International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 16-05-2022, Accepted: 01-06-2022, Published: 18-06-2022
Volume 7, Issue 6, 2022, Page No. 98-103

Natural genomic and antigenic variation in whitefly in okra

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Abstract
Bemisia tabaci or whitefly is the major pest of the Okra crop and causes great damage to the crop. This sucks the cell sap and causes the death of the plant. The whitefly has some special characteristics that as the presence of Vasiform orifice which helps in the release of honeydew and protects the insect body from any damage. Begomovirus is spread through the incidence of whitefly on the crop. The coat protein is a special protein that can adapt the transmission of sympatric different species of *Bamasia tabaci* and this will show the antigenic similarity of coat protein in Begomovirus. The Begomovirus is transmitted through the whitefly (*Bemisia tabaci*) and they have some antigenically related particles. This will cause natural genomic and antigenic variation in whitefly. This review paper provides complete information about whitefly, its incidence, viral spread in different crops like okra, the transmission of begomovirus through whitefly and natural genomic and antigenic variation in whitefly in okra.

Keywords: antigenic, genomic, honeydew, okra, transmission, whitefly

Introduction
Okra a vegetable is commonly known as ladyfinger and the scientific name is *Abelmoschus esculentus*, which belongs to the family Malvaceae. It is an edible green pod having seeds in between and a very good source of fibre, vitamins, minerals and antioxidants (Swanson *et al*., 1998) [34]. The okra is cultivated in the whole world most in sub-tropical parts, the country in which okra is generally grown in the Southern United States, turkey, Iran, Pakistan, India, Burma, Japan, Bangladesh, etc. among all countries India rank first as the total production is about 3.5million tonnes which are 70% of the total production and the total land covered by okra is 0.35million hectare land (according to FAOSTAT, 2008). Okra is known by different names in different places such as ladyfinger in England, in Spanish known as guinea-gumbo, in India known as bhindi and in Portuguese known as Ribeiro. In India, the cultivation of okra is quite easy as the climate is suitable. Okra is used as a vegetable in India known as "bhindi bhaji" along with there are several uses of okra plant like the roots of okra is used in the process of clarification of sugarcane juice to make gur or brown sugar, the seeds of okra which get ripened are used as a coffee substitute along with this the oil of okra is also extracted from the seeds, as the okra oil has a very good taste and soulful smell and the oil contains unsaturated fat and oleic acid too (Goudsmith *et al.,* 1991) [11]. If we talk about the nutrient composition in okra, okra contains no. of nutrients such as carbohydrate (6.4g), fat (0.2g), fibre (1.2g), mineral (0.7g), phosphorus (5.60mg), calcium (66.0mg), iron (0.35mg), copper (0.19mg), riboflavin (0.01mg), vitamin C (13.10mg) and oxalic acid (8.0mg). Okra is not only a vegetable to eat but also it has some medicinal qualities like it can heal genito-urinary disorders and chronic dysentery, along with this it also heals ulcers. By the seeds, okra is propagated and around 90-100days it will take for harvesting as it is an annual plant. Okra has a robust stem, erect and the branch length is about 0.5 to 4.0cm (Zhou *et al*., 2001) [42]. The leaves of the okra are five-lobed as it has an axillary flower. After one or two months of sowing the plant bear its first flower, the fruit has emerged in the form of a capsule and after flowering, it grows quickly. After the 4th and 6th days of pollination, the fruit length is increased along with its diameter and height. The okra cultivation is disturbed sometimes by the infestation of insects and pests such as insects, nematodes, fungi and viruses (Costa, A. S., 1976) [5]. The insects which affect the okra mostly are shoot borer, aphids, ants and whitefly, among them the most problematic insect is the whitefly which causes damage to the okra due to which the yield is decreased. Whitefly is an aphid that sucks the sap of the plant due to which plant wilt and eventually die and to protect themselves they release a wax-like thing known as honeydew which is like a protective layer (Perring *et al*., 1993) [24].
Whitefly is commonly known as *Bemisia tabaci* comes under the family Aleyrodidae and Hemiptera order. There is various genus of whitefly but mainly the three genera of whitefly are common these are Tetraleurodes, Aleuroplatus and Aleurotrachelus (Byrne & Bellows., 1911). The genus with the subfamily Aleurodicinae mainly contains Neotropics. Whitefly is sucking pests because they have piercing and sucking type mouthparts. Both males and females have four membranous wings. The family of whitefly exhibits incomplete metamorphosis because they found complications during metamorphosis (Costa, A. S., 1976) [5].

The Aleyrodidae family of whitefly have a special feature due to the presence of Vasiform orifice. The Vasiform orifice consists of the Operculum and lingula. In males, it is located at the ninth abdominal segment on the dorsum and in females, it is located at eight abdominal segments on the dorsum part (Venkataravanappa *et al*., 2013) [30]. Mainly it is the depression where the anus empties into the honeydew which is the digestive tract but it is not the anus. The dorsal anus is very rarely found in the nymphs but it is easily found in adult flies. Whitefly secretes honeydew which is the sugar-rich, very sticky substance secreted through the anus of the aphids. The adults of whitefly are known as Psyllid adults, their anus turns into enlarged genitalia. In Aleyrodidae, the anus is present in the dorsal side which helps in handling honeydew which is produced by the phloem-feeding insects in a very good amount (Wolfs *et al*., 1991) [40]. Honeydew can also cause some problems for sessile nymphs because it is liquid and viscous due to which it is more prominent to the sooty mould fungus. The nymphs of whitefly cannot go away from the droplets of honeydew. As they release, they excreta away and the honeydew is filled with the vasiform orifice so that the lingula present there is cocked into the liquid and it gets released. Due to this, the honeydew gets released from the insect body. Whitefly shows some unique behaviour in different life stages (Goudsmit *et al*., 1991) [11]. They produce some different types of wax on their body which helps in the protection by covering their body. Different types of waxes are produced by the whitefly and some of them are similar to the coccids. The wax produced by whitefly have setae like projections and it contains columns, plumes and produces gelatinous mass (Sanz *et al*., 2000) [27]. The wax of whitefly is of two colours, from which one is colourless and the other is in white. The colourless is clear and reflects the colour of the leaf surface. The colourless wax forms a very thin layer on the lower side are looks like marginal fringe and spike rays are also found there (Harrison & Robinson., 1999) [13]. This type of wax is mainly found in Trialeudos sp. of whitefly. The white wax is found in the genus Tetraleurodes sp. and Aleuroplatus sp. The wax of an adult changes its colour from yellow to light orange and the texture also changes to a thread-like consistency. Wax is secreted through wax canals; males have four pairs of wax plates and females have only two. The wax contains fatty acids, hydrocarbons, esters and alcohols (Van Lenteren & Noldus., 1990) [36].

Fig 1: Whitefly (*Bemisia tabaci*) and Plants Affected by Whitefly Whitefly as Vector and Factors Influencing Begomovirus Incidence in Okra.

Whitefly causes significant injury to okra, both via direct loss of plant vigour through chewing on cell-sap and by the transmission of numerous viral infections. Gemini viruses have a circulate, non-propagative mode of transmission and a latent infection. as the virus has go through the gut of the insect glands of the salivary (Gray and Banerjee, 1999) [12]. Transmission The effectiveness of begomoviruses differed depending on the sex of whiteflies and Females convey information more efficiently than males. (Czosnek and colleagues, 2001) [7]. the explanation behind this is yet unknown. Begomoviruses can also be spread through grafting, but seed transfer or mechanical inoculation are more common.has yet to be determined (Brown *et al*., 2012) [2]. Weeds Many cases have been recorded as repositories of both Vectors and viruses (Duffus, 1971) [9]. By introducing various begomoviruses into many new plant species, the B-biotype has modified the epidemiology of several begomoviral infections in okra (Sanwal *et al*., 2016) [26]. Thus, infection in the field appears to be entirely dependent on vectors, as shown by the direct association between disease incidence and vector populations (N'guessant *et al*., 1992) [23].

Genomic and Antigenic Variation in Whitefly (*Bemisia tabaci*)

Whiteflies are the major threat as many viruses are transmitted by the action of whitefly, the common diseases are tomato leaf curl, cassava mosaic, and yellow leaf curl in tomato and legumes yellow mosaic along with this in many vegetables like okra, cucurbits, pepper whiteflies cause diseases such as leaf curl and mosaic. In Africa due to mosaic disease the cassava crop losses its value. If we talk about the physiology of whitefly, they have haplodiploid cells and males are generally produced by the process of pathogenetically from the eggs (unfertilized). Whitefly contain the morphology of twin particles and they have DNA either monopartite or bipartite, but in the case of whitefly, they have bipartite genome i.e. DNA-A & DNA-B due to which they can infect the dicotyledonous plant. In DNA-A two types of virion sense are located (figer along with four complimentary whereas, in DNA-B contains only one virion sense along with one complimentary sense only (Domingo *et al*., 1993) [8]. For bi-directional transcription and two components of the genome share a common site including the origin of replication and region of regulation. In okra the disease caused by whitefly is known as okra leaf curl disease in the region of West and North-East Africa, the association of CLuGV and CLuGB found in Egypt and Sudan. The plants which are affected by the whitefly has yellow patches on the leaves and chlorosis. In India, the virus is known as "bhindi yellow vein mosaic disease" found in South-East Asia and over 90 years the disease affected the okra. The widespread of the Geminivirus in okra as the leaf of okra started to curl (Harrison *et al*., 1997) [14]. But the isolates are different from both viruses which were found in India (BYVMV) and Africa (OLCV). OLCV has many features like ACMV (Africa cassava mosaic) which belongs to group A, on the other hand, BYVMV has features like ICMV (Indian cassava mosaic). The vector which transmits the geminivirus is of the same species i.e. *Bemisia tabaci*. The characteristics of the whitefly are similar to the *B.tabaci* (the 4th instar) as described during 1889. The characters reside in the 4th instar such as natural enemy avoidance, UV exposure and characterization of the host plant. The biotype B invade the United States as which have the same features as biotype A but when the study is conducted it has been observed that there are some special characters are there in biotype B like they don't have 4th anterior margin, pair of setal, thoracic tracheal folds which make them unlike from biotype A (Van Lenteren & Noldus., 1990) [36]. The disease which is caused by the whitefly has some distinctive symptoms like yellowing of vein, yellow mosaic, and curling of leaf. From a few years ago the cases of whitefly are increasing day by day. The begomovirus has different hosts in the same geographical area and they are antigenically correlated with one another. The epitope of the Indian cassava mosaic virus is similar to the begomovirus in India and the leaf curl virus and Cassava geminivirus also. The epitope of the Cotton leaf curl virus differs from the cotton leaf crumple virus. This epitope is also related to the Tomato golden mosaic and bean golden mosaic virus. They have a very limited influence on the plant species (Swanson & Harrison., 1993) [33]. This will turn into two parts that are the range of host plants is more plastic and the begomovirus is followed by the RNA plant virus. Here, the begomovirus occurs in different regions so can able to adapt any plant species at a wide range and at different times. The second one is the particle protein of begomovirus, this protein can evolve in different regions of different geography without any host range and works at region-specific operations. The region-specific conditions depend upon the climatic conditions of that area (Domingo *et al.,* 1993) [8]. The different condition ranges are antigenically similar to the begomovirus. The selection pressure is also exerted by *Bemisia tabaci* (whitefly). For the transmission of vectors, both the direct and indirect proofs are used that the begomovirus particle protein and coat protein are very important. The Begomovirus is transmitted through the whitefly (*Bemisia tabaci*) and they have some antigenically related particles (Harrison *et al*., 1997) [14]. Most of the geminiviruses like leafhopper transmitted geminivirus are antigenically un correlated and they also have different co species and vector species. This points to the parallelism between the antigenic affinity and species-specific vector (Venkataravanappa *et al*., 2015) [39]. Secondly the transferring of beet curly top virus coat protein gene of leaf hooper into African cassava mosaic virus. Thirdly, the coat protein virus gene in the whitefly transmits the golden mosaic virus of Sida. Fourthly, the substitution of amino acid in the coat protein of tomato leaf curl virus suppresses the transmissibility of Bemisia tabaci. But the ability to germinate the particles and their replication remain unaffected (Yadav *et al*., 2018) [41]. *Bamasia tabaci* is considered one of the complex species of aphids. The coat protein is a special protein that can adapt the transmission of sympatric different species of *Bamasia sp*. and this will show the antigenic similarity of coat protein in Begomovirus. The *Bemisia tabaci* feed on the different plant species and suck the plant cell sap which works as a test plant (Perring *et al*., 1993) [24]. The *Bemisia tabaci* can able to transmit almost twelve begomoviruses in different regions of the country and the whole world. The vector *Bemisia tabaci* transmits the sympatric vector more than that of the non-sympatric vector (Swanson *et al*., 1998) [34]. The begomovirus is circular, bipartite and is a single-stranded DNA genome that is DNA-A and DNA-B. They are in the size of 2500-3000nt. The begomovirus is a monopartite genome so they do not have DNA-B (Zhou *et al*., 2001) [42].

Enation Leaf Curl Virus (ELCV)

The virus belongs to the genus Begomovirus, which belongs to the Geminiviridae family (Venkataravanappa *et al*., 2014) [37]. Geminiviruses are plant-infecting viruses that are transmitted by the whitefly Bemisia tabaci and infect dicotyledonous plants. They have a peculiar geminate particle shape and circular single-stranded (ss) DNA genomes (Lazarowitz, 1992) [18]. The geminiviruses have a wide host range and are responsible for major economic losses in crops across the world (Harrison and Robinson 1999; Moffat, 1999) [13, 22]. Except for one recent example (Melgarejo *et al*., 2013; Sánchez-Campos *et al*., 2013) [20, 25]. New World begomoviruses contain

genomes made up of two halves, DNA-A and DNA-B, each measuring 2.6–2.8 kb which showing in belove figure. Although a few bipartite begomoviruses have been discovered in the Old World, most contain single-component genomes that are identical to the bipartite viruses' DNA-A component (Brown *et al*., 2012) [2]. The majority of monopartite begomoviruses are associated with betasatellites (previously known as DNA), a class of ssDNA satellites. Betasatellites are half the size of the begomoviruses that they need for replication, insect transmission, and plant mobility (Saunders *et al*., 2000; Jose and Usha, 2003; Cui *et al*., 2004; Li *et al*., 2005) [28, 15, 6, 15]. The first alphasatellite DNA related with enation leaf curl virus (ELCV) in okra has been identified (Chandran *et al*., 2013) [4]. The full-length DNA is 1,350 nucleotides long and demonstrates normal alphasatellite genome structure. It exhibits the greatest nucleotide sequence similarity (79.7%) to the symptomless alphasatellite associated with Hollyhock yellow vein virus (HoYVSLA). Despite being an important Indian vegetable crop that is cultivated all year in all locations of the nation, okra yields are lower due to infection by a variety of diseases, one of most important of which are viral diseases (Usha, 1980) [35]. Yellow vein mosaic virus (Kulkarni, 1924) [16], enation leaf curl (Singh and Dutta, 1986; Singh, 1996) [32, 31], okra leaf curl, and okra mosaic virus have all been identified to cause diseases in okra (Lana, 1975) [17]. Enation leaf curl virus (ELCV) is currently a severe problem in all of India's okra-growing locations (Singh, 1996; Singh *et al*., 2013) [31, 30]. Although the virus is not spread by seed (Givord and Koenig, 1974) [10], but it is associated with whiteflytransmitted begomovirus (Venkataravanappa *et al*., 2014) [37]. Between July and September, the vectors are active in the Gangetic plains of West Bengal during the morning hours (Seth *et al*., 2016) [29].

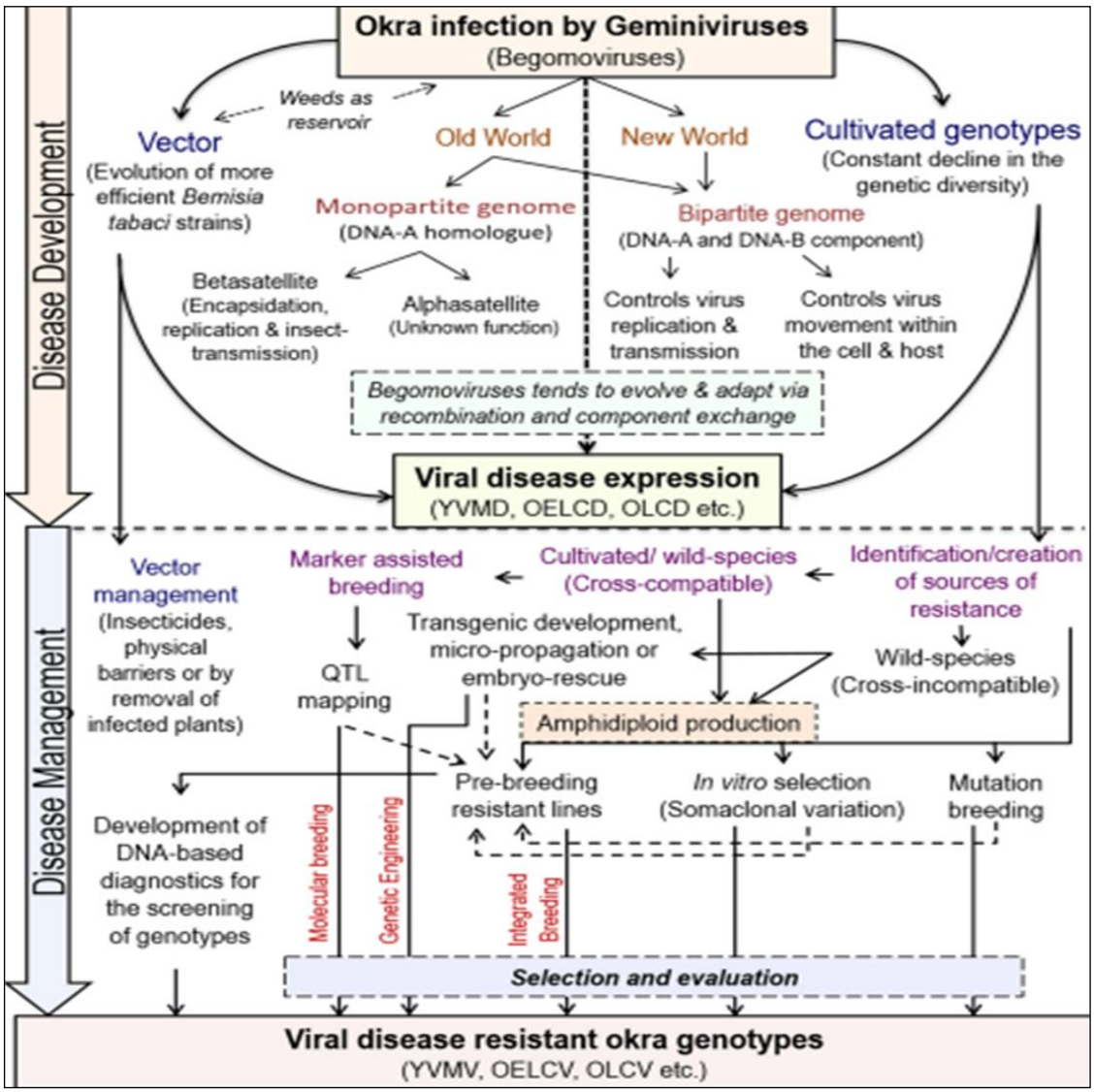

Fig 2: Begomovirus induced disease development and strategies of its management in okra (Mishra *et al*., 2017) [21].

ELCV Disease Severity and Yield Loss

Depending on the age of the plant at the time of infection, the disease can cause severe yield losses ranging from 30percent to 100percent. (Singh, 1996) [31]. He also reported that infected plants at 20, 35, and 50 days after germination had yield losses of 93.8 percent, 83.6 percent, and 49.3 percent, respectively. Plants infected at 5 and 10 days did not produce any fruit, resulting in a 100percentage yield loss. If the plants become infected

within 15-20 days after germination, no yield can be achieved, especially in West Bengal's Gangetic plains (Anonymous, 2016) [1]. This disease will be a future threat to okra production, necessitating a targeted breeding effort to develop resistance to ELCV (Singh *et al*., 2013) [30].

Conclusion

The above discussed is about the whitefly scientifically known as *Bemisia Tabici.* It is an aphid that spread the disease in many crops such as tomato, tobacco, cotton, etc. but among all the most harm was caused on okra in common words known as lady's finger. In okra the whitefly attacks the sac of the plant which leads to wilting and eventually the plant dies. So, to control the whitefly one should know the natural genomic and antigenic variation. Whitefly is the most dangerous aphid as in 1991 it causes huge damage in the U.S. and when the studies were conducted it was observed that it has some distinctive characteristics which make them different from others as it has some survival quality to protect itself from other predators and easily went through the plant. The variation in their genes is upgraded so rapidly that the species are evolving and the new species is even better than the previous one like the silver fly which is a new species of whitefly and causes more damage. To control the whitefly farmers prefer insecticides. Whitefly contain morphology of twin particle and they have ssDNA either monopartite or bipartite, but in the case of whitefly, they have bipartite genome i.e. DNA-A & DNA-B due to which they can infect the dicotyledonous plant, and these are some special ability of whitefly which make them easy to attack the plant. Several studies have been conducted to observe the natural genomic and variation in whitefly to decrease its spread in plants. Also discuss about ELCV disease who severely affected the okra and transmitted by the white fly itself.

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