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Research Article

Correlation, Path Analysis, Heterosis and Inbreeding Depression for Yield and Quality Traits of Okra Lines and their Hybrids

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ABSTRACT

Four diverse advanced lines of okra namely HB 1157, HBT-12, HBT 24 and MR 41 were crossed to get four hybrids Viz., HB 1157 × HBT 24, HB 1157 × MR 41, HBT-12 × HBT 24 and HBT-12 × MR 41. Data generated from these parental lines and their hybrids were analysed to estimate the correlation, path analysis, heterosis and inbreeding depression in okra. Correlation coefficients showed that the selection for number of fruits, branches per plant, plant height, fruit weight and fruit length could improve the fruit yield positively, while inter-nodal length had negative association. Path coefficient analysis revealed that number of fruits per plant, fruit weight, fruit length and plant height had shown positive direct effects, whereas inter-nodal length exhibited highest negative direct effects on fruit yield per plant. Highly significant and positive heterobeltiosis was displayed for yield per plant in all the crosses ranging from 24% (HB 1157 × HBT 24) to 55.12% (HB 1157 × MR 41). Highest per se fruit yield of 275g per plant was estimated in HB 1157 × MR 41 followed by HBT-12 × MR 41 (262g/plant), HBT-12 × HBT 24 (233g/plant) and HB 1157 × HBT 24 (221g/plant). Similarly, HBT-12 × MR 41 took maximum number of days for first appearance of YVMV disease (67.67) followed by HB 1157 × MR 41, which acts as tolerance to YVMV in okra.

Keywords: *Okra, Heterosis, YVMV, Correlation, Inbreeding depression.*

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) commonly known as Bhindi, is a member of Malvaceae family with somatic chromosome number 2n=130. Due to its nutritional, medicinal and economic importance, Okra accounts for about 60% of the fresh vegetables export from India to the Middle East and European countries making it a principal foreign exchange earner (Singh et al., 2014) and providing a better option for Indian farmers to obtain healthier income and hence it's been cultivated over a larger area.

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In any crop improvement programme, knowledge on association of traits between each other and their influence on yield of fruits to aid in selection programme is of significant importance as it contributes indirectly to the success of selection.

Association between the traits, especially in crosses reflects gene linkages and thus helps the breeder in assembling specific combination of traits from two parents of a cross. Further, selection of one trait invariably affects a number of other associated characters. A programme of breeding for improvement of yield and biotic resistance requires information on extent of variation in the available material and the association of characters among themselves. Path coefficient analysis facilitates partitioning of the correlation coefficients of genetic parameters of crop plants into direct and indirect effects of various traits influencing the yield per plant. Correlations and path coefficient analysis of quantitative characters would be of help in choosing the component characters whose selection would result in the improvement of complex characters that are positively correlated.

Hybrids in general are better and early yielders in addition to improved quality traits. Heterosis is a natural phenomenon whereby hybrid offspring from genetically diverse individuals show phenotypic superiority over its parents with respect to traits such as growth rate, reproductive success, resistance, quality and yield (Shull, 1948) and it could be beneficial in positive or negative sense depending on the character under study. Seed source or the variety is the cheapest input in crop production, yet the most important and yield deciding factor in the course. Commercially grown varieties are low yielder as compared to hybrids which have advantages of uniformity in shape and size, increased vigor, early maturity, high yield and resistance to specific pests and pathogens. Hence the present experiment was designed to evaluate the 4 selected diverse okra advanced parental lines with their 4 hybrids for correlation, path analysis and heterosis in relation to the quality and yield components under the conditions of Hisar (Haryana).

MATERIALS AND METHODS

The experiment was carried out during 2015-2016, at the Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar. Geographically, Hisar is situated at latitude of 29º 10' north, longitude of 75º 46' East and an altitude of 215.2 meters above mean sea level on south western border of Rajasthan state. Two high yielding (HBT-12 and HB 1157) and two low yielding (MR 41 and HBT 24) advanced lines of okra were selected as parental material. Four F_1 crosses were made among the selected lines in the high yield × low yield fashion employing hand emasculation and pollination to obtain the F_1 seeds during rainy season 2015.

The four crosses were sown during rainy season 2016 in Randomized complete block design replicated thrice. Each replication consisted two rows each of P_1, P_2 and F_1 with row-to-row and plant-to-plant spacing of 60 cm and 30 cm, respectively thereby maintaining 20 plants per replication in each generations (P_1, P_2 & F_1) and the observations for morphological and yield traits was recorded on randomly selected five competitive plants. Data on nature of association of fruit yield with various other characters is of great importance in order to aid the selection process of Okra; hence, the correlation coefficients among the characters were computed at phenotypic level. The correlation coefficients among all possible character combinations at phenotypic (r_p) level were estimated by employing the formulae given by Al-Jibourie et al. (1958). The path coefficient analysis was performed as per the formula given by Wright (1921) and adopted by Dewey and Lu (1951). Heterosis and inbreeding depression were calculated using available formulae for the same.

RESULTS AND DISCUSSION

Correlation and path analysis

Correlation coefficients alone cannot provide factual depiction of association among the characters. Hence, the estimation of actual contribution of each individual character towards fruit yield per plant in okra is an essential feature. Path coefficient gives a clear description of a complex situation, which reflects at correlation level by revealing whether the association of each individual character with fruit yield is due to their direct effect or is a consequence of their indirect effect *via* other component traits. Thus, path coefficient is essential to know the effectiveness of selection for simultaneous improvement in these characters and the analysis was carried out by considering fruit yield per plant as a dependent character and all others as independent characters.

Data on four selected parents and four hybrids derived from crossing them were used for studying the association with various characters (Table 1) and their path analysis (Table 2) to get a broad idea to ease up the process of selection. Days to first flowering had shown significant positive correlation with fruit length (0.476), fruit weight (0.403), plant height (0.387), number of fruits (0.300) and number of branches (0.270). Number of branches exhibited highly significant and positive association with the fruit length (0.582), number of fruits (0.445), fruit weight (0.385), fruit yield per plant (0.371) and plant height (0.235). Plant height was significant and positively correlated with the fruit weight (0.610), number of fruits (0.605), fruit yield (0.569), fruit length (0.457) and fruit diameter (0.242), while it had significant negative correlation with the first fruiting node (-0.285). High and significant negative association of inter-nodal length was recorded with the fruit yield per plant (-0.458), number of fruits (-0.314) and first fruiting node (-0.284).

Table 1: Phenotypic correlation co-efficient for yield and its contributing traits in okra

	DFF	BR	PT.HT	INT.LGTH	FFN	FT.LGTH	FT.DIA	FT.WT	NO.FT
DFF	1								
BR	0.270*	1							
PT.HT	0.387**	0.235*	1						
INT.LGTH	-0.07	0.086	-0.285*	1					
FFN	-0.028	0.002	0.106	-0.284*	1				
FT.LGTH	0.476**	0.582**	0.457**	0.051	-0.028	1			
FT.DIA	0.117	-0.16	0.242*	-0.11	0.059	0.095	1		
FT.WT	0.403**	0.385**	0.610**	-0.16	0.066	0.604**	-0.077	1	
NO.FT	0.300**	0.445**	0.605**	-0.314**	-0.013	0.401**	0.121	0.432**	1
YLD/PT	0.138	0.317**	0.569**	-0.458**	0.011	0.349**	-0.086	0.568**	0.775**

*Significant at 0.05, **Significant at 0.01

DFF-Days to first flowering, BR - Number of Branches, PT.HT - Plant Height, INT.LGTH – Inter-nodal length, FFN - First Fruiting node, FT.LGTH - Fruit length, FT.DIA - Fruit diameter, FT.WT - Fruit weight, NO.FT - Number of fruits per plant, YLD/PT – Fruit yield per plant.

Fruit length has exhibited significant positive correlation with the fruit weight (0.604), number of fruits (0.401) and fruit yield per plant (0.349). Fruit diameter and first fruiting node have shown no significant association with any other characters except those mentioned earlier. Fruit weight had high and significant positive correlation with the fruit yield per plant (0.568) and number of fruits (0.432), whereas number of fruits exhibited a very highly significant and positive association with the fruit yield per plant (0.775). Similar results of significant positive correlation for green fruit yield in okra with plant height, number of primary branches per plant, number of fruits per plant, fruit length, fruit girth by Chandramouli et al. 2016, Reddy et al. 2013, Rani and Veeraragavathatham (2006).

Only four out of nine characters, namely number of fruits (0.624), fruit weight (0.280), fruit length (0.065) and plant height (0.064) had shown positive direct effects on the fruit yield per plant (Table 2) and all these traits have also exhibited significant positive correlation with the fruit yield per plant. Inter-nodal length had shown highest negative direct effects (-0.248) on fruit yield per plant, followed by days to first flowering (-0.196), fruit diameter (-0.174), number of branches (-0.074) and first fruiting node (-0.070). Number of branches, plant height, fruit length, fruit weight and number of fruits were positive and significantly associated with fruit yield, while inter-nodal length was negative significantly correlated. Number of branches exhibited maximum positive indirect effect *via* fruit diameter (0.012), whereas plant height achieved positive indirect effect through number of fruits (0.039), fruit weight (0.039), fruit length (0.029) and days to first flowering (0.025).

Inter-nodal length was found significantly but negatively correlated with fruit yield, which was contributed indirectly through maximum negative effect of number of branches (-0.021) and fruit length (-0.013). Fruit length realized maximum positive indirect effect *via* fruit weight (0.039), number of branches (0.038) and plant height (0.030). Fruit weight exhibited maximum positive indirect effect by means of plant height (0.171), fruit length (0.169) and number of fruits (0.432) (Table 2). Number of fruits achieved maximum indirect effect through plant height (0.377), number of branches (0.278) and fruit weight (0.270), while the maximum negative indirect effect was expressed *via* inter-nodal length (-0.196).

Table 2: Estimate of direct (diagonal) and indirect effects of component characters on fruit yield per plant in okra

Characters	DFF	BR	PT.HT	INT.LGTH	FFN	FT.LGTH	FT.DIA	FT.WT	NO.FT
DFF	**-0.196**	-0.020	0.025	0.017	0.002	0.031	-0.020	0.113	0.187
BR	-0.053	**-0.074**	0.015	-0.021	0.000	0.038	0.028	0.108	0.278
PT.HT	-0.076	-0.018	**0.064**	0.071	-0.007	0.030	-0.042	0.171	0.377
INT.LGTH	0.014	-0.006	-0.018	**-0.248**	0.020	0.003	0.019	-0.045	-0.196
FFN	0.005	0.000	0.007	0.070	**-0.070**	-0.002	-0.010	0.018	-0.008
FT.LGTH	-0.093	-0.043	0.029	-0.013	0.002	**0.065**	-0.017	0.169	0.250
FT.DIA	-0.023	0.012	0.015	0.027	-0.004	0.006	**-0.174**	-0.022	0.076
FT.WT	-0.079	-0.029	0.039	0.040	-0.005	0.039	0.013	**0.280**	0.270
NO.FT	-0.059	-0.033	0.039	0.078	0.001	0.026	-0.021	0.121	**0.624**

*Significant at 0.05, **Significant at 0.01

DFF-Days to first flowering, BR - Number of Branches, PT.HT - Plant Height, INT.LGTH – Inter-nodal length, FFN - First Fruiting node, FT.LGTH - Fruit length, FT.DIA - Fruit diameter, FT.WT - Fruit weight, NO.FT - Number of fruits per plant, YLD/PT – Fruit yield per plant.

The present findings are in agreement with Bhalekar et al. (2005) who reported that long fruited types with tall plants having more nodes per plant and fruits per plant yielded maximum fruit yield in okra. Similarly, Gangashetty et al. (2010) also reported high path coefficient for higher fruit yield with number of fruits per plant, average fruit weight and plant height. The results of present study also indicated that number of fruits per plant, average fruit weight, fruit length and plant height had considerable direct contribution towards green fruit yield in okra with high indirect effects observed for these traits.

Heterosis and inbreeding depression

Estimates with respect to four crosses studied for various characters are given in Table 3. In the present study, no single cross could exhibit simultaneously significant desirable heterosis for all the characters except HBT-12 × HBT 24, which attributed significant heterosis in desirable direction for most of the characters under the study. Reduced biological fitness due to continuous self-pollination is termed as inbreeding depression, and it is more prevalent in cross pollinated crops. The per cent increase or decrease of heterosis over better parent in F_1 generation and inbreeding depression (ID) was recorded for eleven characters.

All hybrids showed significant heterosis for various characters studied except for number of branches in HBT-12 x MR 41, which was zero and non-significant. Heterosis over the better parent was significant in desirable negative direction for days to first flowering in HBT 12 × HBT 24 (-6.82) and HB 1157 × HBT 24 (-0.23) indicating that these hybrids would be earlier in flowering than that of their better performing parent. HBT 12 × HBT 24 (16.67) recorded significant positive heterosis for number of branches, while HBT-12 x MR 41 (-22.50), HB 1157 × MR 41 (-12.60) and HBT 12 × HBT 24 (-11.01) had shown significant negative heterosis that is desirable for inter-nodal length. First fruiting node noted significant negative heterosis in HBT 12 × HBT 24 (-11.54) and HB 1157 × HBT 24 (-3.23), whereas average fruit weight showed significant positive heterobeltiosis in the crosses HB 1157 × MR 41 (7.35), HBT 12 × HBT 24 (5.69) and HB 1157 × HBT 24 (0.78).

Positive significant heterosis was observed in all the crosses except HBT 12 × HBT 24 (-5.72) for fruit length, while significant negative heterosis was estimated for fruit diameter in all the crosses except HBT-12 x MR 41 (9.44). Significant heterosis in desirable positive sense was estimated in all four crosses under study for plant height, number of fruits per plant and fruit yield per plant. In cross HBT-12 x MR 41, positive ID value was recorded for all studied traits except for first fruiting node (-50.54) and fruit diameter (-23.92). Negative ID was observed in first fruiting node (-25.60), fruit diameter (-6.87) and inter-nodal length (-5.17), while rest of the traits were positive in the cross HB 1157 × MR 41. All characters recorded positive ID in the crosses HBT 12 × HBT 24 and HB 1157 × HBT 24 except for days to first flowering, number of branches, first fruiting node and fruit diameter.

Since no commercial checks were used for the purpose in the experiment, better parent heterosis (heterobeltiosis) was taken as scale to know the best heterotic hybrid. The estimates of heterobeltiosis the present study revealed that the magnitude of heterosis over the better parent in general was moderate for all the characters in all the four crosses studied.

This is mainly due to involvement of well adapted parental lines with very little variation between them for different traits.

Table 3: Heterosis, inbreeding depression (ID) and mean performance of F_1 for quality and yield contributing traits in four okra crosses

No.	Characters	Heterosis, ID (%) and F1 mean	HBT-12 x MR 41	HBT-12 x HBT 24	HB 1157 x MR 41	HB 1157 x HBT 24
1	Days to first flowering	MP heterosis	2.21	-7.12	5.36	-3.73
		BP heterosis	5.95	-6.82	5.72	-0.23
		ID	4.97	-1.56	4.37	-3.6
		F_1 mean	46.3	43.7	46.2	43.9
2	Number of branches	MP heterosis	17.24	24.44	1.59	0
		BP heterosis	0	16.67	-5.88	-13.79
		ID	29.41	-5.71	20	4
		F_1 mean	3.4	2.8	3.2	2.5
3	Plant height(cm)	MP heterosis	22.72	13.65	15.15	8.64
		BP heterosis	13.9	10.61	3.99	8.35
		ID	17.61	11.33	17.73	23.41
		F_1 mean	102.1	104.75	99	103.15
4	Inter-nodal length (cm)	MP heterosis	-27.63	-20.5	-33.27	11.75
		BP heterosis	-22.5	-11.01	-12.6	19.84
		ID	29.27	8.95	-5.21	14.09
		F_1 mean	4.1	3.8	3.26	4.47
5	First Fruiting node	MP heterosis	8.7	-19.3	7.69	-21.05
		BP heterosis	25	-11.54	75	-3.23
		ID	-55.6	-53.91	-21.14	-50.33
		F_1 mean	2.5	2.3	3.5	3
6	Fruit length (cm)	MP heterosis	9.6	-3.51	7.73	7.04
		BP heterosis	5.57	-5.77	7.62	5.42
		ID	21.66	6.22	9.07	16.62
		F_1 mean	10.62	9.48	10.03	10.11
7	Fruit diameter (cm)	MP heterosis	13.41	0.3	-4.73	3.21
		BP heterosis	16.54	23.13	3.15	19.59
		ID	-22.3	-8.48	-6.87	-2.82
		F_1 mean	1.48	1.65	1.31	1.77
8	Fruit weight (g)	MP heterosis	8.52	5.3	16.91	8.49
		BP heterosis	-3.88	-5.69	7.35	0.78

		ID	24.06	17.53	25.64	28.67
		F_1 mean	10.64	10.44	10.96	10.29
9	Number of fruits	MP heterosis	45.8	26.41	34.83	11.23
		BP heterosis	41.81	17.44	34.08	6.67
		ID	41.79	16.07	41.58	32.55
		F_1 mean	25.1	22.9	24	20.8
10	Yield per plant (g)	MP heterosis	56.02	36.33	65.28	30.47
		BP heterosis	45.28	29.45	55.12	24.89
		ID	57.13	29.06	54.79	48.36
		F_1 mean	262.06	233.5	275.11	221.49
11	Days for first appearance of YVMV	MP heterosis	30.55	25.52	17.61	21.66
		BP heterosis	99.03	124.7	93.15	135.81
		ID	24.52	26.12	17.53	30.55

MP: Mid-parent, BP: Better parent, ID: Inbreeding depression

In case of yield per plant all the crosses studied displayed highly significant and positive heterobeltiosis ranging from 24.89 per cent (HB 1157 × HBT 24) to 55.12 per cent (HB 1157 × MR 41) with HB 1157 × MR 41 recording highest *per se* fruit yield of 275.11 g per plant followed by HBT-12 × MR 41 (262.06 g/plant), HBT-12 × HBT 24 (233.50 g/plant) and HB 1157 × HBT 24 (221.49 g/plant).

It was also observed that cross combination HB 1157 × MR 41 which recorded highest better heterosis also ranked first in *per se* performance for yield/plant, average fruit weight and minimum inter-nodal length and fruit diameter that are advantageous. However, *per se* performance for many of the yield contributing traits like number of branches, fruit length and number of fruits per plant were highest in second best heterotic cross for yield, HBT-12 × MR 41. Bhatt et al. (2015), Harne et al. (2015), Kumar et al. (2015), More et al. (2015), Neetu et al. (2015) Patel (2015), Ram et al. (2015) and Tonde et al. (2016) also reported significant and positive high heterosis for okra fruit yield and its related traits in okra which supported the present findings. High heterosis may not necessarily responsible for high mean performance, or vice-versa, because sometimes high heterotic response of a hybrid may be due to poor performance of its parents. In such cases mean performance seems to be more appropriate for selecting the best cross-combinations compared to their heterotic effects. Early yield is a highly desirable attribute in okra in the sense that the prevailing prices in the market are invariably high early in the season and days to first flowering is one such character that represents the earliness of the crop. Fruiting at the earlier nodes represents the earliness of the okra crop and may also contribute to increased number of fruits and yield. The cross combination HBT 12 × HBT 24 took minimum days to first flower (43.70) and first fruiting occurred in earlier node (2.30).

The number of branches contributes directly towards fruit yield per plant as the number of nodes increase leading to more number of fruits. Plant height is desired in the sense that it contributes towards realizing higher number of fruits per plant through increased number of nodes. The maximum number of primary branches per plant was recorded in the cross HBT-12 × MR 41 (3.40) followed by the crosses HB 1157 × MR 41 (3.20) and HBT 12 × HBT 24 (2.80) and tallest plants were recorded in the crosses HBT 12 × HBT 24 (104.75 cm) and HB 1157 × HBT 24 (102.10 cm). Minimum inter-nodal length is advantageous owing to the fact that, it will increase the number of nodes *per se* thereby increasing the number of fruits per plant. Minimum inter-nodal length was observed in HB 1157 × MR 41 (3.26 cm) followed by HBT 12 × HBT 24 (3.80 cm). Average fruit length of 8 cm is most desirable at an edible maturity of 6 days after flowering in okra. Increased length would not be preferred in fresh market since the okra fruit of excess length considered as over matured visually. Longer fruit were provided by the cross HBT-12 × MR 41 (10.62 cm) followed by HB 1157 × HBT 24 (10.11 cm), HB 1157 × MR 41 (10.03 cm) and HBT 12 × HBT 24 (9.48 cm). Fruit diameter should not be more since it gives the okra fruit the over matured look and hence poor acceptance in the market. Minimum fruit diameter was recorded in the crosses HB 1157 × MR 41 (1.31 cm) and HBT-12 × MR 41 (1.48 cm).

Commercially, average fruit weight of 8-10 g is preferred at edible maturity in okra. The highest average fruit weight was observed in the crosses HB 1157 × MR 41 (10.96 g), HBT-12 × MR 41 (10.64 g) and HBT 12 × HBT 24 (10.44 g) while minimum fruit weight of 10.29 g was recorded in HB 1157 × HBT 24. Number of fruits per plant is one of the most important characters that directly influence the yield in okra. As the increased average fruit weight may make the fruits of okra to look over matured, increasing the number of fruits with optimum average fruit weight is the vital objective in most of the breeding programmes. More number of fruits per plant was observed in the cross HBT-12 × MR 41 (25.10) trailed by HB 1157 × MR 41 (24), HBT 12 × HBT 24 (22.9) and HB 1157 × HBT 24 (20.80).

CONCLUSION

Ultimate aim of any breeding process is to improve the yield and quality of the produce. Even though quality is a most vital component, a variety or hybrid with poor yield coupled with superior quality will not be preferred by farmers and also would not be economically viable for producer. Fruit yield per plant was high in the cross HB 1157 × MR 41 (275.11 g/ plant) and HBT-12 × MR 41 (262.06 g/plant) while HB 1157 × HBT 24 (221.49 g/plant) and HBT 12 × HBT 24 (233.50 g/plant) were poor yielders relatively. The cross combination HBT-12 × MR 41 took maximum number of days for first appearance of YVMV disease (67.67) closely followed by HB 1157 × MR 41, which could be highly beneficial to farmers as it delays occurrence of disease and thereby reducing the loss caused by YVMV to the yielding ability of the plant.

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