International Journal of Microbiology Research
ISSN: 0975-5276 & E-ISSN: 0975-9174, Volume 10, Issue 3, 2018, pp.-1097-1103.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000234

Research Article

STUDY ON GENERATION MEAN ANALYSIS FOR QUALITY TRAITS IN LINSEED (*Linum usitatissimum* L.)

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Received: March 23, 2018; Revised: March 27, 2018; Accepted: March 28, 2018; Published: March 30, 2018

Abstract- In the present study generation mean analysis 60 treatments (10P$_1$, 10P$_2$, 10 F$_1$, 10 F$_2$, 10 BC$_1$ and 10 BC$_2$) was chosen to study the nature and magnitude of gene effects for 8 quality traits. analysis of variance was carried out for 8 quality traits. Highly significant difference observed among treatments, for all the characters except protein content (%) and stearic acid. Highly significant difference observed among parents, for all the characters except seed yield per plant (g), protein content (%) and palmitic acid. Highly significant difference observed among F$_1$s, for all the characters except oil content (%), stearic acid, oleic acid, linoleic acid and linolenic acid. Highly significant difference observed among parent vs crosses, for all the characters except protein content (%). Useful heterosis over better parent and mid parent the best crosses. *viz*., NPRR271 X NO 356 and RL-28-1 X L-53 for oil content (%) were considered. Medium heritability was observed in characters like palmitic acid, linoleic acid and linolenic acid, whereas low heritability was observed in characters like seed yield per plant (g), oil content (%), protein content (%), stearic acid and oleic acid. In F$_1$ generation characters likes palmitic acid and oleic acid exhibited high value of genetic advance.

Key words – generation mean, heterosis, inbreeding depression, heritability and genetic advance in Linseed (*Linum usitatissimum* L.)

Citation: Yadav P. C., *et al*., (2018) Study on Generation Mean Analysis for Quality Traits in Linseed (*Linum usitatissimum* L.). International Journal of Microbiology Research, ISSN: 0975-5276 & E-ISSN: 0975-9174, Volume 10, Issue 3, pp.-1097-1103. DOI: http://dx.doi.org/10.9735/0975-5276.10.3.1097-1103

Academic Editor / Reviewer: Maria Toader, Vekaria Deepkumar Manojbhai

Introduction

Linseed (*Linum usitatissimum* L.) is an important oilseed crop grown for both seed as well as fibre. It is mainly grown for oil purpose; it is traditionally grown for edible and industrial purposes in South East Asia (Turkmenistan, Afghanistan and India), Asia Minor and South Russia. Recent medical researchers have found linseed as best herbal source of carbohydrates, Omega -3 and Omega-6 fatty acids, which have beneficial effect on human metabolism. The seed of linseed is a very rich source of nutrients, which contain oil (40 %), protein (26%), fibre (14%), mucilage (12%), water (9%), minerals (4%), potassium (0.74%), phosphorous (0.70%), magnesium (0.38%), calcium (0.21%), sulphur (0.21%), along with sodium, chlorine, iron, zinc, copper etc., in traces. Lignan (1.90-6.16 mg/g) is also found in the seed. The oil contains different fatty acids like alpha linolenic acid (omega-3) 53.21%, linoleic acid (omega-6) 17%, oleic acid 18.51%, stearic acid 4.42% and palmitic acid 4-6%. Linseed is the richest source of omega-3 fatty acid and it contains almost twice as much as of omega-3 in fish oil. The ratio of omega-3 and omega-6 present in linseed is about 4:1, so this is a best herbal source of omega-3 for improvement in human metabolism. World over, linseed is an important crop grown over 27.29 lakh ha with production of 25.20 lakh tons and average productivity of 923 kg/ ha, while national production of 1.525 lakh tons is from 3.38 lakh area ha with low productivity of 473 kg/ha [4]. As far as productivity is concerned, Indian average yield (473 kg/ha) is far below the productivity of UK (1500 kg/ha), Germany (1429 kg/ha), Canada (1538 kg/ha), USA (1076 kg/ha) and China (1000 kg/ha). India is an important linseed producer, which contributes about 11.82 % to world acreage producing about 7 % of world production.

Materials and Method

Generation mean analysis

(a). Building up of material: 20 parents (10 pure line female and 10 pure line male) will be crossed to develop the material. To be evaluated each female and male will be crossed only once during Rabi season 2013-14 to produce seeds of 10 straight crosses.

(b). Raising of F$_{1s}$ material & development of back crosses: The seeds of 10 crosses will be sown to raise F$_1$ population in Rabi- 2014-15. Each **F$_1$** will be back crossed with their respective parents to produce the seeds of BC$_1$ & BC$_2$.The parents will be maintained and fresh crosses will also be made during this season to procure F$_1$seeds of straight crosses.

(c). Plan of the lay-out for experiment: All the 10 F$_{1's}$, 10F$_{2s}$, 10BC$_{1s}$& 10BC$_{2s}$ along with their 10 pure line female & 10 pure line male parents, will be grown in randomized block design with three replication during Rabi 2015-16 at Nawabganj Farm of CSAUA&T Kanpur. [5-7].

Oil content (%): Oil contain was determined by [8]. There were analysed separately for their oil content. Heterosis expressed as per-cent increase or decreases of F1 hybrid over the best commercial check (standard heterosis) were computed as per the method [9, 10].

$$\text{Heterosis over check (standard heterosis)} = \frac{\bar{F}_1 - \overline{CC}}{\overline{CC}} \times 100$$

Where: $\bar{F}_1$= mean performance of F$_1$, $\overline{CC}$ = mean performance of the best commercial check.

Inbreeding depression is estimated when both F$_1$ and F$_2$ generations of the same cross are available. Inbreeding depression was measured as described by [10].

$$\text{Inbreeding depression} = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_1} \times 100$$

Where: F_1 and F_2 are the mean values of F_1 and F_2 progeny respectively of the same cross for a given character. Inbreeding depression may be high, medium, low and nil depending on cross.

Results and Discussion

Analysis of variance (ANOVA)

Highly significant difference observed among treatments, for all the characters except protein content (%) and stearic acid. Highly significant difference observed among parents, for all the characters except seed yield per plant (g), protein content (%) and palmitic acid. Highly significant difference observed among F_1s, for all the characters except oil content (%), stearic acid, oleic acid, linoleic acid and linolenic acid. Highly significant difference observed among parent vs crosses, for all the characters except protein content (%). Such observations were reported by [11].

Six parameter model

The relative estimate of additive and non-additive gene action (dominance and epistasis interactions) based on six parameter model [Table-2] indicated the predominance of additive gene effects (d) in crosses POLF 10 X SJKO 55, NPRR 402 X NP 8 and AHUDERA 170 X SJKO 05 for seed yield per plant; NPHY 29 X LCK 87312, NPRR 271 X NO 356 and NPHY 39 X NO 3 for oil content (%); RL-28-1 X L-53, AHUDERA 170 X SJKO 05 and NP 121 X RR 76 for protein content (%); NP 402 X NP 8, NPRR 271 X NO 356 and RL-28-1 X L-53 for palmitic acid; NPHY 38 X LMHS-5 and NPHY 29 X LCK 87312 for stearic acid; NPHY 29 X LCK 87312, NPHY 38 X LMHS-5 and NPRR 402 X NP 8 for oleic acid; NPHY 28 X 141NO18XRR9, AHUDERA 170 X SJKO 05 and NPHY 39 X NO 3 for linoleic acid; POLF 10 X SJKO 55, NPHY 29 X LCK 87312 and RL-28-1 X L-53 for linolenic acid. Such observations were also reported by [12].

Table-1 *Analysis of variance for 8 quality traits in linseed (Linum usitatissimum L.)*

Source of variation	d.f.	Seed yield per plant(g)	Oil content (%)	Protein content (%)	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolinic acid
Replication	2	0.59	1.97	0.90	0.32	0.26	1.24	1.96	2.62
Treatment	29	2.57*	1.83**	3.03	1.99*	0.71	3.93**	3.88**	6.88**
Parent	19	0.78	1.74**	1.01	0.27	0.58**	3.36**	3.33**	6.67**
F_1S	9	1.79*	0.09	2.03**	1.72**	0.13	0.57	0.55	0.21
Parent vs Crosses	1	43.60**	19.20**	50.41	37.10**	8.40**	45.00**	44.30**	70.90**
Error	58	0.73	0.90	0.75	0.18	0.26	1.34	1.78	2.41

at 5% probability level, ** Significance at 1% probability level.

Table-2 *Estimates of gene effect based on six parameters model for 8 quality traits in linseed (Linum usitatissimum L.)*

Crosses	m	D	H	I	J	L	Type of epistasis
	Seed yield per plant (g)						
NPHY 29 X LCK 87312	4.39**	1.46**	8.01**	6.80**	0.96**	-6.40**	D
SE±	0.10	0.17	0.58	0.54	0.26	0.91	
NP 121 X RR-76	3.82**	0.30**	11.48**	9.28**	0.08	-11.96**	D
SE±	0.21	0.09	0.89	0.87	0.18	1.03	
NPRR 271 X No 356	5.21**	1.75**	4.79**	2.92**	2.05**	-2.89**	D
SE±	0.11	0.03	0.50	0.45	0.20	0.62	
NPRR 402 X NP 8	4.75**	2.42**	4.77**	4.14**	2.86**	-2.36**	D
SE±	0.16	0.12	0.75	0.70	0.23	0.96	
RL-28-1 X L-53	4.37**	1.22**	8.14**	7.09**	2.38**	-7.43**	D
SE±	0.15	0.25	0.81	0.80	0.27	1.22	
AHUDERA 170 X SJKO-05	3.40**	2.08**	12.75**	10.37**	2.89**	-9.90	D
SE±	0.06	0.08	0.35	0.31	0.14	-18.79	
NPHY 39 X No-3	4.77**	2.04**	5.38**	4.28**	2.92**	-1.56	D
SE±	0.04	0.17	0.43	0.38	0.18	0.82	
NPHY 28 X 141N018XRR9	5.57**	1.19**	2.62**	1.13*	1.21**	3.09**	C
SE±	0.11	0.15	0.57	0.53	0.24	0.85	
NPHY-38 X LMHS-5	5.89**	1.21**	0.72	-0.46	1.63**	2.63**	C
SE±	0.09	0.08	0.45	0.39	0.23	0.65	
POLF-6 X SJKO-55	5.53**	2.70**	1.05*	0.53	2.78**	4.60**	C
SE±	0.104	0.106	0.47	0.46	0.12	0.63	

Table-2 *Contd.*

Crosses	M	D	H	I	j	L	Type of epistasis
	Oil content (%)						
NPHY 29 X LCK 87312	35.83**	2.47**	-3.14**	-2.88**	3.01**	8.39**	D
SE±	0.11	0.08	0.50	0.47	0.17	0.66	
NP 121 X RR-76	34.48**	0.53**	0.26	5.23**	0.24	-12.03**	D
SE±	0.15	0.07	0.74	0.63	0.39	1.04	
NPRR 271 X No 356	36.38**	2.74**	-5.55**	-3.96**	3.70**	13.03**	D
SE±	0.08	0.07	0.42	0.35	0.25	0.65	
NPRR 402 X NP 8	35.57**	2.04**	-0.62	-1.72**	3.36**	3.65**	D
SE±	0.15	0.07	0.67	0.62	0.25	0.83	
RL-28-1 X L-53	36.22**	-2.51**	-5.91**	-0.33	-1.11**	-0.01	C
SE±	0.04	0.07	0.57	0.21	0.23	1.12	
AHUDERA 170 X SJKO-05	36.48**	-1.27**	-22.82**	-21.15**	-1.40**	40.35**	D
SE±	0.09	0.07	0.44	0.38	0.21	0.62	
NPHY 39 X No-3	36.65**	1.93**	-13.16**	-11.31**	3.38**	21.84**	D

SE±	0.05	0.05	0.48	0.25	0.30	0.88	
NPHY 28 X 141N018XRR9	35.88**	1.01**	-11.70**	-8.79**	0.47	15.83**	D
SE±	0.10	0.11	0.56	0.48	0.23	0.84	
NPHY-38 X LMHS-5	35.58**	0.68**	-5.78**	-5.08**	2.32**	10.26**	D
SE±	0.05	0.07	0.34	0.26	0.21	0.57	
POLF-6 X SJKO-55	36.73**	0.66**	-9.55**	-6.48**	0.48*	8.11**	D
SE±	0.04	0.12	0.34	0.29	0.20	0.62	

Table-2 *Contd.*

Crosses	Genetic parameters						Type of epistasis
	M	D	H	I	j	L	
	Protein content (%)						
NPHY 29 X LCK 87312	16.00**	-1.44**	2.16**	2.30**	-0.67**	-5.67**	D
SE±	0.03	0.10	0.32	0.24	0.15	0.61	
NP 121 X RR-76	17.30**	0.27**	-6.28**	-7.66**	0.54*	13.57**	D
SE±	0.06	0.08	0.40	0.29	0.28	0.69	
NPRR 271 X No 356	15.27**	-1.08**	4.05**	2.85**	-1.11**	-6.02**	D
SE±	0.12	0.19	0.64	0.64	0.19	0.92	
NPRR 402 X NP 8	15.47**	-0.25	2.27**	2.56**	-0.79**	-1.30	D
SE±	0.10	0.23	0.65	0.64	0.26	1.06	
RL-28-1 X L-53	15.61**	2.93**	3.30**	0.27	2.75**	1.62**	C
SE±	0.04	0.04	0.24	0.19	0.11	0.37	
AHUDERA 170 X SJKO-05	15.62**	0.57**	8.19**	7.95**	1.08**	-13.12**	D
SE±	0.07	0.04	0.39	0.31	0.21	0.59	
NPHY 39 X No-3	15.17**	-1.14**	4.70**	5.49**	-1.35**	-8.39**	D
SE±	0.08	0.08	0.45	0.38	0.23	0.70	
NPHY 28 X 141N018XRR9	16.36**	0.18*	4.84**	4.21**	0.26	-9.07**	D
SE±	0.08	0.09	0.52	0.39	0.34	0.86	
NPHY-38 X LMHS-5	16.06**	-0.64*	0.35	1.12	-0.25	-0.85	D
SE±	0.07	0.25	0.60	0.58	0.29	1.10	
POLF-6 X SJKO-55	16.01**	-1.01**	1.56	0.66	-0.65**	0.87	C
SE±	0.19	0.10	0.83	0.81	0.13	0.98	

Table-2 *Contd.*

Crosses	Genetic parameters						Type of epistasis
	M	d	H	I	j	L	
	Palmitic acid						
NPHY 29 X LCK 87312	3.66**	-1.72**	5.61**	5.20**	-3.09**	-2.83**	D
SE±	0.05	0.04	0.26	0.22	0.14	0.39	
NP 121 X RR-76	7.86**	-2.03**	2.36**	2.79**	-3.82**	-0.32	D
SE±	0.002	0.08	0.16	0.16	0.08	0.32	
NPRR 271 X No 356	6.49**	-3.97**	13.85**	9.23**	-8.67**	19.08**	C
SE±	0.003	0.01	0.27	0.02	0.27	0.54	
NPRR 402 X NP 8	7.33**	-4.93**	14.93**	10.57**	-9.09**	1.68**	C
SE±	0.002	0.006	0.01	0.01	0.008	0.03	
RL-28-1 X L-53	5.13**	-3.33**	8.81**	7.52**	-4.52**	-4.77**	D
SE±	0.002	0.06	0.13	0.12	0.06	0.27	
AHUDERA 170 X SJKO-05	6.21**	-1.59**	4.30**	3.20**	-3.88**	-3.81**	D
SE±	0.07	0.01	0.28	0.28	0.01	0.29	
NPHY 39 X No-3	6.36**	-0.65**	1.07**	1.42**	-1.02**	-3.17**	D
SE±	0.004	0.02	0.05	0.05	0.02	0.10	
NPHY 28 X 141N018XRR9	8.45**	-2.12**	0.95**	-1.14**	-6.49**	18.57**	C
SE±	0.05	0.06	0.24	0.24	0.06	0.32	
NPHY-38 X LMHS-5	9.21**	2.14**	-1.54**	1.02**	3.63**	0.06	D
SE±	0.06	0.10	0.33	0.33	0.10	0.49	
POLF-6 X SJKO-55	8.01**	-0.63**	-4.58**	-4.75**	-0.90**	6.07**	D
SE±	0.01	0.07	0.36	0.16	0.08	0.72	

Table-2 *Contd.*

Crosses	Genetic parameters						Type of epistasis
	M	d	H	I	j	L	
	Stearic acid						
NPHY 29 X LCK 87312	3.57**	0.20**	0.61**	0.65**	-0.10*	-1.80**	D
SE±	0.04	0.03	0.24	0.21	0.06	0.34	
NP 121 X RR-76	1.75**	-0.07**	0.08**	-0.29**	-0.74**	2.50**	C
SE±	0.002	0.006	0.01	0.01	0.008	0.03	
NPRR 271 X No 356	5.16**	-0.13**	1.67**	1.47**	0.09**	-6.70**	D
SE±	0.002	0.008	0.02	0.01	0.02	0.05	
NPRR 402 X NP 8	7.23**	-0.48**	-16.37**	-14.92**	0.94**	10.47**	D
SE±	0.002	0.005	0.01	0.01	0.009	0.03	
RL-28-1 X L-53	4.64**	-0.65**	-5.56**	-3.15**	-1.77**	1.07	D
SE±	0.003	0.005	0.40	0.01	0.40	0.80	
AHUDERA 170 X SJKO-05	2.47**	-0.62**	0.85**	2.30**	1.33**	-2.46**	D

SE±	0.004	0.005	0.02	0.01	0.01`	0.03	
NPHY 39 X No-3	3.65**	-1.29**	-2.35**	-2.04**	-0.99**	4.97**	D
SE±	0.002	0.004	0.01	0.01	0.008	0.02	
NPHY 28 X 141N018XRR9	3.84**	-0.91**	-0.25**	-1.91**	-0.42**	4.09**	D
SE±	0.004	0.01	0.03	0.03	0.01	0.05	
NPHY-38 X LMHS-5	2.72**	2.85**	6.03**	5.50**	1.58**	-4.82**	D
SE±	0.004	0.01	0.02	0.02	0.01	0.04	
POLF-6 X SJKO-55	5.63**	-0.44**	-0.27	0.54**	1.58**	-6.20**	C
SE±	0.02	0.01	0.17	0.12	0.01	0.27	

Table-2 *Contd.*

Crosses	Genetic parameters						Type of epistasis
	M	d	H	I	j	L	
	Oleic acid						
NPHY 29 X LCK 87312	11.22**	15.03**	34.57**	27.90**	10.26**	-13.73**	D
SE±	0.07	0.06	0.90	0.31	0.85	1.74	
NP 121 X RR-76	21.04**	-9.21**	-22.59**	-19.58**	-4.49**	6.87**	C
SE±	0.06	0.09	0.36	0.34	0.09	0.54	
NPRR 271 X No 356	23.61**	0.92**	-13.86**	-6.72**	0.44*	-12.02**	C
SE±	0.007	0.09	0.26	0.18	0.21	0.53	
NPRR 402 X NP 8	21.93**	6.96**	13.10**	9.95**	5.10**	-1.42	D
SE±	0.07	0.13	0.47	0.40	0.29	0.80	
RL-28-1 X L-53	27.33**	-4.70**	-23.23**	-23.31**	-1.64**	24.56**	D
SE±	0.003	0.11	0.29	0.23	0.17	0.58	
AHUDERA 170 X SJKO-05	30.31**	-14.19**	-28.46**	-21.02**	-4.76**	-10.41**	C
SE±	0.07	0.17	0.46	0.46	0.17	0.76	
NPHY 39 X No-3	30.86**	-8.35**	-8.00**	-5.64**	-3.65**	-5.35**	C
SE±	0.04	0.14	0.36	0.34	0.15	0.65	
NPHY 28 X 141N018XRR9	31.03**	-20.94**	-60.87**	-51.05**	-8.83**	27.28**	D
SE±	0.07	0.06	0.32	0.32	0.07	0.40	
NPHY-38 X LMHS-5	15.31**	14.63**	28.60**	20.65**	8.50**	-8.99**	D
SE±	0.002	0.07	0.17	0.14	0.07	0.35	
POLF-6 X SJKO-55	25.91**	-1.31**	-7.67**	-8.46**	-0.26*	4.50**	D
SE±	0.003	0.11	0.23	0.22	0.11	0.46	

Table-2 *Contd.*

Crosses	Genetic parameters						Type of epistasis
	M	d	H	I	j	L	
	Linoleic acid						
NPHY 29 X LCK 87312	25.30**	-1.06	-71.49**	-68.29**	1.52**	70.73**	D
SE±	0.02	0.61	0.46	0.33	0.36	0.92	
NP 121 X RR-76	8.20**	6.51**	20.72**	19.80**	7.10**	-24.12**	D
SE±	0.03	0.21	0.47	0.44	0.24	0.92	
NPRR 271 X No 356	23.07**	9.64**	-3.68**	-12.36**	6.34**	-6.89**	C
SE±	0.05	0.09	0.71	0.27	0.64	1.37	
NPRR 402 X NP 8	16.66**	8.60**	8.14**	8.42**	7.65**	-9.33**	D
SE±	0.21	0.10	0.91	0.88	0.25	1.07	
RL-28-1 X L-53	9.65**	7.42**	14.18**	15.10**	7.72**	-28.75**	D
SE±	0.006	0.20	0.47	0.40	0.31	0.94	
AHUDERA 170 X SJKO-05	7.25**	21.61**	57.79**	57.28**	21.44**	-91.33**	D
SE±	0.07	0.20	0.53	0.50	0.26	0.93	
NPHY 39 X No-3	7.84**	13.46**	23.88**	25.20**	13.48**	-51.37**	D
SE±	0.04	0.17	0.42	0.40	0.20	0.79	
NPHY 28 X 141N018XRR9	10.93**	30.14**	70.49**	58.51**	16.24**	-45.32**	D
SE±	0.08	0.15	0.50	0.44	0.24	0.82	
NPHY-38 X LMHS-5	25.19**	-6.96**	-39.95**	-41.28**	-8.88**	39.61**	D
SE±	0.06	0.09	0.55	0.30	0.11	1.01	
POLF-6 X SJKO-55	17.01**	-3.58**	-32.24**	-27.72**	-5.12**	34.48**	D
SE±	0.03	0.14	0.66	0.32	0.58	1.31	

Table-2 Contd.

Crosses	Genetic parameters						Type of epistasis
	M	d	H	i	j	L	
	Linolenic acid						
NPHY 29 X LCK 87312	56.17**	-12.61**	30.65**	34.48**	-8.77**	-51.98**	D
SE±	0.003	0.08	1.25	0.17	1.24	2.51	
NP 121 X RR-76	61.14**	4.80**	-0.26	-2.72**	1.64**	14.44**	D
SE±	0.04	0.09	0.26	0.24	0.09	0.45	
NPRR 271 X No 356	41.66**	-6.79**	3.63**	9.06**	0.99**	4.26**	C
SE±	0.04	0.10	0.40	0.28	0.28	0.74	
NPRR 402 X NP 8	46.84**	-10.15**	-19.83**	-14.03**	-4.59**	-1.36	C
SE±	0.14	0.15	0.65	0.65	0.15	0.84	

RL-28-1 X L-53	53.24**	1.26**	5.98**	3.84**	0.03	3.84**	C
SE±	0.003	0.14	0.33	0.29	0.22	0.67	
AHUDERA 170 X SJKO-05	53.74**	-5.12**	-35.03**	-41.93**	-13.66**	109.11**	D
SE±	0.06	0.06	0.28	0.27	0.10	0.39	
NPHY 39 X No-3	51.28**	-3.16**	-14.41**	-18.93**	-8.03**	54.41**	D
SE±	0.01	0.05	0.11	0.11	0.05	0.22	
NPHY 28 X 141N018XRR9	45.41**	-6.16**	-8.05**	-3.06**	-1.41**	-7.82**	C
SE±	0.04	0.09	0.28	0.24	0.11	0.47	
NPHY-38 X LMHS-5	25.19**	-6.96**	-39.95**	-41.28**	-8.88**	39.61**	D
SE±	0.06	0.09	0.55	0.30	0.11	1.01	
POLF-6 X SJKO-55	43.43**	5.97**	42.39**	40.39**	3.31**	-38.07**	D
SE±	0.03	0.10	0.24	0.24	0.11	0.45	

The predominance of dominance gene effect was observed in all crosses except NPHY 38 X LMHS-5 and POLF 10 X SJKO 55 was highly positive and significant seed yield per plant (gm). All crosses except NP121 X RR76 was highly negative and significant for oil content (%). Cross NP 121 X RR 76 highly significant negative value while crosses NPHY 29 X LCK 87312, NPRR 271 X No 356, NPRR 402 X NP 8, RL-2-1 X L-53 and AHUDERA 170 X SJKO 55, NPHY 39 X No 3 and NPHY 28 X 141NO18XRR9 was highly positive and significant for protein content (%). All crosses except NPHY 38 X LMHS-5 and POLF 10 X SJKO 55 was highly positive and significant for palmitic acid. Crosses, NPRR 402 X NP 8, RL-28-1 X L-53, NPHY 39 X No 3 and NPHY 28 X 141NO18XRR9 was found with significant negative value for stearic acid. However, crosses NPHY 29 X LCK 87312, NP 121 X RR 76, NPRR 271 X No 356, AHUDERA 170 X SJKO 55 and NPHY 38 X LMHS-5 was highly positive and significant for stearic acid. All crosses except NPHY 29 X LCK 87312, NPRR 402 X NP 8 and NPHY 38 X LMHS- 5 was highly negative and significant for oleic acid. Crosses NPHY 29 X LCK 87312, NPRR 271 X No 356, NPHY 38 X LMHS-5 and POLF 10 X SJKO 55 was highly negative and significant for linoleic acid. However, crosses NP 121 X RR 76, NPRR 402 X NP 8, RL-28-1 X L-53, AHUDERA 170 X SJKO 55, NPHY 39 X No 3, NPHY 28 X 141NO18XRR9 highly positive and significant for linoleic acid. All crosses except NPHY 29 X LCK 87312, NPRR 271 X No 3, RL-28-1 X L-53 and POLF 10 X SJKO 55 was highly negative and significant for inolenic acid. Such observations were also reported by [13].

Among the components of epistatic interactions, additive x additive (i) gene effect was more frequent followed by dominance x dominance (l) and additive x dominance (j) gene effect for most of the characters. The major role of additive x additive gene effect was observed in variable number of crosses, *viz*., seven crosses for seed yield per plant (g), one cross for oil content (%), six crosses for protein content (%), eight crosses for palmitic acid, four crosses for stearic acid, three crosses for oleic acid, six crosses for linoleic acid and four crosses for linolenic acid. The role of dominance x dominance gene effect was observed in nine crosses for seed yield per plant (g), five crosses for oil content (%), two crosses for protein content (%), one cross for palmitic acid, five crosses for stearic acid, three crosses for oleic acid, eight crosses for linoleic acid and three crosses for linolenic acid.

Heterosis and inbreeding depression

The estimates of heterosis over better parent and mid parent in F_1 generation was recorded in percentage and presented in [Table-3]. For Eight Crosses Namely, NPHY 29 X LCK 87312, NP121 X RR 76, NPRR271 X NO 356, RL-28-1 X L-53, AHUDER 170 X SJKO 05, NPHY 39 X NO 3, NPHY 28 X 141NO18XRR9 and POLF 10 X SJKO 55 showed significant positive heterosis for seed yield per plant. crosses, NPHY 29 X LCK 87312, NP121 X RR 76, NPRR271 X NO 356, RL-28-1 X L-53, AHUDERA 170 X SJKO 05, NPHY 39 X NO 3, NPHY 28 X 141NO18XRR9 and NPHYB 38 X LMHS-5 showed significant positive heterosis heterosis over mid parent for seed yield per plant. out of 10 crosses only one cross NPRR 402 X NP 8 showed significant positive heterosis for oil content (%).crosses, NP121 X RR 76, RL-28-1 X L-53, AHUDEARA 170 X SJKO 05, NPHY 39 X NO 3, NPHY 28 X 141NO18XRR9, NPHY 38 LMHS-5 and POLF 10 X SJKO 55 showed significant decrease. out of 10 crosses only two cross NPRR271 X NO 356 and RL-28-1 X L-53 showed significant positive heterosis for protein content (%), crosses, NPRR271 X NO 356 and RL-28-1 X L-53 showed significant positive heterosis over mid parent for protein content (%). crosses NPHY 29 X LCK 87312 and NPHY 38 LMHS-5 showed significant decrease. out of 10 crosses six crosses, NPHY 29 X LCK 87312, NP121 X RR 76, NPRR271 X NO 356, RL-28-1 X L-53, AHUDER 170 X SJKO 05 and NPHY 28 X 141NO18XRR9 showed significant positive heterosis for palmitic acid. crosses, NPRR271 X NO 356, NPRR 402 X NP 8 , RL-28-1 X L-53, AHUDER 170 X SJKO 05 and NPHY 28 X 141NO18XRR9 showed significant positive heterosis over mid parent for palmitic acid. crosses NPHY 39 X NO 3, NPHY 38 LMHS-5 and POLF 10 X SJKO 55 showed significant decrease.

out of 10 crosses six crosses, NP121 X RR 76, NPRR 271 X NO 356, AHUDER 170 X SJKO 05, NPHY 28 X 141NO18XRR9, NPHY 38 X LMHS-5 and POLF 10 X SJKO 55 showed significant positive heterosis for stearic acid. crosses, NP 121 X RR 76, NPRR271X NO 356, NPHY 28 X 141NO18XRR9 and NPHY 38 X LMHS-5 showed significant positive heterosis over mid parent for stearic acid. crosses, NPHY 29 X LCK 87312, NPRR 271 X NO 356, NPRR 402 X NP 8, RL-28-1 X L-53, AHUDEARA 170 X SJKO 05 and POLF 10 X SJKO 55 showed significant decrease.

out of 10 crosses nine crosses, NPHY 29 X LCK 87312, NP121 X RR 76, NPRR 402 X NP 8, RL-28-1 X L-53, AHUDER 170 X SJKO 05, NPHY 39 X NO 3, NPHY 28 X 141NO18XRR9 and POLF 10 X SJKO 55 showed significant positive heterosis for oleic acid. crosses, NPHY 29 X LCK 87312, NPRR 402 X NP 8, NPHY 38 X LMHS-5 and POLF 10 X SJKO 55 showed significant positive heterosis over mid parent for oleic acid. crosses, NP 121 X RR 76, NPRR 271 X NO 356, RL-28-1 X L-53, AHUDEARA 170 X SJKO 05, NPHY 39 X NO 3, NPHY 28 X 141NO18XRR9 and POLF 10 X SJKO 55 showed significant decrease. out of 10 crosses four crosses, NP121 X RR 76, NPRR 271 X NO 356, NPHY 28 X 141NO18XRR9 and NPHY 38 X LMHS-5 55 showed significant positive heterosis for linoleic acid. crosses NPRR 271 X NO 356 and NPHY 28 X 141NO18XRR9 showed significant positive heterosis over mid parent for linoleic acid. crosses, NPHY 29 X LCK 87312, NPRR 271 X NO 356, RL-28-1 X L-53, NPHY 39 X NO 3, NPHY 38 LMHS-5 and POLF 10 X SJKO 55 showed significant decrease. out of 10 crosses six crosses, NP121 X RR 76, NPRR 271 X NO 356, RL-28-1 X L-53, AHUDER 170 X SJKO 05, NPHY 39 X NO 3and POLF 10 X SJKO 55 showed significant positive heterosis for linoleic acid. crosses, NP121 X RR 76, RL-28-1 X L-53, AHUDER 170 X SJKO 05, NPHY 39 X NO 3 and POLF 10 X SJKO 55 showed significant positive heterosis over mid parent for linolenic acid. crosses, NPRR 402 X NP 8, 28 X 141NO18XRR9 and 38 LMHS-5 showed significant decrease. Such observations were reported by [14, 15].

Heritability and genetic advance

High heritability was not present any of them characters, whereas medium heritability was observed in characters like palmitic acid, linoleic acid and linolenic acid, whereas low heritability was observed in characters like seed yield per plant (g), oil content (%), protein content (%), stearic acid and oleic acid. In F_1 generation characters likes palmitic acid and oleic acid exhibited high value of genetic advance, whereas, oil content (%), protein content (%), stearic acid and linoleic acid exhibited moderate value of genetic advance, whereas, seed yield per plant (g) and linolenic acid exhibited low genetic advance. Such observation was also reported [16-19].

Table-3 *Estimates of heterosis over better parents, mid parent and inbreeding depression in percent for 8 quality traits in linseed (Linum usitatissimum L.)*

Crosses combinations	Seed yield per plant (g)			Oil content (%)			Protein content (%)		
	BP	MP	ID	BP	MP	ID	BP	MP	ID
NPHY 29 X LCK 87312	33.59**	21.79*	35.39	0.75	-0.72	1.44	4.18	-0.87	-2.12
NP 121 X RR-76	43.41**	50.42**	41.83	-12.91**	-13.59**	-9.10	10.33**	8.50*	1.42
NPRR 271 X No 356	46.14**	37.16*	24.31	-6.48**	-4.13*	1.31	8.44*	8.22*	3.29
NPRR 402 X NP 8	19.38	10.51	27.37	7.16**	3.13	1.65	1.51	-1.78	4.97
RL-28-1 X L-53	50.57**	18.95*	33.58	-11.18**	-14.37**	-8.90	19.25**	20.69**	11.63
AHUDERA 170 X SJKO-05	27.36**	48.30**	53.37	-4.19*	-4.54*	-3.77	4.80	1.48	4.96
NPHY 39 X No-3	38.80**	18.29*	32.53	-8.49**	-4.94*	-3.15	-3.62	-4.88	1.64
NPHY 28 X 141N018XRR9	24.43*	24.09*	27.20	-6.52**	-7.89**	-5.58	4.51	3.96	0.92
NPHY-38 X LMHS-5	30.40*	20.73*	14.78	2.72	-1.95	-0.92	-2.35	4.59	-0.22
POLF-6 X SJKO-5	9.07	7.77	23.25	-7.87**	-8.30**	-8.09	7.97	5.59	5.87

Table-3 ***Contd.***

Crosses combinations	Palmitic acid			Stearic acid			Oleic acid		
	BP	MP	ID	BP	MP	ID	BP	MP	ID
NPHY 29 X LCK 87312	44.76**	7.70*	36.42	8.66**	-1.05	-4.18	83.73**	36.19**	55.23
NP 121 X RR-76	17.84**	-4.61*	12.27	76.39**	18.46**	27.58	17.41**	-20.84**	-83.57
NPRR 271 X No 356	97.10*	30.07**	63.83	10.95**	4.81**	-91.44	-32.77**	-31.33**	-72.71
NPRR 402 X NP 8	127.22**	40.11**	51.82	-63.36**	-46.60**	-334.66	21.67**	12.62**	22.02
RL-28-1 X L-53	42.13**	18.20**	38.51	-62.41*	-53.08*	-117.99	16.75**	0.36	-25.05
AHUDERA 170 X SJKO-05	84.24**	17.34**	16.15	28.65**	-38.66**	-8.15	17.34**	-35.56**	-124.84
NPHY 39 X No-3	-10.54*	-5.39**	-4.14	-0.35	-7.74**	1.70	10.09**	-8.45**	-20.92
NPHY 28 X 141N018XRR9	90.99**	18.30**	37.72	82.64**	53.87**	18.93	44.60**	-56.99**	-318.57
NPHY-38 X LMHS-5	-11.29	-23.29**	-8.95	65.93**	13.34**	39.95	7.12**	40.96**	44.04
POLF-6 X SJKO-5	6.42	2.33	-10.73	44.62**	-17.09**	-42.77	8.64**	3.52**	-11.67

Table-3 *Contd.*

Crosses combinations	Linoleic acid			Linolinic acid		
	BP	MP	ID	BP	MP	ID
NPHY 29 X LCK 87312	-44.41**	-30.65**	-249.37	0.01	-6.14	3.98
NP 121 X RR-76	13.72*	7.98	34.56	9.51**	3.95**	5.38
NPRR 271 X No 356	158.70**	80.08**	-18.28	5.60*	-10.85**	6.47
NPRR 402 X NP 8	3.75	-1.49	9.45	-23.69**	-13.68**	-28.03
RL-28-1 X L-53	-6.03	-8.73	-1.01	6.17**	3.83**	8.38
AHUDERA 170 X SJKO-05	5.35	3.97	45.54	32.12**	12.18**	15.36
NPHY 39 X No-3	-15.67*	-15.89*	-12.96	19.45**	8.50**	11.09
NPHY 28 X 141N018XRR9	288.62**	52.36**	68.62	-19.79**	-11.22**	-15.16
NPHY-38 X LMHS-5	27.34**	9.60	-66.62	-1.28*	-16.10**	-8.87
POLF-6 X SJKO-5	-38.98**	-32.26*	-78.92	9.23**	3.75**	21.18

Table-4 *Estimates of heritability, genetic advance and genetic advance in percent of mean for 8 quality traits in linseed (Linum usitatissimum L.)*

Characters	Heritability	Population mean		Genetic advance (1%)	Genetic advance in percent of mean
		F1	F2		
Seed yield per plant	0.47	6.95	4.77	0.11	1.89
Oil content (%)	7.40	34.81	35.98	5.73	16.19
Protein content (%)	4.70	16.43	15.88	2.56	15.85
Palmitic acid	16.22	9.89	6.87	3.42	40.81
Stearic acid	8.73	3.31	4.06	4.29	11.65
Oleic acid	9.98	19.71	23.85	20.26	93.02
Linoleic acid	15.46	14.69	15.11	26.87	10.41
Linolinic acid	14.19	52.14	50.01	13.69	2.72

Conclusion

The results of heritability coupled with genetic advance in percent of mean showed that characters palmitic acid, linoleic acid and linolenic acid had moderate heritability among with high genetic advance, palmitic acid and oleic acid. Rest of the traits had low to high heritability with low to moderate genetic gain in generations.

Application of research: 1, 2 sentences

Research Category: Genetics and Plant Breeding

Abbreviations:

Acknowledgement / Funding: Author are thankful to Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh

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Research project name or number: Ph. D Thesis

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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