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Determining relationships among fruit yield and yield components using path coefficient analysis in okra [(*Abelmoschus esculentus* L. (Moench)]

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Abstract

This study was conducted to determine the magnitude of genetic relationships between fruit yield, yield components and quality traits in 37 okra genotypes for two years in order to bring quality breeding. Direct and indirect effects of fruit yield components on fruit yield per plant were investigated. Thirty seven accessions of okra were evaluated in randomized complete block design for various quantitative and quality traits and to quantify the relationships among these traits in diverse okra germplasm. Genetic analysis such as genotypic and phenotypic coefficient of variation and path coefficient analyses were performed. The results obtained showed highly significant variation in all the genotypes. Fruit yield/plant was significantly and positively associated with fruits/plant, average fruit weight and nodes/plant at both genotypic and phenotypic levels; which are important prerequisites to formulate a successful improvement program. Path coefficient analysis revealed that fruits/plant had the maximum positive direct contribution towards fruit yield/plant followed by average fruit weight and nodes/plant. The observed variability in the traits studied strongly indicate the possibility of selecting plants with suitable morphology when considering integration into any improvement programme towards preservation and conservation of okra germplasm.

Key words: *Abelmoschus esculentus* (L.) Moench, correlation coefficient, fruit yield, quality traits, path analysis.

Okra or lady's finger [*Abelmoschus esculentus* (L.) Moench], known as bhindi in India, belongs to family Malvaceae, is an important fruit vegetable extensively grown in temperate, subtropical and tropical regions of the world (Kochhar 1986). The plant is a robust, erect, annual herb, ranging 1-2 m in height with simple leaves, which are alternate and palmately veined. Okra is commonly used for its tender pods. It is also frozen, dehydrated and canned. However, in India tender pods are used as fried vegetable or in curry and sambhar. Frozen bhindi is available in big cities. The dried stem of okra is used for clarification of sugarcane juice. Its fruits have high nutritive, medicinal and industrial value and export potential. The oil from its seeds is utilized in perfume industry. Its fibre is used in paper industry. Fresh okra is an important vegetable which is exported from India to Middle East, UK, Western Europe and USA. Frozen bhindi is also exported to UK. The mucilage has been used as a plasma replacement or blood volume expander (Siemonsma and Kouame 2004). For improving this crop through conventional breeding and selection, adequate knowledge of association between yield and yield related quantitative characters (controlled by polygenes) is essential for the identification of selection procedure. The appropriate knowledge of such interrelationships and its contributing components can significantly improve the efficiency of a breeding program by using selection indices. Correlation and path coefficient analysis are the prerequisites for improvement of any crop including okra for selection of superior genotypes and its traits. The correlation studies simply measure the associations between yield and other traits and thus helps in selection of superior genotypes from diverse genetic populations. The information obtained from the correlation coefficients can be enhanced by partitioning into direct and indirect effects for a set of pair-wise cause-effect interrelationships (Kang *et al.* 1983) and path coefficient analysis permits the same. It is basically a standardized partial regression analysis and deals with a closed system of variables that are linearly related. This information provides a basis for allocation of appropriate weightage to various yield components.

The investigation was undertaken to: 1) determine phenotypic and genotypic correlation coefficients among fruit yield, agronomic and quality traits and 2) partition the correlation analysis to assess the relative importance of direct and indirect effects of agronomic and quality characters on fruit yield in okra.

Materials and Methods

The experiment was conducted at the Departmental Farm of Vegetable Science and Floriculture, CSK Himachal Pradesh Agriculture University Palampur, Himachal Pradesh, India, situated at 32°6' N latitude, 76°3'E longitude and elevation of 1290.8 m above sea level during summer rainy (May-September) season of 2011 and 2012. The climate is humid, sub-temperate, having severe winters and mild summers. The experiment was conducted under field conditions. The experimental site received rainfall of 2500 mm with average minimum and maximum temperature ranging between 31^{0}C (summer) and 13.6^{0}C (winters). The soil of the experiment was silty clay loam and acidic (pH= 5.7) in reaction with high organic matter (1.63%), total nitrogen (262 kg ha^{-1}) and available K (159 kg ha^{-1}).

The experiment was arranged in a randomized complete block design with three replicates. The experimental area was prepared by deep ploughing, proper levelling and then divided into three blocks and each block consisted of 19 beds with a 0.5m drainage channel between two blocks. The okra seeds were sown at distance of 45 × 15-20 cm. Each bed contained 6 lines with 20 plants in each line, thus accommodating 120 plants in each bed. Seeds treated with bavistin (2g/kg seed) to avoid fungal diseases, were sown in well prepared beds during May. 200q/ha of farm yard manure and 75 kg N, 50 kg P, 50 kg K per hectare were applied at field preparation prior to sowing of seeds. Another dose of 75 kg/ha N was applied about a month after sowing and at fruit setting. Sufficient moisture was maintained during growing season by applying flood irrigation at 7-10 days intervals. Intercultural operations were done frequently for getting better growth and yield. All the recommended agronomic package of practices was followed to raise good healthy crop. Thinning was done to maintain appropriate plant density within rows. Weeding and hoeing was done at regular interval. Plant protection measures were also applied uniformly during the period of experiment.

The observations were recorded from 10 competitive plants from each row on twelve quantitative characters like days to 50% emergence, days to 50% flowering, days to first picking, harvest duration, plant height, fruits/plant, average fruit weight, first fruit producing node, nodes/plant, internodal length, fruit length, fruit diameter and three qualitative traits namely dry matter, mucilage and mineral content.

Days to 50% emergence, days to 50% flowering and days to first picking were counted from the time of sowing to emergence, flowering and harvest respectively. Height of plant was measured by scale. Length and diameter of fruit were recorded with the help of a digital vernier calliper whereas fruits per plant were counted very carefully from each plant kept for observation purposes. Fresh fruit weight was measured with the help of an analytical balance. For estimating dry matter content, the fresh fruits were dried in a hot air oven and measured by analytical balance until no further weight loss occurred.

Data analysis

SPAR 1 (Software developed by the Indian Agriculture Statistical Research Institute, New Delhi, India) was used for statistical analysis and the data was subjected to analysis of variance (Panse and Sukhatme 1984). Estimation of genotypic and phenotypic correlations was determined using the formula given by AL-Jibouri *et al.* (1958). Direct and indirect path coefficients were calculated as proposed by Dewey and Lu (1959),

Results and Discussion

Fruit yield is a complex character that depends upon many independent yield contributing characters, which are regarded as yield components. 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.

Correlation coefficient analysis

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component on which selection can be based for improvement in yield. Therefore, knowledge of correlation coefficients between yield and its components may be a valuable indication regarding the components, where selection could be profitable exercise in order to increase yield ability.

From the perusal of the estimates of phenotypic and genotypic coefficients of variation (Table 1), fruit yield per plant was significantly and positively associated with most of

Table 1. Correlation coefficients at the phenotypic (P) and genotypic (G) levels for quantitative and quality traits in okra

Traits		Quantitative traits: Phenological and structural traits						Quantitative traits: Fruit yield traits						Quality traits			
		Days to50% emergence	Days to 50% flowering	Days to first picking	Harvest duration (days)	Plant height (cm)	Fruits/plant	Average fruit weight. (g)	First fruit producing node	Nodes/plant	Internodal length (cm)	Fruit length (cm)	Fruit diameter (cm)	Dry matter (%)	Mucilage (%)	Mineral content (mg/kg)	Fruit yield / plant (g)
Days to 50 % emergence	P		-0.236*	-0.218*	0.154	-0.0041	0.0272	0.0626	0.0882	0.0586	-0.0021	0.121	0.0670	-0.0844	-0.192*	0.214*	0.117
	G		-0.321*	-0.765	0.635*	-0.0723	-0.0989	0.171	0.0541	-0.132	-0.0569	0.125	0.114	-0.245*	-0.278*	0.342*	0.0590
Days to 50% flowering	P			0.589*	- 0.566*	0.149	-0.0642	-0.169	0.100	-0.0472	0.187	0.0892	0.151	0.136	0.121	0.0311	-0.239*
	G			0.922*	- 1.036*	0.205*	-0.234*	-0.248*	0.312*	-0.129	0.264*	0.160	0.194*	0.152	0.132	0.0958	-0.461*
Days to first picking	P				- 0.778*	0.0441	-0.179	-0.0169	0.152	-0.178	0.0769	-0.0139	0.0516	0.242*	0.0871	-0.0553	-0.236*
	G				- 0.876*	0.0363	-0.0639	-0.291*	0.0392	0.0710	0.128	0.178	0.051	0.439*	0.169	-0.0152	-0.273*
Harvest duration (days)	P					-0.169	0.132	-0.0811	-0.212*	0.102	-0.149	0.0080	-0.0280	-0.119	-0.152	0.0010	0.118
	G					-0.381*	-0.0016	0.155	0.134	-0.152	-0.387*	-0.192*	0.0079	-0.308*	-0.348*	-0.109	0.0974
Plant height (cm)	P						-0.056	0.251*	0.122	0.0192	0.756*	0.0851	0.168	0.0163	0.367*	0.122	0.122
	G						-0.0672	0.345*	0.452*	0.112	0.812*	0.112	0.178	0.0057	0.396*	0.134	0.194
Fruits/plant	P							-0.532*	-0.329*	0.852*	-0.510*	0.140	-0.0649	-0.0429	-0.141	-0.152	0.722*
	G							-0.422*	-0.456*	1.089*	-0.759*	0.0089	0.0153	0.0300	-0.252*	-0.268*	0.582*
Average fruit weight (g)	P								0.0852	-0.478*	0.442*	-0.0527	-0.0187	-0.0912	0.0172	0.123	0.211*
	G								0.245*	-0.419*	0.552*	-0.088	-0.0231	-0.181	0.0541	0.178	0.482*
First fruit producing node	P									-0.0015	0.122	-0.123	-0.142	-0.0882	0.131	0.120	-0.321*
	G									-0.126	0.426*	-0.186	-0.514*	-0.391*	0.266*	0.255*	-0.229*
Nodes/plant	P										-0.487*	0.106	-0.108	-0.0399	-0.0892	-0.0971	0.582*
	G										-0.656*	-0.0172	-0.109	-0.0472	-0.183	-0.187	0.639*
Internodal length (cm)	P											0.074	0.218*	0.0167	0.376*	0.169	-0.241*
	G											0.0882	0.237*	0.0181	0.429*	0.194	-0.312*
Fruit length (cm)	P												-0.0452	-0.173	-0.0692	-0.329*	0.0982
	G												-0.0028	-0.188	-0.0659	-0.372*	-0.0763
Fruit diameter (cm)	P													0.137	-0.0901	0.255*	-0.0975
	G													0.141	-0.112	0.271*	-0.0120
Dry matter (%)	P														0.0228	-0.0886	-0.119
	G														0.0289	-0.0899	-0.142
Mucilage (%)	P															0.0321	-0.177
	G															0.0592	-0.249*
Mineral content (mg/kg)	P																-0.0535
	G																-0.091
Fruit yield/plant (g)	P																
	G																

Table 2. Estimates of direct and indirect effects of quantitative and quality traits on fruit yield at phenotypic (P) and genotypic (G) level

Traits		Quantitative traits												Quality traits		
		Phenological and structural traits					Fruit yield traits									
		Days to50% emergence	Days to 50% flowering	Days to first picking	Harvest duration (days)	Plant height (cm)	Fruits/plant	Average fruit weight (g)	First fruit producing node	Nodes/plant	Internodal length (cm)	Fruit length (cm)	Fruit diameter (cm)	Dry matter (%)	Mucilage (%)	Mineral content (mg/kg)
Days to 50 % emergence	P	**0.0261**	-0.0060	-0.0065	0.0036	-0.0001	0.0008	0.0018	0.0024	0.0017	-0.0001	0.0032	0.0018	-0.0026	-0.0052	0.0056
	G	**-0.0172**	0.0054	0.0126	-0.0103	0.0011	0.0019	-0.0024	-0.0008	0.0024	0.0010	-0.0021	-0.0014	0.0040	0.0046	-0.0058
Days to 50% flowering	P	-0.0030	**0.0139**	0.0085	-0.0084	0.0022	-0.0088	-0.0023	0.0014	-0.0007	0.0029	0.0012	0.0021	0.0024	0.0012	0.0004
	G	-0.0261	**0.0828**	0.0747	-0.0862	0.0174	-0.0186	-0.0201	0.0242	-0.0097	0.0210	0.0121	0.0154	0.0118	0.0100	0.0080
Days to first picking	P	-0.0094	0.0228	**0.0386**	-0.0316	0.0017	-0.0070	-0.0006	0.0056	-0.0069	0.0030	-0.0004	0.0020	0.0094	0.0036	-0.0022
	G	0.0013	-0.0014	**-0.0020**	0.0012	-0.0001	0.0001	0.0004	-0.0001	-0.0001	-0.0002	-0.0002	-0.0001	-0.0008	-0.0003	0.0000
Harvest duration (days)	P	0.0078	-0.0311	-0.0432	**0.0538**	-0.0095	0.0064	-0.0042	-0.0112	0.0054	-0.0089	0.0004	-0.0018	-0.0067	-0.0086	0.0000
	G	0.0250	-0.0414	-0.0356	**0.0392**	-0.0154	0.0000	0.0064	0.0052	-0.0055	-0.0152	-0.0075	0.0004	-0.0122	-0.0137	-0.0041
Plant height (cm)	P	-0.0002	0.0072	0.0021	-0.0081	**0.0453**	-0.0023	0.0118	0.0054	0.0006	0.0350	0.0036	0.0076	0.0008	0.0165	0.0063
	G	0.0084	-0.0251	-0.0042	0.0476	**-0.119**	0.0081	-0.0410	-0.0543	-0.0122	-0.0978	-0.0130	-0.0224	-0.0009	-0.0478	-0.0168
Fruits/plant	P	0.0262	-0.0651	-0.184	0.123	-0.0532	**1.030**	-0.536	-0.328	0.868	-0.516	0.133	-0.0661	-0.0344	-0.140	-0.1440.
	G	-0.0899	-0.202	-0.0575	-0.0012	-0.0601	**0.910**	-0.372	-0.409	0.976	-0.686	0.0082	0.0136	0.0199	-0.231	-0.229
Average fruit weight (g)	P	0.052	-0.142	-0.0144	-0.0656	0.192	-0.430	**0.822**	0.0689	-0.383	0.353	-0.0431	-0.0149	-0.0804	0.0134	0.0932
	G	0.159	-0.238	-0.272	0.132	0.320	-0.396	**0.959**	0.221	-0.392	0.510	-0.0742	-0.0213	-0.160	0.0502	0.149
First fruit producing node	P	-0.0041	-0.0052	-0.0075	0.0109	-0.0062	0.0142	-0.0044	**-0.0512**	0.0001	-0.0060	0.0061	0.0078	0.0045	-0.0063	-0.0057
	G	0.0007	0.0026	0.0002	0.0011	0.0038	-0.0038	0.0020	**0.0076**	-0.0010	0.0036	-0.0015	-0.0049	-0.0032	0.0021	0.0020
Nodes/plant	P	0.0041	-0.0032	-0.0121	0.0070	0.0014	0.0592	-0.0327	-0.0001	**0.0689**	-0.0348	0.0065	-0.0073	-0.0030	-0.0060	-0.0069
	G	-0.0146	-0.0140	0.0081	-0.0162	0.0120	0.128	-0.0482	-0.0141	**0.110**	-0.0744	-0.0019	-0.0122	-0.0050	-0.0205	-0.0207
Internodal length (cm)	P	0.0002	-0.0156	-0.0068	0.0131	-0.0642	0.0430	-0.0376	-0.0098	-0.0424	**-0.0859**	-0.0056	-0.0184	-0.0014	-0.0315	-0.0150
	G	-0.0024	0.0092	0.0046	-0.0143	0.0296	-0.0287	0.0201	0.0154	-0.0220	**0.0386**	0.0034	0.0087	0.0006	0.0154	0.0069
Fruit length (cm)	P	-0.0004	-0.0004	0.0001	0.0000	-0.0003	-0.0005	0.0002	0.0004	-0.0004	-0.0002	**-0.0031**	0.0003	0.0007	0.0002	0.0012
	G	0.0016	0.0017	0.0020	-0.0023	0.0014	0.0002	-0.0006	-0.0021	-0.0002	0.0010	**0.0108**	0.0000	-0.0018	-0.0006	-0.0042
Fruit diameter (cm)	P	-0.0010	-0.0022	-0.0007	0.0004	-0.0023	0.0010	0.0004	0.0021	0.0013	-0.0032	0.0006	**-0.0163**	-0.0024	0.0012	-0.0039
	G	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	-0.0003	-0.0001	0.0002	0.0000	**-0.0012**	0.0001	-0.0001	0.0002
Dry matter (%)	P	0.0001	-0.0001	-0.0002	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0001	-0.0001	**-0.0011**	0.0000	0.0001
	G	-0.0058	0.0033	0.0101	-0.0072	0.0002	0.0007	-0.0041	-0.0086	-0.0011	0.0005	-0.0037	0.0032	**0.0242**	0.0006	-0.0023
Mucilage (%)	P	0.0017	-0.0010	-0.0007	0.0013	-0.0031	0.0014	-0.0001	-0.0011	0.0007	-0.0030	0.0006	0.0008	-0.0002	**-0.0082**	-0.0004
	G	0.0058	-0.0022	-0.0032	0.0064	-0.0072	0.0049	-0.0010	-0.0050	0.0033	-0.0080	0.0011	0.0016	-0.0005	**-0.0189**	-0.0011
Mineral content (mg/kg)	P	0.0033	0.0005	-0.0008	0.0000	0.0021	-0.0025	0.0015	0.0017	-0.0015	0.0030	-0.0052	0.0036	-0.0014	0.0005	**0.0174**
	G	0.0096	0.0027	-0.0004	-0.0027	0.0036	-0.0072	0.0042	0.0068	-0.0050	0.0054	-0.0103	0.0074	-0.0025	0.0016	**0.0292**
CC with Fruit yield/plant (g)	P	0.117	-0.239*	-0.236*	0.118	0.122	0.722*	0.211*	-0.321*	0.582*	-0.241*	0.0982	0.0977	-0.119	-0.177*	-0.0535
	G	0.090	-0.461*	-0.273*	0.0974	0.194	0.582*	0.482*	-0.229*	0.631*	-0.312*	-0.0783	-0.0120	-0.142	-0.249*	-0.091

* Significant at 5% level; Residual effect: P=0.1346, G=0.0874 Bold values indicate direct effects and non-bold indicates indirect effects

the characters except days to 50% flowering, days to first picking, first fruit producing node, intermodal length, fruit diameter and various qualitative traits like dry matter, mucilage percentage and mineral content, both at genotypic and phenotypic level. Khan *et al.* (2005); Adiger *et al.* (2011); Jagan et al. (2013); Reddy *et al.* (2013); Mishra *et al.* (2015a) and Islam et al. (2012) also revealed similer results.

At both genotypic and phenotypic level, strong positive and significant associations of fruits/plant, average fruit weight and nodes per plant were recorded with fruit yield/plant. Similarly plant height (0.756, 0.812) and average fruit weight (0.442, 0.552) showed positive and significant correlation with internodal length. The results are in conformity with earlier findings of Singh and Goswami (2014). Internodal length also showed significant and positive correlation with fruit diameter (0.218, 0.237). Positive and significant correlations were also showed by fruits/plant with nodes/plant (0.852, 1.081); plant height with average fruit weight (0.251, 0.345); days to 50% flowering with days to first picking (0.589, 0.922) respectively. More significant genotypic association between different pairs of characters than the phenotypic correlation means that there is strong association between those characters genetically, but the phenotypic value is lessened by the significant interaction of environment. The present findings on genotypic and phenotypic correlation coefficients are in consonance with the earlier findings of Ahiakpa *et al.* (2013); Nwangburuka *et al.* (2012); Sarker *et al*.(2015); Akinyele and Osekita (2006); Bello *et al.* (2006); Mehta et al. (2006); Patro and Sankar (2006); Rashwan (2011), Somashekhar *et al.* (2011) and Yatung *et al.* (2014). Among quality traits, days to 50% emergence (0.214, 0.342) and fruit diameter (0.255, 0.271) showed positive and significant correlation with mineral content; days to first picking with dry matter (0.242, 0.439); plant height (0.367, 0.396) and internodal length (0.376, 0.429) with mucilage percentage which acts as potential selection criteria in breeding programs aiming at higher yield.

On the contrary, days to 50% flowering (-0.239, -0.461), days to first picking (-0.236, -0.273), first fruit producing node (-0.321, -0.229), internodal length (-0.241, -0.312) indicated strong negative and significant correlations with fruit yield/plant. Similar associations was also observed between days to 50% flowering (-0.566, -1.036) and days to first picking (-0.778, -0.876) with harvest duration; fruits/plant with first fruit producing node (-0.329, -0.456) and internodal length (-0.510, -0.759); average fruit weight with nodes/plant (-0.478, -0.417); nodes/plant with internodal length (-0.487, -0.656). Among quality traits, negative and significant association was shown by days to 50% emergence with mucilage content (-0.192, -0.278) and fruit length with mineral content (-0.329, -0.372), respectively. Similar findings have also been reported by Ahiakpa *et al.* (2013) and Somashekhar *et al.* (2011).

Path coefficient analysis

To obtain clear understanding of association between genotype and phenotype, correlation coefficient was partitioned into direct and indirect effects through path coefficient analysis in Table 2. It depicts the effects of different independent characters individually and in combination with other character on fruit yield. The perusal of data revealed that fruits/plant (1.030) had the maximum contribution towards fruit yield/plant followed by average fruit weight (0.822) and nodes/plant (0.0689). The negative direct contribution on fruit yield/plant was shown by plant height (-0.119) followed by internodal length (-0.0859). The results are in line with Yucel *et al.* (2006); Sayar (2014) and Mishra *et al.* (2015b).

Maximum positive indirect effects on fruit yield/plant was exhibited by internodal length (0.510) followed by plant height (0.320), first fruit producing node (0.221) and days to 50% emergence (0.159) via average fruit weight, fruit length (0.133) via fruits/plant and fruits/plant through nodes/plant. The results are in confirmity with Patro and Sankar (2006).

Maximum negative indirect effects on fruit yield/plant were shown by internodal length (-0.686) via fruits/plant followed by average fruit weight (-0.536) via fruits/plant, fruits/plant (-0.430), nodes per plant (-0.392) and days to first picking (-0.272) via average fruit weight respectively. Path coefficient analysis results are in conformity with Simon et al. (2013); Hallur *et al.* (2015); Ahamed *et al.* (2015) and Muluken *et al.* (2016). In order to find a clear picture of the inter–relationship between fruit yield and other components path coefficient analysis has been performed where yield of okra was considered as resultant variable and the rest characteristics as causal variable.

Consequently, the present study illustrated the existence of wide ranges of variations for most of the characters among the okra genotypes, which provides opportunities for genetic gain through selection or hybridization. Fruit yield showed strong positive and significant correlations with most of the characters. Thus, selection may be possible for these characters for improving yield.

Conclusion

In the studied traits, genotypic variances were greater than phenotypic variances, and this indicated that these traits are less influenced by environmental effects. According to the results of the correlation analysis, fruit yield per plant was significantly and positively correlated to fruits/plant, nodes/plant, average fruit weight, plant height and harvest duration whereas negatively correlated with first fruit producing node, days to first picking, internodal length, days to 50% flowering, mucilage, dry matter and mineral content respectively. Improving these traits may increase fruit yield per plant. Path analysis of fruit yield per plant indicated that number of fruits/plant and average fruit weight exerted the greatest direct effect. These traits had major contributions to fruit yield per plant, and hence can increase the success of breeding studies in okra.

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