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Correlation and pathanalysis studies in okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
Thirty two okra genotypes were evaluated in randomized complete block design with two replications. Thirteen characters were measured on randomly selected plants for the analysis of correlation and path analysis. Correlation ad path coefficient analysis studies revealed that fruit yield per plant exhibited high significant positive association with, plant height, fruit length, weight of fruit and number of fruits per plant indicating the importance of these traits in selection for yield. Direct selection based on these traits would result in simultaneous improvement of aforesaid traits and yield *per se* in okra. Path analysis studies revealed high direct effect of days to initiation for first flowering, number of branches per plant, fruit length, weight of fruit and number of fruits per plant also recorded desirable direction with yield. Hence, the genotypes which exhibited better performance for these characters can be used in further improvement of okra.

Keywords: Okra, path analysis, correlation

Introduction
Okra or ladies' finger is a herbaceous annual plant and good source of minerals, antioxidants, fiber and vitamins. The word Abelmoschus perhaps originated from the Arabian word "abul-l-mosk" meaning "source of musk," referring to the musky smell of the seeds (Charrler, 1984) [6]. The green tender fruits of okra are good source of carbohydrate, protein, vitamins (A, B and C) and rich in calcium, potassium and other mineral matters. It's contains 1.9 g protein, 1.2 g fiber, 1.5 mg Fe and 88 IU Vit-A per 100 g of edible portion. The most frequently observed somatic chromosome number, however, is 2n=130, although Datta and Naug (1968) [7] suggest that the numbers 2n=72, 108, 120, 132 and 144 are in regular aeries of polyploidy with n=12.
In our country, a wide variation amongst the okra varieties expressing variation for quantitative and qualitative traits. A logical way to start any crop improvement programme is to assess the variation existing in the available materials. Yield is a complex character resulting from multiplicative interactions of various yield components. Therefore, correlation studies between yield and other traits will be of interest to breeders in planning the hybridization programme and evaluating the individual plants in segregating populations. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. Path analysis splits the correlation coefficient into measures of direct and indirect effects, thus providing understanding of the direct and indirect contribution of each character towards yield.

Materials and Methods
The experiment was laid out in a randomized block design (RBD) with two replications. In each replication, each genotype was grown in double row plot. Individual plot was of 3.0 m length and 1.2 m in width. An inter-row spacing of 60 cm and an intra-row spacing of 30 cm was maintained. Ten plants per row and 20 plants per plot and genotype were maintained. Recommended package of practices and plant protection measures were carried out to raise a successful crop. The experimental material comprising of 32 okra genotypes obtained from VRS, SKLTSHU, Rajendranagar, Hyderabad were systematically evaluated for 13 quantitative and qualitative traits.
Correlation coefficient analysis reveals the association of characters i.e., a change in one

character brought about by a change in the other character Phenotypic and genotypic correlation coefficients between different variables were calculated by using covariance technique (Al-Jibouri *et al*., 1958) [2]. To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated. The simple or total correlations can be calculated at genotypic (r_g), phenotypic(r_p) Environmental (r_e) levels between any two characters. Using the variances and covariances between any two traits, say X_1 and X_2, these correlations can be evaluated as under.

$$\text{Genotypic correlations r } (r_e) = \frac{Cov_e(X_1.X_2)}{\sqrt{var_e(X_1)\ .\ var_e(X_2)}}$$

$$\text{Phenotypic correlations r } (r_p) = \frac{Cov_p(X_1.X_2)}{\sqrt{var_p(X_1)\ .\ var_p(X_2)}}$$

$$\text{Environmental correlations r } (r_e) = \frac{Cov_e(X_1.X_2)}{\sqrt{var_e(X_1)\ .\ var_e(X_2)}}$$

Where

r_g, r_p and r_e - genotypic, phenotypic and environmental correlation Coefficients respectively.

Cov_g, Cov_p and Cov_p - genotypic and phenotypic covariance of xy, respectively.

var_g, var_p and var_e - genotypic and phenotypic variance of x and y, respectively.

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1963) [9] at (n-2) degrees of freedom at 5% and 1% level where 'n' denotes the total number of pairs of observations used in the calculation. Path coefficients were obtained by solving the following simultaneous equations.

$r_{ly} = P_{ly} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots\ldots\ldots + r_{lk}P_{ky}$

Where,

r_{ly} = Simple correlation coefficient between x_1 and y, the dependent character

P_{ly} = Direct effect of x_1 on y, the dependent character

$r_{12}P_{2y}$ = Indirect effect of x_1 on y through x_2.

r_{12} = Correlation coefficient between x_1 and x_2.

$r_{lk}P_{ky}$ = Indirect effect of x_1 only through k^{th} variable.

The direct and indirect contribution of various characters to yield were calculated through path coefficient analysis as suggested by Wright (1921) [13] and elaborated by Dewey and Lu (1959) [8].

Table 1: Scales for path coefficients

Values of direct (or) indirect effects	Rate (or) scale
0.00 to 0.09	Negligible
0.10 to 0.19	Low
0.20 to 0.29	Moderate
0.30 to 0.99	High
> 1.00	Very high

Results and Discussion

Correlation coefficient

Fruit length was recorded highly significant and positive correlation with plant height (0.2841P, 0.3031 G) and weight of the fruit (0.4381 P, 0.4482 G). Negative and significant correlation was noticed with days to initiation for first flowering (-0.3597 P, -0.4534 G), days to 50% flowering (-0.3274 P, -0.4640 G), number of branches plant^{-1} (-0.6168 P, -0.6476 G), fiber content (-0.2558 P, -0.2919 G) and overall YVMV PDI (%) (-0.2546 P, -0.2571 G). Diameter of fruit (cm) showed positive and significant correlation with, number of branches plant^{-1} (0.3851 P, 0.4550 G) and number of fruits plant^{-1} (0.3945 P, 0.4672 G). The correlation coefficient of fruit weight was found to be significant and positive correlation with plant height (0.8181 P, 0.8608 G), fruit length (0.4381 P, 0.4482 G) and number of fruits plant^{-1} (0.5826 P, 0.6224 G). Negative and significant correlation was noticed with days to initiation for first flowering (-0.7839 P, -0.8846 G), days to 50% flowering (-0.4198 P, -0.9143 G), number of branches plant^{-1} (-0.4082 P, -0.4451G), fiber content (-0.8239 P, -0.2919 G) and overall YVMV PDI (%) (-0.7516 P, -0.8252 G). The correlation coefficient of number of fruit plant-1 showed significant and positive correlation with plant height (0.8183 P, 0.8455 G), number of branches plant-1 (0.2838 P, 0.3083G), fruit length (cm), diameter of fruit (0.3945 P, 0.4672 G), weight of fruit (0.5826 P, 0.6224 G). Negative and significant correlation was noticed with days to initiation for first flowering (-0.3597 P, -0.4534 G), fiber content (-0.5995 P, -0.6494 G) and overall YVMV PDI (%) (-0.6736 P, -0.7047G). Fruit yield plant^{-1} (g)recorded positive and significant correlation with character like plant height (0.9016 P, 0.9319 G), fruit length (0.3169 P, 0.3097 G), weight of fruit (0.9422P, 0.9508G), number of fruits plant^{-1} (0.8115 P, 0.8265 G), It also registered significant negative correlation with days to initiation for first flowering (-0.7430P, -0.8406G), days to 50% flowering (-0.2692 P, -0.3371 G), number of branches plant^{-1} (-0.7430P, -0.8406G), fiber content (- 0.8300 P, -0.8998 G) and overall YVMV PDI (%) (-0.7929 P, -0.8446 G). Percent of fiber content exhibited positive and significant correlation with days to initiation for first flowering (0.7285 P, 0.8557 G), days to 50% flowering (0.2552 P, 0.3703 G) and number of branches plant^{-1} (0.2557 P, 0.2598 G) and overall YVMV PDI (%) (0.7217 P, 0.8305 G). Negative and significant correlation was noticed with plant height (-0.7744 P, -0.8308 G), fruit length (-0.2558 P, -0.2919 G), weight of fruit (-0.8239 P, -0.2919 G), number of fruits plant^{-1} (-0.5995 P, -0.6494 G). Overall YVMV PDI (%) exhibited positive and significant correlation with days to initiation for first flowering (0.7075 P, 0.8028 G), days to 50% flowering (0.2458 P, 0.3221 G), fiber content (0.7217 P, 0.8305 G). Negative and significant correlation was noticed with plant height (-0.8616 P, -0.9121 G), number of branches plant^{-1}, fruit length (-0.2546 P,-0.2571 G), weight of fruit (-0.7516 P, -0.8252 G) and number of fruits plant^{-1} (-0.6736 P, -0.7047 G).

Path Analysis

Plant height (cm) had negligible direct negative effect on fruit yield plant^{-1} at phenotypic level (-0.0355) and high negative direct effect at genotypic level (-0.3133). Further, it exhibited high indirect positive effect through weight of fruit (0.7979) and low negative indirect negative effect (-0.1410) on fruit yield plant^{-1} through days to initiation for first flowering at genotypic level. Days to initiation for first flowering had

negligible direct negative effect on fruit yield plant^{-1} at phenotypic level (-0.0025) and low positive direct effect at genotypic level (0.1922). Further, it exhibited moderate indirect positive effect (0.7979) through plant height and high negative indirect negative effect (-0.1410) on fruit yield plant^{-1} through weight of fruit at genotypic level. Days to 50% flowering had negligible direct positive effect on fruit yield plant^{-1} at phenotypic level (0.0145) and negligible direct negative effect at genotypic level (-0.0756). Further, it exhibited low indirect positive effect (0.1424) through days to initiation for first flowering and high negative indirect negative effect (-0.4754) on fruit yield plant^{-1} through weight of fruit at genotypic level. Number of branches plant^{-1} had negligible direct positive effect on fruit yield plant^{-1} at phenotypic level (0.0145) and low direct positive effect at genotypic level (0.1118). Further, it exhibited low indirect positive effect (0.1311) through number of fruits plant^{-1} and high indirect negative effect (-0.4126) on fruit yield plant^{-1} through weight of fruit at genotypic level. At both phenotypic (0.0021) and genotypic level (0.0630), fruit length exhibited negligible positive direct effect on fruit yield plant^{-1}. Further, it exhibited high indirect positive effect (0.4155) through weight of fruit and low indirect negative effect (-0.0950) on fruit yield plant^{-1} through plant height at genotypic level. Diameter of fruit exhibited negligible negative direct effect on fruit yield plant^{-1} at both phenotypic (-0.0519) and genotypic level (-0.0867). Further, it exhibited low indirect positive effect (0.1986) through number of fruits plant^{-1} and negligible indirect negative effect (-0.0649) on fruit yield plant^{-1} through plant height at genotypic level. At both phenotypic (0.7123) and genotypic level (0.9270), weight of fruit exhibited high positive direct effect on fruit yield plant^{-1}. Further, it exhibited moderate indirect positive effect (0.2645) through number of fruits plant^{-1} and moderate indirect negative effect (-0.2697) on fruit yield plant^{-1} through plant height at genotypic level. Number of fruits plant^{-1} exhibited very high positive direct effect on fruit yield plant^{-1} at phenotypic level (1.1918) and high positive direct effect genotypic level (0.4250). Further, it exhibited high indirect positive effect (0.5770) through weight of fruit and moderate indirect negative effect (-0.2649) on fruit yield plant^{-1} through plant height at genotypic level. At both phenotypic (-0.0116) and genotypic level (-0.0084), fiber content exhibited negligible negative direct effect on fruit yield plant^{-1}. Further, it exhibited moderate indirect positive effect (0.2603) through plant height and high indirect negative effect (-0.8476) on fruit yield plant^{-1} through weight of fruit at genotypic level. Overall YVMV PDI (%) had negligible direct positive effect on fruit yield plant^{-1} at phenotypic level (0.0029) and low negative direct effect at genotypic level (-0.1160). Further, it exhibited low indirect positive effect (0.2858) through plant height and high negative indirect negative effect (-0.7649) on fruit yield plant^{-1} through weight of fruit at genotypic level.

The result on genotypic and phenotypic correlation reveals that phenotypic correlation coefficient is comparatively lower than the intensity of genotypic correlation coefficient. This indicates less influence of environment in association studies. Fruit yield plant^{-1}, exhibited high significant positive association with, plant height, fruit length, weight of fruit and number of fruits plant^{-1} indicating the importance of these traits in selection for yield. Direct selection based on these traits would result in simultaneous improvement of aforesaid traits and yield *per se* in okra. The path coefficient analysis done in this study reveals that, the improvement of yield by improving the characters number of branches plant $^{-1}$, fruit length, weight of fruit and number of fruits plant^{-1}. Among all the traits under study, days to initiation for first flowering, number of branches plant^{-1}, fruit length, weight of fruit and number of fruits plant^{-1}, have recorded positive with yield. This suggested that direct selection based on these traits were considered for crop yield improvement.

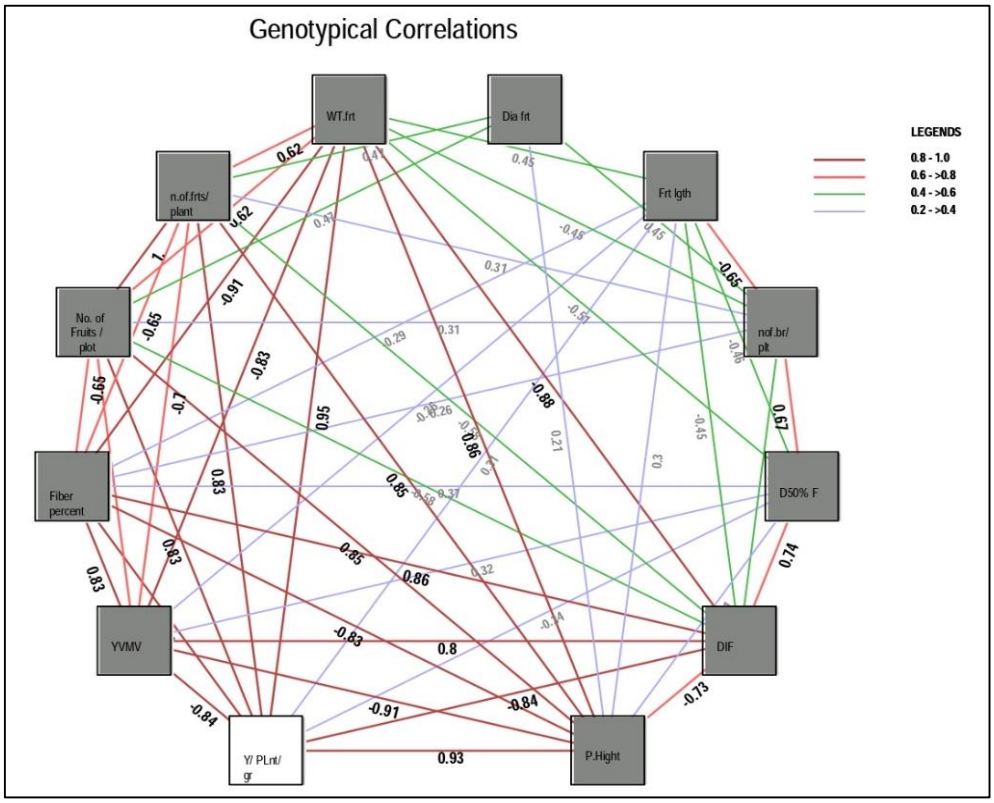

Fig 1: Genotypic correlation diagram

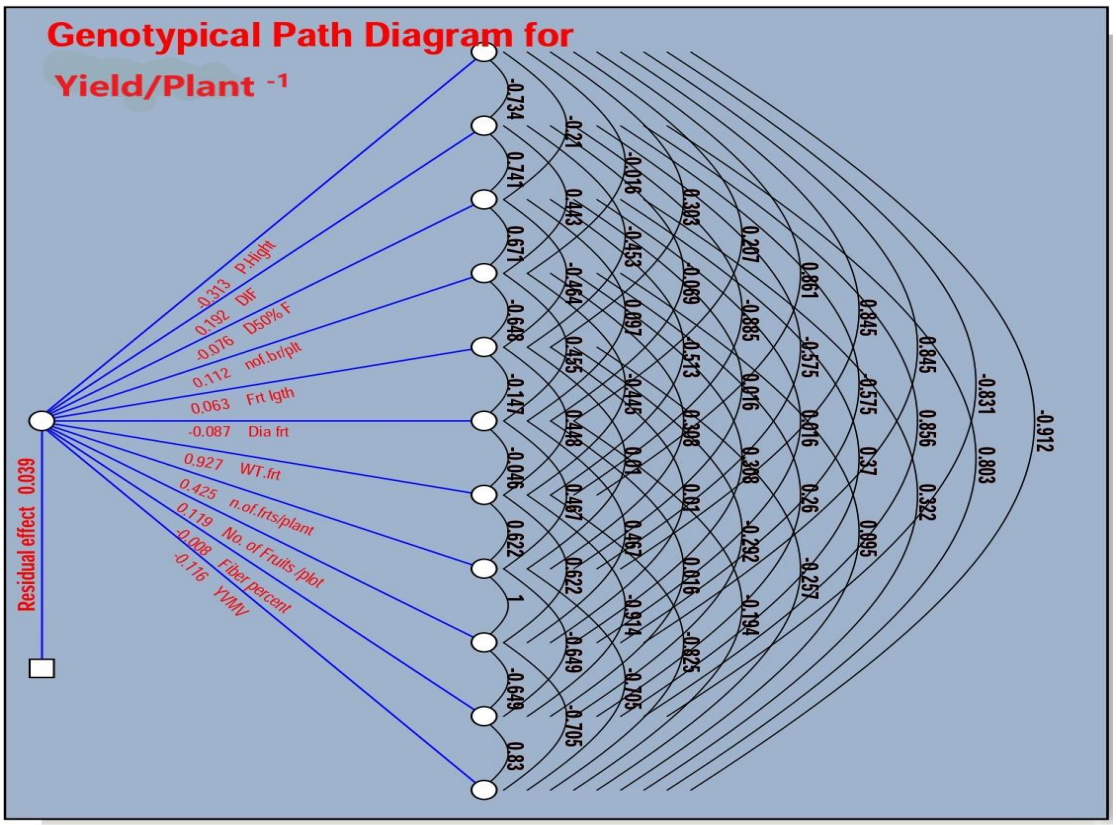

Fig 2: Genotypic path diagram respecting direct and indirect effects on fruit yield plant $^{-1}$

Table 2: List of germplasm lines of okra selected for genetic diversity studies

S. No.	Genotype	Source
1	RHBG-1	VRS, SKLTSHU, HYDERABAD
2	RHBG-2	VRS, SKLTSHU, HYDERABAD
3	RHBG-3	VRS, SKLTSHU, HYDERABAD
4	RHBG-4	VRS, SKLTSHU, HYDERABAD
5	RHBG-5	VRS, SKLTSHU, HYDERABAD
6	RHBG-6	VRS, SKLTSHU, HYDERABAD
7	RHBG-7	VRS, SKLTSHU, HYDERABAD
8	VRO-6	VRS, SKLTSHU, HYDERABAD
9	IC-42490	NBPGR- New Delhi
10	IC-43743	NBPGR- New Delhi
11	IC-45730	NBPGR- New Delhi
12	IC-90219	NBPGR- New Delhi
13	IC-10533	NBPGR- New Delhi
14	IC-10265	NBPGR- New Delhi
15	RHBG-8	VRS, SKLTSHU, HYDERABAD
16	IC-18960	VRS, SKLTSHU, HYDERABAD
17	IC-04328	VRS, SKLTSHU, HYDERABAD
18	RHBG-9	VRS, SKLTSHU, HYDERABAD
19	RHBG-13	VRS, SKLTSHU, HYDERABAD
20	IC-90004	NBPGR- New Delhi
21	IC-111515	NBPGR- New Delhi
22	RHBG-10	VRS, SKLTSHU, HYDERABAD
23	RHBG-11	VRS, SKLTSHU, HYDERABAD
24	RHBG-12	VRS, SKLTSHU, HYDERABAD
25	Arka Anamika	IIHR-Banglore
26	Pusa Sawani	IARI-New Delhi
27	Arka Abhay	IIHR-Banglore
28	Pusa A-4	IARI-New Delhi
29	EC-755648	NBPGR- New Delhi
30	IC-29119	NBPGR- New Delhi
31	IC-22237	NBPGR- New Delhi
32	EC-755647	NBPGR- New Delhi

Table 3: Phenotypic (P) and genotypic (G) correlation coefficients of yield and yield attributes in 32 genotypes of okra

Characters		Plant height (cm)	Days to initiation for first flowering	Days to 50% flowering	Number of branches plant^{-1}	Fruit length (cm)	Diameter of fruit (cm)	Weight of fruit (gr)	Number of fruits plant^{-1}	Fiber content (%)	Overall YVMV PDI (%)	Fruit yield Plant^{-1} (g)
Plant height (cm)	P	1.0000	-0.6828***	-0.1736*	-0.0160	0.2841*	0.1855*	0.8181***	0.8183***	-0.7744***	-0.8616***	0.9016***
	G	1.0000	-0.7337***	-0.2096*	-0.0158	0.3031**	0.2073*	0.8608***	0.8455***	-0.8308***	-0.9121***	0.9319***
Days to initiation for first flowering	P		1.0000	0.7196***	0.3978**	-0.3597**	-0.0314	-0.7839***	-0.4896***	0.7285***	0.7075***	-0.7430***
	G		1.0000	0.7409***	0.4427***	-0.4534***	-0.0686	-0.8846***	-0.5753***	0.8557***	0.8028***	-0.8406***
Days to 50% flowering	P			1.0000	0.5124***	-0.3274**	0.0719	-0.4198***	0.0319	0.2552*	0.2458*	-0.2692**
	G			1.0000	0.6713***	-0.46408***	0.0974	-0.5128***	0.0164	0.3703**	0.3221**	-0.3371**
Number of branches per plant	P				1.0000	-0.6168***	0.3851***	-0.4082***	0.2838*	0.2557*	0.0954	-0.1765
	G				1.0000	-0.6476***	0.4550***	-0.4451***	0.3083**	0.2598*	0.0955	-0.1872
Fruit length (cm)	P					1.0000	-0.1275*	0.4381***	0.0279	-0.2558*	-0.2546*	0.3169**
	G					1.0000	-0.1466*	0.4482***	0.0105	-0.2919*	-0.2571*	0.3097**
Diameter of fruit (cm)	P						1.0000	-0.0564	0.3945**	0.0410	-0.1904*	0.0764
	G						1.0000	-0.0458	0.4672***	0.0155	-0.1937*	0.1037
Weight of fruit (g)	P							1.0000	0.5826***	-0.8239***	-0.7516***	0.9422***
	G							1.0000	0.6224***	-0.9143***	-0.8252***	0.9508***
Number of fruits plant^{-1}	P								1.0000	-0.5995***	-0.6736***	0.8115***
	G								1.0000	-0.6494***	-0.7047***	0.8265***
Fiber content (%)	P									1.0000	0.7217***	-0.8300***
	G									1.0000	0.8305***	-0.8998***
Overall YVMV PDI (%)	P										1.0000	-0.7929***
	G										1.0000	-0.8446***
Fruit yield plant^{-1} (g)	P											1.0000
	G											1.0000

*Significant at 5 per cent level; ** Significant at 1 per cent level ; *** Significant at less than 1 per cent level;

Table 4: Phenotypic (P) and genotypic (G) path coefficient analysis indicating direct and indirect effects of component characters on fruit yield in 32 genotypes of okra

Characters		Plant height (cm)	Days to initiation for first flowering	Days to 50% flowering	Number of branches plant^{-1}	Fruit length (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Number of fruits plant^{-1}	Fiber content (%)	Overall YVMV PDI (%)
Plant height (cm)	P	-0.0355	0.0242	0.0062	0.0006	-0.0101	-0.0066	-0.0290	-0.0290	0.0275	0.0305
	G	-0.3133	0.2299	0.0657	0.0049	-0.0950	-0.0649	-0.2697	-0.2649	0.2603	0.2858
Days to initiation for first flowering	P	0.0017	-0.0025	-0.0018	-0.0010	0.0009	0.0001	0.0019	0.0012	-0.0018	-0.0017
	G	-0.1410	0.1922	0.1424	0.0851	-0.0872	-0.0132	-0.1700	-0.1106	0.1645	0.1543
Days to 50% flowering	P	-0.0025	0.0104	0.0145	0.0074	-0.0047	0.0010	-0.0061	0.0005	0.0037	0.0036
	G	0.0158	-0.0560	-0.0756	-0.0507	0.0351	-0.0074	0.0388	-0.0012	-0.0280	-0.0243
Number of branches per plant	P	-0.0001	0.0028	0.0036	0.0071	-0.0044	0.0027	-0.0029	0.0020	0.0018	0.0007
	G	-0.0018	0.0495	0.0750	0.1118	-0.0724	0.0508	-0.0497	0.0345	0.0290	0.0107
Fruit length (cm)	P	0.0006	-0.0008	-0.0007	-0.0013	0.0021	-0.0003	0.0009	0.0001	-0.0005	-0.0005
	G	0.0191	-0.0286	-0.0292	-0.0408	0.0630	-0.0092	0.0282	0.0007	-0.0184	-0.0162
Diameter of fruit (cm)	P	-0.0096	0.0016	-0.0037	-0.0200	0.0066	-0.0519	0.0029	-0.0205	-0.0021	0.0099
	G	-0.0180	0.0059	-0.0084	-0.0394	0.0127	-0.0867	0.0040	-0.0405	-0.0013	0.0168
Weight of fruit (g)	P	0.5827	-0.5584	-0.2991	-0.2908	0.3121	-0.0402	0.7123	0.4150	-0.5869	-0.5353
	G	0.7979	-0.8200	-0.4754	-0.4126	0.4155	-0.0424	0.9270	0.5770	-0.8476	-0.7649
Number of fruits plant^{-1}	P	0.9753	-0.5835	0.0380	0.3382	0.0333	0.4702	0.6944	1.1918	-0.7145	-0.8027
	G	0.3594	-0.2445	0.0070	0.1311	0.0045	0.1986	0.2645	0.4250	-0.2760	-0.2995
Fiber content (%)	P	0.0090	-0.0084	-0.0029	-0.0030	0.0030	-0.0005	0.0095	0.0069	-0.0116	-0.0083
	G	0.0070	-0.0072	-0.0031	-0.0022	0.0025	-0.0001	0.0077	0.0055	-0.0084	-0.0070
Overall YVMV score	P	-0.0025	0.0021	0.0007	0.0003	-0.0007	-0.0006	-0.0022	-0.0020	0.0021	0.0029
	G	0.1058	-0.0931	-0.0374	-0.0111	0.0298	0.0225	0.0957	0.0817	-0.0963	-0.1160

R SQUARE = 0.9947 RESIDUAL EFFECT = 0.0731

Conclusion

The trait fruit yield plant^{-1}, exhibited high significant positive association with plant height, fruit length, weight of the fruit and number of fruits plant $^{-1}$, indicating the importance of these traits in selection for yield. Direct selection based on these traits would result in simultaneous improvement of abovementioned traits and yield *per se* in okra. Days to initiation of first flowering, number of branches plant^{-1}, fruit

length, weight of the fruit and number of fruits plant^{-1} are important characters to be considered for genetic improvement in fruit yield plant^{-1}, since these characters to be have direct and indirect effect on yield.

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