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Heterosis of okra resistance sources for *okra yellow vein mosaic virus* (*OYVMV*) in okra (*Abelmoschus esculentus*)

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ABSTRACT

Fifty one hybrids of okra [*Abelmoschus esculentus* (L.) Moench] were generated by crossing between seventeen lines and three testers. Seventy one (20 parents + 51 hybrids) genotypes were used for screening against *okra yellow vein mosaic virus (OYVMV)* in open field condition and studied the heterosis for disease resistance and associated yield traits during rainy season and summer season of 2007 and 2008. The disease pressure of OYVMV was high in rainy season crop because of high humidity and rainfall along with more multiplication of whiteflies. Eight parents (VRO 5, VRO 6, AC 108, Arka Abhay, EC 305612, IIVR 435, IIVR 401 and SA 2) and 30 and 33 F_1 crosses were found highly resistant for OYVMV disease during both rainy and summer season. Summer season crop was more producible for number of fruits and fruit yield/plant than rainy season crop due to low disease incidence. Those crosses which involved the parents IIVR 198, SA 2, Arka Abhay, AC 108, and VRO 5, gave better heterosis performance for disease resistance and associated yield traits.

Key words: Heterosis, Okra, OYVMV resistance, Yield traits

Okra [*Abelmoschus esculentus* (L.) Moench] is placed in Malvaceae family and originated in tropical Africa but can be grown in tropical and sub-tropical regions of the world (Ali *et al.* 2012). It is a most edible vegetable crop and popular for its green tender fruits grown throughout India during summer and rainy seasons (Solankey *et al.* 2013). India is the largest producer of okra in the world with the total area 0.533 million ha, production of pods 6.346 million tonnes and productivity 11.9 metric tonnes/ha (Anonymous 2014). Among the various biotic diseases yellow vein mosaic virus is a most serious disease and caused substantial yield losses (80-90%) in okra crops (Sastry and Singh 1974, Ali *et al.* 2005). The disease is characterized by a homogenous knotted, yellow veins and yellowish or creamy color of green leaf, stunted plant growth and bear very few deformed small fruits (Ali *et al.* 2005, 2012). This YVMV disease of okra spread in the humid and heavy rainfall areas and transmitted by a vector whitefly (*Bemisia tabaci* Gen.) belonging to genus begomovirus and family of geminivireadea (Chakraborty *et al.* 1999). A cultivar Pusa Sawani developed as a tolerant to YVMV by using a resistance gene from strain IC-1542 (Singh and Joshi 1960) but now days this is indicated to be susceptibile for this disease. In a study it was found that the infection rate has reached up to 100% if field yield loss ranges between 50% and 94% (Ali *et al.* 2011). Today, availability of little resistance stock of cultivars/varieties of okra is available which may be due to change of strain in virus (Singh *et al.* 1962). The major problem in okra cultivation is lack of high-yielding varieties along with location specific and resistant/tolerant hybrids. The transfer of OYVMV resistant gene through breeding has another best way of getting resistant and high yielding cultivars/variety in often cross-pollinated crops like okra, which is need of breeders (Nerkar and Jambhale 1985). Heterosis is a special genetic mechanism wherein the distant genotypes are brought together in a specific pattern to express their ability to make a dramatic shift in the magnitude of a particular trait (Mehta *et al.* 2007). Heterosis breeding may be a successful approach in okra, where the heterosis for yield and its components were extensively studied (Verma and Sood 20015) but it is still for resistance study. Seeing the importance of this YVMV disease in okra crop, the present investigation was conducted with the objective to screen diverse okra genotypes and F_1 hybrids against OYVMV under rainy and summer seasons in field condition, to determine the heterotic response of F_1's against disease and yield traits.

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MATERIALS AND METHODS

Experimental materials comprised 20 genotypes of okra (Table 2), received from gene bank of Indian Institute of Vegetable Research, Varanasi. Selected genotypes were evaluated in open field and crossed in 'line (17) × tester (3)' mating design. A total of 51 F_1 crosses were made. All the 71 entries were evaluated in a randomized block design with three replications during the two cropping seasons (rainy and summer) of 2007 and 2008 at the Vegetable Research Farm, Department of Hoticulture, Institute of Agricultural Science, Banaras Hindu University, Varanasi. This institute is located near Ganga River at 25.1^0 N latitude, 83.3^0 E longitude and an altitude of 123.23 msl. Each replication was taken three rows for each entry of 10 plants with spacing of 60 cm between rows to row and 45 cm between plant to plant, respectively. The standard agronomical cultural practices were followed throughout years of the crop season. No insecticide or pesticide was used.

During the screening the OYVMV disease incidence was scored on 0-4 scale (Table 1). Data was recorded at 15 days intervals (30 day, 45 day, 60 day and 75 days) from 2 to 4 leaf stages of plants. Percent disease incidence (PDI), response value (RV) and coefficient of infection (CI) were calculated by given formula of Banerjee and Kaloo (1987).

$$PDI = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

$$CI = RV \times PDI$$

where, PDI = percent disease incidence, RV = response value, CI= coefficient of infection.

The environmental emphasis and disease incidence was considered for two years of different season, viz. rainy and summer, when the average temperature was 29.7 and 30.2; rainfall was 45.5 and 1.4; relative humidity was 69.2 and 35.7 and PDI value was 99.3 and 85.3 (Fig 1).

Only those horticultural data were recorded which were directly affected by *okra yellow vein mosaic virus* (*OYVMV*), for example, plant height, number of fruits/plant and fruit yield/plant. These data were recorded for all the entries (51 F_1's and 20 parents) during harvesting period of the crops. The magnitude to heterosis as the difference in F_1s performance over better parent in percentage was presented as per Singh *et al.* (1996) and calculated by using following formula:

$$BPH \text{ (Better Parent Heterosis) } \% = (F_1 - BP) \div BP \times 100$$

RESULTS AND DISCUSSION

In 20 parental lines, 8 parents (VRO 5, VRO 6, AC 108, Arka Abhay, EC 305612, IIVR 435, IIVR 401 and SA 2) were found highly resistant in both rainy and summer season (Table 2). However, four genotypes, IIVR 342, IC 140906, Arka Anamika and Parbhani Kranti were resistant in rainy season and highly resistant during summer season. Five parents (IC 128883, IC 45806, IC 218844, IC 140934 and Pusa Sawani) exhibited highly susceptible reaction during the both seasons. Another study by Bhagat (2000) was in conformity with our study, he also reported that the variety Pusa Sawani expressed the highly susceptible reaction against yellow vein mosaic virus. Similar studies for screening of resistant and susceptible against okra yellow vein mosaic virus disease has been reported by many workers (Bhagat 2000, Anand *et al.* 2007 and Bhattiprolu and Rahman 2008, Ali *et al.* 2012). Among the 51 F_1 crosses, 30, 6 and 1 were highly resistant, resistant and moderately resistant, respectively in rainy season. Whereas, in summer season number of F_1 crosses was 33 (highly resistant), 10 (resistant) and 6 (moderately resistant). This was also observed that a total 30 and 3 F_1's were found as a common for highly resistant and resistant during both rainy and winter season (Table 3). It is remarkable to note that high resistance in the crosses is due to the presence of resistance in respective parents for yellow vein mosaic virus (Jambhale and Nerkar 1981). Similar study of resistant and susceptible stories in okra F_1's were reported by Jambhale and Nerkar

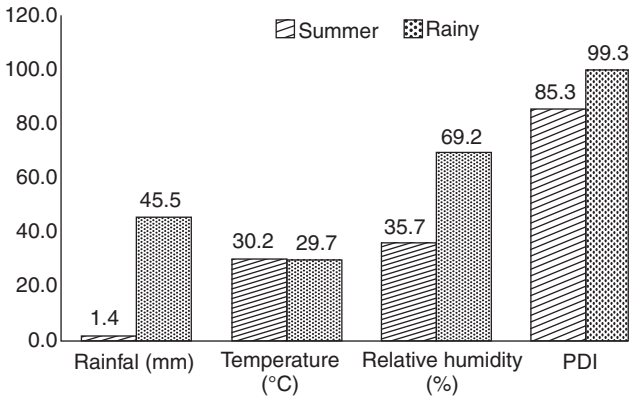

Fig 1 Response of climate change on OYVMV disease incidence

Table 1 Scale for classifying disease reaction in okra to YVMV disease

Symptoms	Severity grade	Response value	Coefficient of infection	Reaction
Symptoms absent	0	0	0 – 4	HR
Very mild symptoms up to 25% leaves	1	0.25	4.1 – 9	R
Appearance of disease between 26-50% leaves	2	0.50	9.1 – 19	MR
Symptom between 51-75% leaves	3	0.75	19.1 – 39	MS
Severe disease infection at 75% leaves	4	1.00	39.1 – 69	S
Above 75% leaves	>4	>1.00	69.1 – 100	HS

HR= Highly resistant, R= Resistant, MR= Moderately resistant, MS= Moderately susceptible, S= Susceptible, HS= Highly susceptible.

Table 2 Disease incidence for yellow vein mosaic virus in parents of okra during rainy and summer season

Genotypes	Season	Severity grade	Response value	Per cent of disease infection	Coefficient of infection	Reaction
IC 128883	Rainy	4	1.00	95.67	95.67	HS
	Summer	4	1.00	78.00	78.00	HS
VRO 5	Rainy	1	0.25	4.33	1.08	HR
	Summer	1	0.25	2.67	0.67	HR
VRO 6	Rainy	1	0.25	6.67	1.67	HR
	Summer	1	0.25	3.00	0.75	HR
AC 108	Rainy	1	0.25	4.00	1.00	HR
	Summer	1	0.25	3.33	0.83	HR
IC 45806	Rainy	4	1.00	99.00	99.00	HS
	Summer	4	1.00	79.00	79.00	HS
IC 218877	Rainy	4	1.00	95.00	95.00	HS
	Summer	3	0.75	74.00	55.50	S
IC 218844	Rainy	4	1.00	97.67	97.67	HS
	Summer	4	1.00	82.00	82.00	HS
Arka Abhay	Rainy	1	0.25	8.33	2.08	HR
	Summer	1	0.25	1.67	0.42	HR
IC 43720	Rainy	4	1.00	97.33	97.33	HS
	Summer	2	0.50	38.00	19.00	MR
IIVR 342	Rainy	1	0.25	16.67	4.17	R
	Summer	1	0.25	8.33	2.08	HR
IC 140906	Rainy	1	0.25	19.67	4.92	R
	Summer	1	0.25	15.67	3.92	HR
IIVR 198	Rainy	2	0.50	39.00	19.50	MS
	Summer	1	0.25	17.33	4.33	R
EC 305612	Rainy	1	0.25	15.33	3.83	HR
	Summer	1	0.25	14.33	3.58	HR
IIVR 435	Rainy	1	0.25	15.67	3.92	HR
	Summer	1	0.25	12.67	3.17	HR
IIVR 401	Rainy	1	0.25	15.00	3.75	HR
	Summer	1	0.25	8.67	2.17	HR
SA 2	Rainy	1	0.25	11.33	2.83	HR
	Summer	1	0.25	6.33	1.58	HR
IC 140934	Rainy	4	1.00	99.33	99.33	HS
	Summer	4	1.00	85.33	85.33	HS
Arka Anamika	Rainy	1	0.25	20.33	5.08	R
	Summer	1	0.25	1.33	0.33	HR
Pusa Sawani	Rainy	4	1.00	81.67	81.67	HS
	Summer	4	1.00	76.00	76.00	HS
Parbhani Kranti	Rainy	1	0.25	19.33	4.83	R
	Summer	1	0.25	7.00	1.75	HR

HR= Highly resistant, R= Resistant, MR= Moderately resistant, MS= Moderately susceptible, S= Susceptible, HS= Highly susceptible.

(1981), Ali *et al.* (2000, 2012), Debnath and Nath (2002), Debnath and Nath (2003) and Prabhu and Warade (2007).

In present study it was found that a large number of parents and F_1's were in the range of moderately resistant to highly resistant and few parents and F_1's were in the range of moderately susceptible to highly susceptible disease reaction in summer season and rainy season (Table 2 and 3). This was indicated that the disease pressure was low in summer and high in rainy season (Fig 1). This may be due to that summer season was not favorable to disease development and multiplication of whiteflies as well as the rainy season was good and suitable for survival of vector whiteflies. The incidence of the disease in a particular crosses and parents varied from season to season, it may be due to the influence in the environmental conditions. Contrary to our results Singh (1990) reported that hot weather with little rainfall was favorable for disease development of OYVMV and also for multiplication of *Bemisia tabaci*. Earlier it was also reported that the incidence of OYVMV disease was higher during the rainy

Table 3 Disease incidence for yellow vein mosaic virus in hybrids (F1's) during rainy (R) and summer (S) season

Coefficient of infection and reaction	No. of F_1's in rainy seasons	Name of F_1's hybrid in rainy seasons	No. of F_1's in summer seasons	Name of F_1's hybrid in summer seasons
0 – 4.0 (HR)	30	VRO - 5 × AA, VRO - 5 × PS, VRO- 5 × PK, VRO - 6 × PK, AC - 108 × AA, AC - 108 × PS, AC - 108 × PK, IC - 45806 × AA, IC - 45806 × PS, IC - 45806 × PK, IIVR-342 × PK, IC - 140906 × AA, IC - 140906 ×PS, IC-140906 × PK, IIVR-198 × AA, IIVR-198 × PS, IIVR-198×PK, EC-305612 × AA, EC - 305612 × PS, EC - 305612 × PK, IIVR-435 × AA, IIVR-435 × PS, IIVR-435 × PK, IIVR-401 × AA, IIVR-401 × PS, IIVR-401 × PK, SA - 2 × AA, SA - 2 × PS, SA - 2 × PK, IIVR-342 × AA	33	VRO - 5 × AA, VRO - 5 × PS, VRO - 5 × PK, VRO - 6 × PK, AC - 108 × AA, AC - 108 × PS, AC - 108 × PK, IC - 45806 × AA, IC - 45806 × PS, IC - 45806 × PK, IIVR-342 × PK, IC - 140906 ×AA, IC - 140906 × PS, IC - 140906 × PK, IIVR-198 × AA, IIVR-198 × PS, IIVR-198 × PK, EC - 305612 × AA, EC - 305612 × PS, EC - 305612 × PK, IIVR-435 × AA, IIVR-435 × PS, IIVR-435 × PK, IIVR-401 × AA, IIVR-401 × PS, IIVR-401 × PK, SA - 2 × AA, SA - 2 × PS, SA - 2 × PK, IIVR-342 × AA, VRO-6 × AA, VRO-6 × PS, Arka Abhay × AA
4.1 – 9.0 (R)	6	VRO - 6 × AA, VRO - 6 × PS, IC-218844 × PK, Arka Abhay × AA, Arka Abhay × PK, IC - 140934 × PK	10	IC - 128883 × AA, IC - 128883 × PK, IC - 218877 × AA, IC - 218877 × PK, IC - 218844 × PK, Arka Abhay × PK, IC - 43720 × AA, IC - 140934 × AA, IC - 140934 × PS, IC - 140934 × PK
9.1 – 19.0 (MR)	1	IC - 128883 × PK	6	IC-128883 × PS, IC- 218877 × PS, IC-218844 × AA, Arka Abhay × PS, IC - 43720 × PS, IC-43720 × PK
19.1–39.0 (MS)	12	IC-128883 × AA, IC - 218877 × AA, IC-218877 × PS, IC-218877 × PK, IC-218844 × AA, Arka Abhay × PS, IC - 43720 × AA, IC-140934 × AA, IC-140934×PS, IC-43720 × PS, IC - 43720 × PK, IIVR-342 × PS	2	IC-218844 × PS, IIVR-342 × PS
39.1– 69.0 (S)	2	IC-128883 × PS, IC-218844 × PS	0	
69.1–100 (HS)	0	Nil	0	

Arka Anamika= AA; Pusa Sawani= PS; Parbhani Kranti= PK; HR = Highly resistant, R = Resistant, MR = Moderately resistant, MS = Moderately susceptible, S = Susceptible, HS = Highly susceptible.

Table 4 Heterosis of 'L × T' for seven characters of best five crosses in okra during rainy and summer seasons of two years

Characters	F_1's of rainy season	BPH	F_1's of summer season	BPH
CI (OYVMV)	IIVR-198 × PK	-94.82**	SA-2 × PK	-97.17**
	SA-2 × PK	-93.99**	IIVR-198 × PK	-96.48**
	SA-2 × AA	-91.17**	SA-2 × AA	-93.99**
Plant height	IIVR-198 × AA	20.28**	IIVR-198 × AA	11.03*
	IIVR-198 × PK	19.24**	IIVR-198 × PK	10.40*
	Arka Abhay × AA	17.12**	IIVR-401 × PK	9.56*
Number of fruits/plant	EC - 305612 × PS	26.10**	IIVR-198 × PK	61.27**
	AC - 108 × PK	20.59**	IC - 140906 × PK	49.51**
	VRO - 5 × PK	17.77*	IC - 43720 × PS	31.75**
Fruit yield/plant (g)	VRO - 5 × PS	37.80**	Arka Abhay × AA	55.00**
	AC - 108 × PS	36.59**	EC - 305612 × AA	48.20**
	EC - 305612 × PS	35.01**	AC - 108 × AA	37.76**

*Significant at 5%; **Significant at 1%; BPH= better parent heterosis; Arka Anamika= AA; Pusa Sawani= PS; Parbhani Kranti= PK; HR= Highly resistant, R= Resistant, MR= Moderately resistant, MS= Moderately susceptible, S= Susceptible, HS= Highly susceptible.

season when relative humidity was very high in support of our findings (Sangar 1997, Bhagat *et al.* 2001).

The exploitation of heterosis over better parents is considered as one of the desirable, sustainable and eco-friendly approach. Among the 71 genotypes (51 F_1's and 20 parents) used for study of heterosis with four variables (CI of OYVMV, plant height, number of fruits/plant, fruit yield/plant). Only three best hybrids selected for each trait according to their highest heterosis performance in both rainy and summer seasons (Table 4).

The highest heterosis over better parent for coefficient of infection (CI) of OYVMV disease was observed during rainy and summer season in the crosses of SA 2 × Arka Anamika (-91.17 and -93.99), SA 2 × Parbhani Kranti (-93.99 and -97.17) and IIVR 198 × Parbhani Kranti (-94.82 and -96.48). The negative and low heterosis for OYVMV was an indication of the resistance of okra crop. These identified resistant F_1 crosses indicated that the resistance gene was dominant over susceptibility of disease and controlled by a single dominant gene (Thakur 1976, Ali *et al.* 2000, 2012).

Among the 51 F_1s, two best crosses IIVR 198 × Arka Anamika and IIVR 198 × Parbhani Kranti showed highest and positive significant heterosis over better parents for the plant height during both rainy and summer season. Whereas, the cross combination Arka Abhay × Arka Anamika (17.12) in rainy season and IIVR 401 × Parbhani Kranti (9.56) in summer season showed positive heterosis over better parent for plant height (Table 4). Rewale *et al.* (2003), Mehta *et al.* (2007) and Verma and Sood (2015) reported high heterotic value for this trait. Most of the crosses exhibited good amount of heterosis over better parents for number of fruits/plant because this trait is one of the most important characters for yield in okra. The crosses EC- 305612 × PS (26.10%), AC-108 × Parbhani Kranti (20.59%) and VRO-5 × Parbhani Kranti (17.77%) had high magnitude of heterosis over better parent in rainy season while in summer season the crosses 198 × Parbhani Kranti (61.27%), IC-140906 × Parbhani Kranti (49.51%) and IC-43720 × PS (31.75%) for number of fruits/plant. Rewale *et al.* (2003), Mehta *et al.* (2007), Weerasekara *et al.* (2008) and Solankey *et al.* (2013) also reported the similar result for number of fruits per plant in okra. Nowadays, production of high yielder okra varieties/hybrids made an important target to okra breeders and farmers in each season. Among the crosses, VRO-5 × Pusa Sawani (37.80), AC-108 × Pusa Sawani (36.59), EC-305612 × Pusa Sawani (35.01) showed positive and highly significant heterosis over better parent in rainy season for fruit yield/plant. Whereas, in summer season the crosses of Arka Abhay × Arka Anamika (55.00), EC-305612 × Arka Anamika (48.20), AC-108 × Arka Anamika (37.76) were observed positive and highly significant heterosis over better parent for fruit yield/plant. These are in accordance with the findings of Rewale *et al.* (2003), Weerasekara *et al.* (2008), Solankey *et al.* (2013) and Verma and Sood (2015).

We showed that the summer season crop was more productive for number of fruits and fruit yield/plant than rainy season crop. It may be due to low disease incidence in okra crop during summer season (Sangar 1997, Bhagat *et al.* 2001). It was also observed that the crosses IIVR-198 × Parbhani Kranti, SA-2 × Parbhani Kranti, SA-2 × Arka Anamika, IIVR-198 × Arka Anamika, EC - 305612 × Arka Anamika, AC - 108 × Pusa Sawani, Arka Abhay × Arka Anamika and VRO - 5 × Pusa Sawani produced higher plant height, number of fruit and fruit yield per plant as well as resistant to OYVMV disease. This may be due to the multiplicative interaction of parents enhanced to yield capacity or presence of OYVMV resistance/tolerance gene in hybrids (Thakur 1976, Ali *et al.* 2000).

Therefore it can be concluded that the 8 parents and 33 F_1 crosses were found highly resistant for OYVMV disease during both rainy and summer screening season. The disease pressure was highest in rainy season due to more multiplication of whiteflies. Among the 51 F_1 crosses, only hybrids showed highest heterosis over better parents for OYVMV disease and associated yield traits which were crossed by the parents IIVR 198, SA 2, Arka Abhay, AC 108, and VRO 5. Summer season crop was high yield producible due to low disease incidence in okra. These parents and hybrids which were given good response for resistance and heterosis percent can be used in resistant breeding programme for enhancement of required yield.

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