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Genetic Assessment of Combining Ability for Seed-Yield and Its Related Traits in Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Crosses were made in line × tester mating design between a set of five IITA soybean released varieties and three plant introduced (PI) accessions obtained from World Vegetable Center, Taiwan. In order to produce sufficient seeds, F_1 crosses were selfed, subsequently F_2 populations along with their parents were planted in a randomized complete block design at two locations in Nigeria with three replications. Agronomic traits *viz.* days to flowering, days to poding, plant height, number of pods/plant and seed yield/plant were measured. Testers and lines showed significant differences for all the measured traits except days to flowering for testers. Considering the significance and magnitude of general combining ability (GCA) effect, line TGx 1988-5F was observed desirable for earliness, while line TGx 1989-19F was the best combiner for number of pods/plant and seed yield/plant. On the other hand, best tester for seed yield was PI 230970. Crosses TGx 1835-10E × PI 459025B and TGx 1987-62F × PI 459025B had significant and highest SCA effect for seed yield/plant. These two crosses appeared to be most promising for soybean yield improvement programme.

Key words: General combining ability, Line × Tester, Soybean, Specific combining ability.

INTRODUCTION

The fulfillment of increasing demand for nutritious diet is a continuous global challenge especially for developing regions such as sub-Saharan Africa (SSA) where majority of inhabitants still depends on agriculture. Notably, the prevalence of under-nourishment appears to have risen in SSA from 20.8 to 22.7 percent between 2015 and 2016 and the number of people undernourished rose from 200 to 224 million, accounting for 25 per cent of the people undernourished in the world (FAO, 2017). Accessibility of animal protein is a constraint for majority of Africa's populace, as it is quite expensive, hence, they often consume starch based diet especially root and tuber crops (Schonfeldt and Hall, 2012). Soybean can serve as a dietary substitute for higher-fat animal products, because soybean seeds contain about 37-42% protein content with all essential amino acids and 17-24% oil content comprising 85% poly un-saturated fatty acid with two essential fatty acids free from cholesterol (Balasubramaniyan and Palaniappan, 2003). Nigeria occupies maximum soybean acreage in SSA but ranks second in soybean production after South Africa (FAOSTAT, 2017). In Nigeria, soybean is consumed in the form of various food products such as *dawadawa* (a traditional soup condiment), soy *ogi*, biscuits, soy flour, soy yoghurt and soymilk (Poopola and Akueshi, 1986). Therefore, increase in soybean production may help to address the challenges of food and nutritional security in Nigeria.

However, tropical regions, like Nigeria are characterized by hot and humid weather conditions which enhance the incidence of pest and diseases such as soybean rust (SBR) caused by *Phakopsora pachyrhizi*. The yield loss due to SBR may vary but it has the potential to cause more than 80% yield loss under favourable conditions (Chander *et al*., 2019).

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For any successful breeding programme to improve quantitative characters such as grain yield, it is essential to know precisely the genetic factors contributing to yield and its related characters (Nath *et al*., 2018). According to Dar *et al*. (2014), *per se* performance of parents is not always a true indicator of its potential, rather a combining ability study is needed. Among the various ways of determining the combining ability potential of parents and crosses, line × tester analysis is most commonly used method which was initially developed for selecting suitable parents with good

general combining ability (GCA) and crosses with high specific combining ability (SCA) for exploitation in pedigree breeding (Kempthorne, 1957). However, there are few reports to utilize line × tester analysis for combining ability analysis in self-pollinating crops such as soybean (Bastawisy *et al*., 1997; Sood *et al*., 2000; Mebrahtu and Devine, 2008). The present study was, therefore, undertaken to evaluate the combining abilities of five IITA released varieties using three plant introduction (PI) accessions as testers which are source of resistance against SBR.

MATERIALS AND METHODS

Parental lines were mated in line × tester design using five highly promiscuous IITA soybean released varieties [Tropical Glycine crosses (TGx)] as lines and three rust resistant accessions obtained from World Vegetable Center, Taiwan as testers (Table 1). The accessions; PI 230970, PI 462312 and PI 459025B contained single rust resistance gene *Rpp2*, *Rpp3* and *Rpp4*, respectively. In order to obtain sufficient number of seeds in each cross, all the F_1 crosses were further advanced by selfing in the screen house at IITA, Ibadan. All the F_2 populations along with their parents were evaluated in randomized complete block design with three replications using a spacing of 75 cm x 8 cm (between and within rows) at two locations in Nigeria (Ibadan and Fashola). The experimental plot was represented by two-meter length, covering an area of 3.0m^2. To raise a good and healthy crop, standard agronomic practices were followed during the entire growing season. Data were collected on days to flowering (by counting no. of days from sowing to appearance of flower), days to poding (by counting no. of days from sowing to pod development), plant height (at harvesting, length of plant from base to tip in cm), number of pods/plant (by counting the total number of pods on a plant) and seed yield/ plant (by measuring the total seed weight of an individual plant in grams). Harvesting and threshing were done manually. Data collection for days to flowering and days to poding was done on a plot basis while remaining traits were recorded by averaging the trait value of 40 representative plants in each plot.

Estimates of GCA and SCA based on data combined across locations for line × tester mating design were estimated using SAS version 9.4 software.

GCA lines (L) = $\bar{x}_j - \bar{Y}$

GCA tester (T) = $\bar{x}_i - \bar{Y}$

SCA (L x T) = $\bar{x}_{ij} - \bar{x}_j - \bar{x}_i + \bar{Y}$

Where

$\bar{x}_j$ = mean of F_2 population with a given line averaged over all replications, locations and testers

$\bar{x}_i$= mean of F_2 population with a given tester averaged over all replications, locations and lines

$\bar{x}_{ij}$ = mean of a given F_2 population (L × T) averaged over replications and locations.

$\bar{Y}$ = experimental mean.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA)

Combined ANOVA across locations revealed significant (at $p< 0.01$) differences in both the locations for all the traits (Table 2), indicating the discriminatory nature of the two locations among the studied genotypes. All the lines and testers used in present study also differs with respect to all traits except testers for days to flowering. There was significant interaction between location and line for number of pods/plant and seed yield/plant, indicating that the performance of the lines used for the study was not consistent in Ibadan and Fashola with respect to these two traits.

Similarly, significant interaction between location and tester was also observed for plant height and number of pods/ plant, indicating that in both locations, there was no consistency for plant height and number of pods/plant for testers. In the present study, GCA was observed greater than SCA for all characters except for days to flowering indicating the preponderance of additive gene action in the inheritance of these traits (Raut *et al*., 2000; Durai and Subbalakshmi, 2009).

Table 1: Description of genotypes used in present study.

Genotype	Country of origin	Source	Year of release	Desirable characteristics
TGx 1989-19F	Nigeria	IITA, Nigeria	2014	Resistant to bacterial pustule, frog eye leaf spot and highly promiscuous
TGx 1987-10F	Nigeria	IITA, Nigeria	2010	Resistant to bacterial pustule, frog eye leaf spot and highly promiscuous
TGx 1988-5F	Nigeria	IITA, Nigeria	2014	Resistant to bacterial pustule, frog eye leaf spot and highly promiscuous
TGx 1987-62F	Nigeria	IITA, Nigeria	2010	Resistant to bacterial pustule, frog eye leaf spot and highly promiscuous
TGx 1835-10E	Nigeria	IITA, Nigeria	2008	Resistant to bacterial pustule, frog eye leaf spot and highly promiscuous
PI 230970	Japan	WorldVeg, Taiwan	-	Source of soybean rust (SBR) resistant gene *Rpp2*
PI 462312	India	WorldVeg, Taiwan	-	Source of SBR resistant gene *Rpp3*
PI 459025B	China	WorldVeg, Taiwan	-	Source of SBR resistant gene *Rpp4*

IITA-International Institute of Tropical Agriculture, WorldVeg- World Vegetable Centre.

Table 2: Combined analysis of variance of soybean lines and testers for yield and its-related traits across two locations in Nigeria (Ibadan and Fashola).

Source of variation	DF	Days to flowering	Days to poding	Plant height (cm)	Number of pods/plant	Seed yield /plant (g)
Replication	2	7.08	3.89	50.19*	136.36	46.40
Site (S)	1	2496.44**	3062.5**	16406.30**	28524.50**	1789.89**
Line (L)	4	90.41**	111.29**	60.71**	536.70**	49.03*
Tester (T)	2	37.68	90.08**	652.39**	1055.39**	51.61*
S × L	4	24.21	7.03	32.84	575.24**	93.32**
S × T	2	57.63	14.23	244.91**	577.23**	24.75
L × T	8	48.12*	26.12	13.43	18.26	12.80
S × L × T	8	12.94	17.72	9.91	38.27	12.72
GCA	7	1.33	6.21	28.59	64.82	4.19
SCA	14	9.14	4.27	-0.15	-17.29	-1.40
Error	58	20.71	13.30	13.89	70.12	16.99

Note: df denotes degree of freedom. *, ** significantly different at 5% and 1% probability level, respectively.

Table 3: GCA effects of soybean lines and testers for seed yield and its-related traits across Ibadan and Fashola, Nigeria.

Genotypes	Days to flowering	Days to poding	Plant height (cm)	Number of pods/plant	Seed yield /plant (g)
Lines					
TGx 1835-10E	-1.63	-1.50*	-2.57*	-3.01	-0.81
TGx 1987-62F	1.42	2.99*	2.04	4.03	1.01
TGx 1987-10F	-0.69	0.58	2.52*	-0.84	-0.67
TGx 1988-5F	-2.24*	-2.38*	0.70	-5.01	-1.84
TGx 1989-19F	3.14*	3.54*	1.14	17.82*	2.31*
S.E. (G_i)	1.03	0.55	1.20	5.06	1.04
Testers					
PI 230970	0.27	0.32	3.99	3.67	1.51*
PI 459025B	-1.87	-2.74*	-6.37*	-9.10*	-0.82
PI 462312	-0.53	-0.88	-2.24	-3.59	-0.60
S.E. (G_i)	1.13	0.56	2.33	3.58	0.74

*, ** significantly different at 5% and 1% probability level respectively

GCA effects of the parents

Estimates of GCA effects for seed yield and its-related traits of soybean lines and testers across both locations are presented in Table 3. Among the lines, TGx 1988-5F had significant GCA effect for days to flowering and poding in the desired negative direction and the line TGx 1835-10E had significant GCA effect in the desired negative direction for days to poding and reduced plant height, while the line TGx 1989-19F appeared to be the best combiner for number of pods/plant and seed yield/plant.

Per se performance of testers across the locations showed that PI 230970 was the best combiner for seed yield, while accession PI 459025B was observed good combiner in the desired negative direction for plant height (dwarfness) and days to poding (earliness). In the past, substantial level of GCA in soybean for yield and its related traits have also been reported by de Almeida lopes *et al*. (2001), Pandini *et al*. (2002), Agrawal *et al*. (2005), Mebrahtu and Devine (2008) and Tadesse *et al*. (2016).

SCA effects of the crosses

A perusal of estimates of SCA effects of line × tester crosses for seed yield and its related traits across Ibadan and Fashola (Table 4) revealed that significant and desirable negative SCA effect for earliness in days to flowering was observed in crosses; TGx 1987-62F × PI 462312, TGx 1988-5F × PI 459025B and TGx 1989-19F x PI 459025B, while the cross TGx 1987-62F × PI 462312 also showed significant SCA for earliness with respect to days to poding. Significant SCA effects for reduced plant height were observed in the crosses; TGx 1987-62F × PI 230970, TGx 1988-5F × PI 230970, TGx 1988-5F × PI 459025B and TGx 1988-5F × PI 462312. Significant and positive SCA for seed yield was displayed by crosses; TGx 1835-10E × PI 459025B and TGx 1987-62F × PI 459025B. Based on line × tester mating design, de Almeida Lopes *et al.* (2001) and Tadesse *et al.* (2016) also reported crosses with good SCA for seed yield and its related traits in soybean.

TGx 1835-10E, TGx 1987-62F and PI 459025B which

Table 4: SCA effects of soybean crosses for seed yield and its-related traits across Ibadan and Fashola, Nigeria.

Cross	Days to flowering	Days to poding	Plant height (cm)	Number of pods/plant	Seed yield/ plant (g)
TGx 1835-10E × PI 230970	1.70	2.31	1.02	0.05	-0.65
TGx 1835-10E × PI 459025B	-1.27	-0.30	0.43	2.57	2.13*
TGx 1835-10E × PI 462312	-0.43	0.17	2.89*	0.09	0.43
TGx 1987-62F × PI 230970	-1.69	-1.69	-2.41*	-0.71	0.01
TGx 1987-62F × PI 459025B	4.18**	-0.80	1.40	-0.61	2.13*
TGx 1987-62F × PI 462312	-2.49*	-2.99*	0.22	-3.29	-2.63*
TGx 1987-10F × PI 230970	-0.74	0.94	-1.70	-6.00*	-1.48
TGx 1987-10F × PI 459025B	1.96	1.11	-1.40	-1.07	-2.38*
TGx 1987-10F × PI 462312	-1.21	-1.58	1.59	-1.41	-0.20
TGx 1988-5F × PI 230970	1.48	1.18	-2.10*	0.50	0.49
TGx 1988-5F × PI 459025B	-2.16*	-1.26	-2.37*	0.42	-0.93
TGx 1988-5F × PI 462312	0.68	1.54	-1.96*	0.79	-0.35
TGx 1989-19F × PI 230970	-0.74	-1.23	0.98	2.16	0.19
TGx 1989-19F × PI 459025B	-2.71*	-0.35	2.90*	-0.24	0.26
TGx 1989-19F × PI 462312	3.46**	4.79*	-0.30	-0.24	-0.63
S.E. (S_{ij})	1.07	1.25	0.94	1.84	1.06

*, ** significantly different at 5% and 1% probability level, respectively.

were observed low combiners for seed yield/plant, produced crosses with highest SCA for seed yield/plant. Sharma and Phul (1994) also reported that parents having low combining ability produce cross with high SCA effects. Even though, SCA effects do not contribute much in the improvement of self-pollinating crops like soybean, but high SCA effects are of interest, if they are associated to complementary genes, instead of dominance effects (de Almeida Lopes *et al.*, 2001). Thus, best crosses with high SCA are expected to generate high frequency of transgressive segregants which could be used to isolate pure lines superior in seed yield (Gadag *et al.*, 1999; Felahi *et al*., 2013).

CONCLUSION

Preponderance of additive gene action was observed for most of the traits studied, suggesting that early generation selection for these traits in soybean will be effective. Two crosses namely; TGx 1835-10E × PI 459025B and TGx 1987-62F × PI 459025B exhibited significant and high SCA effect for seed yield that may be further used for soybean varietal improvement. It is suggested that, in order to effectively utilize crosses with good SCA estimates, an *inter-se* crossing in all possible combinations should be adopted, because multiple parents into a central gene pool may effectively speed up recombination and break genetic barriers, subsequently selection for superior lines could be applied to whole population at advance stage across environments.

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