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Generation mean analysis for grain yield and its related traits in linseed

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Abstract
The present investigation was undertaken to estimate additive and dominance components including epistasis by three parameter model (joint scaling test) and gene action and genetic components by six parameter model for some quantitative and qualitative traits in linseed. The estimates of additive and dominance components through joint scaling test as well as epistasis interaction through six parameter model indicated that additive component has significant role in the expression of number of primary branches per plant, number of seeds per capsule, capsule diameter and test weight indicating that transgressive segregants of these characters can be useful for improvement of these traits in segregating generations. Dominance component played a major role in controlling the expression of number of primary branches per plant, number of seeds per capsule, seed yield per plant, test weight and rust disease reaction.
Among epistatic gene interactions, additive x additive (i) and dominance x dominance (l) interactions effect showed significant impact in comparison to additive x dominance (j) interaction in controlling the expression of plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, capsule diameter, days to maturity, seed yield per plant, oil content, wilt disease reaction and rust disease reaction by additive x additive (i) interaction, days to 50 per cent flowering, plant height, number of capsules per plant and number of seeds per capsule by dominance x dominance (l) interaction and days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, oil content, wilt disease reaction and rust disease reaction by additive x dominance (j) interaction.

Keywords: Generation mean analysis, Joint scaling test, Scaling test, *Linum usitatissimum*

Introduction
Linseed or flax (*Linum usitatissimum* L.) commonly known as alsi or tisi is one of the most important industrial oilseed crops of India. Its seeds contain about 33-45 per cent oil. It is generally unsuitable for culinary purposes due to high linolenic acid content (47-58%) but it is an excellent source for industrial purposes. Its oil is used in manufacturing of surface coating oils, varnish, linoleum, oil cloth, printing inks and similar other products (Choudhary *et al.*, 2016) [5]. Recent discovery is the use of linseed oil in processing of cementing roads in USA (Walsh, 1965).Linseed oil is rich in Omega-3 and Omega-6 fatty acids known to influence blood platelet aggregation, lower the blood cholesterol concentration and prevent coronary heart disease.
Globally, its production is 26.54 lakh tones from an area of 26.25 lakh ha with an average productivity of 1011 kg./ha. India ranks third in area after Canada, Kazakhstan and China but goes down to fourth rank in case of total production. As far as productivity is concerned our national average of 496 kg/ha is surpassed by almost all major linseed growing countries *viz.*, Canada (1405 kg/ha), USA (1323 kg/ha), China (1248 kg/ha) and Kazakhstan (755 kg/ha) (Anonymous, 2016) [1]. In our country the crop occupies 2.84 lakh ha with a production of 1.41 lakh tones culminating in low productivity of 496 kg/ha. India contributes about 10.81 % and 5.31 % to world area and production respectively. The major part of linseed growing area lies in the states of Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Bihar, Odisha, Jharkhand,

West Bengal, Nagaland and Assam accounting for more the 97 % of the nation (Anonymous, 2016) [1].

The main reasons for low productivity of linseed in the country are inherent low yielding capacity of existing varieties, late maturity, and susceptibility of present day's varieties to diseases and pests, lack of stability of yield and cultivation of crop under poor agronomic management on marginal lands. The development of superior varieties than the existing ones mainly depends on judicious selection of promising parents from the gene pool for hybridization to obtain transgressive segregants. Hence, the present investigation was formulated to find out information about additive, dominance and epistasis effects through generation mean analysis in six promising hybrids. Magnitude of dominance × dominance gene action were found maximum in almost all the traits therefore, improvement may be effective by adopting heterosis breeding in further generation.

Materials and Method

The present investigation was undertaken to estimate additive and dominance components including epistasis by three parameter model (joint scaling test) and gene action and genetic components by six parameter model for some quantitative and qualitative traits. The basic materials for the present investigation comprised of five improved varieties of linseed namely, Meera, Shekhar, T-397, KL -221 and JLS -9 through which six crosses as Meera x T-397, Meera x KL-221, Meera x JLS-9, Shekhar x T-397, Shekhar x KL-221 and Shekhar x JLS-9 were made and their different populations *viz.*, F_1s, F_2s, BC_1s, BC_2s were developed and evaluated along with five parents and one check (LC-54) in Randomized Block Design with three replications at experimental area of Plant Breeding and Genetics, BAU, Kanke, Ranchi during *Rabi* 2014-15. Recommended package of practices for linseed were adopted to raise healthy crop. Observations were recorded on 17 characters including quantitative and qualitative traits *i.e.* days to 50 per cent flowering, days to maturity, plant height (cm), number of primary branches per plant, number of capsules per plant, number of seeds per capsule, 1000 seed weight (g), seed yield/ plant (g), oil content (%), fatty acids content in per cent, wilt disease reaction and rust disease reaction. Data were recorded on 10 randomly selected plants from P_1s, P_2s, F_1s and check, 30 from F_2s and 20 from BC_1s, BC_2s. The joint scaling test and generation mean analysis were done following Cavalli (1952) [4] and Hayman (1958) [8] respectively.

Results and Discussion

Estimation of additive and dominance components including epistasis by three parameter model (joint scaling test)

Joint scaling test was applied to test the adequacy of additive-dominance model as well as presence or absence of epistasis. Significance of χ^2 values indicated the evidence of epistasis in respective crosses for the traits under study.

Table-1 exhibited that epistasis was found in almost all the crosses (varying from one to six out of six crosses) for the traits under study. Further, importance of only additive component was realized for plant height in cross Shekhar x KL-221, number of primary branches per plant in crosses Meera x KL-221, Shekhar x T-397 and Shekhar x JLS-9, number of seeds per capsule in crosses Meera x T-397 and Meera x JLS-9, capsule diameter in crosses Meera x JLS-9, Shekhar x T-397 and Shekhar x KL-221, test weight in crosses Meera x KL-221, Shekhar x T-397, Shekhar x KL-221 and Shekhar x JLS-9 and oil content in crosses Meera x T-397 and Shekhar x JLS-9 under study. Major role of additive gene action for these traits are also observed by Patel *et al.* (1997) [14], Propescu *et al.* (1998), Singh (2000) [17], Bhateria *et al.* (2001) [2], Kashyap and Rastogi (2006) [10], Nakhlawy (2006) [12], Sood *et al.* (2007a) [18], Sood *et al.* (2009) [19] and Kiran *et al.* (2012) [11].

In contrast, dominance component was found to be played an important role in different crosses for the expression of traits e.g. days to 50 per cent flowering (Shekhar × JLS-9), plant height (Meera × KL-221), number of primary branches per plant (Meera × KL-221), (Shekhar × T-397) and (Shekhar × JLS-9), number of seeds per capsule (Shekhar × T-397), capsule diameter (Meera × T-397) and (Shekhar × T-397), seed yield per plant (Meera × T-397), test weight (Meera × KL-221), wilt disease reaction (Shekhar × KL-221) and (Shekhar × JLS-9) and rust disease reaction (Meera × JLS-9). Similar findings were reported by Tak (1996), Popescu *et al.* (1998) [15], Rao *et al.* (2001) [16], Gauraha and Rao (2011) [7], Kiran *et al.* (2012) [11] and Pali and Mehta (2014) [13].

However, both additive and dominance (ignoring the sign) components were equally important for the inheritance of yield and few yield contributing traits in all crosses, *viz;* Meera × T-397, Meera × KL-221, Meera × JLS-9, Shekhar × T-397, Shekhar × KL-221 and Shekhar × JLS-9.

However, the relative estimates of two types of gene actions (additive and dominance) varied from cross to cross for same character because of the limitations of this procedure. Firstly, χ^2 estimates cannot be compared at zero degree of freedom and secondly, sequential elimination technique could not be carried out to estimate the actual significant component contributing to the traits in present sets of materials.

Estimation of gene action and genetic components by six parameter model

The knowledge regarding the estimates of relative magnitude of various gene effects including epitasis is of great importance in formulating the most appropriate breeding procedure. Therefore, for those crosses where the joint scaling test suggests the presence of epistasis, six parameter model gives reliable estimates of main gene effects as well as epistatic interactions.

Among epistatic gene interactions, additive × additive (i) and dominance × dominance (l) gene effects were equally more frequent for almost all the traits in respective crosses followed by additive × dominance (j) gene interaction indicating significant role of additive × additive and dominance × dominance gene effects for the expression of traits under study. Further, additive × additive gene effect had got significant effect for the inheritance of some quantitative as well as qualitative trait in different cross combinations for traits i.e. number of primary branches per plant (Meera × T-397), (Meera × JLS-9) and (Shekhar × KL-221), number of capsules per plant (Meera × T-397), (Meera × KL-221), (Meera × JLS-9) and (Shekhar × KL-221), number of seeds per capsule (Meera × KL-221), capsule diameter (Shekhar × JLS-9), seed yield per plant (Meera × KL-221), (Shekhar × T-397), (Shekhar × KL-221) and (Shekhar × JLS-9), oil content (Meera × JLS-9) and (Shekhar × T-397), palmitic acid content (Meera × T-397), (Meera × KL-221), (Meera × JLS-9), (Shekhar × T-397), (Shekhar × KL-221) and (Shekhar × JLS-9), stearic acid content (Meera × T-397), (Meera × KL-221), (Shekhar × T-397) and (Shekhar × KL-221), oleic acid content (Meera × T-397), (Meera × JLS-9), (Shekhar × T-397) and (Shekhar × JLS-9), and linoleic acid content (Meera × T-397), (Meera × KL-221), (Meera × JLS-9), (Shekhar × KL-221) and (Shekhar × JLS-9) whereas additive × additive gene effect exhibited reducing (-) effect for expression of plant height (Meera × JLS-9),days to maturity (Shekhar × KL-221) and (Shekhar × JLS-9), linolenic acid content (Shekhar × KL-221) and (Shekhar × JLS-9), wilt disease reaction (Meera × T-397,) (Meera × KL-221), (Meera × JLS-9), (Shekhar × T-397) and rust disease reaction (Meera × T-397), (Meera × KL-221), (Shekhar × T-397), (Shekhar × KL-221) and (Shekhar × JLS-9). It may be desirable for the isolation of early maturity, high yielding, high oil content and diseases resistant segregates. The results are in conformity with those of Singh (2000) [17], Bhateria *et al*. (2001) [2], Bhateria *et al*. (2006) [3], Kashyap and Rastogi (2006) [10] and Sood *et al.* (2007a) [18].

The additive × dominance (J) gene effect play important role in expression of traits such as days to 50 per cent flowering (Meera × T-397), (Meera × KL-221) and (Shekhar × T-397), plant height (Shekhar × T-397), number of primary branches per plant (Shekhar × KL-221), number of capsules per plant (Meera × T-397), (Meera × KL-221), (Shekhar × T-397) and (Shekhar × KL-221), number of seeds per capsule (Meera × KL-221), days to maturity (Shekhar × KL-221) and (Shekhar × JLS-9), seed yield per plant (Shekhar × T-397), oil content (Meera × KL-221), palmitic acid content (Shekhar × T-397), stearic acid content (Meera × KL-221) and (Shekhar × JLS-9), oleic acid content (Meera × T-397) and (Meera × KL-221), linolenic acid content (Meera × KL-221), (Shekhar × T-397) and (Shekhar × JLS-9), wilt disease reaction (Meera × T-397), (Meera × KL-221), (Meera × JLS-9), (Shekhar × T-397) and rust disease reaction (Meera × T-397), (Meera × KL-221) and (Shekhar × T-397). Similar type of result was also reported by Tak and Gupta (1989) [21], Singh (2000) [17], Bhateria *et al*. (2001) [2], Bhateria *et al*. (2006) [3], Kashyap and Rastogi (2006) [10] and Sood *et al*. (2007a) [18].

The role of dominance × dominance (i) gene effects were observed significant enhancing (+) effects for the inheritance of traits like number of capsules per plant (Shekhar × T-397), number of seeds per capsule (Shekhar × KL-221 and Shekhar × JLS-9), seed yield per plant (Meera × JLS-9), oil content (Meera × KL-221), palmitic acid content (Shekhar × JLS-9), stearic acid content (Shekhar × JLS-9), oleic acid content (Meera × KL-221) and (Shekhar × KL-221) and linoleic acid content (Shekhar × T-397) whereas reducing (-) effects were observed for days to 50 per cent flowering (Meera × T-397), (Meera × KL-221) and (Shekhar × T-397), plant height (Shekhar × T-397), linolenic acid content (all six crosses) and rust disease reaction (Shekhar × KL-221). These findings were also reported by Bhateria *et al*. (2006) [3], Kashyap and Rastogi (2006) [10], Sood *et al.* (2007a) [18], Gauraha and Rao (2011) [7], Pali and Mehta (2014) [13].

From the above observations, it is quite obvious that additive and dominance gene effects appeared to be major contributor for the inheritance of almost all the traits. Further, additive gene effect was mostly positively significant for the expression of yield and yield contributing traits whereas negatively (desirable) significant values were observed for both diseases reaction. In contrast dominance gene effect exhibited reducing (-) effect for the expression of yield and yield contributing traits, under such situation, it is suggested that while handling the segregating population, selection would be more fruitful. It is delayed for some more generations till dominance effects and epitasis are reduced due to selfing.

On the basis of present study it was found that yield and its component characters showed the significance of either of the main gene effects and/or epistatic interactions. The crosses which showed significance of only additive and/or additive × additive gene effects then pedigree or modified pedigree method of selection would be more effective in early segregating generations for the improvements of the characters. On the other hand, if dominance and dominance × dominance gene effects were present in higher magnitude then heterosis breeding may be used for the improvement of the traits. If the presence of large amount of non-additive gene action due to dominance, additive x dominance and dominance x dominance then biparental mating followed by recurrent selection may hasten the rate of genetic improvement for yield and yield attributing traits. Such approach may also be helpful to accumulate desirable genes and facilitate breaking of linkage. For exploiting both additive and non-additive gene effects the diallel selective mating system as suggested by Jensen (1970) [9] and reciprocal recurrent selection may be adopted for developing elite populations and simultaneous selection of high yielding lines of linseed.

Table-1 exhibited that duplicate type of epistasis were recorded for days to 50 per cent flowering, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, capsule diameter, days to maturity, seed yield per plant, test weight, oil content, palmitic acid content, stearic acid content, oleic acid content, linoleic acid content, linolenic acid content, wilt disease reaction and rust disease reaction. On the other complementary gene interaction (epistasis) were observed for traits like number of seeds per capsule, palmitic acid content, stearic acid content, linoleic acid content, linolenic acid content and rust disease reaction whereas none of the cross showed complementary epistasis. Similar finding were observed by Comstock *et al*. (1948) [6] is likely to be useful for the effective utilization of additive and non-additive gene effects. Singh (2000) [17], Rao *et al*. (2001) [16], Kashyap and Rastogi (2006) [10], Nakhlawy (2006) [12], Gauraha and Rao (2011) [7], Kiran *et al*. (2012) [11], Pali and Mehta (2014) [13] have also reported similar findings in linseed.

Table 1: Joint scaling test and estimates of gene effects based on six parameter model for seventeen qualitative and quantitative yield attributing characters in linseed.

Traits	Cross	Joint scaling test (3 parameter model)			χ^2	Six parameter model						Epistasis
		m	d	h		m	d	h	i	j	l	
Days to 50 % flowering	Meera x T-397	64.83**	5.17**	30.17**	36.97**	74.33**	-10.67**	7.83**	12.00**	-15.83**	-22.33**	D
	Meera x KL-221	60.17**	3.17**	39.17**	43.26**	73.67**	-7.33**	14.83**	18.67**	-10.50**	-24.33**	D
	Meera x JLS-9	68.00**	4.00**	10.67*	0.14	--	--	--	---	--	--	--
	Shekhar x T-397	58.83**	2.50**	47.17**	4.78*	74.67**	1.00**	16.17**	15.33**	-1.50*	-31.00**	D
	Shekhar x KL-221	74.17**	0.50	2.50	1.13	--	--	--	---	--	--	--
	Shekhar x JLS-9	88.67**	1.33**	-41.00**	0.01	--	--	--	---	--	--	--
Plant height	Meera x T-397	55.17**	4.07**	3.90*	1.76	--	--	--	--	--	--	--

	Meera x KL-221	65.45**	8.38**	-13.82*	0.73	--	--	--	--	--	--	--
	Meera x JLS-9	74.22**	11.08**	-33.32**	6.93**	61.93**	0.50**	-15.82**	-13.40**	-10.58**	17.50**	D
	Shekhar x T-397	45.30**	-6.67**	31.23**	11.19**	56.87**	-0.97	15.03**	11.80**	5.70*	-16.20**	D
	Shekhar x KL-221	50.12**	-2.35**	18.32**	1.28	--	--	--	--	---	--	-
	Shekhar x JLS-9	54.62**	0.35	-7.32	1.30	--	--	--	--	--	--	--
No. of primary branches per plant	Meera x T-397	-1.53**	1.00**	13.57**	15.74**	4.03**	1.87**	8.70**	6.13**	0.87	-4.87**	D
	Meera x KL-221	0.77**	1.10**	5.80**	0.15	--	--	--	--	--	--	--
	Meera x JLS-9	-0.85*	1.18**	11.28**	4.21*	3.97**	2.17**	7.98**	5.27**	0.98	-3.30**	D
	Shekhar x T-397	2.63**	0.30**	4.50**	0.75	--	--	--	--	--	--	--
	Shekhar x KL-221	1.00**	0.40**	6.93**	6.98**	3.93**	2.20**	4.80**	2.80**	1.80*	-2.13**	D
	Shekhar x JLS-9	2.52**	0.48**	2.68**	1.56	--	--	--	--	--	--	--
No. of capsules per plant	Meera x T-397	-16.03**	6.17**	179.43**	8.22**	55.67**	27.17**	107.37**	81.27**	21.00**	-72.07**	D
	Meera x KL-221	-17.27**	6.93**	179.10**	18.36**	53.07**	15.73**	102.23**	81.73**	8.80**	-76.87**	D
	Meera x JLS-9	-4.00	4.07**	128.03**	2.54*	3.97**	2.17**	7.98**	5.27**	0.98	-3.30**	D
	Shekhar x T-397	119.80**	2.80**	-97.80**	14.45**	88.30**	25.77**	-28.20**	-57.93**	22.97**	69.60**	D
	Shekhar x KL-221	6.97*	3.57**	129.77**	4.04*	58.80**	21.40**	77.57**	54.13**	17.83**	-52.20**	D
	Shekhar x JLS-9	90.23**	0.70	-95.20**	0.48	--	--	--	--	--	--	--
No. of seeds per capsule	Meera x T-397	7.00**	0.27**	-0.53	1.39	--	--	--	--	--	--	--
	Meera x KL-221	8.60**	0.27**	-5.80**	14.53**	51.07**	15.73**	102.23**	81.73**	8.80**	-76.87**	D
	Meera x JLS-9	6.83**	0.30**	-1.77*	0.19	--	--	--	--	--	--	--
	Shekhar x T-397	5.17**	0.10	3.37**	1.58	--	--	--	--	--	--	--
	Shekhar x KL-221	6.70**	0.10	-1.43	3.49*	6.51**	0.07	0.77**	-0.13	-0.03	2.20**	C
	Shekhar x JLS-9	8.27**	0.13*	-5.33**	5.04*	6.33**	-0.07	-2.40**	-1.73**	-0.20	2.93**	D
Capsule diameter (mm)	Meera x T-397	3.98**	0.62	5.02**	0.12	--	--	--	--	--	--	--
	Meera x KL-221	10.07**	0.13	-4.37**	1.18	--	--	--	--	--	--	--
	Meera x JLS-9	7.22**	0.32**	0.72	0.24	--	--	--	--	--	--	--
	Shekhar x T-397	6.32**	0.82**	2.65**	1.81	--	--	--	--	--	--	--
	Shekhar x KL-221	6.87**	0.33**	-0.43	0.33	--	--	--	--	--	--	--
	Shekhar x JLS-9	3.42**	0.52**	8.35**	17.41**	6.83**	0.10	5.32**	4.60**	-0.42	-3.03**	D
Days to maturity	Meera x T-397	129.17**	5.17**	-0.17	0.46	--	--	--	--	--	--	--
	Meera x KL-221	122.00**	7.00**	15.00**	1.74	--	--	--	--	--	--	--
	Meera x JLS-9	129.83**	7.17**	-7.17	0.46	--	--	--	--	--	--	--
	Shekhar x T-397	129.67**	5.00**	-3.33	1.92	--	--	--	--	--	--	--
	Shekhar x KL-221	134.50**	6.83**	-21.83**	11.29**	126.67**	-3.67**	-9.50**	-6.00**	-10.50**	12.33**	D
	Shekhar x JLS-9	133.00**	7.00**	-29.33**	11.15**	123.00**	-1.67**	-10.67**	-4.67**	-8.67**	18.67**	D
Seed yield per plant (g)	Meera x T-397	1.78**	0.25	8.85**	1.48	--	--	--	--	--	--	--
	Meera x KL-221	-2.10**	0.67**	16.87**	10.96**	4.63**	3.37**	10.07**	7.27**	2.70	-6.80**	D
	Meera x JLS-9	-4.78**	0.82**	21.08**	24.01**	129.00**	-5.33**	3.83	-1.33	-12.50**	11.00**	_
	Shekhar x T-397	-5.83**	0.10**	21.07**	10.44**	3.27**	4.57**	15.33**	11.27**	4.47*	-5.73**	D
	Shekhar x KL-221	-1.58*	0.52**	11.98**	3.02*	3.30**	-0.03	7.55**	6.60**	-0.55	-4.43**	D
	Shekhar x JLS-9	-2.60**	0.67**	15.30**	61.70**	3.20**	-0.60**	7.90**	7.47**	-1.27	-7.40**	D
Test weight (g)	Meera x T-397	9.13**	0.40**	-3.33**	4.08*	8.07**	0.60**	-0.93**	-0.93**	0.20	2.40**	D
	Meera x KL-221	5.63**	0.63**	4.03**	1.64	--	--	--	--	--	--	--
	Meera x JLS-9	9.68**	0.52**	-5.92**	5.79*	7.73**	0.07**	-1.88**	-1.60*	-0.45	4.03**	D
	Shekhar x T-397	6.68**	0.15**	0.32	0.18	--	--	--	--	--	--	--
	Shekhar x KL-221	6.72**	0.38**	-0.95	0.75	--	--	--	--	--	--	--
	Shekhar x JLS-9	8.57**	0.27**	-4.40**	1.90	--	--	--	--	--	--	--
Oil content (%)	Meera x T-397	36.02**	0.25**	-0.32	0.32	--	--	--	--	--	--	--
	Meera x KL-221	37.65**	0.75**	-4.05**	24.06**	36.10**	3.50**	-2.15**	-1.40**	2.75*	1.90**	D
	Meera x JLS-9	31.17**	0.50**	15.17**	34.80**	36.17**	-3.00**	4.83**	5.33**	-3.50**	-10.33**	D
	Shekhar x T-397	24.42**	0.25**	33.05**	21.75**	35.67**	-2.50**	11.95**	12.33**	-2.75**	-21.10**	D
	Shekhar x KL-221	32.25**	0.75**	8.75**	69.72**	35.50**	-3.00**	4.25**	4.00	-3.75	-4.50	--
	Shekhar x JLS-9	36.17**	0.50**	-0.17	1.87	--	--	--	--	--	--	--
Palmitic acid content (%)	Meera x T-397	-1.77**	-0.26**	21.83**	533.89**	7.61**	-1.62**	15.69**	14.58**	-1.37	-6.13**	D
	Meera x KL-221	-3.42**	2.69**	31.21**	3571.75**	6.78**	-7.70**	9.60**	13.28**	-10.39**	-21.61**	D
	Meera x JLS-9	-24.13**	2.69**	96.52**	3826.15**	7.83**	1.14**	31.33**	34.00**	-1.55	-65.19**	D
	Shekhar x T-397	-0.79**	-0.75**	16.23**	181.54**	5.17**	3.51**	7.61**	13.11**	4.25**	-8.63**	D
	Shekhar x KL-221	-6.27**	2.20**	33.47**	8212.57**	5.34**	4.39**	12.98**	15.65**	2.19	-20.49**	D
	Shekhar x JLS-9	6.39**	2.20**	-1.82**	180.38**	6.67**	-1.23**	2.92**	2.99**	-3.42*	4.74**	C
Stearic acid content (%)	Meera x T-397	-26.78**	-0.18**	91.75**	283.40**	4.10**	2.05**	31.77**	32.30**	2.23	-59.99**	D
	Meera x KL-221	-21.91**	-3.07**	78.73**	89851.57**	5.57**	1.91**	31.21**	30.32**	4.98**	-47.53**	D
	Meera x JLS-9	25.37**	-3.30**	-14.87**	257.30**	17.65**	-6.52**	-16.03**	-16.73**	-3.21*	-1.16**	C
	Shekhar x T-397	2.00**	-0.10**	6.36**	63.68**	4.60**	2.40**	4.06**	3.61**	2.50	-2.30**	D
	Shekhar x KL-221	-6.43**	-2.98**	34.59**	13766.82**	4.88**	-5.41**	10.65**	14.92**	-2.42	-23.95**	D
	Shekhar x JLS-9	11.21**	-3.22**	-24.65**	2332.57**	5.47**	1.29**	1.69**	-2.48**	4.51**	26.34**	C
Oleic acid contents (%)	Meera x T-397	-8.67**	-0.23**	60.62**	320.45**	11.81**	12.23**	21.30**	26.63**	12.46**	-39.32**	D
	Meera x KL-221	38.75**	-6.57**	-48.19**	50682.76**	23.44**	7.55**	-13.06**	-14.45**	14.11**	35.14**	D
	Meera x JLS-9	-26.85**	2.50**	118.19**	40375.13**	14.99**	-3.54**	49.18**	42.09**	-6.04**	-69.01**	D
	Shekhar x T-397	9.63**	2.15**	29.20**	17336.03**	20.51**	-0.76**	14.32**	10.71**	-2.91	-14.89**	D
	Shekhar x KL-221	34.35**	-4.19**	-28.45**	19706.33**	24.03**	-15.86**	-12.84**	-7.67**	-11.68**	15.61**	D
	Shekhar x JLS-9	-21.25**	4.88**	109.07**	129683.95**	14.24**	-6.05**	32.88**	38.86**	-10.93**	-76.19**	D
Linoleic acid content (%)	Meera x T-397	-13.56**	1.38**	71.86**	3676.95**	10.39**	-7.33**	23.95**	28.37**	-8.71**	-47.90**	D
	Meera x KL-221	3.81**	0.79**	29.07**	580.73**	12.81**	-4.60**	6.96**	11.60**	-5.39**	-22.11**	D
	Meera x JLS-9	-15.52**	-0.73**	96.67**	1104.72**	16.98**	-2.78**	33.34**	32.45**	-2.04	-63.32**	D
	Shekhar x T-397	14.59**	-0.32**	-1.85**	61.87**	14.21**	1.27**	0.33**	-1.49**	1.59	2.18**	C
	Shekhar x KL-221	-1.59**	-0.92**	31.90**	361.62**	10.77**	0.10**	17.54**	15.29**	1.02	-14.35**	D

	Shekhar x JLS-9	3.22**	-2.44**	26.29**	1512.62**	13.59**	0.04	15.19**	11.99**	2.47	-11.10**	D
Linolenic acid contents (%)	Meera x T-397	40.54**	-0.27**	20.20**	25.48**	48.11**	0.71**	10.07**	8.37**	0.98	-10.13**	D
	Meera x KL-221	27.24**	1.87**	36.38**	827.13**	41.91**	-11.79**	22.29**	19.53**	-13.65**	-14.08**	D
	Meera x JLS-9	-57.88**	-0.14*	237.97**	4.30*	24.78**	1.09**	92.65**	106.65**	1.23	-145.32**	D
	Shekhar x T-397	36.32**	-3.28**	42.01**	3342.06**	50.47**	-6.94**	14.58**	9.58**	-3.66*	-27.43**	D
	Shekhar x KL-221	50.09**	-1.14**	11.13**	329.31**	51.78**	4.34**	-4.39**	-6.33**	5.48**	-15.52**	C
	Shekhar x JLS-9	58.18**	-3.14**	-3.20**	78.72**	55.05**	-15.21**	-9.32**	-12.41**	-12.07**	-6.12**	C
Wilt-disease reaction (%).)	Meera x T-397	99.00**	1.00*	-146.67**	4.88*	40.00**	-27.67**	-89.33**	-64.67**	-28.67**	57.33**	D
	Meera x KL-221	105.17**	1.50*	-153.83**	5.39*	43.33**	-30.33**	-93.50**	-71.33**	-31.83**	60.33**	D
	Meera x JLS-9	116.67**	1.33**	-166.00**	9.47**	53.33**	-20.00**	-87.33**	-82.67**	-21.33**	78.67**	D
	Shekhar x T-397	161.17**	-0.83**	-276.50**	7.71**	54.00**	-21.67**	-152.16**	-128.67**	-20.83**	124.33**	D
	Shekhar x KL-221	93.33**	-0.33	-99.67**	0.37	--	--	--	--	--	--	--
	Shekhar x JLS-9	78.83**	-0.50	-48.83**	4.05	--	--	--	--	--	--	--
Rust-Disease reaction (%).)	Meera x T-397	83.83**	1.17*	-135.17**	5.73*	31.67**	-19.67**	-73.50**	-50.00**	-20.83**	61.67**	D
	Meera x KL-221	70.83**	-1.17**	-92.17**	7.56**	33.33**	-29.33**	-57.83**	-34.67**	-28.17**	34.33**	D
	Meera x JLS-9	50.00**	0.33	-30.67**	1.13	--	--	--	--	--	--	--
	Shekhar x T-397	109.17**	-2.17**	-177.50**	13.92**	40.00**	-21.33**	-99.17**	-78.67**	-19.17*	78.33**	D
	Shekhar x KL-221	44.83**	-4.50**	-13.83*	3.83*	36.67**	-2.67	-18.83**	-12.00*	1.83	-5.00*	C
	Shekhar x JLS-9	65.33**	-3.00**	-60.67**	4.95*	40.67**	-1.00	-38.00**	-34.00**	2.00	22.67**	D

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