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Combining Ability Analysis to Identify Potential Parents and Hybrids for Yield and Its Related Traits in Soybean

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Authors' contributions

This work was carried out in collaboration between the two authors OFA and LSF. Author OFA designed the study, wrote the protocol and the first draft of the manuscript. Author LSF performed the statistical analysis. Authors OFA and LSF managed the analysis of the study. Author OFA managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A half diallel study was conducted using seven genotypes of soybean to identify superior parents suitable for developing high yielding new cultivars and hybrids in soybean. The mean squares due to GCA was significant for four characters out of five characters studied. The significance of GCA indicated that additive genes were important in controlling these characters. The parents TGx1989 – 21F exhibited maximum GCA for plant height, TGx1835 – 40E for number of branches and TGx1830–20E for number of pods, total pod weight and seed yield. The GCA effects indicated that parents TGx1835 – 40E, TGx1989 – 21F and TGx1830–20E were the best parents to be used in crossing programmes for the selection of desirable plants from segregating populations. The hybrids TGx1990 – 55F x TGx1990 – 37F expressed highest SCA effects for plant height and number of branches, TGx1990 – 37F x TGx1830–20E for number of pods and TGx1990 – 3F x TGx1990–57F for total pod weight and seed yield suggesting that these hybrids have the potential to be used for soybean hybrid development.

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1. INTRODUCTION

Soybean (*Glycine max*) is a legume that grows in tropical, subtropical and temperate climates. Soybean is now cultivated throughout east and south East Asia where people depends on it for food, animal feed and medicine. Soybean is an important source of high quality inexpensive protein and oil. Soybean has the highest protein content (40-42%) of all other food crops and is second only to groundnut in terms of oil content (18-22% comprising 85% unsaturated fatty acids and is free from cholesterol) among food legumes so it is highly desirable in the human diet [1]. Diallel analysis is one of the mating designs that help plant breeders in making decisions regarding the type of breeding method to be used and selection procedures to be adopted for selection from segregating populations. It has been used primarily to estimate genetic variances when parents are either random individuals or inbred lines from a random mating population in linkage equilibrium. They have also been used to estimate GCA and SCA effects from crosses of fixed lines [2,3]. The average performance of genotypes in a series of hybrid combination is called GCA and is used to measure additive variance and additive genes whereas the performance of a genotype in specific crosses is called SCA and is used to measures non-additive genes [4]. Diallel analysis provides a mating design whereby the selected parents are crossed in all possible combinations and the mean values are used for predicting combining ability of the parents (GCA) and hybrids (SCA) to enlighten the nature of gene action involved in the inheritance of traits [5]. Diallel mating system have provided genetic understanding for a chosen set of parents [6] and have been used to study various characters in many crops. It has been utilized for cassava (*Manihot esculenta*), chickpea (*Cicer arientinum*), maize (*Zea mays*), common bean (*Phaseolus vulgaris*), soybean (*Glycine max*) cowpea (*Vigna unguiculata*) among others [7,8,9]. The present research was carried out for identifying superior parents having high GCA and hybrids with good SCA for the development of new soybean cultivars and hybrids, respectively.

2. MATERIALS AND METHODS

A set of seven parents was sown for making crosses in 7 x 7 half diallel mating design in the screen house of the Federal University of Technology, Akure, Ondo – State, Nigeria in 2013. The crosses were attempted in seven genotypes of soybean, *Glycine max* (TGx1835 – 40E; TGx1990 – 55F; TGx1990 – 3F; TGx1990 – 37F; TGx1989 – 21F; TGx1830–20E and TGx1990–57F) and the F_1 seeds were obtained. In 2014, the F_1s along with their parents were sown in a Randomised Complete Block Design with three replications. The data were recorded on plant height, number of branches per plant, number of pods per plant, total pod weight and seed yield per plant. The plant spacing was 60cm and 20 cm between and within rows respectively. After two weeks from planting, thinning was done for proper plant stand, growth and development. Data were collected from ten competitive plants for the above mentioned traits. All standard agronomic practices were carried out following the recommended rate as when due. After taking observations on each trait, the data were statistically analysed following Griffing method 1 model II for analysis of variance for general combining ability and specific combining ability and also mean separation following tukey mean pairwise comparison.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The mean performance of the parents and their hybrids for plant height (Table 1) indicated that among the parents, TGx1989 – 21F was the tallest plant measuring (74.73 cm) followed by TGx1830–20E (58.02 cm). Among the hybrids, the tallest plant was TGx1990 – 37F x TGx1989 – 21F measuring (77.40 cm) followed by TGx1835 – 40E x TGx1989 – 21F (74.19 cm). The mean squares from analysis of variance revealed significant differences among the genotypes, GCA and SCA variances (Table 2) indicated that additive and dominance genes were controlling plant height, hence, it can be improved through selection from segregating populations and is also useful for hybrid development. The estimates of GCA in Table 3 showed that TGx1989 – 21F had maximum positive GCA effects (7.20) followed by TGx1835 – 40E (2.93). The SCA effects in Table 4 indicated that TGx1990 – 55F x TGx1990 – 37F had a maximum SCA effect (4.88) followed by TGx1835 – 40E x TGx1990 – 3F (2.65).This findings is in harmony with the findings of [10] who reported that mean squares due to GCA and SCA were highly significant for plant height.

Table 1. Average performance of parents and their hybrids for various quantitative traits in soybean

Parent	PHTH	NBP	NPP	TPW (g)	SYP (g)
P1	51.34^{y-ab}	9.4^{abc}	136.63^{d-o}	37.54^{d-l}	27.38^{f-k}
P2	53.75^{w}	9.17^{abc}	120.38^{mno}	32.19^{hi}	21.87^{jk}
P3	54.80^{vw}	7.35^{c}	94.97^{o}	25.79^{l}	16.41^{k}
P4	56.00^{uvw}	9.70^{abc}	141.69^{c-o}	40.38^{d-l}	27.81^{e-k}
P5	74.73^{m-t}	9.20^{abc}	135.10^{e-o}	36.61^{e-l}	26.20^{f-k}
P6	58.02^{t-w}	9.80^{abc}	146.00^{c-o}	42.96^{c-l}	29.30^{d-k}
P7	54.50^{w}	9.12^{abc}	130.96^{g-o}	35.92^{e-i}	26.03^{f-k}
Parent average	57.87	9.42	132.47	37.68	26.18
Hybrid					
P1 X P2	58.20^{t-w}	8.80^{bc}	124.17^{l-o}	35.02^{f-l}	25.75^{g-k}
P1 X P3	61.30^{r-w}	8.15^{bc}	116.00^{no}	32.79^{g-l}	25.50^{g-k}
P1 X P4	52.80^{w}	9.20^{abc}	133.94^{f-o}	38.30^{d-l}	28.10^{e-k}
P1 X P5	74.19^{n-t}	9.13^{abc}	132.15^{g-o}	36.32^{e-l}	27.22^{f-k}
P1 X P6	56.23^{u-w}	9.27^{abc}	149.00^{c-o}	44.34^{c-l}	32.34^{d-k}
P1 X P7	57.12^{u-w}	9.04^{abc}	128.13^{t-o}	35.40^{f-l}	26.17^{f-k}
P2 X P3	49.56^{z-ab}	9.03^{abc}	123.58^{q-o}	32.75^{g-l}	24.54^{g-k}
P2 X P4	60.72^{r-w}	9.51^{abc}	141.06^{c-o}	38.84^{d-l}	26.70^{f-k}
P2 X P5	69.40^{q-w}	9.37^{abc}	130.17^{h-o}	38.41^{d-l}	26.09^{f-k}
P2 X P6	59.27^{s-w}	9.52^{abc}	147.73^{c-o}	41.56^{c-i}	27.19^{f-k}
P2 X P7	51.09^{z-ab}	9.39^{abc}	127.14^{i-o}	37.30^{d-l}	26.01^{f-k}
P3 X P4	49.77^{z-ab}	9.76^{abc}	138.57^{d-w}	41.10^{c-l}	30.24^{d-k}
P3 X P5	71.60^{f-v}	9.20^{abc}	137.20^{d-w}	38.53^{d-i}	27.20^{f-k}
P3 X P6	58.16^{t-w}	9.93^{abc}	145.22^{c-o}	42.61^{c-i}	30.46^{d-k}
P3 X P7	52.87^{w}	8.79^{bc}	133.34^{g-o}	36.42^{e-l}	25.49^{g-k}
P4 X P5	77.40^{k-r}	9.77^{abc}	142.43^{c-o}	42.26^{c-i}	29.72^{d-k}
P4 X P6	52.63^{bc-ab}	10.03^{abc}	147.23^{c-o}	47.04^{c-l}	33.09^{d-k}
P4 X P7	55.53^{vw}	8.94^{bc}	132.77^{g-o}	37.01^{d-t}	28.10^{e-k}
P5 X P6	58.56^{t-w}	9.30^{abc}	143.03^{c-o}	46.99^{c-i}	31.03^{d-k}
P5 X P7	51.74^{g-ab}	9.27^{abc}	127.55^{c-o}	35.15^{f-l}	24.81^{g-k}
P6 X P7	60.68^{r-w}	8.82^{bc}	136.67^{d-o}	38.31^{d-i}	28.15^{e-k}
Hybrid average	57.68	9.23	131.48	37.16	26.85

PHTF= Plant Height at Flowering (cm); NBP= Number of Branches per Plant; NPP = Number of Pods per Plant; TPW = Total Pod Weight (g); SYP = Seed Yield per Plant (g).
P1= TGx1835 – 40E; P2= TGx1990 – 55F; P3 = TGx1990 – 3F; P4 = TGx1990 – 37F; P5 = TGx1989 – 21F; P6 = TGx1830–20E; P7=TGx1990–57F

Table 2. Mean square of GCA and SCA for various quantitative traits in soybean

SOV	Df	PHT (cm)	NBP	NPP	TPW (g)	SYP (g)
Replications	2	171.10**	35.10**	6826.95**	2735.13**	697.70**
Genotypes	27	357.84**	1.65	682.05**	279.86**	194.34**
GCA	6	1083.49**	1.43	1671.26**	516.51**	377.75*
SCA	20	60.57**	1.33	655.05	274.30	167.17
Error	54	14.42	1.63	279.55	90.95	62.00

, significance at 5% and 1% level of probability respectively*
SOV= Source of Variation; GCA= general combining ability; SCA= specific combining ability; PHT= Plant Height at Harvesting (cm); NBP= Number of Branches per Plant; NPP = Number of Pods per Plant; TPW = Total Pod Weight (g); SYP = Seed Yield per Plant (g)

3.2 Number of Branches per Plant

The mean performance of the parents and their hybrids showed that among the parents in Table 1, TGx1830–20E recorded the highest number of branches (9.80) followed by TGx1990 – 37F recording (9.70). Among the hybrids, the highest number of branches was recorded in TGx1990 – 37F x TGx1830–20E (10.03). The GCA effects as shown in Table 3 showed that

TGx1835 – 40E recorded the maximum GCA effects (0.19) followed by TGx1989 – 21F (0.18). The SCA effects estimates in Table 4 indicated that TGx1990 – 55F x TGx1990 – 37F recorded that maximum SCA effects (0.55) followed by TGx1835 – 40E x TGx1990–57F (0.47). The result further suggested that parents TGx1835 – 40E and TGx1989 – 21F were good general combiners and can be utilised in hybridization programme for improving number of branches per plant in soybean through selection from segregating populations.

Table 3. General combining ability (GCA) effects of parents for various quantitative traits in soybean

Parents	PHT (cm)	NBP	NPP	TPW (g)	SYP (g)
P1	2.93**	0.19	3.98	0.75	0.01
P2	2.10**	-0.17	-4.58*	-1.62	-1.94
P3	-0.90	-0.04	-3.70	-3.21*	-2.52*
P4	-1.19*	0.01	3.04	1.26	1.29
P5	7.20**	0.18	1.91	0.04	0.58
P6	1.34*	0.08	7.48**	4.66**	3.85**
P7	-2.93**	0.03	0.17	-0.37	-0.12
SE (gi - gj)	0.68	0.20	2.58	1.47	1.22

PHT= Plant Height at Harvesting (cm); NBP= Number of Branches per Plant; NPP = Number of Pods per Plant; TPW = Total Pod Weight (g); SYP = Seed Yield per Plant (g).
P1= TGx1835 – 40E; P2= TGx1990 – 55F; P3 = TGx1990 – 3F; P4 = TGx1990 – 37F; P5 = TGx1989 – 21F; P6 = TGx1830 – 20 E; P7 = TGx1990 – 57F

Table 4. Specific combining ability (SCA) effects of hybrids for various quantitative characters in soybean

Hybrids	PHT (cm)	NBP	NPP	TPW (g)	SYP (g)
P1x P2	-3.87**	-0.50	3.47	0.96	0.86
P1x P3	2.65*	0.19	-2.39	-0.91	0.19
P1x P4	1.72	-0.17	0.83	0.39	0.34
P1x P5	0.15	-0.05	3.82	1.40	1.24
P1x P6	1.19	0.03	1.65	1.19	1.32
P1x P7	2.51*	0.47	3.02	2.33	1.94
P2x P3	-3.00**	-0.01	-4.18	-0.14	-0.06
P2x P4	4.88**	0.55	10.71*	3.97	2.45
P2x P5	-0.63	0.33	3.33	3.15	3.35
P2x P6	0.31	0.35	-2.64	-3.82	-3.57
P2x P7	0.70	0.30	-4.18	0.15	-1.39
P3x P4	0.41	-0.33	-1.90	-1.44	-1.32
P3x P5	0.31	-0.45	3.13	3.21	2.57
P3x P6	-0.28	-0.17	-1.12	-0.58	-0.89
P3x P7	-2.41*	0.36	13.62**	9.44**	7.44**
P4x P5	0.46	0.34	0.60	0.43	0.60
P4x P6	2.01	0.04	14.00**	8.57**	6.37**
P4x P7	0.78	-0.09	7.35	5.24**	4.45*
P5x P6	0.68	0.02	2.93	2.71	1.92
P5x P7	0.55	0.03	5.95	3.74	4.29*
P6 x P7	2.36*	0.42	3.59	2.57	0.10
SE (Sij - Skl)	1.52	0.44	5.77	3.30	2.72
SE (Sij - Sik)	1.67	0.48	6.32	3.60	2.98

PHT= Plant Height at Harvesting (cm); NBP= Number of Branches per Plant; NPP = Number of Pods per Plant; TPW = Total Pod Weight (g); SYP = Seed Yield per Plant (g).
P1= TGx1835 – 40E; P2= TGx1990 – 55F; P3 = TGx1990 – 3F; P4 = TGx1990 – 37F; P5 = TGx1989 – 21F; P6 = TGx1830–20E; P7=TGx1990–57F

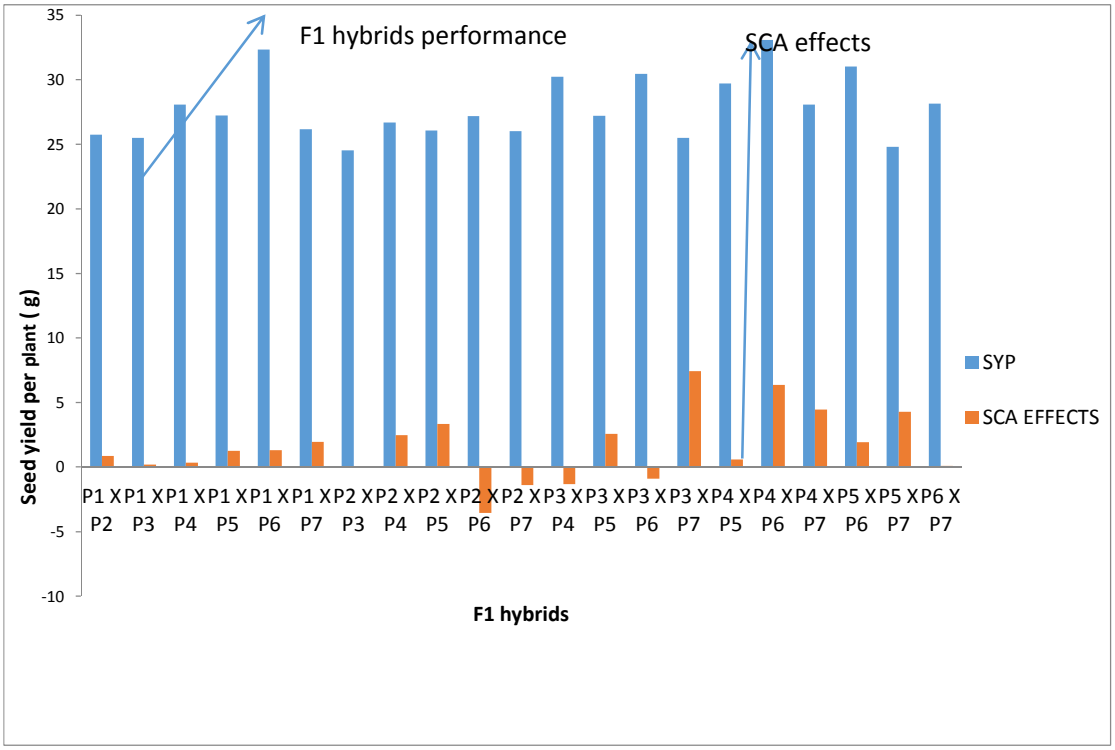

Fig. 1. Relationship of F1 hybrids performance and SCA effects for soybean seed yield per plant

P1= TGx1835 – 40E; P2= TGx1990 – 55F; P3 = TGx1990 – 3F; P4 = TGx1990 – 37F; P5 = TGx1989 – 21F; P6 = TGx1830–20E; P7=TGx1990–57F

3.3 Number of Pods per Plant

The mean performance of the parents and the hybrids (Table 1) showed that among the parent, TGx1830–20E had the maximum number of pods (146) followed by TGx1990 – 37F recording (141.69). Among the hybrids, the highest number of pods was recorded in TGx1835 – 40E x TGx1830–20E (149). The mean squares from analysis of variance (Table 2) revealed significant differences among the genotypes and significant GCA variance. The significant GCA indicated that additive genes controlled the expression of this trait. The GCA effects in Table 3 showed that TGx1830–20E had the maximum GCA effects (7.48) followed by TGx1835 – 40E (3.98). The SCA effects in Table 4 indicated that TGx1990 – 37F x TGx1830–20E had maximum SCA effects (14.00) followed by TGx1990 – 3F x TGx1990–57F. (13.62). TGx1835 – 40E and TGx1830–20E were good general combiners and could be utilized in hybridization programme for improving number of pods through selection from segregating population. The findings in this study corroborates the findings of [11].

3.4 Total Pod Weight

The mean performance of the parents and their hybrids in Table 1 indicated that among the parents, TGx1830–20E recorded the highest total pod weight (42.96 g) while among the hybrids, TGx1990 – 37F x TGx1830–20E recorded the highest total pod weight (47.06g). The mean squares from analysis of variance revealed significant differences among the genotypes and significant GCA in Table 2. The significant GCA variance indicated that additive gene effect was responsible for controlling total pod weight. The estimates of GCA effects in Table 3 showed that TGx1830–20E had the highest GCA effects (4.66) followed by TGx1990 – 37F (1.26). The top 3 crosses for SCA effects were TGx1990 – 3F x TGx1990–57F, TGx1990 – 37F x TGx1830–20E and TGx1990 – 37F x TGx1990–57F which exhibited 9.44, 8.57 and 5.24 SCA effects, respectively in Table 4. The

expression of total pod weight through additive gene action corroborates the findings of [12].

3.5 Seed Yield per Plant

Table 1 revealed that the parent, TGx1830–20E recorded the highest seed yield (29.30 g) among parents while TGx1990 – 37F x TGx1830–20E recorded the highest seed yield (33.09 g) among the hybrids. The significant GCA variance in Table 2 showed that additive gene action controls the expression of this trait. With regards to GCA effects in Table 3, four parents gave positive and three parents gave negative GCA effects being maximum in TGx1830–20E (3.85). Among the hybrids, sixteen out of the twenty–one cross combinations exhibited positive SCA effects being maximum in TGx1990 – 3F x TGx1990–57F (7.44) followed by TGx1990 – 37F x TGx1830–20E (6.37) followed by TGx1990 – 37F x TGx1990–57F (4.45). The magnitude of GCA was higher than SCA variance which indicated the predominance of additive genes influencing soybean yield.

4. CONCLUSION

From the present study, significant GCA variance was observed in plant height, number of pods, total pod weight and seed yield per plant, whereas non-significant SCA variance was observed in all the other characters except plant height. This result showed that additive gene action was important in the expression of almost all studied characters. Among the parents, TGx1989 – 21F was good general combiner for plant height, TGx1835 – 40E for number of branches and TGx1830–20E for number of pods, total pod weight and seed yield per plant. Hence, these parents could be considered potential parents in hybridization and selection programmes for developing new soybean varieties. The hybrid TGx1990 – 55F x TGx1990 – 37F expressed high SCA effects for plant height and number of branches, TGx1990 – 37F x TGx1830–20E for number of pods and TGx1990 – 3F x TGx1990–57F for total pod weight and seed yield. Hence, these hybrids could be considered for hybrid seed production with respect to these traits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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