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Combining Ability Analysis for Yield Component and Biochemical Traits in Soybean [*Glycine max* (L.) Merrill]

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A B S T R A C T

An investigation was taken up in soybean involving a set of five ovule parents (BRAGG, RKS 18, Co 2, Co (Soy) 3 and JS 335) and five pollen parents (LPA 5-1, LPA 5-2, LPA 5-3, LPA 13-1 and LPA 18) crossed in a line × tester mating fashion to study the general and specific combining ability and the gene action determining the yield component and biochemical traits. The lines are normal in phytic acid content. However, testers are low in phytic acid content. Twenty five crosses were made between these lines and testers in order to know the genetics of yield component and biochemical traits, during *Kharif*, 2013-14. Individual cross combinations along with their parents were studied for 13 characters during *Rabi* 2014. While comparing the performance of parents for *per se* and *gca* effects for low phytic acid content and yield components Co (Soy) 3 and LPA 5-2 were considered as superior parents for breeding programme. The crosses RKS 18 × LPA 5-2, Co (Soy) 3 × LPA 5-2 and Co (Soy) 3 × LPA 5-1, Co (Soy) 3 × LPA 13-1 exhibited superior *per se* performance and one of the parent possessed good general combining ability for yield component and biochemical traits which indicates additive type of gene action.

Introduction

Soybean is one of the most important legumes in many countries of the world which has been given recent predominance because of its broader utility and versatility for both human and animal nutrition. So, there is a need to increase the yield by selection of parents having good potentiality for yield and its related characters. The selection of suitable parents for an efficient breeding programme, the breeder has to know the genetic information especially about the nature of combining ability and the type of gene action governing the inheritance of economically important quantitative characters. Combining ability of genotypes gives essential information to select the genotypes as parents to produce better segregants and the knowledge of the type of gene action involved in the expression of yield and yield components is essential to choose an appropriate breeding strategy to isolate desirable segregants in the later generations. Therefore, the present investigation was taken up to study the combining ability parents for yield component and biochemical traits in soybean.

Materials and Methods

Five ovule parents *viz.,* BRAGG, RKS 18, Co 2, Co (Soy)3 and JS 335 and five pollen parents, *viz.,* LPA 5-1, LPA 5-2, LPA 5-3, LPA 13-1 and LPA 18 were raised in two staggered sowing at 3 days interval in order to achieve programmed pollination in the crossing block at the Department of Pulses, Tamil Nadu Agricultural University, Coimbatore during *Rabi,* 2013-14. The lines are normal in phytic acid content and testers are low in phytic acid content.

Female parents were raised in five rows of four meter length with a spacing of 60×30 cm in order to ensure good growth and profuse flowering and fruiting.

Males were raised in two rows of four meter length by adopting a spacing of 30×15 cm. Crosses were made between these lines and testers in order to develop low phytic acid genotypes with high yield.

The parents were crossed in line × tester mating fashion to synthesize 25 F_1s. Crossed pods were collected and forwarded for F_1 evaluation.

Five plants were randomly selected in F_1s and their parents in each replication and observations were recorded for days to 50 per cent flowering, days to maturity, plant height (cm), number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, 100-seed weight (g), seed yield per plant (g), harvest index (%), phytic acid content (mg/g), Protein content (%) and Oil content (%). The mean values of five plants were utilized for estimation of general combining ability of parents and specific combining ability of hybrids for grain yield and its component traits using the Line x Tester analysis as suggested by Kempthorne (1957).

Results and Discussion

Analysis of variance indicated the presence of significant differences among genotypes for all the characters studied (Table 1). Significant variances were observed among hybrids and parents for all the characters. Higher magnitude of variance in case of hybrids as compared to parents had been observed for most of the characters indicating the presence of positive heterosis. However, negative heterosis is also desirable and observed for some characters *viz.,* days to 50 per cent flowering, days to maturity and phytic acid content.

Analysis of variance for combining ability analysis (Table 2) indicated the presence of significant differences among the lines for all the characters studied except for days to maturity whereas significant differences were observed among the testers for all the characters except for days to 50 per cent flowering. While, significant differences were observed among the line × tester interaction for all the characters except for days to 50 per cent flowering and days to maturity. The significant variance of line × tester interaction indicated the preponderance of specific combining ability. The results showed the presence of considerable variability among the hybrids rather than among the lines and testers. Hence it is possible to select superior hybrids with high yield.

The magnitude of specific combining ability variances was much greater than those of general combining ability variances for all the characters studied except days to 50 per cent flowering indicating the preponderance of non-additive gene action in the expression of these traits (Table 3). Hence improvement of these yield related characters could be accomplished by selection at later filial generations. Similar results were observed by Mahesh *et al.,* (2014).

Choice of parents

The *per se* performance was considered as the first important criterion for evaluation. The *per se* performances of parents for yield components and biochemical traits were compared with general mean (Table 4). Based on *per se*, the line parents RKS 18 and Co (Soy) 3 recorded significantly superior mean for plant height, number of clusters per plant, number of pods per plant, seed yield per plant, harvest index and oil content.

Among the tester parent, LPA 5-1 recorded superior mean for plant height, number of clusters per plant, number of pods per plant, hundred seed weight, seed yield per plant and oil content and the parent LPA 5-2 exhibited the similar performance for number of clusters per plant, number of pods per plant, seed yield per plant, protein content and oil content. Hence the parents RKS 18, Co (Soy) 3, LPA 5-1, LPA 5-2 were considered as more superior than other parents for yield components and biochemical traits and were considered as desirable for recombination breeding.

The second criterion for selection is the general combining ability (*gca*) effects of the parents which is a factor that predicts the average performance of a line in a number of hybrid combinations (Table 5). Combining ability always decides the breeding value or genetic worth of the parent. The estimates of *gca* effect showed that among the lines, RKS 18 was found to be superior as it showed significant and positive *gca* effect plant height, number of branches per plant, number of clusters per plant, number of pods per plant, hundred seed weight, seed yield per plant, harvest index and oil content. The line parent Co (Soy) 3 was a good general combiner for plant height, number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, hundred seed weight, seed yield per plant, harvest index, protein content and oil content, however, it recorded significant negative *gca* effect for phytic acid content. Among the tester parents, LPA 5-1 recorded significant positive *gca* effect for plant height, number of clusters per plant, number of pods per plant, hundred seed weight, seed yield per plant, and oil content while LPA 5-2 for number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, hundred seed weight, seed yield per plant, harvest index, protein content and oil content, however, it recorded significant negative *gca* effect for phytic acid content.

Selection of parents based on *per se* performance and *gca* effects is of great importance in breeding programmes, because it provides useful information on the choice of parents in terms of expected performance of hybrids and progenies (Dhillon, 1975). While comparing the performance of parents for *per se* and *gca* effects for low phytic acid content and yield components Co (Soy) 3 and LPA 5-2 were considered as superior parents for breeding programme.

Choice of crosses

The specific combining ability (*sca*) effect alone may not be the appropriate choice for exploitation of heterosis because the hybrid with low mean value may also possess high *sca* effect. Hence, the cross combinations were identified based on two criteria *viz.*, *per se* performance and the gene action involved in the crosses for further exploitation.

Based on *per se* performance for various traits, the crosses *viz.*, RKS 18 × LPA 5-2 Co (Soy) 3 × LPA 5-2, Co (Soy) 3 × LPA 5-1 and Co (Soy) 3 × LPA 13-1 were considered as desirable crosses for yield along with low phytic acid content (Table 6).

Table.1 Analysis of variance for parents and hybrids for yield and yield related traits in soybean

Source	Df	Days to 50 per cent flowering	Days to maturity	Plant height	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield per plant	Harvest index	Phytic acid content	Protein content	Oil content
Hybrids	24	7.75*	13.98**	99.21**	1.51**	58.92**	1248.45**	0.06**	2.84**	139.78**	54.21**	1.85**	4.72**	8.44**
Parents	9	8.89*	24.56**	263.75**	1.29**	70.55**	1663.32**	0.11**	1.36**	55.47**	31.26**	6.13**	4.47**	2.41**
Hybrids *vs* Parents	1	33.44**	67.27**	8.38	6.04**	39.18**	192.62**	0.00	0.38	15.05**	168.54**	2.18**	0.65	2.13**
Error	34	4.09	3.77	4.37	0.09	1.35	8.32	0.01	0.15	2.06	3.91	0.04	0.24	0.12

*, ** Significant at 5 % and 1 % level of probability, respectively.

Table.2 Analysis of variance for combining ability analysis for yield and yield related traits in soybean

Source	df	Days to 50 per cent flowering	Days to maturity	Plant height	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield per plant	Harvest index	Phytic acid content	Protein content	Oil content
Lines	4	26.72**	12.77	406.15**	4.53**	241.18**	4659.70**	0.04*	10.18**	427.32**	154.46**	3.55**	4.12**	33.90**
Testers	4	10.22	41.57**	117.95**	2.99**	68.50**	1835.44**	0.06**	1.37**	207.39**	130.08**	2.75**	9.36**	6.61**
L × T	16	2.38	7.38	17.79**	0.38**	10.97**	248.89**	0.06**	1.37**	50.99**	10.19**	1.19**	3.72**	2.54**
Error	24	5.42	4.75	5.42	0.11	1.04	9.42	0.01	0.14	2.18	4.19	0.04	0.27	0.11

*, ** Significant at 5 % and 1 % level of probability, respectively.

Table.3 Magnitude of combining ability variance for yield and yield related traits in soybean

Characters	GCA	SCA	GCA/SCA
Days to 50 per cent flowering	0.20	-1.52	-0.13
Days to maturity	0.25	1.32	0.19
Plant height	3.05	6.19	0.49
Number of branches per plant	0.04	0.13	0.31
Number of clusters per plant	1.80	4.96	0.36
Number of pods per plant	37.48	119.73	0.31
Number of seeds per pod	-0.01	0.02	-0.41
Hundred seed weight	0.06	0.61	0.09
Seed yield per plant	3.33	24.40	0.14
Harvest index	1.65	3.00	0.55
Phytic acid content	0.02	0.58	0.04
Protein content	0.04	1.72	0.02
Oil content	0.22	1.21	0.18

Table.4 *Per se* performance of parents for yield and yield related traits in soybean

Parents	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight (g)	Seed yield per plant (g)	Harvest index	Phytic acid content (mg/g)	Protein content (%)	Oil content (%)
Lines													
BRAGG	33.00[a]	85.50[a]	26.10	5.20	16.10	67.40	2.30[a]	9.85	14.92	0.50[a]	5.11	35.94	17.34[a]
RKS 18	36.00[a]	89.00	50.00**	6.20[a]	27.60**	119.70**	2.00[a]	11.30[a]	26.05**	0.57*	6.23	33.91	18.27**
Co 2	33.50[a]	88.00	23.60	5.30	13.60	59.60	2.00[a]	10.33[a]	12.53	0.49[a]	5.10	37.00[a]	16.96[a]
Co (Soy) 3	36.00[a]	86.00[a]	49.60**	6.10[a]	26.00**	117.30**	2.00[a]	11.03[a]	25.27**	0.55[a]	6.03	36.14[a]	18.56**
JS 335	30.50[a]	79.50[a]	24.90	4.70	12.40	50.50	2.50**	11.07[a]	13.84	0.46	5.29	38.44*	16.27
Testers													
LPA 5-1	35.50[a]	82.50[a]	51.80**	6.30[a]	27.20**	121.30**	2.10[a]	11.99*	24.48**	0.54[a]	2.02**	36.90[a]	19.05**
LPA 5-2	36.00[a]	84.00[a]	34.20[a]	5.90[a]	25.60**	104.00**	2.00[a]	10.96[a]	22.73*	0.52[a]	1.90**	38.77**	18.19**
LPA 5-3	36.50[a]	83.00[a]	37.40[a]	5.70[a]	17.60	75.90	2.00[a]	10.73[a]	15.67	0.46	2.73**	38.35*	16.98[a]
LPA 13-1	35.00[a]	86.00[a]	42.20**	5.80[a]	19.20[a]	87.50[a]	2.00[a]	10.95[a]	18.10[a]	0.49	3.06**	37.70[a]	17.82[a]
LPA 18	31.50[a]	78.00*	24.20	3.70	15.50	48.60	2.60**	12.82**	14.53	0.46	2.11**	38.12[a]	15.49
General mean	33.26	82.60	35.85	5.95	21.26	87.80	2.14	10.98	19.54	0.53	3.68	37.28	17.22
S.E.	1.43	1.37	1.48	0.21	0.82	2.04	0.07	0.27	1.02	1.4	0.14	0.35	0.25
CD (P=0.05)	4.07	3.90	4.20	0.60	2.34	5.80	0.21	0.78	2.89	3.97	0.39	0.98	0.70
CD (P=0.01)	5.42	5.20	5.60	0.80	3.12	7.73	0.28	1.03	3.85	5.30	0.52	1.31	0.94

[a] and *,** On par and significantly superior than the general mean at 5 %, 1 % level of probability, respectively.

Table.5 Estimates of general combining ability (*gca*) effects for yield and yield related traits in soybean

Parents	Days to 50 per cent flowering	Days to maturity	Plant height	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield per plant	Harvest index	Phytic acid content	Protein content	Oil content
Lines													
BRAGG	0.38	0.42	-6.36 **	-0.90 **	-3.42 **	-14.33 **	-0.06	-1.68 **	-6.65 **	-4.77 **	0.82 **	-0.15	-1.97 **
RKS 18	0.78	1.32	6.43 **	0.56 **	4.88 **	20.79 **	0.00	0.33 **	5.23 **	3.54 **	0.41 **	0.04	1.71 **
Co 2	1.38	0.62	-3.41 **	0.08	-3.84 **	-15.21 **	-0.06	-0.09	-3.92 **	0.09	-0.35 **	-0.32	-1.00 **
Co (Soy) 3	0.28	-1.08	7.31 **	0.70 **	5.84 **	26.25 **	0.10 **	0.93 **	8.58 **	4.16 **	-0.65 **	1.06 **	2.21 **
JS 335	-2.82 **	-1.28	-3.95 **	-0.44 **	-3.48 **	-17.49 **	0.00	0.51 **	-3.24 **	-3.03 **	-0.23 **	-0.63 **	-0.94 **
Testers													
LPA 5-1	-0.62	0.52	1.81 *	0.06	1.62 **	6.79 **	-0.04	0.36 **	1.68 **	0.57	0.32 **	0.28	0.11
LPA 5-2	0.18	-0.88	-1.74 *	0.60 **	2.96 **	14.01 **	0.12 **	0.43 **	6.20 **	4.84 **	-0.84 **	1.09 **	0.68 **
LPA 5-3	1.68 *	2.02 **	1.23	0.24 *	0.04	0.33	-0.06	-0.15	-0.09	-0.11	-0.02	0.56 **	0.44 **
LPA 13-1	-0.82	1.42 *	3.75 **	-0.02	-0.70 *	1.03	-0.06	-0.26 *	-1.52 **	0.03	0.54 **	-0.60 **	0.15
LPA 18	-0.42	-3.08 **	-5.03 **	-0.88 **	-3.94 **	-22.15 **	0.02	-0.38 **	-6.27 **	-5.32 **	0.00	-1.34 **	-1.39 **
S.E. (*gca* effects)	0.74	0.69	0.74	0.10	0.32	0.97	0.04	0.12	0.47	0.65	0.06	0.17	0.10

*, ** Significant at 5 % and 1 % level of probability, respectively.

Table.6 *Per se* performance of hybrids for yield and yield related traits in soybean

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight (g)	Seed yield per plant (g)	Harvest index	Phytic acid content (mg/g)	Protein content (%)	Oil content (%)
BRAGG X LPA 5-1	33.50[a]	80.50[a]	33.00[a]	5.30	18.70	72.50	2.10[a]	11.36[a]	16.38	0.49	4.22	36.03	16.08
BRAGG X LPA 5-2	34.00[a]	83.00[a]	24.85	5.50[a]	18.60	76.50	2.00[a]	8.64	12.59	0.54[a]	3.74[a]	36.23	15.01
BRAGG X LPA 5-3	36.50[a]	86.00[a]	28.10	5.30	19.50[a]	76.30	2.00[a]	9.13	12.68	0.48	4.86	37.39[a]	14.52
BRAGG X LPA 13-1	31.00[a]	85.50[a]	34.60[a]	5.20	17.90	80.50	2.00[a]	9.12	13.21	0.49[a]	5.04	37.83[a]	15.45
BRAGG X LPA 18	31.00[a]	77.00**	25.80	4.90	16.90	66.80	2.30[a]	8.05	11.07	0.45	4.05[a]	38.47*	14.63
RKS 18 X LPA 5-1	33.00[a]	84.50[a]	43.30**	6.70*	29.60**	126.80**	2.00[a]	10.98[a]	26.36**	0.58*	5.01	38.73**	18.32**
RKS 18 X LPA 5-2	32.50[a]	79.00[a]	43.20**	7.60**	33.30**	138.20**	2.50**	12.87**	39.59**	0.64**	2.26**	39.70**	20.31**
RKS 18 X LPA 5-3	34.50[a]	85.50[a]	43.40**	6.80**	26.60**	102.50**	2.10[a]	11.40[a]	23.95**	0.57*	2.72**	37.75[a]	19.73**
RKS 18 X LPA 13-1	33.50[a]	87.00	47.90**	6.30[a]	24.50**	105.20**	2.00[a]	10.61[a]	20.85[a]	0.56[a]	5.66	35.68	18.76**
RKS 18 X LPA 18	34.50[a]	80.50[a]	32.50	6.10[a]	19.10[a]	75.50	2.10[a]	10.50[a]	14.58	0.51[a]	4.19	35.03	16.97[a]
Co 2 X LPA 5-1	33.50[a]	84.50[a]	37.60[a]	6.40[a]	18.50	76.90	2.00[a]	10.66[a]	15.69	0.53[a]	4.01[a]	38.45*	16.58[a]
Co 2 X LPA 5-2	33.50[a]	83.50[a]	25.70	6.50	17.30	71.80	2.00[a]	10.28[a]	14.61	0.55[a]	3.16**	37.17[a]	15.09
Co 2 X LPA 5-3	36.00[a]	84.50[a]	35.50[a]	6.80**	20.70[a]	89.70[a]	2.30[a]	11.35[a]	23.57**	0.58**	2.57**	38.73**	18.44**
Co 2 X LPA 13-1	33.50[a]	81.50[a]	35.30[a]	6.50[a]	17.40	73.10	2.00[a]	10.60[a]	13.64	0.55[a]	3.56[a]	35.49	15.68
Co 2 X LPA 18	34.50[a]	79.00[a]	27.00	4.90	15.60	56.70	2.10[a]	11.33[a]	12.08	0.48	2.79**	35.28	14.74

Table.6 Continued...

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight (g)	Seed yield per plant (g)	Harvest index	Phytic acid content (mg/g)	Protein content (%)	Oil content (%)
Co (Soy) 3 X LPA 5-1	32.50[a]	81.00[a]	43.60**	7.20**	29.70**	131.30**	2.40*	12.01**	33.73**	0.62**	2.75**	37.64[a]	20.27**
Co (Soy) 3 X LPA 5-2	33.50[a]	79.50[a]	44.30**	7.90**	32.50**	137.60**	2.50**	12.84**	39.57**	0.64**	2.00**	40.18**	20.89**
Co (Soy) 3 X LPA 5-3	34.50[a]	82.00[a]	45.00**	7.20**	25.20**	106.70**	2.00[a]	11.05[a]	23.52**	0.55[a]	3.56[a]	38.93**	19.03**
Co (Soy) 3 X LPA 13-1	32.00[a]	81.50[a]	44.20**	6.90**	28.20**	117.70**	2.30[a]	12.03**	28.70**	0.58*	2.42**	38.98**	19.93**
Co (Soy) 3 X LPA 18	33.00[a]	80.50[a]	37.60[a]	5.00	22.30[a]	82.20[a]	2.00[a]	11.43[a]	16.54	0.50[a]	3.86[a]	36.27	16.44
JS 335 X LPA 5-1	28.50*	82.00[a]	29.70	5.40[a]	20.30[a]	70.70	2.00[a]	11.46[a]	15.44	0.50[a]	3.43[a]	37.28[a]	14.85
JS 335 X LPA 5-2	31.50[a]	80.50[a]	31.40	6.20[a]	21.80[a]	90.20[a]	2.30[a]	12.23**	23.83**	0.55[a]	2.45**	38.89**	17.65[a]
JS 335 X LPA 5-3	31.00[a]	82.00[a]	32.30[a]	5.80[a]	16.90	70.70	2.00[a]	11.01[a]	14.98	0.49[a]	4.01[a]	36.69[a]	16.03
JS 335 X LPA 13-1	30.00[a]	81.50[a]	34.90[a]	5.70[a]	17.20	72.90	2.10[a]	11.04[a]	15.19	0.51[a]	3.83[a]	35.73	16.48
JS 335 X LPA 18	29.00*	77.50*	30.10	5.40[a]	15.10	52.30	2.30[a]	11.49[a]	13.55	0.48	2.96**	34.95	15.79
General mean	33.26	82.60	35.85	5.95	21.26	87.80	2.14	10.98	19.54	52.73	3.68	37.28	17.22
S.E.	1.43	1.37	1.48	0.21	0.82	2.04	0.07	0.27	1.02	1.4	0.14	0.35	0.25
CD (P=0.05)	4.07	3.90	4.20	0.60	2.34	5.80	0.21	0.78	2.89	3.97	0.39	0.98	0.70
CD (P=0.01)	5.42	5.20	5.60	0.80	3.12	7.73	0.28	1.03	3.85	5.30	0.52	1.31	0.94

[a] and *,** On par and significantly superior than the general mean at 5 %, 1 % level of probability, respectively.

Table.7 Estimates of specific combining ability (*sca*) effects for yield and yield related traits in soybean

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield per plant	Harvest index	Phytic acid content	Protein content	Oil content
BRAGG X LPA 5-1	0.92	-2.42	1.92	0.00	-1.24	-8.81 **	0.06	1.74 **	1.51	-0.82	-0.48 **	-1.44 **	0.83 **
BRAGG X LPA 5-2	0.62	1.48	-2.68	-0.34	-2.68 **	-12.03 **	-0.20 *	-1.05 **	-6.80 **	0.05	0.19	-2.05 **	-0.81 **
BRAGG X LPA 5-3	1.62	1.58	-2.40	-0.18	1.14	1.45	-0.02	0.02	-0.41	-0.81	0.49 **	-0.36	-1.06 **
BRAGG X LPA 13-1	-1.38	1.68	1.58	-0.02	0.28	4.95 *	-0.02	0.12	1.54	0.12	0.12	1.24 **	0.16
BRAGG X LPA 18	-1.78	-2.32	1.56	0.54 *	2.52 **	14.43 **	0.20 *	-0.83 **	4.16 **	1.46	-0.33 *	2.62 **	0.88 **
RKS 18 X LPA 5-1	0.02	0.68	-0.57	-0.06	1.36	10.37 **	-0.10	-0.65 *	-0.40	-0.27	0.72 **	1.06 **	-0.61 *
RKS 18 X LPA 5-2	-1.28	-3.42 *	2.88	0.30	3.72 **	14.55 **	0.24 **	1.16 **	8.33 **	2.30	-0.87 **	1.23 **	0.81 **
RKS 18 X LPA 5-3	-0.78	0.18	0.11	-0.14	-0.06	-7.47 **	0.02	0.28	-1.02	0.05	-1.22 **	-0.18	0.47
RKS 18 X LPA 13-1	0.72	2.28	2.09	-0.38	-1.42	-5.47 *	-0.08	-0.4	-2.70 *	-1.03	1.16 **	-1.10 **	-0.21
RKS 18 X LPA 18	1.32	0.28	-4.53 *	0.28	-3.58 **	-11.99 **	-0.06	-0.4	-4.21 **	-1.05	0.22	-1.01 *	-0.46
Co 2 X LPA 5-1	-0.08	1.38	3.57 *	0.12	-1.02	-3.53	-0.04	-0.53	-1.91	-1.81	0.47 **	1.14 **	0.36
Co 2 X LPA 5-2	-0.88	1.78	-4.78 **	-0.32	-3.56 **	-15.85 **	-0.20 *	-1.00 **	-7.51 **	-3.43 *	0.79 **	-0.95 *	-1.70 **
Co 2 X LPA 5-3	0.12	-0.12	2.05	0.34	2.76 **	15.73 **	0.28 **	0.65 *	7.75 **	4.37 **	-0.63 **	1.15 **	1.89 **
Co 2 X LPA 13-1	0.12	-2.52	-0.67	0.3	0.2	-1.57	-0.02	0.01	-0.76	1.21	-0.2	-0.94 *	-0.58 *
Co 2 X LPA 18	0.72	-0.52	-0.19	-0.44	1.64 *	5.21 *	0	0.86 **	2.44 *	-0.34	-0.43 **	-0.4	0.03

Table.7 Continued...

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height	Number of branches per plant	Number of clusters per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield per plant	Harvest index	Phytic acid content	Protein content	Oil content
Co (Soy) 3 X LPA 5-1	0.02	-0.42	-1.15	0.3	0.5	9.41 **	0.20 *	-0.22	3.63 **	3.77 *	-0.49 **	-1.05 **	0.85 **
Co (Soy) 3 X LPA 5-2	0.22	-0.52	3.1	0.46	1.96 *	8.49 **	0.14	0.53	4.96 **	1.2	-0.07	0.68	0.90 **
Co (Soy) 3 X LPA 5-3	-0.28	-0.92	0.83	0.12	-2.42 **	-8.73 **	-0.18 *	-0.67 *	-4.80 **	-2.5	0.66 **	-0.03	-0.73 **
Co (Soy) 3 X LPA 13-1	-0.28	-0.82	-2.49	0.08	1.32	1.57	0.12	0.41	1.81	-0.11	-1.03 **	1.18 **	0.46
Co (Soy) 3 X LPA 18	0.32	2.68	-0.31	-0.96 **	-1.34	-10.75 **	-0.26 **	-0.06	-5.61 **	-2.36	0.93 **	-0.79 *	-1.48 **
JS 335 X LPA 5-1	-0.88	0.78	-3.79 *	-0.36	0.42	-7.45 **	-0.1	-0.34	-2.84 *	-0.86	-0.22	0.29	-1.43 **
JS 335 X LPA 5-2	1.32	0.68	1.46	-0.1	0.58	4.83 *	0.04	0.35	1.02	-0.13	-0.04	1.09 **	0.81 **
JS 335 X LPA 5-3	-0.68	-0.72	-0.61	-0.14	-1.4	-0.99	-0.08	-0.28	-1.52	-1.11	0.70 **	-0.57	-0.57 *
JS 335 X LPA 13-1	0.82	-0.62	-0.53	0.02	-0.36	0.51	0.02	-0.14	0.11	-0.18	-0.05	-0.38	0.17
JS 335 X LPA 18	-0.58	-0.12	3.45 *	0.58 *	0.78	3.09	0.14	0.42	3.23 **	2.29	-0.38 *	-0.42	1.02 **
S.E. (*sca* effects)	1.65	1.54	1.65	0.23	0.72	2.17	0.08	0.26	1.04	1.45	0.14	0.37	0.23

*, ** Significant at 5 % and 1 % level of probability, respectively.

Among the other high yielding crosses, RKS 18 × LPA 5-2 exhibited significant positive *sca* effects for number of clusters per plant, number of pods per plant, number of seeds per pod, hundred seed weight, seed yield per plant, protein content and oil content coupled with negative *sca* effects for days to maturity and phytic acid content. It indicated the presence of non-additive gene action and hence selection can be effective in this cross in F_2 or later generations. The cross Co (Soy) 3 × LPA 5-2 recorded significant positive *sca* effects for number of clusters per plant, number of pods per plant, seed yield per plant and oil content. The cross Co (Soy) 3 × LPA 5-1 recorded significant positive *sca* effects for number of pods per plant, number of seeds per pod, seed yield per plant, harvest index and oil content coupled with significant negative *sca* effects for protein and phytic acid content. The cross Co (Soy) 3 × LPA 13-1 recorded positive *sca* for protein content and negative *sca* for phytic acid content and non-significant *sca* effects for other characters. The significant *sca* values indicating that above crosses could be best utilized for heterosis breeding due to non-additive gene action (Table 7). Similar results of desirable *sca* effects have been reported for seed yield and phytic acid content by Singh *et al.*, (2010) and Ahmad *et al.*, (2013). The crosses RKS 18 × LPA 5-2, Co (Soy) 3 × LPA 5-2 and Co (Soy) 3 × LPA 5-1, Co (Soy) 3 × LPA 13-1 exhibited superior *per se* performance and one of the parent possessed good general combining ability for yield related traits which indicates additive type of gene action. Hence, selection can be exercised in early generation itself in this cross. This cross could be exploited by pedigree method to obtain segregants with high yield and low phytic acid content.

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