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Relationship between Combining Ability and *per se* Performance for Yield and Yield Components in Okra (*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

Correlation coefficient analysis using mean values of parents and hybrids revealed that the characters plant height, number of branches/plant, first flowering and fruiting node, fruit length and weight, total number of fruits and number of marketable fruits/plant and fruit and shoot borer (*Earias vitella*) infestation on fruits were identified as yield components in okra (*Abelmoschus esculentus* (L.) Moench). Significance of correlation coefficients between *per se* values and general combining ability (GCA) effects indicated a strong association ($P = 0.05$) between GCA effects and *per se* values, suggesting that the combining ability of parents can be predicted based on their *per se* performance for number of branches/plant, internodal length, days to 50% flowering, first flowering and fruiting nodes, fruit length, width and weight, total and marketable yield/plant, FSB infestation on fruits and shoots and *Yellow vein mosaic virus* infestation on fruits and plants. Significance of correlation coefficients between mean values and specific combining ability (SCA) effects indicated a strong association ($P = 0.05$) between combining ability effects and mean values, suggesting that combining ability of crosses can be predicted based on their *per se* performance for all growth, earliness and yield parameters under study in okra.

Keywords: correlation, general combining ability, key characters, *per se* values, specific combining ability
Abbreviations: FSB, fruit and shoot borer; **GCA**, general combining ability; **IC**, indigenous collection; **SCA**, specific combining ability; **YVMV**, *Yellow vein mosaic virus*

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) belonging to Malvaceae family, is a warm season fruit vegetable, which is extensively cultivated in the tropics, sub-tropics and warmer portions of the temperate region of the world. Even though India is the largest producer of okra (4.53 million t year^{-1}) from the largest area of 0.43 million ha, the present productivity (10.5 t ha^{-1}) is very low when compared to the developed countries (NHB 2010). This is mainly because of low yield potential of current varieties and a reduction in yield due to frequent attack of fruit and shoot borer (FSB) and *Yellow vein mosaic virus* (YVMV). Hence, there is a need for the development of high-yielding F_1 hybrids to improve the productivity of okra.

Hybridization is a prominent breeding method for the improvement of productivity in okra (Mehta *et al*. 2007; Weerasekara *et al*. 2007; Jindal *et al*. 2009). In breeding high-yielding varieties of crop plants, the breeder is often faced with the problem of selecting parents and crosses. The proper choice of parents for hybridization is very crucial in generating high-yielding heterotic hybrids and superior transgressive segregants. The common approach of selecting parents on the basis of *per se* performance does not necessarily lead to fruitful results (Allard 1963). The choice of parents, in general, is based on the general principle that the parents under selection should have a high combining ability for yield and yield components. Combining ability analysis is one of the potential tools for identifying prospective parents for hybridization and shifting productive hybrids from a set of crosses in the F_1 generation (Griffing 1956). In recent years, the use of diallel cross analysis has been made extensively to test the combining ability of the single crosses in okra (Jindal *et al*. 2009; Singh *et al*. 2009).

Information regarding the association among growth, earliness and yield parameters helps to determine the yield components. The importance of correlation coefficient analysis in identifying yield components in okra has been emphasized by several groups (Jaiprakashnarayan and Mulge 2004; Bello *et al*. 2006; Mehta *et al.* 2006; Patro *et al.* 2006; Pal *et al*. 2008). Thus, vegetable breeders are in absolute need of identifying parents with high combining ability for yield and yield components, which is a cumbersome and time consuming process as it involves extensive evaluation of all cross combinations along with their parents in proper designs or models.

Knowledge of the association between combining ability and *per se* performance plays a decisive role at this juncture whether it would be better to make use of *per se* performance of a genotype as an indication of its combining ability. Establishment of the relationship between combining ability and *per se* performance can help to eliminate the undesirable genotypes based on their *per se* performance for desirable key characters. Studies on this aspect in okra were made earlier by Jaiprakashnarayan *et al*. (2008) who found that the combining ability of parents and crosses can be predicted on the basis of their *per se* performance. Ultimately, superior genotypes can be assessed for combining ability in a simple design and thus help to increase the efficiency of a breeding programme to achieve ultimate goals.

Hence, an attempt was made in the present investigation to identify the yield components and to establish the association between *per se* performance of parents and their

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Table 1 Simple correlation coefficients among growth, earliness and yield parameters of okra.

Variable	1	2	3	4	5	6	7	8	9
1	1.000	0.055	0.453*	-0.111	0.077	0.077	0.208	0.030	0.307*
2		1.000	0.079	0.279*	0.578*	0.578*	0.263	-0.014	0.387*
3			1.000	-0.101	0.080	0.080	-0.005	0.224	0.286*
4				1.000	0.525*	0.525*	0.002	-0.099	0.052
5					1.000	1.000***	0.203	-0.126	0.203
6						1.000	0.203	-0.126	0.203
7							1.000	-0.233	0.638*
8								1.000	0.137
9									1.000

Table 1 (Cont.)

Variable	10	11	12	13	14	15	16	17
1	0.506*	0.522*	0.568*	0.607*	0.071	0.021	-0.207	-0.230
2	0.244	0.262*	0.425*	0.461*	-0.069	-0.051	-0.106	-0.053
3	-0.130	-0.084	0.073	0.118	0.061	0.057	-0.274*	-0.270*
4	-0.068	-0.051	-0.002	-0.004	-0.232	-0.207	0.054	0.113
5	0.124	0.166	0.221	0.265	-0.162	-0.116	-0.127	-0.092
6	0.124	0.166	0.221	0.265	-0.162	-0.116	-0.127	-0.092
7	0.212	0.141	0.554*	0.527*	0.229	0.137	0.236	0.232
8	-0.024	-0.018	0.074	0.088	0.221	0.063	-0.158	-0.061
9	0.031	-0.044	0.655*	0.624*	0.448*	0.315*	0.118	0.143
10	1.000	0.965*	0.773*	0.778*	0.002	-0.086	0.107	0.074
11		1.000	0.698*	0.755*	-0.149	-0.205	-0.137	-0.152
12			1.000	0.980*	0.291*	0.123	0.162	0.162
13				1.000	0.189	0.042	-0.018	-0.019
14					1.000	0.761*	0.201	0.220
15						1.000	0.158	0.141
16							1.000	0.978*
17								1.000

* Significant at 5 % level

1= Plant height (cm); 2= No. of branches per plant; 3= Internodal length (cm); 4= Days to 50% flowering; 5= First flowering node; 6= First fruiting node; 7= Fruit length (cm); 8= Fruit width (cm); 9= Fruit weight (g); 10= Total no. of fruits per plant; 11= No. of marketable fruits per plant; 12= Total yield per plant (g); 13= Marketable yield per plant (g); 14= FSB infestation on fruits (%); 15= FSB infestation on shoots (%); 16= YVMV infestation on fruits (%); 17= YVMV infestation on plants (%)

general combining ability effects, *per se* performance of hybrids and their specific combining ability effects for yield and yield components of okra.

MATERIALS AND METHODS

Ten horticulturally superior and nearly homozygous germplasm lines of okra with an intermediate level of genetic diversity (IC282248, IC27826-A, IC29119-B, IC31398-A, IC45732, IC89819, IC89976, IC90107, IC99716 and IC111443) were crossed in a half diallel fashion during the summer of 2009. The resulting 45 crosses along with their 10 parents were evaluated in a randomized block design with three replications under three diverse environments tailored at a single location (Vegetable Research Station, ARI, Rajendranagar), by changing the date of sowing *viz*., 1st June (early *kharif*), 1st July (mid *kharif*) and 1st August (late *kharif*), 2009. In each replication, each genotype was grown in a double row plot of 3 m length. A row-to-row spacing of 60 cm and a plant-to-plant spacing of 30 cm was maintained. In each replication, observations were recorded on five randomly selected plants of each genotype for all the traits except days to 50% flowering, total number of fruits/plant, number of marketable fruits/plant, total yield/plant, marketable yield/plant, FSB infestation on fruits and shoots and YVMV infestation on fruits and plants, which were recorded on a whole-plot basis. The environment-wise mean replicated data on various biometric traits of all the three environments were subjected to pooled analysis of variance of RBD as per the standard statistical procedure (Panse and Sukhatme 1985) to estimate *per se* values of parents and crosses and pooled analysis of variance for combining ability as per the Griffig's method-2 and model-1 (Griffing 1956) to estimate combining ability effects of parents and crosses over environments as outlined by Singh (1973). Simple correlation coefficients were worked out among 17 growth, earliness and yield attributes using mean values to identify the yield components in okra. Simple correlation coefficients were also calculated between mean values of parents and their general combining ability (GCA) effects and mean values of crosses and their specific combining ability (SCA) effects for various traits separately to identify the association between *per se* performance and combining ability. Correlation analysis was carried out according to the standard statistical procedure (Panse and Sukhatme 1985). The significance of the correlation coefficients was tested by referring to a standard table (Snedecor and Cochran 1989).

RESULTS AND DISCUSSION

The correlation coefficient analysis of seventeen quantitative traits (**Table 1**) revealed strong association among growth, earliness and yield parameters of okra under study. Complex characteristics such as yield must be related to many individually distinguishable characteristics. It is obvious that fruit yield is a complex character that depends up on many independent yield contributing characters, which are regarded as yield components. All changes in yield must be accompanied by changes in one or more characters (Graffius 1964). All changes in the components need not however, be expressed by changes in yield. This is due to varying degree of positive and negative associations between yield and its components and among components themselves. Therefore, selection should be based on these component characters after assessing their association with fruit yield per plant. In plant breeding, correlation analysis provides information about yield components and thus helps in selection of superior genotypes from diverse genetic populations (Robinson *et al*. 1951; Johnson *et al*. 1955).

Of the 17 characters under study, plant height, number of branches and internodal length largely determine the fruit bearing surface and thus considered as growth attributes. Growth parameters can serve as an indicator for higher yield through higher biomass production. Okra bears pods at almost all nodes on main stem and primary branches. Plant height (**Table 1**) was positively and significantly associated with internodal length ($r = 0.453^*$), fruit weight (r =

0.307*), total number of fruits/plant (r = 0.506*) and number of marketable fruits/plant (r = 0.522*), total yield/plant (r = 0.568*) and marketable yield/plant (r = 0.607*). Jaiprakashnarayan and Mulge (2004) and Bello *et al*. (2006) also reported a positive association of plant height with total yield/plant as evident from significant correlation coefficients (r_g = 0.256** and 0.78*, respectively). Positive association of plant height with internodal length (r_g = 0.8184**) and total number of fruits/plant (r_g = 0.3904**) was reported by Gandhi *et al*. (2002). Positive association of plant height with total yield/plant (r_g = 0.8184**) was also reported by Dakahe *et al*. (2007).

Number of branches/plant was positively and significantly associated with days to 50% flowering (r = 0.279*), first flowering node (r = 0.578*) and first fruiting node (r = 0.578*), fruit weight (r = 0.387*), number of marketable fruits/plant (r = 0.262*), total and marketable fruits/plant (r = 0.461*). Patro *et al*. (2006) also reported positive association of number of branches/plant with total yield/plant (r_g = 0.337*) in okra. Internodal length had positive association with fruit weight (r = 0.286*) and negative association with YVMV infestation of fruits (r = -0.274*) and plants (r = -0.270*). These findings are in agreement with the earlier findings of Mehta *et al.* (2006).

Days to 50% flowering, first flowering node and first fruiting node are the indicators of earliness in okra. Early flowering not only gives early pickings and better returns but also widens fruiting period of the plant. Flowering and fruiting at lower nodes are helpful in increasing the number of fruits per plant as well as getting early yields. Days to 50% flowering were positively and significantly associated with first flowering node (r = 0.525*) and first fruiting node (r = 0.525*). Positive association of days to 50% flowering with first flowering node (r_g = 0.484**) and first fruiting node (r_g = 0.498**) was also reported by Jaiprakashnarayan and Mulge (2004). First flowering node had perfect positive correlation with first fruiting node (r = 1.00), indicating cent per cent fruit set in the early stages of flowering and fruiting in the material under study.

Fruit number, length, width and weight are considered to be the fruit traits in okra. Fruit length had positive correlation with fruit weight (r = 0.638*) and total yield/plant (r = 0.554*) and marketable yield/plant (r = 0.624*). Positive association of fruit length with total yield/plant (r_g = 0.3916*) and fruit weight (r_g = 0.169*) was reported by Dakahe *et al*. (2007) and Jaiprakashnarayan and Mulge (2008), respectively. Fruit weight had positive association with total yield/plant (r = 0.655*) and marketable yield/plant (r = 0.624*) and FSB infestation on fruits (r = 0.448*) and shoots (r = 0.315*). Positive association of fruit weight with total yield/plant (r_g = 0.79**) was reported by Ariyo *et al*. 1987. Total number of fruits/plant had positive correlation with number of marketable fruits/plant (r = 0.965*), total yield/plant (r = 0.773*) and marketable yield/plant (r = 0.778*). Positive association of total number of fruits/plant with total yield/plant (r_g = 0.9088**) was reported by Jaiprakashnarayan and Mulge (2004). Number of marketable fruits/plant had positive correlation with total yield/plant (r = 0.698*) and marketable yield/plant (r = 0.755*). The present findings are in consonance with the earlier findings of Jaiprakashnarayan *et al*. (2004), Bello *et al*. (2006) and Mehta *et al.* (2006) who also reported positive association of fruit length, fruit weight and total number of fruits/plant with total yield/plant in okra. Total yield/plant had positive strong correlation with marketable yield/plant (r = 0.980*) and FSB infestation on fruits (r = 0.291*). FSB infestation on fruits had a positive correlation with FSB infestation on shoots (r = 0.761*) and YVMV infestation on fruits had positive correlation with YVMV infestation on plants (r = 0.978*). Pal *et al*. (2008) also reported positive association of fruit length (r_g = 0.18**), fruit weight (r_g = 0.92*) and total number of fruits/plant (r_g = 0.95**) with marketable yield /plant in okra.

From the results of correlation coefficient analysis, it is evident that the characters plant height, number of branches/plant, first flowering and fruiting node, fruit length and weight and total number of fruits/plant and number of marketable fruits/plant had strong positive association with fruit yield/plant, suggesting that fruit yield can be improved by making selection on the basis of the aforesaid characters, which are considered as major yield attributes in okra. It is suggested that these characters should be considered during direct selection for genetic improvement of yield in okra. The contribution of components of yield is through component compensation mechanism (Adams 1967). Higher the plant height with more number of branches on the main stem, higher is the number of fruits per plant because of accommodation of more number of nodes for a given internodal length. Similar positive association of fruit yield was reported by Dakahe *et al*. (2007) for plant height, Reddy *et al*. (1985) for number of branches/plant, Singh *et al*. (2006) for fruit length, fruit weight and number of fruits/plant, while negative association of total yield with first flowering and fruiting node was reported by Jaiprakashnarayan and Mulge (2004).

Correlation coefficients between general combining ability effects and *per se* values of parents were positive and significant (**Table 2**) for number of branches/plant (r = 0.953*), internodal length (r = 0.724*), days to 50% flowering (r = 0.851*), first flowering node (r = 0.789*), first fruiting node (r = 0.789*), fruit length (r = 0.948*), fruit width (r = 0.942*), fruit weight (r = 0.952*), total yield/plant (r = 0.870*), marketable yield/plant (r = 0.858*), FSB infestation on fruits (r = 0.980*), FSB infestation on shoots (r = 0.967*), YVMV infestation on fruits (r = 0.721*) and YVMV infestation on plants (r = 0.767*), suggesting that combining ability of parents can be precisely predicted based on their *per se* performance for these traits. Non-significantly positive correla-tion coefficients between general combining ability effects and *per se* values of parents for plant height (r = 0.564), total number of fruits/plant (r = 0.598) and number of marketable fruits/plant (r = 0.562), indicted that the combining ability of parents cannot be predicted precisely through their *per se* values. These results are in agreement with the earlier findings of Jaiprakashnarayan *et al*. (2008), who observed close association between *per se* performance and general combining ability of parents for days to 50% flowering, average fruit weight, number of fruits/plant and total yield/plant in okra.

Simple correlation coefficients between specific combining ability effects and *per se* performance of crosses were positive and significant (**Table 3**) for all growth, earliness and yield parameters under study in okra. There was strong correlarion between specific combining ability effects and *per se* performance of crosses for plant height (r = 0.878*), number of branches/plant (r = 0.625*), internodal length (r = 0.862*), days to 50% flowering (r = 0.851*), first flowering node (r = 0.788*), first fruiting node (r = 0.788*), fruit length (r = 0.691*), fruit width (r = 0.523*), fruit weight (r = 0.576*), total number of fruits/plant (r = 0.948*), number of marketable fruits/plant(r = 0.937*), total yield/plant (r = 0.829*), marketable yield/plant (r = 0.826*), FSB infestation on fruits (r = 0.454*), FSB infestation on shoots (r = 0.577*), YVMV infestation on fruits (r = 0.937*) and YVMV infestation on plants (r = 0.959*). Significance of correlation coefficients between *per se* values and SCA effects indicated strong association between *per se* performance and combining ability, suggesting that combining ability of crosses can be precisely predicted based on their *per se* performance for all the growth, earliness and yield parameters under study in okra. The results indicated that specific combining ability effects of crosses can be predicted based on their *per se* performance for all the growth, earliness and yield parameters studied. If the crosses developed do not fix into diallel or line × tester or any other designs used for estimation of combining ability affects, still good specific combiners can be spotted based on their *per se* performance in hybrids. The present findings are in consonance with the earlier findings of Jaiprakashnarayan *et al*. (2008), who also observed close association between

Table 2 Correlation coefficients between general combining ability effects and *per se* performance of parents of okra.

Character	Correlation coefficient
Plant height (cm)	0.564
No. of branches per plant	0.953*
Internodal length (cm)	0.724*
Days to 50% flowering	0.851*
First flowering node	0.789*
First fruiting node	0.789*
Fruit length (cm)	0.948*
Fruit width (cm)	0.942*
Fruit weight (g)	0.952*
Total no. of fruits per plant	0.598
No. of marketable fruits per plant	0.562
Total yield per plant (g)	0.870*
Marketable yield per plant (g)	0.858*
FSB infestation on fruits (%)	0.980*
FSB infestation on shoots (%)	0.967*
YVMV infestation on fruits (%)	0.721*
YVMV infestation on plants (%)	0.767*

* Significant at 5% level

Table 3 Correlation coefficients between specific combining ability effects and *per se* performance of crosses of okra.

Character	Correlation coefficient
Plant height (cm)	0.878*
No. of branches per plant	0.625*
Internodal length (cm)	0.862*
Days to 50% flowering	0.851*
First flowering node	0.788*
First fruiting node	0.788*
Fruit length (cm)	0.691*
Fruit width (cm)	0.523*
Fruit weight (g)	0.576*
Total no. of fruits per plant	0.948*
No. of marketable fruits per plant	0.937*
Total yield per plant (g)	0.829*
Marketable yield per plant (g)	0.826*
FSB infestation on fruits (%)	0.454*
FSB infestation on shoots (%)	0.577*
YVMV infestation on fruits (%)	0.937*
YVMV infestation on plants (%)	0.959*

* Significant at 5% level

per se performance and specific combing ability of crosses for days to 50% flowering, fruit length, average fruit weight, number of fruits /plant and total yield/plant in okra.

CONCLUSION

Of the 17 characters under study, the characters plant height, number of branches/plant, first flowering and fruiting node, fruit length and weight, total number of fruits and number of marketable fruits/plant and FSB infestation on fruits are identified as yield components in okra. Specific combining ability of crosses can be precisely predicted through their *per se* performance for all 17 characters under study, while general combining ability of parents can be precisely predicted through their *per se* performance for majority of the characters except plant height, total number of fruits/plant and number of marketable fruits/plant in okra.

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