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PHENOTYPIC SCREENING OF OKRA HYBRIDS AGAINST YELLOW VEIN MOSAIC DISEASE AND SHOOT AND FRUIT BORER UNDER FIELD CONDITIONS

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ABSTRACT

The present study aimed to phenotypically screen the okra hybrids and their parents so as to identify tolerant or resistant genetic material against yellow vein mosaic disease (YVMD) and okra shoot and fruit borer (OSFB). The present study included a total of 55 single cross hybrids, 16 parents, and one hybrid check "OH-102" which were evaluated during monsoon 2019 at three locations (Navsari, Achhalia, and Vyara) in Gujarat (India) in RBD design. The number of plants and fruits affected in each genotype was counted at final harvest and percent incidence calculated for YVMD and SFB. Okra genotypes were screened to know their response on the basis of plant and fruit damage severity scale. Among 72 genotypes (55 hybrids + 11 lines + 5 testers), none was free from YVMD and SFB incidence. Among the parents, 'Arka Anamika' and 'Arka Abhay', categorized as moderately resistant to YVMD and SFB at all test locations, were identified as the most promising donors for future breeding. Among 55 hybrids and check 22, 17, and 14 hybrids and check "OH-102" categorized as moderately resistant for YVMD, 15, 13, 9 hybrids for Okra Shoot Borer (OSB) and 13, 15, 16 hybrids for Okra Fruit Borer (OFB) and check "OH-102" categorized as fair resistance at Navsari, Achhalia and Vyara, respectively. The least YVMD and OSFB incidence in hybrids showed relatively high/ average yield performance for fruit yield per plant at all locations, so these can be used in the further future breeding program.

Keywords: *Abelmoschus esculentus*, disease intensity, okra, shoot and fruit borer, yellow vein mosaic virus, yield

INTRODUCTION

Yellow vein mosaic disease (YVMD) causes substantial yield loss (80-90%) in okra or bhindi [*Abelmoschus esculentus* (L.) Moench] which can occur at all crop growth stages (Ali *et al.*, 2005; Das *et al*., 2013). YVMD is a major limitation in okra production in India. This disease is caused by a complex comprising of monopartite begomovirus bhindi yellow vein mosaic virus (BYVMV, family: Geminiviridae) and a small satellite DNA beta component (Jose and Usha, 2003). In India, the virus was reported by Kulkarni from Mumbai (Kulkarni, 1924). The virus is now prevalent in all okra-growing regions of the world. In India, 100% infection of YVMD in the field is quite usual with yield losses ranging from 50 to 94% (Shetty *et al*., 2013; Markam *et al.*, 2017). In Pakistan, yield losses of up to 84% on the susceptible varieties, and in Ghana >50% disease incidence in okra farms have been reported (Mubeen *et al.*, 2021). YVMD spreads fast in humid and heavy rainfall areas and is transmitted by the vector whitefly (*Bemisia tabaci* Gen.), a severe pest of many crops in the world (Mubeen *et al.,* 2021). Okra cv. 'Pusa Sawani' was developed as tolerant to BYVMV using a resistance gene from line 'IC-1542' (Singh and Joshi, 1962) but now is characterized as susceptible to YVMD. It was found that the infection rate reached up to 100% and field yield loss ranged between 50 and 94% (Ali *et al.*, 2012).

Apart from viruses, several other insect pests attack on okra such as okra shoot and fruit borer (OSFB), jassid, aphid, whitefly, and cotton leaf roller. Among these pests, OSFB (*Earias vittella* Fab.) is considered the most important damaging pest (Aziz *et al*., 2011) which causes quantitative and qualitative loss of okra. Unfortunately, okra is the worst sufferer of shoot and fruit borer (*Earias vittella*) infestation, which is the main bottleneck for the cultivation of this crop. Under different agro-climatic conditions, the losses may vary from 10.1 to 50.0% and shoot and fruit borer alone causes damage up to 71% (Pareek and Bhargava, 2003). In general, the overall pod damage is about 49% reported (Kanwar and Ameta, 2007) and up to 100% of fruits may be damaged by okra shoot and fruit borer (Radake and Undirwade, 1981). When the crop is young, larvae bore into tender shoots and tunnel downwards which wither, drop down, and growing points are killed. In fruits, the larvae bore inside these and feed on inner tissues which become deformed in shape with no market value. The infested fruits become unfit for human consumption, thus resulting in 35 to 76% decrease in yield and causing severe damage to the crop leading with yield losses to the extent of 35-90% (Narayanan *et al*., 2016; Patel *et al.*, 2021).

Okra is a highly cross-pollinated crop and can be exploited for the production of F_1 hybrids. Heterosis leads to an increase in yield, adaptability, disease and insect resistance, general vigour, and quality. Knowledge of varietal preference based on resistance against YVMD and tolerance against okra shoot and fruit borer can play a vital role in successful okra production and management in the future. Unfortunately, limited efforts have been done in this direction and the major problem of low production in okra cultivation appears due to the lack of location-specific high-yielding varieties/hybrids and lack of resistant or tolerant varieties/hybrids against okra YVMD and SFB (Narayanan *et al.,* 2016; Patel *et al.*, 2021). The transfer of okra BYVMV resistance gene and OSFB tolerance gene through breeding is another way of developing resistant, high-yielding, hybrids/varieties in cross-pollinated crops like okra. In Gujarat, the south Gujarat region is a humid and heavy rainfall area and is most famous for okra cultivation, but the major problems in this belt are high YVMC incidence and SFB infestation (Jethava, 2014). To overcome this problem, there is a need to design a farmer participatory breeding program and develop location-specific varieties/hybrids which are resistant/ tolerant against okra YVMC and SFB. To develop strong varieties/ hybrids, screening of okra genetic biodiversity for the identification of resistant sources of YVMV disease resistance and OSFB tolerance is the first step in a breeding program. To generate a new genetic variation by hybridization among the available genetic resources, it is necessary to increase the genetic base of cultivated okra (Reddy, 2011; Das *et al.*, 2013; Devi *et al.*, 2020; Patel *et al.*, 2021). Selection of suitable parents and assessment of the degree of incidences of insect pests in resulting crosses form an important step in the development of new F_1 hybrids (Duggi *et al.*, 2013). Although many researchers have worked on screening okra against YVMD and OSFB, still a lot is needed to characterize the okra genotypes against viruses and OSFB. Keeping this in view, the present study aimed to screen okra hybrids for resistance or tolerance against YVMD and okra shoot and fruit borer (OSFB) under natural field conditions at three locations which might be important for the management of this disease and pests.

MATERIALS AND METHODS

A total 55 F_1 hybrids were derived by crossing 11 lines and 5 testers using Line X tester mating design during August 2018 at the Regional Horticulture Research Station, NAU, Gujarat (India).

Seventy two okra genotypes among them 11 lines (AOL-12-52, AOL-12-59, AOL-13-73, AOL-12-144, AOL-12-133, AOL-14-32, JOL-69-05, JOL-11-12, JOL-13-05, JOL-14-10 and JDNOL-11-12), 5 testers (GJO-3, GAO-5, Parbhani Kranti, Arka Anamika and Arka Abhay), 55 derived F_1 hybrids and one standard check (Syngenta based Okra Hybrid, OH-102, Source: *https://www.syngenta.co/product/seed/okra/oh-102*) were screened against the YVMD incidence and shoot and fruit borer under natural field conditions with three replications in a randomized block design at the three locations *viz.*, Agricultural University at Navsari, (Gujarat), Cotton Sub-Research Station at Achhalia (Gujarat) and Regional Rice Research Station at Vyara, (Gujarat) during August 2019. The size of the plots was 1.2 x 3 m^2 and seeds were sown at a spacing of 60 x 30 cm. The crop was raised following all standard agronomical practices and no chemical pesticides were used. Analysis of variance (ANOVA) for different location data and pooled data over the locations were estimated using statistical software OPSTAT developed by Sheoran *et al.* (2020). The YVMD incidences were recorded on 5 randomly selected plants with respect to the number of plants affected at seven days intervals. The average YVMD incidence was calculated at the final harvest stage, the number of plants affected in each genotype was counted and expressed in percentage by using the following formula of Ali *et al.* (2005).

$$\text{YVMD incidence (\%)} = \frac{\text{Number of plants infected by YVMV}}{\text{Total number of plants}} \text{ X } 100$$

The scale for YVMD resistance was related to the severity range (SR). A SR of 0% indicated immune (0), 1-10% indicated highly resistant (1), 11-25% indicated moderately resistant (2), 26-50% indicted tolerance (3), 51-60% indicated moderate susceptibility (4), 61-70% indicated susceptible and 71-100% indicated highly susceptible. The observations on the shoot and fruit borer were recorded on 5 randomly selected plants with respect to shooting damage till the flowering stage, while flower and fruit damage was recorded till the fruiting and final harvesting stage, respectively, at 7 days intervals. The average percentage damage and intensity of damage to shoot and fruit were calculated by counting damaged shoots and fruits on selected plants in each plot and counting the total number of shoots and fruits on selected plants, respectively. The shoot and fruit damages were calculated by adopting the following formulae of Rai and Satpathy (1998) and Narayanan *et al.* (2016).

$$\text{Shoot borer incidence (\%)} = \frac{\text{Number of plants infected by shoot borer}}{\text{Total number of plants}} \text{ X } 100$$

$$\text{Fruit borer incidence (\%)} = \frac{\text{Number of fruits infected by fruit borer}}{\text{Total number of fruits}} \text{ X } 100$$

The category for shoot and fruit borer resistance was related to shoot and fruit infestation percentage. An infestation 0% indicated immune (1), 0.1-10% indicated highly resistant (2), 10.1-20% indicated fairly resistant (3), 20.1-30% indicated tolerance (4), 30.1-40% indicated susceptible (5), 40.1% and above indicated highly susceptible (6).

RESULTS AND DISCUSSION

Pooled analysis of variance over locations revealed that variance due to the location was highly significant for YVMD and SFB incidence, which indicated that location was effective in influencing the performance of genotypes. ANOVA revealed that the mean squares of genotypes differed significantly for YVMD and SFB incidence at an individual as well as pooled over locations, which indicated the presence of a considerable genetic variability among genotypes (Table 1 & 2).

The interaction between genotype and location for YVMD was insignificant which implies that the interaction was absent indicating that the genotypes behaved independently over locations. Inter-

Table 1: Analysis of variance for YVMD and shoot & fruit borer incidence in okra at various locations

Source of variation	D.F.	YVMD incidence (%)			Shoot borer incidence (%)			Fruit borer incidence (%)		
	Location	Navsari	Achhalia	Vyara	Navsari	Achhalia	Vyara	Navsari	Achhalia	Vyara
Replication	2	309.76	726.50	100.00	281.56	403.24	237.50	17.17	14.25	57.16
Genotype	71	775.25**	689.54**	579.01**	198.49**	228.94**	249.53**	198.38**	174.99**	148.33**
Error	142	184.28	218.24	135.78	113.29	111.22	74.59	22.65	10.67	8.86

*,** Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Table 2: Analysis of variance for YVMD, shoot and fruit borer incidence in okra of pooled data over the location

Source	DF	YVMD incidence (%)	Shoot borer incidence (%)	Fruit borer incidence (%)
Location (L)	2	1042.78**	833.64**	174.17**
Replication	2	378.76	307.43	29.53
Genotype (G)	71	1818.00**	351.41**	446.82**
G × L	142	112.90	162.78**	37.44**
Pooled Error	426	179.44	99.70	14.06

*,** Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

action effect for shoot borer and fruit borer incidence was significant, which indicated that the locations had influenced SFB incidence and all genotypes reacted differentially to different locations (Table 2). The data presented in Tables 4 and 5 shows the percent incidence of YVMD and OSFB; and reaction with yield in okra genotype at different locations.

Yellow vein mosaic disease incidence: The range and percent disease intensity and the reaction of different geno-types to YVMD was recorded under field conditions (Tables 3 and 4). YVMD intensity among parents varied from 13.3 (Arka Abhay) to 63.3% (AOL-12-144), 20.0 (Arka Anamika) to 63.3% (AOL-14-32) and 23.3 (Arka Abhay) to 63.3% (AOL-12-52) at Navsari, Achhalia and Vyara, respectively. YVMD intensity among hybrids varied from 13.3 (JOL-11-12 x Arka Anamika, JOL-11-12 x Arka Abhay, JDNOL-11-12 x Arka Anamika) to 66.7% (AOL-13-73 x Parbhani Kranti, AOL-12-133 x GJO-3), 13.3 (AOL-12 133 x Arka Anamika, AOL-12-133 x Arka Abhay, JOL-69-05 x Arka Anamika) to 63.3% (JOL-69-05 x Parbhani Kranti) and 20.0 (AOL-14-32 x Arka Anamika, JOL-69-05 x Arka Abhay, JOL-14-10 x Arka Anamika, JOL-14-10 x Arka Abhay) to 66.7% (JOL-69-05 x GJO-3, JOL-11-12 x Parbhani Kranti) at Navsari, Achhalia and Vyara, respectively.

None of the parents and hybrids was found free from YVMD incidence (Table 4). Among parents, Arka Anamika and Arka Abhay were categorized as moderately resistant against YVMD, whereas among 55 hybrids, 22, 17 and 14 hybrids were categorized as moderately resistant against YVMD at Navsari, Achhalia and Vyara, respectively. The standard check 'OH-102' was moderately resistant at Navsari and Achhalia, while at Vyara it was found tolerant against YVMD. In the present study, many hybrids exhibited low percent damage against YVMD. Similar finding for YVMD incidence and reaction with okra yield performance have previously been reported by Nirosha *et al.*

Table 3: The range of YVMD and SFB damage incidence in okra genotypes at various locations

Genotypes	Yellow vein mosaic disease incidence (%)			Shoot borer damage incidence (%)			Fruit borer damage incidence (%)		
	Navsari	Achhalia	Vyara	Navsari	Achhalia	Vyara	Navsari	Achhalia	Vyara
Parents									
Minimum	30.00	40.00	43.33	26.67	23.33	26.67	26.08	24.69	19.48
Maximum	63.33	63.33	63.33	46.67	46.67	50.00	46.51	40.20	38.14
Hybrids									
Minimum	13.33	13.33	20.00	13.33	13.33	13.33	14.53	14.64	14.64
Maximum	66.67	63.33	66.67	46.67	46.67	50.00	46.70	41.89	40.12
$CD_{0.05}$	21.91	23.84	18.81	26.48	17.02	13.94	24.49	5.87	4.80
SEM±	7.84	8.53	6.73	9.47	6.09	4.99	8.76	1.89	1.72

(2015), Rynjah *et al.* (2018), Kumar and Tayde (2018), and Patel *et al.* (2021).

Shoot borer damage intensity: The shoot borer damage intensity among parents varied from 16.0 to 46.7%, 16.7 to 46.7% and 16.7 to 50.0% at Navsari, Achhalia and Vyara, respectively. In the case of hybrids, shoot borer damage intensity varied from 13.3 to 46.7%, 13.3 to 46.7%, and 13.3 to 50.0% at Navsari, Achhalia and Vyara, respectively. None of the parents or hybrids was free from shoot borer damage incidence (Table 4). Among parents, Arka Anamika and Arka Abhay were identified as fairly resistant against shoot borer damage intensity at Navsari, Achhalia and Vyara. Among 55 hybrids, 15, 13 and 9 hybrids were categorized as fairly resistant against shoot borer damage intensity at Navsari, Achhalia and Vyara, respectively; and the standard check "OH-102" was categorized as fairly resistant at Navsari and Achhalia, while at Vyara it was categorized as tolerant against shoot borer damage. Parents 'AOL-14-32' and 'JOL-11-12' at Navsari, 'AOL-12-133' and 'JOL-13-05' at Achhalia and 'AOL-12-59', 'AOL-13-73', 'AOL-12-144'¸ 'AOL-12-133', 'AOL-14-32' and 'Parbhani Kranti' at Vyara were categorized as highly susceptible against shoot borer damage intensity. Among 55 hybrids, 3, 2 and 5 hybrids were categorized as highly susceptible against shoot borer damage intensity at Navsari, Achhalia and Vyara, respectively.

Table 4: Reaction of okra genotypes to yellow vein mosaic disease (YVMD) and okra shoot borer (OSB) incidence (based on shoot damage) and okra fruit borer (OFB) incidence (based on fruit damage) at Navsari, Achhalia and Vyara in Gujarat (India)

Rating scale and reaction	Severity range (%)	Navsari		Achhalia		Vyara	
		Parent	Hybrid	Parent	Hybrid	Parent	Hybrid
		Yellow vein mosaic disease intensity (%)					
(0) Immune	0	None	None	None	None	None	None
(1) Highly resistant	01-10	None	None	None	None	None	None
(2) Moderately resistant	11-25	2	23	2	18	2	14
(3) Tolerant	26-50	7	22	8	36	4	36
(4) Moderately susceptibility	51-60	6	7	2	12	9	18
(5) Susceptibility	61-70	1	4	4	6	1	4
(6) Highly susceptibility	71-100	None	None	None	None	None	None
		Okra shoot borer intensity (%)					
(1) Immune	0	None	None	None	None	None	None
(2) Highly resistant	0.1-10	None	None	None	None	None	None
(3) Fairly resistant	10.1-20	2	16	2	14	2	9
(4) Tolerant	20.1-30	3	21	4	26	2	28
(5) Susceptible	30.1-40	9	16	8	14	6	14
(6) Highly susceptible	40.1 and above	2	3	2	2	6	5
		Okra fruit borer intensity (%)					
(1) Immune	0	None	None	None	None	None	None
(2) Highly resistant	0.1-10	None	None	None	None	None	None
(3) Fairly resistant	10.1-20	2	14	3	16	3	17
(4) Tolerant	20.1-30	4	24	6	24	3	26
(5) Susceptible	30.1-40	8	14	6	14	10	12
(6) Highly susceptible	40.1 and above	2	4	1	2	None	1

Fruit borer damage intensity: The fruit borer damage intensity among parents varied from 17.8 (Arka Abhay) to 46.5% (AOL-13-73), 15.4 (Arka Abhay) to 40.2% (AOL-13-73) and 16.3 (Arka Anamika) to 38.1% (AOL-12-133) at Navsari, Achhalia and Vyara, respectively. The fruit borer damage intensity among hybrids varied from 14.5 (AOL-12-144 x Arka Abhay) to 46.7% (AOL-13-73 x Parbhani Kranti), 14.64 (JOL-69-05 x Arka Anamika) to 41.89% (AOL 12-59 x Arka Anamika) and 14.64 (JOL-69-05 x Arka Anamika) to 40.12% (AOL-12-133 x Parbhani Kranti) at Navsari, Achhalia and Vyara, respectively. None of the genotypes was free from fruit borer damage incidence (Table 4). Among parents, Arka Anamika and Arka Abhay at Navsari, GAO-5, Arka Anamika and

Arka Abhay at Achhalia and AOL-12-144, Arka Anamika and Arka Abhay at Vyara were categorized as fair resistance against fruit borer damage intensity. Among 55 hybrids and check, 13, 15 and 16 hybrids were categorized as fair resistance against fruit borer damage intensity at Navsari, Achhalia and Vyara, respectively. Standard check “OH-102” was categorized as fairly resistant against fruit borer damage at all test locations. Parents *viz.*, AOL-13-73 and JOL-11-12 at Navsari, AOL-13-73 at achhaliawere categorized as highly susceptible to fruit borer damage. Among 55 hybrids, 4, 2 and 1 hybrids were categorized as highly susceptible to fruit borer damage at Navsari, Achhalia and Vyara, respectively. Many hybrids showed lesser % damage against okra shoot and fruit borer. Similar finding for incidence of the shoot and fruit borer and reaction with okra yield performance has previously been reported in okra by Gautam *et al.* (2014), Patel (2015), Dave and pandya (2017), Khan *et al.* (2017), Navneet and Tayde (2018) and Patel *et al.* (2021).

Out of the 72 genotypes screened, none genotype was free from YVMD and shoot and fruit borer incidence. Among parents, Arka Anamika and Arka Abhay was categorized as moderately resistant against YVMD, shoot and fruit borer at Navsari, Achhalia and Vyara. Parents exhibited moderately resistant or tolerant reactions so were identified as the most promising donors to develop varieties/hybrids resistant or tolerant against YVMD and shoot and fruit borer. Among 55 hybrids, 22, 17 and 14 hybrids at Navsari, 15, 13 and 9 hybrids at Achhalia and 13, 15 and 16 hybrids at Vyara were categorized as moderately resistant against YVMV, shoot borer and fruit borer, respectively. So, these hybrids can be commercialized in okra growing zones due to high yield and low disease and pest incidence and may be exploited in further okra yield improvement programs, adaptability, reproducibility, disease and insect resistance, general vigor, and quality.

The yield performance and disease/insect reaction of high-yielding hybrids are presented in Table 5. The high-yielding hybrids JOL-14-10 x Arka Abhay and JOL-14-10 x GJO-3 were moderately

Table 5: YVMD and shoot & fruit borer incidence reaction on high-yielding hybrids of okra at Navsari, Achhalia and Vyara, Gujarat, India

Navsari	Yield plant^{-1} (g)	DI/SBI/FBI (%)	Rxn	Achhalia	Yield plant^{-1} (g)	DI/SBI/FBI (%)	Rxn	Vyara	Yield plant^{-1} (g)	DI/SBI/FBI (%)	Rxn
				YVMD incidence (%)							
JOL-14-10 x Arka Abhay	310.96	20.00	MR	JOL-14-10 x GJO-3	335.60	23.33	MR	JOL-13-05 x GJO-3	282.84	33.33	T
-	-	-	-	JDNOL-11-12 x GAO-5	320.34	30.00	T	AOL-12-144 x GJO-3	275.07	46.67	T
-	-	-	-	AOL-12-52 x Arka Anamika	310.22	16.67	MR	-	-	-	-
				Shoot borer incidence (%)							
JOL-14-10 x Arka Abhay	310.96	26.67	T	JOL-14-10 x GJO-3	335.60	26.67	T	JOL-13-05 x GJO-3	282.84	30.00	T
-	-	-	-	JDNOL-11-12 x GAO-5	320.34	26.67	T	AOL-12-144 x GJO-3	275.07	30.00	T
-	-	-	-	AOL-12-52 x Arka Anamika	310.22	20.00	MR	-	-	-	-
				Fruit borer incidence (%)							
JOL-14-10 x Arka Abhay	310.96	15.83	MR	JOL-14-10 x GJO-3	335.60	17.05	MR	JOL-13-05 x GJO-3	282.84	23.39	T
-	-	-	-	JDNOL-11-12 x GAO-5	320.34	21.48	T	AOL-12-144 x GJO-3	275.07	17.56	MR
-	-	-	-	AOL-12-52 x Arka Anamika	310.22	16.97	MR	-	-	-	-

DI: YVMD incidence (%), SBI: Shoot borer incidence (%); FBI: Fruit borer incidence (%), Rxn = Reaction; MR: Moderately resistant, T: Tolerant, and S: Susceptible resistant to YVMD and fruit borer, and tolerant to shoot borer at Navsari and Achhalia, respectively. The highest yielding hybrid JOL-13-05 x GJO-3 was reported as tolerance for YVMD, shoot borer and fruit borer at Vyara. In the present study, the least per cent YVMD and shoot and fruit borer incidence in hybrids showed relatively high/average yield performance for fruit yield plant^{-1} at all locations. The parents and hybrids which exhibited moderately resistant or tolerant reactions may be used in future breeding programs to develop varieties/hybrids which are highly location specific and highly resistant or tolerant reactions against YVMD and shoot and fruit borer infestation. Similar findings were observed by Reddy *et al*. (2011), Patel (2015), Kumar and Tayde (2018) and Patel *et al*. (2021) for YVM disease reaction and Patel (2015), Navneet and Tayde (2018) and Patel *et al.* (2021) for the shoot and fruit borer infestation.

Conflict of interest: The authors declare that they have no competing interests.

Author's contributions: Akshay I. Patel conceptualized the idea of developing F1 hybrids, evaluating them for YVMD in different hotspot locations of Gujarat, and finalization of screening methods and analysis of data. R.D. Vekariya collected & analyzed the data and prepared the manuscript. Arpita A. Patel collaborated with R.D. Vekariya and Akshay I. Patel in the finalization of the paper.

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