Screening of okra genotypes across environments for resistance against shoot and fruit borer, yellow vein mosaic virus and enation leaf curl virus under natural field conditions

Abstract:

India is a key player in okra production with Andhra Pradesh leading state in cultivation. However, the crop faces significant challenges from Yellow Vein Mosaic Virus (YVMV) and enation leaf curl virus (ELCV) which severely impact yield and quality. The study conducted at the Vegetable Research Farm, Regional Horticultural Research Station, evaluated 37 okra genotypes for resistance against these biotic stresses. The genotypes, including 8 parents and 28 hybrids were assessed under three different environments in a Randomized Block Design. The results revealed that none of the genotypes were immune to shoot and fruit borer infestation, YVMV and ELCV. However, some hybrids demonstrated resistance or tolerance to these stresses with the top three hybrids displaying high levels of resistance against shoot and fruit borer infestation, moderate resistance against YVMV and high tolerance to ELCV. Nevertheless, none of the hybrids showed consistent immunity across all environments.

Introduction:

Okra (*Abelmoschus esculentus* L. Moench) is one of the most important & extensively cultivated vegetable and commonly known as "*bhendi*", lady's finger or "*gumbo*". It is native of Tropical Africa. Okra belongs to genus *Abelmoschus* of malvaceae family. It is cultivated in tropical, subtropical and warm temperate regions around the world like India, Africa, Turkey and other neighboring countries. India ranks first in area and production for about 72 % of the total area under okra in the world. In India, 63.7 lakh MT of okra is produced from an area of 5.1 lakh ha with an overall productivity of 12 MT ha^{-1} (Anon., 2021[a])[3]. Major okra producing states are Andhra Pradesh, West Bengal, Bihar and Orissa. Andhra Pradesh is the leading state with 20% of production in India. It is also grown as an important vegetable crop in the State of Gujarat with a production of 9.4 lakh tones from an area of 7.7 lakh hectare (Anon., 2021[b])[4]. It is mainly cultivated in Surat, Tapi, Gandhinagar, Vadodara, Anand, Dahod, Banaskantha, Navsari, Chhotaudaipur and Panchmahal districts of Gujarat, among them highest area and production in Surat, whereas maximum productivity in Dang district.

Apart from yield, an important challenge would be to develop a variety/hybrid which responds well to resources and resistant to yellow vein mosaic virus. Although okra is subjected to attack by many insect pests, the fruit borer (*Earias spp.*) is the major pest causing damage to the extent of 3.5-90 % (Krishnaiah *et al.*, 1976). Yellow Vein Mosaic Virus (YVMV) is a devastating viral disease transmitted through white fly (*Bemisia tabaci*) in okra. YVMV belongs to the genus Begomovirus, family Geminiviridae. This viral disease causes colossal losses in the crop by affecting the quality and yield of the fruits. 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. Currently, productivity of cultivated okra is gradually decreasing in the tropics due to infection by the begomovirus, enation leaf curl virus (ELCV) which has other hosts also grown in the regions. ELCV was first reported from Indian Institute of Horticultural Research, Hesarghatta, Bengaluru (Karnataka) by Singh and Dutta, (1986)[23]. ELCV disease causes yield loss between 80 per cent and 90 per cent (Singh, 1996)[22] and is widely emerging as an important threat to production and there is a need to evolve resistance against the causal virus.

Frequent pickings, high operational cost and residues of pesticides entering food chain are the limiting factors for chemical control of this disease. Use of synthetic pesticides for managing pests and diseases is the immediate and most practiced method by the farmers but, okra being a vegetable with shorter harvesting intervals, poses residual hazards to the consumers. Therefore, emphasis is now been shifted in favour of host plant resistance, particularly insect and disease resistant/tolerant varieties are more economical and environmentally safe (Sanford and John, 1994)[6]. Hence, development of high yielding and tolerant/resistant varieties is the major necessity. Interspecific and intervarietal hybridization followed by selection have been adopted to develop high yielding and resistant varieties. However, frequent breakdown of resistance of most of the resistant varieties is a matter of concern and this needs continuous attention of the breeders.

The information on previous disease and insect screening results over the years may assist us in understanding the status and development of disease or insects over the years and also different methods employed in screening the genotypes. Screening genetic biodiversity of okra for identification of resistant genotypes and employing them in the crop improvement programme is an important step of disease resistance breeding. Therefore, there is an urgent need to develop okra hybrids which show resistance/ tolerance against these biotic stresses. Thus, in the present study, 37 genotypes of okra comprising 8 parents, their 28 hybrids and one commercial check GJOH-4 was carried out under three different environments to evaluate against OFSB infestation, infection of YVMV and ELCV under natural condition.

Material and Methods:

The experimental material was developed at Vegetable Research Farm, Regional Horticultural Research Station, NAU, Navsari during *Kharif* 2022 by crossing 8 parents using Half Diallel design. The evaluation programme was carried out under three consecutive environments *viz.*, sowing in 15th February, 2023 (E_1), 1st March, 2023 (E_2) and 15th March, 2023 (E_3) during summer 2022 (evaluation). The experiment was conducted in Randomized Block Design (RBD) with three replications which included 37 genotypes comprising of 8 parents (GNO-1, GAO-5, NOL-21-12, NOL-21-23, NOL-21-37, NOL-21-40, NOL-21-54 and NOL-21-84); their resultant 28 hybrids and one standard check 'GJOH-4'.

For shoot borer, the number of plants infected from the total plant in each genotypes were counted and expressed in percentage after 45 days of sowing by using the following formula:

$$\text{Shoot borer infestation (\%)} = \frac{\text{number of pods infested by shoot borer}}{\text{total number of pods observed}} \times 100$$

For fruit borer number of fruit damaged from total no. of fruits in each treatment was counted and expressed in *percent* at each harvesting using the following formula:

$$\text{Fruit borer infestation (\%)} = \frac{\text{number of pods infested by fruit borer}}{\text{total number of pods observed}} \times 100$$

For YVMV, it was calculated on the basis of number of plants infected with YVMV from total number of plants in parents, hybrids and standard check in percentage of incidence was calculated.

$$\text{YVMV incidence (\%)} = \frac{\text{number of plants infected by YVMV}}{\text{total number of plants observed}} \times 100$$

For ELCV, number of plants affected in each plot were counted and expressed in percentage by using the following formula:

$$\text{ELCV incidence (\%)} = \frac{\text{number of plants infected by ELCV}}{\text{total number of plants observed}} \times 100$$

Results and Discussion:

The results obtained by screening of 37 genotypes on the basis of per cent pest infestation under field condition for shoot borer and fruit borer incidence is mentioned in Table 4 and 5, respectively. Among the parents, intensity of shoot borer incidence ranged between 3.33 (NOL-21-84) to 16.67 per cent (GNO-1 and NOL-21-40) in E_1, 6.67 (NOL-21-84) to 20.00 per cent (GNO-1, NOL-21-23, NOL-21-40 and NOL-21-54) in E_2, 10.00 (NOL-21-84) to 23.33 per cent (NOL-21-12 and NOL-21-54) in E_3 and among hybrids, it varied between 3.33 (NOL-21.23 × NOL-21-54; NOL-21-23 × NOL-21-40) to 23.33 per cent (NOL-21-12 × NOL-21-37) in E_1, 6.67 (NOL-21-23 × NOL-21-54; NOL-21-23 × NOL-21-84) to 23.33 per cent (GNO-1 × NOL-21-40; NOL-21-23 × NOL-21-37) in E_2, 10.00 (GNO-1 × NOL-21-12; NOL-21-23 × NOL-21-37 and NOL-21-23 × NOL-21-40) to 30.00 per cent (GAO-5 × NOL-21-12; GAO-5 × NOL-21-37; GAO-5 × NOL-21-40; NOL-21-12 × NOL-21-23 and NOL-21-12 × NOL-21-40) in E_3.

Among the parents, intensity of fruit borer incidence ranged between 9.37 (NOL-21-40) to 17.70 per cent (GNO-1) in E_1, 11.27 (NOL-21-54) to 17.70 per cent (NOL-21.12) in E_2, 15.27 (GAO-5) to 20.80 per cent (NOL-21-23) in E_3 and among hybrids, it varied between 6.27 (NOL-21-12 × NOL-21-84) to 21.47 per cent (GNO-1 × NOL-21-12) in E_1, 9.57 (GAO-5 × NOL-21-23) to 22.53 per cent (NOL-21-40 × NOL-21-54) in E_2, 9.07 (NOL-21-23 × NOL-21-54) to 22.96 per cent (NOL-21-54 × NOL-21-23) in E_3.

Out of the 37 genotypes, none of the genotypes were free from shoot and fruit borer incidence. Among parents, NOL-21-84; GNO-1; GAO-5 and NOL-21-37 for shoot borer when GNO-1; GAO-5 and NOL-21-12 for fruit borer were found to perform better. Among 28 hybrids, eleven in E_1, six in E_2 and three in E_3 exhibited highly resistant reaction against shoot borer, five in E_1, one in E_2 and two in E_3 exhibited highly resistant reaction against fruit borer. However, many hybrids showed lesser damage (in per cent) against okra shoot and fruit borer. Lesser incidence of okra shoot and fruit borer was also observed in okra by Afzal *et al.* (2015)[1], Dave and Pandya (2017)[6], Mouli and Tayde (2017)[14], Jalgaonkar *et al.* (2018)[7], Kumar and Tayde (2018[b])[12], Subbireddy *et al.* (2018)[24], Raghuwanshi *et al.* (2019)[18], Vekariya (2019)[25], Patel (2015)[17], Jayanth (2021)[9] and Sakariya (2022)[21].

The results obtained by screening of 37 genotypes on the basis of per cent disease incidence under field condition for YVMV and ELCV are mentioned in Table 6 and 7, respectively. Among the parents, YVMV intensity varied between 13.33 (GAO-5) to 30.00 per cent (NOL-21-54 and NOL-21-84) in E_1, 10.00 (NOL-21-37) to 23.33 per cent (NOL-21-12) in E_2, 10.00 (NOL-21-37 and NOL-21-40) to 30.00 per cent (NOL-21-84) in E_3. Among hybrids, it ranged from 3.33 (NOL-21-40 × NOL-21-54) to 36.67 per cent (GAO-5 × NOL-21-12) in E_1, 10.00 (GAO-5 × NOL-21-84) to 50.00 per cent (NOL-21-23 × NOL-21-37) in E_2, 10.00 (GNO-1 × NOL-21-37; GNO-1 × NOL-21-54; NOL-21-12 × NOL-21-37; NOL-21-12 × NOL-21-40 and NOL-21-40 × NOL-21-84) to 36.67 per cent (AOL-10-22 × GAO-5 × NOL-21-40) in E_3.

Among the parents, ELCV intensity varied between 00.00 (NOL-21-23; NOL-21-37 and NOL-21-54) to 20.00 per cent (GNO-1) in E1, 3.33 (NOL-21-84) to 30.00 per cent (NOL-21-54) in E_2, 16.67 (NOL-21-40) to 30.00 per cent (GAO-5) in E_3 whenever in hybrids, it ranged from 00.00 (GAO-5 × NOL-21-40; NOL-21-12 × NOL-21-23; NOL-21-23 × NOL-21-37; NOL-21-37

× NOL-21-54; NOL-21-37 × NOL-21-84 and NOL-21-54 × NOL-21-84) to 13.33 per cent (GNO-1 × NOL-21-54; GNO-1 × NOL-21-84; GAO-5 × NOL-21-12; GAO-5 × NOL-21-37; GAO-5 × NOL-21-54 and NOL-21-23 × NOL-21-84) in E_1, 0.00 (GAO-5 × NOL-21-84) to 23.33 per cent (GAO-5 × NOL-21-12; NOL-21-12 × NOL-21-54 and NOL-21-37 × NOL-21-54) in E_2, 10.00 (GNO-1 × NOL-21-84; NOL-21-12 × NOL-21-23 and NOL-21-12 × NOL-21-84) to 33.33 per cent (NOL-21-37 × NOL-21-54) in E_3.

Out of the 37 genotypes, none of the genotypes were free from YVMV and ELCV. Among parents, NOL-21-37 and NOL-21-40 for YVMV and GNO-1 and NOL-21-40 for ELCV (Highly tolerant) were found to perform better. Among 28 hybrids, five in E_1, one in E_2 and five in E_3 registered highly tolerant reaction against YVMV and six in E_1, one in E_2 and none in E_3 showed highly tolerant reaction against ELCV. In the present investigation, many hybrids showed lesser damage in per cent against YVMV. Lesser incidence of YVMV was also observed in okra by Kumar and Reddy (2015)[11], Patel (2015)[17], More (2015)[13], Kumar and Tayde (2018[a])[12], Rynjah *et al.* (2018)[20], Vekariya (2019)[25], Das *et al.* (2020)[5] and Joshi *et al.* (2020)[10]. Also, many hybrids showed lesser damage in per cent against ELCV. Lesser incidence of ELCV was also observed in okra by Patel (2015)[17], More (2015)[13], Yadav *et al.* (2018[b])[26], Vekariya (2019)[25], Jamil *et al.* (2020)[8], Joshi *et al.* (2020)[10], Nagendra (2020)[15], Jayanth (2021)[9] and Sakariya (2022)[21].

Fruit yield and reaction of high yielding hybrids to okra shoot and fruit borer, YVMV and ELCV in E_1, E_2 and E_3 in okra are summarized in the Table 6. to 7.. All the top three hybrids in each environments showed fairly resistance or highly resistant against shoot borer incidence (except NOL-21-40 × NOL-21-84 in E_3 showed tolerant). As same way all the top three hybrids showed highly resistance against fruit borer incidence, moderately resistance against YVMV incidence and also all same hybrids were found highly tolerant for ELCV incidence (except GAO-5 × NOL-21-40 and NOL-21-54 × NOL-21-84 in E_1 showed resistant). Similar observations were reported by Kumar and Tayde (2018[a])[12], Vekariya (2019)[25], Jayanth (2021)[9] and Sakariya (2022)[21].

However, none of the hybrids gave immune/resistant reaction for shoot and fruit borer, YVMV and ELCV in all environments. Hence, parents and hybrids showing moderately resistant or tolerance reaction can be used in further breeding programmes to develop varieties/hybrids resistant or tolerant to shoot and fruit borer, YVMV, ELCV along with good agronomic traits.

Table 1: Scale for shoot and fruit borer resistance (Rai and Satpathy, 1998)[19]

Grade	Fruit infestation	~~Categoty~~
1	0	Immune (I)
2	0.1-10	Highly resistant (HR)
3	10.1-20	Fairly resistant (FR)
4	20.1-30	Tolerant (T)
5	30.1-40	Susceptible (S)
6	40.1 and above	Highly susceptible (HS)

Table 2: Scale for yellow vein mosaic virus resistance (Ali *et al*., 2005)[2]

Sr. No.	Rating Scale	Severity Range (%)
1	Immune	0
2	Highly resistant	1-10
3	Moderately resistant	11-25
4	Tolerance	26-50
5	Moderately susceptible	51-60
6	Susceptible	61-70
7	Highly susceptible	71-100

Table 3: Disease rating scale of ELCV disease ~~(Nazeer *et al.*, 2014)~~[16]

Disease Index (%)	Severity Grade	Symptoms	Remarks
0	0	No symptoms	Resistant
1-20	1	Thickening of only secondary and tertiary veins	Highly tolerant
21-30	2	Thickening of only secondary and primary (mid-rib) veins	Tolerant
31-50	3	Vein thickening, leaf curling or enation or both	Susceptible
>50	4	Stunting along with vein thickening, leaf curling or enation	Highly susceptible

Table 4: Field evaluation of 37 genotypes of okra for shoot borer infestation and reaction in individual environment

~~Genotypes~~	~~Shoot Borer Infestation (%)~~			~~Shoot Borer Reaction~~		
	~~E_1~~	~~E_2~~	~~E_3~~	~~E_1~~	~~E_2~~	~~E_3~~
Parents						
GNO-1	16.67	20	16.67	FR	FR	FR
GAO-5	13.33	16.67	16.67	FR	FR	FR
NOL-21-12	13.33	16.67	23.33	FR	FR	T
NOL-21-23	6.67	20	20	HR	FR	FR
NOL-21-37	13.33	10	20	FR	HR	FR
NOL-21-40	16.67	20	30	FR	FR	T
NOL-21-54	10	20	23.33	HR	FR	T
NOL-21-84	3.33	6.67	10	HR	HR	HR
Hybrids						
GNO-1 × GAO-5	13.33	20	26.67	FR	FR	T
GNO-1 × NOL-21-12	16.67	20	10	FR	FR	HR
GNO-1 × NOL-21-23	6.67	10	13.33	HR	HR	FR
GNO-1 × NOL-21-37	16.67	16.67	20	FR	FR	FR
GNO-1 × NOL-21-40	10	23.33	20	HR	T	FR
GNO-1 × NOL-21-54	13.33	20	20	FR	FR	FR
GNO-1 × NOL-21-84	13.33	16.67	23.33	FR	FR	T
GAO-5 × NOL-21-12	16.67	20	30	FR	FR	T
GAO-5 × NOL-21-23	20	16.67	26.67	FR	FR	T
GAO-5 × NOL-21-37	16.67	16.67	30	FR	FR	T

GAO-5 × NOL-21-40	13.33	20	30	FR	FR	T
GAO-5 × NOL-21-54	6.67	10	20	HR	HR	FR
GAO-5 × NOL-21-84	16.67	20	26.67	FR	FR	T
NOL-21-12×NOL-21-23	13.33	20	30	FR	FR	T
NOL-21-12 × NOL-21-37	23.33	20	30	T	FR	T
NOL-21-12 × NOL-21-40	10	13.33	20	HR	FR	FR
NOL-21-12 × NOL-21-54	10	13.33	20	HR	FR	FR
NOL-21-12 × NOL-21-84	13.33	16.67	26.67	FR	FR	T
NOL-21-23 × NOL-21-37	20	23.33	10	FR	T	HR
NOL-21-23 × NOL-21-40	10	13.33	10	HR	FR	HR
NOL-21-23 × NOL-21-54	3.33	6.67	13.33	HR	HR	FR
NOL-21-23 × NOL-21-84	10	6.67	13.33	HR	HR	FR
NOL-21-37 × NOL-21-40	3.33	10	16.67	HR	HR	FR
NOL-21-37 × NOL-21-54	6.67	10	16.67	HR	HR	FR
NOL-21-37 × NOL-21-84	16.67	20	26.67	FR	FR	T
NOL-21-40 × NOL-21-54	16.67	20	20	FR	FR	FR
NOL-21-40 × NOL-21-84	10	20	23.33	HR	FR	T
NOL-21-54 × NOL-21-84	20	13.33	23.33	FR	FR	T
GJOH-4 (Standard check)	10	16.67	13.33	HR	FR	FR

HR: Highly resistant, FR: Fairly resistant, T: Tolerant

Table 5: Field evaluation of 37 genotypes of okra for fruit borer infestation and reaction in individual environment

Genotypes	Fruit Borer Infestation (%)			Fruit Borer Reaction		
	E_1	E_2	E_3	E_1	E_2	E_3
Parents						
GNO-1	17.70	15.33	16.53	FR	FR	FR
GAO-5	12.27	12.40	15.27	FR	FR	FR
NOL-21-12	9.90	17.70	17.43	HR	FR	FR
NOL-21-23	13.47	20.78	20.80	FR	T	T
NOL-21-37	12.37	15.33	16.53	FR	FR	FR
NOL-21-40	9.37	16.23	20.53	HR	FR	T
NOL-21-54	13.00	11.27	15.60	FR	FR	FR
NOL-21-84	16.93	17.17	20.13	FR	FR	T
Hybrids						
GNO-1 × GAO-5	11.67	13.10	15.27	FR	FR	FR
GNO-1 × NOL-21-12	21.47	17.10	20.47	T	FR	T
GNO-1 × NOL-21-23	12.60	12.73	17.30	FR	FR	FR
GNO-1 × NOL-21-37	11.17	13.07	12.93	FR	FR	FR
GNO-1 × NOL-21-40	16.83	15.20	19.50	FR	FR	FR
GNO-1 × NOL-21-54	13.67	16.93	22.30	FR	FR	T
GNO-1 × NOL-21-84	11.87	15.43	19.90	FR	FR	FR

GAO-5 × NOL-21-12	11.73	11.77	16.43	FR	FR	FR
GAO-5 × NOL-21-23	13.70	9.57	11.47	FR	HR	FR
GAO-5 × NOL-21-37	15.43	10.87	18.47	FR	FR	FR
GAO-5 × NOL-21-40	14.83	14.90	12.13	FR	FR	FR
GAO-5 × NOL-21-54	14.07	19.60	16.60	FR	FR	FR
GAO-5 × NOL-21-84	9.57	10.43	18.30	HR	FR	FR
NOL-21-12×NOL-21-23	10.60	13.53	22.96	FR	FR	T
NOL-21-12 × NOL-21-37	11.37	17.27	20.82	FR	FR	T
NOL-21-12 × NOL-21-40	17.60	20.97	9.93	FR	T	HR
NOL-21-12 × NOL-21-54	9.47	20.13	11.43	HR	T	FR
NOL-21-12 × NOL-21-84	6.27	20.57	19.50	HR	T	FR
NOL-21-23 × NOL-21-37	10.70	15.87	19.80	FR	FR	FR
NOL-21-23 × NOL-21-40	20.47	15.17	12.73	T	FR	FR
NOL-21-23 × NOL-21-54	13.60	12.80	9.07	FR	FR	HR
NOL-21-23 × NOL-21-84	13.53	18.83	15.80	FR	FR	FR
NOL-21-37 × NOL-21-40	12.27	19.23	16.90	FR	FR	FR
NOL-21-37 × NOL-21-54	9.33	19.23	19.57	HR	FR	FR
NOL-21-37 × NOL-21-84	11.90	22.33	17.13	FR	T	FR
NOL-21-40 × NOL-21-54	10.03	22.53	19.43	FR	T	FR
NOL-21-40 × NOL-21-84	13.30	12.30	14.63	FR	FR	FR
NOL-21-54 × NOL-21-84	9.67	13.83	20.47	HR	FR	T
GJOH-4 (Standard check)	10.10	14.90	14.83	FR	FR	FR

HR: Highly resistant, FR: Fairly resistant, T: Tolerant

Table 6: Field evaluation of 37 genotypes of okra for YVMV disease infestation and reaction in individual environment

Genotypes	**YVMV Infestation**			**YVMV Reaction**		
	E_1	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**
Parents						
GNO-1	16.67	16.67	13.33	MT	MT	MT
GAO-5	13.33	16.67	20	MT	MT	MT
NOL-21-12	20	23.33	23.33	MT	MT	MT
NOL-21-23	23.33	20	16.67	MT	MT	MT
NOL-21-37	20	10	10	MT	HT	HT
NOL-21-40	16.67	16.67	10	MT	MT	HT
NOL-21-54	30	16.67	16.67	T	MT	MT
NOL-21-84	30	20	30	T	MT	T
Hybrids						
GNO-1 × GAO-5	13.33	26.67	26.67	MT	T	T
GNO-1 × NOL-21-12	13.33	23.33	13.33	MT	MT	MT
GNO-1 × NOL-21-23	26.67	23.33	16.67	T	MT	MT
GNO-1 × NOL-21-37	13.33	33.33	10	MT	T	HT

GNO-1 × NOL-21-40	23.33	23.33	16.67	MT	MT	MT
GNO-1 × NOL-21-54	30	20	10	T	MT	HT
GNO-1 × NOL-21-84	26.67	26.67	16.67	T	T	MT
GAO-5 × NOL-21-12	36.67	20	33.33	T	MT	T
GAO-5 × NOL-21-23	26.67	13.33	23.33	T	MT	MT
GAO-5 × NOL-21-37	13.33	23.33	26.67	MT	MT	T
GAO-5 × NOL-21-40	13.33	20	36.67	MT	MT	T
GAO-5 × NOL-21-54	16.67	13.33	26.67	MT	MT	T
GAO-5 × NOL-21-84	13.33	10	20	MT	HT	MT
NOL-21-12×NOL-21-23	33.33	26.67	20	T	T	MT
NOL-21-12 × NOL-21-37	16.67	20	10	MT	MT	HT
NOL-21-12 × NOL-21-40	6.67	23.33	10	HT	MT	HT
NOL-21-12 × NOL-21-54	10	20	16.67	HT	MT	MT
NOL-21-12 × NOL-21-84	13.33	23.33	23.33	MT	MT	MT
NOL-21-23 × NOL-21-37	16.67	50	30	MT	T	T
NOL-21-23 × NOL-21-40	10	13.33	13.33	HT	MT	MT
NOL-21-23 × NOL-21-54	13.33	23.33	16.67	MT	MT	MT
NOL-21-23 × NOL-21-84	13.33	20	13.33	MT	MT	MT
NOL-21-37 × NOL-21-40	13.33	36.67	30	MT	T	T
NOL-21-37 × NOL-21-54	13.33	23.33	20	MT	MT	MT
NOL-21-37 × NOL-21-84	6.67	16.67	16.67	HT	MT	MT
NOL-21-40 × NOL-21-54	3.33	16.67	20	HT	MT	MT
NOL-21-40 × NOL-21-84	23.33	33.33	10	MT	T	HT
NOL-21-54 × NOL-21-84	23.33	20	30	MT	MT	T
GJOH-4 (Standard check)	20	26.67	20	MT	T	MT

HT: Highly tolerant, MT: Moderately Tolerant, T: Tolerant

Table 7: Field evaluation of 37 genotypes of okra for ELCV disease infestation and reaction in individual environment

Genotypes	**ELCV Infestation**			**ELCV Reaction**		
	E_1	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**
Parents						
GNO-1	20	16.67	16.67	HT	HT	HT
GAO-5	6.67	20	30	HT	HT	T
NOL-21-12	6.67	26.67	20	HT	T	HT
NOL-21-23	0	13.33	23.33	R	HT	T
NOL-21-37	0	20	26.67	R	HT	T
NOL-21-40	6.67	10	16.67	HT	HT	HT
NOL-21-54	0	30	26.67	R	T	T
NOL-21-84	13.33	3.33	23.33	HT	HT	T
Hybrids						
GNO-1 × GAO-5	10	13.33	23.33	HT	HT	T

GNO-1 × NOL-21-12	6.67	20	30	HT	HT	T
GNO-1 × NOL-21-23	6.67	20	26.67	HT	HT	T
GNO-1 × NOL-21-37	10	13.33	20	HT	HT	HT
GNO-1 × NOL-21-40	3.33	3.33	23.33	HT	HT	T
GNO-1 × NOL-21-54	13.33	16.67	26.67	HT	HT	T
GNO-1 × NOL-21-84	13.33	3.33	10	HT	HT	HT
GAO-5 × NOL-21-12	13.33	23.33	23.33	HT	T	T
GAO-5 × NOL-21-23	10	16.67	16.67	HT	HT	HT
GAO-5 × NOL-21-37	13.33	13.33	26.67	HT	HT	T
GAO-5 × NOL-21-40	0	3.33	13.33	R	HT	HT
GAO-5 × NOL-21-54	13.33	6.67	23.33	HT	HT	T
GAO-5 × NOL-21-84	6.67	0	13.33	HT	R	HT
NOL-21-12×NOL-21-23	0	3.33	10	R	HT	HT
NOL-21-12 × NOL-21-37	10	20	20	HT	HT	HT
NOL-21-12 × NOL-21-40	3.33	13.33	30	HT	HT	T
NOL-21-12 × NOL-21-54	3.33	23.33	20	HT	T	HT
NOL-21-12 × NOL-21-84	10	6.67	10	HT	HT	HT
NOL-21-23 × NOL-21-37	0	10	20	R	HT	HT
NOL-21-23 × NOL-21-40	3.33	10	20	HT	HT	HT
NOL-21-23 × NOL-21-54	6.67	16.67	16.67	HT	HT	HT
NOL-21-23 × NOL-21-84	13.33	6.67	16.67	HT	HT	HT
NOL-21-37 × NOL-21-40	6.67	3.33	13.33	HT	HT	HT
NOL-21-37 × NOL-21-54	0	23.33	33.33	R	T	T
NOL-21-37 × NOL-21-84	0	16.67	23.33	R	HT	T
NOL-21-40 × NOL-21-54	10	13.33	16.67	HT	HT	HT
NOL-21-40 × NOL-21-84	6.67	20	20	HT	HT	HT
NOL-21-54 × NOL-21-84	0	3.33	13.33	R	HT	HT
GJOH-4 (Standard check)	3.33	3.33	20	HT	HT	HT

HT: Highly tolerant, T: Tolerant

Conclusion:

Among the 37 genotypes evaluated, none of the genotype was free from shoot and fruit borer infestation, YVMV and ELCV incidence. None of the genotype performed consistently in all three environments.

References:

1. Afzal, M.; Mukhtar, M. K.; Tahir, H. M.; Ibrar-ul-haq; Babar, M. H. and Sherawat. S. M. (2015). Screening of different okra genotypes against fruit borer (*Earias spp.*) (Lepidoptera: Noctuidae) on okra crop. *Pakistan J. Zool*., **47** (6): 1631-1635.
2. Ali, S. K.; Habib, A.; Rasheed, S. and Iftikhar, Y. (2005). Correlation of environmental conditions with okra yellow vein mosaic virus and *B. tabaci* population density. *Int. J. Agric. Biol.*, **7**: 142-144.
3. Anonymous, (2021[a]). Horticulture Crops for 2020-21 (2nd Advance Estimates), National Horticulture Board, New Delhi, India, Retrieved from http://nhb.gov.in/StatisticsViewer [Accessed 10th November, 2021].
4. Anonymous, (2021[b]). Director of Horticulture, Agriculture, Farmers Welfare and Cooperation Department, Gujarat, India. Retrieved from https://doh.gujarat.gov.in/horticulture-census.htm [Accessed 10th November, 2021].
5. Das, A.; Yadav, R. K.; Choudhary, H.; Singh, S.; Khade, Y. P. and Chandel, R. (2020). Determining genetic combining ability, heterotic potential and gene action for yield contributing traits and YVMV resistance in Okra. *Pl. Gene. Resources: Characterization and Utilization*, **1**: 14.
6. Dave, P. P. and Pandya, H. V. (2017). Screening of okra genotypes against *Earias vittella* (Fabricius) in Gujarat. *J. Ento. Zool. Studies*., **5** (6): 2160-2166.
7. Jalgaonkar, V. N.; Mahla, M.; Naik, K.; Vyas, A. and Golvankar, G. (2018). Varietal preference of okra shoot and fruit borer, *Earias vittella* (Fab.) in summer season under field condition in Konkan region of Maharashtra. *Int. J. Curr. Microbiol. Appl. Sci*., **7**: 2397-2402.
8. Jamil, I.; Mandal, A.K.; Devi, A.P.; Bhattacharjee, T.; Maurya, P.K.; Dutta, S. and Banik, S. (2020). Screening of genotypes against viral diseases and assessment of yield loss due to yellow vein mosaic virus in okra grown in the eastern part of India. *Indian Phytopatho*., **12** (4): 1-9.
9. Jayanth, S. (2021). Genetic and stability analysis for pod yield and its contributing characters in okra [*Abelmoschus esculentus* (L.) Moench], *Thesis Ph. D. (Horti.),* Navsari Agricultural University*,* Navsari.192 p.
10. Joshi, J. L.; Anbuselvam, Y. A.; Ranganayaki, S.; Ajish Muraleedharan and Kumar, C. P. S. (2020). Screening of okra genotypes for YVMV disease using ISSR markers. *Pl. Arch.*, **20** (2): 3776-3777.
11. Kumar, S. and Reddy, M. T. (2015). Morphological characterization and agronomic evaluation of yellow vein mosaic virus resistant single cross hybrids for yield and quality traits in okra. *Open Access Library J*., **2**: 1-17.
12. Kumar, K. I. and Tayde, A. R. (2018[a]). Screening of okra genotypes against yellow vein mosaic virus disease (OYVMV) under Field conditions in Allahabad. *J. Pharma. and Phyto*., **7** (1): 660-662.
13. More, S. J. (2015). Line × Tester analysis over environments in okra [*Abelmoschus esculentus* (L.) Moench]. Ph.D. (Agri.) Thesis (Unpublished). Navsari Agricultural University, Navsari.
14. Mouli, G. C. and Tayde, A. R. (2017). Screening of some okra varieties against *Earias vittella* under Allahabad field conditions. *J. Pharma. and Phyto*., **6** (4): 943-945.

15. Nagendra (2020). Heterosis and combining ability studies in okra [*Abelmoschus esculentus* (L.) Moench]. *Thesis M. Sc. (Hort.)*, Navsari Agricultural University, Navsari, Gujarat. 107 p.
16. Nazeer, W.; Tipu, A. L.; Ahmad, S.; Mahmood, K.; Mahmood, A. and Zhoumail, B. Z. (2014). Evaluation of Cotton Leaf Curl Virus Resistance in BC_1, BC_2, and BC_3 Progenies from an Interspecific Cross between *Gossypium arboreum* and *Gossypium hirsutum*. *Pl. One*, **9** (11): 118-121.
17. Patel, H. B. (2015). Genetic analysis of yield and its quality parameters in okra [*Abelmoschus esculentus* (L.) Moench], M.Sc. (Horticulture) Thesis (Unpublished). Navsari Agricultural University, Navsari.
18. Raghuwanshi, P. K.; Singh, U. C.; Bhadoria, N. S.; Tomar, S. P. S. and Bharti, O. P. (2019). Screening of okra genotypes against shoot and fruit borer, *Earias vittella* (Fab.) in Gwalior (Madhya Pradesh). *Int. J. Chem. Stud*., **7** (5): 2957-2959.
19. Rai, S. and Satpathy, S. (1998). Recent advances in *screening for insect resistance in vegetables*, Summer school on advanced technologies in improvement of vegetable crops including cole crops. May 4-24, IARI, New Delhi, pp.67-74.
20. Rynjah, S.; Sathiyamurthy, V. A.; Saraswathi, T. and Harish, S. (2018). Field screening of okra [*Abelmoschus esculentus* (L.) Moench] genotypes against okra yellow vein mosaic virus disease. *J. Pharma. and Phyto*., **7** (5): 1852-1854.
21. Sakariya, S. (2022). Genetic and stability analysis for pod yield and its contributing characters in okra [*Abelmoschus esculentus* (L.) Moench] using line × tester. Ph.D. (Horti.) Thesis (Unpublished). Navsari Agricultural University, Navsari.
22. Singh, S. J. (1996). Assessment of losses in okra due to enation leaf curl virus. *Indian J. Virol.*, **12**: 51-53.
23. Singh, S. J. and Dutta, O. P. (1986). Enation leaf curl of okra - a new virus disease. *Indian J. Virol*., **2**: 114- 117.
24. Subbireddy, K. B.; Patel, H. P.; Patel, N. B. and Bharpoda, T. M. (2018). Screening of okra cultivars and genotypes for their resistance to fruit borers in middle Gujarat. *Pest Manage. Horti. Ecosys.*, **24** (1): 36-43.
25. Vekariya, R. D. (2019). Genetic study and stability analysisover environmentsin okra [*Abelmoschus esculentus* (L.) Moench]. *Thesis Ph. D. (Agri.),* Navsari Agricultural University, Navsari. pp. 232.
26. Yadav, Y.; Maurya, P. K.; Bhattacharjee, T.; Banerjee, S.; Jamir, I.; Mandal, A. K.; Dutta, S. and Chattopadhyay, A. (2018). First evidence on heterotic affinity and combining ability of cultivated okra [*Abelmoschus esculentus* (L.) Moench] inbred lines for tolerance to enation leaf curl virus disease. *Agric. Res. and Tech*., **18** (5): 3795-3802.