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Study the genetic component and combining ability for yield and its components in okra [*Abelmoschus esculentus* (L). Monech.]

Vivek Pandey*1
*Department of Vegetable Science , CSAUA&T Kanpur Uttar Pradesh
[1]Punjab Agricultural University, Regional Research Station, Gurdaspur, Punjab
Corresponding Email :- vivek.pandey.ghazipur@gmail.com

ABSTRACT
The present investigation, "Genetic analysis of yield and its components in okra [Abelmoschus esculentus (L). Monech.]" was conducted with 108 treatment (45 F_{1S}, 45 F_2s develop through line x tester technique along with 15 lines viz., VRO-5, VRO-4, VRO-3, Azad Bhindi-2, KS-312, P-7, Azad Bhindi-3 (Azad Krishna), 7109, BO-2, Arka Abhay, Arka Anamika, 7219, VRO-6, 7110, KS-440 and three testers viz., Azad Bhindi-4 (Azad Mohini), Parbhani Kranti, Azad Bhindi-1(Azad Ganga), in a Randomized Block Design with three replication at the Research Farm of the Department of Vegetable Science, C.S. Azad University of Agriculture & Technology, Kalyanpur Kanpur in Kharif 2012. The observations were recorded on 10 randomly selected plants for 10 quantitative traits namely, days to flowering, height of plant (cm), number of branches plant $^{-1}$, number of nodes plant $^{-1}$, number of first fruiting node, length of internode (cm), length of fruit (cm), width of fruit (cm), number of fruits plant $^{-1}$ and yield plant $^{-1}$ (g). Analysis of variance showed highly significant differences for all the characters under study. Wide range of variability was observed for all the characters in all the generations. Among lines, AB-2, 7110, P-7, VRO-6, AB-3 and KS-440 were identified as good general combiners on the basis of combining ability for most of the yield contributing traits in both the generations. However, tester AB-1 was found to be good general combiner for most of the yield contributing traits. Based on sca effects, the cross combinations KS-440 x AB-1 and AB-2 x PK were found desirable for fruit yield plant $^{-1}$ in both the generations.
Keywords: *Okra, genetic component, combining ability, gca and sca*

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INTRODUCTION
Okra or *Bhindi* [*Abelmoschus esculentus* (L.) Moench] is one of the most important vegetable crops of India. It belongs to family Malvaceae having chromosome number 2n = 130. It behaves as an often cross–pollinated crop although it is potential self pollinated crop with 8.75 to 9.61 percent out crossing [21,22]. It is a crop of warm wet season in the Northern India, but it is also taken as winter crop in the frost free area of Central and South India, particularly Gujarat and Maharashtra. Green immature fruits are utilized in various ways. In spite of varied utility, the production potential of okra is still low. It is mainly due to low yield, pest resistance, early maturing and stable varieties/hybrid besides some other factors. Therefore, there is an urgent need to develop variety having high yield as well as good nutritional quality with multi-resistance, which may fit in intensive cropping system for boosting up its production. The crop is highly motivated by environmental fluctuations, selection based on the phenotypic value of the plant will not lead to the desired gain in the right direction and hence it will prove ignominious. The success of a breeding programme is mainly dependent upon the promising parents from gene pool. A clear understanding of components of variation and their effects, general and specific combining abilities of the traits under consideration will help the breeders in deciding the appropriate breeding method to improve the genetic makeup as well as to make a dent in productivity.

MATERIAL AND METHODS
The material for the present investigation comprises of fifteen genotypes/varieties and three testers as described in Table 1, selected on the basis of genetic variability for various characters from the germplasm pool available and maintained at the Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture & Technology Kalyanpur Kanpur.

Table 1: Distinguish features of the parents under study in okra [*Abelmoschus esculentus* (L.) Moench]

Sl. No.	Name of variety/ Strains	Symbol	Source	Distinguish features
1.	Azad Bhindi-1 (Azad Ganga)	AB-1	C.S.A.U.A.T., Kalyanpur, Kanpur	Tall height, branched medium, green thick fruiter, resistant to yellow vein mosaic virus (YVMV) and high yielding.
2.	Azad Bhindi-2	AB-2	C.S.A.U.A.T., Kalyanpur, Kanpur	Medium height, branching medium, green and thin fruited, resistant to yellow vein mosaic virus (YVMV)
3.	Azad Bhindi-3 (Azad Krishna-Red)	AB-3	C.S.A.U.A.T., Kalyanpur, Kanpur	Plant, leaf petiole and fruits red in colour tall long fruited, yield 110-130 q/ha, moderately resistant
4.	Kalyanpur selection-312	Ks-312	C.S.A.U.A.T., Kalyanpur, Kanpur	Dwarf, small green fruited and tolerant to yellow vein mosaic virus (YVMV), yield 100-110 q/ha.
5.	Varanasi resistant okra-5	VRO-5	IIVR Varanasi	resistant to yellow vein mosaic virus (YVMV), long fruited and green, yield 100-120 q/ha.
6.	Arka Abhay	AA	IIHR Hissargatta, Banglore	Resistant to yellow vein mosaic virus(YVMV) and yield.115 q/ha
7.	7110	-	-	Resistant to yellow vein mosaic virus(YVMV) and yield.100 q/ha
8.	Bhubneshwar okra-2	BO-2	O.U.A.T. Bhubnesher, Orissa	Resistant to yellow vein mosaic virus (YVMV) long green fruited, medium height yield 100-110 q/ha.
9.	Arka Anamika	AA	IIHR Hissargatta, Banglore	Resistant to yellow vein mosaic virus (YVMV), medium thin fruited.
10	P-7	P-7	P.A.U Ludhiana Punjab	Resistant to yellow vein mosaic virus (YVMV) long green fruited, medium height yield 95 q/ha
11	Varanasi resistant okra-6	VRO-6	IIVR Varanasi	Resistant to yellow vein mosaic virus (YVMV), long fruited and green, yield 100-120 q/ha.
12.	Azad Bhindi-4 (Azad Mohini)	AB-4	C.S.A.U.A.T., Kalyanpur, Kanpur	Resistant to yellow vein mosaic virus(YVMV) and yield.110-120 q/ha
13	Varanasi resistant okra-4	VRO-4	IIVR Varanasi	Resistant to yellow vein mosaic virus(YVMV) and yield.115-120 q/ha
14	Varanasi resistant okra-3	VRO-3	IIVR Varanasi	Resistant to yellow vein mosaic virus(YVMV) and yield.100-110 q/ha
15	Kalyanpur selection-305	Ks-305	C.S.A.U.A.T., Kalyanpur, Kanpur	Dwarf, small green fruited and tolerant to yellow vein mosaic virus (YVMV), yield 100-110 q/ha.
16	7109	7109	C.S.A.U.A.T., Kalyanpur, Kanpur	Susceptible to yellow vein mosaic virus(YVMV) and yield.100-110 q/ha
17	7219	7219	C.S.A.U.A.T., Kalyanpur, Kanpur	Susceptible to yellow vein mosaic virus(YVMV) and yield.100-110 q/ha
18.	Prabhani kranti	PK	Mahatma pulley Agriculture University, Parbhani (Maharasthra)	Tall, long green fruited, branched and Resistant to yellow vein mosaic virus (YVMV)

Economic parent – AB-2 and Azad Bhindi-1 (Azad ganga)

These 15 lines were crossed with three tester using line x tester mating design to evolve 45 F_1s during *zaid* season 2011 and subsequent F_2 generation during *kharif* season 2011. All the 45 F_1's and 45 F_2's along with eighteen parents were sown during *kharif* 2012 in a Randomized Block Design with three replications at the Research Farm of the Department of the Vegetable Science of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The plant to plant and row to row spacing were maintained at 50 cm. The data obtained for 10 characters *viz*., days to flowering, height of plant (cm), number of branches plant $^{-1}$, number of nodes plant $^{-1}$, number of first fruiting node, length of internodes (cm), length of fruit (cm), width of fruit (cm), number of fruits plant $^{-1}$, yield plant $^{-1}$ (g), was statistically analyzed as per Kempthorne [1] and Arunachalam [2].

RESULT AND DISCUSSION

In the present study line x tester technique was employed to investigate the nature and magnitude of gene action along with related parameters through component and combining ability analysis. Combining ability refers to the ability of a genotype to transmit superior performance to its crosses. Selection of suitable varieties/ strains and their crosses for effective use is a perquisite in order to purpose a systematic and effective breeding programme leading to rapid and substantial improvement. The analysis of variance (Table 2) showed highly significant differences both for GCA and SCA in both the generations showing high amount of variability between parents and crosses. Higher value of variance gca in comparison to variance SCA for the traits in both generations showed the presence of additive genes for the expression of these characters. On comparison of per se performance of the parents to their gca effects in both the generations (Table 3), it was found that the *per se* performance in all the characters showed best general combiner in both the generations. In no case the poor per se performance was the best general combiner. Therefore, under such situation when the characters are unidirectional controlled by a set of alleles, additive effects are important and the choice of parents on the basis of per se performance could be quite useful. However, in certain cases where non allelic interaction are playing role the choice of the parents should be based on combining ability effects.

For development of open pollinated varieties or hybrids in okra or in any often cross pollinated crop, the genetic worth of parents used in crossing programme play a very vital role. The general combining ability (gca) is a primary function of additive genetic variance indicating average performance of line in a series of cross combination [3, 4]. The best common parents on the basis of per se performance and gca effects in both the generations are presented in Table 3. The lines, AB-2, 7110, P-7, VRO-6, AB-3 and KS- 440 were identified as good general combiner for most of the yield contributing traits based on both generations. The tester, AB-1 was also stable in the performance across generations and thus identified as a good general combiner. Therefore it is suggested that line AB-2, 7110, P-7, VRO-6, AB-3, KS-440 and tester AB-1 may be utilized for hybridization programme for getting better transgressive segregants in later generations.

Miller *et al.* [5] suggested that the cross may be studied for combining ability in F_1 instead of F_2, when the objective is to breed pure varieties. However this suggestion still needs sulestantiation before it could be adopted for practical utilization. Further the varieties/ genotypes showing good gca for a particular component may be used in the component, thereby effecting improvement in yield. Genotypes, AB-1, VRO-6, and AB-2, showing good general combining ability for yield appear to be worthy of exploitation in practical plant breeding. These must be utilized in hybridization programme. Similar reports were suggested by Kumar *et al.* [7], Pal and Sabena [6], Solankey and Singh [9], Kumar and Pathania [8] and Singh *et al.* [10]. The good general combiner may be used in developing population involving all possible combinations among themselves and may be subjected to biparental mating in early generation which helps in increasing genetic variability due to faster rate of recombination.

Gca effects consist of both additive and / or additive x additive components of gene action [3, 4, 11 12] are fixable. The additive effect of parents due to gca are of practical use, whereas non allelic interactions are non predictable and cannot be easily manipulated. An examination of the best combiners has revealed that majority of them are drives form India origin. Hence, the derivatives present in okra varieties/ strains in future breeding programme will not be effective only for yield but also for other traits.

Specific combining ability effects on the other hand, representing dominance and epistasis component will not contribute much for improvement in self pollinated crops except in case when commercial exploitation of heterosis or composite breeding programme is convenient. However, crosses involving high general combiners and showing high sca effects may be utilized for futher breeding programme. Desirable transgressive segregates are expected to be produced by making large number of crosses [2]. Mather [15] reported that the superiority of mean of hybrid did not indicate their ability to produce transgressive segregates due to non fixable effects. However, in okra, the study of sca in segregating generation may be helpful for upgrading the breeding material.

The crosses showed significant sca effect in desirable direction for all the characters under study. The significant and desirable crosses in order of merit are shown in Table 4. The crosses, showing specific combining ability effect and per se performance for yield plant $^{-1}$ also exhibited superiority over better parent suggesting that these hybrids may be exploited through heterosis breeding performance. It is general observation that good cross combinations are obtained between high x high and poor ones between low x low general combiner. In the present study superior cross combination involved high x high, high x low, high x moderate, moderate x moderate, moderate x low and low x low, general combiner for that characters under study. This suggested that good cross combinations are not always obtained between high general combiners. Singh [16] also found crosses with high specific combining ability effect emerging from low x low general combiners. If the crosses showing high specific combining ability involve both the parent as a good general combiner, they should be exploited in practical breeding. In case the crosses showing high specific combining ability involve one good and other moderate combiner then such a combination maybe exploited through desirable transgressive segregants. If high x high general combiner are involved it focuses the additive gene action. In order to exploit different types of gene action in a population, it is suggested that a breeding procedure which may accumulate the fixable type of gene effects and at the same time maintenance considerable heterozygosity for exploiting the dominance gene effect, might prove most beneficial in improving the population under study.

Table 2: Estimate of components of variance, their ratio and average degree of dominance for 10 characters in okra [*Abelmoschus esculentus* (L.) Moench].

Genetic components		Days to flowering	Height of plant (cm)	No. of branches per plant	No. of nodes per plant	No. of first fruiting node	Length of internode	Length of fruit (cm)	Width of fruit (cm)	No. of fruits per plant	Fruit yield per plant (g)
$\hat{\sigma}^2$ (male)	F_1	6.619	430.221	0.119	0.073	0.600	0.751	-0.034	-0.003	1.055	80.484
	F_2	3.996	379.553	-0.002	0.077	0.505	0.724	0.098	0.028	0.421	62.584
$\hat{\sigma}^2$ g (Female)	F_1	1.466	35.333	-0.021	0.699	0.148	0.149	2.361	0.065	1.560	566.545
	F_2	0.433	43.675	0.028	0.359	0.147	0.142	0.421	0.005	1.280	199.852
$\hat{\sigma}^2$ g (pooled)	F_1	16.020	749.073	0.450	1.356	1.228	1.569	1.492	0.159	3.281	360.476
	F_2	10.947	692.124	0.227	1.057	1.097	1.537	0.419	0.070	2.673	741.990
$\hat{\sigma}^2$ s (male x female)	F_1	3.487	18.063	0.143	0.643	0.149	0.249	0.538	0.117	0.879	332.511
	F_2	3.637	42.873	0.108	0.441	0.190	0.272	-0.102	0.004	1.425	494.266
$\hat{\sigma}^2$ A	F_1	23.043	145.162	0.385	0.711	2.100	2.604	1.460	0.033	4.559	645.977
	F_2	13.610	129.432	0.009	0.496	1.781	2.510	0.607	0.098	2.260	341.850
$\hat{\sigma}^2$ D	F_1	13.942	72.850	0.573	2.572	0.596	0.996	2.152	0.467	3.517	130.044
	F_2	14.543	71.492	0.433	1.765	0.762	1.089	0.409	0.018	5.702	197.064
($\hat{\sigma}^2$ A/ $\hat{\sigma}^2$ D)	F_1	1.652	20.173	0.671	0.276	3.523	2.613	0.678	0.072	1.296	4.967
	F_2	0.935	7.546	0.022	0.281	2.335	2.304	-1.484	5.269	0.369	0.172
($\hat{\sigma}^2$ s/ $\hat{\sigma}^2$ g)$^{1/2}$	F_1	0.778	0.222	1.220	1.910	0.532	0.618	1.213	3.722	0.878	0.448
	F_2	1.033	0.364	6.628	1.885	0.654	0.658	0.820	0.435	1.588	2.404

$\hat{\sigma}^2$ g = Variance due to gca; $\hat{\sigma}^2$ A/ $\hat{\sigma}^2$ D = Variance ratio

$\hat{\sigma}^2$ s= Variance due to sca; ($\hat{\sigma}^2$ s/ $\hat{\sigma}^2$ g)$^{1/2}$ = Average degree of dominance

$\hat{\sigma}^2$ A= Additive variance; $\hat{\sigma}^2$ A= 2 $\hat{\sigma}^2$ g

$\hat{\sigma}^2$ D= Dominance variance; $\hat{\sigma}^2$ D= $\hat{\sigma}^2$ s

The cross combinations having desirable and significant sca effects for the traits involving parents with low x low gca status should not be exploited in self or often cross pollinated crops like okra as such hybrid combinations are produced due to non additive gene effects. Although the finding of Pederson [17], Bos [18] and Sneep [19] were not in agreement with those of Jensen [13] and Reddin &Jensen [20] that inter mating in F_2 might result in remarkable improvement in raising the productivity or increase in the number of plants with the desirable types.

Table 3 : Ranking of desirable parents on the basis of gca effect and *per se* performance

Characters	Good *per se* performance				Good general combiners				Common parent			
	Line		Tester		Line		Tester		Line		Tester	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Days to flower	AB-2, 7110, KS-312, BRO-3, 7109, BO-2	AB-2, 7110, KS-312, VRO-6, VRO-3	AB-1, AB-4	AB-4, AB-1	AB-2, 7110, KS-312	AB-2, 7110, KS-312	AB-1	AB-4	AB-2, 7110, KS-312	AB-2, 7110, KS-312	AB-1	AB-4
Height of plant (cm)	P-7, AB-3, A. Anamika, A. Abhay, 7219	AB-3, P-7, VRO-5, VRO-6, A. Anamika,	P. Kranti, AB-4	P. Kranti, AB-1	P-7, AB-3, A. Anamika	AB-3, P-7, A. Abhay	P. Kranti	P. Kranti	P-7, AB-3, A. Anamika	AB-3, P-7	P. Kranti	P. Kranti
Number of branches per plant	P-7, VRO-6, A. Anamika, 7110	KS-440, VRO-3, KS-312, VRO-6, VRO-5	AB-4,	AB-4,	P-7, VRO-6	KS-440, VRO-3	AB-4	AB-4	P-7, vro-5	KS-440, VRO-3	AB-4	AB-4
Number of nodes per plant	7219, P-7, AB-2, VRO-5, VRO-6	VRO-6, P-7, VRO-5, A. Abhay	P. Kranti	P. Kranti, AB-4	7219, P-7	VRO-6, P-7, VRO-5	P. Kranti,	P. Kranti,	7219, P-7	VRO-6, P-7	P. Kranti	P. Kranti
Number of first fruiting node	AB-3, A. Anamilka, P-7, 7109, VRO-5, VRO-4, KS-312	AB-3, A. Anamika, P-7, VRO-5, VRO-4, KS-312	AB-4, P. Kranti. AB-1	AB-4, P. Kranti,	AB-3, A. Anamika	AB-3, A. Anamika	AB-4, P. Kranti,	AB-4	AB-3, A. Anamika, P-7	AB-3, A. Anamika	AB-4, P. Kranti	AB-4
Length of internode (cm)	VRO-6, KS-312, BO-2, 7219	7219, VRO-6, KS-312, BO-2, A. Abhay	P. Kranti, ab-1, ab-4	P. Kranti, AB-1	A. Anamika, KS-440, VRO-6, KS-312	A. Anamika, BO-2, 7110	P. Kranti, AB-1	P. Kranti, AB-1	A. Anamika, KS-440	A. Anamika, 7110	P. Kranti, AB-1	P. Kranti, AB-1
Length of fruit (cm)	VRO-6, KS-440, 710, BO-2, VRO-4, AB-2	7110, KS-440, VRO-6, BO-2, VRO-3	AB-1	AB-1	VRO-6, KS-440, VRO-3	7110, KS-440, AB-2	AB-1	AB-1	VRO-6, KS-440	7110, KS-440	AB-1	AB-1
Width of fruit (cm)	AB-3, BO-2, KS-440, AB-2, A. Anamilka	7219, AB-2, VRO-6, 7110	P. Kranti	P. Kranti, AB-1	AB-3, BO-2, AB-2	7219, AB-2, AB-3, KS-440	P. Kranti	P. Kranti, AB-1	AB-3, BO-2, AB-2	7219, AB-2	P. Kranti,	AB-1, P. Kranti
Number of fruits per plant	AB-2, VRO-5, AB-3, 7219, VRO-3, VRO-6	AB-2, VRO-5, VRO-3, 7219	AB-1, P. Kranti	AB-1	AB-2, VRO-5, AB-3	AB-2, VRO-5, VRO-6	AB-1	AB-1	AB-2, VRO-5, AB-3	AB-2, VRO-5	AB-1	AB-1
Yield per plant (g)	VRO-6, AB-2, AB-3, 7119, VRO-5	7110, 7219, AB-2, VRO-5, VRO-6	AB-1, AB-4	P. Kranti, AB-1	VRO-6, AB-2	7110, 7219, AB-2	AB-1	P. Kranti, AB-1	VRO-6, AB-2	7110, 7219, AB-2	AB-1	P. Kranti, AB-1

Table 4: Ranking of desirable crosses based on per se performance and sca effect in 10 characters in okra [*Abelmoschus esculentus* (L.) Moench]

Characters	Good per se performance	Good crosses on the basis of sca effect	Common crosses on the basis of per se performance and sca effect.
Days to flowering	AB-4 x BO-2, AB-4 x 7219, AB-4 x KS-440, AB-1 x VRO-3, AB-1 x 7219	AB-4 x AB-2, AB-4 x 7219, PK x AB-2 PK x 7109, AB-1 x VRO-3	AB-4 x 7219, AB-1 x VRO-3
Height of plant (cm)	AB-4 x 7109, PK x VRO-4, PK x KS-312, AB-1 x VRO-4, AB-1 x KS-312	AB-4 x VRO-6, PK x KS-312, PK x 7109, PK x BO-2, PK x A.Abhay	PK x KS-312
Number of	AB-4 x VRO-3, AB-4 x	AB-4 x VRO-6, PK x VRO-4,	PK x 7110

branches per plant	A.Anamika, PK x 7110, AB-1 x KS-440	PK x 7110, AB-1 x VRO-4, AB-1 x 7219	
Number of nodes per plant	AB-4 x A.Anamika, PK x VRO-3, PK x 7110, AB-1 x KS-312, AB-1 x 7110	AB-4 x A. Anamika, AB-4 x KS-312, PK x VRO-3, AB-1 x VRO-3, AB-1 x 7110	AB-4 x A. Anamika, PK x VRO-3, AB-1 x 7110
Number of first fruiting node	AB-4 x VRO-3, AB-4 x KS-440, PK x 7219, AB-1 x BO-2, AB-1 x 7219	AB-4 x VRO-5, AB-4 x AB-2, AB-4 x 7219, PK x KS-312, PK x VRO-6	-
Length of internode (cm)	AB-4 x P-7, AB-4 x 7219, AB-4 x KS-440, AB-4 x VRO-3, PK x KS-440	AB-4 x VRO-3, AB-4 x AB-2, PK x VRO-3, AB-1 x VRO-5, AB-1 x 7109	PK x VRO-3
Length of fruit (cm)	AB-4 x VRO-5, PK x VRO-5, PK x VRO-3, PK x AB-3, AB-1 x 7109	AB-4 x VRO-5, PKx VRO-5, PK x AB-3, PK x A. Anamika, AB-1 x 7219	AB-4 x VRO-5, PK x VRO-5, PK x AB-3
Width of fruit (cm)	AB-4 x VRO-3, AB-4 x P-7, AB-4 x A.Anamika, AB-4 x KS-440, AB-1 x VRO-3	PK x VRO-5, PK x A. Anamika, PK x VRO-6, PK x KS-440, AB-1 x VRO-6	AB-1 x VRo-6
Number of fruits per plant	AB-4 x VRO-5, AB-4 x 7219, PK x P-7, AB-1 x P-7, AB-1 x BO-2	AB-4 x AB-3, AB-4 x VRO-6, PK x VRO-5, AB-1 x BO-2, AB-1 x 7219	-
Yield per plant (g)	AB-4 x A. Abhay, AB-4 x VRO-5, PK x P-7, AB-1 x AB-3, AB-1 x BO-2	AB-4 x VRO-5, AB-4 x P-7, AB-4 x A. Abhay, AB-1 x AB-2, AB-1 x AB-3	AB-4 x A.Abhay, AB-4 x VRO-5, AB-1 x AB-3

CONCLUSION

In the general combining ability, relative magnitude of variance revealed that additive component was of major importance in the expression of all the characters. Specific combining ability effects indicate that choice of parents for hybridization can be based on per se performance of parents. The gene action prevailing in present study through various analyses showed non additive and / or dominance. Hence recurrent and line x tester mating can also be applied for improving the yield potential of this crop. At the last but not least the single seed descent selection methods is most suitable for the improvement of the crop.

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