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Research Article

Genetic analysis of association studies in segregating population of okra [*Abelmoschus esculentus* (L.) Moench]

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ABSTRACT : Two populations of the okra *viz.*, single cross F_2, and double cross F_2 were developed using BH-1, BH-2, BH-3, BH-4, BH-5 and BH-6. The objective was to determine the genetic variability, nature of association among different yield attributes and their direct and indirect contribution towards yield. From the analysis of variance, it was observed that mean squares due to genotypes were significant for all the traits, indicating the presence of genetic variability in the experimental material. The values of PCV were higher than that of GCV values for all the twelve characters indicating influence of environmental effects in the expression of these characters and it was found more in DC F_2 compared to SC F_2 population. The GCV, heritability and genetic advance were higher for plant height, fruit yield per plant, fruit weight and days to 50 per cent flowering which might be attributed to additive gene action of inheritance in DC F_2 population. From the correlation and path co-efficient analyses, it is revealed that the top priority should be given to selection based on numbers of fruit per plant, fruit length, fruit diameter and fruit weight for yield improvement and could be considered while formulating selection indices in the improvement of okra. Path co-efficient analysis revealed that fruit weight had maximum direct contribution (0.869) towards fruit yield followed by number of fruits per plant (0.323) and fruit length (0.079). This revealed that DC F_2 population showed more variability compared to SC F_2 because it involves diverse parents in its development compared to SC F_2 population.

KEY WORDS : Okra, Single cross F_2, Double cross F_2, Genetic variability, Correlation, Path analysis

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INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the important vegetable crop grown for its tender green fruits throughout India, Turkey and other neighboring countries. It has high nutritive value and export potential. To improve yield and other characters, information on genetic variability and inter-relationship among different traits is necessary. The improvement in any crop is proportional to the magnitude of its genetic variability present in the germplasm (Adiger *et al.*, 2011). The genotypic coefficient of variation indicates the range of genetic variability present in different characters. The partitioning of total variance so as to assess the true breeding nature of a particular trait under selection is important as the phenotypic expression of the character is the result of interaction between the genotype and environment. A relative comparison of heritability and expected genetic advance gives an idea about the nature of gene governing a particular character. Yield, which is a multiplicative product function of various yield attributing

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plant characters, but direct selection for yield is often misleading and hence, knowledge of inter-relationship between pairs of these characters and yield is essential to bring a rational improvement in the desirable traits. The correlation coefficients alone are inadequate to understand the cause and effect relationships. However, path analysis furnishes a method of partitioning the correlation coefficient between various characters into direct and indirect effects; provide the actual contribution of an attribute and its influence through other traits.

Correlation co-efficient analysis measures the mutual relationship between two plant characters and determines component characters in which selection can be based for genetic improvement in yield. Whether the association of these characters due to their direct effect on yield or is a consequence of their indirect effects via other component characters may be answered through path coefficient analysis. Such information reveals the possibility of simultaneous improvement of various attributes and also helps in increasing the efficiency of selection of complex inherited traits. Keeping this in view, the present investigation was aimed at assessing the genetic variability, association of various characters and direct and indirect path effects of nine independent components on fruit yield in six SC F_2 populations and sixteen derived DC F_2 from half diallel fashion without reciprocal crosses.

EXPERIMENTAL METHODS

The experimental material comprised of F_2 populations of single cross (6 SC F_2) and double cross (15 DC F_2) population in commercial okra hybrids BH1, BH-2, BH-3, BH4, BH-5 and BH-6 on the basis of per se performance, adaptation and geographical diversity. Six single cross F_2 population and sixteen double cross F_2 population were evaluated in Randomized Block Design with two replications during *Kharif* 2012 at K.R.C. College of Horticulture, Arabhavi. Each entry was sown in one row of 6 m length with inter and intra row spacing of 60 cm and 45 cm, respectively, and all the recommended cultural practices were followed. Data on twelve quantitative characters *viz.*, plant height, number of primary branches per plant, number of secondary branches per plant, plant spread North-South and East- West direction, days to first flowering, days to 50 per cent flowering, fruit length, fruit diameter, average number of fruits per plant, average fruit weight and total fruit yield per plant were recorded. Mean values were subjected to analysis of variance, genotypic and phenotypic correlation coefficient and path coefficient was computed by using the formula of (Dewey and Lu, 1959).

EXPERIMENTAL RESULTS AND ANALYSIS

The mean values were worked for quantitative characters in single and double cross F_2 populations. The double cross F_2 populations exhibited higher mean fruit yield than single cross F_2 population. Similarly an increase in the mean values in double cross F_2 population was also noticed for plant height (61.13 cm), number of primary branches (6.98), days to 50 per cent flowering (47.31), fruit diameter (15.44 mm), average number of fruits (17.84), average fruit weight (17.14 g) and total fruit yield per plant (301.36 g). The double cross F_2 recorded lower mean values for number of secondary branches (1.61), plant spread in North-South (60.45 cm) and East-West direction (60.39 cm), days to first flowering (39.50) and fruit length (15.01 cm). Similar results reported by Prakash *et al.* (2012) and Nwangburuka *et al.* (2012). Thus, based on mean values it is possible to identify and select the superior segregants for utilization in breeding programme to develop good inbred lines (Table 1).

In the F_2 populations of single and double crosses, the higher phenotypic coefficient of variability was recorded for number of primary branches and secondary branches per plant whereas, higher genotypic coefficient of variability was recorded for number of secondary branches in double cross F_2 population. Similar results were reported by Osekita and Akinyele (2008) in 45 F_2 population of double cross okra. The presence of high phenotypic and genotypic coefficients of variability indicates presence of more variation in the population to select superior segregants in the advanced generation.

However, low genotypic and phenotypic coefficient of variability for days to first flowering, days to 50 per cent flowering, plant height, plant spread for North-South and East-West direction, fruit diameter , average fruit weight and total fruit yield per plant were noticed for both single and double cross F_2 populations. Similar results were obtained for plant height by Monpara and Chhatrola (2010) in 55 genotypes, for fruit length by Prakash *et al.* (2012) in 50 genotypes.

In this study, for all the characters genotypic coefficient of variability is lower than phenotypic coefficient of variability. The difference between genotypic coefficient of variability and phenotypic coefficient of variability was very less both in single and double cross F_2 populations; it indicates lesser environmental influence in the expression of a particular character. The high heritability coupled with high genotypic variance and high genetic advance (GA) were observed for the characters *viz.*, plant height, number of secondary branches in double cross F_2 population whereas, for plant spread for both North-South and East-West, and average fruit weight in single cross F_2 population. This indicates there is a lesser environmental influence on the expression of these characters and governed by additive gene action and hence goes for simple selection among the population. Similar results were reported for fruit yield per plant, number of fruits per plant, fruit diameter and plant height by Nwangburuka *et al.* (2012) and Ezhilarasi and Senthulkumar (2012) for number of branches and fruit length.

The moderate heritability coupled with moderate genotypic variance and moderate GA for the characters, number of primary branches and average number of fruits per plant in single and double cross F_2 populations and total fruit yield in single and double cross F_2 population was observed. These traits appear to be predominantly controlled by both additive and non-additive genetic components. These findings are in agreement with the results obtained by Prakash *et al.* (2012) and Osekita and Akinyele (2008).

The low heritability coupled with low genotypic variance and high GA for the characters, average number of fruit, fruit diameter in single and double cross F_2 populations and fruit length in double cross F_2 population was observed. These traits appear to be predominantly controlled by non-additive genetic components, therefore, it is advisable to go for development of hybrids or heterosis breeding. These findings are in agreement with the results obtained by Osekita and Akinyele (2008).

The selections can be more effective in F_2 population of double cross F_2 compared to single cross as they exhibited the higher magnitude of variability, heritability and genetic advance as per cent over mean than single cross for most of the yield contributing traits. Similar observations were also made by Prakash *et al.* (2012) in okra.

Genotypic correlation was studied for fruit yield per plant and its component traits in all single and double cross F_2 Population. Genotypic correlations of fruit length (0.622 and 0.619), fruit diameter (0.583 and 0.286), average fruit weight (0.653 and 0.929) and number of fruits per plant (0.231 and 0.486) exhibited significant positive association with fruit yield per plant in single cross and double cross F_2 (Table 2) population, respectively. The results obtained in this study are in confirmation with Kumar *et al.* (2009) and Nasit *et al.* (2010).

The characters, fruit length, fruit diameter, fruit weight and number of fruits per plant, not only exhibited significant association with fruit yield per plant, but also showed

Table 1 : Estimates of genetic variability for quantitative characters in single and double cross F_2 populations of okra

Characters	Genotypes	Mean	Range	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA (%)
Plant height (cm)	SC F_2	59.99	42.00 – 80.00	17.23	13.93	6.52	5.84	79.45	57.70
	DC F_2	61.39	41.00 – 78.00	20.54	17.24	7.11	6.48	82.65	65.65
Number of primary branches	SC F_2	5.33	3.73 - 6.87	1.88	0.72	20.88	12.57	36.40	15.61
	DC F_2	6.98	4.33 - 8.33	2.68	1.52	24.58	17.60	49.83	19.73
Number of secondary branches	SC F_2	2.06	0.67 - 2.50	0.35	0.33	19.55	18.75	90.56	20.44
	DC F_2	1.61	0.47 - 2.65	0.43	0.41	24.00	23.21	96.02	25.43
Plant spread North-South (cm)	SC F_2	60.60	40.00 – 79.00	20.59	14.92	7.45	6.30	70.90	44.36
	DC F_2	60.45	48.00 – 77.00	18.55	12.87	7.06	5.82	67.34	40.08
Plant spread East-West (cm)	SC F_2	61.13	49.00 – 71.00	18.01	12.02	6.99	5.63	63.96	37.74
	DC F_2	60.39	43.00 – 77.00	17.34	11.35	6.88	5.51	63.42	36.60
Days to first flowering	SC F_2	41.80	32.50 – 48.23	2.10	0.87	3.56	2.20	38.14	30.48
	DC F_2	39.50	35.95 - 42.5	2.39	1.17	3.77	2.49	42.44	28.81
Days to50% flowering	SC F_2	46.68	48.89 - 49.33	1.79	0.29	2.80	1.11	16.08	44.74
	DC F_2	47.31	41.66 - 49.66	1.86	0.37	2.86	1.19	18.95	51.27
Fruit length (cm)	SC F_2	16.14	13.71 - 18.70	4.43	2.34	13.39	9.59	50.81	22.36
	DC F_2	15.01	13.22 - 16.78	4.46	2.37	13.35	9.34	48.13	21.85
Fruit diameter (mm)	SC F_2	14.39	12.95 - 15.87	1.34	0.81	7.88	6.09	59.25	28.45
	DC F_2	15.44	13.74 - 17.16	1.32	0.79	7.79	5.94	57.14	27.51
Average no. of fruits per plant	SC F_2	17.56	13.02 - 21.70	5.58	2.98	13.59	9.83	52.01	5.20
	DC F_2	17.84	10.60 - 24.39	6.06	3.46	14.16	10.60	55.59	5.56
Average fruit weight (g)	SC F_2	14.77	12.84 - 16.71	1.93	1.43	8.67	7.02	60.37	22.95
	DC F_2	17.14	14.29 - 20.01	3.16	2.67	11.03	9.73	71.35	34.07
Total fruit yield per plant (g)	SC F_2	263.80	153.62 - 376.71	84.45	31.09	3.34	2.01	36.03	34.43
	DC F_2	301.36	210.98 – 403.16	105.45	52.09	3.71	2.54	46.34	50.19

SC= Single cross hybrids, DC= Double cross hybrids, PV = Phenotypic variance, GV= Genotypic variance, PCV= Phenotypic coefficient of variation GCV= Genotypic coefficient of variation, h^2 = Heritability, GA= Genetic advance

Table 2 : Genotypic correlation for growth and yield contributing traits in okra

Characters	Genotypes	Plant height (cm)	Number of primary branches	Plant spread North-South (cm)	Plant spread East-West (cm)	Days to 50% flowering	Fruit length (cm)	Fruit diameter (mm)	Average number of fruits per plant	Average fruit weight (g)	Total fruit yield per plant (g)
Plant height (cm)	SC F_2	1.000	0.315	0.597**	0.588**	-0.557*	-0.524*	-0.046	-0.239	0.211	-0.142
	DC F_2	1.000	0.195	0.607**	0.786**	0.354	0.041	0.327	0.002	0.291	0.312
Number of primary branches	SC F_2		1.000	0.769**	0.277	-0.475*	-0.566**	-0.867**	-0.645**	-0.793**	-0.736**
	DC F_2		1.000	0.362	0.344	0.186	0.246	0.033	0.033	0.262	0.290
Plant spread North-South (cm)	SC F_2			1.000	0.232	-0.305	-0.387	-0.962**	-0.708**	-0.576**	-0.406
	DC F_2			1.000	0.858**	0.419	-0.037	0.432	-0.039	-0.194	-0.098
Plant spread East-West (cm)	SC F_2				1.000	-0.279	0.180	-0.262	-0.778**	-0.189	-0.035
	DC F_2				1.000	0.361	-0.106	0.272	-0.160	-0.038	-0.021
Days to 50% flowering	SC F_2					1.000	0.265	0.239	0.359	0.129	-0.142
	DC F_2					1.000	-0.264	-0.251	-0.439	-0.101	-0.190
Fruit length (cm)	SC F_2						1.000	0.364	-0.106	0.053	0.622**
	DC F_2						1.000	0.245	0.679**	0.379	0.619**
Fruit diameter (mm)	SC F_2							1.000	0.753**	0.764**	0.583**
	DC F_2							1.000	0.358	0.143	0.286
Average number of fruits per plant	SC F_2								1.000	0.646**	0.231
	DC F_2								1.000	0.143	0.486*
Average fruit weight (g)	SC F_2									1.000	0.653**
	DC F_2									1.000	0.929**
Total fruit yield per plant (g)	SC F_2										1.000
	DC F_2										1.000

SC- Single cross, DC- Double cross Note- * and ** indicate significance of values at P=0.05 and 0.01 is 0.444 and 0.565

Table 3 : Direct (diagonal) and indirect genotypic path effects of different characters towards fruit yield per plant in single and double cross F_2 population of okra

Characters	Genotypes	Plant height (cm)	Number of primary branches	Plant spread North-South (cm)	Plant spread East- West (cm)	Days to 50% flowering	Fruit length (cm)	Fruit diameter (mm)	Average No. of fruits per plant	Average fruit weight (g)	Correlation with Fruit yield per plant (g)
Plant height (cm)	SC F_2	8.369	-2.236	0.905	-4.578	-1.030	-0.643	-0.523	1.331	-1.738	-0.142
	DC F_2	0.033	0.000	0.046	-0.006	0.011	0.003	0.001	0.001	0.253	0.312
Number of primary branches	SC F_2	2.637	-7.096	7.210	-2.153	-0.878	-0.694	-9.880	3.594	6.524	-0.736**
	DC F_2	0.001	0.001	0.027	-0.003	0.006	0.019	0.000	0.011	0.227	0.290
Plant spread North-South (cm)	SC F_2	0.808	-5.456	9.379	-1.808	-0.565	-0.475	-10.972	3.944	4.739	-0.406
	DC F_2	0.002	0.001	0.076	-0.006	0.013	-0.003	0.001	-0.012	-0.169	-0.098
Plant spread East-West (cm)	SC F_2	4.922	-1.963	2.179	-7.784	-0.515	0.221	-2.982	4.336	1.551	-0.035
	DC F_2	0.002	0.001	0.065	-0.007	0.011	-0.008	0.001	-0.052	-0.033	-0.021
Days to 50% flowering	SC F_2	-4.661	3.369	-2.863	2.168	1.850	0.325	2.727	-2.000	-1.057	-0.142
	DC F_2	0.001	0.000	0.032	-0.003	0.031	-0.021	-0.001	-0.142	-0.088	-0.190
Fruit length (cm)	SC F_2	-4.385	4.016	-3.631	-1.403	0.490	1.227	4.154	0.591	-0.437	0.622**
	DC F_2	0.000	0.000	-0.003	0.001	-0.008	0.079	0.001	0.219	0.330	0.619**
Fruit diameter (mm)	SC F_2	-0.384	6.149	-9.025	2.036	0.442	0.447	1.401	-4.198	-6.286	0.583**
	DC F_2	0.001	0.000	0.033	-0.002	-0.008	0.019	0.002	0.116	0.125	0.286
Average number of fruits per plant	SC F_2	-1.999	4.576	-6.637	6.056	0.664	-0.130	8.587	-5.573	-5.312	0.231
	DC F_2	0.000	0.000	-0.003	0.001	-0.014	0.054	0.001	0.323	0.124	0.486*
Average fruit weight (g)	SC F_2	1.768	5.629	-5.404	1.468	0.238	0.065	8.714	-3.600	-8.225	0.653**
	DC F_2	0.001	0.000	-0.015	0.000	-0.003	0.030	0.000	0.046	0.869	0.929**

SC- Single cross DC- double cross
Genotypic residual effect for Single cross F_2:0023, Double cross F_2: 0.0011, the diagonal bold figures represent direct effect.

significant positive association among themselves. This suggested that these characters should be considered while selecting plants for fruit yield improvement in these single and double cross population (Akinyele and Osekita, 2006).

The inter correlation among the important characters of fruit yield revealed that number of fruits per plant was non significantly associated with plant height and number of branches per plant (Nasit *et al.*, 2010). Plant height had positive correlation with plant spread in both North-South and East-West direction in most of the Population. It is obvious that, taller the plant more will be the canopy coverage; number of fruits, thus resulting in higher fruit yield was reported by (Akinyele and Osekita, 2006).

Average fruit weight (0.653 and 0.929) and fruit length (0.622 and 0.619) were positively correlated with fruit yield per plant in all single and double cross F_2 population, respectively while, fruit diameter (0.583) in single cross F_2 population, average number of fruits per plant (0.486) in double cross F_2 population had positive correlation with fruit yield per plant. The inter correlation of fruit weight had positive correlation with fruit diameter in single cross F_2 and negatively correlated with plant spread. Thus, suggesting that as fruit diameter increases fruit weight also increases. But, as fruit diameter increases, fruit length and number of seeds per fruit will reduce. These findings are in agreement with Adiger *et al.* (2011) and Nasit *et al.* (2010).

In the path co-efficient analysis (Table 3 and 4), there was correspondence between direct effect and phenotypic correlation for most of the component characters with fruit yield per plant in the single and double cross F_2 Population. Further, it revealed high direct effect of fruit length, fruit diameter and fruit weight on fruit yield per plant. Similar findings were reported by Guddandamath *et al.* (2011). Hence, desirable improvement may be brought about by selecting genotypes with more number of fruits per plant and higher fruit weight. Fruit weight recorded highest direct effect (0.869) followed by number of fruits per plant (0.323), plant height (0.033), fruit length (0.079), days to 50% flowering (0.031) in DC F_2 population and plant spread in East-west direction (-7.784) followed by number of primary branches (-7.096), average number of fruits (-5.573) and days to 50% flowering exhibited highest negative direct effect (-4.661) in SC F_2. Adiger *et al.* (2011) and Kumar *et al.* (2009) obtained similar results earlier. All characters mentioned earlier, which contributed directly and positively to fruit yield per plant possess significant correlations suggesting that the association between these traits is perfect and it was due to genetic factors only. Looking to the indirect effects, high positive indirect effect was found in case of number of fruits per plant via number of branches per plant, plant height and fruit length. These have also been corroborated (Guddadamath *et al.*, 2011). Therefore traits like fruit weight and number of

Table 4 : Direct (diagonal) and indirect phenotypic path effects of different characters towards fruit yield per plant in single and double cross F_2 population of okra

Characters	Genotypes	Plant height (cm)	Number of primary branches	Plant spread North-South (cm)	Plant spread East- West (cm)	Days to 50% flowering	Fruit length (cm)	Fruit diameter (mm)	Average number of fruits per plant	Average fruit weight (g)	Correlation with Fruit yield per plant (g)
Plant height (cm)	SC F_2	3.455	0.382	0.414	-1.859	-0.641	-1.719	-0.216	0.183	-0.141	-0.142
	DC F_2	0.003	0.000	0.045	-0.005	0.011	0.003	0.001	0.001	0.250	0.309
Number of primary branches	SC F_2	1.089	1.211	3.300	-0.874	-0.547	-1.856	-4.083	0.495	0.529	-0.736**
	DC F_2	0.001	0.002	0.027	-0.002	0.006	0.019	0.000	0.011	0.225	0.280
Plant spread North-South (cm)	SC F_2	0.334	0.931	4.292	-0.734	-0.352	-1.270	-4.535	0.543	0.384	-0.406
	DC F_2	0.002	0.001	0.074	-0.006	0.013	-0.003	0.001	-0.012	-0.167	-0.097
Plant spread East-West (cm)	SC F_2	2.032	0.335	0.997	-3.161	-0.321	0.591	-1.232	0.597	0.126	-0.035
	DC F_2	0.002	0.001	0.063	-0.007	0.012	-0.008	0.001	-0.051	-0.033	-0.021
Days to 50% flowering	SC F_2	-1.924	-0.575	-1.310	0.880	1.152	0.869	1.128	-0.275	-0.086	-0.142
	DC F_2	0.001	0.000	0.031	-0.002	0.032	-0.021	-0.001	-0.141	-0.088	-0.188
Fruit length (cm)	SC F_2	-1.811	-0.685	-1.661	-0.570	0.305	3.281	1.717	0.082	-0.035	0.622**
	DC F_2	0.000	0.000	-0.003	0.001	-0.008	0.078	0.001	0.217	0.326	0.613**
Fruit diameter (mm)	SC F_2	-0.158	-1.049	-4.130	0.827	0.276	1.195	4.712	-0.578	-0.510	0.584**
	DC F_2	0.001	0.000	0.032	-0.002	-0.008	0.019	0.003	0.115	0.123	0.283
Average number of fruits per plant	SC F_2	-0.825	-0.781	-3.037	2.459	0.413	-0.348	3.549	-0.768	-0.431	0.231
	DC F_2	0.000	0.000	-0.003	0.001	-0.014	0.053	0.001	0.320	0.123	0.481*
Average fruit weight (g)	SC F_2	0.730	-0.961	-2.473	0.596	0.148	0.174	3.601	-0.496	-0.667	0.653**
	DC F_2	0.001	0.000	-0.014	0.000	-0.003	0.030	0.000	0.046	0.860	0.919**

SC- single cross DC- double cross,

Phenotypic residual effects for single cross F_2: 0.0091, double cross F_2: 0.0186, the bold diagonal figures represent direct effect fruits per plant had high positive direct effect on fruit yield per plant. So, selection based on fruit weight and number of fruits per plant will be effective in advanced generations. These findings are in agreement with Mahapatra *et al.* (2007) and Das *et al.* (2012).

Low residual effect indicated that the selection of traits for path coefficient analysis is appropriate and no characters were neglected. In the present investigation, number of fruits per plant, fruit weight, plant height, number of primary branches per plant, days to 50% flowering and plant spread in North-South and East-West direction were important components characters. Hence, they must be given due weightage when a plant breeder practices selection.

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