Indian Journal of Agricultural Sciences **89** (4): 688–94, April 2019/Article
https://doi.org/10.56093/ijas.v89i4.88868

Studies of genetic variability and association of yield traits and YVMV disease in *Abelmoschus* species

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Received: 6 July 2018; Accepted: 29 October 2018

ABSTRACT

Germplasm (44) from 6 wild *Abelmoschus* species and 4 cultivars from cultivated species [*Abelmoschus esculentus* (L.) Moench] were evaluated during *kharif* 2015 and 2016 to assess the genetic variability and character association in yield attributes and YVMV disease. Significant differences among accessions for mean performance with respect to 13 quantitative traits revealed presence of sufficient variation in the experimental material used. Mean Percent Disease Incidence (PDI) YVMV, revealed lowest PDI in *A. moschatus* (IC-141055) (7.73%) followed by IC90476-1(8.61%) and IC47092 (11.0%). These wild accessions indicated their scope in future breeding programs for resistance to BYVMV. Estimates of genotypic coefficients of variability (GCV) and phenotypic coefficients of variability (PCV) ranged from 6.15-59.14 and 13.98- 62.13 respectively. Heritability in broad sense (h^2), genetic advance (GA) and genetic advance as percentage of mean (GAM) ranged from 19-98%, 0.40-84.20, 5.58- 98% respectively. Further classification revealed high GCV (>20.00%), high heritability (>60.00%) and high GAM (>20.00%) for most of the yield components and PDI of BYVMV, except for first flowering node and stem diameter. Character association study publicized significant positive association and high positive direct effect of fruit weight (0.85), number of fruits per plant (0.532), stem diameter (0.088), plant height (0.069) and fruit diameter (0.046) on fruit yield per plant. Therefore, direct selection based on these combinations of traits help in harnessing their positive direct effects on yield per plant in okra improvement programmes.

Key words: *Abelmoschus*, Correlation coefficient, Genetic advance, Genetic variability, Heritability, Path coefficient

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the delicious, tender fruit vegetable having food, non-food and medicinal uses. High level of dietary fibre, flavanoids, rich source of minerals, like Ca, Fe, Mg, Cu and Mn has made okra an important component of Indian diet (Kumar *et al.* 2016). India is the largest producer of okra with 6.0 million tonnes production (72.9% of total world production) from 0.501 million hectare area (Anonymous, 2017). Although India is the largest producer of okra but its productivity potential is low due to an array of biotic stresses adversely affecting the yield and quality of the product. The important biotic bottlenecks include Bhendi Yellow Vein Mosaic Virus (BYVMV) and insect pests, like whitefly (*Bemisia tabaci* Gen.) and leafhopper [*Amarasca biguttula biguttula* (Shir.)]. Considering its nutritional, food and socio-economic importance, its genetic improvement has drawn utmost attention.

Knowledge of genetic parameters, like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (h^2), genetic advance (GA) and character association are prerequisite for okra improvement programme (Nwangburuka *et al.* 2012). Correlation and path-coefficient analysis provide information about the association between two traits and the partitioning of the relationship into direct and indirect effects showing the relative importance of each of the causal factors. Several researchers have emphasized on wild relatives of okra as an important source of useful genes for breeding programmes and resistance to BYVMV, Jassids (leaf hopper) and other biotic and abiotic stresses (Arumugam *et al.*1975, Dhankar *et al.* 2005).Therefore, considering the importance of wild germplasm and their genetic analysis for future use, the present study was undertaken to analyze the genetic variability and association among yield and biotic stresses in okra germplasm comprised of accessions from 6 different wild species of okra.

MATERIALS AND METHODS

The present investigation was carried out at the Research Farm of Division of Vegetable Science of the institute located at 28°35'N, 70°18'E, altitude 226m above sea level (asl) during the *kharif* season of 2015 and 2016. Experimental material consisted of 44 accessions of 6 okra wild species belonging to *Abelmoschus caillei* (3), *A. manihot* var.

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tetraphyllus (17), *A. moschatus* (16), *A. tuberculatus* (3), *A. ficulneus* (2) and *A. angulosus* (3) along with 4 check cultivars of cultivated species *A. esculentus* viz. cv. Pusa Sawani, cv. Pusa A-4, cv. DOV-66 (Pusa Bhindi 5) and cv. DOV-92. The experiment was laid out in Completely Randomized Block Design (RCBD) with 2 replications. All the scientific agronomic package of practices were followed to raise a healthy crop, except spraying of insecticides to control the whitefly, the vector for begomovirus (es) causing BYVMV.

Five plants of each accession in each replication were randomly selected for recording the observations on 13 yield and its component characters. The accessions were screened under natural epiphytotic condition for BYVMV following the infector row method (Nene *et al*. 1972). The response of the virus was assessed based on per cent disease incidence [PDI = (Number of diseased plants/Total number of plants) × 100] in a given accession at 15 days interval and later averaged to get mean PDI. The mean replicated data on various other biometric traits and mean PDI were subjected to analysis of variance as per the standard statistical procedure (Panse and Sukhatme 1985). Phenotypic and genotypic components of variance were estimated by using the formula given by Cochran and Cox (1957). Expected genetic gain or advance under selection and correlation coefficient were computed by using the formula of Johnson *et al*. (1955). Path coefficient analysis was carried out as per Dewey and Lu (1959).

RESULTS AND DISCUSSION

Mean performance

Mean and ranges are the simple measures of variability which are presented in Table 1. Mean performance of 44 wild accessions and 4 cultivated genotypes differed significantly from each other for all the traits under study, except for node at first flower appearance. Mean performance ranged between 5.8 (IC-393008) to 9.5 (IC-90343) for first flowering node, 43.6 (DOV-66) to 86.3 (IC-470737) for days to first flowering, 2.26 (*A. caillei)* to 11.13 (IC-212557) for internodal length (cm), 12.64 (IC-90343) to 31.54 (EC-316077) for number of nodes on main stem, 51.56 (IC-90396) to 160.73 (IC-469584) for plant height (cm), 0.39 (IC-203834) to 2.27 (IC-90499) for stem diameter (cm), 2.7 (DOV- 92) to 13.4 (IC-47092) for number of branches per plant, 1.57 (IC-90511) to 14.09 (Pusa Sawani) for fruit length (cm), 1.03 (IC-111500) to 2.95 (*A. moschatus*) for fruit diameter (cm), 10.15 (IC-470752) to 28.5 (EC-316077) for number of fruits per plant, 2.32 (IC-470752) to 14.45 *(A. caillei)* for fruit weight (g), 7.73 (*A. moschatus*) to 71.34 (Pusa Sawani) for PDI of BYVMV (%) and 46.26 (IC-141045) to 245.13 (245.13) for fruit yield per plant (g). Based on mean PDI of BYVMV, lowest PDI was recorded in *A. moschatus* (7.73%) followed by IC90476-1 (8.61%) and IC47092 (11.0%). These wild accessions indicated their scope in future breeding programmes for resistance to BYVMV. significant differences among accessions for mean performance and broader ranges of mean values revealed presence of sufficient variation in the experimental material used. These findings were in consonance with the findings of earlier workers (Dhankar and Dhankar 2002, Singh *et al*. 2006) in okra.

Genetic variability

Estimates of GCV and PCV (Table 2) ranged from 6.15% (first flowering node) to 59.14% (fruit length) and 13.98% (first flowering node) to 62.13% (fruit length) respectively. GCV estimates were highest for fruit length (59.14%) followed by fruit weight (50.20%), PDI of BYVMV incidence (46.83%) and lowest was observed in first flowering node (6.15%). Similarly, PCV was highest for fruit length (62.13%) followed by fruit weight (52.59%), PDI of BYVMV incidence (47.27%) and lowest for first flowering node (13.98%). In general. PCV were slightly higher than the corresponding GCV. However, the difference between PCV and GCV being very low for majority of the characters, namely days to first flowering, number of nodes on main stem, plant height, fruit length, fruit weight, PDI of BYVMV, number of jassids, whiteflies and yield /plant suggesting more prevalence of genetic governance of these characters, and thus selection on phenotypic basis would hold good. Slightly higher PCV to GCV were also obtained by Sharma and Prasad (2015) and Senapati *et al.* (2011). Further, the PCV and GCV values were classified as low (<10 %), moderate (10- 20%) and high (>20%) as suggested by Sivasubramanian and Menon (1973). In the present investigation, GCV and PCV were high for all the characters, viz. days to first flowering, internal nodal length, no. nodes on main stem, plant height (cm), stem diameter (cm), no. of branches per plant, fruit length (cm), no. of fruits per plant, fruit weight (g), per cent BYVMV incidence, number of jassids/leaf/plant, number of whiteflies/leaf/plant and fruit yield per plant (g), except moderate PCV (13.98%) and low GCV (6.15%) for first flowering node and moderate GCV (18.19%) for fruit diameter. Present GCV and PCV estimates corroborated with the studies of Reddy *et al*. (2012) and Nwangburuka *et al*. (2012). In the present investigation, differences between PCV and GCV estimates for important biotic stresses, namely % BYVMV incidence was low. It indicates more of genetic control than environment in governing the trait and scope and importance of germplasm used in the study for selection of BYVMV resistant accessions for future use in breeding programmes.

Heritability and genetic advance

Estimates of heritability in broad sense (h^2), genetic advance (GA) and genetic advance as percentage of mean (GAM) are presented in Table 2. Heritability, GA and GAM values ranged from 19-98%, 0.40-84.20, 5.58- 98% respectively.The heritability values were classified as low (<30%), moderate (30- 60%) and high (>60%) while that of GAM as low (<10%), moderate (10-20%) and high (>20%) as suggested by Johnson *et al*. (1955). Estimates of heritability were high for days to first flowering (92%),

Table 1 Mean performance of 48 wild okra genotypes for yield and yield attributes

Genotype	First flowering node	Days to first flowering	Inter nodal length (cm)	No. nodes on main stem	Plant height (cm)	Stem diameter (cm)	No. of branches/ plant	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/plant	Fruit weight (g)	PDI of BYVMV (%)	Fruit yield/ plant
Abelmoschus esculentus													
PUSA A4	7.60	46.30	5.00	20.07	92.39	1.66	3.20	12.77	1.67	19.70	12.17	57.81	170.09
Pusa Sawani	6.90	46.25	4.90	25.36	97.14	1.95	3.06	14.09	1.36	19.45	12.10	71.34	138.49
DOV 66	7.30	43.60	4.38	27.67	118.44	2.11	3.00	12.83	1.35	24.30	14.22	12.89	245.13
DOV 92	7.40	48.25	5.08	27.24	125.31	1.28	2.70	13.43	1.44	22.15	14.11	14.24	234.32
A. caillei													
IC-069250	6.60	48.05	2.26	20.22	85.32	1.43	3.70	12.92	2.02	17.65	14.45	27.65	216.04
IC306722	7.40	48.70	2.70	24.00	84.14	1.78	3.60	12.90	2.32	19.65	12.41	14.72	197.35
IC-264697	7.10	46.60	3.58	19.64	98.92	1.60	2.80	11.68	1.67	17.10	13.54	21.08	203.82
A. manihot var. tetraphyllus													
IC90511	7.25	49.80	4.67	15.43	82.02	1.63	9.35	1.57	1.94	12.65	4.35	26.18	71.89
IC141025	7.17	53.25	4.13	18.81	58.04	1.53	9.20	2.24	1.60	16.15	3.23	20.58	98.47
IC141040	7.67	49.15	6.80	18.00	58.20	1.20	10.80	2.93	1.90	15.10	4.48	34.74	50.90
IC470735	7.80	48.55	5.10	24.35	70.98	1.52	12.50	2.00	1.98	19.50	4.09	24.80	101.61
IC470743	7.70	48.40	7.91	18.51	80.02	1.21	13.05	3.53	1.79	15.75	3.72	54.39	50.53
IC141045	7.15	50.30	4.52	23.55	76.80	1.29	10.20	1.95	1.73	20.32	2.58	32.69	46.26
IC9548	7.40	48.40	4.88	18.66	69.32	1.76	10.20	2.75	1.72	15.35	3.81	55.38	53.67
IC90409	6.80	52.65	3.88	24.08	64.77	1.73	11.10	2.79	1.61	21.10	4.90	22.64	112.31
IC90499	7.30	49.95	4.85	18.36	95.97	2.27	9.80	2.02	1.38	15.50	5.21	41.96	63.89
IC90508	7.00	55.55	5.79	24.66	73.47	1.58	12.75	3.29	1.23	21.12	3.16	23.05	75.07
IC90476-1	8.20	49.20	7.14	19.11	91.97	1.71	7.80	2.89	2.28	22.19	4.32	8.61	124.84
IC90515	7.40	54.45	8.37	27.33	71.41	2.00	10.50	3.14	1.90	23.05	3.96	16.98	91.29
IC90505	8.10	48.65	5.83	20.15	69.76	1.48	11.60	3.70	1.24	16.40	2.93	28.77	64.70
(IC-90476-2)	8.65	52.85	6.11	27.49	68.82	1.91	11.55	2.53	1.36	23.19	3.27	28.48	60.32
IC47092	7.60	54.05	5.77	20.32	62.18	1.45	13.40	2.51	1.32	17.04	4.00	11.00	65.42
IC111500	7.20	51.25	5.87	23.83	73.23	1.46	10.00	2.69	1.03	20.78	3.90	18.44	72.72
IC385287	7.40	51.50	4.90	24.37	81.84	1.45	9.50	1.84	1.68	21.22	3.24	20.89	61.07
A. moschatus													
IC141065	7.10	77.10	7.65	26.98	117.67	1.57	9.60	5.80	2.21	23.65	7.35	22.60	138.13
IC140985	6.00	83.20	8.20	22.57	121.89	1.24	7.80	7.13	1.88	19.60	7.76	23.06	139.08

Contd.

Table 1. (*Concluded*)

Genotype		First flowering node	Days to first flowering	Inter nodal length (cm)	No. nodes on main stem	Plant height (cm)	Stem diameter (cm)	No. of branches/ plant	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/plant	Fruit weight (g)	PDI of BYVMV (%)	Fruit yield/ plant
IC140970		7.05	79.20	6.60	26.05	131.47	0.81	9.40	7.04	1.78	23.42	7.65	26.36	157.11
IC316073		7.40	79.20	6.59	21.34	137.78	1.64	7.60	4.89	2.29	18.05	6.90	42.08	148.17
IC393008		5.80	78.85	7.62	20.10	117.11	1.15	9.00	7.45	1.94	17.75	9.09	28.85	122.13
IC469584		6.00	81.00	8.88	25.34	160.73	1.61	10.80	6.40	2.09	22.20	6.78	27.44	154.56
IC339520		6.90	74.05	6.86	20.05	119.75	1.37	6.20	7.37	2.44	16.35	6.50	54.86	111.80
IC470737		6.50	86.30	7.86	27.93	129.58	1.45	7.80	9.50	2.64	25.40	7.94	41.46	110.04
IC140986		6.80	81.80	8.69	30.07	153.06	1.53	6.70	6.67	2.13	26.29	7.10	17.29	154.82
IC140113		6.95	77.00	7.88	25.76	117.03	1.73	7.40	6.98	2.53	21.90	7.79	19.42	173.42
IC212557		6.10	80.25	11.13	24.75	135.39	1.29	6.30	8.07	2.23	20.45	8.06	33.64	164.84
IC141056		6.05	80.20	9.84	29.22	122.22	1.46	6.65	5.66	1.95	25.95	8.01	49.91	92.69
EC316077		7.00	79.50	10.05	31.54	107.64	1.24	13.15	6.90	1.88	28.50	6.01	18.97	171.31
(IC-141055)		6.70	77.25	10.26	25.92	131.88	1.72	7.80	7.48	2.95	23.85	6.89	7.73	198.11
NIC-4676		6.80	79.15	10.66	30.78	122.54	0.84	9.05	6.30	2.19	26.49	5.20	35.64	106.38
Egypt-R		7.50	74.20	10.49	25.06	113.07	1.56	4.10	7.26	2.13	21.80	5.70	40.04	132.08
A. tuberculatus														
IC436706		9.40	55.45	2.88	13.44	53.61	1.04	3.70	4.14	2.16	13.20	5.92	50.72	105.79
IC90396		8.50	48.65	3.38	12.99	51.56	0.81	4.80	5.13	2.45	17.30	7.03	40.45	125.41
IC90343		9.50	56.50	4.19	12.64	63.83	1.37	4.30	4.56	2.30	14.05	6.71	24.56	93.42
A. ficulneus														
IC90364		8.00	48.85	2.88	13.13	67.28	1.04	4.30	3.95	1.50	11.00	5.35	44.18	61.47
IC550661		6.30	46.35	6.28	16.09	79.68	1.10	3.60	4.11	1.68	14.00	4.57	55.28	64.14
A. angulosus var. grandiflorus														
IC213314		6.50	50.95	5.90	16.29	74.52	0.54	5.30	4.63	1.81	13.85	3.58	46.47	72.55
IC470752		6.95	55.10	8.34	12.79	67.95	0.68	4.70	4.48	2.05	10.15	2.32	32.27	69.42
IC203834		6.90	55.45	6.89	17.03	76.62	0.39	3.00	4.25	1.93	14.90	3.11	41.44	48.02
Mean		7.23	60.03	6.34	22.06	94.25	1.42	7.68	5.86	1.89	19.3	6.49	31.54	116.35
SEm±		0.64	2.92	0.84	1.58	7.62	0.24	0.87	0.79	0.22	1.65	0.72	1.44	7.61
Range	Maximum	5.8	43.6	2.26	12.64	51.56	0.39	2.7	1.57	1.03	10.15	2.32	7.73	46.26
	Minimum	9.5	86.3	11.13	31.54	160.73	2.27	13.4	14.09	2.95	28.50	14.45	71.34	245.13
CD (P=0.05)		-	8.30	2.38	4.51	21.67	0.68	2.47	2.24	0.62	4.70	2.05	4.09	21.65
CD (P=0.01)		-	11.08	3.18	6.02	28.91	0.91	3.30	2.99	0.83	6.27	2.73	5.46	28.89

Table 2 Genotypic (Upper right) and phenotypic (Lower left) correlation coefficients of 13 quantitative traits in wild okra genotypes

Character	First flowering node	Days to first flowering	Inter nodal length	No. nodes on main stem	Plant height (cm)	Stem diameter (cm)	No. of branches/ plant	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/plant	Fruit weight (g)	PDI of BYVMV (%)	Fruit yield/ plant
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**1.000**	-0.865**	-0.981**	-0.672**	-0.999**	0.046	-0.060	-0.501**	-0.352**	-0.428**	-0.410**	-0.011	-0.419**
2	-0.367**	**1.000**	0.809**	0.564**	0.816**	-0.174	0.150	0.118	0.651**	0.612**	0.039	-0.039	0.256*
3	-0.303**	0.687	**1.000**	0.603**	0.679**	-0.226*	0.279**	-0.022	0.499**	0.624**	-0.229*	-0.061	0.030
4	-0.316**	0.449**	0.424**	**1.000**	0.676**	0.533**	0.295**	0.308**	0.040	0.958**	0.259*	-0.349**	0.427**
5	-0.424**	0.729**	0.531**	0.556**	**1.000**	0.110	-0.125	0.504**	0.452**	0.683**	0.457**	-0.111	0.606**
6	0.834**	-0.079	-0.051	0.268**	0.164	**1.000**	0.252*	0.190	-0.197	0.473**	0.317**	-0.269**	0.322**
7	-0.012	0.143	0.225*	0.270**	-0.085	0.153	**1.000**	-0.666**	-0.287**	0.255*	-0.646**	-0.287**	-0.462**
8	-0.191	0.118	-0.041	-0.300**	0.458**	0.088**	-0.593**	**1.000**	0.140	0.304**	0.983**	0.051	0.852**
9	0.011	0.486**	0.288**	0.002	0.325**	-0.14	-0.152	0.15	**1.000**	0.209*	0.128	-0.046	0.346**
10	-0.247*	0.455**	0.404**	0.924**	0.529**	0.232*	0.221*	0.274**	0.11	**1.000**	0.277**	-0.418**	0.498**
11	-0.102	0.048	-0.174	0.223*	0.418**	0.211*	-0.553**	0.882**	0.081	0.227*	**1.000**	-0.043	0.878**
12	-0.017	-0.089	-0.049	-0.311**	-0.104	0.1944	-0.253*	0.046	-0.024	-0.348**	-0.040	**1.000**	-0.355**
13	-0.139	0.241*	0.039	0.398**	0.561**	0.219*	-0.411**	0.799**	0.244*	0.425**	0.837**	-0.343**	

* and ** indicate significance of values at P=0.05 and P=0.01, respectively.

internodal length (76%), number of nodes on main stem (82%), plant height (87%), number of branches per plant (87%), fruit length (91%), number of fruits per plant (75%), fruit weight (91%), PDI of BYVMV incidence (98%), number of jassid or nymphs/leaf/plant (94%), number of whiteflies/leaf/plant (90%) and green fruit yield/plant (96%). Heritability estimates were moderate for stem diameter (45%) and fruit diameter (55%) while low only for first flowering node (19%). The estimates of GAM were also high for days to first flowering (45.41%), internodal length (60.49%), number of nodes on main stem (41.02%), plant height (55.96%), stem diameter (30.01%), number of branches per plant (79.99%), fruit length (115.96%), fruit diameter (27.79%), number of fruits per plant (36.78%), fruit weight (98.70%), PDI of BYVMV incidence (95.56%), number of jassid or nymphs/leaf/plant (64.95%), number of whiteflies/leaf/plant (90%) and green fruit yield/plant (91.94%). Low GAM (<10.00%) recorded only for first flowering node (19%).

During the selection for the improvement of any character knowledge of broad sense heritability and GAM are necessary because broad sense heritability is based on total genetic variance, which includes both fixable (additive) and non-fixable (dominance and epistatic) variances. When heritability is mainly due to non- additive genetic effects (dominance and epistasis), genetic advance will be low, while in cases where heritability is chiefly due to additive gene effects, a high genetic advance may be expected. In the present investigation, except for first flowering node, high GAM coupled with high heritability has been observed for all the characters including PDI of BYVMV incidence is the indication of prevalence of additive genetic effects (fixable) involved in their expression and such additive gene effects are predicted to show good response to phenotype based selection in crop improvement programme. Hence, it is advisable for straight phenotype based selection to improve these characters. High heritability along with high GAM estimates were also obtained by Das *et al.* (2012), Prakash *et al.* (2017), Singh *et al.* (2006) and Reddy *et al.* (2012) in okra. Low heritability coupled with low GAM observed first flowering node is the sign of prevalence of non-additive gene action and influence of environment. As a result showing limited scope for improvement of this trait through selection.

Correlation coefficient

Yield and yield components, in general, are polygenic in nature and are subjected to different amount of non-heritable variation. Fruit yield/plant in okra is the result of interaction of number of inter-related characters. Therefore, selection should be based on the component characters after assessing their correlation with fruit yield/plant. In the present investigation genotypic correlation coefficients (rg) were higher in magnitude than phenotypic correlation coefficients (rp) in most of the cases (Table 3). Fruit yield per plant showed highest significant positive correlation at both phenotypic and genotypic levels with fruit weight (rg= 0.878, rp= 0.837) followed by fruit length (rg= 0.852, rp= 0.799), plant height (rg= 0.606, rp= 0.561), number of fruits per plant (rg= 0.498, rp= 0.425), number of nodes on main stem (rg= 0.427, rg= 0.398), fruit diameter (rg= 0.346, rg=0.244), basal stem diameter (rg=0.332, rp=0.219) and days to first flowering (rp=0.256, rg=0.241) . Significant positive association of above traits with yield per plant showed their role in improving fruit yield in okra (Singh *et al.* 2017. Reddy *et al.* 2013. Das *et al.* 2012. Prasath *et al.* 2017). The number of branches per plant (rg=-0.462, rp=-0.410), per cent BYVMV incidence (rg=-0.355, rp= -0.343) found to be negative significant correlation at both phenotypic and genotypic level and first flowering node (rg=-0.419) only at genotypic level for fruit yield per plant. This indicates that due attention should be given for selection of combination of flowering at lower node and lower incidence of BYVMV in improving fruit yield of okra.Similar results were obtained by Singh *et al.* (2017) and Prasath *et al.* (2017).

Path coefficient analysis

Path coefficient analysis (Table 4) is an efficient technique to partition the correlation coefficient of each of the trait with yield into direct and indirect effects which helps in explaining relative importance of each of the trait and their reliability in selection making. Fruit weight (0.85) exhibited highest positive direct effect on fruit yield per plant followed by number of fruits per plant (0.532), internodal length (0.148), stem diameter (0.088), plant height (0.069) and fruit diameter (0.046). These traits also possessed their significant positive correlation with fruit yield per plant (except internodal length) indicating that direct selection based on these traits help in yield improvement. These findings corroborated with Sharma and Prasad (2015), Senapati *et al.* (2011) and Singh *et al.* (2017). Number of nodes on main stem (-0.574) followed by % BYVMV incidence (-0.268), first flowering node (-0.061), fruit length (-0.062), number of branches per plant (-0.039) and days to first flowering (-0.031) exhibited negative direct effects on fruit yield per plant. Among these negatively effecting traits, first flowering node and PDI of BYVMV incidence also possessed negative significant correlation with fruit yield per plant indicating their true relation.

Growth attributes, like number of nodes on main stem, fruit length and days to first flowering showed negative direct effect on fruit yield per plant although positively correlated with fruit yield per plant. In such a situation, obtained positive significant correlation with fruit yield per plant may be due to the positive indirect effects. As a result negative direct effect showing number of fruits per plant showed significant positive correlation due to positive indirect effects via number of fruits per plant (0.510), fruit weight (0.221), PDI of BYVMV (0.093), internodal length (0.089), plant height and stem diameter (0.047). Similarly, positive indirect effects are responsible for positive significant correlation of fruit length and days to first flowering with fruit yield per plant. Under these

Table 3 Genotypic path coefficient among different characters of wild okra genotypes

Character	First flowering node	Days to first flowering	Inter nodal length	No. nodes on main stem	Plant height (cm)	Stem diameter (cm)	No. of branches/ plant	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/plant	Fruit weight (g)	PDI of BYVMV (%)	Fruit yield/ plant
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**-0.061**	0.027	-0.145	0.386	-0.074	0.004	0.002	0.031	-0.016	-0.228	-0.348	0.003	-0.419**
2	0.053	**-0.031**	0.120	-0.324	0.056	-0.015	-0.006	-0.007	0.030	0.326	0.033	0.023	0.256*
3	0.060	-0.025	**0.148**	-0.346	0.047	-0.020	-0.011	0.001	0.023	0.332	-0.194	0.016	0.03
4	0.041	-0.018	0.089	**-0.574**	0.047	0.047	-0.012	-0.019	0.002	0.510	0.221	0.093	0.427**
5	0.065	-0.026	0.101	-0.388	**0.069**	0.010	0.005	-0.032	0.021	0.363	0.389	0.030	0.606**
6	-0.003	0.005	-0.033	-0.306	0.008	**0.088**	-0.010	-0.012	-0.009	0.252	0.270	0.072	0.322**
7	0.004	-0.005	0.041	-0.169	-0.009	0.022	**-0.039**	0.042	-0.013	0.136	-0.549	0.077	-0.462**
8	0.031	-0.004	-0.003	-0.177	0.035	0.017	0.026	**-0.062**	0.006	0.162	0.836	-0.014	0.852**
9	0.021	-0.020	0.074	-0.023	0.031	-0.017	0.011	-0.009	**0.046**	0.111	0.109	0.012	0.346**
10	0.026	-0.019	0.092	-0.550	0.047	0.042	-0.010	-0.019	0.010	**0.532**	0.235	0.112	0.498**
11	0.025	-0.001	-0.034	-0.149	0.032	0.028	0.025	-0.061	0.006	0.147	**0.850**	0.011	0.878**
12	0.001	0.003	-0.009	0.200	-0.008	-0.024	0.011	-0.003	-0.002	-0.222	-0.034	**-0.268**	-0.355**

Residual effect=0.36.

circumstances, to make use of these positive indirect effects a restricted simultaneous selection model is to be followed i.e. restrictions are to be imposed to nullify the undesirable indirect effects and simultaneous prioritized selection on positive indirect effects. These findings corroborated with Das *et al.* (2012) and Choudhary and Sharma (1999). In the present study, residual effect was low (0.36) suggesting inclusion of maximum fruit yield influencing characters of okra in the present analysis.

Based on the results obtained it was found that, significant differences among accessions for mean performance revealed presence of sufficient variation in the experimental material. Mean PDI of BYVMV, revealed lowest PDI in *A. moschatus* (IC-141055) (7.73%) followed by IC-90476-1 (8.61%) and IC-47092 (11.0%). These wild accessions indicated their scope in future breeding programmes for resistance to BYVMV. High genetic variability and heritability estimates obtained for most of the earliness, growth, yield and PDI of BYVMV indicated the prevalence of additive genetic effects (fixable) governing their expression. Character association study revealed significant positive association and high positive direct effect fruit weight (0.85), number of fruits per plant (0.532), stem diameter (0.088), plant height (0.069) and fruit diameter (0.046) on fruit yield per plant. Therefore, direct selection based on these combinations of traits help in harnessing their positive direct effects on yield per plant in okra improvement programmes.

REFERENCES

Anonymous. 2017. Indian Horticultural Database. http://www.nhb.gov.in.

Arumugam R, Chelliah S and Muthukrishnan C R. 1975. *Abelmoschus manihot*: a source of resistance to bhindi yellow vein mosaic. *Madras Agricultural Journal* **62**: 310–2.

Chaukhande P, Chaukhande P B and Dod V N. 2011. Correlation and path analysis studies in okra [*Abelmoschus esculentus* (L.) Moench]. *Abstr. Natl. Symp. Veg. Biodiv.* April 4-5, 2011, ISVS, Varanasi, JNKVV, Jabalpur, IIVR, Varanasi, p 30.

Choudhary D N and Sharma R K. 1999. Correlation and path analysis in okra [*Abelmoschus esculentus* (L.) Moench]. *Haryana Journal of Horicultural Sciences* **28** (3&4): 221–2.

Cochran W G and Cox G M. 1957. *Experimental Designs*. John Wiley and Sons, Inc., New York, p 611.

Das S, Chattopadhyay A, Chattopadhyay S B, Dutta S and Hazra P. 2012. Genetic parameters and path analysis of yield and its components in okra at different sowing dates in the Gangetic plains of eastern India. *African Journal of Biotechnology* **11**(95): 16132–41.

Dhankar B S and Dhankar S K. 2002. Genetic variability, correlation and path analysis in okra [*Abelmoschus esculentus* (L.) Moench]. *Journal of Vegetation Science* **29**(1): 63–5.

Dhankar S K, Dhankar B S and Yadava R K. 2005. Inheritance of resistance to yellow vein mosaic virus in an interspecific cross of okra. *Indian Journal of Agricultural Sciences* **75**: 287–90.

Dewey D R and Lu K H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**: 515–8.

Hazra P and Basu D. 2000. Genetic variability, correlation and path analysis in okra. *Annals of Agricultural Research* **21**(3): 452–3.

Johnson H W, Robinson H F and Comstock R S. 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Jounal* **47**: 314–8.

Kumar R, Yadav R K, Bhardwaj R, Baranwal V K and Chaudhary H. 2016. Studies on genetic variability of nutritional traits among BYVMV tolerant okra germplasm. *Indian Journal of Horticulture* **73**(2): 202–7.

Nene Y L, Srivastava S K and Naresh J S. 1972. Evaluation of black-gram (*Phaseolus mungo* Roxb.) and greengram (*Phaseolus aureus* Roxb.) varieties and germplasms for resistance to yellow-mosaic virus of green-gram. *Indian Journal of Agricultural Sciences* **42**: 251–4

Nwangburuka C C and Denton O A. 2012. Heritability, character association and genetic advance in six agronomic and yield related characters in leaf *Corchorus olitorius*. *International Journal of Agricultural Research* **7**(7): 365–75.

Panse V G and Sukhatme P V. 1985. *Statistical methods forAgricultural workers*. 4th ed. Indian council of Agricultural Research, New Delhi, India. pp 63–9.

Prakash K, Pitchaimuthu M and Akshata H. 2017. Studies on variability, correlation and path analysis of traits contributing to fruit yield and its components in okra (*Abelmoschus esculentus* L. Moench). *Electroic Journal of Plant Breeding* **8**(1): 134–41.

Prasath G, Reddy K R and Saidaiah P. 2017. Correlation and path coefficient analysis of fruits yield and yield attributes in Okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Current Microbiology and Applied Sciences* **6**(3): 463–72.

Reddy M T, Babu K H, Ganesh M, Reddy K C, Begum H, Reddy P B and Narshimulu G. 2012. Genetic variability analysis for the selection of elite genotypes based on pod yield and quality from the germplasm of okra (*Abelmoschus esculentus* L. Moench). *Journal of Agricultural Technology* **8**(2) 639–55.

Reddy M T, Babu K H, Ganesh M, Reddy K C, Begum H, Reddy R S K and Babu J D. 2013. Correlation and path coefficient analysis of quantitative characters in okra [*Abelmoschus esculentus* (L.) Moench]. *Songklanakarin Journal of Science and Technology* **35**(3): 243–50

Senapati N, Mishra H N, Beura S K, Dash S K, Prasad G and Patnaik A. 2011. Genetic analysis in Okra hybrids. *Environment and Ecology* **29**(3A): 1240–4.

Sharma A K and Prasad K. 2015. Genetic divergence, correlation and path coefficient analysis in okra. *Indian Journal of Agricultural Research* **49**(1): 77–82.

Singh B, Pal A K and Singh S. 2006. Genetic variability and correlation analysis in okra [*Abelmoschus esculentus* (L.) Moench.]. *Indian Journal of Horticulture* **63**(3): 281–5.

Singh N, Singh D K, Pandey P, Panchbhaiya A and Rawat M. 2017. Correlation and Path Coefficient Studies in Okra [*Abelmoschus esculentus* (L.) Moench]. *International Journal of Current Microbiology and Applied Sciences* **6**(7): 1096–101.

Sivasubramanian S and Menon M. 1973. Heterosis and inbreeding depression in rice. *Madras Agricultural Journal* **60**: 1139.