Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
https://www.phytojournal.com
JPP 2023; 12(6): 101-106
Received: 03-07-2023
Accepted: 07-08-2023

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Linseed yield attributes, variability, correlation, and path analysis in rainfed and irrigated conditions in the Vindhyan region of Eastern Uttar Pradesh

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DOI: https://doi.org/10.22271/phyto.2023.v12.i6b.14762

Abstract
At the Field Experimentation Centre, Department of GPB, SHUATS, Prayagraj, the study was carried out with 30 genotypes of linseed in a Randomized Block Design which was replicated three times. The yield and yield traits of 30 linseed genotypes were evaluated, and the results revealed that the phenotypic coefficient of variance was higher than the associated GCV and PCV, respectively. Under rainfed conditions, seed yield per plant showed significant and positive correlations with the quantity of seeds/plant, the weight of a 1000 seeds, and the number of days till flowering, whereas under irrigated conditions, seed yield per plant showed significant and positive correlations with the quantity of seeds per plant, the weight of a 1000 seeds, the number of primary branches per plant, and the height of the plant at the genotypic level and it shows the significant and positive correlations with number of seeds per plant, 1000-seed weight and primary branches per plant at phenotypic level.

Keywords: GCV, PCV, correlation, linseed, irrigated

Introduction
The genera Linum and family Linaceae include the linseed, *Linum usitatissimum* L. (2n = 30). One of the initial plant species are cultivated for oil and fibre, it is a self-pollinated species sown during the rabi season (Lay and Dybing 1939) [9]. It was originated in the Mediterranean and southwest Asia (Vavilov, 1935) [20]. Linseed is grown on 3.26 million hectares around the world, producing 3.18 million tonnes at a productivity of 1011.20 kg/ha. With an area of 0.32 million ha, a production of 0.17 million tonnes, and a productivity of 543.8 kg/ha, India ranked sixth in the world (FAOSTAT 2018) [5] for linseed cultivation. The 'Linen' obtained from flax fibre is one of the best raw materials for textile. The best Linen textiles such as damasks, lace, and sheeting are graded. Flax fibre is strong, non-lignified, soft, flexible, glossy, shiny, and pale yellow in colour, with a high-water absorption quality. Flax is composed of 80-90% cellulose. The oil content of seed fluctuates between 33 and 45%. Linseed contains a high concentration of omega fatty acids. Omega fats are classified into two types: omega-3 and omega-6 fatty acids. Linolenic acid, 13 eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) are all essential fatty acids are nutritionally important. Genetic variability is critical in breeding or selection program of any crops. The low genetic variability observed in the crop necessitates strengthening of the breeding programmes through introduction of new germplasm, collection of local genotypes and adopting interspecific hybridization. The magnitude of heritable variation in the traits studied has vast importance in understanding the potential of the genotype for further breeding programme. Correlation is the mutual relationship between the variables, it aids in estimating the most effective procedures. A path coefficient is a standardized, partial regression coefficient that measures the direct influence of one trait upon another trait. To determine the direct and indirect effects of seed yield components on seed yield, it is essential to calculate correlations of the yield components among themselves and with seed yield.

Materials and Methods
The investigation was carried out at the Field Experimentation Centre, SHUATS, Prayagraj during the growing season 2019-2020. The experiment was set up in RBD design with three replications. Thirty linseed genotypes were collected from the Directorate of Research, SHUATS, Prayagraj, NBPGR, New Delhi and PC Unit, AICRP on Linseed. The unit plot size

was 3.5 x 1.8 m with a spacing of 30 cm between rows. The crop was grown following the recommended cultural practices. Harvesting of linseed was done on different dates based on the maturity of capsule. Harvesting was started from second week of April. Data were recorded for the Days to 50% flowering, Plant height (cm), Number of primary branches per plant, Number of secondary branches per plant, Number of capsules per plant, Number of seeds per capsule, Days to maturity, Number of seeds per plant. Test weight (g), Seed yield per plant (g). The phenotypic and genotypic correlation coefficient for all possible character pairs were computed to study inter relationship. Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values, Path coefficient analysis and was used to calculate the direct and indirect contribution of various traits towards yield.

Results and Discussion

In addition to estimating the direct and indirect effects of seed yield characters, the diversity among genotypes, correlation coefficients between various significant yield and yield components, and other yield characteristics were also calculated. For yield and yield basic characters, the mean square from the analysis of variance (ANOVA) is shown in Table First. (a & b). Since there were significant variations between the genotypes for every attribute, it can be estimated from mean square values

Table 1 (a): Analysis of variance for quantitative characters under rainfed condition in Linseed

S. No.	Characters	Mean Sum of Squares		
		Replications (DF=2)	Treatments (DF=29)	Error (DF=58)
1	Days to 50% flowering	0.58	68.81**	1.12
2	Plant height	4.85	366.31**	1.21
3	Number of primary branches per plant	0.10	1.20**	0.00
4	Number of secondary branches per plant	1.03	228.25**	0.16
5	Number of capsules per plant	1.23	1314.92**	4.62
6	Number of seeds per capsule	0.10	1.18	0.03
7	Number of seeds per plant	25.64	93680.43**	297.25
8	Days to maturity	2.34	199.24**	4.33
9	Test weight	0.00	2.24**	0.01
10	Seed yield per plant	0.10	1.17**	0.03

* Significant at 5% and ** Significant at 1% level of significance respectively

Table 1 (b): Analysis of variance for quantitative characters under irrigated condition in Linseed

S. No.	Characters	Mean Sum of Squares		
		Replications (DF=2)	Treatments (DF=29)	Error (DF=58)
1	Days to 50% flowering	0.54	77.78**	2.09
2	Plant height	5.75	339.46**	0.88
3	Number of primary branches per plant	0.71	1.53**	0.05
4	Number of secondary branches per plant	0.53	103.92**	1.68
5	Number of capsules per plant	0.90	1291.51**	3.18
6	Number of seeds per capsule	0.02	1.18	0.02
7	Number of seeds per plant	15.56	97360.24**	171.84
8	Days to maturity	5.14	162.79**	2.48
9	Test weight	0.00	2.21**	0.00
10	Seed yield per plant	0.09	1.13**	0.02

* Significant at 5% and ** Significant at 1% level of significance respectively

In Table Second, the estimated range, mean, genotypic and phenotypic variances, and genotypic and phenotypic coefficients of variation (GCV and PCV, respectively) are shown (a & b). Overall, for every character, the PCV estimations were greater than the GCV values. This revealed that the various assessed characters had an inheritance correlation. High phenotypic variance for irrigated condition was recorded for number of seeds per plant (32567.98) followed by number of capsules per plant (432.62), plant height (113.74), days to maturity (55.92), number of secondary branches per plant (35.76), days to 50% flowering (27.32), Test weight (0.73), number of primary branches plant (0.54). Number of seeds per capsule (0.41) and seed yield per plant (0.39). High genotypic variance for rainfed condition was recorded for number of seeds per plant (32396.13) followed by number of capsules per plant (429.44), plant height (112.86), days to maturity (53.43), number of secondary branches per plant (34.07), days to 50% flowering (25.22), Test weight (0.73), number of primary branches plant (0.49). Number of seeds per capsule (0.38) and seed yield per plant (0.36) respectively (Table Second (a)). High phenotypic coefficient of variation for rainfed condition was recorded for number of seeds per plant (47.94) followed by number of capsules per plant (41.38) and number of secondary branches per plant (40.17) and number of primary branches per plant (21.29). Moderate phenotypic coefficient of variation was recorded for number of seed yield per plant (20.92) followed by plant height (14.72) and Test weight (11.04). Low phenotypic coefficient of variation was recorded for number of seeds per capsule (9.06), days to maturity (6.74), and days to 50% flowering (6.32). High phenotypic coefficient of variation for rainfed condition was recorded for number of seeds per plant (47.72) followed by number of capsules per plant (41.16) and number of secondary branches per plant (40.13) and number of primary branches per plant (21.04). Moderate phenotypic coefficient of variation was recorded for number of seed yield per plant (19.90) followed by plant height (14.65) and Test weight (10.96). Low phenotypic coefficient of variation was recorded for number of seeds per capsule (8.68), days to maturity (6.52), and days to 50% flowering (6.16) respectively (Table Second(b)) which emphasized the wide scope of selection for the improvement

of these characters from a considerable amount of variability present. These results were in accordance with the findings of Gauraha *et al.* (2011a) [6], Ahmad *et al.* (2014) [1], Kanwar *et al.* (2014) [8], Hussain *et al.* (2015) [7], Paul *et al.* (2015) [13], Singh *et al.* (2015) [17], Choudhary *et al.* (2016) [3], Sahu *et al.* (2016) [15] and Meena *et al.* (2020) [10].

Table 2 (a): Genetic variability parameters for 10 quantitative characters in rainfed condition

S. No.	Characters	Genotypic variance	Phenotypic variance	Environmental variance	Coefficient of variation (%)	
					GCV	PCV
1	Days to 50% flowering	22.56	23.69	1.13	6.16	6.32
2	Plant height	121.70	122.91	1.21	14.65	14.72
3	Number of primary Branches per plant	0.39	0.40	0.01	21.04	21.29
4	Number of secondary Branches per plant	76.03	76.19	0.16	40.13	40.17
5	Number of capsules per plant	436.76	441.39	4.62	41.16	41.38
6	Number of seeds per capsule	0.38	0.41	0.03	8.68	9.06
7	Number of seeds per plant	31127.73	31424.98	297.25	47.72	47.94
8	Days to maturity	64.97	69.30	4.33	6.52	6.74
9	Test weight	0.74	0.75	0.01	10.96	11.04
10	Seed yield per plant	0.37	0.41	0.04	19.90	20.92

Table 2 (b): Genetic variability parameters for 10 quantitative characters in irrigated condition

S. No.	Characters	Genotypic variance	Phenotypic variance	Environmental variance	Coefficient of variation (%)	
					GCV	PCV
1	Days to 50% flowering	25.22	27.32	2.09	6.09	6.33
2	Plant height	112.86	113.74	0.88	13.50	13.56
3	Number of primary Branches / plants	0.49	0.54	0.05	20.08	21.13
4	Number of secondary Branches/ plants	34.07	35.76	1.68	25.94	26.94
5	Number of capsules/plants	429.44	432.62	3.18	39.24	39.38
6	Number of seeds/capsules	0.38	0.41	0.02	8.53	8.82
7	Number of Seeds/ plants	32396.13	32567.98	171.84	45.78	45.90
8	Days to maturity	53.43	55.92	2.48	5.67	5.80
9	Test weight	0.73	0.73	0.00	10.85	10.86
10	Seed yield per plant	0.36	0.39	0.02	18.85	19.58

Estimation of simple correlation coefficient was made among ten important yield characters with Seed yield of the 30 linseed genotypes. The Value of 'r' and the characters correlated are presented in Table Third (a) & (b). Correlation coefficient in rainfed condition revealed that seed yield per plant exhibited significant and positive association with number of seeds per capsules (0.258*) followed by number of seeds per plant (0.234*) while non-significant and positive association with number of capsules per plant (0.180), test weight (0.136) and number of primary branches per plant (0.002). On the other hand, it also exhibited significant and negative association exhibited with days to maturity (-0.265*), number of secondary branches per plant (-0.210*) while non- significant and negative association with days to flowering (-0.170) and plant height (- 0.127). Correlation coefficient in irrigated condition revealed that seed yield per plant exhibited highly significant and positive association with number of seeds per capsule (0.294**) and significant and positive association with number of seeds per plant (0.251*). It also exhibited significant and negative association with days to maturity (-0.286*), number of secondary branches per plant (-0.222*) it also exhibited non-significant and positive association with number of capsules per plant (0.190), and number of primary branches per plant (0.007). Such significant association of number of capsules per plant with seed yield has also been observed by Pali and Mehta (2013) [12]. Tariq *et al.* (2014) [19], Rajanna *et al.* (2014) [14], Singh *et al.* (2015) [17], Mohit *et al.* (2016) [11], Dash *et al.* (2016) [21] and Meena *et al.* (2020) [10].

Table 3 (a): Correlation coefficient between yield and its related traits in 30 Linseed genotypes at phenotypic level for rainfed condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW	SYPP
DF	1	0.174	0.073	0.302	0.235*	0.126	0.221*	0.839**	0.099	-0.170
PH		1	0.174	-0.006	-0.026	0.164	0.002	0.239*	-0.252*	-0.127
NPBP			1	0.333**	0.212*	0.147	0.217*	0.043	0.446*	0.002
NSBP				1	0.253*	0.036	0.234*	0.216*	0.321**	-0.210*
NCP					1	0.601**	0.986**	0.157	-0.019	0.180
NSC						1	0.601*	0.060	-0.044	0.258*
NSPP							1	0.136	-0.029	0.234*
DM								1	0.078	-0.265*
TW									1	0.136
SYPP										1

Key: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules per Plant; NSC-Number of Seeds per Capsules; NSPP-Number of Seeds per Plant; DM-Days to maturity and TW-Test Weight; SYPP-Seed Yield per Plant

Table 3 (b): Correlation coefficient between yield and its related traits in 30 Linseed genotypes at genotypic level for rainfed condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW	SYPP
DF	1	0.177	0.079	0.310**	0.243*	0.122	0.226*	0.839**	0.107	-0.204
PH		1	-0.174	-0.006	-0.027	0.170	0.001	0.246*	-0.256	-0.132
NPBP			1	0.339**	0.217*	0.155	0.221*	0.049	0.451**	0.007
NSBP				1	0.255*	0.038	0.235	0.220*	0.324**	-0.222*
NCP					1	0.640**	0.989**	0.168	-0.020	0.190
NSC						1	0.735**	0.055	-0.044	0.294**
NSPP							1	0.143	-0.030	0.251*
DM								1	0.086	-0.286*
TW									1	0.145
SYPP										1

Key: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules per Plant; NSC-Number of Seeds per Capsules; NSPP-Number of Seeds per Plant; DM-Days to maturity and TW-Test Weight;

Association of characteristics determined by correlation may not provide an exact picture of the relative significance of direct and indirect influence of each of the yield components toward yield. In true sense, in order to find a clear picture of the interrelationships among the fruit yield and yield components, direct and indirect effects were worked out using path analysis. This analysis at both genotypic and phenotypic levels was done with the help of genotypic and phenotypic levels. {Table 4 (a) & (b)}. As per genotypic level in rainfed condition, the highest positive direct effect on seed yield was found for number of seeds per capsule (0.258), number of seeds per plant (0.234), number of capsules per plant (0.180), test weight (0.136) and number of primary branches per plant (0.001) whereas negative direct effect was found for days to maturity (-0.267), number of secondary branches per plant (-0.210), days to 50 % flowering (-0.170) and plant height (-0.127). As per phenotypic level in rainfed condition, the highest positive direct effect on seed yield was found for number of seeds per capsule (0.294), number of seeds per plant (0.250), number of capsules per plant (0.190), test weight (0.145) and number of primary branches per plant (0.007) whereas negative direct effect was found for plant height (-0.132), days to 50% flowering (- 0.204), number of secondary branches per plant (-0.222) and days to maturity (-0.286). As per genotypic level in irrigated condition, the highest positive direct effect on seed yield was found for number of seeds per capsule (0.306), number of secondary branches per plant (0.267), number of seeds per plant (0.259), number of capsules per plant (0.194), test weight (0.149), number of primary branches per plant (0.145) and days to 50% flowering (0.049) whereas negative direct effect was found for plant height (-0.214) and days to maturity (-0.245). As per phenotypic level in irrigated condition, the number of seeds / capsule (0.324), number of secondary branches / plant (0.298), number of seeds /plant (0.272), number of capsules / plant (0.206), number of primary branches per plant (0.165), and test weight (0.154) had the greatest positive direct effect on seed yield, while days to maturity had the greatest negative direct effect., plant height (-0.216) and days to flowering (-0.065). These results are in agreement with the findings of Kanwar *et al.*, (2014) [8], Chandrawati *et al.*, (2016) [2] and Sharma *et al.*, (2016) [18].

Table 4 (a): Effects of yield on related qualities, both direct and indirect at phenotypic level under rainfed condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW
DF	0.113	0.019	0.008	0.034	0.026	0.014	0.025	0.095	0.011
PH	-0.001	-0.002	0.0005	0.0001	0.0001	-0.0004	0.010	-0.0006	0.001
NPBP	-0.010	0.024	-0.138	-0.046	-0.029	-0.020	-0.030	-0.006	-0.061
NSBP	-0.110	0.002	-0.121	-0.364	-0.092	-0.013	-0.085	-0.078	-0.117
NCP	-1.431	0.160	-1.293	-1.539	-6.081	-3.659	-6.001	-0.959	0.119
NSC	-0.144	-0.188	-0.168	-0.042	-0.688	-1.143	-0.814	-0.069	0.050
NSPP	1.59	0.010	1.561	1.683	7.091	5.114	7.186	0.978	-0.215
DM	-0.213	-0.060	-0.011	-0.055	-0.040	-0.015	-0.034	-0.254	-0.019
TW	0.036	-0.093	0.164	0.118	-0.007	-0.016	-0.011	0.028	0.368
SYPP	-0.170	-0.127	0.001	-0.210	0.180	0.258	0.234	-0.267	0.136

KEY: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules / Plant; NSC-Number of Seeds per Capsules; NSPP-Number of Seeds/ Plant; DM-Days to maturity and TW-Test Weight; SYPP-Seed Yield per Plant.

Table 4(b): Effects of yield on related qualities, both direct and indirect at genotypic level for rainfed condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW
DF	0.116	0.020	0.009	0.036	0.028	0.014	0.026	0.104	0.012
PH	-0.001	-0.007	0.001	0.001	0.0002	-0.001	0.001	-0.001	0.001
NPBP	-0.012	0.027	-0.155	-0.052	-0.033	-0.024	-0.034	-0.007	-0.070
NSBP	-0.118	0.002	-0.129	-0.382	-0.097	-0.014	-0.090	-0.084	-0.123
NCP	-1.807	0.204	-1.612	-1.892	-7.414	-4.747	-7.334	-1.247	0.15
NSC	-0.156	-0.218	-0.197	-0.048	-0.817	-1.276	-0.939	-0.070	0.057
NSPP	1.963	0.006	1.923	2.04	8.577	6.377	8.671	1.246	-0.263
DM	-0.232	-0.064	-0.012	-0.057	-0.043	-0.014	-0.037	-0.260	-0.022
TW	0.043	-0.064	0.181	0.130	-0.008	-0.018	-0.012	-0.034	0.402
SYPP	-0.204	-0.132	0.007	-0.222	0.190	0.294	0.250	-0.286	0.145

Key: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules / Plant; NSC-Number of Seeds per Capsules; NSPP-Number of Seeds/ Plant; DM-Days to maturity and TW-Test Weight; SYPP-Seed Yield per Plant.

Table 5(a): Effects of yield on related qualities, both direct and indirect at phenotypic level for irrigated condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW
DF	-0.139	-0.034	-0.047	0.002	-0.015	-0.022	-0.019	-0.067	-0.011
PH	-0.005	-0.021	-0.005	0.004	0.003	-0.001	0.003	-0.008	0.001
NPBP	0.018	0.015	0.055	0.004	0.0001	0.010	0.002	0.009	0.022
NSBP	0.001	0.014	-0.018	-0.071	-0.033	-0.030	-0.035	-0.005	-0.018
NCP	-0.741	1.059	0.041	-3.082	-6.560	-4.071	-6.477	-1.130	0.213
NSC	-0.175	-0.057	-0.216	-0.469	-0.678	-1.092	-0.792	-0.016	0.003
NSPP	1.048	-1.117	0.282	3.829	7.511	5.515	7.606	1.092	-0.241
DM	-0.073	-0.059	-0.024	-0.012	-0.025	-0.002	-0.021	-0.149	-0.023
TW	0.016	-0.013	0.081	0.052	-0.006	-0.001	-0.006	0.032	0.203
SYPP	-0.049	-0.214	0.145	0.267	0.194	0.306	0.259	-0.245	0.149

Key: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules/ Plant; NSC-Number of Seeds per Capsules; NSPP-Number of Seeds / Plant; DM-Days to maturity and TW-Test Weight; SYPP-Seed Yield per Plant.

Table 5(b): Effects of yield on related qualities, both direct and indirect at genotypic level for irrigated condition

Characters	DF	PH	NPBP	NSBP	NCP	NSC	NSPP	DM	TW
DF	-0.223	-0.058	-0.084	0.002	-0.027	-0.034	-0.032	-0.113	-0.019
PH	0.011	0.042	0.012	-0.008	-0.006	0.002	-0.006	0.017	-0.002
NPBP	0.036	0.027	0.095	0.027	-0.001	0.020	0.003	0.016	0.040
NSBP	0.001	0.021	-0.029	-0.103	-0.049	-0.046	-0.053	-0.009	-0.027
NCP	-1.000	1.348	0.074	-3.953	-8.265	-5.354	-8.167	-1.455	0.267
NSC	-0.228	-0.084	-0.320	-0.677	-0.007	-1.494	-1.117	-0.004	0.005
NSPP	1.403	-1.430	0.353	4.967	9.561	7.233	9.676	1.409	-0.305
DM	-0.084	-0.068	-0.028	-0.015	-0.029	-0.0005	-0.024	-0.166	-0.026
TW	0.019	-0.015	0.093	0.058	-0.007	-0.001	-0.007	0.036	0.223
SYPP	-0.065	-0.216	0.165	0.298	0.206	0.324	0.272	-0.269	0.154

Key: DF-Days to flowering 50%; PH-Plant Height; NPBP-Number of Primary Branches; NSBP-Number of Secondary Branches; NCP-Number of Capsules / Plant; NSC-Number of Seeds / Capsules; NSPP-Number of Seeds per Plant; DM-Days to maturity and TW-Test Weight; SYPP-Seed Yield per Plant

Conclusion

It is concluded from the present investigation that significant genetic variation was found among all the genotypes studied IC-564621 followed by RL-13191-1, RL-130517, SLS-11X17(16)-1 showed highest seed yield and other characters under rainfed as well as irrigated conditions. High amount of genotypic and phenotypic coefficient of variation was observed for all the characters under both conditions. High Genetic Advances coupled with high heritability for seed yield per plant in both the conditions indicate the presence of additive genetic variance. Hence pure line and progeny selection method of breeding can be employed. Correlation and path coefficient studies revealed that selection based on the characters number of seeds per plant, test weight and primary branches per plant bring out desired improvement toward high yielding suitable genotypes. Further, it was observed that linseed genotypes show better performance under irrigated conditions than rainfed conditions. The best performing genotype under rainfed conditions hold promise to be released as new variety after confirming the consistency of the results.

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