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Genetic variability analysis for the selection of elite genotypes based on pod yield and quality from the germplasm of okra (*Abelmoschus esculentus* L. Moench)

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Genetic variability on 100 genotypes of okra revealed high magnitude of genetic variability and high degree of transmission of majority of the growth, earliness and yield associated traits under study. High magnitude of genotypic coefficient of variation (>20.00 %) for number of branches per plant, total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g) and yellow vein mosaic virus infestation on plants (%) indicated high degree of genetic variability offering great scope for selection of these characters. The characters plant height (cm), number of branches per plant, internodal length (cm), days to fifty per cent flowering, first flowering node, first fruiting node, fruit length (cm), fruit weight (g), total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g), yellow vein mosaic virus infestation on fruits and plants (%) having high heritability (>60.00 %) coupled with high expected genetic advance (>20.00 %) revealed that a very significant improvement is possible through selection for all these characters. On the basis of mean performance for pod yield and its components and acceptable pod quality traits, ten germplasm lines namely IC282248, IC27826-A, IC29119-B, IC31398-A, IC45732, IC89819, IC89976, IC90107, IC99716 and IC111443 were found to be horticulturally superior, which can be utilized for the development of open pollinated varieties or hybrids.

Key words: genetic advance, genetic variability, heritability in broad sense, mean performance, okra, pod quality

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Introduction

Okra (*Abelmoschus esculentus* L. Moench) is native of East Africa. It is widely distributed and cultivated in the tropics, sub-tropics and warmer portions of the temperate region of the world on a varying scale (Kochhar, 1986). India is one of the leading producers of okra with a production of 4.528 million tonnes year^{-1} from an area of 0.432 million ha. Although, the productivity of okra (NHB, 2010) in India is higher (10.50 tonnes ha^{-1}) than world average productivity (7.35 tonnes ha^{-1}), but lower than that of Egypt (15.70 tonnes ha^{-1}). This is because of low yielding potential of current varieties and reduction in yield due to frequent attacks of pests and diseases, especially the fruit and shoot borer (FSB) and yellow vein mosaic virus (YVMV). Further, the economic returns to the okra growers are also low owing to the sub-optimal pod quality.

For a successful breeding programme, the evaluation of germplasm is pre-requisite on which the future line of action is based. The value of germplasm collection depends not only on the number of accessions it possesses, but also up on the genetic variability present in those accessions for yield and yield components. Yield and yield components, in general, are polygenic in nature and are subjected to different amount of non-heritable variation (Lush, 1940). In any selection programme, emphasis on yield and its component characters lies solely on their heritability and genetic advance. High heritability alone is not enough to make efficient selection, unless the information is accompanied by substantial amount of genetic variation (Johnson *et al*., 1955). Hence, knowledge of nature and magnitude of genetic variability present in germplasm and the degree of transmission of the economic traits is of greater help in selecting the parents for planning a suitable breeding strategy.

To turn okra into a perfect candidate for sustainable agriculture, the crop should be attractive to both producers and consumers in terms of yield and quality, respectively. Several researchers have studied the potential of improvement of okra through the study of its genetic resources (Ariyo, 1990; Hamon, 1991). Considerably high magnitude of variability and high degree of transmission of the various growth, earliness and yield associated traits has been reported in okra germplasm (Singh and Singh, 1977; Kaul *et al*., 1978; Ariyo, 1989; Ariyo, 1992; Dhall *et al*., 2003; Manivannan *et al*., 2007; Yadav *et al*., 2007). This high variability and high heritability coupled with high genetic advance is a key to crop improvement. The existing variability has been exploited in various breeding programmes, which resulted in the development and release of a good number of varieties in okra. However, the released varieties cannot be continued longer due to genetic drift and susceptibility to various pests and diseases especially the fruit and shoot borer and yellow vein mosaic virus. This demands continuous development and replacement of current varieties by new high yielding varieties with acceptable pod quality in okra.

The present investigation was undertaken to ascertain the nature and magnitude of genetic variability and degree of transmission of yield and its components so as to identify the horticulturally superior genotypes of okra utilizing a large number of indigenous and exotic collections.

Materials and methods

The experimental material for the present study comprised of 100 germplasm lines of okra obtained from National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Thrissur (Table 1). The entire germplasm was evaluated in a randomized block design with two replications at Vegetable Research Station, Rajendranagar during *kharif*, 2008. Each germplasm line was raised in a single-row plot of 3.00 m length x 0.60 m width. A spacing of 60 x 30 cm was adapted. A plant population of 10 plants per row, per plot and per germplasm line was maintained. Recommended package of practices was followed to raise the successful crop. Regular plant protection measures were carried out to safeguard the crop from pests and diseases. Biometric data were recorded on five randomly selected plants in each germplasm line in each replication for plant height (cm), number of branches per plant, internodal length (cm), first flowering node, first fruiting node, fruit length (cm), fruit width (cm) and fruit weight (g) and on whole plot basis for days to 50 % flowering, total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g), fruit and shoot borer infestation on fruits and shoots (%) and yellow vein mosaic virus infestation on fruits and plants (%). The mean replicated values of fruit and shoot borer infestation on fruits and shoots (%) and yellow vein mosaic virus infestation on fruits were subjected to square root transformation to restore the distribution to normality. The mean replicated data on various biometric traits were subjected to analysis of variance as per the standard statistical procedure (Panse and Sukhatme, 1985). Phenotypic and genotypic components of variance were estimated as per the formulae suggested by Lush (1940). Estimates of phenotypic and genotypic coefficients of variation were calculated as per the standard formulae (Burton, 1952). The broad sense heritability was estimated for all the characters as the ratio of genotypic variance to total or phenotypic variance (Lush, 1940). The expected genetic gain or advance under selection for each character was estimated by following the method suggested by Johnson *et al*., (1955). Pod quality traits like number of ridges on fruit, fruit colour, fruit tip, fruit shape, fruit straightness and fruit ribbing were visually observed on ten fruits in each genotype.

Table 1. List of germplasm lines of okra (*Abelmoschus esculentus* (L.) Moench) utilized for genetic variability analysis.

Genotype	Genotype	Genotype	Genotype	Genotype
IC032850	IC282245	IC18542	IC52298	IC90211
IC032855-A	IC282246	IC22237	IC52298-B	IC90213
IC033065-B	IC282248	IC26375	IC52299	IC90219
IC033301 Sel 86	IC282256	IC27826-A	IC58710	IC90230
IC033302	IC218900	IC28359	IC86008	IC90231
IC033329	IC282276	IC29119-B	IC89334	IC90233
IC033345	IC282294	IC29359-D	IC89712	IC90234
IC033350	IC128123	IC31398-A	IC89819	IC90246
IC043279-A	IC140898	IC31398-B	IC89948	IC90249
IC043737	EC329398	IC32398-A	IC89976	IC90251
IC043745-B	IC218903	IC33854-A	IC90074	IC90262
IC043748-B	EC169447	IC33854-B	IC90077	IC99716
IC043751-B	EC169498	IC33854-C	IC90082	IC99724
IC045791	EC169515	IC33953	IC90107	IC99757
IC069113-Sel 87	EC329356	IC39137-A	IC90168	IC99780
IC069261	IC003307	IC42485-B	IC90171	IC103913
EC133408	IC008991	IC42530	IC90175	IC103998
IC282228	IC013664	IC45732	IC90205	IC111440
IC113904	IC018530	1C45747	IC90209	IC111443
IC282238	IC18537-A	IC48948	IC90210	IC413579

Results

The analysis of variance (Table 2) revealed highly significant differences among 100 genotypes for 17 quantitative characters in okra. The simple measures of variability like mean and range are presented in Table 2. The ranges of mean values revealed sufficient variation for all the traits under study. In the material under study, maximum range of variability (Table 3) was observed for total yield per plant (89.96 to 350.08 g) followed by marketable yield per plant (64.17 to 292.80 g) and plant height (79.90 to 172.00 cm).

Table 2. Analysis of variance for yield and yield attributes in okra germplasm

Character	Mean sum of squares		
	Replications (1)	Treatments (99)	Error (99)
Plant height(cm)	106.0550	1024.7858**	53.7870
No. of branches per plant	0.7688	1.6914**	0.2645
Internodal length (cm)	0.2312	2.7556**	0.0814
Days to 50% flowering	0.7200	25.4949**	1.7503
First flowering node	0.0760	1.9067**	0.1320
First fruiting node	0.0760	1.9288**	0.1425
Fruit length(cm)	0.0113	5.1179**	0.0739
Fruit width(cm)	0.0092	0.0554**	0.0039
Fruit weight(g)	1.2514	11.2355**	0.5335
Total no. of fruits per plant	0.5335	24.6718**	1.6754
No. of marketable fruits per plant	0.4792	20.4454**	1.0824
Total yield per plant(g)	0.4306	6397.1924**	403.3458
Marketable yield per plant (g)	109.4312	5015.9839**	256.8422
FSB infestation on fruits (%)	0.0022	0.1060**	0.0273
FSB infestation on shoots (%)	0.0303	0.1339**	0.0385
YVMV infestation on fruits (%)	0.0634	0.8683**	0.0410
YVMV infestation on plants (%)	8.0000	304.0202**	39.3131

** Significant at 1 % level, Values in parenthesis denote degrees of freedom

Table 3. Mean values and ranges for yield and yield attributes in okra germplasm

Character	Mean ± S.Em	Range	
		Minimum	Maximum
Plant height (cm)	122.27±5.16	79.90	172.00
No. of branches per plant	2.78±0.36	1.10	4.90
Internodal length (cm)	6.76±0.20	5.37	10.00
Days to 50% flowering	46.40±0.93	36.50	57.00
First flowering node	5.19±0.26	3.50	9.10
First fruiting node	5.23±0.27	3.50	9.20
Fruit length(cm)	12.51±0.19	8.60	16.30
Fruit width(cm)	1.87±0.04	1.45	2.40
Fruit weight (g)	14.42±0.51	10.75	20.55
Total no. of fruits per plant	13.07±0.91	6.76	20.83
No. of marketable fruits per plant	10.46±0.73	4.74	17.43
Total yield per plant (g)	187.63±14.13	89.96	350.08
Marketable yield per plant (g)	150.11±11.28	64.17	292.80
FSB infestation on fruits (%)	2.88±0.12	2.36	3.63
FSB infestation on shoots (%)	2.42±0.14	1.66	2.85
YVMV infestation on fruits (%)	3.44±0.14	2.01	4.91
YVMV infestation on plants (%)	44.90±4.41	30.00	65.00

For all the characters under study, phenotypic variances were higher than the corresponding genotypic variances (Table 4). The phenotypic variance was highest for total yield per plant (3400.27) followed by marketable yield per plant (2636.41) and plant height (539.29). Similarly, the genotypic variance was also highest for total yield per plant (2996.92) followed by marketable yield per plant (2379.57) and plant height (485.50). The phenotypic variance was lowest for fruit width (0.03) followed by FSB infestation on fruits (0.07) and FSB infestation on shoots (0.09). Similarly, the genotypic variance was lowest for fruit width (0.03) followed by FSB infestation on fruits (0.04) and FSB infestation on shoots (0.05).

The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values were classified as low (<10.00 %), moderate (10.00-20.00%) and high (>20.00%) as suggested by Sivasubramanian and Menon (1973). The estimates of PCV (Table 4) were highest for number of branches per plant (35.55 %) followed by marketable yield per plant (34.21 %) and number of marketable fruits per plant (31.37 %), while lowest for days to 50 % flowering (7.95 %) followed by FSB infestation on fruits (8.96 %) and fruit width (9.19%). The estimates of GCV (Table 4) were highest for marketable yield per plant (32.50 %) followed by number of branches per plant (30.36 %) and number of marketable fruits per plant (29.75 %), while lowest for FSB infestation on fruits (6.89 %) followed by days to 50 % flowering (7.43 %) and fruit width (8.57 %).

The estimates of PCV (Table 4) were of high magnitude (>20.00 %) for number of branches per plant (35.55 %), total number of fruits per plant (27.77 %), number of marketable fruits per plant (31.37 %), total yield per plant (31.08 %), marketable yield per plant (34.21 %) and YVMV infestation on plants (29.18 %), of moderate magnitude (10.00 to 20.00 %) for plant height (18.99 %), internodal length (17.61 %), first flowering node (19.46 %), first fruiting node (19.44 %), fruit length (12.88 %), fruit weight (16.82 %), FSB infestation on shoots (19.62 %) and YVMV infestation on fruits (19.62 %) and of low magnitude (<10.00 %) for days to 50 % flowering (7.95 %) and fruit width (9.19 %).

The estimates of GCV (Table 4) were of high magnitude (>20.00 %) for number of branches per plant (30.36 %), total number of fruits per plant (25.94 %), number of marketable fruits per plant (29.75 %), total yield per plant (29.18 %), marketable yield per plant (32.50 %) and YVMV infestation on plants (25.62 %), of moderate magnitude (10.00 to 20.00 %) for plant height (18.02%), internodal length (17.10 %), first flowering node (18.16%), first fruiting node (18.05 %), fruit length (12.70 %), fruit weight (16.04 %), YVMV infestation on fruits (18.71 %) and of low magnitude (<10.00 %) for days to

50% flowering (7.43 %), fruit width (8.57 %), FSB infestation on fruits (6.89 %) and FSB infestation on shoots (9.02 %).

In general, the magnitude of phenotypic coefficients of variation (PCV) was higher than the corresponding genotypic coefficients of variation (GCV) for all the seventeen characters under study (Table 4). However, the magnitudinal differences between the estimates of GCV and PCV were highest for number of branches per plant (5.19) followed by YVMV infestation on plants (3.56).

The heritability values were classified as low (<30.00%), moderate (30.00-60.00%) and high (>60.00%) as suggested by Johnson *et al*., (1955). The estimates of heritability (Table 4) were of high magnitude (>60.00 %) for plant height (90.00 %), number of branches per plant (73.00 %), internodal length (94.00%), days to 50% flowering (87.00 %), first flowering node (87.00 %), first fruiting node (86.00 %), fruit length (97.00 %), fruit width (87.00 %), fruit weight (91.00 %), total number of fruits per plant (87.00 %), number of marketable fruits per plant (90.00 %), total yield per plant (88.00 %), marketable yield per plant (90 %), YVMV infestation on fruits (91.00 %) and YVMV infestation on plants (77.00 %) and of moderate magnitude (30-60 %) for FSB infestation on fruits (59.00 %) and FSB infestation on shoots (55.00 %).

The estimates of genetic advance and genetic advance as per cent of mean were classified as low (<10.00 %), moderate (10.00-20.00%) and high (>20.00%) as suggested by Johnson *et al*., (1955). The estimates of genetic advance as per cent of mean (Table 4) were of high magnitude (>20.00 %) for plant height (35.22 %), number of branches per plant (53.42 %), internodal length (34.20 %), first flowering node (34.89 %), first fruiting node (34.54 %), fruit length (25.78 %), fruit weight (31.51 %), total number of fruits per plant (49.93 %), number of marketable fruits per plant (58.12 %), total yield per plant (56.43 %), marketable yield per plant (63.60 %), YVMV infestation on fruits (36.77 %) and YVMV infestation on plants (46.35 %) and of moderate magnitude (10.00 to 20.00 %) for days to 50 % flowering (14.28 %), fruit width (16.47 %), FSB infestation on fruits (10.90 %) and FSB infestation on shoots (13.82 %).

Table 4. Genetic parameters for yield and yield attributes in okra germplasm

Character	Variance		Coefficient of variation		h^2	GA*	GAM*
	G	P	G	P			
1	539.29	485.50	18.99	18.02	0.90	43.07	35.22
2	0.98	0.71	35.55	30.36	0.73	1.49	53.42
3	1.42	1.34	17.61	17.10	0.94	2.31	34.20
4	13.62	11.87	7.95	7.43	0.87	6.63	14.28
5	1.02	0.89	19.46	18.16	0.87	1.81	34.89
6	1.04	0.89	19.44	18.05	0.86	1.81	34.54
7	2.60	2.52	12.88	12.70	0.97	3.22	25.78
8	0.03	0.03	9.19	8.57	0.87	0.31	16.47
9	5.88	5.35	16.82	16.04	0.91	4.54	31.51
10	13.17	11.50	27.77	25.94	0.87	6.53	49.93
11	10.76	9.68	31.37	29.75	0.90	6.08	58.12
12	3400.27	2996.92	31.08	29.18	0.88	105.87	56.43
13	2636.41	2379.57	34.21	32.50	0.90	95.47	63.60
14	0.07	0.04	8.96	6.89	0.59	0.31	10.90
15	0.09	0.05	12.13	9.02	0.55	0.33	13.82
16	0.45	0.41	19.62	18.71	0.91	1.26	36.77
17	171.67	132.35	29.18	25.62	0.77	20.81	46.35

* Significant at 5% level, G= Genotypic; P=Phenotypic; GA=Genetic advance; GAM=Genetic advance as per cent of mean

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 (%)

Table 5. Growth, earliness and yield attributes of ten horticulturally superior genotypes selected from the germplasm of okra

Genotype	Character									
	1	2	3	4	5	6	7	8	9	10
IC282248	164.00	1.50	6.06	37.00	4.50	4.50	14.30	1.80	15.12	20.56
IC27826-A	140.00	2.20	5.37	37.50	4.35	4.35	13.20	1.90	13.15	20.72
IC29119-B	143.00	1.40	6.94	38.00	4.00	4.00	13.90	1.90	13.95	17.09
IC31398-A	160.00	1.40	6.96	38.00	3.90	3.90	13.40	2.00	13.50	19.08
IC45732	163.00	2.90	6.76	37.00	4.40	4.40	14.90	1.90	16.20	19.70
IC89819	163.00	3.00	6.91	38.50	5.20	5.20	15.70	1.90	17.35	18.39
IC89976	162.00	1.90	6.06	37.00	4.40	4.40	15.40	1.80	16.80	20.83
IC90107	172.00	2.10	7.33	37.50	4.60	4.60	13.70	1.70	12.75	18.84
IC99716	157.00	1.70	7.63	36.50	4.20	4.20	11.50	2.10	14.60	16.86
IC111443	165.00	2.30	7.72	39.00	5.30	5.30	12.50	2.00	15.50	18.58

Genotype	Character						
	11	12	13	14	15	16	17
IC282248	16.62	310.84	251.30	10.00(3.16)	7.05(2.65)	9.15(3.02)	60.00
IC27826-A	17.23	272.46	226.54	6.90(2.63)	4.15(2.03)	9.96(3.15)	60.00
IC29119-B	14.10	238.48	196.91	9.45(3.08)	6.50(2.55)	8.03(2.81)	50.00
IC31398-A	16.31	257.61	220.18	7.20(2.68)	4.10(2.03)	7.34(2.70)	35.00
IC45732	16.75	319.20	271.42	8.35(2.89)	5.45(2.34)	6.62(2.57)	40.00
IC89819	15.43	319.02	267.55	7.85(2.81)	5.00(2.24)	8.27(2.88)	45.00
IC89976	17.43	350.08	292.80	6.95(2.63)	4.30(2.07)	9.40(3.06)	55.00
IC90107	16.89	240.20	215.21	5.60(2.36)	2.75(1.65)	4.79(2.18)	30.00
IC99716	14.84	246.07	216.67	6.95(2.63)	3.95(1.99)	5.01(2.23)	35.00
IC111443	16.35	287.82	253.46	7.90(2.81)	5.10(2.26)	4.04(2.01)	30.00

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 (%)

Table 6. Pod quality traits of ten horticulturally superior genotypes selected from the germplasm of okra

Genotype	No. of ridges on fruit	Fruit pubescence	Fruit colour	Fruit tip	Fruit shape	Fruit straightness	Fruit ribbing
IC282248	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC27826-A	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC29119-B	5	Downy	Green	Blunt	Angular	Straight	Non ribbed
IC31398-A	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC45732	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC89819	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC89976	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC90107	5	Downy	Green	Blunt	Angular	Curved	Non ribbed
IC99716	5	Downy	Green	Blunt	Angular	Straight	Non ribbed
IC111443	5	Downy	Green	Blunt	Angular	Curved	Non ribbed

Discussion

The success of a breeding programme for the genetic improvement of quantitative characters depends on the magnitude of genetic variability available in the germplasm and the extent to which the desirable characters are heritable. The determination of genetic variability and partitioning it into heritable and non-heritable components using the genetic parameters *viz*., phenotypic and genotypic coefficients of variation, heritability and genetic advance is necessary to have an insight into genetic nature of yield and its components on which selection can be effectively carried out. Character like yield is complex in inheritance and is improved through its component traits. High yield can be achieved by selection of those yield contributing characters that have high heritability coupled with high genetic advance. Therefore, the components of variance and heritable components with genetic parameters such as genotypic coefficient of variation, heritability estimates and genetic advance as per cent of mean are important tools to plan a suitable breeding strategy. Hence, for the improvement of okra, detailed investigation on genetic architecture of pod yield and its attributes should be the main concern.

In India, germplasm collections of okra have been made both from indigenous as well as exotic sources by NBPGR, New Delhi. India is one of the countries with largest collection of cultivated okra (*Abelmoschus esculentus* (L.) Moench) with a set of 1302 lines in the National Seed Gene Bank, NBPGR, New Delhi (Dhankar and Mishra, 2006). As such the potential of the available germplasm is not fully known. These collections are being made available for further testing and utilization in different parts of the country. Further, being an often-cross pollinated crop, the cultivated okra has a narrow genetic base and concerted efforts, are therefore, required for exploring the full potential of available okra germplasm resources in the gene bank. Hence, the existing germplasm accessions need detailed evaluation for various horticultural traits to assess the nature and magnitude of genetic variability among accessions, which is crucial for selecting elite genotypes based on yield and yield components and pod quality to feed the breeding programmes.

In the present investigation, the significance of mean squares due to genotypes for all the characters under study indicated the presence of an appreciable amount of variability among the genotypes. All the seventeen characters under study exhibited high variability as evident from the major components of variability such as phenotypic and genotypic coefficients of variation, heritability and genetic advance. Hence, there is lot of scope for improvement of these characters in okra by selection.

The range of mean values could present a rough estimate about the variation in magnitude of variability present among genotypes. The characters showing high range of variation have more scope for improvement. All the seventeen characters under study exhibited high variability as evident from the ranges of mean values. However, the characters total yield per plant, marketable yield per plant and plant height having wide range of variation in mean values indicated the presence of high variability for these characters and thus offering greater scope for selecting desirable genotypes. These findings are in consonance with the findings of earlier workers (Dhankar and Dhankar, 2002; Singh *et al.*, 2006; Mohapatra *et al.*, 2007) in okra.

The genotypic variance was very low for fruit width, FSB infestation on fruits and shoots indicating that major part of the total variation was not heritable. High genotypic variance as observed for total yield per plant, marketable yield per plant and plant height indicated greater stability of the genotypes under different environmental conditions. Therefore, genotypes with such characters are likely to exhibit uniform performance over locations and seasons. Such a high genotypic variance was also reported by Vijay and Manohar (1990) for total yield per plant and by Rao (1996) for plant height in okra.

The estimates of phenotypic variability cannot differentiate between the effects of genotype and environment. Hence, the study of genetic variability is effective in partitioning out the real genetic differences. The estimates of GCV and PCV are of greater use in determining the variability present in the material. In general, the magnitude of phenotypic coefficients of variation (PCV) was higher than the corresponding genotypic coefficients of variation (GCV) for all the seventeen characters under study, indicating that the apparent variation was not only due to genotype but also due to the favorable influence of environment and selection for these traits sometimes may be misleading. This environmental effect could be due to heterogeneity in soil fertility status and other unpredictable factors. Similar projections and findings have been made by Vijay and Manohar (1990), Meghwal and Khandelwal (1994) and Chandra *et al*. (1996). However, there was a close correspondence between the estimates of phenotypic and genotypic coefficients of variation for majority of the characters under study indicating the fact that the environment influence is very low. In contrast, the high magnitudinal differences between the estimates of GCV and PCV for number of branches per plant and YVMV infestation on plants revealed that these traits were influenced by the environmental effects to a large extent and the greater role of environment in the expression of these traits. This also implies that one should not rely on mean phenotypic values for direct selection of these traits. Gandhi *et al*. (2001) also reported high magnitudinal differences between GCV and PCV for number of branches per plant in okra.

In the present investigation, germplasm lines were found to possess a high to low phenotypic and genotypic variation as revealed by phenotypic and genotypic coefficients of variation. The characters like number of branches per plant, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant and YVMV infestation on plants, having high genotypic coefficients of variability possesses better potential for further gain and improvement through selection. Higher the genotypic coefficient of variation, more are the chances of improvement in those characters. High magnitude (>20.00%) of genotypic and phenotypic coefficients of variation were also reported by Jaiprakashnarayan *et al*. (2006), Mehta *et al*. (2006) and Singh *et al*. (2006) for number of branches per plant, Dhall *et al*. (2003) for total number of fruits per plant, Gandhi *et al*. (2001), Bendale *et al*. (2003), Mehta *et al*. (2006) and Singh *et al*. (2006) for total yield per plant and Dhall *et al*. (2003) for marketable yield per plant and YVMV infestation on plants. Low magnitude (<10.00%) of genotypic and phenotypic coefficients of variation were also reported by Singh *et al*. (2006) and Mohapatra *et al*. (2007) for fruit width and Meghwal and Khandelwal (1994), Gandhi *et al*. (2001), Jaiprakashnarayan *et al*. (2006), Mehta *et al*. (2006), Singh *et al*. (2006), Dakahe *et al*. (2007) and Mohapatra *et al*. (2007) for days to fifty per cent flowering in okra. Moderate magnitude (10.00-20.00%) of genotypic and phenotypic coefficients of variation were also reported by Singh *et al*. (2006) for plant height, Bendale *et al*. (2003), Meghwal and Khandelwal (1994) for internodal length, Singh *et al*. (2006) for first flowering node, Jaiprakashnarayan *et al*. (2006) for first fruiting node, Dhall *et al*. (2003) and Singh *et al*. (2006) for fruit length and Bendale *et al*. (2003), Dhall *et al*. (2003) and Mohapatra *et al*. (2007) for fruit weight.

The economic returns from okra not only depend on pod yield, but also on its quality, which is conglomerate of several horticultural traits. In breeding programmes of okra, the characters that need to be given emphasis include medium tall to tall plants, short internodes, low position of first flowering and fruiting node, high number of fruiting nodes and early maturity for enhanced productivity; medium long to short, green, smooth (downy), five ridged, angular, straight fruits with blunt tip for enhanced fruit quality and appearance and tolerance to biotic stresses for stable and sustainable production. Germplasm needs to be evaluated for these traits to identify accessions to feed the breeding programmes.

Of the seventeen characters under study, plant height, number of branches and internodal length largely determine the fruit bearing surface and thus considered as growth attributes. Okra bears pods at almost all nodes on main stem and primary branches. 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. Shorter distance between nodes accommodates more number of nodes on main stem, which will ultimately lead to higher fruit number and higher fruit production.

Hence, high mean value is desirable for plant height and number of branches, while low mean value is desirable for internodal length to accommodate more number of nodes and to get higher fruit yield in okra. Days to fifty per cent 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. Low mean value is highly desirable for all these three attributes of earliness. Total number of fruits per plant and fruit length, width and weight are considered to be associated directly with total yield per plant, for which high mean value is desirable. The FSB infestation on fruits and shoots and YVMV infestation on fruits and plants are the major yield detriments for which lower mean values are desirable.

On the basis of mean performance for pod yield and its components and acceptable pod quality traits, ten germplasm lines namely IC282248, IC27826-A, IC29119-B, IC31398-A, IC45732, IC89819, IC89976, IC90107, IC99716 and IC111443 were found to be horticulturally superior, which can be utilized for the development of open pollinated varieties or hybrids. Several researchers have also stressed about the potential of improvement of okra through the study of its genetic resources (Ariyo, 1990; Hamon, 1991). The germplasm in this crop has been accomplished and directly released for commercial cultivation (primary introductions) or it has been used as donors for specific traits in breeding varieties (Pratibha, 1995). Several varieties of okra have been developed and released by direct use of indigenous germplasm (Pusa Makhmali, Co-1 and Gujarat Bhindi-1) and exotic germplasm (Harbhajan) or through incorporation of useful genes from local germplasm through breeding programmes (Pusa Sawani, Punjab Padmini, Selection-2, Parbhani Kranti, P-7 and Arka Anamika). The exotic collections from USA namely Perkin's Long Green and Clemon's spineless were directly released as primary introductions in India (Dhankar and Mishra, 2006).

Heritability in broad sense is the ratio of genotypic variance to total variance in non-segregating population (Hanson *et al*., 1956). The estimates of heritability were of high magnitude (>60.00%) for plant height, number of branches per plant, internodal length, days to 50% flowering, first flowering node, first fruiting node, fruit length, fruit width, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant, YVMV infestation on fruits and YVMV infestation on plants indicating that though the characters are least influenced by the environmental effects, the selection for the improvement of such characters may not be useful, because broad sense heritability is based on total genetic variance which includes both fixable (additive) and non-fixable (dominance and epistatic) variances. High magnitude (>60.00%) of heritability estimates were also reported by Bendale *et al*. (2003), Jaiprakashnarayan *et al*. (2006), Singh *et al*. (2006) and Mohapatra *et al*. (2007) for all the three growth attributes (plant height, number of branches and internodal length) , Singh *et al.* (2006) and Mohapatra *et al.* (2007) for days to 50% flowering and first flowering node, Jaiprakashnarayan *et al.* (2006) for first fruiting node, Singh *et al.* (2006) and Mohapatra *et al.* (2007) for all fruit traits (fruit length, width and weight) and total number of fruits per plant, Mehta *et al.* (2006), Singh *et al.* (2006) and Mohapatra *et al.* (2007) for total yield per plant and Dhall *et al.* (2003) for YVMV infestation on plants. The estimates of heritability were of moderate magnitude (30.00-60.00%) for FSB infestation on fruits and FSB infestation on shoots indicating that these characters are moderately influenced by environmental effects and genetic improvement through selection will be moderately difficult due to masking effects of the environment on the genotypic effects.

Knowledge of extent of improvement possible through selection is useful in designing breeding programme. Genetic advance under selection is the improvement in the mean genotypic value of the selected families over the base population. The genetic advance shows the improvement that can be made in a particular character by applying certain amount of selection intensity. The genetic advance to be expected depends up on the selection differential, the genotypic coefficient of variation and the square root of the heritability ratio (Johnson *et al.*, 1955). The genotypic coefficient of variation x selection differential estimates the maximum effectiveness of selection and heritability indicates how closely the goal can be achieved. However, by increasing the diversity of genotypes of okra, the expected genetic advance can still be increased. The estimates of genetic advance as per cent of mean were of high magnitude (>20.00%) for plant height, number of branches per plant, internodal length, first flowering node, first fruiting node, fruit length, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant, YVMV infestation on fruits and YVMV infestation on plants indicating that these characters are governed by additive genes and selection will be rewarding for improvement of such traits. This suggests that such characters can be improved by direct selection. Therefore, such characters having high heritability coupled with high genetic advance would be effective in crop improvement programme through selection methods.

The estimates of genetic advance as percent of mean were of moderate magnitude (10 to 20%) for days to 50 % flowering, fruit width, FSB infestation on fruits and FSB infestation on shoots. Moderate magnitude (10.00-20.00%) of genetic advance as per cent of mean was also reported by Singh *et al.* (2006) and Mohapatra *et al.* (2007) for days to fifty per cent flowering and Singh *et al.* (2006) for fruit width. High magnitude (>20.00%) of genetic advance as per cent of mean was also reported by Singh *et al.* (2006), Mohapatra *et al.* (2007)

and Jaiprakashnarayan *et al*. (2006) for all growth attributes, Jaiprakashnarayan *et al*. (2006) for first fruiting node, Mehta *et al*. (2006) for fruit length and weight, Singh *et al*. (2006), Dakahe *et al*. (2007) and Mohapatra *et al*. (2007) for total number of fruits per plant, Mehta *et al*. (2006), Singh *et al*. (2006), Dakahe *et al*. (2007) and Mohapatra *et al*. (2007) for total yield per plant and Dhall *et al*. (2003) for marketable yield per plant and for YVMV infestation on plants.

Estimates of heritability along with genetic advance are more useful in predicting the value of selection than heritability alone (Johnson *et al*., 1955). High estimates of heritability (>60.00%) coupled with high genetic advance as percent of mean (>20.00%) for plant height, number of branches per plant, internodal length, first flowering node, first fruiting node, fruit length, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant, YVMV infestation on fruits revealed that most likely the heritability is due to additive gene effects and selection may be effective. Such value of high heritability and high genetic advance may be attributed to the action of additive genes (Panse, 1957).

On the whole, from the analysis of variance it is evident that the germplasm utilized in the present investigation possessed considerable genetic variation. All the characters showed considerable variability in the observed traits as it is evident from the estimates of mean, range, coefficients of variation, heritability, genetic advance and genetic advance as per cent of mean. The spectrum of large variability for economically important characters will provide the breeder a good scope for the genetic improvement in okra. High heritability and genetic advance were observed for majority of the characters, which suggested that they are controlled by few genes. On the basis of mean performance for pod yield and its components and acceptable pod quality traits, ten germplasm lines namely IC282248, IC27826-A, IC29119-B, IC31398-A, IC45732, IC89819, IC89976, IC90107, IC99716 and IC111443 could be useful for making selection to fix the desirable characters to be exploited for developing suitable parental materials.

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