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Estimation of genetic variability in diverse germplasm of okra [*Abelmoschus esculentus* (L.) Moench.]

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Abstract

An experiment was conducted to assess the genetic variability and character association using diverse germplasm of okra grown at the Research Farm of Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi. Results of analysis of variance (ANOVA) and high genotypic (GCV) and phenotypic coefficient of variation (PCV) values indicate existence of ample amount of variability for yield traits among the genotypes. For majority traits, greater but negligible high PCV values than GCV indicate minor environmental influence on traits expression. Moderate to high heritability and genetic advance was observed for important yield traits such as plant height, fruit weight, and number of branch/plant, number of fruits per plant and fruit yield per plant implying involvement of additive gene effects. Significantly high and positive correlations of fruit yield per plant was recorded with fruit weight (0.952**), number of fruits per plant (0.726**), plant height (0.726**), number of nodes on main stem (0.509**) and days to 50% flowering (0.489**). Incidence of YVMV disease at different growth stages of plant showed negative correlation with fruit yield. Furthermore, path analysis results showed positive direct effect of fruit weight (0.062) on fruit yield per plant followed by inter nodal length (0.059), number of fruits per plant (0.035), days to 50% flowering (0.032) and fruit length (0.006). Significant positive correlation and positive direct effect on fruit yield per plant signifies that direct selection for these traits will be effective to evolve high yielding okra varieties.

Keywords: Okra, Genetic variability, Heritability, Correlation, Path analysis, YVMV.

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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench,] also called as Bhindi or lady's finger is an economically important vegetable of *malvaceae* family. Okra is proved to be an amphidiploid between *Abelmoschus tuberculatus* (2n=58) and with 2n =72 *A. ficulenus* (Datta & Naug 1968) with basic number (x) = 12 and somatic chromosome number 2n=130 (Joshi and Hardas 1956). Tender pods of okra consumed mostly fresh and to limited extent in processed forms after canning, dehydration and freezing (Chattopadhyay et al., 2011). Okra pods are rich source of digestible fibre (Agbo et al. 2008) and phytonutrients such as of fats, carbohydrates, protein, vitamins (Lamont et al. 1999; Saifullah et al. 2009; Haruna et al. 2016) and minerals such as calcium, potassium and trace elements like copper, manganese, iron, zinc, nickel, and iodine (Lee et al. 2000). Mucilage content of okra and edible seed oil has industrial and medicinal significance (Lengsfeld et al. 2004). It's a crop of Ethiopian origin (Vavilov 1951), now spread all over world and predominantly cultivated throughout tropics and warmer parts of the temperate zone (Thompson and Kelley 1957; Charrier 1984; Kisher et al. 2016). India is the largest producer of okra with production share of 72.9% of total world production. Okra has a major share in foreign exchange earnings through export (NHB 2018).

Okra being an often cross pollinated crop (Choudhury et al. 1970; Shalaby 1972) exhibit low inbreeding depression and significant genetic diversity (Duranti 1964). Diverse germplasm with improved traits are basic necessity for improvement of any crop. To evolve improved/high yielding varieties of okra, a thorough knowledge about nature and magnitude of genetic variability, heritability and association among the various traits is essential (Gandhi et al. 2001). Hence identification of elite lines exhibiting desirable traits with a high GCV and PCV, high heritability, and a high genetic advance is essential in order to use them in successive breeding programmes (Yadav et al. 2019). Furthermore, with this information diverse and desirable parental combination can be selected to create superior segregating progenies with maximum genetic variability for effective selection (Barrett and Kidwell 1998) to recover transgressive segregates (Joshi et al. 2004) and for introgression of desirable genes from diverse germplasm into the available genetic base (Thompson and Nelson 1998). Keeping above facts, the current study was aimed to assess the genetic variability for yield traits and to investigate the relationship between the yield contributing traits facilitate selection of superior genotypes for future breeding programmes.

Materials and Methods

The present experiment was carried out at the Research Farm of Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi, situated on latitude 28°40' N, longitude 77°12' E and at an altitude of 228.6 m above mean sea level (MSL). Experimental material includes15 diverse genotypes of okra (Table 1) collected from major research institute working on okra improvement. Genotypes were grown at spacing of 60 x 30 cm in Randomized Complete Block Design in three replications. Genotypes were evaluated for growth and yield traits such as First flowering node, Days to 50% flowering, Plant height (cm), No. of nodes on main stem, No. of branch per plant, Leaf length (cm), Leaf width (cm), Fruit weight, Fruit length (cm), Fruit diameter (cm), Inter nodal length(cm), No. of fruits per plant, Fruit yield per plant (g), and yellow vein mosaic disease incidence at 30, 45, 60 and 75 days after sowing (Per cent disease incidence (PDI)= (No. of diseased plant / Total no of plants) × 100).

The data acquired were subjected to analysis of variance (ANOVA) to determine significance and CD was calculated at P= 0.05 and 0.01 to separate the means of replicate for significance (Panse and Sukhatme 1954). To estimate variability, phenotypic coefficient of variation (PCV) and genotypic coefficient variation (GCV) were calculated as suggested by Burton, 1952. GCV and PCV were divided into three categories, low

Table1: List of genotypes used in the experiment

Sl. No.	Genotype	Sources
1	IC 685583	NBPGR, New Delhi
2	Hisar Unnat	HAU, Hisar
3	Pusa Sawani	IARI, New Delhi
4	Arka Anamika	IIHR, Bangaluru
5	Parbhani Kranti	VNMAU, Parbhani
6	VRO-6	IIVR, Varanasi
7	DOV 2-4-5	IARI, New Delhi
8	DOV-77	IARI, New Delhi
9	DOV-66	IARI, New Delhi
10	DOV-92	IARI, New Delhi
11	DOV-26	IARI, New Delhi
12	DOV-12	IARI, New Delhi
13	DOV-22	Sungro Seeds Pvt. Ltd.
14	Punjab-8	PAU, Ludhiana
15	IC 090491	NBPGR, New Delhi

(<10%), moderate (20%) and high (>20% as per Sivasubramanian and Menon (1973). Genetic advance and heritability were calculated by using the formula recommended by Lush (1949) and Allard (1960). Genetic advance as percent of mean was categorized into low (<10.00%), moderate (10.00-20.00%) and high (>20.00%) as suggested by Johnson *et al.* (1955). Correlation coefficient was measured as per formulae given by Al Jabouri (1958). Path coefficient analysis was worked out as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Results and Discussion

Analysis of variance: Analysis of variance carried out for various economic traits of 15 okra genotypes is presented in the Table 2. The results indicate the presence of significant variability in yield traits among different genotypes used in study. Similar findings were reported by Gondane and Lal (1994) and Alam and Hossain (2008). Presence of adequate variability in germplasm is essential for effective selection to improve yield and related traits.

Mean performance for horticultural important traits: Range values are simple ways of measuring variability. Broader range mean values recorded in our study, reflected presence of sufficient variability for the

Table 2: Analysis of variance for yield contributing traits in diverse okra genotypes

Source of variation	D.F	FFN	PH (cm)	NNMS	NF/P	FL (cm)	FD (cm)	NB/P	F Wt. (g)	LL (cm)	LW (g)	INL (cm)	PDI at 30 DAS	PDI at45 DAS	PDI at 60 DAS	PDI at 75 DAS	FY/P (g)
Replication	2	0.36	16.35	0.05	0.77	1.26	0.00	0.17	0.74	0.66	1.09	0.92	10.25	14.65	18.36	22.35	62.28
Treatment	14	0.67**	1453.19**	11.53**	9.28**	18.76**	0.15**	4.06**	8.86**	9.05**	4.25**	9.58**	132.02**	430.22**	1342.2**	4366.5**	2080.1**
Error	28	0.08	3.37	0.43	1.06	0.47	0.01	0.25	0.53	0.19	0.40	0.29	0.98	2.13	14.33	7.94	69.45

**significant at 1% level of probability * significant at 5% level of probability

FFN- First flowering node, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing characters between genotypes studied (Table 3). First flowering node ranged from 8.00 nodes to 6.33 nodes while days to 50% flowering ranged from 45.33 days and 55.07days. Genotypes Punjab 8 and VRO 6 exhibited earliness indices with 6.67 and 6.33 mean values for first flowering node respectively. Another earliness parameter estimate, days to 50 % flowering indicated early flowering nature of DOV 66 (45.33 days) followed by Parbhani Kranti (46.27 days). Highest average plant height and number of nodes on main stem and inter nodal length was observed in Punjab-8. Likewise, least average plant height and inter nodal length was observed in IC685583 with values 63.72 cm and 4.19cm respectively, these results suggests inter-relation between these traits. A significant variation was observed for plant height with values ranging between 119.78 cm to 63.72 cm. Highest Average leaf length and width was obtained in Punjab 8 (15.75cm) and Prabhani Kranti (12.66cm) respectively. The average fruit length and diameter values ranged from 14.50 cm to 6.84 cm and 2.25 cm to 1.41 cm respectively. Longest fruits produced by DOV 92(14.50 cm) while DOV 22 (6.84 cm) produced shorter fruits. Highest Average fruit weight was observed in DOV 2 4 5 (13.44g) followed by DOV 12 (12.64g) while Pusa Sawani recorded lowest values i.e 8.10g. Highest fruit per plant per plant were observed in DOV 2 4 5 (17.37) followed by DOV 66 (15.50). The fruit yield per plant values ranged from 181.67 to 92.43 which indicate significant presence of variability among genotypes. The highest fruit yield was obtained from DOV 92 (181.67) followed by DOV 12 (171.86) while Pusa Sawani (111.78) recorded lowest per plant yield.

The wider range of variability was obtained for yield and its components i.e. days to 50% flowering, plant height, number of nodes on main stem, fruit length, number of fruits per plant, fruit weight, number branches per plant, inter nodal length and fruit yield per plant. These outcomes were in accordance with the findings of the earlier workers (Dhankhar and Dhankhar 2002; Singh and Singh 2006) in okra. However, significant variation present in the disease incidence at different growth stages of plant i.e at 30, 45, 60 and 75 days after sowing. The characters displaying high range of variation specifies more opportunities for improvement. On the other hand, presence of lower range of variability for traits like, first flowering node and fruit diameter indicates less scope for improvement.

Table 3: Mean performance of diverse okra genotypes for yield contributing characters and YVMV disease incidence parameters

Sl No.	Genotypes	FFN	DFF	PH (cm)	NNMS	NF/P	FL (cm)	FD (cm)	NB/P	F Wt. (g)	LL (cm)	LW (g)	INL (cm)	PDI at 30 DAS	PDI at45 DAS	PDI at 60 DAS	PDI at 75 DAS	FY/P (g)
1	IC685583	7.20	50.34	63.72	12.53	14.60	9.66	1.62	5.67	8.43	11.35	10.40	4.19	0.00(0.71)	0.00 (0.71)	9.67 (3.18)	18.92(4.40)	123.03
2	IC090491	7.60	49.61	72.53	10.20	12.17	11.18	2.09	6.33	9.76	12.66	11.64	5.79	17.68(4.26)	24.72(5.02)	32.36(5.76)	37.82(6.19)	119.76
3	Hissar Unnat	6.87	52.67	66.85	12.20	13.73	8.16	1.87	5.93	10.00	12.23	9.71	4.42	2.57 (1.75)	7.83(2.88)	16.39(4.11)	21.28(4.66)	137.33
4	Pusa Sawani	7.67	48.33	74.56	12.53	13.80	10.58	1.95	7.27	8.10	9.65	8.65	6.66	25.43(5.09)	34.03(5.87)	57.62(7.62)	78.43(8.88)	111.78
5	Arka Anamika	7.27	50.67	67.16	12.87	13.73	13.76	1.78	5.80	8.69	10.77	9.40	4.62	0.00 (0.71)	2.34 (1.68)	9.58 (3.17)	19.46(4.46)	119.30
6	Parbhani Kranti	7.73	46.27	72.70	12.27	14.13	8.63	1.90	7.67	11.00	14.83	12.66	7.36	0.00 (0.71)	8.72 (3.03)	17.49(4.24)	27.16(5.25)	155.47
7	Punjab 8	6.67	63.67	119.78	17.53	14.67	14.43	1.81	9.53	9.09	15.75	11.32	10.16	0.00 (0.71)	0.00 (0.71)	6.41 (2.62)	10.56(3.32)	133.27
8	DOV-2 -4-5	7.93	55.07	115.57	16.73	18.54	9.97	1.73	8.53	13.44	11.69	9.67	4.92	12.44(3.60)	18.37(4.34)	24.59(5.00)	32.92(5.78)	165.84
9	DOV 66	6.87	45.33	81.67	12.87	15.50	12.57	2.16	6.27	10.49	13.78	10.23	8.73	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	3.00 (1.87)	171.86
10	DOV 77	8.00	47.19	79.65	11.27	13.07	6.96	1.46	7.93	7.04	11.76	10.03	7.82	0.00 (0.71)	16.58(4.13)	26.27(5.17)	31.66(5.67)	92.43
11	DOV 92	7.67	51.71	118.33	15.00	15.00	13.66	1.53	5.73	11.00	9.93	7.83	4.71	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	2.00 (1.58)	181.67
12	DOV 26	7.67	48.87	113.33	12.67	13.80	11.00	1.72	6.87	11.67	12.52	10.02	6.34	0.00 (0.71)	9.34 (3.13)	19.61(4.60)	28.84(5.41)	161.09
13	DOV 12	7.80	46.39	71.58	11.80	13.60	8.26	1.58	6.27	12.64	13.38	11.09	5.57	0.00 (0.71)	0.00 (0.71)	17.32(4.22)	22.72(4.81)	150.40
14	DOV 22	7.27	47.13	65.17	12.20	13.40	6.84	1.56	5.73	9.65	11.42	10.65	4.28	22.38(4.78)	36.79(6.10)	53.26(7.33)	70.13(8.40)	129.27
15	VRO 6	6.33	49.40	70.00	12.20	14.13	10.33	1.80	6.47	10.21	10.45	9.82	5.21	5.39 (2.43)	14.74(3.88)	25.16(5.06)	47.43 6.92)	144.25
Mean		7.37	61.61	83.51	12.99	14.07	10.40	1.78	6.80	10.08	12.14	10.21	6.05	1.88	2.91	4.23	5.17	141.79
Range	Min.	6.33	45.33	63.72	10.20	12.17	6.84	1.41	5.67	7.04	9.65	7.83	4.19	0.71	0.71	0.71	1.58	92.43
	Max.	8.00	63.67	119.78	17.53	18.54	14.50	2.25	9.53	13.44	15.75	12.66	10.16	5.09	6.10	7.62	8.88	181.67
SE (d)		0.41	4.70	17.84	1.10	1.36	1.49	0.43	0.84	1.21	0.73	1.06	0.90	7.62	6.11	8.94	10.94	13.93
CD at 5%		0.20	2.29	8.71	0.53	0.66	0.72	0.21	0.41	0.59	0.36	0.51	0.44	3.72	2.98	4.36	5.34	6.80

The PDI value within parenthesis ( ) indicates the Arc sine transformation values, FFN- First flowering node, DFF- Days to 50% flowering, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing

Genotypic and phenotypic coefficient of variation: To assess the amount of variability and to know the extent of environmental influence on trait expression, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated (Table 4). The highest GCV value was observed for PDI at 30 DAS (70.44%) followed by PDI @ 45 DAS and lower values were obtained for days to 50% flowering (9.32) followed by first flowering node (10.81). The highest value of PCV was recorded in PDI @ 30 DAS (72.35%) followed by PDI @ 45 DAS (65.34) and lowest values were recorded for days to 50% flowering (11.43), first flowering node (12.70) and leaf width (20.75). Higher PCV and GCV values were recorded for majority estimated yield traits indicate existence of ample amount of variability among the genotypes. Thus, simple selection can be employed in early generation to exploit available variation. Similar results earlier recorded by Sravanthi et al. (2021), Hamisu et al. (2021) and Nuksungla et al. (2020). On the other hand, the low PCV and GCV value for days to 50% flowering and first flowering node suggests higher influence of environment on these traits, which rule out the possibility of trait improvement through simple phenotype based selection (Das et al. 2012; Thirupathi et al. 2012 and Ehab et al. 2013). PCV value of all the characters under study was greater than GCV values suggesting the role of environmental effects on these traits expression. However, the difference between PCV and GCV was narrow for majority of economic traits indicating the minor environmental influence (Manjumdar et al. 1969). Hence, phenotype based selection will be effective to improve these traits. Marginally higher PCV to GCV values were also obtained by Mittal et al. (1996), Sharma and Prasad (2015) and Senapati et al. (2011).

Heritability and Genetic advance: Heritability and genetic advance parameters are effective measure for predicting the possible trait improvement through selection. All the characters under study showed moderate to high heritability, indicating predominance of additive genetic effect (Table 4). Hence, crop improvement by selecting these traits would be effective. The broad sense heritability ranged from 67.15 % to 96.42%. High values were recorded for plant height (92.24) while moderately to high values were obtained for inter nodal length (88.56), Fruit weight (82. 10) and number of branch/plant (80.22). The medium values of heritability were obtained in number of fruits per plant (67.15), number of nodes on main stem (72.32) and first flowering node (75.42). Coefficients of variation can only elucidate extent of variability in the germplasm. However, it fails to explain the inheritance of trait. So, heritability serves as good index to measure trait transmission from parents to progeny, hence empowers the breeder to adopt the correct amount of selection pressure in a particular environment (Falconer 1981), and helps to decide suitable trait to be considered in selection program in order to isolate phenotypically superior genotypes (Johnson et al. 1955).

Heritability has greater impact in defining the effectiveness of selection for a particular trait only when it is measured along with the predicted genetic advance (Johnson et al. 1995). Highest genetic advance value was recorded in fruit yield per plant (49.65), plant height (42.65) and lowest value was observed in fruit diameter

Table 4: Values of Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), Heritability (h^2), Genetic advance (GA) and GA as per cent mean

Characters	Mean	Range		GCV (%)	PCV (%)	Heritability (%)	GA	GA as % mean
		Min.	Max.					
First flowering node	7.37	6.33	8.00	10.81	12.70	75.42	0.77	10.44
Days to 50% flowering	49.57	45.33	63.67	9.32	11.43	85.15	5.36	10.81
Plant height (cm)	84.11	63.72	119.78	44.23	47.45	92.24	42.65	50.70
No. of nodes on main stem	12.99	10.20	17.53	24.75	29.47	72.32	3.32	25.55
No. of fruits per plant	14.24	12.17	18.54	20.89	22.27	67.15	2.75	19.31
Fruit length (cm)	10.55	6.84	14.50	43.56	47.45	93.75	4.84	45.87
Fruit diameter (cm)	1.81	1.41	2.25	20.46	24.22	85.23	0.63	34.80
No. of branch/plant	6.80	5.67	9.53	28.32	32.22	80.22	2.28	33.52
Fruit weight(g)	10.08	7.04	13.44	26.12	32.24	82.10	3.65	36.21
Leaf length (cm)	12.14	9.65	15.75	26.85	29.32	90.52	3.56	29.32
Leaf width (cm)	10.21	7.83	12.66	18.12	20.75	73.56	2.42	23.70
Inter nodal length (cm)	6.05	4.19	10.16	35.23	39.22	88.56	3.23	53.38
PDI at 30 DAS	3.61	0.71	5.09	70.44	72.35	85.65	18.69	51.77
PDI at 45 DAS	2.91	0.71	6.10	62.38	65.34	90.12	20.37	70.00
PDI at 60 DAS	4.13	0.71	7.62	54.65	58.26	94.35	32.64	79.03
PDI at 75 DAS	5.27	1.58	8.88	46.52	49.54	96.42	41.26	82.22
Fruit yield / plant (g)	142.78	92.43	181.67	36.28	38.23	91.52	49.65	34.77

(0.63), first flowering node (0.77) and number of branches per plant (2.28). The genetic advance as per cent of mean ranged from 10.44-82.22%. Highest values were observed in disease incidence at different stages. The characters namely, plant height (50.70), fruit length (45.87), fruit weight (36.21) and fruit yield per plant (34.77) showed moderate value. While, low values were obtained in first flowering node (10.44), days to 50% flowering (10.81), number of fruits per plant (19.31) and leaf width (23.70). Genetic advance decides the progress in the mean genotypic values of selected genotype over the base population and hence helps breeder in efficient selection program. Higher magnitude of heritability values and genetic advance were previously reported by Reddy and Dhaduk (2014), Nwangburuka et al. (2012) and Hazra and Basu (2000).

Correlation coefficient analysis: For successful crop improvement programme desirable relationship between component traits is as essential as the existence of genetic variability in the breeding population (Grafius 1959), which is measured through Correlation analysis. In case of traits with low heritability, phenotypic correlation and environmental correlation plays an important role. But, for characters with high heritability genetic correlation is crucial (Falconer et al. 1989). Most of the yield and yield contributing traits are quantitatively inherited, hence subjected to different amounts of non-heritable variation. Since in okra, fruit yield per plant greatly depends on component traits, selection for yield is more often based on component characters. Estimation of both magnitude and direction of correlation coefficient among yield and yield related traits will help plant breeder to select desirable traits which are highly correlated among themselves and with yield. In our study genotypic correlation coefficient was higher than the phenotypic correlation coefficient for most of the traits (Table 5 and 6). This denotes less influence of environment towards trait phenotypic expression and higher trait heritability. The present result has similarity with earlier findings of Bello et al. (2006) and Mehta et al. (2006). Though both genetic and phenotypic correlation contributed towards growth and yield components of okra only genetic and heritable relationship is more vital.

In the present investigation, significant high and positive correlations of fruit yield per plant was recorded with fruit weight (0.952**), number of fruits per plant (0.726**), plant height (0.726**), number of nodes on main stem (0.509**) and days to 50% flowering (0.489**). Incidence of YVMV disease at different growth stages of plant showed negative correlation with fruit yield, but these were non–significant in values. The days to 50% flowering showed high positive and significant correlation with fruit yield per plant (0.489**), fruit weight (0.460**) and number of fruits per plant (0.430**). Another character i.e. plant height showed highly significant and positive correlations with number of nodes on main stem (0.782**), number of fruits per plant (0.584**), number of branches per plant (0.550**), fruit yield per plant (0.540**), fruit length (0.539**) and fruit weight (0.401**). Likewise, number of nodes on main stem showed highly significant and

Table 5: Genotypic correlation coefficients values of yield contributing traits

Sl. No.	Observations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	FFN	1.000	-0.289	0.171	-0.129	-0.007	-0.309	-0.333	0.127	0.195	-0.120	-0.025	-0.125	-0.219	0.240	0.253	0.151	0.189
2	DFF		1.000	0.188	0.403**	0.430**	-0.070	-0.176	0.188	0.460**	0.071	-0.104	-0.218	0.122	-0.174	-0.126	-0.143	0.489**
3	PH (cm)			1.000	0.782**	0.584**	0.539**	-0.146	0.550**	0.401**	0.182	-0.252	0.290	-0.323	-0.234	-0.366	-0.412**	0.540**
4	NNMS				1.000	0.823**	0.539**	-0.119	0.575**	0.295	0.194	-0.221	0.260	-0.123	-0.331	-0.385	-0.380*	0.509**
5	NF/P					1.000	0.285	-0.135	0.352*	0.492**	-0.028	-0.302*	-0.075	-0.132	-0.285	-0.358	-0.316*	0.726**
6	FL (cm)						1.000	0.357*	0.129	0.022	0.078	-0.271	0.420**	-0.502	-0.493	-0.611	-0.565**	0.100
7	FD (cm)							1.000	0.052	0.025	0.299	0.251	0.356	-0.165	0.081	-0.059	-0.032	-0.038
8	NB/P								1.000	0.035	0.494**	0.274	0.641	-0.273	0.096	0.103	0.051	0.170
9	F Wt. (g)									1.000	0.216	0.098	-0.261	-0.060	-0.154	-0.167	-0.190	0.952**
10	LL (cm)										1.000	0.799**	0.627**	-0.244	-0.355	-0.277	-0.349*	0.143
11	LW (cm)											1.000	0.312*	-0.057	0.002	0.135	0.086	-0.041
12	INL (cm)												1.000	-0.448	-0.249	-0.275	-0.290	-0.230
13	PDI at 30 DAS													1.000	0.559**	0.528	0.542**	-0.091
14	PDI at 45 DAS														1.000	0.898**	0.886**	-0.175
15	PDI at 60 DAS															1.000	0.982**	-0.221
16	PDI at 75 DAS																1.000	-0.230
17	FY/P (g)																	1.000

**Significant at 1% level of probability *Significant at 5% level of probability

FFN- First flowering node, DFF- Days to 50% flowering, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing

Table 6: Phenotypic correlation coefficients among yield contributing traits of diverse okra genotypes

Sl. No.	Observations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	FFN	1.000	-0.19	0.174	-0.132	-0.005	-0.309	-0.323	0.120	0.195	-0.114	-0.024	-0.132	-0.212	0.234	0.225	0.138	0.189
2	DFF		1.000	0.176	0.390*	0.412**	-0.062	-0.141	0.174	0.449**	0.075	-0.101	-0.210	0.113	-0.145	-0.121	-0.122	0.455**
3	PH (cm)			1.000	0.742**	0.522**	0.520**	-0.135	0.542**	0.416**	0.173	-0.234	0.278	-0.303	-0.222	-0.332*	-0.402**	0.525**
4	NNMS				1.000	0.815**	0.514**	-0.149	0.545**	0.236	0.185	-0.213	0.245	-0.121	-0.308	-0.345*	-0.370*	0.503**
5	NF/P					1.000	0.225	-0.146	0.334*	0.460**	-0.023	-0.312*	-0.049	-0.130	-0.262	-0.336*	-0.309*	0.717**
6	FL (cm)						1.000	0.357*	0.123	0.034	0.074	-0.245	0.425**	-.459**	-0.455*	-.605**	-0.528**	0.090
7	FD (cm)							1.000	0.049	0.028	0.274	0.243	0.324	-0.162	0.074	-0.045	-0.028	-0.028
8	NB/P								1.000	0.026	0.458**	0.236	0.636**	-0.262	0.076	0.102	0.042	0.140
9	F Wt. (g)									1.000	0.232	0.076	-0.224	-0.059	-0.125	-0.157	-0.175	0.942**
10	LL (cm)										1.000	0.719**	0.615**	-0.235	-0.326	-0.248	-0.349*	0.123
11	LW (g)											1.000	0.310*	-0.046	0.001	0.129	0.074	-0.035
12	INL (cm)												1.000	-.435**	-0.209	-0.256	-0.246	-0.226
13	PDI at 30 DAS													1.000	0.545**	0.512**	0.532**	-0.075
14	PDI at 45 DAS														1.000	0.850**	0.846**	-0.145
15	PDI at 60 DAS															1.000	0.946**	-0.208
16	PDI at 75 DAS																1.000	-0.212
17	FY/P (g)																	1.000

**Significant at 1% level of probability *Significant at 5% level of probability

FFN- First flowering node, DFF- Days to 50% flowering, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing

positive correlations with number of fruits per plant (0.823**), plant height (0.782**), number of branches per plant (0.575**), fruit length (0.539**), fruit yield per plant (0.509**) and days to 50% flowering (0.403**). It showed significant but negative correlation with PDI at 75 DAS. The number of fruits per plant had positive and significant relationship with number of nodes on main stem (0.823**), fruit yield per plant (0.726**), plant height (0.584**), fruit weight (0.492**), days to 50% flowering (0.430**) and number of branches per plant (0.352*). Similarly fruit weight has high positive significant correlation with fruit yield per plant (0.952**) and no. of fruits per plant (0.492**). The result found was previously supported by Singh et al. (2017), Reddy et al. (2013) and Das et al. (2012).

The PDI value at 75 DAS also showed significant and positive correlation with PDI at 30 DAS (0.542**), PDI at 45 DAS (0.886**) and PDI at 60 DAS (0.982**). However, it had significantly negative correlations with fruit length (-0.565**), plant height (-0.412**), number of nodes on main stem (-380*), leaf length (-349*) and number of fruits per plant (-0.316*). This shows the significant negative impact of disease incidence on plant growth, development and yield. Similar results were recorded by Singh and Singh (2006) and Prasath *et al.* (2017) for YVMV. The results of our experiments suggest the positive association of fruit yield per plant and component traits such as fruit weight (0.952**), number of fruits per plant (0.726**), plant height (0.726**), number of nodes on main stem (0.509**) and days to 50% flowering (0.489**). Hence, these traits can be considered in breeding programme to evolve high yielding okra varieties. The correlation is the net effect of the segregating genes and gene interactions, simultaneous positive impact of genes on both traits leads to positive correlation and genes enhancing only one and negatively affecting other causes the negative correlation (Falconer 1981). A strong correlation between traits may also be due to linkage and pleiotropy (Sparque 1966). Correlation studies helps in indirect selection of targeted trait though selection based on strongly associated component traits expecting a positive response (Neyhart et al. 2019). Thus it simplifies crop improvement through facilitating efficient selection.

Path coefficient analysis: Simple correlation coefficient may not exactly explain the mutual relationship between yield and related component traits. Therefore, path coefficient analysis is done for critical analysis of specific direct and indirect effects of characters and to examine their relative contribution in yield determination (Wright, 1921). Hence, it enables breeder to easily notify important component traits contributing to yield in large extent and helps in identification of phenotypically superior genotypes from diverse germplasm. In the current study, we present results of path analysis of those characters which displayed significant correlation with yield (Table 7 and 8). Fruit weight (0.062) displayed positive direct effect on fruit yield per plant followed by inter nodal length (0.059), number of fruits per plant (0.035),days to 50% flowering (0.032) and fruit length (0.006). These characters also exhibited significant positive correlation with fruit yield per plant signifying that direct selection

Table 7: Genotypic path coefficient of yield contributing traits with fruit yield per plant

Sl No.	Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	FFN	-0.019	0.021	-0.062	0.002	-0.312	-0.002	0.241	-0.022	0.155	0.000	0.001	-0.026	0.00	0.202	0.133	0.201	0.189
2	DFF	-0.012	0.032	-0.015	-0.011	-0.213	0.000	0.210	-0.214	0.412	-0.005	0.030	-0.047	0.00	0.102	0.125	0.041	0.489**
3	PH (cm)	-0.008	0.000	-0.048	-0.012	0.312	0.001	0.321	-0.048	0.215	0.023	0.027	0.026	0.00	0.210	0.214	0.045	0.540**
4	NNMS	0.009	0.013	-0.036	-0.016	0.425	0.005	0.231	-0.054	0.244	0.062	0.226	0.024	0.012	0.304	0.012	0.210	0.509**
5	NF/P	0.010	0.032	-0.026	-0.012	0.035	0.000	-0.112	-0.025	-0.109	0.024	0.054	0.088	0.013	0.102	0.032	0.210	0.726**
6	FL (cm)	0.011	0.042	-0.033	-0.010	0.365	0.006	-0.045	-0.007	0.015	0.000	0.014	0.025	0.021	0.305	0.012	0.221	0.100
7	FD (cm)	0.009	0.000	0.042	0.007	0.056	0.000	-0.066	-0.007	0.014	0.001	-0.024	0.066	0.00	0.022	0.061	0.412	-0.038
8	NB/P	-0.008	0.024	-0.042	-0.009	0.234	0.000	-0.018	0.089	0.056	0.001	-0.025	0.124	0.00	0.123	0.024	0.102	0.170
9	F Wt. (g)	-0.004	0.012	-0.022	-0.005	-0.084	0.012	0.124	-0.004	0.062	0.002	-0.023	-0.027	0.00	0.322	0.032	0.124	0.952**
10	LL (cm)	0.002	0.035	-0.012	-0.006	0.312	0.000	-0.222	-0.046	0.210	0.003	-0.125	0.109	0.211	0.205	0.012	0.012	0.143
11	LW (cm)	0.000	0.016	0.016	0.010	-0.067	-0.023	-0.118	-0.027	0.014	0.002	-0.067	0.074	0.210	0.201	0.023	0.204	-0.041
12	INL (cm)	0.003	0.028	-0.018	-0.012	0.412	0.001	-0.124	-0.065	-0.176	0.002	-0.145	0.059	0.00	0.102	0.00	0.012	-0.230
13	PDI at 30 DAS	-0.05	-0.212	-0.566	0.023	-0.351	0.052	0.012	-0.03	0.08	0.012	0.021	0.065	-0.013	0.023	0.025	0.022	-0.091
14	PDI at 45 DAS	0.211	0.203	0.423	0.012	-0.233	0.041	0.042	0.04	0.14	0.231	0.012	0.025	0.002	-0.131	0.024	0.044	-0.175
15	PDI at 60 DAS	0.213	0.222	0.312	0.122	-0.134	0.033	0.034	0.02	0.16	0.251	0.021	0.051	0.010	0.012	-0.067	0.021	-0.221
16	PDI at 75 DAS	0.120	0.213	0.221	0.243	0.144	0.054	0.054	0.05	0.24	0.234	0.034	0.021	0.201	0.041	0.043	-0.012	-0.230

Residual effect= 0.0326 **Significant at 1% level of probability *Significant at 5% level of probability

FFN- First flowering node, DFF- Days to 50% flowering, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing

Table 8: Phenotypic path coefficient of yield contributing traits with fruit yield per plant

Sl no.	Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	FFN	-0.032	0.024	-0.042	0.010	-0.132	-0.005	0.188	-0.025	0.140	0.022	0.005	-0.023	0.01	0.212	0.1.26	0.214	0.189
2	DFF	-0.005	0.045	-0.020	-0.013	-0.225	0.001	0.215	-0.521	0.405	-0.023	0.034	-0.042	0.02	0.213	0.213	0.035	0.455**
3	PH (cm)	-0.005	0.002	-0.032	-0.041	0.213	0.002	0.123	-0.044	0.201	0.056	0.048	0.026	0.010	0.255	0.254	0.075	0.525**
4	NNMS	0.012	0.017	-0.021	-0.043	0.213	0.010	0.152	-0.056	0.252	0.054	0.226	0.023	0.011	0.344	0.264	0.209	0.503**
5	NF/P	0.013	0.031	-0.014	-0.021	0.024	0.001	-0.127	-0.025	-0.144	0.042	0.026	0.085	0.012	0.142	0.057	0.208	0.717**
6	FL (cm)	0.015	0.046	-0.032	-0.023	0.021	0.017	-0.046	-0.014	0.029	0.020	0.035	0.025	0.022	0.266	0.047	0.295	0.090
7	FD (cm)	0.010	0.001	0.041	0.019	0.023	0.020	-0.046	-0.015	0.019	0.023	-0.038	0.067	0.12	0.028	0.075	0.425	-0.028
8	NB/P	-0.009	0.023	-0.042	-0.010	0.312	0.030	-0.017	-0.046	0.048	0.025	-0.025	0.134	0.04	0.195	0.039	0.165	0.140
9	F Wt. (g)	-0.012	0.015	-0.020	-0.012	-0.045	0.020	0.126	-0.015	0.054	0.054	-0.033	-0.043	0.06	0.318	0.036	0.137	0.942**
10	LL (cm)	0.021	0.031	-0.021	-0.015	0.213	0.021	-0.223	-0.032	0.209	0.014	-0.134	0.122	0.203	0.212	0.018	0.017	0.123
11	LW (cm)	0.005	0.011	0.019	0.012	-0.054	-0.033	-0.108	-0.014	0.015	0.023	-0.012	0.046	0.212	0.233	0.029	0.215	-0.035
12	INL (cm)	0.005	0.023	-0.017	-0.015	0.324	0.041	-0.135	-0.012	-0.114	0.024	-0.132	0.216	0.23	0.166	0.01	0.062	-0.226
13	PDI at 30 DAS	-0.055	-0.205	-0.254	0.045	-0.342	0.135	0.016	-0.210	0.048	0.011	0.024	0.036	-0.021	0.245	0.023	0.042	-0.075
14	PDI at 45 DAS	0.231	0.205	0.401	0.058	-0.154	0.046	0.047	0.050	0.192	0.225	0.018	0.064	0.018	0.329	0.016	0.064	-0.145
15	PDI at 60 DAS	0.221	0.301	0.312	0.165	-0.214	0.038	0.039	0.022	0.165	0.208	0.044	0.069	0.022	0.254	-0.257	0.251	-0.208
16	PDI at 75 DAS	0.223	0.021	0.201	0.255	0.121	0.065	0.097	0.051	0.244	0.228	0.053	0.055	0.217	0.085	0.022	-0.520	-0.212

Residual effect= 0.0437 **Significant at 1% level of probability *Significant at 5% level of probability

FFN- First flowering node, DFF- Days to 50% flowering, PH- Plant height (cm), NNMS- No. of nodes on main stem, NF/P- No. of fruits per plant, FL- Fruit length (cm), FD- Fruit diameter (cm), NB/P- No. of branch per plant, FW- Fruit weight, LL- Leaf length (cm), LW- Leaf width (cm), INL- Inter nodal length, FY/P- Fruit yield per plant (g), PDI- Per cent Disease Incidence, DAS- Days After Sowing

of these traits would enhance yield. These findings were showing similarity with Sharma and Prasad (2015) for fruit weight, fruit diameter, number of fruits per plant and plant height; Chaukhande et al. (2011) for inter nodal length; Senapati et al. (2011) for fruit length and Singh et al. (2017) for final stem diameter. But few characters such as first flowering node (-0.019), fruit diameter (-0.066), leaf width (-0.067) and PDI at 30 DAS (-0.013), 45 DAS (-0.131) 60 DAS (-0.067) and 75 DAS (-0.012) exhibited negative direct effect on fruit yield per plant.

Beside that some growth parameters like plant height (-0.048) and number of nodes on main stem (-0.016) which exhibited negative direct effect on fruit yield per plant despite positively correlated with fruit yield. In this case, positive significant correlation obtained due to positive indirect effects through days to 50% flowering, fruit length, fruit weight, number of fruits per plant, number of branches per plant, leaf length, inters nodal length and per cent disease incidence at different stages of plant growth. In this situation for best utilization of these positive indirect effects, recurrent selection model must be followed to diminish unwanted indirect effects. These findings were supported by Das et al. (2012) for plant height, Saifullah et al. (2010) for number of nodes on main stem, Magar and Mendrep (2009) for plant height; Sharma and Prasad (2015) and

Prasath et al. (2017) for no. of branches per plant; and Das et al. (2012) for number of nodes on main stem. As the residual effect was very low i.e. 0.0326, it reflects involvement of maximum yield influencing characters contributing through both direct and indirect path had been included in this present study.

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सारांश

भिण्डी में अनुवांशिक विविधता तथा गुण सम्बन्धों को ज्ञात करने विविध जननद्रव्यों का मूल्यांकन, शोध प्रक्षेत्र, भा.कृ.अनु.प.–भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली में किया गया। भिन्नता विश्लेषण तथा उच्च अनुवांशिक प्रारूप गुणांक व बाहयदृश्य प्रारूप गुणांक मूल्यों से स्पष्ट हुआ कि प्रभेदों में उपज गुणों के प्रति विविधता प्रचुर है। अनुवांषिक गुणांक प्रमुख गुणों के लिये, अधिक लेकिन नगण्य उच्च बाहयदृश्य प्रारूप से संकेत मिलता है कि गुण प्रदर्शन में कमतर पर्यावरणीय प्रभाव रहा है। मध्यम से उच्च वंशागतित्व तथा अनुवांशिक उन्नति प्रमुख उपज घटकों जैसे– पौध ऊँचाई (0.726) मुख्य तना पर पार्श्व गाँठ की संख्या एवं 50 प्रतिशत पुष्पन के दिन (0.489) के लिये पाया गया। पित्त शिरा मोजैक विषाणु रोग को पौध विकास की विभिन्न अवस्था से नकारात्मक सह–सम्बन्ध फल उपज के साथ पाया गया। आगे, पथ विश्लेषण के परिणाम से सकारात्मक सीधा प्रभाव फल भार (0.062) का प्रति पौध उपज से पाया गया तथा इसके बाद पार्श्व गाँठ लम्बाई (0.059), फल संख्या प्रति पौध (0.035), 50 प्रतिशत पुष्पन के दिन (0.032) एवं फल की लम्बाई (0.006) का स्थान रहा। सार्थक सकारात्मक सह–सम्बन्ध एवं सकारात्मक प्रत्यक्ष प्रभाव फल उपज प्रति पौध पर होने से प्रतीत होता है कि इन गुणों के लिये सीधे तौर पर चयन करने से अधिक उपज देने वाली भिण्डी की किस्मों को विकसित किया जा सकता है।

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