Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(6): 752-755
Received: 29-09-2017
Accepted: 30-10-2017

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Genetic variability studies in F_2 and F_3 segregating generations for yield and its components in linseed (*Linum usitatissimum* L.)

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Abstract
The present investigation was carried out during 2015-16 and 2016-17 using the experimental material consisting of parents Meera, T-397 and Sekhar and backcross progenies of (Meera X T-397) X Meera and (Sekhar X T-3397) X Sekhar. For both the crosses, F_2 and F_3 populations were grown in the *rabi* 2015-16 and 2016-17 respectively. An estimate of GCV and PCV for all characters studied revealed that the phenotypic coefficient of variation (PCV) was higher than their corresponding genotypic coefficient of variation (GCV). In F_2 generation of cross (Meera X T-397) X Meera, high heritability coupled with high genetic advance as percent of mean was observed for yield per plant, primary branches per plant, capsules per plant and 1000-seed weight. In F_3 generation, high heritability coupled with high genetic advance as percent of mean was observed for capsules per plant and yield per plant. In F_2 generation of cross (Sekhar X T-397) X Sekhar, high heritability coupled with high genetic advance as percent of mean was observed for yield per plant, capsules per plant, primary branches per plant and 1000-seed weight whereas in F_3 generation, only two characters, namely, yield per plant and capsules per plant showed high heritability coupled with high genetic advance as percent of mean. The traits with high heritability and high genetic advance as percent of mean may be subjected to mass or progeny or family selection or any selection scheme, aimed at exploiting additive (fixable) genetic variance, a widely adapted genotype can be developed, possessing good quality and high productivity.

Keywords: Genetic advance, Heritability, Linseed, Segregating generations

Introduction
Linseed or flax (*Linum usitatissimum* L.) is one of the oldest crops cultivated by man. It is important crop of tropical as well as temperate zone of the world. Based on diversity of plant types, linseed has two centers of origin *i.e.,* South West Asia and the Mediterranean region of Europe (Darlington, 1963) [1]. It has a significant position with about 32 per cent share in total technical oil pool which is having industrial importance. The oil cake is a most valuable feeding cake to both milch and flattering animals. The cake is also used as manure and is a very good source of nitrogen to soil. Fibres obtained from the stem are known for their length, strength and beauty. They are spun into linen yarns which are used in making the best quality textiles. They are also used for the manufacture of rough textiles such as blankets, carpets, galicha, mattresses, etc. The remaining materials after fibre extraction can successfully be utilized as pulp for manufacturing straw boards, writing papers and parchment paper. The stalks are used as fuel. Crop improvement depends on the magnitude of genetic variability and extent to which the desired characters are heritable. This has in turn attracted the attention of biometrician to study the genetic aspects of economically important characters, such as yield, its components. Segregating populations are more important for improving plant types by operating further selection improvement. The present study was formulated to quantify the extent of genetic variation available for yield and yield components in the segregating generations (F_2's and F_3's of two crosses) of linseed and to assess the genetic gain that can be made by selection. To achieve this goal, the breeder has the option of selecting desirable genotypes in early generations or delaying intense selection until advanced generations, when progenies are nearly homozygous. In early stages of breeding programs, direct estimates of yield are quite difficult.

Materials and methods
The present investigation was carried out during 2015-16 and 2016-17 using the experimental

material consisting of parents Meera, T-397 and Sekhar and backcross progenies of (Meera X T-397) X Meera and (Sekhar X T-3397) X Sekhar. For both the crosses, F_2 and F_3 population was grown in the *rabi* 2015-16 and 2016-17 respectively with spacing of 30 cm and 10 cm between and within the rows respectively with 4 meter row length. Recommended agronomic practices were followed throughout the crop growth period to raise a healthy crop in both the years. Observation on 500 randomly selected plants were taken for the characters, days to 50 % flowering, days to maturity, plant height (cm), primary branches per plant, capsules per plant, seeds per capsule, capsule diameter (mm), yield per plant (g) and 1000-seed weight (g). Standard statistical procedures were used for the analysis of mean variance, genotypic and phenotypic coefficients of variation, heritability and genetic advance. As suggested by Sharma (1998) [2].

Result and discussion

Genetic variability is a pre-requisite for successful selection of superior progenies from segregating generations for further selection. Genetic variability can be created by hybridization or mutation. F_2 is an ideal generation in which segregation and recombination are maximum for imposing selection. F_3 generation is equally important in the process of selection. The magnitude of recombination potential depends on the genetic diversity of the parents. A population is said to be superior when it shows high mean coupled with high variability (Savitha and Usha, 2015) [3]. The present investigation aims to determine the magnitude and extent of variability and pattern of segregation in F_2 and F_3 generations of two crosses of linseed. The mean, standard deviations, CV (%), variances and environmental variances for different characters of the parents of both the crosses for F_2 (2015) and F_3 (2016) have been shown in table-1 and table-2**.** The salient results for both the crosses are given in tables-3. For both the crosses, widest range of variability was observed for capsules per plant in both the generations. An estimate of GCV and PCV for all characters studied revealed that the phenotypic coefficient of variation (PCV) was higher than their corresponding genotypic coefficient of variation (GCV), indicating the influence of environment on the expression of these characters. Similar result was obtained by Choudhary *et al.* 2017) [4]. High GCV and PCV was observed for yield per plant followed by primary branches per plant, capsules per plant and 1000-seed weight and moderate for plant height and seed per capsule in F_2 generation of cross (Meera X T-397) X Meera, while in F_3, high PCV and GCV was observed for yield per plant followed by capsules per plant and primary branches per plant whereas moderate for seed per capsule. In cross (Sekhar X T-397) X Sekhar, the GCV and PCV was high for yield per plant followed by capsules per plant and primary branches per plant. Moderate PCV was seen for plant height, while moderate GCV was recorded for 1000-seed weight, seeds per capsule and plant height. In F_3, yield per plant and capsules per plant showed high PCV and GCV while moderate PCV and GCV were exhibited by seeds per capsule and primary branches per plant. Similar results were reported by (Choudhary *et al*. 2017) [4], (Kanwar *et al*. 2014) [5], (Tyagi *et al*. 2014) [6] and (Pali and Mehta, 2013) [7] for different characters in linseed suggesting sufficient amount of variability and thus offering better scope for genetic improvement through selection of these traits.

In F_2 generation of cross (Meera X T-397) X Meera, high heritability coupled with high genetic advance as percent of mean was observed for yield per plant, primary branches per plant, capsules per plant and 1000-seed weight and high heritability coupled with moderate genetic advance as percent of mean was recorded for plant height and seeds per capsule. In F_3 generation, high heritability coupled with high genetic advance as percent of mean was observed for capsules per plant and yield per plant. High heritability coupled with moderate genetic advance as percent of mean was observed for days to 50% flowering and moderate heritability with moderate genetic advance as percent of mean was observed for primary branches per plant. Similar result was reported by (Akbar *et al.* 2003) [8]. In F_2 generation of cross (Sekhar X T-397) X Sekhar, high heritability coupled with high genetic advance as percent of mean was observed for yield per plant, capsule per plant, primary branches per plant and 1000-seed weight whereas high heritability coupled with moderate genetic advance as percent of mean was observed for plant height and moderate heritability with moderate genetic advance as percent of mean was observed for seeds per capsule, whereas in F_3 generation, only two characters, namely, yield per plant and capsules per plant showed high heritability coupled with high genetic advance as percent of mean, whereas seed per capsule and plant height exhibited high heritability coupled with moderate genetic advance as percent of mean. Similar findings were reported by (Sahu and Sahu, 2016), [9] (Shalini *et al.* 2016), [10] (Siddiqui *et al*. 2016) [11], (Ahmad *et al* .2014) [12] and (Tyagi *et al*. 2014) [6]. The traits with high heritability and high genetic advance as percent of mean may be subjected to mass or progeny or family selection or any selection scheme, aimed at exploiting additive (fixable) genetic variance, a widely adapted genotype can be developed, possessing good quality and high productivity whereas, for characters showing high heritability accompanied with moderate genetic advance as percent of mean and moderate heritability accompanied with moderate genetic advance as percent of mean selection for such traits may be rewarding in both the crosses.

Table 1: Mean, standard deviations, coefficient of variation (%), variances and environmental variances for different characters of the parents (Meera and T-397) in 2015-16 and 2016-17.

Parameters	Days to 50 per cent flowering (Days)				Days to maturity (Days)				Plant height (cm)			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397
Mean	68.2	63.2	77.8	70.2	107.6	103.6	122.8	109.6	60	38	76.4	57.6
SD	0.45	0.44	0.45	0.45	0.89	1.82	0.84	3.78	2.55	1.58	4.39	2.88
CV (%)	0.66	0.7	0.57	0.64	0.83	1.75	0.68	3.45	4.24	4.16	5.75	5.00
Variance	0.2	0.2	0.2	0.2	0.8	3.3	0.7	14.3	6.5	2.5	19.3	8.3
Environmental Variance	0.2		0.2		2.05		7.5		4.5		13.8	

Table 1 contd….

Parameters	Primary branches per plant				Capsules per plant				Seeds per capsule			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397
Mean	2.8	2.2	3.4	3.8	21.6	24	51.8	61.4	7.4	7.4	8.4	9
SD	0.44	0.44	0.89	1.30	4.03	3.53	28.83	11.32	0.54	1.14	1.14	0.71
CV (%)	15.97	20.32	26.30	34.31	18.69	14.73	55.67	18.44	7.4	15.40	13.57	7.86
Variance	0.2	0.2	0.8	1.7	16.3	12.5	831.7	128.3	0.3	1.3	1.3	0.5
Environmental Variance	0.2		1.25		14.4		480		0.8		0.9	

Table 1 contd…

Parameters	Capsule diameter (mm)				Yield per plant (g)				1000 seed weight (g)			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397	Meera	T-397
Mean	6.42	6.04	6.81	6.71	0.91	0.59	2.68	2.52	6.23	5.15	7.36	6.08
SD	0.22	0.25	0.16	0.21	0.13	0.10	1.74	0.50	0.15	0.55	0.29	0.43
CV (%)	3.5	4.18	2.3	3.12	15.2	16.62	64.80	19.72	2.43	10.68	3.91	7.04
Variance	0.05	0.06	0.02	0.04	0.02	0.009	3.01	0.25	0.02	0.30	0.08	0.18
Environmental Variance	0.06		0.03		0.014		1.63		0.16		0.13	

Table 2: Mean, standard deviations, coefficient of variation (%), variances and environmental variances for different characters of the parents (Sekhar and T-397) in 2015-16 and 2016-17.

Parameters	Days to 50 per cent flowering (Days)				Days to maturity (Days)				Plant height (cm)			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397
Mean	66.2	63.2	69.6	70.2	105.4	103.6	111.4	109.6	33.4	38	57	57.6
SD	0.45	0.45	0.55	0.45	0.55	1.81	1.14	3.78	3.36	1.58	3.32	2.88
CV (%)	0.67	0.71	0.79	0.64	0.52	1.75	1.02	3.45	10.06	4.16	5.82	5.00
Variance	0.2	0.2	0.3	0.2	0.3	3.3	1.3	14.3	11.3	2.5	11	8.3
Environmental Variance	0.2		0.25		1.8		7.8		6.9		9.65	

Table 2 contd…

Parameters	Primary branches per plant				Capsules per plant				Seeds per capsule			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397
Mean	2.6	2	2.6	3.8	20.8	24	37.4	61.4	7.8	7.4	9.6	9
SD	0.89	0.44	0.89	1.30	8.22	3.53	11.12	11.32	0.84	1.14	0.55	0.71
CV (%)	34.40	20.32	34.40	34.31	39.55	14.73	29.75	18.44	10.72	15.40	5.70	7.85
Variance	0.8	0.2	0.8	1.7	67.7	12.5	123.8	128.3	0.7	1.3	0.3	0.5
Environmental Variance	0.5		1.25		40.1		126.05		1		0.4	

Table 2 contd…

Parameters	Capsule diameter (mm)				Yield per plant (g)				1000 seed weight (g)			
	2015-16		2016-17		2015-16		2016-17		2015-16		2016-17	
	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397	Sekhar	T-397
Mean	6.81	6.04	6.94	6.71	0.89	0.59	1.76	2.52	5.50	5.15	6.69	6.08
SD	0.36	0.25	0.24	0.21	0.35	0.09	0.54	0.49	0.07	0.55	0.17	0.43
CV (%)	5.26	4.18	3.43	3.12	39.96	16.56	30.79	19.72	1.31	10.68	2.61	7.04
Variance	0.13	0.06	0.06	0.04	0.13	0.009	0.29	0.25	0.005	0.30	0.03	0.18
Environmental Variance	0.09		0.05		0.07		0.27		0.15		0.11	

Table 3: Genetic variability parameters for different characters in F2 and F3 population of linseed crosses

Parameters	Days to 50 per cent flowering (Days)				Days to maturity (Days)				Plant height (cm)			
	(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar	
	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3
Range	62-86	62-81	62-72	60-79	103-130	109-138	103-130	115-132	24-62	39-75	24-62	40-78
Mean	67.49	71.09	66.71	68.79	112.91	124.65	113.91	122.98	43.02	55.84	44.34	55.18
GCV (%)	2.44	7.87	2.55	5.18	2.88	6.65	2.89	3.05	15.67	7.52	12.81	8.31
PCV (%)	2.53	7.89	2.63	5.23	3.15	7.01	3.12	3.81	16.43	10.05	14.11	10.04
Heritability (%)	93.16	99.36	93.54	98.07	83.82	90.18	85.79	64.38	90.99	56.15	82.39	68.55
GAM (%)	3.30	11.57	3.45	7.40	3.68	9.27	3.72	3.53	19.51	7.90	15.65	10.08

Table 3 contd…

Parameters	Primary branches per plant				Capsules per plant				Seeds per capsule			
	(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar	
	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3
Range	1-6	1-11	1-7	2-8	4-82	18-215	8-89	12-190	3-10	5-10	3-10	5-10
Mean	2.38	4.67	2.31	4.21	34.66	83.31	34.63	69.33	7.18	8.19	6.90	8.56
GCV (%)	41.76	21.41	39.19	13.25	39.56	34.5	41.06	44.11	18.30	10..85	16.18	12.86
PCV (%)	45.80	32.13	49.69	29.63	41.05	43.38	44.95	46.99	22.14	15.88	21.71	14.84
Heritability (%)	83.17	44.44	62.19	20	92.89	63.24	83.45	88.12	68.36	46.74	55.55	75.2
GAM (%)	40.94	17.28	28.12	7.72	37.88	34.85	33.12	52.37	19.04	9.44	14.84	14.59

Table 3 contd….

Parameters	Capsule diameter (mm)				Yield per plant (g)				1000 seed weight (g)			
	(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar		(Meera X T-397) X Meera		(Sekhar X T-397) X Sekhar	
	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3	F2	F3
Range	3.35-8.9	4.87-8.83	4.95-8.9	5.44-7.8	0.1-5.23	0.91-11.88	0.110-5.36	0.3-12.69	2.56-9.13	3.2-10.3	2.95-8.87	5.65-8.84
Mean	6.8	7.03	6.42	6.55	1.63	4.30	1.55	3.56	6.06	8.14	6.02	7.58
GCV (%)	7.92	6.3	6.49	3.89	60.28	37.85	58.24	48.69	20.04	8.32	19.88	6.31
PCV (%)	8.68	6.83	8.08	5.19	60.73	48.11	60.64	50.84	21.12	9.46	21.12	7.65
Heritability (%)	83.51	85.15	64.38	56.39	98.53	61.91	92.23	91.71	90.03	77.51	90.27	68.19
GAM (%)	9.88	7.89	7.28	4.03	50.02	35.32	40	60.52	23.25	9.99	22.49	7.03

Acknowledgement
We are thankful to the Department of Genetics and Plant Breeding, Birsa Agricultural University, Kanke, Ranchi for providing all necessary facilities and support during the course of investigation.

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