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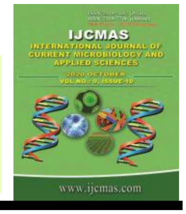

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Combining ability Analysis for Yield and Yield Components in Okra [*Abelmoschus esculentus* (L.) Moench]

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A B S T R A C T

Information on magnitude of combining ability were obtained for fruit yield and its related components; involving eight parents and their 28 F_1 hybrids (excluding reciprocal cross) along with a commercial hybrid check 'GJOH-4' of okra in randomized block design with three replications. The magnitude of *sca* variance was higher than *gca* variance for all the traits revealed preponderance of non-additive gene action for all the traits. The estimation of *gca* effects indicated that parents *viz.*, Arka Abhay and NOL-18-14 were good general combiner for fruit yield and its related traits. The estimation of s*ca* effects indicated that hybrids, *viz.*, Arka abhay x GAO-5, Arka abhay x NOL-18-14 and GAO-5 x NOL-18-14 were exhibited high heterosis coupled with high *sca* effects also.

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an important fruit vegetable crop cultivated in various states of India. Several species of the genus *Abelmoschus* are grown in many parts of the world among them *Abelmoschus esculentus* is most commonly cultivated in Asia and has a great commercial demand due to its nutritional values. In India area, production and productivity of okra in year 2018-19 is 511 ('000 ha), 62.19 lakh tonnes and 12.17 MT/hectares, respectively (Anon., 2019). Combining ability is referred as an ability of a parent to transmit its performance to its off springs. As the combining ability often depends upon complex interaction systems among genes, certain combinations nick well to produce superior off springs, whereas, others involving equally promising parents produce disappointing progeny. The concept of combining ability was initially developed by Sprague and Tatum in 1942. Combining ability indicates capacity of individual parents to transmit superior performances to its off springs. General combining ability (*gca*) is the average performance of a parent in a series of crosses and specific combining ability (*sca*) is an average performance and reflections of those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of line involved. Sprague and Tatum (1942) revealed that *gca* is basically due to additive effects of gene, whereas *sca* is due to inter-allelic interactions. Diallel analysis is the quickest method of understanding the genetic nature of polygenic characters and it also helps to ascertain the prepotency of parents.

Materials and Methods

The present study consists of 8 different okra genotypes viz., Arka Abhay, GOA-5, NOL-18-9, NOL-18-12, NOL-18-14, NOL-18-15, NOL-18-16, and NOL-18-17. The parents were crossed in half diallel mating design excluding reciprocals to produce 28 hybrids in *summer* 2019. The F_1 hybrids were obtained were evaluated at College farm, N. M. College of Agriculture, N. A. U., Navsari in *kharif*-2019, with three replications using okra hybrid GJOH-4 as standard check. Each and every genotype was grown in single line using 60 cm x 30 cm spacing. The different 11 quantitative characters like days to 50 % flowering, plant height (cm), branches per plant, fruit weight (g), fruit length (g), fruit diameter (cm), fruit per plant, fruit yield per plant, internodal length (cm), number of seeds per fruit, 100 seed weight (g) has been recorded. Data was analyzed as per Griffing's Method-II and Model-I (fixed-effect model) which involves direct crosses and parents.

Results and Discussion

The analysis of variance for combining ability for different traits was presented in Table 1. The analysis of variance for combining ability revealed that mean sum of square due to general combining ability and specific combining ability were significant for all the characters under study. It revealed that involvement of both additive as well as non-additive gene action responsible for inheritance of fruit yield and yield related traits in okra.

Similar result was reported by Patil *et al.*, (2016), Tiwari *et al.*, (2016), Wakode *et al.*, (2016), Devi *et al.*, (2017), Paul *et al.*, (2017), Rameshkumar *et al.*, (2017) and Lokeswari *et al.*, (2018). However, the magnitudes of variance *gca* were lower than variance *sca* for all the traits indicating the predominance of the non-additive gene action, for all the traits.

The estimates of general combining ability effects for each parent are presented in table 2. In the present investigation, Arka Abhay and NOL-18-14 were good general combiner for fruit per plant, internodal length as well as branches per plant; NOL-18-14 was for fruit yield per plant and fruit weight; Arka Abhay, GAO-5 and NOL-18-14 were for plant height; NOL-18-12 and NOL-18-14 were for fruit length; GAO-5 and NOL-18-14 were for fruit diameter, Arka Abhay was for days to 50 % flowering; NOL18-9 and NOL-18-17 were for number of seed per fruit while NOL-18-9, NOL-18-16 and NOL-18-17 were for 100 seed weight. Similar result was reported by Patel *et al.*, (2015b), Kumar *et al.*, (2016), Tiwari *et al.*, (2016), Lyngdoh *et al.*, (2017), More *et al.*, (2017), Satish *et al.*, (2017), Hadiya *et al.*, (2018), Makdoomi *et al.*, (2018), Demta and Surin (2019), and Pithiya *et al.*, (2020) in okra.

Specific combining ability effect helps in identification of superior cross combination (good specific combiners) for commercial exploitation of heterosis. In present investigation, eight hybrids *viz*., NOL-18-12 x NOL-18-15, NOL-18-19 x NOL-18-16, Arka Abhay x GAO-5, NOL-18-15 x NOL-18-16, NOL-18-15 x NOL-18-17, Arka Abhay x NOL-18-14, GAO-5 x NOL-18-14, GAO-5 x NOL-18-12 were found significant and positive *sca* effects for fruit yield per plant. The estimates of *sca* effects (Table-3) revealed that none of the hybrid exhibited consistently significant and desirable *sca* effects for all the characters.

Table.1 Analysis of variance (MSS) for combining ability in respect to various characters in okra

Sr. No.	Sources of variation	DF	Days to 50% flowering	Plant height (cm)	Branches per plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Fruit yield per plant (g)	Internodal length (cm)	Number of seeds per fruit	100 seed weight (g)
1	*gca*	7	3.15*	350.13**	0.38**	2.91**	5.43**	0.02**	6.76**	3788.16**	2.04**	43.50**	0.52**
2	*sca*	28	2.70**	92.99**	0.13**	1.16**	1.16**	0.08**	2.11**	786.42**	0.98**	28.82**	0.16**
3	Error	70	1.14	10.48	0.03	0.30	0.27	0.002	0.30	114.84	0.14	6.97	0.03
4	σ^2_{gca}	-	0.20	33.97	0.04	0.26	0.52	0.001	0.65	367.33	0.19	3.65	0.04
5	σ^2_{sca}	-	1.56	82.51	0.10	0.86	0.89	0.005	1.81	671.58	0.83	21.85	0.13
6	$\sigma^2_{gca}/\sigma^2_{sca}$	-	0.13	0.41	0.34	0.30	0.58	0.20	0.36	0.55	0.23	0.17	0.37

* - Significant at 5 % and **- Significant at 1%

Table.2 General combining ability effects for different characters in okra

Sr. No.	Parents	Days to 50% flowering	Plant height (cm)	Branches per plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruits Per plant	Fruit yield per plant (g)	Internodal length (cm)	Number of seeds per fruit	100 seed Weight (g)
1.	Arka Abhay	-0.66*	6.13**	0.21**	0.003	-0.58**	0.03	0.41*	3.49	-0.32**	0.57	0.10
2.	GAO -5	-0.23	3.84**	0.08	0.10	-0.34*	0.04*	0.19	5.76	0.36**	1.31	0.12*
3.	NOL-18-9	0.44	-4.53**	-0.10	0.06	-0.95**	-0.01	-0.64**	-8.96**	0.34**	-1.67*	-0.39**
4.	NOL-18-12	-0.19	-1.06**	0.02	0.09	0.51**	-0.04*	0.23	2.84	-0.07	-0.89	0.10
5.	NOL-18-14	-0.56	9.71**	0.33**	1.14**	1.46**	0.06**	1.69**	42.21**	-0.81**	4.09**	0.32**
6.	NOL-18-15	0.28	-4.13**	-0.17**	-0.70**	-0.06	-0.04*	-0.79**	-19.25**	0.03	-0.62	0.11*
7.	NOL-18-16	-0.13	-7.25**	-0.23**	-0.40*	0.16	0.01	-0.65**	-16.65**	-0.15	-0.02	-0.19**
8.	NOL-18-17	1.04**	-2.70**	-0.14**	-0.29	-0.21	-0.05**	-0.44**	-9.44**	0.63**	-2.77**	-0.17**
	S. E. (g_i) ±	0.32	0.96	0.05	0.16	0.15	0.02	0.16	3.17	0.11	0.78	0.05

* - Significant at 5 % and **- Significant at 1%

Table.3 Specific combining ability effects for different characters in okra

Sr. No.	Hybrids	Days to 50% flowering	Plant height (cm)	Branches per plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Fruit yield per plant (g)	Internodal length (cm)	Number of seeds per fruit	100 seed weight (g)
1.	Arka Abhay x GAO-5	-1.14	15.16**	0.50**	0.99	0.66	0.14**	1.05*	32.34**	-2.31**	9.03**	0.37*
2.	Arka Abhay x NOL-18-9	0.52	10.57**	0.14	0.36	0.00	0.03	0.47	3.69	-0.12	-2.79	-0.35*
3.	Arka Abhay x NOL-18-12	-1.18	-3.67	-0.04	-0.27	-0.49	-0.10	-1.26*	-24.94*	0.96**	-1.10	0.33*
4.	Arka Abhay x NOL-18-14	0.86	5.40	-0.15	1.02*	0.58	0.09	1.29*	27.72**	0.01	0.92	-0.39
5.	Arka Abhay x NOL-18-15	2.36*	-19.90**	-0.39*	-0.93	-0.77	-0.15**	-1.11*	-27.70**	1.15**	-5.90*	-0.25
6.	Arka Abhay x NOL-18-16	-1.91	-1.61	-0.26	0.67	-0.05	-0.09	-2.18**	-26.03*	0.77*	-0.84	0.32
7.	Arka Abhay x NOL-18-17	-0.74	4.34	-0.01	-0.57	0.20	0.03	0.75	10.33	0.36	8.32**	0.13
8.	GAO-5 x NOL-18-9	0.42	-11.78**	-0.46**	-0.79	-0.73	-0.05	-1.11*	-14.71	1.57**	-5.14*	-0.38*
9.	GAO-5 x NOL-18-12	-1.28	7.88*	0.16	1.24*	1.10*	0.05	0.69	25.26*	0.98**	1.82	-0.03
10.	GAO-5 x NOL-18-14	-1.58	5.12	0.39*	1.25*	-0.53	-0.09	0.70	26.69*	0.18	-0.83	0.29
11.	GAO-5 x NOL-18-15	-0.74	-4.18	0.08	-1.12*	0.04	-0.14**	-0.09	-20.59*	0.11	-8.92**	0.26
12.	GAO-5 x NOL-18-16	-0.68	-5.13	0.01	-0.06	0.59	0.03	-1.97**	-29.43**	1.30**	-0.98	0.66**
13.	GAO-5 x NOL-18-17	0.16	-12.64**	-0.35*	-1.32*	-0.99*	-0.05	-0.17	-27.50**	1.22**	0.44	-0.59**
14.	NOL-18-9 x NOL-18-12	1.39	2.32	0.33*	0.06	-0.15	0.13*	1.78**	19.84	-0.87*	-0.26	0.84**
15.	NOL-18-9 x NOL-18-14	1.42	-3.24	0.16	0.04	0.95	-0.08	-1.81**	-17.10	-0.02	1.42	-0.34*
16.	NOL-18-9 x NOL-18-15	0.59	-12.04**	-0.48**	-1.13*	-0.10	-0.05	-2.00**	-28.34**	0.23	-3.60	-0.04
17.	NOL-18-9 x NOL-18-16	-1.68	3.28	0.51**	0.37	1.41**	0.05	2.79**	36.69**	-0.17	4.40	0.23
18.	NOL-18-9 x NOL-18-17	-0.18	-9.23**	-0.44**	-1.52**	-1.04*	-0.05	-1.68**	-41.75**	1.07**	-2.78	-0.09
19.	NOL-18-12 x NOL-18-14	-3.28**	4.55	0.11	-0.03	-0.17	0.07	0.99	16.24	-0.59	8.04**	0.07
20.	NOL-18-12 x NOL-18-15	-1.44	5.29	0.34*	0.80	0.94	0.04	2.00**	37.49**	-0.14	9.02**	0.41*
21.	NOL-18-12 x NOL-18-16	2.29*	-13.59**	-0.40*	-1.44**	-1.73**	-0.03	-0.01	-23.84*	-0.71*	-3.18	-0.79**
22.	NOL-18-12 x NOL-18-17	0.12	8.06*	0.38*	1.34*	2.26**	0.01	-0.81	14.92	-1.22**	-5.36*	-0.34*
23.	NOL-18-14 x NOL-18-15	-0.74	2.19	0.50**	0.64	0.23	0.02	0.68	18.05	-0.52	3.10	0.13
24.	NOL-18-14 x NOL-18-16	-0.68	-16.99**	-0.57**	-1.89**	0.24	0.00	-1.33*	-42.51**	0.68	-3.70	0.00

Table.3 Conti…

Sr. No.	Hybrids	Days to 50% flowering	Plant height (cm)	Branches per plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruits per plant	Fruit yield per plant (g)	Internodal length (cm)	Number of seeds per fruit	100 seed weight (g)
25.	NOL-18-14 x NOL-18-17	2.49*	-0.60	0.07	0.33	1.39**	-0.12*	0.93	14.11	-0.63	-4.14	0.34*
26.	NOL-18-15 x NOL-18-16	-2.18*	10.01**	-0.08	0.59	0.62	0.11*	2.08**	31.47**	-1.19**	9.55**	-0.70**
27.	NOL-18-15 x NOL-18-17	-0.01	8.63**	0.30	2.21**	1.95**	0.08	0.67	29.47**	-0.98**	-2.76	-0.12
28.	NOL-18-16 x NOL-18-17	-0.28	-0.71	-0.24	0.81	-1.51**	-0.14**	-0.87	-2.63	-0.17	-5.70*	0.08
	S. E. (sij) ±	0.97	2.94	0.15	0.50	0.47	0.05	0.50	9.72	0.34	2.39	0.16

* - Significant at 5 % and **- Significant at 1%

Table.4 Best general combiners and best specific combining crosses along with their *per se* performance as well as best heterotic crosses for different characters in okra

Sr. No.	Traits	Best performing parents		Good general combiners		Best cross *per se* performance		Most heterotic cross over check "JGOH-4"		Best specific crosses		
		Parents	Mean	Parents	*gca* effect					Cross	*sca* effect	Combination
1.	DFF	Arka Abhay	45.00	Arka Abhay	-0.66**	NOL-18-12 x NOL-18-14	41.67	NOL-18-12 x NOL-18-14	-10.71**	NOL-18-12 x NOL-18-14	-3.28**	Average x Average
2.	PH	NOL-18-14	92.80	NOL-18-14	9.71**	Arka Abhay x GAO-5	96.73	Arka Abhay x GAO-5	45.76**	Arka Abhay x GAO-5	15.16**	Good x Good
3.	BPP	Arka Abhay	3.13	NOL-18-14	0.33**	Arka Abhay x GAO-5, GAO-5 x NOL-18-14	3.40	Arka Abhay x GAO-5, GAO-5 x NOL-18-14	37.84**	NOL-18-9 x NOL-18-16	0.51**	Average x Poor
4.	FW	NOL-18-14	15.83	NOL-18-14	1.14**	GAO-5 x NOL-18-14	16.72	GAO-5 x NOL-18-14	18.36**	NOL-18-15 x NOL-18-17	2.21**	Poor x Poor
5.	FL	NOL-18-14	13.55	NOL-18-14	1.46**	NOL-18-14 x NOL-18-17	14.61	NOL-18-14 x NOL-18-17	34.44**	NOL-18-12 x NOL-18-17	2.26**	Good x Average
6.	FD	NOL-18-14	1.65	NOL-18-14	0.06**	Arka Abhay x GAO-5	1.68	Arka Abhay x GAO-5	16.90**	Arka Abhay x GAO-5	0.14**	Average x Poor
7.	FPP	NOL-18-14	17.60	NOL-18-14	1.69**	Arka Abhay x NOL-18-14	18.33	Arka Abhay x NOL-18-14	19.05**	NOL-18-9 x NOL-18-16	2.79**	Poor x Poor
8.	FYPP	NOL-18-14	276.07	NOL-18-14	42.21**	GAO-5 x NOL-18-14	287.90	GAO-5 x NOL-18-14	29.41**	NOL-18-12 x NOL-18-15	37.49**	Average x Poor
9.	IL	NOL-18-14	5.38	NOL-18-14	-0.81**	Arka Abhay x GAO-5	4.29	Arka Abhay x GAO-5	28.44**	Arka Abhay x GAO-5	-2.31**	Good x Poor
10.	NSPF	NOL-18-12	41.00	NOL-18-17	-2.77**	NOL-18-12 x NOL-18-17	38.27	NOL-18-12 x NOL-18-17	-9.32	GAO-5 x NOL-18-15	-8.92**	Average x Average
11.	HSW	NOL-18-9	3.87	NOL-18-9	-0.39**	NOL-18-12 x NOL-18-16	3.70	NOL-18-12 x NOL-18-16	-15.91**	NOL-18-12 x NOL-18-16	-0.79**	Average x Good

* - Significant at 5 % and **- Significant at 1%

1. Days to 50 % flowering, 2. Plant height (cm) 3. Branches per plants 4. Fruit weight (g) 5. Fruit length (cm) 6. Fruit diameter (cm) 7. Fruit per plant 8. Fruit yield per plant 9. Internodal length 10. Number of seeds per fruit 11. 100 seed weight

Similar result was reported by Lyngdoh *et al.,* (2017), Shwetha *et al.,* (2018), Demta and Surin (2019) and Pithiya *et al.,* (2020). A summarized account of the best parents, *per se* performance best general combiners, best heterotic crosses and best specific combinations revealed that the best performing parents may be a best general combiner. Further, the best general combiner or best parents *per se* may not always produce best specific combinations for all the characters. Therefore, it is more desirable to select crosses based on the *per se* performance rather than magnitude of *sca* effects. Similar result has been earlier reported by Patel *et al.,* (2015b), More *et al.,* (2017), Satish *et al.,* (2017), Lokeswari *et al.,* (2018) and Demta and Surin (2019). The cross showing low *sca* effects may exhibit high *per se* performance also. Similar result has been reported by Patel *et al.,* (2015b), Lyngdoh *et al.,* (2017) and Hadiya *et al.,* (2018). From the top six hybrids, three hybrids *viz.,* GAO-5 x NOL-18-14, Arka Abhay x NOL-18-14 and Arka Abhay x GAO-5 manifested high heterosis coupled with high and significant *sca* effects for fruit yield per plant, while three hybrids *viz.,* NOL-18-14 x NOL-18-15, NOL-18-14 x NOL-18-17 and NOL-18-12 x NOL-18-14 exhibited high heterosis coupled with non-significant *sca* effect.

The hybrids exhibiting high *per se* performance for fruit per plant result from average x average, average x good and good x poor hybrid combinations. It is interesting to note that the average general combining parents when crossed do not always produce high *sca* effects; likewise poor general combining parents did not always produce low *sca* effects. Similar results have been reported by Patel *et al.,* (2015), Lyngdoh *et al.,* (2017), More *et al.,* (2017), Satish *et al.,* (2017), Hadiya *et al.,* (2018), Gavint *et al.,* (2018) and Kayande *et al.,* (2018).

Appraisal of data (Table 4) revealed that for most of the characters; hybrids exhibiting higher *sca* effects for fruit yield and yield contributing characters involved poor x poor, average x poor, good x poor and average x average combiner parents, indicating the presence of both additive and non-additive gene effects for controlling fruit yield and its contributing characters. These results are in agreement with Shwetha *et al.,* (2018), Demta and Surin (2019) and Pithiya *et al.,* (2020). The hybrids *viz.,* NOL-18-15 x NOL-18-17 and NOL-18-9 x NOL-18-16 showed good *sca* effects with involved poor x poor combining parents indicating over dominance and epistatic interactions. This may be due to genetic diversity in the form of heterozygous loci.

Marked negative and significant *sca* effects in crosses between average x good, average x average and good x poor combiners could be attributed to the lack of co-adaptation between favourable alleles of the parents involved. Whereas marked positive and significant *sca* effects in crosses between poor x poor, good x good, average x poor and good x average general combiners could be ascribed to better complementation between favourable alleles of the parents involved [Patel and Mehta (1985)].

The *sca* effect represents dominance effect and can be related with heterosis. The correlation between *per se* performance and the *sca* effect of hybrids for majority of the characters indicated that *sca* effects of a cross can reasonably be predicted from *per se* performance. However, the inspection of *sca* effects and mean performance of individual crosses indicated that the crosses having high *sca* effects did not always possess high mean (Table 4).

However, the crosses involving high *sca* effects did not always involve parents with high *gca* effects, thereby, suggesting the presence of intra-allelic gene interactions. The *sca* effects of certain crosses in the undesirable direction could be due to the failure of desirable alleles of the parents to co-operate. As a result, a cross from good general combiner parents may exhibit poor *sca* effects. Table 4 revealed that there was some degree of correspondence between *per se* performance and *sca* effects of hybrids as well as *gca* effects of parents and estimates of heterosis for most of characters. Hence, *gca* and *sca* effects and *per se* performance all play a role in manifestation of heterosis for various characters. From the about discussion it is clear that hybrids NOL-18-12 x NOL-18-14 (for days to 50 % flowering), Arka Abhay x GAO-5 (for plant height and fruit diameter and internodal length), NOL-18-12 x NOL-18-16 (for 100 seed weight) exhibited higher *gca* and *sca* effects with high mean performance.

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