 https://dx.doi.org/10.4314/agrosh.v22i1.2

HETEROSIS AND COMBINING ABILITY ESTIMATES FOR OKRA (*Abelmoschus esculentus* L. MOENCH) VARIETIES FOR YIELD ATTRIBUTING CHARACTERS IN SUDAN SAVANNA OF NIGERIA

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ABSTRACT

Two location trials were conducted at the Teaching and Research Farm of the University of Maiduguri and screen house of the Faculty of Agriculture during 2018/2019 dry season to estimate the combining ability variance, general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of crosses with six okra genotypes. They include: three improved varieties NHAe 47-4, LD-88, Clemson spineless and three locals, Chalawa, Syria and Sola, crossed in a 3 x 3 line x tester mating design to generate nine F_1 hybrids. All the F_1s along with their parents were evaluated in a Randomized Complete Block Design (RCBD) and Completely Randomise Design (CRD), with 3 replications. Positive heterosis were observed for number of fruits per plant in the crosses Chalawa x NHAe47-4, Chalawa x Clemson Spineless, this directly indicated their important contributions toward total fruit yield in okra. The variance of GCA and SCA revealed that both additive and non-additive gene actions were important in the control of most agronomic.The ratio of GCA/ SCA indicates greater preponderance of non-additive gene action for the characters in all the traits except number of leaves per plant and days to 50% flowering which were controlled by additive gene actions. The parent Syria was the overall best general combiner among the lines for all characters in the field and Chalawa was the overall best general combiner for all characters measured among lines in the screen house. LD88 recorded the highest GCA effects for all of the characters among testers in both experiments**.** Similarly, in the field, the hybrid Sola x NHAe47-4 recorded the maximum SCA effect for all characters except days to 50% flowering; Syria x NHAe47-4 was the best SCA for most characters except plant height and also the cross between Syria x Clemson Spineless was the best SCA for most characters except number of fruits per plant. In the screen house, the cross between Chalawa x NHAe47-4, showed superior SCA for all characters measured. Appreciable level of heterosis was observed for most of the characters studied, the overall maximum positive significant heterosis for total fruit yield (kg/ha) was observed in crosses Syria x LD88 (52.80) and Chalawa x NHAe47-4(123.30) over better parents. The preponderance of non-additive genetic effect and the tremendous level of heterosis observed among the characters in the parents and their crosses studied would be great asset in choosing the okra varieties for intercrossing and development of hybrids varieties for commercial production of okra.

Key Words: Okra, Crosses, Heterosis, Combining Ability and Okra leaf curl virus

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable crop grown in both the tropical and sub-tropical regions of the world (Eshiet and Brisibe, 2015). It ranks first before tomato, eggplant and most of the cucurbits (Babatunde *et al.*, 2017) with India producing 6,346,370 tons followed by Nigeria with about 2,390,500 tons representing 65.95% and 24.84% respectively of the world production (FAOSTAT, 2017). The crop is widely grown both as irrigated and as rain-fed in Northern Nigeria. The plant is robust erect herb 1-2m tall depending on the variety and the fruit has high mucilage content. It grows well on the lowlands of tropic and sub-tropics under warm temperature, but the best variety of okra is produced on well manure soil (Mays *et al.*, 2012). Okra is a self-pollinated crop. Breeding method for the improvement of a crop depends primarily on the nature and magnitude of gene action involved in the expression of quantitative and qualitative traits (Valluru *et al.,* 2020). Hence, the genetic improvement of yield and its contributing characters require the selection of appropriate breeding procedures which is dependent upon the general combining ability (GCA) of parents and specific combining ability (SCA) of hybrids (Jag and Singh, 2012).The general combining ability is the manifestation of additive gene action for the selection of parents, and the specific combining ability in respect of a particular character in the hybrid is the capitalization of Non- additive gene action (Jag and Singh, 2012). Additive and non-additive variance components are important in the genetic control of yield and its associated traits. This will help to formulate suitable breeding strategy and isolate potential parents and promising crosses for further exploitation (Reddy et al., 2012). Prediction of progeny performance in recurrent selection schemes (i.e., based on phenotypes of progeny testing only) is usually based on genotypic value (i.e., best unbiased linear prediction (BLUP) values or even adjusted means without shrinkage towards the mean, which includes additive and non-additive genetic effects), estimated without any genetic relationship information (Hallauer *et al*. 2010).The non additive effects correspond to the dominance and epistasis components, where the former represents the interaction of alleles at a particular locus and the latter results from the interaction between alleles at different loci (Odilon *et al.* 2017).

Heterosis, also called hybrid vigour increases in such characteristics as size, growth rate, fertility, and yield of a hybrid organism over those of its parents. Plant and animal breeders exploit heterosis by mating two different pure-bred lines that have certain desirable traits. The first-generation offspring generally show, in greater measure, the desired characteristics of both parents (Birchler e*t al.*, 2010).

MATERIALS AND METHODS

Experimental Location and Field Layout

The experiment was carried out at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri (latitude 110 80'N, and longitude 130 19'E) and screenhouse of the Faculty of Agriculture University of Maiduguri (latitude 11^0 48' 40' N and longitude 13^0 12' 23' E) during the 2018/2019 dry season under irrigation. Both locations are in the Sudan Savannah agro ecological zone of Nigeria.

Development of F_1 generations

Experimental material for the present investigation involves two sets of okra cultivars. The first set consisted of three commercially cultivated okra cultivars (Chalawa, Syria and Sola) from the seed unit of Borno state Agricultural Development programme (BOSADP) and the second set consisted of three improved varieties LD88, NHAe47-4 and Clemson Spineless obtained from National Horticultural Research Institute, Ibadan (NIHORT) were planted during February, 2018 in Teaching and Research Farm University of Maiduguri crossed in (3 x 3) Line x Tester mating design to generate nine F_1 hybrids. A randomized complete block design (RCBD) with three replicates was used. In each replication, 16 stands were grown in 2x2m plot with males occupying the two side rows and the female occupying the center row. The spacing of 60 x 30cm was maintained for inter and intra rows.

Field Experiment

All the F_1s along with their parents were evaluated in Teaching and Research Farm University of Maiduguri, laid in a Randomized Complete Block Design (RCBD). A total land area of 276 m^2, divided into 45 plots of 2 m x 2 m with 1 m spacing between replications. The surrounding secondary vegetation was cleared with cutlasses and hoes and the debris removed from the site (Ojiako *et al.*, 2018). Light watering was applied using a watering can every morning and evening. This was continued for a week for the rapid and good establishment of the germinated seedlings. Data were collected on five randomly selected plants in each replication on 6 characters *viz*., plant height, number of leaves per plant, days to 50% flowering, number of fruits per plant, weight fruit per plant (g) and total yield kg/ha. Statistical analysis of the data was computed on all measured traits using the Statistical Analysis System (SAS) software for Windows Version 9.2 (SAS, 2011). The SAS GLM procedure employed for the ANOVA. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at 0.05 percent probability suggested by (Gomez and Gomez, 1984). Significance of better-parent heterosis was determined using't' test as suggested by Wynne *et al*. (1970).

Screenhouse Experiment

Pot experiment was conducted using 36 plastic pots (diameter: 63cm, height: 20.5cm) positioned in a screenhouse in 2019. The soil was sampled from cultivated layer (0-

30cm) near the experimental site. The soil sample was spread on plastic sheet and exposed to the sun for air-drying. The soil was crushed and cleared of rocks. Poultry manure 10kg was incorporated to the soil. Each pot was uniformly packed with 35kg of soil, the bottom and side of each pot had holes for draining excess water. The 15 treatments were laid in CRD (Completely Randomise Design) and replicated three times. Okra seeds were sown in pots.

RESULTS

Heterosis (%) for Crosses over Better Parents of Okra

Heterosis was estimated as percent increase or decrease of F_1 values over better parent (BP). The extent of heterosis for different characters of Okra is presented in Table 1. The result in the field indicated that four out of nine crosses exhibited significant positive heterosis over better parent for number of leaves per plant, where **Syria x NHAe47-4** had the highest number of leaves per plant **(**45.06) followed by Chalawa x Clemson Spineless (39.82), Syria x LD88 (30.25) and Chalawa x NHAe47-4 (31.10). As for days to 50% flowering, the cross between Sola x NHAe47-4 (-14.37) showed highest negative heterosis. However, Syria x Clemson Spineless (-35.53) exhibited significant negative heterosis for number of fruits per plant. Similarly, the cross between **Sola x LD88 (**-82.96), Sola x NHAe47-4 (-80.79), **Sola x Clemson Spineless (**-61.96), Syria x Clemson Spineless (-74.59) and Chalawa x Clemson Spineless showed highest significant negative heterosis for weight of fruit per plant (-90.85). Also, four crosses exhibited significant negative heterosis for total fruits yield (kg/ha) where **Sola x LD88 (**-65.81) showed the highest significant negative heterosis followed by Syria x Clemson Spineless (-58.29), Sola x NHAe47-4(-54.47) and Sola x Clemson Spineless (-50.01) while Chalawa x NHAe47-4(123.30) had significant positive percent over better parent heterosis for total fruit yield (kg/ha).

The result in Table 1 for Screen House indicated that the crosses between Chalawa x Clemson Spineless (37.18) and **Sola x Clemson Spineless (**29.49) expressed significant positive better heterosis over higher parent for plant height. On the other hand, Sola x NHAe47-4(-23.26) showed highest significant negative heterosis over better parent for number of leaves. Also, number of fruits per plant showed highest positive heterosis in crosses between Chalawa x NHAe47-4(64.87), Chalawa x Clemson Spineless (62.16) and **Sola x LD88 (**-35.19) exhibited significant negative heterosis. However, Chalawa x NHAe47-4(37.91) and Chalawa x Clemson Spineless (37.84) exhibited highest significant positive heterosis for weight of fruit per plant. As for total fruits yield per hectare, Syria x LD88 (52.80) exhibited highest significant positive better heterosis over parent.

Table1: Estimates of Heterosis (%) over Better Parent of Okra Varieties

	Unimaid Farm						Screen House					
Crosses	**PLHT**	**NLV**	**DFD**	**NFPT**	**WFPT**	**TFY**	**PLHT**	**NLV**	**DFD**	**NFPLT**	**WFPT**	**TFY**
Sola x LD88	10.29	4.82	-2.69	8.33	-82.96**	-65.81**	5.13	1.18	2.53	-35.19*	8.72	3.62
Sola x NHAe47-4	8.82	15.66	-14.37*	31.67	-80.79**	-54.47**	-0.61	-23.26*	-3.18	31.91	-1.96	11.75
Sola x Clemson Spineless	-9.41	-5.60	3.87	-25.00	-61.96**	-50.01**	29.49*	6.83	3.23	-19.15	-11.72	20.84
Syria x LD88	3.75	30.25*	-1.08	-17.11	-40.47	-22.29	-1.39	7.06	0.00	-24.07	-2.18	52.80**
Syria x NHAe47-4	-6.25	45.06**	-3.78	-17.11	-51.63	-28.60	-10.37	-8.72	0.00	4.55	1.11	13.99
Syria x Clemson Spineless	-5.88	-3.83	4.86	-35.53*	-74.59**	-58.29**	-0.64	0.00	3.31	-6.82	-14.61	-0.46
Chalawa x LD88	-14.86	-7.32	-5.38	7.69	-42.67	-21.84	18.75	-14.04	-7.59	-16.67	-23.02	-7.63
Chalawa x NHAe47-4	14.86	31.10*	10.00	13.33	9.44	123.30**	23.17	11.63	-6.37	64.87*	37.84*	-8.16
Chalawa x Clemson Spineless	5.88	39.82**	1.72	-6.67	-90.85**	-30.66	37.18*	-7.02	6.12	62.16*	37.91*	-8.56

Key: * = P≤0.05 and ** = P≤0.01 Levels of Probability

PLHT=plant height (cm), NLV=number of leaves per plant, DFD=days to 50% flowering, NFPT=number of fruits per plant, WFPLT=weight of fruit per plant (g), TFY=total fruits yield (kg/ha).

Analysis of Combining Ability Variance

The mean squares from analysis of variance of combining ability and components of variance of okra observed in combined across locations are presented in Table 2. The variance component estimate of testers was consistently higher than lines for all the characters assessed except for number of fruits per plant (9.09). However, variance component for line x tester on the other hand, revealed consistently higher values for characters assessed except for plant height (0.68). Generally, the variance component for SCA was higher than GCA in most of the traits assessed except for number of leaves per plant (17.65). The GCA/SCA ratio shows that high value was obtained in number of leaves per plant (3.21). The proportional contribution to total variance of lines, testers and their interactions revealed that contribution of line x tester interaction were consistently higher than both lines and testers. However, contribution of lines was much lower than line x tester interaction for most characters assessed except number of fruits per plant (70.55). Similarly, the tester indicated that the highest Contribution to total variance was obtained in number of leaves per plant (55.66). The proportional contribution to total variance of lines, testers and their interactions revealed that contribution of line x tester interaction were consistently higher than both lines and testers. However, contribution of lines was much lower than line x tester interaction for most characters assessed except number of fruits per plant (70.55). Similarly, the tester indicated that the highest contribution to total variance in number of leaves per plant (55.66).

The result in Table 2 for screen house shows that the variance component estimate of testers was consistently higher than lines for all the characters assessed except for plant height (0.93), number of leaves per plant (2.698). Similarly, variance component for line x tester, revealed consistently higher values for characters assessed except for days to 50% flowering (0.66). However, the variance components for SCA were higher than GCA in most of the traits assessed except days to 50% flowering (0.86). Also, the GCA/SCA ratio shows high values which were obtained in days to 50% flowering (3.99). The proportional contribution to total variance of lines, testers and their interactions revealed that contribution of line x tester interaction were consistently higher than both lines and testers. Similarly, contribution of lines was much lower than line x tester interaction for most characters assessed except weight of fruits per plant (26.62). On the other hand, the tester indicated the highest contribution to total variance in days to 50% flowering (51.14) and weight of fruits per plant (68.33).

Table 2: Combining Ability Variance, Components of Variance and Proportional Contribution to Total Variance for Six Characters of okra

		Unimaid Farm						Screen House					
Source of Variation	Df	PLHT	NLV	DFD	NFPT	WFPT	TFY	PLHT	NLV	DFD	NFPT	WFPT	TFY
Replication	2	693.45**	15.79**	38.74**	413.29**	105.48**	25344.2**	153.78**	15.31**	14.36**	41.93**	624.16**	693.45**
Site	1	6014.56**	4.74	546.69**	1406.99**	498.07**	103576**	322.67**	0.46	108.04**	68.91**	404.97**	6014.56**
Genotype	8	242.80	6.03	19.35**	429.79**	413.64**	9307.92**	30.58**	10.96**	9.63	111.67**	30.63**	242.80
Line	2	778.34**	5.57	34.79**	236.79*	2.39	6527.88**	43.72**	11.56**	23.81**	236.93**	571.36**	778.34**
Tester	2	150.09**	12.46**	4.41	992.58**	100.67**	23947.9**	36.31**	16.72**	3.06	156.09**	941.75**	0.137
Line x Tester	4	96.37**	3.05	13.60**	244.88*	9.72	336.47**	28.00	7.78**	5.83**	26.84**	70.72**	96.37
Site x Genotype	8	99.01**	13.28**	29.02**	463.19**	26.69**	13137**	48.50**	6.338**	36.32**	116.71**	171.34**	991.00**
Site x Line	4	92.84**	23.35**	5.35	490.03**	11.69**	15424.1**	28.22	1.41**	69.35**	14.01**	72.06**	92.84
Site x Tester	4	240.88**	7.46**	41.19**	966.23**	84.52**	32094.4**	17.64	13.02**	33.59**	338.12**	278.65**	240.88
Residual	32	31.16	3.16	4.77	198.25	5.29	265.72	16.03	5.46	6.17	57.36	13.16	167.32
Variance component estimate													
Line		0.24	0.14	0.38	9.09	26469.03	249360.5	5.62	21.846	0.11	5.19	6761.063	5023.68
Tester		2.72	12.72	2.25	2.27	93071.81	87327.81	0.93	2.698	1.61	70.36	18464.19	50805.82
Line x Tester		0.68	3.88	8.18	1.08	328937	830082.4	16.89	281.44	0.66	17.83	37625.77	228257.7
GCA		1.61	17.65	1.46	3.42	4700.63	240242.6	3.20	26.815	3.43	5.31	50450.5	111659
SCA		2.72	15.50	32.70	13.68	566123.1	3320330	166.91	67.556	0.86	71.33	150503.1	913030.6
GCA/SCA		0.59	3.21	0.04	0.25	0.026	0.042	0.019	0.161	3.99	0.074	0.034	0.122
Proportional Contribution to total Variance													
Line		23.37	7.21	32.24	70.55	43.55	33.13	46.43	14.31	17.93	7.43	26.62	23.07
Tester		6.64	55.66	12.71	0.53	9.22	18.10	2.18	13.88	51.14	23.53	68.33	32.98
Line x Tester		69.99	37.13	55.05	28.92	47.23	48.77	51.39	71.815	30.92	69.04	5.05	43.96

Key:* = P≤0.05 and ** = P≤0.01 Levels of Probability, PLHT=plant height (cm), NLV=number of leaves per plant, DFD=days to 50% flowering, NFPT=number of fruits per plant, WFPLT=weight of fruit per plant (g), TFY=total fruits yield (kg/ha).

Estimates of General Combining Ability (GCA) Effects of Parents for Six Agronomic Characters of Okra in both Field and Screen House

Estimates of general combining ability (GCA) effects of parent for six agronomic characters of okra in both field and screen house in line x tester analysis are presented in Table 3. The result in the field showed that LD88 was the overall best general combiner among tester because it showed significant GCA effect for all the characters measured. It is closely followed by NHAe47-4 which showed superiority as the best general combiner for five characters plant height (-3.11), number of leaves per plant (-1.22), days to 50% flowering (2.44), weight of fruits per plant (-16.05) and total fruits yield /ha (1097). It is observed that Clemson Spineless was the lowest GCA among the testers for weight of fruits per plant (118.0) and total fruits yield kg/ha (-7.55kg).

The results among lines indicated that Syria was the best combiner among the lines for all characters plant height (1.04), number of leaves per plant (1.78), numbers of fruits per plant (1.67), days to 50% flowering (-0.93), weight of fruits per plant (-271.00) and total fruits yield /ha (-504.25kg). However, Sola showed best combinations for number of leaves per plant (2.15), number of fruits per plant (0.63), weight fruits per plant (83.00) and total fruits yield per hectare (-318.75kg). Chalawa was the lowest in terms of GCA effect with three significant GCA effect for plant height (-2.19), weight of fruits per plant (188.00) and total fruit yield per hectare (823.00).

The result in Table 3 for screen house shows that LD88 was the best combiner among testers for all characters measured except days to 50% flowering. It is followed by NHAe47-4 was the best combiner for number leaves per plant (8.33), number of fruits per plant (2.89), weight fruits per plant (-24.08) and total fruits yield kg/ha (-190.09). Similarly, Clemson Spineless showed as best combiner for plant height (1.37), weight of fruits per plant (71.83) and total fruits yield per hectare (-186.03kg).

The results among lines indicated that Chalawa was the best general combiner for all characters plant height (3.15), number of leaves per plant (2.70), numbers of fruits per plant (-1.74), days to 50% flowering (2.56), weight of fruits per plant (-159.08) and total fruits yield /ha (-360.65kg). Similarly, Sola was the good combiner for plant height per plant (-3.40), number leaves per plant (3.26), number of fruits per plant (-1.67), weight of fruits per plant (65.67) and total fruits yield kg/ha (414.04). However, Syria was found to be the worst general combiner with three significant GCA effect for number of leaves per plant (-5.96), weight of fruits per plant (93.42) and total fruits yield per hectare (-53.75kg).

Table 3: Estimates of General Combining Ability (GCA) Effects of Parents for Six Agronomic Characters of Okra in both Field and Screen House

	Unimaid Farm						Screen House					
Parents	**PLHT**	**NLV**	**DFD**	**NFPT**	**WFPT**	**TFY**	**PLHT**	**NLV**	**DFD**	**NFPT**	**WFPT**	**TFY**
Testers												
LD88	2.06**	1.00**	-2.22**	-1.37**	-101.05**	-342**	-2.29**	-6.78**	0.15	-2.44**	95.92**	376.93**
NHAe47-4	-3.11**	-1.22**	2.44**	-0.04	-16.05**	1097**	0.96	8.33**	-0.96	2.89**	-24.08**	-190.09**
Clemson spineless	1.06	0.22	-0.22	1.41	118.00**	-755**	1.37**	-1.56	0.81	-0.44	71.83**	-186.03**
SE±	1.11	0.43	0.79	0.61	5.49	16.27	0.73	1.45	0.49	0.86	4.85	9.43
Lines												
Syria	1.04**	1.78**	1.67**	-0.93**	-271.00**	-504.25**	0.26	-5.96**	1.04	-0.89	93.42**	-53.75**
Sola	-0.80	2.15**	-0.56	0.63**	83.00**	-318.75**	-3.40**	3.26**	0.70	-1.67**	65.67**	414.04**
Chalawa	-2.19**	-0.93	-1.11	-0.31	188.00**	823.00**	3.15**	2.70**	-1.74**	2.56**	-159.08**	-360.65**
SE±	0.51	0.57	0.63	0.24	8.09	13.98	0.95	1.05	0.64	0.78	6.14	10.31

Key: * = P≤0.05 and ** = P≤0.01 Levels of Probability

PLHT=plant height (cm), NLV=number of leaves per plant, DFD=days to 50% flowering, NFPT=number of fruits per plant, WFPLT=weight of fruit per plant (g), TFY=total fruits yield (kg/ha).

Estimates of Specific Combining Ability (SCA) Effects of Crosses in Six Agronomic Characters of Okra in both Field and Screen House

Estimates of specific combining ability (SCA) effect of parent for six agronomic characters of okra in both field and screen house is presented in Table 4. Result in field showed crosses between Sola x NHAe47-4 and Syria x Clemson spineless were the overall best specific combiners for five characters assessed, which was closely followed by Syria x NHAe47-4 which showed superiority as best specific combiner for plant height (-4.00), number of leaves per plant (-3.85), weight of fruits per plant (-241.25) and total fruits yield kg/ha (-769.05). Similarly, the cross between Sola x Clemson spineless was the best specific combiner for all traits accessed except days to 50% flowering and number of fruits per plant. On the other hand, cross between Syria x LD88 was the best specific combiner for days to 50% flowering (2.56), number of fruits per plant (3.56), weight of fruits per plant (-309.75) and total fruits yield per hectare (-909.00). The cross between Chalawa x Clemson Spineless showed superiority as good combiner for all characters measured except number of fruits per plant. The cross between Chalawa x LD88 was the best specific combiner for weight of fruits per plant (202.05) and total fruits yield per hectare (1307.05) However, Chalawa x NHAe47-4 was the best combiner for days to 50% flowering (3.11), weight of fruits per plant (-304.75) and total fruits yield per hectare (-527.25). Similarly, Sola x LD88 was the worst specific combiner with two significant SCA effect for weight of fruits per plant (107.25) and total fruits yield per hectare (-389.05).

The results in Table 4 for screen house showed that the cross between Chalawa x NHAe47-4 was the overall best specific combiner for all characters measured, followed by Chalawa x Clemson and Sola x LD88 which were best specific combiners for five characters accessed. The cross between Sola x Clemson Spineless was the best specific combiner for number of leaves per plant (-4.00), days to 50% flowering (-1.96), number of fruits per plant (4.44), weight of fruits per plant (7.33) and total fruits yield per hectare (-355.55). However, cross between Syria x Clemson Spineless was the best specific combiner for all characters accessed except plant height and days to 50% flowering. Similarly, cross between Sola x NHAe47-4 showed superiority as best specific combiner in number of fruits per plant (3.89), weight of fruits per plant (-44.17) and total fruits yield kg/ha (680.65). However, cross between Syria x LD88 was best specific combiner for plant height (3.78), weight of fruits per plant (-26.92) and total fruit yield kg/ha (-50.90). The between Syria x NHAe47-4 was the worst specific combiner which shows significant SCA for weight of fruits per plant (54.83) and total fruits yield kg/ha (-135.28). Similarly, Chalawa x LD88 was a good combiner for number of fruits per plant (-2.33), weight of fruits per plant (9.92) and total fruits yield kg/ha (376.00).

Table 4: Estimates of Specific Combining Ability (SCA) Effects of Crosses

	Unimaid Farm						Screen House					
Crosses	PHT	NLV	DED	NFPT	WFPT	TFY	PHT	NLV	DED	NFPT	WFPT	TFY
Sola x LD88	1.33	1.37	-1.44	-1. 11	107.25**	-398.05**	2.81**	-2.89**	1.19**	0.56	36.83**	-325.01**
Sola x NHAe47-4	2.67**	2.48**	1.78	2.22**	134.00**	1168.00**	-0.85	1.04	0.19	3.89**	-44.17**	680.65**
Sola x Clemson Spineless	-4.00**	-3.85**	-0.33	-0.67	-241.25**	-769.05**	-0.96	-4.00**	-1.96**	4.44**	7.33**	-355.55**
Syria x LD88	-0.44	-1.85	2.56**	3. 56**	-309.75**	-909.00**	3.78**	-1.19	-1.03	1.78	-26.92**	-50.90**
Syria x NHAe47-4	-1.44	-3.74**	-4.89**	-2. 67**	170.75**	-640.75**	-0.19	-0.11	0.37	0.44	54.83**	-135.28**
Syria x Clemson Spineless	1.89**	5.59**	2.33**	-1.00	139.00**	1549.75**	0.37	-3.67**	0.07	-2.22**	-27.92**	186.18**
Chalawa x LD88	-0.89	0.48	-1.11	-1.56	202.05**	1307.05**	-0.63	-0.89	-0.15	-2.33**	9.92**	376.00**
Chalawa x NHAe47-4	-1.22	1.26	3.11**	-0.11	-304.75**	-527.25**	8.89**	-8.78**	-1.15**	-4.33**	-10.67**	-545.38**
Chalawa x Clemson Spineless	2.11**	-1.74	-2.00**	1. 11	102.25**	-780.25**	-0.41	9.67**	1.30**	6.67**	20.58**	169.38**
SE±	0.82	0.98	0.91	0.76	8.26	17.92	0.59	0.77	0.56	1.08	3.20	11.07

Key: * = P≤0.05 and ** = P≤0.01 Levels of Probability
PLHT=plant height (cm), NLV=number of leaves per plant, DFD=days to 50% flowering, NFPT=number of fruits per plant, WFPLT=weight of fruit per plant (g), TFY=total fruits yield (kg/ha).

DISCUSSION

The positive heterosis were observed for number of fruits per plant in the crosses Chalawa x NHAe47-4, Chalawa x Clemson Spineless and also the cross between Chalawa x NHAe47-4 and Chalawa x Clemson Spineless exhibited highest significant positive heterosis for weight of fruit per plant in the screen house. This means that the number of fruits per plant and weight of fruits per plant are the most important determinants of production or yield. Thus, selection based on these characters will be quite beneficial in okra breeding programmes for formulating selection indices for the improvement of okra. This study is in agreement with Reddy *et al*. (2012) who reported that selection based on pod size, weight and number per plant are some of the most variable quantitative characters of okra for an efficient process to increase pod yield per plant.

In the field experiment, positive heterosis for number of leaves were observed in crosses Syria x NHAe47-4, Chalawa x Clemson Spineless, Syria x LD88 and Chalawa x NHAe47-4. This suggests that the high number of leaves per plant will increase assimilation during their photosynthetic activities and thereby, increase crop yield. In that vein, Anwanobong and Ebiamadon (2015) reported that greater number of leaves in any particular variety will produce a better crop yield due to the higher photosynthetic capacity thus, produce a better crop yield.

The cross between Chalawa x Clemson Spineless and Sola x Clemson Spineless showed significant positive heterosis over better parent for higher plant height in the screen house, this suggest that higher plant height accommodates more number of nodes and this will lead to higher number of fruits. Similar observations were reported by Prakash *et al.* (2019) who said positive heterosis is desirable for plant height and number of branches to accommodate great number of nodes and to get higher fruit yield in okra.

The negative heterosis recorded for days to 50% flowering, in the cross Sola x NHAe47-4 in the field is desirable for breeding for earliness. This result is in harmony with the earlier findings of Kishor *et al.* (2013) who reported that significant negative heterosis is a highly desirable attribute of earliness.

In the field experiment, the significant positive difference observed in GCA indicated the importance of additive gene effect in the control of number of leaves per plant. While SCA indicated the importance of non-additive gene effect in the control of plant height, days to 50% flowering, number of fruits per plant, weight of fruits per plant and total fruits kg/ha. Same observation was obtained in the screen house where additive gene control days to 50% flowering. However, plant height, number of leaves per plant, number of fruits per plant, weight of fruits per plant and total fruits yield kg/ha were controlled by non- additive genes. These findings are in agreement with those of several researchers (Wammanda *et al*., 2010; Reddy *et al*., 2011) who in their researches revealed the importance of both additive and non-additive genetic components in the inheritance of fruit yield and its components. Additive gene action observed in the present study for thirteen traits indicate that high heritability, increases in the selection during early segregating generations and direct selection in segregating generations will be effective by using the conventional breeding methods such as pedigree or pure line selections.

In the field, the estimate of variance components in all combining ability analysis exhibits that the ratio of GCA/ SCA indicate greater preponderance of non-additive gene action for the characters in all the traits except number of leaves per plant which is controlled by additive gene actions. Similar result was obtained in the screen house, where all the characters indicated greater preponderance of non-additive gene action except days to 50% flowering which is controlled by additive gene actions. It is then obvious that non-additive genetic effect was more important than additive genetic effect as most of the ratio were less than unity. Similar results were also reported for yield and its components in okra by several researches (Laxman *et al*., 2013 and Adiger *et al*., 20l3). This investigation therefore revealed that both the additive and non-additive gene effects were important in the genetic control of all the traits. Therefore, these parental lines could be exploited in hybridization and selecting desirable segregants from segregating generations in okra.

The tester LD88 showed superior GCA for all of the characters measured. However, Syria was considered the overall best general combiner among the lines for all characters measured in the field. On the other hand, in the screen house, LD88 was found good and generally combined for all characters accessed except days to 50% flowering. Similarly, Chalawa was an excellent combiner for all characters among lines. These high general combiners are recommended for use in breeding programmes to generate genetic variability in desirable direction for effective selection to improve the respective traits, indicating that these parents have the potential for the development of heterotic segregates for these characters. The work supports the findings of Sugani *et al.* (2017) who reported that parental varieties that showed good general combining ability may be used in a multiple crossing programme for isolating high yielding varieties in okra. Also, Ahmad (2002) in his conclusion stated that selected lines from such multiple crosses could be released as conventional varieties or used as improved parents for F_1s hybrid production.

In the field the hybrid Sola x NHAe47-4, Syria x NHAe47-4 and Syria x Clemson spineless were excellent specific combiners with five significant SCA effect out of six traits accessed. However, in the screen house the cross between Chalawa x NHAe47-4, showed superior SCA for all characters measured. The higher SCA could be used for further selection to obtain high yielding varieties. This finding is comparable with the findings of Dabhi *et al.* (2010) who reported that crosses with higher SCA could be exploited through heterosis breeding and may also give transgressive segregants in subsequent generations and therefore, it would be worthwhile to use them for improvement in fruit yield.

CONCLUSION

It can be concluded that variance of GCA and SCA effects revealed that both additive and non-additive genetic components were involved for various agro-economic traits. The presence of additive gene action would enhance improvement through simple selection for exploitation of dominance and epistatic effects. Thus, non-additive gene action could be exploited through heterosis breeding feasible to support okra productivity.

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