Int.J.Curr.Microbiol.App.Sci (2018) *7*(12): 594-608

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 12 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.712.074

Evaluation of Elite Genotypes for YVMV Resistance in Okra [*Abelmoschus esculentus* (L.) Moench]

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Keywords

Genotypes, Okra, Diversity, Genetic advance; Heritability, YVMV incidence

Article Info

Accepted:
07 November 2018
Available Online:
10 December 2018

A B S T R A C T

Okra genotypes were evaluated for their genetic variability, character associationships and genetic divergence among fifteen quantitative traits by adopting Randomized Block Design. Significant variation were observed for all the traits except incidence of YVMV at 30 DAS indicating the vast scope for selection. Among the genotypes, 2014\OKYVRES-5 and 2014\OKYVRES-11 (0.00 to 1.39%) was identified as most resistant line with low incidence of YVMV disease at all the stages of crop growth. The genotype, 2014\OKYVRES-1 recorded significantly moderate no. of fruits (11.20), fruit length (12.63 cm), fruit girth (5.81cm) and average fruit weight (8.53cm) with highest total yield (4.39 kg plot^{-1} and 54.20 qha^{-1}). The genotype showed significant tolerance to YVMV upto 30 to 45 DAS of incidence. The genetical studies indicated that direct selection through traits like no. of fruits plant^{-1}, days to 50% flowering, plant height, fruit length and YVMV incidence at 30, 75 and 90 DAS will be effective for improvement in okra especially to develop a genotype having resistance and/or tolerance to YVMV. Being most divergent Cluster I (2014\OKYVRES-11 and 2014\OKYVRES-1) and Cluster II (VRO-6), hence expected hybridization might result in highly heterotic hybrid and other segregants. Incidence of YVMV is contributing maximum towards divergence suggested that special attention should given to this character while designing crop improvement programme in okra.

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] has captured a fore standing position among vegetables. In India, okra is one of the most important vegetable crop grown for its tender green fruits during summer and rainy seasons. Okra (*Abelmoschus esculentus* (L) Moench) is probably an amphidiploids (allotetraploid) having somatic chromosome number 130 and belonging to the family Malvaceae. It is an often cross pollinated crop. Occurrence of out crossing upto an extent of 4 to 19 percent with the maximum of 42.2 per cent is noticed with the insect assisted pollination. According to Vavilov, it was probably domesticated in the Ethopian region but according to Murdoc, it is in West Africa. India has the credibility of

producing 168.6 million tonnes of vegetables from an area of 9.542 million hectares during 2016-17 (IAC, 2016-17) being the second among the vegetable producing countries in the world next only to China. Okra fruit is principally consumed fresh or cooked form. In India about eight *Abelmoschus* species are found, out of which only *Abelmoschus esculentus* is known cultivated species while the rest species are truly wild types in nature. Species resistant to Okra Yellow Vein Mosaic Virus (YVMV) are *Abelmoschus caillei, Abelmoschus manihot, Abelmoschus tetraphyllus* and *Abelmoschus crinitus*.

Cultivation of okra in India is challenged due to severe incidence of YVMV where symptoms of homogenous interwoven network of yellow veins enclosing islands of green tissues is noticed. There is reduction of leaf chlorophyll and the infected plants give a stunted look and produce small-sized pale yellow fruits (Gupta and Paul, 2001). The virus is neither sap nor seed transmitted in nature, rather the virus transmission occurs through the insect vector white fly (*Bemisia tabaci*). It is the most important viral disease of okra causing huge yield loss. This Begomovirus belongs to family Geminiviradeae which covers many of the crop viruses. The production losses due to YVMV have been reported to range from 50-94 per cent (Sastry and Singh, 1974). Unfortunately many of the existing released varieties of okra are showing the signs of susceptibility to YVMV. Several cultivable varieties exhibited tolerance / resistance to this virus at the time of release, but this tolerance / resistance have broken down with time. Several wild species of cultivated okra showed high degree of resistance to YVMV but here, transfer of resistance from wild relatives has been hampered by sterility problems and was difficult to produce subsequent generations or even carry out backcrosses.

In the distant hybridization programmes genetically diverse parents are involved, hence in the segregating generations there are more scope for the selection of desirable recombinants. Assessing the genetic variability among the advanced generation selections in comparison with parents will show their extent of possession of desirable genes.

Materials and Methods

The present investigation was carried out during summer, 2016 at All India Co-ordinated Research Project on Vegetable Crops, Horticultural Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, situated at latitude of 200 15' N and 850 53'East longitude, above 60 km away from Bay of Bengal and at an altitude of 22.5 meter above mean sea level(MSL). The experiment was carried out for screening of best okra line (s) tolerant / resistant to YVMV under field condition and finding out genetic diversity in okra. The experimental material for this study, comprised of 14 genotypes with three checks (Arka Abhay, Arka Anamika and VRO-6) collected from IIVR, Varanasi and IIHR, Bengaluru, arranged in a Randomized Block Design (RBD) having three replication, with spacing of 50 cm between rows to row and 30 cm between plant to plant, respectively. Seeds of the okra genotypes were sown in separate plots. The field was ploughed three times after incorporation of FYM during final land preparation @ $15tha^{-1}$ and levelled properly. Seeds were soaked in water over night to obtain better germination. A fertilizer dose of 100:50:50 N: P_2O_5 : K_2O kg ha^{-1} were applied after sowing. The standard agronomical cultural practices were followed throughout years of the crop season. No insecticide or pesticide was used.

From each plot, observations on various biometric characters were recorded by

selecting randomly ten competitive plants of each genotype in a replication which were tagged properly to record data. Observation were recorded for 15 quantitative characters viz., Plant height (cm)at final harvesting stage, Plant girth, Leaf length, Leaf width, Leaf area index, Node at which first flower appeared Days to first flowering Days to 50% flowering Number of fruits plant^{-1}, Fruit length, Fruit girth, Fruit weight, Avg. fruit weight, Number of ridges per fruit, YVMV incidence(30, 45, 60, 75 and 90 DAS).

The disease scoring of YVMV incidence were calculated by counting the number of plants infected with Yellow Vein Mosaic Virus (YVMV) disease at 30, 45, 60, 75 and 90 days respectively in each replication and were expressed in percentage. The value was converted to its ASIN or SQAURE ROOT values for calculations.

The analysis of variance for the design of experiment was carried out according to the procedure outlined by Panse and Sukhatme (1967). The heritability estimates were used to measure the degree of correspondence between phenotypic value and breeding value. It is worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953) and expressed in percentage according to Weber and Moorty (1952). Genetic advance was estimated as per the formula suggested by Johnson *et al.,* (1995). Knowledge of correlation between yield and its contributing characters are basic and for most endeavor to find out guidelines for plant selection. Path coefficient analysis was done according to formula given by Dewey and Lu (1959). Multivariate analysis by means of Mahalanobis D2 statistic is a powerful tool in quantifying the divergence among genotypes. Grouping of the genotypes into various clusters was done by using Tocher's method as described by Rao (1952).

Results and Discussion

Mean of the 15 characters of 14 genotypes were recorded in (Table 1). From the mean table it was observed that, Significantly tallest plant was recorded in genotype 2014OKYVRES-9(111.72) compare to 2014\OKYVRES-9 (5.12). Similarly maximum values of leaf parameters were recorded in the genotypes like 2014\OKYVRES-8(17.03 cm) for leaf length, 2014\OKYVRES-11(18.52 cm) for leaf width and 2014\OKYVRES-1 (264.29 cm^2) for leaf area index. While lowest values were observed in VRO-6(11.81 cm), 2014\OKYVRES-6(10.18 cm) and 2014\OKYVRES-3(121.25 cm^2) for above leaf parameters. Here check varieties like Arka Abhay and VRO-6 performed better in plant height and plant girth and were statistically at par with the highest values. In okra, it is more beneficial to produce the flowers at lower nodes with early flowering habit for a better and profitable yield under commercial scale. The result indicated that the genotype 2014\OKYVRES-3 (6.67 cm) recorded the lowest among others for appearance of 1st flower and was statistically at par with 2014\OKYVRES-10(6.80 cm) and VRO-6 (6.87 cm) proving the better performance over check(s). Days to 1st flowering with 2014\OKYVRES-8(24.67 days) followed by 2014\OKYVRES-11(25.67 days). Similar trend was observed in days to 50% flowering. The present study invariably showed that, the genotypes 2014\OKYVRES-3(12.07) for no. of fruits per plant, Arka Abhay for fruit length (15.87 cm), fruit girth(6.03 cm) and average fruits weight(9.83 g) and 2014\OKYVRES-1 (4.39 kg plot^{-1}) for fruit yield recorded significantly highest values, suggesting the superiority of the genotypes than the rest of the genotypes including the checks. However statistical parity were observed with 2014\OKYVRES-2 (12.00) for no. of fruits plant^{-1} while Arka

Anamika and 2014\OKYVRES-2 for average fruit weight (8.73 cm). Similar findings for Arka Anamika were also found by Prasad *et al.,* (2016). Significantly highest total yield (kg plot^{-1}) was found in 2014\OKYVRES-2(4.22) and VRO-6 (4.12). Similar results were also found by Vijay and Joshi (2013) under Akola condition for check variety (VRO-6). The result indicated significant variations among the genotypes for percentage of disease infection at 45, 60, 75 and 90 DAS of crop growth under field condition. Among the genotypes evaluated 2014\OKYVRES- 5 showed resistance to YVMV incidence (0.00%) at 30DAS. However statistical parity was observed in most of the genotypes. At 45 DAS, 2014\OKYVRES-3 and 2014\ OKYVRES-5(0.00%) showing significant resistance to YVMV as compared to the other genotypes. Similar report of tolerance of YVMV resistance was also identified by Nataraj *et al.,* (2013). The result also indicated that the standard susceptible check VRO-6 showed susceptibility to YVMV at 30 DAS under Bhubaneswar condition. The susceptible check VRO-6 showed the susceptibility to YVMV at every stages of growth, about 78.17% of incidence at 90 DAS. Arka Anamika and Arka Abhay showed significant tolerance to YVMV (24.64-36.90) % at 45-60 DAS. This result for Arka Abhay was seemed parallel to the result of Kumar *et al.,* (2015). The genotype 2014\OKYVRES-7 showed highest percentage of incidence at 60 DAS (63.40%) among tested genotypes while in case of checks, VRO-6 (68.33%) was screened as the most susceptible variety. The result also clearly suggested that in spite of higher incidence of YVMV at 60 DAS onwards (68.33-78.17) %, the genotype VRO-6 recorded better fruit yield.

Study on Coefficient of Variance (C.V.)

The coefficient of variance with respect to 17 characters are presented in Table 4, which ranged from 2.40(Leaf length) to 48.01(incidence of YVMV at 45 DAS).

The coefficient of variation indicated that low variability of<5% for parameter such as Plant height (4.84), fruit girth (2.86), Plant girth (2.62) and leaf length (2.40). Similarly, moderate variability (CV from 5-10%) was observed for parameters like days to first flowering (5.21), days to 50% flowering (5.72), first flowering node (5.01), average fruit weight (6.83), leaf width (5.73), leaf area index (5.53) and fruits plant^{-1} (9.60). High variability (CV of >10%) was observed for fruit length (10.68), total yield (kg plot^{-1}) (17.63), incidence of YVMV at30, 45,60,75 and 90 DAS (34.16,48.01,34.70,36.28 and 34.12).

Study on genetic variability and heritability

The result on analysis of variance (Table 1, 2 and 3) clearly demonstrated the significant variation for all the parameters under study in okra except 30 DAS of YVMV incidence. The analysis of variance for different characters is presented.

The vegetative growth parameters i.e., plant height, plant girth, leaf length, leaf width and leaf area index showed significant variation among tested genotypes.

The study suggested that, there is a vast scope for considerable crop improvement in okra through characters such as plant height, days to 1st flowering, days to 50% flowering, fruit weight, average fruit weight, fruits per plant, incidence of YVMV at different stages as well as fruit yield kg.

The given perusal of result (Table 4 and 5) indicate wide range of both phenotypic and genotypic variance for all the 17 characters.

Table.1 Mean performance of okra for vegetative growth and flowering parameters

Sl. no	Genotype	Plant height (cm)	Plant girth (cm)	Leaf Length (cm)	Leaf Width (cm)	Leaf Area Index (cm^2)	1st Flowering node	Days to first flowering	Days to 50% flowering
1.	2014\OKYVRES-1	96.71	6.50	16.19	13.16	264.29	7.60	29.00	35.00
2.	2014\OKYVRES-2	109.31	5.63	12.66	10.77	167.13	6.93	27.33	34.33
3.	2014\OKYVRES-3	87.533	5.94	13.61	10.80	121.25	6.67	26.00	34.33
4.	2014\OKYVRES-4	99.01	5.31	13.28	11.41	123.89	7.93	27.67	37.33
5.	2014\OKYVRES-5	84.77	5.18	13.97	13.87	179.37	6.93	30.00	37.67
6.	2014\OKYVRES-6	84.22	5.15	11.94	10.18	125.29	7.53	28.67	37.00
7.	2014\OKYVRES-7	104.56	4.79	13.28	15.11	155.92	7.67	29.33	36.33
8.	2014\OKYVRES-8	108.14	5.77	17.03	13.37	209.16	7.87	24.67	31.33
9.	2014\OKYVRES-9	111.72	5.12	13.04	11.49	124.40	7.40	27.67	36.67
10.	2014\OKYVRES-10	98.52	5.27	14.07	15.07	128.26	6.80	30.33	36.33
11.	2014\OKYVRES-11	110.28	5.81	14.26	18.52	203.00	7.27	25.67	36.33
12	Arka Abhay-C	104.20	5.48	13.32	11.47	128.22	7.63	30.33	36.33
13.	Arka Anamika-C	98.23	6.35	14.23	13.44	127.15	7.67	31.33	39.33
14.	VRO-6-C	114.03	6.22	11.81	15.68	125.67	6.87	28.00	34.00
	Grand mean	**100.80**	**5.61**	**13.76**	**13.17**	**155.93**	**7.34**	**28.29**	**35.88**
	SE(m)±	2.82	0.08	0.19	0.44	4.98	0.21	0.85	1.18
	CD(P=0.05)	8.18	0.24	0.55	1.26	14.46	0.61	2.47	3.45
	CV	4.84	2.62	2.40	5.73	5.53	5.01	5.21	5.72

Table.2 Mean performance of okra genotype for fruit yield attributing parameters

Sl. No	Genotype	Fruits $plant^{-1}$	Fruit Length	Fruit girth	Average fruit weight(g)	Yield (kg $plot^{-1}$)
1.	2014\OKYVRES-1	11.20	12.63	5.81	8.53	4.39
2.	2014\OKYVRES-2	12.00	12.56	5.74	8.73	4.22
3.	2014\OKYVRES-3	12.07	10.07	5.97	7.90	2.55
4.	2014\OKYVRES-4	11.87	13.33	5.88	8.40	3.29
5.	2014\OKYVRES-5	9.93	12.04	5.75	7.83	3.97
6.	2014\OKYVRES-6	9.60	11.59	5.85	7.43	2.90
7.	2014\OKYVRES-7	11.40	10.99	5.93	7.43	3.05
8.	2014\OKYVRES-8	10.33	12.70	5.86	7.30	3.61
9.	2014\OKYVRES-9	10.80	13.86	5.69	8.00	3.72
10.	2014\OKYVRES-10	9.80	13.13	5.79	8.13	3.58
11.	2014\OKYVRES-11	11.47	12.39	5.94	7.90	3.76
12	Arka Abhay-C	9.80	15.87	6.03	9.83	2.47
13.	Arka Anamika-C	10.20	13.41	5.80	8.73	2.96
14.	VRO-6-C	11.00	12.24	5.40	7.50	4.12
	Grand mean	**10.82**	**12.63**	**5.82**	**8.12**	**3.47**
	SE(m)±	0.60	0.78	0.10	0.32	0.35
	CD(P=0.05)	1.74	2.26	0.28	0.93	1.03
	CV	9.60	10.68	2.86	6.83	17.63

Table.3 Mean performance of okra genotypes against incidence of YVMV (%)

SL. No	Genotype	Days after incidence of YVMV				
		30	**45**	**60**	**75**	**90**
1.	2014\OKYVRES-1	1.30 (6.51)	26.80 (30.39)	43.3 (41.03)1000	61.23 (52.35)	66.75 (56.44)
2.	2014\OKYVRES-2	0.63 (5.33)	18.00 (24.45)	38.81 (37.90)	45.24 (41.83)	50.95 (45.45)
3.	2014\OKYVRES-3	0.00 (4.05)	0.00 (4.05)	0.74 (5.56)	0.74 (5.56)	2.96 (8.49)
4.	2014\OKYVRES-4	0.00 (4.05)	8.33 (14.20)	9.03 (14.69)	11.72 (17.80)	11.72 (19.80)
5.	2014\OKYVRES-5	0.00 (4.05)	0.00 (4.05)	0.62 (5.33)	0.62 (5.33)	1.26 (6.44)
6.	2014\OKYVRES-6	0.00 (4.05)	1.89 (7.29)	2.52 (8.59)	3.15 (9.32)	3.15 (11.08)
7.	2014\OKYVRES-7	0.00 (4.05)	32.30 (32.98)	63.40 (54.32)	71.80 (60.88)	76.51 (64.92)
8.	2014\OKYVRES-8	0.00 (4.05)	12.08 (17.92)	49.10 (44.48)	59.62 (50.55)	60.30 (50.95)
9.	2014\OKYVRES-9	0.00 (4.05)	5.15 (12.73)	8.45 (16.82)	11.11 (19.42)	12.48 (20.61)
10.	2014\OKYVRES-10	0.00 (4.05)	0.62 (5.33)	6.94 (12.61)	8.20 (13.51)	8.83 (13.93)
11.	2014\OKYVRES-11	0.00 (4.05)	0.69 (5.47)	0.70 (5.47)	1.38 (6.63)	1.39 (6.63)
12	Arka Abhay-C	0.64 (5.36)	15.14 (22.68)	24.64 (28.98)	30.90 (33.23)	34.09 (35.42)
13.	Arka Anamika-C	0.00 (4.05)	17.84 (24.43)	30.35 (33.08)	36.90 (37.21)	38.21 (38.02)
14.	VRO-6-C	0.65 (5.39)	40.00 (38.74)	68.33 (55.94)	73.00 (58.96)	78.17 (63.06)
	Grand mean	**4.51**	**17.48**	**26.05**	**29.47**	**31.51**
	SE(m)±	0.88	4.85	5.23	6.17	6.21
	CD(P=0.05)	-	14.08	15.18	17.94	18.05
	CV	34.16	48.01	34.71	36.28	34.12

N:BFigures in parentheses indicate corresponding angular values

Table.4 Estimation of coefficient of variance (C.V.) of different parameters in okra

SL.No	Characters	Range	General Mean	CV	GV	PV
1.	Plant height(cm)	84.22-114.03	100.80	4.84	90.21	114.01
2.	Plant girth(cm)	4.80-6.50	5.61	2.62	0.25	0.28
3.	Leaf Length(cm)	11.81-17.03	13.76	2.40	2.02	2.13
4.	Leaf Width(cm)	10.17-18.52	13.17	5.73	5.36	5.93
5.	Leaf Area Index(cm^2)	121.25-264.29	155.93	5.53	189.15	1965.43
6.	Nodes at which first flower appeared	6.67-7.93	7.34	5.01	0.14	0.27
7.	Days to first flowering	24.67-31.33	28.29	5.22	3.07	5.25
8.	Days to 50% flowering	31.33-39.33	35.88	2.72	2.42	6.64
9.	No. of fruits per plant	9.60-12.07	10.82	9.60	0.41	1.48
10.	Fruit length	10.07-15.87	12.63	10.68	1.26	3.08
11.	Fruit girth	5.40-6.03	5.82	2.86	0.01	0.04
12.	Average fruit weight(g)(average of 10 fruits $entry^{-1}$	7.30-9.83	8.12	6.83	0.37	0.68
13.	Fruit Yield kg $plot^{-1}$	2.47-4.39	3.47	17.63	0.25	0.63
14.	YVMV incidence 45DAS	4.05-38.74	17.48	48.01	112.89	183.32
15.	YVMV incidence 60 DAS	5.33-55.94	26.06	34.11	313.34	395.14
16.	YVMV incidence 75 DAS	5.33-66.80	29.47	36.28	394.65	508.98
17.	YVMV incidence 90 DAS	6.44-64.92	31.51	34.12	432.52	548.20

Table.5 Estimation of genetic parameter, heritability, genetic advance in okra

SL. No	Characters	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1.	Plant height(cm)	9.42	10.59	79.00	17.40	17.26
2.	Plant girth(cm)	8.99	9.37	92.00	0.99	17.78
3.	Leaf Length(cm)	10.33	10.61	94.00	2.85	20.73
4.	Leaf Width(cm)	17.57	18.48	90.00	4.53	34.41
5.	Leaf Area Index(cm^2)	27.89	28.43	96.00	87.87	56.35
6.	Nodes at which first flower appeared	5.01	7.08	50.00	0.54	7.29
7.	Days to first flowering	6.19	8.10	58.00	2.76	9.75
8.	Days to 50% flowering	4.33	7.18	36.00	1.93	5.38
9.	No. of fruits per plant	5.88	11.26	27.00	0.68	6.34
10.	Fruit length	8.88	13.89	41.00	1.48	11.69
11.	Fruit girth	2.04	3.51	34.00	0.14	2.45
12.	Average fruit weight(g)(average of 10 fruits $entry^{-1}$	7.48	10.13	54.00	0.12	11.38
13.	Fruit Yield kg $plot^{-1}$	14.46	22.81	46.00	0.65	18.90
14.	YVMV incidence 45DAS	60.28	77.45	61.00	17.17	98.25
15.	YVMV incidence 60 DAS	67.93	76.28	79.00	32.47	124.61
16.	YVMV incidence 75 DAS	67.40	76.55	77.00	36.03	122.27
17.	YVMV incidence 90 DAS	65.98	74.28	78.90	38.05	120.74

Table.6 Phenotypic correlation between all pairs of 18 characters in okra germplasm

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.000	0.469***	-0.250	0.003	0.2717	-0.101	0.293	-0.035	-0.228	-0.052	-0.201	-0.390*	0.011	0.216	0.077	-0.301	0.044	-0.086
2		1.000	-0.245	0.190	0.001	0.271	0.152	-0.213	-0.274	0.046	-0.270	-0.079	-0.204	-0.161	-0.338*	-0.245	-0.315*	-0.124
3			1.0000	0.100	0.268	-0.180	0.088	0.093	0.026	0.345*	0.067	0.179	0.118	0.468**	0.503***	0.462**	0.468**	0.248
4				1.000	0.228	0.295	0.183	-0.074	0.304*	-0.070	0.175	0.067	-0.035	0.080	0.175	0.322*	0.223	-0.018
5					1.000	0.159	0.564***	0.080	0.043	-0.083	-0.059	-0.316*	0.089	0.076	0.014	0.000	-0.013	-0.024
6						1.000	0.109	-0.255	0.241	-0.055	0.081	0.323*	-0.230	-0.231	-0.206	-0.089	-0.159	-0.354*
7							1.000	0.177	0.009	-0.279	-0.060	-0.019	0.109	0.099	0.005	0.062	0.051	-0.053
8								1.000	0.376*	0.125	0.336*	0.095	0.281	0.316*	0.251	0.263	0.263	0.186
9									1.000	0.211	0.719***	-0.034	0.078	-0.024	0.117	0.181	0.143	0.183
10										1.000	0.336*	0.003	-0.027	0.087	0.137	0.144	0.115	0.229
11											1.000	0.092	0.233	0.010	0.190	0.255	0.241	0.435**
12												1.000	-0.151	0.061	0.098	0.195	0.146	0.201
13													1.000	0.417**	0.296	0.195	0.280	0.039
14														1.000	0.902***	0.750***	0.877***	0.181
15															1.000	0.867	0.975	0.213
16																1.000	0.915	0.270
17																	1.00	0.247
18																		1.00

*Significant at 5% (p=0.05) **Significant at 1% (p=0.01) ***Significant at 0.1% (p=0.001)

1. Days to 1st flowering ; 2. Days to 50% flowering; 3. Plant height; 4. First flowering node; 5. Fruit length; 6. Fruit girth; 7. Average fruit weight; 8. Plant girth; 9. Leaf length; 10. Leaf width; 11. Leaf area index; 12. Fruits plant^{-1}; 13. 30 DAS YVMV %; 14. 45 DAS YVMV %; 15. 60 DAS YVMV %; 16.75 DAS YVMV %; 17. 90 DAS YVMV %; 18. Total yield (kg plot^{-1})

Table.7 Clustering pattern of 14 okra genotypes

Cluster No.	Number of Genotype(s)	Name of the genotypes
I	03	2014\OKYV RES-1, 2014\OKYV RES-8 2014\OKYV RES-11
II	02	2014\OKYV RES-2, VRO- 6
III	03	2014\OKYV RES-3, Arka Abhay, Arka Anamika
IV	06	2014\OKYV RES-4, 2014\OKYV RES-9 2014\OKYV RES-6, 2014\OKYV RES-7 2014\OKYV RES-5, 2014\OKYV RES-10

Table.8 Intra (Diagonal) and Inter cluster average(D^2) corresponding D values(in parenthesis)among groups(Euclidean^2: cluster distance: ward)

Cluster	I	II	III	IV
I	474.462(21.78)	751.533(27.41)	707.933(26.61)	708.226(26.61)
II		287.583(16.96)	427.350(20.67)	585.330(24.19)
III			162.163(12.73)	385.966(19.65)
IV				233.743(15.29)

Table.9 Mean of 18 characters in different clusters of okra genotypes

Sl. No.	Cluster Characters	I	II	III	IV
1.	Days to First Flowering	26.44	27.67	29.22	28.94
2.	Days to 50% Flowering	34.22	34.17	36.67	36.89
3.	Plant Height cm	105.04	111.67	96.66	97.14
4.	First Flowering Node	7.58	6.90	7.32	7.38
5.	Fruit Length cm	12.57	12.40	13.12	12.49
6.	Fruit Girth cm	5.87	5.57	5.93	5.81
7.	Average Fruit Weight	7.91	8.12	8.82	7.87
8.	Plant Girth (cm)	6.02	5.93	5.92	5.14
9.	Leaf Length (cm)	15.83	12.24	13.72	13.26
10.	Leaf Width (cm)	15.02	13.23	11.91	12.85
11.	Leaf Area Index (cm^2)	225.49	146.40	125.54	139.52
12.	Total Yield (Kg/Plot)	3.92	4.17	2.66	3.42
13.	Fruits/ Plant	11.00	11.50	10.69	10.57
14.	30 DAS YVMV % (ASIN)	4.87	5.36	4.49	4.06
15.	45 DAS YVMV % (ASIN)	17.93	31.60	17.05	12.77
16.	60 DAS YVMV % (ASIN)	30.33	46.92	22.54	18.73
17.	75 DAS YVMV % (ASIN)	36.51	50.40	25.33	21.04
18.	90 DAS YVMV % (ASIN)	38.01	54.26	27.31	22.80

Table.10 Direct (diagonal and bold) and indirect effects of 11 component traits on fruit yield in 14 okra genotypes

	1	2	3	4	5	6	7	8	9	10	11
1	**0.089**	-0.022	0.012	-0.019	-0.0142	-0.029	-0.023	-0.028	0.000	0.025	-0.005
2	-0.024	**0.095**	0.008	0.011	0.045	0.049	0.044	0.045	0.026	-0.016	0.018
3	-0.013	-0.077	**-0.091**	-0.010	-0.011	-0.002	-0.005	-0.005	-0.053	-0.012	0.000
4	-0.001	0.001	0.001	**0.004**	0.001	0.001	0.001	0.001	0.001	-0.001	-0.001
5	0.019	-0.058	-0.014	-0.046	**-0.120**	-0.108	-0.095	-0.106	-0.012	0.029	-0.008
6	0.179	-0.276	-0.012	-0.145	-0.485	**-0.537**	-0.482	-0.526	-0.011	0.118	-0.050
7	-0.001	0.002	0.000	0.001	0.004	0.005	**0.006**	0.005	0.000	-0.000	0.001
8	-0.244	0.360	0.043	0.200	0.673	0.748	0.709	**0.764**	-0.003	-0.123	0.117
9	0.001	0.014	0.031	0.006	0.005	0.001	0.000	-0.000	**0.054**	-0.009	-0.018
10	-0.132	0.080	-0.057	0.103	0.110	0.101	0.035	0.074	0.078	**-0.456**	-0.142
11	-0.019	0.059	-0.000	-0.043	0.020	0.293	0.068	0.049	-0.105	0.097	**0.315**
12	-0.147	0.248	-0.078	0.062	0.231	0.257	0.259	0.272	-0.025	-0.347	0.228

RESIDUAL EFFECT = 0.84251. Days to 50% flowering 2. Plant Height cm 3.Average Fruit Weight 4.30 DAS YVMV % (ASIN) 5.45 DAS YVMV % (ASIN) 6. 60 DAS YVMV % (ASIN) 7. 75 DAS YVMV % (ASIN) 8.90 DAS YVMV % (ASIN) 9.Fruit Length cm 10. Fruit Girth cm 11.Fruits/ Plant 12. Total Yield (Kg/Pl)

Fig.1 Phenotypical path diagram for fruit yield (kg/plot)

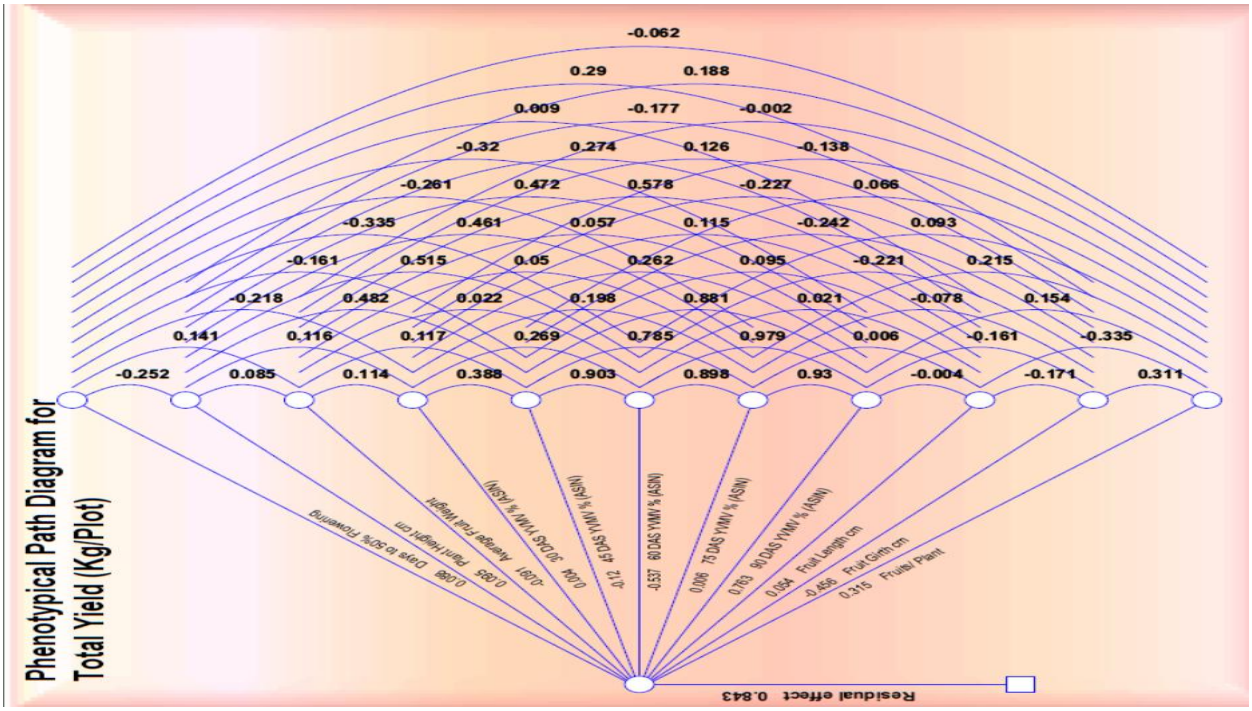
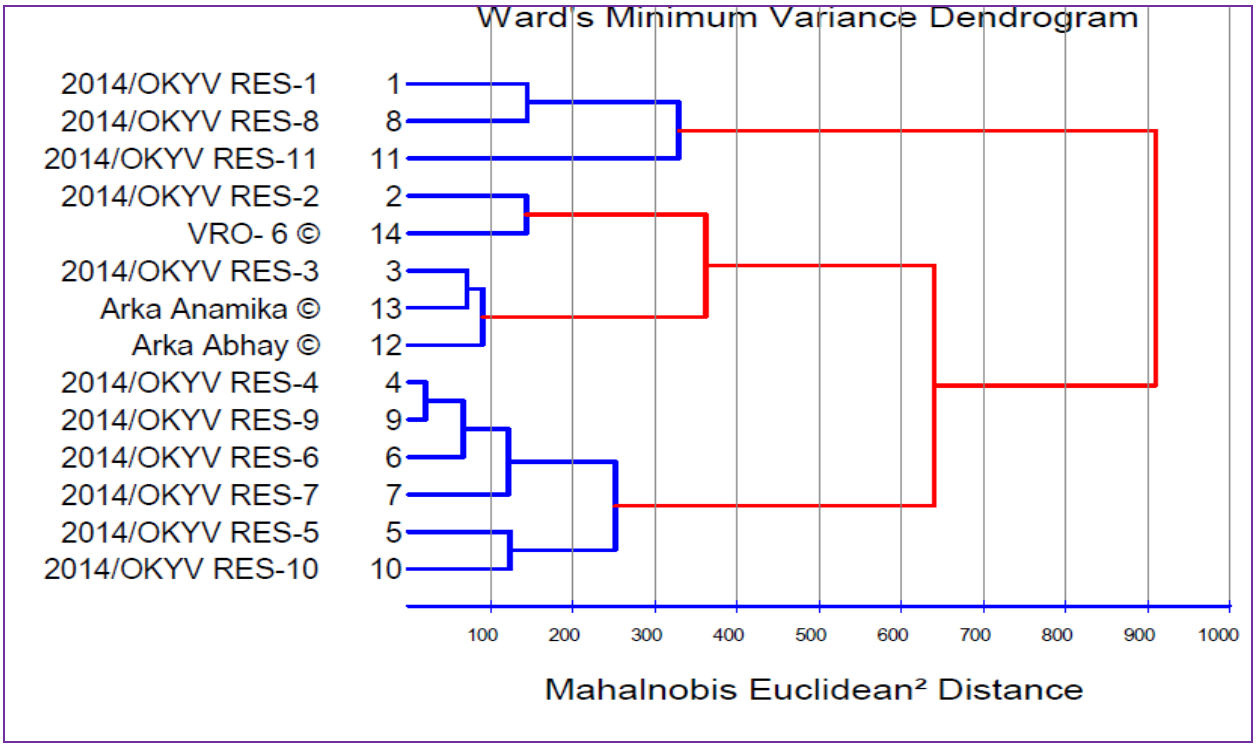


Fig.2 Clustering of fourteen genotypes



The difference between PV and GV was minimum for plant girth, fruit girth, average fruit weight, fruit yield and YVMV incidence at 45 and 60 DAS indicating least influence by environment. Similarly, relatively higher difference was observed for plant height, leaf area index, flowering parameters and incidence of YVMV at 75 and 90 DAS indicating the major part was contributed through additive interaction instead of dominant and epistatic component. Khan *et al.,* (2005) also observed similar trend for various characters which are present in the result. The presence of high to moderate GCV for leaf width, leaf area index and YVMV incidence at 45, 60, 75 and 90 DAS clearly indicates the presence of wide variability among the tested genotype. Hence selection for these characters may be useful in crop improvement. The present result seems very close to the findings of Khajuria *et al.,* (2016). The result of present study indicated that high heritability of above 60% have been obtained for vegetative parameter as well as incidence of YVMV at every stages, which clearly suggested that these characters might be highly heritable and less influenced by environment. In the present study, high heritability coupled with high GA for plant height, leaf area index and incidence of YVMV at 45, 60, 75 and 90 DAS, indicating that these traits are simply inherited characters, even most of them are under polygenic control, but these traits could be improved through simple selection method. Therefore, these traits can be attributed to additive gene action regulating their inheritance and the phenotypic selection for their improvement could be achieved by adopting simple selection method (Panse, 1957). The results also indicted that these above characters not only showing relatively high heritability and GAM (%) but also relatively high values of GCV than rest of the characters under study altogether. Therefore, direct selection through these characters will be effective for improvement in okra especially to develop a genotype having tolerance and/or resistance to YVMV. Similar reports of high values of three genetic parameters has been reported in okra by Mehta *et al*., (2006) for fruit yield and Mishra *et al.,* (2015) for most of the traits in okra.

Study on character association

The results on phenotypic correlation (Table 6) clearly suggested that there was a strong inheritance association between the various characters in okra. A strong positive association of character with yield may be attributed to linkage and pleiotropy (Sparque, 1966).In the present study, significant and positive correlation observed for Fruit yield with leaf area index. On the other hand, the fruit yield was significant but negatively correlated with fruit girth. These results clearly suggested that selection for these component traits simultaneously will effective in improving the fruit yield in okra. The interesting result revealed that at 30 DAS, the incidence of YVMV was significantly and negatively correlated with number of fruits plant^{-1}than 45, 60, 75 and 90 DAS suggesting for effective screening of okra genotype against YVMV, selection should be done at 30 DAS only. Similar observation of reduction of YVMV with increase in age of okra seedlings were reported by Pun *et al*., (1999) and Khaskheli *et al*., (2017).

Direct and indirect effect of characters

The correlations of fruit yield with other characters were partitioned into components of direct and indirect effect that would reflect on the nature of these associations and the relative importance of the components in determining the fruit yield (Fig 1). Hence, in order to study, the direct and indirect effects of various plant characters on okra fruit yield are presented in (Table 7). The results revealed that maximum positive direct effect

was contributed by YVMV incidence at 90 DAS on the fruit yield (kg/plot) of okra. Further fruit length, fruits per plant, days to 50% flowering, plant height and YVMV incidence at 30 and 75 DAS also produced. positive direct effect of lower magnitude. On contrary YVMV incidence at 60 DAS had negative direct effect on fruit yield, YVMV incidence at 45DAS, fruit girth and average fruit weight also have negative effect on fruit yield. The low positive and negative direct effect resulted might be due to cancellation by the respective indirect effects via these characters. The indirect effect of plant height, YVMV incidence at all stages have contribution towards a good yield. The present findings are in parallel with Bhaleker *et al.,* (2005) with the opinion that plant free from YVMV and having a good height, long fruits and more no. of fruits yielded maximum in okra. Similarly Gangashetty *et al.,* (2010) also reported that high fruit yield have high path coefficient for fruits plant^{-1}, fruit weight and plant height. The results of present study also indicated that plant height, days to 50% flowering, fruitsplant^{-1},fruit length and lower incidence of YVMV upto 60 DAS had considerable direct contribution towards fruit yield in okra. High indirect effects to these traits are also observed. Thus, during screening of genotypes against YVMV under field conditions in okra, importance should be given to isolate the superior types at least within 60 DAS, to develop the superior genotypes with higher fruit yield potential and having resistance and/or tolerance to YVMV. Here these findings are more or less similar to the findings of Narkhede *et al.,* (2015).

Study on genetic divergence

14 genotypes were grouped into 4 different genetic clusters on the basis of intra and inter cluster distance (Fig. 2). The results indicated that all the genotypes were grouped into four different clusters, comprising three genotypes including checks in Cluster I, two genotypes including checks in Cluster II, three genotypes including checks in Cluster III and rest are in Cluster IV (Table 8). From the present investigation, the average inter-cluster distance revealed that the most divergent clusters were cluster I and II, followed by cluster IV and I and cluster III and I (Table 9). So promising hybrid derivatives can be obtained by crossing parents of these divergent groups probably because of complementary interaction among genetically divergent parents. From the performance study, it was clearly demonstrated regarding the superiority of 2014\OKYVRES-1 with respect to fruit yield and tolerance to YVMV under field condition which are grouped in cluster- I. Similarly, the best two lines isolated with resistance to YVMV were 2014\OKYVRES-2 and VRO-6 from cluster-II. Thus, the development of hybrids by utilizing cluster I and II will not only produce the genotypes having desirable quantitative parameters but also resistance and/or tolerance to YVMV in okra. Similar reports have been reported by Prakash and Pitchaimuthu (2010), Prakash Keure (2010), Mishra *et al.,* (2015) and Ramgiry *et al.,* (2017) in okra which is similar to our findings of present investigation.

Characteristics features of four clusters

The cluster means of 18 characters for 4 clusters of okra genotypes are presented in Table 10, It indicted that cluster I consisting of three genotypes having highest value in1st flowering node (7.58), plant girth (6.02), leaf length (15.83), leaf width (15.02) and leaf area index (225.49) with minimum days to first flowering (26.44). For rest of the character moderate expression were observed. Similarly, cluster II having two genotype showed the maximum values for plant height (111.67), YVMV incidence at 30,45,60,75 and 90 DAS with minimum value for fruit

length (12.40), fruit girth (5.57), leaf length (12.24). Rest characters have moderate expression. The cluster III with three genotypes showed the maximum values for days to 1st flowering (29.22), fruit length (13.12), fruit girth (5.93), average fruit weight (8.82) with minimum value 2.66 for total yield. Rest characters have moderate expression.

The cluster IV with six genotype showed maximum value for days to 50% flowering (36.89) with minimum values for plant girth (5.14), fruits per plant (10.57), YVMV incidence at 30,45,60,75 and 90 DAS. The rest of the character shows moderate expression.

The genotype 2014\OKYVRES-5 and 2014\OKYVRES-11 were identified as most resistant line with low incidence of YVMV disease at all the stages of crop growth. Similarly, the genotypes VRO-6 and 2014\OKYVRES-1 was identified as most superior genotype with significant highest fruit yield and showed tolerance to YVMV upto 30 to 45 DAS. These genotypes may be further utilized in hybrid breeding programme as parent material for improvement in yield and YVMV resistance in okra. Information on genetic diversity and population structure will be essential for providing further insight into the breeding history and genetic relationship of crop germplasm.

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How to cite this article:

Niraja Rani Patra, Niharika Jyotirekha Nayak and Baisakh, B. 2018. Evaluation of Elite Genotypes for YVMV Resistance in Okra [*Abelmoschus esculentus* (L.) Moench]. *Int.J.Curr.Microbiol.App.Sci.* 7(12): 594-608. doi: https://doi.org/10.20546/ijcmas.2018.712.074