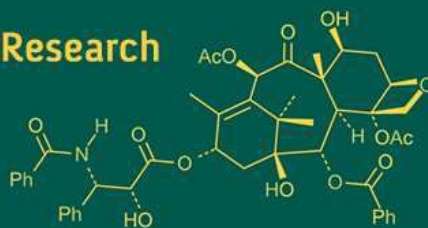
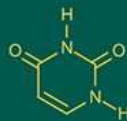


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Studies on heterosis for seed yield and its related traits in soybean [*Glycine max* (L.) Merrill]

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Abstract

A field experiment was conducted to estimate the magnitude of heterosis for different traits in soybean. Magnitude of heterosis studies were carried in 36 crosses derived from crossing of 12 lines with 3 testers and these F₁s along with parents were evaluated in Randomized Block Design with three replications at Research field, ARS, Kota during *kharif* 2021. Based on estimate of heterosis over mid parent, better parent and standard check (JS 95-60) the best soybean crosses for seed yield and its related traits were identified. For seed yield/plant, the maximum magnitude of positive heterosis over standard check was expressed by cross AUKS 212 x SL 958, RKS 113 x SL 958, RVSM 2011-35 x NRC 138, AUKS 212 x NRC 1238 and AUKS 212 x JS 20-34. These crosses also exhibited high heterobeltiosis as well as average heterosis for seed yield and other attributing traits in desirable directions. Therefore, these potential hybrids may be utilized for heterosis breeding as well as for isolating the promising transgressive segregants in advanced generation in soybean.

Keywords: Heterosis, soybean, field experiment, seed yield, F₁ crosses, mid parent heterosis

Introduction

Soybean [*Glycine max* (L.) Merrill.] is one of the most important oil seed crop which have first rank in oil seed production and it is also contribution (38%) in India among the oil seed crops (Joshi *et al.* 2016) [4]. Soybean is a member of the family *Leguminosae* and sub-family *Papilionaceae* with chromosome number 2n=40. Soybean regarded as 'wonder crop' is the richest and easiest source of best quality proteins and fats. It contains about 40% protein and 20% oil with poly unsaturated fatty acids specially Omega 6 and Omega 3 fatty acid, 4.5% minerals, 3.7% fibre, 30-40 per cent carbohydrate and 4-5 per cent ash (Hulse, 1996) [6]. Demand for soybean is still rising day by day as it has become the major oil seed and also serves as raw material for various industries. It is expected that soybean production will increase for as population and living standards increase in India (James, 2010) [7]. Most soybean varieties were developed through mutation, introduction, or selection of local soybean varieties, whereas the majority were created through crossing two or more parents. Recently, the interaction between parents and crosses of plants has become an interesting topic of discussion. One of agriculture's most significant genetic contributions is heterosis (Pandini *et al.* 2002) [11]. Heterosis, also called hybrid vigor, is a phenomenon in which heterozygous hybrids perform better than their parents. This phenomenon is very helpful for plants in reproduction and environmental adaptation. Additionally, hybrid breeding is one of the most effective strategies to improve the grain yield of many crops, so it is very important for agricultural output (Liu *et al.* 2020) [14]. There are three types of heterosis: best parent, regular variety (check parent), and mid parent (heterobeltiosis). Positive heterosis, or hybrid vigor, is the term used to describe offspring from crossings with traits superior to those of their parents (Ghazy and Fouad 2021) [15]. Breeders can select the best cross-combination to use as the basis for selecting superior genotypes by using their knowledge of heterosis. Additionally, understanding the magnitude of heterosis can assist breeders in designing strategies and determining how dominant genes affect the crosses (Pandini *et al.* 2002) [11]. Most projects for improving soybean varieties attempt to boost crop yield. Therefore, for yield potential, positive heterosis is often preferred (number of pods). In contrast, early maturity (early flowering) traits are more likely to exhibit negative heterosis (Ghazy and Fouad 2021) [15].

Therefore, it's crucial to comprehend the diverse genebased behaviours of each character. Therefore, keeping aforesaid considerations in view, present study was planned to estimate the extent of heterosis over mid parent, better parent and standard check (JS 95-60) in 36 F₁s of soybean for eleven characters.

Materials and Methods

Fifteen diverse soybean genotypes adapted to various agro-climatic regions were crossed in Line x Tester fashion which comprised of twelve lines (L₁-L₁₂) viz., RKS 18, RKS 113, AUKS 199, AUKS 200, AUKS 212, RVSM 2011-35, JS 20-98, AUKS 202, AUKS 208, AUKS 218, JS 21-72 and NRC 165 and three testers (T₁-T₃) viz., JS 20-34, NRC 138 and SL 958 during *Kharif*, 2020 at Agricultural Research station, Ummedganj Kota research field of AICRP on soybean to obtain thirty six inter-varietal crosses. Field experimentation on heterosis analysis comprised of 36 F₁s along with fifteen parents were grown in randomized block design with three replications during *Kharif*, 2021. Each parent was sown in two rows along with a single row of F₁'s hybrids of three meter in length by adopting the spacing 45 x 10 cm. The recommended package and practice were followed to raise healthy crop during crop period. The observations were recorded on five randomly selected competitive plants of each genotype per replication for 11 quantitative traits viz., plant height (cm), number of branches per plant, days to 50 per cent flowering, days to maturity, number of pods per plant, pod length (cm), number of seeds per pod, 100 seed weight, seed yield per plant, biological yield per plant and harvest index (%). The mean data on above traits were used to compute mean heterosis, heterobeltiosis, standard heterosis (Hays *et al.* 1955) [16] Variety 'JS 95-60' was used as the standard (check) parent as it is one of the best released and popular variety in central zone of India by using the formula suggested by Fonseca and Patterson, 1968 [8].

Results and Discussion

The mean sum of square due to genotypes shows significant variability for all traits suggested clearly that the parents inclusion in these studies have varied differently among themselves for various quantitative traits relates to seed yield and other yield attributes. The extent of heterosis depends on the magnitude of nonadditive gene action and wide genetic diversity among parents. The scope of exploitation of hybrid vigour depends on directions and magnitude of heterosis and type of gene action involved. Heterosis is measured as per cent increase or decrease over mid parent (relative heterosis), over better parent (heterobeltiosis) and over best parent (economic heterosis). The estimates of heterosis among 36 crosses over mid parent, better parent and standard parent were presented in Table 1 to 3 and the relative merit of superiority is discussed character wise. The standard check variety is JS 95-60. The magnitude of heterosis varies widely for different traits as well as for different crosses. Usually, negative heterosis has been considered desirable for the traits like days to 50% flowering and days to maturity. For days to 50% flowering and days to maturity, among thirty six crosses evaluated, three crosses viz., NRC 165 x JS 20-34, AUKS 202 x JS 20-34 and NRC 165 x NRC 138 exhibited significant negative mid, better and standard parent heterosis. Hence, these crosses could be exploited in the future breeding programme

for selecting elite transgressive segregants for earlier maturity. The results were in agreement with the findings of Nag *et al.* (2018 and 2020) [9], Abd El and Nassar (2013) [11]. Higher heterosis for plant height had an added advantage of increasing the number of branches and number of pod per plant by which it increases the yield. For plant height, highly significant positive standard heterosis was recorded for RVSM 2011-35 x SL 958 with 46.06 % followed by JS 20-98 x SL 958 and AUKS 212 x SL 958 with 41.89 and 37.21 % respectively. Whereas, highly significant positive heterosis over better parent was reported by AUKS 199 x SL 958, AUKS 212 x SL 958 and AUKS 208 x SL 958 with 47.28, 39.99 and 29.64 % respectively. These results were in close agreement with report of Painkra *et al.* (2017) [17] and Nag *et al.* (2020) [9]. The number of branches per plant are believed to be positively associated with high seed yield per plant resulting in high productivity. Therefore, the cross combinations with a greater number of branches per plant were to be identified. Eleven hybrids were identified have significant over standard check with desirable direction while JS 21-72 x NRC 138 exhibited highest economic heterosis with high *per se* performance. Whereas, none of the crosses showed significant heterobeltiosis. Painkra *et al.*, (2017) [12], Nag *et al.* (2018 and 2020) [9] also reported significant positive heterosis for number of branches per plant in soybean. The number pods per plant is the direct component of seed yield therefore improvement in pods per plant will increase seed yield. Out of 36 crosses, 34 crosses were exhibited significantly positive standard heterosis and seven crosses were showed the heterosis over mid parent for this trait. Two crosses AUKS 199 x JS 20-34 and JS 21-72 x NRC 138 were exhibited significantly positive heterosis at three level viz., standard heterosis, heterobeltiosis and average heterosis for number of pods per plant. The results are in harmony with the findings of Samant *et al.* (2014) [13] and Nag *et al.* (2018 & 2020) [9].

The hybrids with positive heterosis for number of seeds per pod are desirable to increase the yield. For number of seeds per pod, cross combination AUKS 212 x JS 20-34, AUKS 202 x JS 20-34, NRC 165 x JS 20-34, RKS 113 x SL 958 and AUKS 202 x SL 958 exhibited significant heterosis at all the three level in desired direction. Other nine and six cross combinations were exhibited significant standard heterosis and average heterosis respectively. These findings in soybean were in agreement with the findings of Samant *et al.*, (2014) [13] and Nag *et al.* (2020) [9] which focusing number of seeds per pod vital yield contributing character. Heterosis for pod length revealed that cross combinations NRC 165 x JS 20-34, AUKS 212 x NRC 138, RVSM 2011-35 x SL 958 and AUKS 218 x SL 958 exhibited significant heterosis at all the three level in desired direction.

Pod length is one of the important yield attributing trait which decides the seed number and size. Heterosis for pod length revealed that cross combinations NRC 165 x JS 20-34, AUKS 212 x NRC 138, RVSM 2011-35 x SL 958 and AUKS 218 x SL 958 exhibited significant heterosis at all the three level in desired direction. Twelve crosses and ten crosses exhibited significant positive heterosis over mid parent and over the standard check for pod length respectively. Similar observation was made by Samant *et al.* (2014) [13] and Nag *et al.* (2018 & 2020) [9] in soybean.

The 100-seed weight is an important yield component trait, which determines the *per se* performance in soybean having direct positive association with seed yield and heterosis in

positive direction is desirable for this trait. Heterosis over mid parent was positive and significant in eleven hybrids. Regarding the character 100-seed weight, cross combinations viz., RVSM 2011-35 x JS 20-34, AUKS 208 x JS 20-34 and JS 21-72 x NRC 138 exhibited significant heterosis at all the three level in desired direction. The cross AUKS 202 x SL 958 showed significant average heterosis as well as heterobeltiosis in desired direction whereas, crosses AUKS 200 x JS 20-34 and AUKS 200 x SL 958 showed significant average heterosis and non-significant economic heterosis and heterobeltiosis in desired direction. Cross combinations viz., RKS 113 x JS 20-34, AUKS 199 x SL 958, AUKS 212 x SL 958, AUKS 218 x SL 958, and JS 21-72 x SL 958 exhibited significant average heterosis while AUKS 212 x SL 958 noted significant average heterosis with high *per se* performance. Samant *et al.*, (2014)^[13], and Nag *et al.* (2020)^[9] reported significant heterosis in the desired direction for 100-seed weight in soybean.

Seed yield is a complex character and depends on all other yield-attributing characters. Higher yield can be achieved by the improvement of one or more direct components of yield.

Heterosis for seed yield per plant revealed that out of 36 crosses, thirty-one exhibited significant economic heterosis for seed yield per plant. The cross combinations AUKS 212 x SL 958, RKS 113 x SL 958, RVSM 2011-35 x NRC 138, AUKS 212 x NRC 138, AUKS 212 x JS 20-34, RVSM 2011-35 x JS 20-34, RKS 18 x NRC 138, RKS 18 x SL 958, RKS 18 x JS 20-34, AUKS 200 x NRC 138, AUKS 199 x NRC 138 and AUKS 199 x JS 20-34 were observed significant heterosis at all the three level in desired direction while, RVSM 2011-35 x SL 958, JS 21-72 x NRC 138 and AUKS 218 x NRC 138 showed significant economic heterosis as well as average heterosis and also exhibited non-significant heterobeltiosis in desired direction. The cross AUKS 212 x SL 958 noted highest standard heterosis with high *per se* performance. Bhavani *et al.* (2017)^[3] Nag *et al.* (2018 & 2020)^[9] also observed similar result in soybean. Hybrid with significant heterosis in desired direction with high *per se* performance for seed yield per plant could be utilized in future breeding programme to exploit better segregant.

Table 1: Estimation of heterosis for days to 50% flowering, days to maturity, plant height and number of branches per plant in soybean.

Crosses	Days to 50% flowering			Days to maturity			Plant height (cm)			Number of branches per plant		
	MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
RKS 18 x JS 20-34	0.48	10.64**	7.22*	1.28	3.73**	1.09	-2.34	4.59	1.88	-30.35**	-33.67**	-21.92**
RKS 113 x JS 20-34	-4.89*	13.83**	10.31**	-2.28*	3.73**	1.09	3.42	18.03*	14.98	-31.96**	-34.53**	-16.64**
AUKS 199 x JS 20-34	1.48	9.57**	6.19*	1.67	2.24*	-0.36	-10.41	-5.49	-17.05*	-43.33**	-47.45**	-27.63**
AUKS 200 x JS 20-34	3.81	15.96**	12.37**	1.81	4.85**	2.18*	-5.78	-1.24	-3.79	-15.15**	-27.30**	-14.41**
AUKS 212 x JS 20-34	-11.31**	4.26	1.03	-0.89	3.73**	1.09	-8.84	-8.55	-10.92	-8.68*	-16.84**	-2.10
RVSM 2011-35 x JS 20-34	-9.82**	7.45*	4.12	-0.71	4.85**	2.18*	5.69	28.03**	24.71**	16.26**	-3.32	13.81**
JS 20-98 x JS 20-34	9.25**	31.91**	27.84**	1.58	8.21**	5.45**	-5.87	10.10	7.25	-16.42**	-27.04**	-14.11**
AUKS 202 x JS 20-34	-4.71	-3.19	-6.19*	-1.30	-1.12	-3.64**	23.51**	25.20**	21.96**	-14.79**	-25.77**	-12.61**
AUKS 208 x JS 20-34	0.00	2.13	-1.03	2.78**	3.36**	0.73	-6.50	-2.31	-4.84	-4.84	-14.80**	0.30
AUKS 218 x JS 20-34	-7.76**	7.45*	4.12	0.35	5.97**	3.27**	-18.25**	-7.26	-9.66	8.23*	-4.34	12.61**
JS 21-72 x JS 20-34	-1.80	15.96**	12.37**	4.61**	10.07**	7.27**	2.97	22.98**	19.80*	16.55**	5.10	23.72**
NRC 165 x JS 20-34	-3.23	-2.17	-7.22*	0.19	0.37	-2.55*	-9.03	-4.59	-7.06	-20.92**	-38.27**	-27.33**
RKS 18 x NRC 138	-8.06**	-1.02	0.00	-2.90**	-1.11	-2.55*	0.26	0.89	10.83	-43.21**	-49.18**	-31.47**
RKS 113 x NRC 138	8.30**	26.53**	27.84**	4.20**	9.96**	8.36**	0.49	7.40	17.97*	-31.27**	-33.18**	-9.91*
AUKS 199 x NRC 138	-7.25**	-2.04	-1.03	0.00	0.00	-1.45	1.41	14.15	0.20	-25.17**	-25.95**	1.98
AUKS 200 x NRC 138	-13.08**	-5.10	-4.12	-3.42**	-1.11	-2.55*	-17.62**	-16.45*	-10.77	-61.42**	-68.69**	-57.78**
AUKS 212 x NRC 138	11.11**	27.55**	28.87**	6.03**	10.33**	8.73**	-2.94	2.92	0.88	-19.58**	-30.96**	-6.91
RVSM 2011-35 x NRC 138	0.00	16.33**	17.53**	-1.58	3.32**	1.82	-23.78**	-13.80	-5.31	-18.19**	-35.41**	-12.91**
JS 20-98 x NRC 138	15.15**	35.71**	37.11**	5.92**	12.18**	10.55**	-5.99	2.83	12.95	-17.83**	-32.16**	-8.53*
AUKS 202 x NRC 138	-5.64*	-5.15	-5.15	0.37	0.74	-1.45	8.32	13.61	13.69	16.22**	-4.23	29.13**
AUKS 208 x NRC 138	-4.08	-4.08	-3.09	0.74	0.74	-0.73	-0.48	1.25	7.46	-22.53**	-34.52**	-11.71**
AUKS 218 x NRC 138	0.45	14.29**	15.46**	4.39**	9.59**	8.00**	17.22**	24.57**	36.83**	12.27**	-6.24	26.43**
JS 21-72 x NRC 138	-6.19**	8.16**	9.28**	2.29*	7.01**	5.45**	6.13	18.41*	30.07**	13.87**	-3.12	30.63**
NRC 165 x NRC 138	-4.21	-1.09	-6.19*	-0.37	0.37	-2.55*	9.25	10.74	18.40*	-23.77**	-43.21**	-23.42**
RKS 18 x SL 958	2.96	23.01**	43.30**	-3.10**	11.39**	13.82**	-3.17	12.05	24.64**	-18.90**	-27.09**	-2.70
RKS 113 x SL 958	5.56**	16.03**	56.70**	4.80**	15.95**	26.91**	0.96	9.55	36.88**	-1.34	-3.60	28.65**
AUKS 199 x SL 958	-12.03**	7.34**	20.62**	-7.86**	8.12**	6.55**	10.49	47.28**	29.27**	-8.08**	-9.51**	24.62**
AUKS 200 x SL 958	-1.10	16.38**	39.18**	-2.62**	11.27**	14.91**	-4.11	13.59	21.31*	-29.03**	-42.17**	-22.82**
AUKS 212 x SL 958	-0.70	11.02**	45.36**	-2.74**	9.22**	16.36**	12.36*	39.99**	37.21**	-3.97	-17.19**	10.51*
RVSM 2011-35 x SL 958	-5.23**	4.62*	40.21**	-5.28**	5.37**	14.18**	2.56	5.38	46.06**	-21.35**	-37.67**	-16.82**
JS 20-98 x SL 958	6.90**	16.54**	59.79**	-1.80*	8.25**	19.27**	2.57	8.77	41.89**	-34.31**	-45.54**	-27.33**
AUKS 202 x SL 958	-21.26**	3.09	3.09	-11.67**	4.09**	1.82	-25.24**	-8.00	-7.94	-13.52**	-28.44**	-4.50
AUKS 208 x SL 958	-5.88**	22.45**	23.71**	-6.92**	9.23**	7.64**	9.04	29.64**	37.59**	11.35**	-5.49	26.13**
AUKS 218 x SL 958	-9.93**	1.60	30.93**	-7.39**	3.02**	11.64**	-6.23	2.34	26.50**	-15.48**	-29.12**	-5.41
JS 21-72 x SL 958	-3.86*	7.03**	41.24**	-4.08**	7.09**	15.27**	-10.94*	-7.34	25.35**	-2.03	-16.29**	11.71**
NRC 165 x SL 958	-18.88**	9.78**	4.12	-9.49**	7.12**	4.00**	-5.70	11.63	19.36*	-0.66	-25.74**	-0.90

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

Table 2: Estimation of heterosis for number of pods per plant, number of seeds per pod, pod length and 100-Seed weight in soybean.

Crosses	Number of pods per plant			Number of seeds per pod			Pod length (cm)			100- Seed weight (g)		
	MP	BP	SC	MP	BP	SC	MP	BP	SC	MP	BP	SC
RKS 18 × JS 20-34	4.54	-2.40	51.45**	9.00*	6.21	11.25**	0.69	-3.04	-3.22	-4.40*	-9.39**	-13.33**
RKS 113 × JS 20-34	-2.07	-6.75	38.76**	-11.97**	-13.20**	-11.25**	3.94	0.00	0.00	3.98*	0.91	-3.48
AUKS 199 × JS 20-34	14.31**	11.86*	57.27**	6.75	4.40	3.75	0.51	0.51	-7.11	0.39	-2.12	-6.38**
AUKS 200 × JS 20-34	-3.64	-7.30	34.97**	0.31	0.00	0.00	8.88*	4.95	4.55	3.85*	1.59	1.59
AUKS 212 × JS 20-34	9.54	2.75	57.82**	11.80**	10.43*	12.50**	10.83**	5.26	8.15*	2.63	1.94	-1.16
RVSM 2011-35 × JS 20-34	7.46	2.67	51.67**	-4.40	-15.12**	8.75*	8.60*	1.15	8.34*	8.04**	6.14**	5.22**
JS 20-98 × JS 20-34	-1.28	-2.16	34.04**	-11.59**	-14.20**	-9.38*	1.00	-1.46	-4.27	-3.73*	-8.03**	-12.03**
AUKS 202 × JS 20-34	0.12	-1.56	32.46**	12.50**	11.80**	12.50**	8.98*	7.69	-0.47	-5.39**	-8.18**	-12.17**
AUKS 208 × JS 20-34	-15.62**	-16.38**	12.51	1.33	-4.40	-5.00	5.88	5.61	-1.90	14.22**	13.45**	10.00**
AUKS 218 × JS 20-34	-5.14	-9.45	34.02**	-3.83	-9.44*	1.88	5.59	-1.93	5.69	-9.45**	-13.64**	-17.39**
JS 21-72 × JS 20-34	4.95	4.76	40.96**	9.42**	5.88	12.50**	-3.69	-7.55	-7.11	2.81	0.29	0.87
NRC 165 × JS 20-34	-10.13*	-14.25*	27.05**	30.49**	28.35**	31.88**	16.90**	7.79*	18.01**	-2.16	-7.27**	-11.30**
RKS 18 × NRC 138	6.77	0.37	55.75**	7.23*	6.47	13.13**	-1.09	-1.42	-0.95	-6.12**	-13.43**	-12.17**
RKS 113 × NRC 138	-13.51**	-17.06**	23.42**	-8.27*	-10.00*	-4.37	2.41	2.17	2.65	-0.08	-5.71**	-4.35*
AUKS 199 × NRC 138	6.42	4.90	47.49**	-1.61	-6.82	-1.00	-6.14	-9.91*	-9.48*	-4.75**	-9.71**	-8.41**
AUKS 200 × NRC 138	8.96	5.59	53.73**	-3.03	-5.88	0.00	2.32	1.89	2.37	1.29	0.57	2.03
AUKS 212 × NRC 138	12.74*	6.49	63.58**	8.71*	6.47	13.13**	11.10**	9.87*	12.89**	-1.97	-4.14*	-2.75
RVSM 2011-35 × NRC 138	11.76*	7.54	58.86**	-4.53	-12.68**	11.87**	8.22*	4.87	12.32**	0.14	-1.00	0.43
JS 20-98 × NRC 138	7.61	7.45	47.20**	-10.32**	-10.59**	-5.00	-0.14	-1.79	-1.33	-6.07**	-12.71**	-11.45**
AUKS 202 × NRC 138	-10.98*	-13.11*	18.68*	3.32	0.59	6.88	9.84**	4.25	4.74	-10.98**	-16.00**	-14.78**
AUKS 208 × NRC 138	-10.64*	-12.10*	20.05*	-13.18**	-20.59**	-15.62**	2.94	-0.94	-0.47	-10.15**	-12.14**	-10.87**
AUKS 218 × NRC 138	10.02*	5.78	56.55**	2.86	0.00	12.50**	4.23	0.70	8.53*	1.62	-5.71**	-4.35*
JS 21-72 × NRC 138	17.41**	16.33**	58.89**	-2.94	-2.94	3.13	2.36	2.36	2.84	4.16**	3.71*	5.22**
NRC 165 × NRC 138	-27.72**	-30.55**	2.90	-4.90	-6.47	-0.62	9.71**	5.19	15.17**	-10.61**	-17.57**	-16.38**
RKS 18 × SL 958	4.31	2.31	65.08**	-1.75	-3.10	1.50	-4.24	-7.89*	-0.47	-0.42	-0.67	-14.49**
RKS 113 × SL 958	13.90**	9.47	76.63**	10.84**	10.64*	13.13**	0.23	-3.51	4.27	1.07	-1.13	-11.01**
AUKS 199 × SL 958	-4.45	-10.60*	44.25**	-12.38**	-15.34**	-13.75**	-8.75*	-15.35**	-8.53*	6.47**	3.67	-5.80**
AUKS 200 × SL 958	-5.13	-9.76	45.60**	-6.50	-7.36	-5.62	-4.61	-8.33*	-0.95	7.94**	0.43	0.43
AUKS 212 × SL 958	7.31	4.74	68.99**	3.07	3.07	5.00	-0.18	-2.63	5.21	7.05**	1.05	-2.03
RVSM 2011-35 × SL 958	2.93	-1.41	59.07**	-13.04**	-21.95**	0.00	8.37**	7.89*	16.59**	1.10	-5.56**	-6.38**
JS 20-98 × SL 958	-9.41	-16.25**	35.13**	-8.43*	-10.06*	-5.00	-3.00	-7.89*	-0.47	-0.25	-0.83	-13.62**
AUKS 202 × SL 958	-17.19**	-25.22**	20.65*	16.67**	15.95**	18.13**	14.72**	5.26	13.74**	13.09**	10.63**	-0.43
AUKS 208 × SL 958	-14.34**	-22.09**	25.70**	6.58	-0.61	1.25	6.13	-1.32	6.64	1.19	-4.48*	-7.39**
AUKS 218 × SL 958	1.97	-2.25	57.72**	8.45*	3.33	16.25**	8.04*	7.89*	16.59**	4.61*	4.17	-9.57**
JS 21-72 × SL 958	11.64*	2.20	64.90**	8.11*	5.88	12.50**	2.27	-1.32	6.64	3.42*	-4.03*	-3.48
NRC 165 × SL 958	-20.40**	-23.65**	23.19**	-3.85	-4.26	-1.62	4.58	3.90	13.74**	0.93	0.67	-13.33**

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

Table 3: Estimation of heterosis for Seed yield per plant, Biological yield per plant and Harvest index (%) in soybean.

Crosses	Seed yield per plant (g)			Biological yield per plant (g)			Harvest index (%)		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
RKS 18 × JS 20-34	22.53**	13.08**	65.93**	25.08**	18.24**	64.45**	-2.05	-4.76	1.01
RKS 113 × JS 20-34	-8.70	-14.61**	21.73**	1.33	-8.88**	41.35**	-10.35*	-13.91*	-13.76*
AUKS 199 × JS 20-34	14.44**	12.86*	44.04**	19.19**	14.58**	53.83**	-4.20	-6.39	-6.22
AUKS 200 × JS 20-34	1.03	-7.80	38.67**	2.74	-7.10**	42.35**	-1.75	-2.77	-2.59
AUKS 212 × JS 20-34	37.52**	20.60**	98.52**	20.99**	14.75**	58.49**	14.19**	5.07	25.28**
RVSM 2011-35 × JS 20-34	36.10**	22.09**	90.80**	22.30**	13.18**	64.78**	11.71*	7.85	16.07**
JS 20-98 × JS 20-34	-2.75	-3.56	21.73**	-2.41	-10.40**	32.73**	-1.15	-8.39	-8.22
AUKS 202 × JS 20-34	-3.92	-8.31	13.80	4.82	2.34	33.08**	-8.49	-14.57*	-14.42*
AUKS 208 × JS 20-34	-11.80*	-12.73*	8.31	-2.42	-3.26	21.95**	-9.64	-11.30*	-11.13*
AUKS 218 × JS 20-34	0.50	0.21	24.37**	-1.55	-2.16	22.73**	2.19	1.30	1.48
JS 21-72 × JS 20-34	8.25	6.19	37.01**	3.04	2.11	26.49**	5.01	2.02	8.37
NRC 165 × JS 20-34	3.43	-0.47	23.53**	10.24**	10.23**	36.55**	-6.16	-9.62	-9.46
RKS 18 × NRC 138	34.87**	28.36**	88.34**	25.06**	23.48**	71.74**	7.57	3.57	9.85
RKS 113 × NRC 138	-19.20**	-22.03**	11.16	-4.76*	-10.75**	38.44**	-15.50**	-18.07**	-19.56**
AUKS 199 × NRC 138	13.56**	11.45*	47.74**	14.46**	13.90**	54.42**	-1.17	-2.47	-4.25
AUKS 200 × NRC 138	16.94**	10.00*	65.45**	11.61**	5.18*	61.17**	4.64	4.60	2.70
AUKS 212 × NRC 138	34.90**	21.78**	100.45**	27.70**	26.53**	74.75**	5.59	-3.73	14.78**
RVSM 2011-35 × NRC 138	44.52**	33.56**	108.72**	22.40**	18.19**	72.08**	18.00**	12.82*	21.42**
JS 20-98 × NRC 138	2.37	-0.08	32.46**	0.85	-3.42	43.07**	0.93	-5.58	-7.30
AUKS 202 × NRC 138	2.36	-5.28	25.56**	3.09	0.98	36.91**	-0.90	-6.61	-8.31
AUKS 208 × NRC 138	-7.12	-11.00*	17.99*	6.01*	2.29	38.69**	-12.47*	-13.22*	-14.79**
AUKS 218 × NRC 138	11.23*	7.38	42.35**	3.68	-0.19	35.32**	7.13	7.00	5.32
JS 21-72 × NRC 138	10.89*	9.41	45.04**	1.67	-3.55	30.76**	8.61	4.50	11.00
NRC 165 × NRC 138	-11.54*	-17.49**	9.38	6.50**	1.90	38.15**	-17.06**	-19.34**	-20.81**
RKS 18 × SL 958	21.55**	21.53**	78.40**	12.36**	11.58**	57.36**	7.82	7.00	13.47*
RKS 113 × SL 958	47.12**	44.99**	112.85**	21.47**	15.96**	79.87**	20.42**	13.37*	18.40**
AUKS 199 × SL 958	-14.85**	-20.41**	16.84*	-1.41	-3.78	35.70**	-13.85**	-17.49**	-13.83*
AUKS 200 × SL 958	0.93	-0.28	49.99**	-1.43	-5.35*	45.03**	2.23	-0.87	3.53
AUKS 212 × SL 958	38.50**	31.01**	115.65**	26.13**	24.82**	76.04**	9.65*	2.84	22.63**
RVSM 2011-35 × SL 958	11.59**	8.20	69.10**	1.39	-0.20	45.31**	9.84*	8.21	16.46**
JS 20-98 × SL 958	-21.27**	-26.78**	7.48	-6.04**	-8.30**	35.85**	-16.61**	-24.16**	-20.79**
AUKS 202 × SL 958	7.70	-4.78	39.78**	1.15	-2.79	37.09**	6.73	-2.25	2.09
AUKS 208 × SL 958	-12.98**	-20.48**	16.73*	-0.75	-6.02*	32.55**	-12.19*	-15.52**	-11.77*
AUKS 218 × SL 958	4.45	-3.88	41.10**	-8.69**	-13.73**	21.66**	14.42**	11.13*	16.06**
JS 21-72 × SL 958	7.93	1.40	48.85**	-3.65	-10.27**	26.55**	11.75*	10.81*	17.71**
NRC 165 × SL 958	-7.85	-17.91**	20.51**	-5.03*	-10.81**	25.79**	-2.82	-8.24	-4.17

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

All 36 crosses exhibited significant standard heterosis for biological yield per plant. Fifteen crosses and thirteen crosses exhibited significant heterosis over mid parent and over better parent in desirable direction for biological yield per plant. Thirteen hybrids exhibited significant heterosis at all the three level in desired direction with high *per se* performance. These results were supported by the findings of Samant *et al.* (2014) [13] and Nag *et al.* (2018 & 2020) [9] in soybean. Harvest index indirectly influences the seed yield through partitioning photosynthates in source and sink. The source of photosynthates is leaf thereby increasing the leaf area will indirectly increase seed yield by more photosynthesis. Regarding the harvest index, cross combination RVSM 2011-35 x NRC 138, RKS 113 x SL 958, JS 21-72 x SL 958 and AUKS 218 x SL 958 exhibited significant heterosis at all the three levels in desired direction such result earlier reported by Ibrahim (2014) [2] and Samant *et al.* (2014) [13].

The by and large results of heterosis studies revealed that the cross combinations, AUKS 212 x SL 958, RKS 113 x SL 958, RVSM 2011-35 x NRC 38, AUKS 212 x NRC 138, AUKS 212 x JS 20-34, RVSM 2011-35 x JS 20-34, RKS 18 x NRC 138, RKS 18 x SL 958 and RVSM 2011-35 x SL 958 were identified as promising hybrids having significant heterosis with high *per se* performance in desired direction

for seed yield and most of the yield contributing characters in soybean. These crosses could be utilized for comprehensive soybean breeding programme to get potential transgressive segregants in the advanced generations.

Conclusion

Most of the yield contributing characters showed considerable heterosis, hence their exploitation in the heterosis breeding will be useful. Soybean being the self-pollinated crop and non-availability of workable male sterility system it is difficult to exploit hybrid vigour in near future. Hence these hybrids could be effectively utilized to develop high yielding varieties along with desirable traits in soybean.

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