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Studies on genetic variability and character association in okra [*Abelmoschus esculentus* (L.) Moench] for yield and its contributing traits

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Abstract
Fifty accessions of okra were evaluated in augmented randomized block design (ARBD) during rabi season 2019 at College of Horticulture, Bengaluru. The experimental results ANOVA reveal that all the traits differ significantly (p=0.05) indicating the presence of sufficient variation among okra accessions for all the traits studied. High value of GCV and PCV and high estimates of heritability coupled with greater genetic advance were observed in the traits like number of fruits per plant (24.52%, 25.94%, 89.33%, 47.81%), yield per plant (24.46%, 26.28%, 86.63%, 46.97%) and yield per hectare (24.39%, 26.29%, 86.03%, 46.67%). Whereas the moderate GCV, PCV, high heritability coupled high GA was recorded in plant height (13.98%, 15.86%, 77.8%, 25.45%), number of branches per plant (16.05%, 20.11%, 63.65%, 26.41%), number of nodes per plant (14.41%, 18.62%, 59.93%, 23.02%), internodal length (14.35%, 15.54%, 85.19%, 27.31%), fruit length (10.84%, 11.89%, 83.03%, 20.37%), fruit diameter (11.8%, 12.34%, 91.31%, 23.25%) and fruit firmness (12.56%, 13.72%, 83.88%, 23.74%). Highly significant positive correlation was observed between number of fruits per plant and total yield per plant (0.89) followed by days to 50% flowering and days to first flowering (0.78), plant height with number of nodes per plant (0.73), total yield per plant (0.72) and number of fruits per plant (0.68). Path analysis indicate direct positive effect of number of fruits per plant (0.978), average fruit weight (0.361), plant height (0.122), days to fifty percent flowering (0.121) and fruit diameter (0.099) on fruit yield per plant. Similarly, on the other hands fruit length (-0.151), days to fifty percent flowering (-0.091) and number of nodes per plant (-0.068) had direct negative effect on fruit yield per plant.

Keywords: Okra, GCV, PCV, heritability, genetic advance, correlation, path analysis

Introduction
Okra or Bhendi (*Abelmoschus esculentus* L. Moench) belongs to the family Malvaceae and it is one of the most popular and widely grown vegetable crop in the world. It originates from East Africa and can be grown in tropics and sub-tropics. It is the rich source of minerals like calcium, phosphorus, potassium, sulphur, dietary fibers, protein and vitamin-c. India accounts for about 62% total world production and it ranks first in Okra production in the world, with an area of 0.53 million hectares with the production of 6.47 million tons and the productivity of 12.10 t ha^{-1}. In Karnataka it is cultivated in 5.35 thousand hectare which produces 64 thousand tones 12.07 t ha^{-1}.

The presence genetic variability among okra accessions will play a significant role in breeding program as it helps to develop high yielding okra varieties. It is important for selection and breeding to desired plant landraces (Prakash *et al*., 2017) [23]. In order to develop high yielding Okra varieties it is necessary to study both genetic and phenotypic variations, heritability and genetic advancement among the genotypes available. Along with these correlation and path studies will give the better understanding of how these various yield and yield attributing traits relate to each other and thus aid in selection process in identifying the factors which contributes most to yield. Keeping all these in view the present experiment was carried out to study genetic variability parameters in okra to assist crop improvement.

Materials and Methods
Fifty accessions of okra collected from different sources were used in this experiment. These accessions were evaluated for yield and yield contributing traits in the field of Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru (Karnataka), India. The experiment was laid out in augmented randomized block design (ARBD) during *rabi* season 2019.

Each accessions were accommodated in different rows with the spacing of 60cm between rows and 45cm between plants. Irrigation, weed control and other cultural practices were followed as per the package of practices of University of Horticultural Sciences, Bagalkot (Anon., 2016) [3]. Observations were recorded for growth, yield and quality parameters in five randomly selected healthy plants from each accessions and their mean values were subjected to statistical analysis (ANOVA) as suggested by Panse and Sukatme, (1967) [34]. Genotypic and phenotypic variances as proposed by Burton (1952) [5] and heritability estimates as per Falconer (1981) [12] and genetic advance estimates according to Johanson *et al*. (1995). Genotypic and phenotypic coefficients of variation were estimated according to Burton and Devane (1953) [6].

Results and Discussion

Analysis of variance indicated highly significant differences among the accessions for all the parameters studied (Table 1), indicating the existence of genetic variation among the accessions. Mean performance of all the accessions had wide range for all the parameters which is the prerequisite for successful selection during crop improvement. Similar results were also reported by Narkhede *et al*. (2015) [19], Thulasiram *et al*. (2017) [31], Patra *et al*. (2018) [21], Shwetha *et al*., (2022) [28] and Jemal *et al*. (2022) [13].

In general Phenotypic coefficient of variation (PCV) was higher in magnitude than the corresponding genotypic coefficient of variation (GCV), indicating the environmental influence on the traits studied. High PCV and GCV were observed for yield per plant (26.28% and 24.46%), yield per hectare (26.29%, 24.39%), number of fruits per plant (25.94% and 24.52%) and number of branches per plant (20.11% and 16.05%) respectively (Table 2). Moderate PCV and GCV were observed for number of nodes per plant (18.62% and 14.41%), plant height at 70DAS (15.86% and 13.98%), internodal length (15.54% and 14.35%), number of seeds per fruit (12.10% and 9.54%), fruit length (11.89% and 10.84%), average fruit weight (10.10%, 8.59%) and fruit diameter (12.34% and 11.80%) respectively. While, relative low values of PCV and GCV was observed for days to fifty per cent flowering (4.78% and 4.44%) and days to first flowering (4.12% and 3.91%) (Table 2). As most of the traits had high and moderate variation indicating sufficient variability among the genetic material which could be utilized through selection or hybridization. These results were in accordance with the results of Vrunda *et al*. (2018) [33], for number of branches per plant, fruit yield/plant, internodes length, number of fruits/plant and plant height, Rambabu *et al*. (2019) [24] for days to 50% flowering, days to first harvest and 100 seed weight, Ashraf *et al*. (2020) [4] for total yield per plant, Melaku *et al*. (2020) [18] and Shwetha *et al*. (2022) [28] for total yield per plot and total yield per hectare.

As these results give only the knowledge of extent of variation which would not be sufficient in breeding. Hence, there is necessary to study other parameters of variability *viz*., heritability in broad sense along with genetic advance and genetic gain indicate the effectiveness of selection. Even though all the traits had high heritability they may be influenced by environment specifying the need for high genetic advancement. High heritability coupled with high genetic advance was recorded for number of fruits per plant (89.33%, 47.81%) yield per plant (86.63%, 47.81%) yield per hectare (86.03%, 46.67%) internodal length (85.19%, 27.31%) number of branches per plant (63.65%, 26.41%) plant height 70 DAS (77.80%, 25.45%) fruit firmness (83.88%, 23.74%) fruit diameter (91.31%, 23.25%) number of nodes per plant (59.93%, 23.02%) fruit length (83.03%, 20.37%) (Table 2) indicating these traits are governed by additive genes for which selection would be effective. These results were supported by the findings of Melaku *et al*. (2020) [18], Ranga *et al*. (2021) [25] and Jemal *et al*. (2022) [13].

High heritability coupled with moderate genetic advance was observed for number of seeds per fruit (62.22%, 15.53%) average fruit weight (72.40%, 15.09%) and number of ridges per fruit (75.73%, 13.61%) (Table 2) indicating these traits are governed by both additive and non-additive genes and selection can be done by considering other parameters also. These results are in agreement with the earlier findings of Narkhede *et al*. (2015) [19] for number of fruits per plant, Makhdoomi *et al*. (2018) [17] and Shwetha *et al*. (2022) [28] for plant height.

Moderate estimates of heritability and genetic advance were recorded for days to 50% flowering (86.25%, 8.50%) and days to first flowering (89.89%, 7.65%) (Table 2) indicating these traits are governed by non-additive genes and selection of such traits may not be fruitful. Similar results were also reported by Temam *et al*. (2020) [30], Ranga *et al*., (2021) [25] and Sravanthi *et al*., (2021) [29].

Further the character association studies is crucial to understand the correlation and path of different traits which help in gaining the knowledge of relationships between yield and yield related traits. The highest significant positive correlation coefficient analysis was observed between number of fruits per plant and total yield per plant (0.89), it also had significant positive association with number of nodes per plant (0.52), number of branches (0.34), days to 50% flowering and days to first flowering (0.78). Plant height had significant positive association with number of nodes per plant (0.73), total yield per plant (0.72), number of fruits per plant (0.68). Significant positive association was also observed between average fruit weight and fruit length (0.33), fruit width (0.30) (Table 3). These results were in accordance with the results of Raval *et al*. (2019) [26], Ranga *et al*. (2021) [25].

In contrast to this significant negative correlation was observed between number of fruits per plant and days to fifty percent flowering (-0.33), days to first flowering (-0.30), average fruit weight (-0.28), number of seeds per fruit (-0.32), between internodal length and number of nodes per plant (-0.35) (Table 3). These indicate the negative effect of traits with each other. These results were also observed by Duggi *et al*. (2013) [10], Neyhart *et al*. (2019) [20], Ranga *et al*. (2021) [25].

Path coefficient analysis revealed the route cause of association between the traits where it determines both direct and indirect effects of traits. Number of fruits per plant (0.978), had the highest direct and positive effect on fruit yield per plant followed by average fruit weight (0.361), plant height (0.122), days to fifty percent flowering (0.121) and fruit diameter (0.099). Similarly, on the other hands fruit length (-0.151), days to fifty percent flowering (-0.091), number of nodes per plant (-0.068), internodal length (-0.059) and number of ridges per plant (-0.031) (Table 4) had the negative direct effect on yield per plant in okra at both phenotypic level. The characteristics described above with positive direct effects should be taken into account while establishing a selection strategy for developing high yielding okra cultivars. Similar results were observed by Ranga *et al*., (2021) [25], Reddy *et al*. (2013) [27], Dwivedi and Sharma (2017) [11] and Das *et al*. (2012) [7].

Table 1: Analysis of variance (mean sum of squares) for growth, earliness and yield parameters in okra

SI. No.	Source of variation/Characters	Treatment (Ignoring Blocks)	Treatment: Check	Treatment: Test vs. Check	Treatment: Test	Block (Eliminating Treatments)	Residuals
	Degrees of freedom	**53**	**3**	**1**	**49**	**4**	**12**
1	Days to first flowering	3.06 **	6.58 **	1.04 ns	2.89 **	0.43 ns	0.29
2	Days to 50% flowering	5.44 **	14.18 **	16.97 **	4.67 **	0.88 ns	0.64
3	Plant height at 70DAS (cm)	220.71 **	134.11 ns	738.27 **	215.45 **	39.91 ns	47.84
4	Number of branches per plant	0.28 *	1.1 **	0.26 ns	0.23 *	0.04 ns	0.08
5	Number of nodes per plant	3.77 ns	0.38 ns	1.3 ns	4.03 *	2.74 ns	1.61
6	Internodal length (cm)	2.01 **	0.58 ns	17.97 **	1.77 **	0.76 ns	0.26
7	Number of ridges per fruit	0.21 **	0.06 ns	0.57 **	0.21 **	0.06 ns	0.05
8	Fruit length (cm)	2.96 **	0.48 ns	31.99 **	2.51 **	0.01 ns	0.43
9	Fruit diameter (mm)	3.9 **	0.62 ns	4.22 **	4.1 **	0.38 ns	0.36
10	Fruit firmness (N)	0.03 **	0.23 **	0.0026 ns	0.02 **	0.0023 ns	0.0031
11	Number of seeds per fruit	39.92 *	65.49 *	0.01 ns	39.17 *	16.43 ns	14.8
12	Average fruit weight (g)	2.49 **	1.84 ns	11.17 **	2.35 **	0.63 ns	0.65
13	Number of fruits per plant	28.66 **	18.66 *	4.48 ns	29.77 **	3.05 ns	3.17
14	Yield per plant (g)	6972.54 **	8235.99 **	12806.79 **	6776.12 **	307.82 ns	905.96
15	Yield per hectare (t)	9.59 **	11.11 **	19.69 **	9.3 **	0.52 ns	1.3

*and** indicate significance of values at p= 0.05 and p= 0.01, respectively. NS= Non significant

Table 2: Estimates of range, genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance over per cent of mean in okra

SI. No.	Character	Mean ± S.Em	Range		GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
			Min	Max					
1	Days to first flowering	41.2	37.00	44.00	3.91	4.12	89.89	3.15	7.65
2	Days to 50% flowering	45.24	40	49.25	4.44	4.78	86.25	3.84	8.5
3	Plant height (cm) at 70 DAS	92.58	66.79	122.51	13.98	15.86	77.8	23.56	25.45
4	Number of branches per plant	2.4	1.12	3.12	16.05	20.11	63.65	0.63	26.41
5	Number of nodes per plant	10.78	6.4	14.76	14.41	18.62	59.93	2.48	23.02
6	Internodal length (cm)	8.57	6.19	11.61	14.35	15.54	85.19	2.34	27.31
7	Number of ridges per fruit	5.23	4.79	6.44	7.58	8.71	75.73	0.71	13.61
8	Fruit length (cm)	13.33	9.22	16.39	10.84	11.89	83.03	2.72	20.37
9	Fruit diameter (mm)	16.4	8.25	21.28	11.8	12.34	91.31	3.81	23.25
10	Fruit firmness (N)	1.01	0.74	1.42	12.56	13.72	83.88	0.24	23.74
11	Number of seeds per fruit	51.73	36.44	64.7	9.54	12.1	62.22	8.03	15.53
12	Average fruit weight (g)	15.18	12.66	19.21	8.59	10.1	72.4	2.29	15.09
13	Number of fruits per plant	21.03	12.39	32.96	24.52	25.94	89.33	10.06	47.81
14	Yield per plant (g)	313.2	107.31	447.88	24.46	26.28	86.63	147.12	46.97
15	Yield per hectare (t)	11.6	3.91	16.57	24.39	26.29	86.03	5.41	46.67

Table 3: Phenotypic correlation coefficients among growth and yield parameters in okra

Traits	DFF	D50F	PH	NB	NN	INL	NR	FL	FD	FF	NFP	AFW	NS	YPP
DFF	1.00	0.78**	-0.11	0.02	-0.16	0.18	0.30*	0.16	-0.06	-0.02	-0.30*	0.19	0.20	-0.26
D50F		1.00	-0.07	-0.09	-0.17	0.20	0.26	0.10	-0.04	0.23	-0.33*	0.20	0.19	-0.25
PH			1.00	0.19	0.73**	0.14	-0.01	0.28	0.12	0.03	0.68**	0.07	-0.27	0.72**
NB				1.00	0.17	-0.03	0.06	0.22	-0.22	-0.10	0.34*	0.07	-0.19	0.36*
NN					1.00	-0.35*	-0.18	0.40**	0.16	0.03	0.52**	0.02	-0.19	0.51**
INL						1.00	0.24	-0.11	0.18	-0.10	-0.01	0.20	-0.09	0.08
NR							1.00	0.18	-0.13	-0.17	-0.06	-0.02	-0.03	-0.12
FL								1.00	0.12	-0.09	0.25	0.33*	-0.02	0.25
FD									1.00	0.05	-0.01	0.30*	0.01	0.16
FF										1.00	-0.14	-0.05	0.02	-0.18
NFP											1.00	-0.28*	-0.32*	0.89**
AFW												1.00	0.21	0.09
NS													1.00	-0.20
YPP														1.00

Critical r_p value at 5% = 0.281 *Significant at p = 0.05 Critical r_p value at 1% = 0.362 **Significant at p = 0.01

DFF = Days to first flowering
D50F = Days to 50% flowering
PH = Plant height (cm) at 70 DAS
NB = Number of branches per plant
NN = Number of nodes per plant
INL = Internodal length (cm)
NR = Number of ridges per fruit
FL = Fruit length (cm)
FD = Fruit diameter (mm)
FF = Fruit firmness (N)
NS = Number of seeds per fruit
AFW = Average fruit weight (g)
NFP = Number of fruits per plant
YPP = Yield per plant (g)

Table 4: Phenotypic path coefficient analysis for yield and its components in okra

Traits	DFF	D50F	PH	NB	NN	INL	NR	FL	FD	FF	NFP	AFW	NS	YPP (rp)
DFF	-0.091	0.094	-0.013	0.001	0.011	-0.011	-0.009	-0.024	-0.006	0.002	-0.294	0.069	0.011	-0.260
D50F	-0.071	0.121	-0.009	-0.005	0.012	-0.012	-0.008	-0.015	-0.004	-0.019	-0.323	0.072	0.010	-0.250
PH	0.010	-0.008	0.122	0.011	-0.050	-0.008	0.000	-0.042	0.012	-0.002	0.665	0.025	-0.015	0.72**
NB	-0.002	-0.011	0.023	0.060	-0.012	0.002	-0.002	-0.033	-0.022	0.008	0.333	0.025	-0.010	0.36*
NN	0.015	-0.021	0.089	0.010	-0.068	0.021	0.006	-0.060	0.016	-0.002	0.509	0.007	-0.010	0.51**
INL	-0.016	0.024	0.017	-0.002	0.024	-0.059	-0.007	0.017	0.018	0.008	-0.010	0.072	-0.005	0.080
NR	-0.027	0.031	-0.001	0.004	0.012	-0.014	-0.031	-0.027	-0.013	0.014	-0.059	-0.007	-0.002	-0.120
FL	-0.015	0.012	0.034	0.013	-0.027	0.007	-0.006	-0.151	0.012	0.007	0.245	0.119	-0.001	0.250
FD	0.005	-0.005	0.015	-0.013	-0.011	-0.011	0.004	-0.018	0.099	-0.004	-0.010	0.108	0.001	0.160
FF	0.002	0.028	0.004	-0.006	-0.002	0.006	0.005	0.014	0.005	-0.081	-0.137	-0.018	0.001	-0.180
NFP	0.027	-0.040	0.083	0.021	-0.035	0.001	0.002	-0.038	-0.001	0.011	0.978	-0.101	-0.018	0.89**
AFW	-0.017	0.024	0.009	0.004	-0.001	-0.012	0.001	-0.050	0.030	0.004	-0.274	0.361	0.012	0.090
NS	-0.018	0.023	-0.033	-0.011	0.013	0.005	0.001	0.003	0.001	-0.002	-0.313	0.076	0.055	-0.200

DFF = Days to first flowering
D50F = Days to 50% flowering
PH = Plant height (cm) at 70 DAS
NB = Number of branches per plant
NN = Number of nodes per plant
INL = Internodal length (cm)
NR = Number of ridges per fruit
FL = Fruit length (cm)
FD = Fruit diameter (mm)
FF = Fruit firmness (N)
NS = Number of seeds per fruit
AFW = Average fruit weight (g)
NFP = Number of fruits per plant
YPP = Yield per plant (g)

Conclusion

The study indicated the presence of considerable genetic variability in the genetic material. The wide range of genetic variation was observed for all the traits studied. There was high heritability among all the traits studied coupled with high genetic advance for yield parameters. Most of the yield and its attributing traits also showed significant positive association between them indicating the high scope for crop improvement through selection and hybridization.

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