) has been selected as the experimental materials and evaluated in randomized block design with three replications during *Rabi* 2021-22. Two rows of each entry were grown having row length 5 meter. Row to row spacing and plant to plant spacing were kept 30 cm and 5 cm, respectively. All the recommended package and practices were adopted to raise a good crop. Data were recorded on five competitively randomly selected plants in each genotype and each replication for the characters, namely, flower diameter, plant height, number of primary branches per plant, capsule diameter, number of capsules per plant, number of seeds per capsule, seed length and seed yield per plant. Before taking data, each plant was tagged. Data of days to 50% flowering and days to 50% maturity were taken on plot basis of each genotype from each replication. Seeds sample of clean harvested seeds of each genotype from each replication were taken for 1000-seed weight and oil content. The mean data of 31 genotypes of three replications for twelve quantitative characters were subjected. The following statistical analyses were done by INDOSTAT software. The analysis of variance was carried to test the differences among genotypes by F-test according to the procedure of Panse and Sukhatme (1967). Single correlation coefficients were computed at genotypic and phenotypic levels between pair of characters adopting following formula given by Johnson *et al*. (1955) and Al - jibouri *et al*. (1958). Path analysis by Dewey and Lu (1959) and direct and indirect effects were rated as follows by Lenka and Mishra (1973).

Table 1 : List of germplasm accessions.

S. no.	Genotype
1	BRLS 119 X TL 99
2	BRLS 119 X Kota Barani Alsi 3
3	BRLS 119 X Uma
4	BRLS 119 X RLC 153
5	BRLS 119 X BRLS 120
6	BRLS 119 X Pratap Alsi 2
7	TL 99 X Kota Barani Alsi 3
8	TL 99 X Uma
9	TL 99 X RLC 153
10	TL 99 X BRLS 120
11	TL 99 X Pratap alsi 2
12	Kota Barani Alsi 3 X Uma
13	Kota Barani Alsi 3 X RLC 153
14	Kota Barani Alsi 3 X BRLS 120
15	Kota Barani Alsi 3 x Pratap Alsi 2
16	Uma X RLC 153
17	Uma X BRLS 120
18	Uma X Pratap Alsi 2
19	RLC 153 X BRLS 120
20	RLC 153 X Pratap Alsi 2
21	BRLS 120 X Pratap Alsi 2
22	BRLS 119
23	TL 99
24	Kota Barani Alsi 3
25	Uma
26	RLC 153
27	BRLS 120
28	Pratap Alsi 2
29	Shekhar (ZC)
30	T 397(NC)
31	Sabour Tisi 2(LC)

Results and Discussion

The analysis of variances for design of experiment exhibited that the mean sum of squares due to genotypes were highly significant for all the twelve quantitative characters under study (Table 2). These results indicated that there were significant differences among the genotypes for each character under study in accordance with Paul *et al*. (2017) and Ranjanna *et al*. (2014). The mean value, range and coefficient of variation among the genotypes of various characters are presented in Table 3. Maximum range of variation was found for number of capsules per plant (57.10 – 170.30) followed by plant height (56.77 cm – 86.70 cm). Flower diameter (2.17 cm- 3.08 cm) exhibited minimum range of variation. The highest value of seed yield per plant was found in Kota Barani Alsi 3 × Pratap Alsi 2 (7.69 g) and the lowest in TL 99 x Uma (0.91 g). Among all the three check, Sabour Tisi 2 (5.61 g) had the highest seed yield per plant. The genotype, namely, TL 99 x RLC 153 (6.89 g), Uma x BRLS 120 (7.41 g) and Kota Barani Alsi 3 x Pratap Alsi 2 (7.69 g) were found to have significantly higher seed yield than the best check. The highest 1000- seed weight was found in genotype, Uma x BRLS 120 (8.84 g) and the lowest in Uma (4.29 g). These findings were in accordance with Kumari *et al*. (2017).

Estimates of phenotypic, genotypic and environmental variances are depicted in Table 3. Genotypic variance was found to be lower than the corresponding phenotypic variance, whereas, it was higher than the environmental variance for all the twelve quantitative characters under studied. The highest value of phenotypic (770.08) and genotypic (710.21) variance were found for number of capsules per plant followed by plant height. The lowest

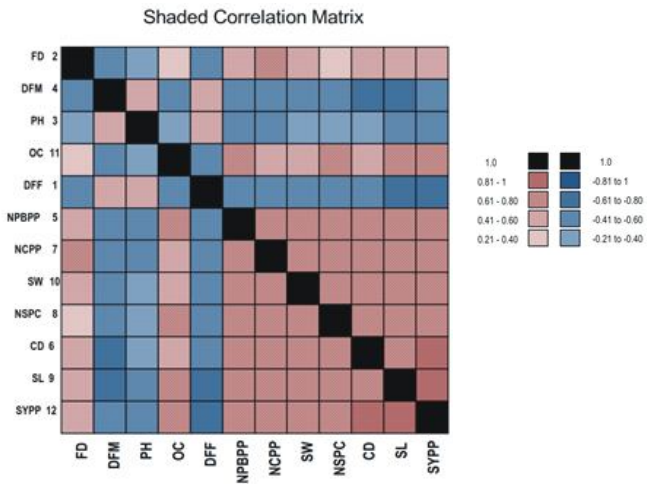

Fig. 1 : Correlation among twelve studies characters in the studied linseed genotypes.

phenotypic (0.04) and genotypic (0.03) variance was found for seed length. The same result was reported by Kanwar *et al*. (2014), Dhirhi and Mehta (2019) and Singh *et al*. (2019). Estimates of phenotypic, genotypic and environmental coefficient of variances are depicted in Table 3. Genotypic coefficient of variation of each character was found to be lower than phenotypic coefficient of variation, whereas, it was higher than environmental coefficient of variation. The highest estimates of PCV (42.5%) and GCV (41.02%) were estimated for seed yield per plant, followed by number of capsules per plant. Moderate PCV and GCV were found for 1000- seed weight followed by number of primary branches per plant, number of seeds per capsule, seed length and plant height. The lowest value for PCV and GCV were found for days to 50% flowering followed by days to 50% maturity. These results are in accordance

Table 2 : Analysis of variance for twelve quantitative characters in linseed.

	Mean sum of squares			
S. no.	**Source of Variation / Characters**	**Replications (d.f.=2)**	**Treatments (d.f.=30)**	**Error (d.f.=60)**
1.	Days to 50% flowering	16.14	18.28**	3.54
2.	Flower diameter (cm)	0.05	0.11**	0.01
3.	Plant height (cm)	4.54	177.28**	14.05
4.	Days to 50% maturity	1.21	43.54**	1.89
5.	Number of primary branches per plant	0.08	3.78**	0.26
6.	Capsule diameter (mm)	0.08	0.89**	0.08
7.	Number of capsules per plant	12.83	2190.50**	59.88
8.	Number of seeds per capsule	0.22	2.66**	0.09
9.	Seed length (mm)	0.02	2.67**	0.02
10.	1000–Seed weight (g)	0.26	4.16**	0.49
11.	Oil content%	13.91	8.83**	1.45
12.	Seed yield per plant (g)	0.11	8.22**	0.20

with the report made by various workers in linseed viz; Tyagi *et al*. (2014), Paul and Kumari (2014), Choudhary *et al*. (2017), Dhirhi and Mehta (2019).

Heritability is key in character transmission across generations, while genetic advance, representing the mean genotypic value over the parental population, measures genetic gain in selection. High heritability coupled with high genetic advance over percent of mean was observed for number of primary branches per plant**,** number of capsules per plant, number of seeds per capsules, seed length, 1000- seed weight, seed yield per plant. It revealed that the heritability represents additive gene effects and early generations selection may be more desirable for these characters. A heritability estimate alone is worthless, but when combined with genetic advance, it is more useful in estimating the ultimate effect of selection. These findings are similar to the results recorded by Yadav and Singh (2016), Upadhyay *et al*. (2019) and Singh *et al*. (2019). Number of capsules per plant (92.2) highest heritability estimates followed by number of seeds per capsules (90.3) and Days to 50% maturity (88.0) and others as sown in Table 3. Highest estimates of genetic advance as a per cent of mean was found for seed yield per plant (61.55), number of capsules per plant (49.45), number of primary branch per plant (31.08), 1000- seed weight (28.87), seed length (25.14) and number of seeds per capsules (23.75).

Genotypic and phenotypic correlation coefficients

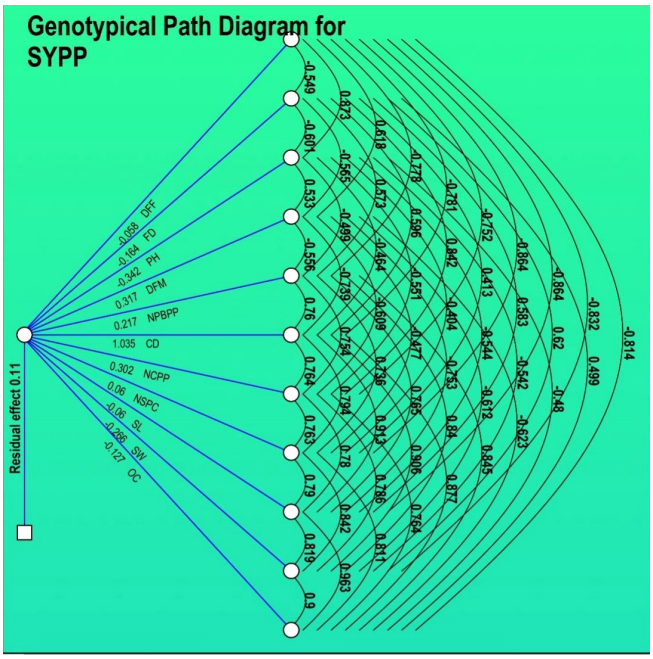

Fig. 2 : Diagram of factors influencing yield at genotypic level.

have been computed for pair of all the twelve quantitative characters of linseed genotypes depicted in Table-4 and Fig. 1. The magnitude of genotypic correlation coefficient was higher than the corresponding phenotypic correlation for all of the characters, revealing that environment had a smaller role in the expression of the traits, and indicated that an inherent association between these traits at genetic level. Seed yield per plant had significant and positive

Table 3 : Estimates of genetic variability parameters for twelve characters in linseed.

S. no.	Characters	Mean	Range	CD (5%)	CV (%)	SE±(m)	σ^2p	σ^2g	PCV (%)	GCV (%)	h^2bs (%)	GA	GAPM
1	DF 50 %	78.47	70.67-82.67	3.07	2.4	1.09	8.45	4.91	3.71	2.83	58.1	3.48	4.44
2	FD	2.76	2.17-3.08	0.13	2.93	0.05	0.04	0.03	7.25	6.63	83.7	0.35	12.51
3	PH	73.48	56.77-86.70	6.12	5.1	2.16	68.46	54.41	11.26	10.04	79.5	13.55	18.44
4	DM 50 %	106.16	101.00 -116.33	2.24	1.29	0.79	15.77	13.88	3.74	3.51	88.0	7.20	6.78
5	PBPP	6.5	4.37-8.76	0.83	7.82	0.29	1.43	1.17	18.41	16.67	82.0	2.02	31.08
6	CD	7.13	5.76 – 8.15	0.47	4.08	0.17	0.35	0.27	8.33	7.27	76.1	0.93	13.06
7	CP	106.61	57.10-170.30	12.64	7.26	4.47	770.08	710.21	26.03	25	92.2	52.72	49.45
8	SC	7.63	5.63 – 9.46	0.5	3.98	0.18	0.95	0.86	12.77	12.13	90.3	1.81	23.75
9	SL	7.61	5.64 – 9.78	0.23	1.88	0.08	0.9	0.88	12.49	12.34	87.7	1.91	25.14
10	TSW	6.68	4.29 – 8.84	1.14	10.48	0.4	1.71	1.22	19.61	16.58	71.5	1.93	28.87
11	OC%	35.74	32.62 – 39.88	1.96	3.37	0.69	3.91	2.46	5.53	4.39	63.0	2.56	7.17
12	SYP	3.99	0.91 – 7.69	0.73	11.15	0.26	2.87	2.67	42.51	41.02	83.1	3.25	61.55

Abbreviation: DF 50%: Days to 50% flowering, FD: Flower diameter, PH: Plant height, DM 50%: Days to 50% maturity, PBPP: Number of primary branches per plant, CD: Capsule diameter, CP: Number of capsules per plant, SC: Number of seeds per capsules, SL: Seed length, TSW: 1000- Seed weight, OC%: Oil content %, SYP: Seed yield per plant, SEm±: Standard error of mean; CD: critical difference; CV: Coefficient of variation; ó2p= Phenotypic variance; ó2g= genotypic variance; GCV: Genotypic coefficient of variation, PCV: Phenotypic coefficient of variation; h2bs= Heritability (broad sense); GA= Genetic advance; GAPM= Genetic advance as a percent of mean.

Table 4 : Phenotypic and genotypic correlation coefficient between pairs of twelve quantitative characters in linseed.

	FD	PH	DM 50%	PBPP	CD	CP	SC	SL	TSW	OC%	SYP
DF 50%	-0.409**(-0.549)	0.576**(0.873)	0.442**(0.618)	-0.501**(-0.778)	-0.576**(-0.782)	-0.595**(-0.752)	-0.571**(-0.864)	-0.678**(-0.864)	-0.541**(-0.832)	-0.418**(-0.814)	-0.711**(-0.950)
FD		-0.401**(-0.601)	-0.478**(-0.566)	0.465**(0.573)	0.470**(0.596)	0.747**(0.842)	0.336**(0.413)	0.532**(0.583)	0.464**(0.619)	0.352**(0.499)	0.565** (0.652)
PH			0.476**(0.533)	-0.423**(-0.499)	-0.375**(-0.464)	-0.481**(-0.551)	-0.351**(-0.405)	-0.479**(-0.544)	-0.389**(-0.542)	-0.338**(-0.479)	-0.575**(-0.666)
DM 50 %				-0.443**(-0.556)	-0.615**(-0.739)	-0.545**(-0.609)	-0.430**(-0.477)	-0.696**(-0.753)	-0.463**(-0.612)	-0.451**(-0.623)	-0.562**(-0.619)
PBPP					0.621**(-0.760)	0.639**(0.754)	0.672**(0.736)	0.679**(0.765)	0.629**(0.839)	0.627**(0.845)	0.732** (0.845)
CD						0.657**(0.764)	0.673**(0.794)	0.775**(0.913)	0.664**(0.906)	0.508**(0.877)	0.809** (0.943)
CP							0.748**(0.763)	0.698**(0.780)	0.629**(0.786)	0.748**(0.764)	0.785** (0.849)
SC								0.685**(0.790)	0.750**(0.842)	0.631**(0.811)	0.561** (0.866)
SL									0.683**(0.819)	0.749**(0.963)	0.847** (0.896)
TSW										0.563**(0.900)	0.776** (0.916)
OC%											0.657** (0.878)

****:** Significant at 1% level of probability

Note: (Genotypic correlation coefficients are shown under parentheses.)

Note: DF 50%: Days to 50% flowering, **FD:** Flower diameter, **PH:** Plant height, **DM 50%:** Days to 50% maturity, **PBPP:** Number of primary branches per plant, **CD:** Capsule diameter, **CP:** No. of capsules per plant, **SC:** Number of seeds per capsule, **SL:** Seed length, **TSW:** 1000-Seed weight, **OC%:** Oil content%, **SYP:** Seed yield per plant.

phenotypic correlation coefficient with flower diameter (0.565**), number of primary branches per plant (0.732**), capsule diameter (0.809**), number of capsules per plant (0.785**), number of seeds per capsule (0.561**), seed length (0.847**), 1000-seed weight (0.776**) and oil content % (0.657**), whereas, significant and negative phenotypic correlation coefficient with days to 50% flowering (-0.711**), plant height (-0.575**) and days to 50 % maturity (-0.562**). Days to 50% flowering showed significant and negative phenotypic correlation coefficient with flower diameter (-0.409**), number of primary branches per plant (-0.501**), capsule diameter (-0.576**), number of capsules per plant (- 0.595**), number of seeds per capsules (-0.571**), seed length (-0.678**), 1000- seed weight (-0.541**) and oil content % (-0.418**). However, it showed significantly positive correlation with plant height (0.576**) and days to 50 % maturity (0.442**). The significant positive correlation of seed length with seed yield per plant was also supported by Kumari *et al*. (2017). Moreover, the finding of significant and positive correlation between seed yield and number of capsules per plant is supported by Rajanna *et al*. (2014), Sharma *et al*. (2016) and Meena *et al*. (2020). Similarly, the significant and positive correlation for seed yield with 1000-seed weight was reported by Ankit *et al*. (2018) and Meena *et al*. (2020).

Yield, a complex quantitative character is governed by a number of independent characters, each of which contributes to yield both directly and indirectly through other characters. When correlation analysis is combined with path coefficient, it is possible to see more clearly the cause-and-effect connections among the characters. Path coefficients were computed by using phenotypic correlation coefficients between seed yield per plant and its component traits are presented in Table 5 and Fig. 2. Direct phenotypic effects ranged from -0.092 to 0.274. The maximum direct and positive effect was recorded for capsule diameter (0.274) followed by seed length (0.190), 1000- seed weight (0.164) and number of seeds per capsule (0.146) on seed yield per plant. Whereas, the maximum direct and negative effect on seed yield per plant was found maximum for plant height (-0.168) followed by days to 50% flowering (-0.092) on seed yield per plant. The maximum indirect and positive effect on seed yield per plant was recorded for seed length (0.213) via capsule diameter, followed by number of seeds per capsule (0.185) via capsule diameter and 1000- seed weight (0.182) via capsule diameter. Whereas, the maximum indirect and negative effect on seed yield per plant was recorded for days to 50%

Table 5 : Direct (diagonal) and indirect phenotypic effect of eleven characters towards seed yield per plant in linseed.

S. no.	Characters	DF 50%	FD	PH	DM 50%	PBPP	CD	CP	SC	SL	TSW	OC %	SYP
1	DF 50%	**-0.092**	0.038	-0.053	-0.041	0.046	0.053	0.055	0.053	0.063	0.05	0.039	-0.711
2	FD	-0.031	**0.076**	-0.031	-0.037	0.036	0.036	0.057	0.026	0.041	0.035	0.027	0.565
3	PH	-0.097	0.067	**-0.168**	-0.08	0.071	0.063	0.081	0.059	0.081	0.066	0.057	-0.575
4	DM 50%	0.05	-0.054	0.054	**0.112**	-0.05	-0.069	-0.061	-0.048	-0.078	-0.052	-0.051	-0.562
5	PBP	-0.033	0.031	-0.028	-0.029	**0.066**	0.041	0.042	0.045	0.045	0.042	0.042	0.732
6	CD	-0.158	0.129	-0.103	-0.169	0.17	**0.274**	0.18	0.185	0.213	0.182	0.139	0.809
7	CP	-0.027	0.033	-0.021	-0.024	0.029	0.029	**0.045**	0.031	0.033	0.028	0.025	0.774
8	SC	-0.083	0.049	-0.051	-0.063	0.098	0.098	0.1	**0.146**	0.109	0.102	0.092	0.785
9	SL	-0.129	0.101	-0.091	-0.132	0.129	0.147	0.142	0.142	**0.19**	0.13	0.142	0.847
10	TSW	-0.089	0.076	-0.064	-0.076	0.103	0.109	0.104	0.115	0.112	**0.164**	0.092	0.776
11	OC %	-0.022	0.019	-0.018	-0.024	0.034	0.027	0.03	0.034	0.04	0.03	**0.053**	0.657

The residual effect = 0.339

Note: DF 50%: Days to 50% flowering, **FD**: Flower diameter, **PH**: Plant height, **DM 50%**: Days to 50% maturity, **PBPP**: Number of primary branches per plant**, CD**: Capsule diameter, **CP**: No. of capsules per plant, **SC**: Number of seeds per capsules, **SL**: Seed length, **TSW**: 1000- Seed weight, **OC%**: Oil content %, **SYP**: Seed yield per plant.

maturity (-0.169) via capsule diameter followed by days to 50 % flowering (-0.158) via capsule diameter and days to 50 % maturity (-0.132) via seed length. Direct effect of oil content % on seed yield per plant was found negligible and positive with magnitude (0.053). Its indirect effects via number of primary branches per plant, oil content %, flower diameter, capsule diameter, number of capsules per plant, number of seeds per capsule and seed length was positive and negligible while, its indirect effects via plant height, days to 50% maturity and days to 50% flowering were negative and negligible. The magnitude of residual effect of phenotypic path was found 0.339. Similar finding was reported by Tiwari *et al*. (2012), Ibrar *et al*. (2016), Patial *et al*. (2018), Meena *et al*. (2020).

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Availability of data and material : All data are given in the manuscript.

Code availability : Publicly available statistical tools are used in this study.

Authors' contributions : AK and RBPN executed and designed the experiment, data collection and analysis of experimental data; interpretation of experimental findings. RK prepared and edited the draft of the manuscript. RBPN supervised the overall experiment; all authors read and edited the draft of the manuscript.

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