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A Review on: Diseases of the “Okra” (*Abelmoschus esculentus*) and its present scenario

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Abstract

Okra is one of the important vegetable crops, having very amazing nutrition quality as well as ethnomedicinal properties. It is extensively cultivated for its edible green fruits. Its medicinal properties and usage has been reported by various part of world. It is used in the traditional systems of medicine such as Ayurveda, Siddha and Unani. In the present review; we have focused the biotic stresses of the okra cultivation. We have briefly discussed the Insect pest and its importance. In later part of the manuscript we mainly concentrated on the viral disease of the okra and its impact on the production and productivity. Finally, control measures of the viral disease of okra elaborated in connection with the advancing of the tools as well as the modern approaches.

Keywords: Biotic stress, Ethanomedicinal, CRISPR/Cas9, Begomoviruses, YVMV

Introduction

Okra *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical and warm temperate regions around the world. It is grown as kitchen garden crop as well as on large commercial farms. It has been cultivated commercially in India, Pakistan, Bangladesh, Burma, Afghanistan, Iran, Turkey, Western Africa, Yugoslavia, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States.

In India; it is cultivated in summer season in north India and also as a winter crop in Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. It fails to grow in the high hills and areas which experience very low temperatures.

According to FAO statistics, it has been observed that in the world okra grown in about 1.06 million hectares with a production of 8.06 million tonnes during 2011. India is the largest producer of okra occupying 46.87% area with 71.76% of production globally. The other major okra producing countries are Nigeria, Sudan, Iraq Coted'Ivoire and Pakistan with share of production is 13.15%, 3.18%, 1.96%, 1.6% and 1.27% respectively. In India the major okra producing states are West Bengal, Bihar, Orissa, Andhra Pradesh, Gujarat, Jharkhand and Karnataka.

Okra is known by many vernacular names in different regions of the world. It contains an important source of vitamins C, calcium, potassium (IBPGR, 1990), proteins, carbohydrates (Lamont, 1999; Owolarafe and Shotonde 2004; Gopalan *et al.*, 2007) ^[23, 29, 17], and plays a vital role in human diet (Kahlon *et al.*, 2007; Saifullah and Rabbani 2009) ^[18, 32]. Every part of okra has a commercial value. 100 g edible portion of okra pods and leaf contains different constituent mentioned in table 1. Carbohydrates are mainly present in the form of mucilage (Liu *et al.*, 2005) ^[25]. The mucilage is highly soluble in water. Okra seeds contain about 20% protein and 40% oil (Charrier, 1984) ^[8].

The roots and stems of okra are used for cleaning the cane juice from which gur or brown sugar is prepared (Chauhan, 1972) ^[9]. Stem bark is used for fibre extraction. The fruits also serve as soup thickeners. Okra seeds are roasted, ground and used as coffee additive or substitute (Moekchantuk and Kumar, 2004) ^[26]. Mature fruits and stems having fibre are used in paper industry. Okra leaves are considered good cattle feed, and the leaf buds and flowers are also edible (Doijode, 2001) ^[11]. Okra seed oil is viewed as alternative source for edible oil; rich in unsaturated fatty acids such as oleic acid and linoleic acid. The oil content of the seed is quite high at about 40%. Moreover, okra mucilage is suitable for industrial and medicinal applications (Akinyele and Temikotan, 2007) ^[4].

Industrially, okra mucilage is usually used for glace paper production and also has a confectionery use. Okra has found medical application as a plasma replacement or blood volume expander (Adetuyi *et al.*, 2008; Kumar *et al.*, 2010) ^[1, 19].

Table 1: Different constituents present in 100 g pod and leaf of okra

Constituent	Pod (100 g)	Leaf (100g)
Water	88.6 g	81.50 g
Energy	144.00 kJ (36 kcal)	235.00 kJ (56.00 kcal)
Carbohydrate	8.20 g	11.3 g
Fat (g)	0.20 g	0.60 g
Protein	2.10 g	4.40 g
Fibre	1.70	2.10 g
Calcium	84 mg	532.00 mg
Potassium	90 mg	70.00 mg
Iron	1.20 mg	0.70 mg
Ascorbic acid	47 mg	59.00 mg
Riboflavin	0.08 mg	2.80 mg
Thiamine	0.04 mg	0.25 mg
Niacin	0.60 mg	0.20 mg
B-carotene	185.00 µg	385.00 µg

(Source: Gopalan *et al.*, 2007; Varmudy, 2011.) ^[17]

Incidence of the Insect pest on okra

Insect pests reported to infest okra in Ghana include flea

beetles (*Podagrica sp.*), cotton stainer (*Dysdercus superstitus*), white fly (*Bemisia tabaci*), and green stink bug (*Nezera viridula*) among others. Flea beetles (*Podagrica sp.*) are more dangerous among the insect pest. The feeding activity of *Podagrica sp.* causes damage comprising of characteristic perforations of leaves, and irregular holes reduce the photosynthetic surface area of the leaves leading to a great reduction of yield in okra.

Incidence of disease on okra

There are many reports on the occurrence of several pests and diseases on okra. Insect pest infestation is one of the most limiting factors for accelerating yield potential of okra. The crop is susceptible to damage by various insects, fungi, nematodes and viruses at various growth stages of crops. Some of the important insects are fruit and shoot borer, aphids, white flies, ants, etc. The list of commonly occurring disease on okra in mentioned in table 2 The common viruses which infect okra are *Yellow vein mosaic virus* (YVMV), *Okra mosaic virus* (OkMV) and *Okra leaf curl virus* (OkLCV). The most serious viral disease of okra is caused by *yellow vein mosaic virus* (YVMV) universally faced by all okra growers (Alegbejo *et al.*, 2008; Benchasri, 2012) ^[1, 5].

Table 2: List of commonly occurring diseases on okra

Common disease	Scientific name	Susceptible crop stage	References
Powdery mildew	<i>Erysiphe cichoracearum</i>	Vegetative	Kumar <i>et al.</i> , 2010 ^[19]
Damping-off	<i>Pythium vexans</i>	Seedling- early vegetative	Ek-amnuay, 2007
Pod spot	<i>Alternaria sp</i>	Fruit setting	Kumar <i>et al.</i> , 2010 ^[19]
Anthraxnose	<i>Colletotrichum spp</i>	Flowering/Fruiting	Charrier, 1984; Lamont, 1999 ^[23]
Leaf Spot	<i>Pseudocercospora abelmoschi</i>	Vegetative stage	Charrier, 1984; Moekchantuk and Kumar 2000 ^[8]
Virus			
Yellow Vein Mosaic	<i>Yellow vein mosaic virus</i>	Early vegetative-harvest	Givord and Denboer 1980 ^[16] ; Rashid <i>et al.</i> , 2002 ^[30]
Okra Leaf Curl	<i>Okra leaf Curl virus</i>	Vegetative- harvest	Ghanem, 2003
Okra mosaic	<i>Okra mosaic virus</i>	Vegetative -harvest	Fauquet and Thouvenel 1987 ^[14]
Okra Enation Leaf Curl Disease	<i>Okra enation leaf curl virus</i>	Vegetative -harvest	Singh, 1996 ^[38]

In 1924; First time Kulkarni reported YVMD is caused by the Yellow vein mosaic virus from India (Kulkarni, 1924) ^[21]. Later it was reported from the other part of the world (Table 3). This disease was characterized by the several group of scientist time to time from different parts counties for degrees of chlorosis, yellowing of veins (Uppal *et al.*, 1940) ^[40] and small leaves, stunted growth, yellowing of veinlets and distorted fruits (Venkataravanappa *et al.*, 2012a) ^[42]. Yield Losses ranges between 50 to 94% if the incidence of the Yellow Vein Mosaic disease 100% (Fajinmi and Fajinmi, 2010) ^[13].

Okra Enation Leaf Curl Disease is another important disease of virus caused by *Okra Enation Leaf Curl Virus* (OELCV). It was first reported from the Karnataka, India in early 1980 (Singh, 1996) ^[38]. Incidence of this virus leads to development of various types of the symptoms. Its characteristics symptoms include curling of the leaf, thickening of vein and reduction of leaf surface area (Singh, 1996) ^[38]. In case of the severe infestation causes yield loss up to 80-90% (Singh, 1996) ^[38]. Sanwal *et al.* (2014) ^[31] reported some of the popular varieties

like Parbhani Kranti, P-7, Arka Anamika, Arka Abhay had loosed resistance to OELCV.

Okra mosaic virus (OkMV) is another important virus that infects okra; belongs to Tymovirus genus. It was first reported from *Abelmoschous esculentus* (okra) in Côtéd'Ivoire (Fauquet and Thouvenel 1987) ^[14]. It is a persistent virus; infects all stages of the crop and transmitted by the whitefly. Okra leaf curl disease of the okra is caused by *Okra leaf curl virus* (OkLCV) and it belongs to *Begomovirus* genus. *Okra leaf curl virus* infects okra plant from vegetative stage to the harvesting stage. Krishna Reddy *et al.*, (2003a) ^[20] showed fruit distortion mosaic disease of okra caused by *Tobacco streak virus*. This virus causes characteristic symptoms as chlorotic spots, chlorotic leaf blotches, distortion of leaves, chlorotic streaking, and distortion of fruits. Yield losses due to this virus were reported up to 63% in okra growing area of India. Apart from these diseases; there are several reports of the incidence of the Begomoviruses from the different parts of the world as mentioned in the table 3.

Table 3: List of Begomoviruses affecting okra as reported from various parts of the world

S. No.	Begomovirus	Country	References
1	Bhendi yellow vein mosaic virus (BYVMV)	India	Kulkarni, 1924 ^[21]
2	Okra Enation Leaf Curl Virus (OELCV)	Nigeria	Atiri, 1984 ^[3]
3	Okra Leaf Curl Virus (OLCV)	Côte d'Ivoire	N'guessant, 1991 ^[27]
4	Okra Enation Leaf Curl Virus (OELCV)	Côte d'Ivoire	N'guessant <i>et al.</i> , 1992 ^[28]
5	Okra enation leaf curl Virus (OELCuV)	India	Singh, 1996 ^[38]
6	BYVMV	Pakistan	Zhou <i>et al.</i> , 1998 ^[47]
7	Okra yellow crinkle virus (OYCrV)	Bamako, Mali	Shih <i>et al.</i> , 2007 ^[36]
8	Bhendi yellow vein Maharashtra virus	India	Brown <i>et al.</i> , 2012 ^[6]
9	Bhendi yellow vein Delhi virus (BYVDeV)	India	Venkataravanappa <i>et al.</i> , 2012a ^[42]
10	Bhendi yellow vein Haryana virus	India	Brown <i>et al.</i> , 2012 ^[6]
11	Radish leaf curl virus	India	Kumar <i>et al.</i> , 2012 ^[22]
12	Bhendi yellow vein Bhubhaneswar virus (BYVBhV)	India	Venkataravanappa <i>et al.</i> , 2012a ^[42]
13	Okra leaf curl Cameroon virus (OLCuCMV)	Cameroon	Leke <i>et al.</i> , 2013 ^[24]
14	OELCuV	India	Singh <i>et al.</i> , 2013 ^[35]
15	Okra leaf curl disease-associated DNA 1, isolate OBKG (OLCuA) Okra yellow crinkle Cameroon alphsatellite (OYCrCMA) OELCuV	India	Chandran <i>et al.</i> , 2013 ^[7]
16	BYVMV	India	Venkataravanappa <i>et al.</i> , 2013 ^[37]
17	Bhendi yellow vein Madurai virus	India	Venkataravanappa <i>et al.</i> , 2014 ^[44]
18	OELCuV	India	Venkataravanappa <i>et al.</i> , 2015a ^[45]

Management of the Disease

In order to increase the production and productivity of okra; there are need of integrated and efficient management of these diseases. Incidence or severity of disease of Okra depends on the environmental condition and susceptibility of the species of okra (Shetty *et al.*, 2013) ^[35]. YVMV disease of okra is most reported by various groups of scientists among begomoviruses.

Wild relative germplasms such as *Abelmoschus angulosus* are complete resistant to the YVMV. Apart from this, wild ssp. Manihot and genotype IC1542 showed symptomless resistance (Dhankhar *et al.*, 2005) ^[10]. There are several approaches were also reported from various scientist that are mentioned below.

Management of the begomovirus in okra

In the conventional methods, the improvement of the okra cultivar depends on availability of the resistant source (Dhankhar *et al.*, 2005) ^[10]. Moreover, emergence of the mutant race of begomovirus becomes more menace to the resistant cultivar or wild germplasm (Venkataravanappa *et al.*, 2012a) ^[42]. Due to this reason till now, no cultivated okra variety or hybrid had shown absolute resistance. There are alternative sources of resistance to begomovirus available from the wild species. These species named as *A. manihot*, *A. crinitus*, *A. angulosus*, including certain landraces of *A. tetraphyllus* (Singh *et al.*, 2007) ^[39]. The transfer of the resistant gene from the wild species to the cultivated species (*A. esculentus*) is major constraints. This problem is overcome by the application of the biotechnological approaches.

Biotechnological Approaches

Development of durable resistance variety against to begomoviruses for long time; poses a severe challenge to both breeders and pathologists because of these viruses are highly diverse in nature and mutation rate is very high, and constantly generate new forms via recombination.

Therefore, use of novel biotechnological tools will help in the achieving resistance against begomovirus in okra. Identification of closely linked markers linked to the resistance genes and its pyramiding for the combining multiple disease resistance genes in agronomical desirable cultivar. With the advancement of the techniques, tools and approaches; is possible to transfer of the resistance gene from kingdom to

another kingdom using genetic transformation.

For controlling of the begomoviruses, many pathogen-derived as well as non-pathogen derived approaches are available including RNA interference (RNAi) mediated resistance for CLCuD (Sattar *et al.*, 2013) ^[24, 33]; Until now, biotechnological approaches are mainly focused for controlling of the only helper begomoviruses and not for the associated satellites, which adds several functions to the helper begomoviruses. Newly established approaches is a multiplexed clustered regulatory interspaced short palindromic repeats (CRISPR)/CRISPR associated nuclease 9(Cas9) system was developed, where a cassette of sgRNA is designed to target not only the whole CLCuD-associated begomovirus complex.

Conclusion

Okra cultivation is confined to developing countries of Asia and Africa. Area under these countries is more than the 90%. Now a day's genomic era is booming, but in case of the okra very little attention has been paid to its genetic improvement and genomic information on *Abelmoschus* is practically absent (Schafleitner *et al.*, 2013) ^[34]. With the improvement of the genomic information will be leads to development of several closely traits linked markers. There is report of the development of the transgenic okra, but the regulation of biosafety challenge is major hurdle. With current and rapid rising technologies such as next generation sequencing (NGS), genome-wide selection (GWS), marker-assisted recurrent selection (MARS), chromosome engineering, RNAi, and targeted gene replacement using zinc-finger nucleases, nanobiotechnology and genome editing (CRISPR/Cas9). These technologies will be helps in the future for the development of okra having better features for viral disease resistance (Varshney *et al.*, 2011) ^[46]. Therefore, it is necessary to use interdisciplinary approaches and modern technologies to deal with the severe challenges of viral disease.

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