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STATUS OF TOMATO VIRUSES IN NIGERIA

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ABSTRACT
Tomato (*Solanum lycopersicum* L.) is an important crop, extensively cultivated as vegetable and fruit worldwide for its nutritional supply of vitamins, minerals, antioxidants and carbohydrates to humans. Its production in Nigeria is dominated by poor resource peasant farmers as their major means of livelihood. Virus diseases have been considered as an economically important biotic factor mitigating profitable tomato production during wet and dry seasons of Nigeria. The increase in number of new viruses and emergence of host resistance-breaking strains of known virus species causing significant yield losses on tomato is of great concern and these vary from one location to another. The status of research on viruses infecting cultivated tomato in Nigeria is discussed.

Keywords: Tomato, viruses, status, Nigeria.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important crop extensively cultivated as vegetable and fruit worldwide for its nutritional supply of vitamins, minerals, antioxidants and carbohydrates to humans (Lenucci *et al.*, 2006; Reiss *et al.*, 2012). In Nigeria, tomato is grown throughout the country. However, the major production centers are located between latitudes 7.5 °N and 13 °N with a temperature range of 25 – 34 °C (Villareal, 1980) that extensively spread across about 679 clusters covering 171,179 hectares of land in 12 Northern States of the Savanna (GEMSA4, 2016). Tomato production in Nigeria is dominated by poor resource peasant farmers as their major means of livelihood. Yield losses due to the menace of biotic stress however pose a serious threat to the profitable production of tomato wherever the crop is grown in the Country. Viral diseases play a very significant role in these losses (Alegbejo, 2015). Tomato is infected by over 200 diseases of which 20% are caused by viruses worldwide (Martelli and Quacquarelli, 1982; Lukyanenko, 1991; Salvador *et al.*, 1996). These viruses belong to seven families (*Bromoviridae, Bunyaviridae, Closteroviridae, Flexiviridae, Geminiviridae, Luteoviridae* and *Potyviridae*) and 33 genera from which only 15 are considered to be of economic importance viz: *Alfalfamovirus, Begomovirus, Carlavirus, Crinivirus, Cucumovirus, Ilarvirus, Luteovirus, Nepovirus, Potexvirus, Potyvirus, Tobamovirus, Tombusvirus, Topocuvirus, Tospovirus,* and *Tymovirus* (Green, 1991; Pringle, 1999). Nono-Womdim *et al.* (2004) documented five virus genera (*Begomovirus, Tobamovirus, Cucumovirus, Tospovirus,* and *Potyvirus*) as prevalent tomato viruses in tropical Africa but recently 7 virus genera (*Begomovirus, Cucumovirus, Nepovirus, Tobamovirus Tombusvirus, Tospovirus,* and *Potyvirus*) have been considered as economically important biotic factors mitigating successful tomato production both during the wet and dry seasons of Nigeria. With the continuous increase in the number of new viruses been implicated to infect tomato and the emergence of new resistant-breaking strains of known viruses of the crop worldwide (Kashina, 2017) is expedient to avert yield loses from disease outbreak likely to be caused by such viruses. These can be achieved by documenting an update on the status of important viruses infecting tomato in the country, frequent surveillance and monitoring to diagnose and characterize emerging tomato virus species and strains, assessing their significance on crop yield, understanding their epidemiology, developing disease preventive strategies and creating awareness to farmers on the incidence and effective management measures of these viruses. This will also provide relevant information geared toward research priorities in breeding programs for development of resistant cultivars and integrated management of tomato viruses in Nigeria. This article documents research on important viruses infecting tomato in Nigeria.

Tomato Yellow Leaf Curl (TYLCV)

Tomato yellow leaf curl virus (TYLCV; family *Geminiviridae,* genus *Begomovirus*) has a single-stranded circular DNA genome ranging from 2.5 – 3.0 kb encapsidated in a twinned icosahedral virion particles measuring about 20 × 30 nm (Brown *et al.*, 2012). Different strains of tomato yellow leaf curl virus have been reported in Africa (Chiang *et al*., 1997; Monci *et al*., 2000; Pietersen *et al*., 2000; Nono-Womdim, 2003). Occurrence of *tomato yellow leaf curl virus*- Nigeria (TYLCV-NG) was reported in Nigeria having 84-86% coat protein sequence

difference with species from Israel and Saudi Arabia (reviewed by Kashina, 2017). TYLCV was also reported as a common and most important tomato virus occurring in famers' fields in Sokoto, Zamfara (Bello *et al*., 2017), Kano, Jigawa and Gombe states of Nigeria. TYLCV has a wide host range of plant species from many families such as *Acanthacea, Asteraceae, Caricaceae, Euphorbiaceae, Fabaceae, Malvaceae, Pedaliaceae, Plantaginaceae, and Solanaceae* (Nono-Womdim *et al.,* 1996; Kashina *et al.,* 2002). Tomato plants infected by TYLCV express typical symptoms such as yellowing, puckering and size reduction in the terminal leaves, curling of lower leaves and stunting (Kashina *et al.,* 2003; Bello *et al.,* 2017). The age or developmental stage of the plant at which infection occurs determines the severity of foliage symptoms and yield reduction (Nono-Womdim, 2003). Whitefly (*Bemisia tabaci* Gennadius) is the principal vector that transmits TYLCV in a circulative, non-propagative and persistent manner (reviewed by Scholthof *et al.,* 2011). The virus can also be transmitted by grafting (Nono-Womdim, 2003). However, very recently Kil *et al.* (2016) reported for the first time the transmission of TYLCV through infected seeds and tomato seedlings. TYLCV causes one of the most important tomato diseases capable of causing up to 20-90% fruit yield loss (Lana and Adegbola, 1977). Attempt to control whiteflies with various synthetic insecticides spray have not be reported to be effective over time due to fast development of resistance to insecticides (Horowitz *et al.,* 2005) and recently discouraged due to their deleterious effects on the environment. Manipulations of cultural practices, control of the insect vector and the use of resistant varieties have been reported to be effective on the management of TYLCV (Momol *et al.,* 2001; Kil *et al.,* 2016).

***Tomato Mosaic Virus* (ToMV)**

Tomato mosaic virus (ToMV; family *Virgaviridae,* genus *Tobamovirus*) is a stable single molecule positive ssRNA virus infecting plant species with cosmopolitan distribution (Hollings and Hottinga, 1976; Deepak, 2018). Infected host cells contain crystalline and amorphous X-bodies while virus particles even though distributed throughout the host plants, are specifically located in the cytoplasm. The virus characterized is by longevity (LIV) *in vitro* of 500 days, dilution end point (DEP) range of 10^{-5} -10^{-7} and thermal activation point (TAP) of 85-90 ^{o}C (Regenmortel and Meshi 1995; Brunt, *et al.,* 1996; Alegbejo, 2015). Several strains of ToMV availed but two (pathotypes 0 and 1) were reported on tomato in Africa (Nono-Womdim *et al*., 1996). ToMV disease has worldwide spread and is reported as a common and important disease of tomato in Nigeria (Simon and Sobulo, 1975). ToMV is widely distributed in the South western States (Ogun, Ondo, Osun and Oyo) (Lana and Adegbola, 1977; Olawale *et al*., 2015; Ayo-John and Odedara, 2017) and Sudan savanna (Zamfara and Sokoto states) of Nigeria (Bello *et al*., 2017). Tomato, okra, pepper, tobacco, potatoes and African nightshade are the primary host of ToMV (Alegbejo, 2003; Nono-womdim, 2003). ToMV symptoms usually starts with a light to dark green colour between the veins of young leaves of tomato plants infected with this virus. Expression of the "mosaic" pattern for which the virus is named begins after that stage. Leaves may curl, mottle, chlorosis and become fern-like in appearance. Other symptoms include stunted growth, fruit deformities and severe reduction in fruits produced. There may be internal browning of fruits when cut open (AVRDC, 2004; Kumar *et al.,* 2011; https://tomatodiseasehelp.com/mosaic-virus). There is no report of any known natural vector for the virus but can be transmitted by contact between plants, grafting, mechanical inoculation and up to 94% transmitted by seed in tomato. Hoon and Jin (2002) reported that contaminated seeds carrying the virus on their seed coat and infested plant debris are the primary sources of inoculum of ToMV in the field. Yield losses of over 25% have been reported from severe infection in glass house in Nigeria due to ToMV attack (Lana and Adegbola, 1977; Alegbejo, 2015). ToMV is very difficult to management due to it persistence in the soil (Sastry and Zitter, 2014). Management measures include planting of virus free seeds and resistant tomato cultivars, avoiding planting in ToMV contaminated soils. Disinfection of equipment with milk solution (5ml milk / 100ml of distle water) after each use. (Nono-womdim, 2003; Boben *et al.,* 2007).

***Tomato Leaf Curl Virus* (ToLCV)**

Tomato leaf curl virus (ToLCV; family *Geminiviridae*, genus *Begomovirus*) is a very devastating and economically significant pathogen of cultivated tomatoes in tropical and sub-tropical regions (Brunt *et al*., 1996; Novo-Womdim *et al*., 1996; Lapidot *et al.,* 2001; Maske *et al.,* 2018). ToLCV have been reported to occur in Nigeria with major distribution across the northern Guinea, Sudan and Sahel ecological zones and spatial spread in the rainforest and derived savanna zones of the Country (Alegbejo, 1995; Alegbejo and Ogunlana 1995a; Erinle and Alegbejo, 1996; Alegbejo and Banwo, 2006). It is the most limiting factor in tomato production between January and May in the northern states of Nigeria (Alegbejo, 1995; Alegbejo and Ogunlana, 1995a; Alegbejo, 2000a). Tomato leaf curl virus have been associated with a wide range of crop host plant species belonging to the Family Solanaceae (*Capsicum annuum* L., *C. frutescens* L., *Lycopersicon Nicotiana sylvestris* Speg and Comes, *N. benthamiana* Domin, *N. glutinosa* L., and *Nicotiana tabacum* L. v*ars* Samsun); Family Malvaceae *(Corchorus tinctorius* L., *Hibiscus syriacus* L., *Abelmulcus esculentus* L. and *Gossypium hirsutum* L.); Family Fabaceae (*Arachis hypogaea* L., *and Phaseolus vulgaris* L.); Family Pedaliaceae (*Sesamum indicum* L.); Family Asteraceae (*Sonchus oleraceus* L.). Others include *Vernonia* spp. *Carica papaya*, *Chaerogphyllum* spp., *Cynanchum acutum* L., *Hyoscyamus desertorum* L., and *Nicandra physaloides* (L.) Gaert (Cohen and Nitzany, 1966; Nakhla *et al*., 1978; Cohen and Antignus, 1994; Nakhla *et al*., 1994; Nono- Womdim *et al*., 1996; Alegbejo, 1997; Alegbejo, 2000a). ToLCV disease is expressed by leaf chlorosis, inward and upward leaf curling, brittle, wrinkled

veins, veinlets bushy growth, leaf distortion, shrinking of leaf surface, stunted plant growth, excessive branching, abnormal growth of plants and flower and fruit abscission (Alegbejo and Ogunlana 2000; Shelat *et al.,* 2014). Transmission of ToLCV is mainly through grafting and whitefly (*Bemisia tabaci* Gennadius) in a persistent manner (Gerling and Mayer, 1995; Alegbejo, 2000b; Alegbejo and Banwo, 2005). ToLCV is reported to limit the profitable tomato production during the dry season in the Northern states of Nigeria (Alegbejo 1995; Alegbejo and Ogunlana 1995b), causing annual revenue loss of about ₦5-120 million naira, yield loss of 50% in Kaduna and 100% in Sokoto, Katsina and Borno (Alegbejo, 2015). Use of resistant cultivars is an effective management measure (Alegbejo, 1995, 2004a; Alegbejo and Banwo, 2006). Cultural control measures such as ensuring weed-free farms and avoiding planting tomato near other solanaceous crops; intercropping tomato with tall cereals (maize or sorghum); mulching of soil with dry grass or polyethylene sheets and removal and destroys early infected plants (Alegbejo, 2015). Use of synthetic chemicals to control insect vector (*Bemisia tabaci* Gen.) of the virus was reported to be effective (Uvah *et al.,* 1990).

***Tomato bushy stunt virus* (TBSV)**

TBSV, the type member of the Genus *Tombusvirus* in the family *Tombusviridae* is a unipartite, isometric, single-stranded positive sense RNA virus with 33 nm in diameter (Martelli *et al.,* 1988; 2001). It is composed of 17% nucleic acid and 83% protein with the virions located in the plant cell organelles such as cytoplasm, nuclei, nucleoli, mitochondria and vacuoles. Infected plant cells contain crystalline and unusual inclusion bodies (Yamamura and Scholthof, 2005; Lommel and Sit, 2008; Hull, 2014). TBSV has a thermal inactivation point of 80-90 ^{0}C; longevity *in vitro* 130-150 days and dilution end point 10^{-6} (Martelli *et al.,* 1988; Fischer and Lockhart, 1977). TBSV is widespread and causes economically important diseases in several crops (Martelli, 1981; Martelli *et al*., 2001). Abraham *et al.* (2019a) documented the first report on serological detection of TBSV infecting irrigated tomato in northern (Kano, Gombe and Jigawa states) Nigeria. TBSV might also be distributed in South Western States (Alegbejo, 2015). Naturally, TBSV has restricted crop host range. It infects primarily vegetables and few legumes such as: *Solanum esculentum* L. *Capsicum* spp., *Nicotiana* spp., *Petunia* sp., *Phaseolus vulgaris* L., *Solanum* sp., *Dahlia* spp., *Dianthus barbatus* L., etc., (Yamamura and Scholthof, 2005; Alegbejo, 2015). TBSV diseased tomato plants show reduced size, cupped, downward curled leaves, twisting and necrosis that may kill the young shoot (http://ipm.ucanr.edu/PMG/r783102411.html). The rapid and excessive growth of the lateral shoots results to twisted and stunted plant growth thereby giving it a bushy appearance. Fruit may be mottled or blotched and yield is greatly reduced (Luis-Arteaga *et al.,* 1996; Ali *et al*., 2015; Abraham *et al.,* 2019a). There is no known vector of *Tomato bushy stunt virus;* although virus incidence is often associated with the soil and may be spread with irrigation water and TBSV enter into host plants through wounds in damaged root cells (http://ipm.ucanr.edu/PMG/r783102411.html). The virus is also transmitted either naturally through infected seeds, pollen, propagative material or manually by the use of contaminated cutting tools (Mahy *et al.,* 2009; Nawaz *et al*., 2014; DANR, 2016). Tomato fruit yield is significantly reduced if virus infection occurs early in the season. Yields are reduced and fruits become smaller and show chlorotic rings and blotches that lower the economic value of the crop (Luis-Arteaga *et al.,* 1996; Yamamura and Scholthof, 2005; Alegbejo, 2015). Management measures include Avoidance of tomato bushy stunt virus contaminated soils and long crop rotations may be effective (http://ipm.ucanr.edu/PMG/r783102411.html). Eliminate all volunteer plants. Sow only seeds harvested from healthy plants or transplant only healthy seedlings (Alegbejo, 2015; DANR, 2016).

***Tomato Aspermy Virus* (TAV)**

Tomato aspermy virus (TAV; family Bromoviridae, genus *Cucumovirus*) is made up of a tripartite genome of messenger positive sense single-stranded RNAs designated RNA 1, 2 and 3 in decreasing order of molecular size of 3.41 kb, 3.074 kb, and 2.214 kb respectively which are encapsidated in 28 nm isometric particles (Palukaitis and Garicia-Arenal, 2003; Wispelaere *et al*., 2005; ICTVdB Management, 2006). The virus has longevity *in vitro* (LIV) of 2-6 days, thermal inactivation point (TIP) of 50-60 °C, and dilution end point (DEP) of $\log_{10}^{-1}$ (Habili and Francki 1974; ICTVdB Management, 2006). Recently TAV has been reported to occur in Sokoto, Zamfara (Bello *et al.,* 2017), Kano, Jigawa and Gombe states of Nigeria causing significant yield loss. Chrysanthemum and tomato are the most well-known natural hosts of TAV, but *Capsicum annuum* and cucumber have also been reported as natural crop host (Blencowe and Caldwell, 1949; Holdings and Stone, 1971; Schmelzer *et al*., 1977). TAV infected tomato plants developed characteristic systemic symptoms such as leaf mottling, stunted growth, malformed, small sized and seedless fruits (Raj *et al.,* 2011; Bello *et al.,* 2017). In nature, aphids (*Aphis gossypii* Glover and *Myzus persicae*) easily transmit the virus non-persistently (Chen and Francki, 1990; Perry and Francki, 1992; Shi *et al*., 1997). It is also transmitted by dodder and infected plant sap (Raj *et al*., 2009). In susceptible species of tomato, TAV causes crop dwarfism with small seedless fruits resulting in significant yield losses in production (ICTVdB Management, 2006). Cultural and biological insect pest management measures are considered most effective for managing TAV vectors thereby avoiding the challenge of insect pest resistance due to frequent insecticide applications (Palumbo *et al*., 2001). Some common cultural practices reported to be effective against tomato virus diseases include: vector manipulation, removal of inoculum sources, cross-protection, planting of resistant varieties, and exclusion of both the virus and its vector (Hilje *et al*., 2001; Lapidot and

Friedmann, 2002; Greer and Dole, 2003; Yang *et al*., 2004; Mutwiwa *et al*., 2005).

***Tomato Ring Spot Virus* (ToRSV)**

ToRSV is one of the crop yield most annihilating members in the genus *Nepovirus* and family *Secoviridae* (CABI, 2018). The particles are unstable, icosahedral, sedimenting as three components and containing single-stranded RNA of 28 nm in diameter (Samuitiene *et al.,* 2003). The infectious genome of ToRSV is shared between two species of + ssRNA (RNA1 and 2), the 5' end of each having a VPg and the 3' end being polyadenylated (Stace-Smith, 1984; Sanfaçon *et al.,* 2008, 2009; Hull, 2014). Abraham *et al.* (2019b) documented the first report on the occurrence of the ToRSV in irrigated tomato fields in northern Nigeria. ToRSV attacks about 285 plant species in 159 genera of 55 botanical families (Edwardson and Christie, 1997; EPPO, 2005). In nature, ToRSV occurs mostly in woody, ornamental plants, fruit crops including tomato, cucumber, raspberries, grapes, peaches, cherries and other *Prunus* spp., black currants, gooseberries, strawberries, *Pelargonium*, *Hydrangea*, *Gladiolus* and *Fraxinus americana* (EPPO/CABI, 1997; EPPO, 2005; Zitikaité and Staniulis, 2006; Tzanetakis and Martin, 2013; González *et al*., 2017). Ringspots of similar size on leaves and fruits is the typical symptom expression induced by ToRSV. Stunted growth, leaf mottling with circular chlorotic spots are also common symptoms (Murant, 1981; Fuchs *et al*., 2010; Abraham, *et al.,* 2019b). Early infection of fruits may show faint to clear, grey to brown, corky, superficial and frequently concentric rings or portions of rings. Fruit production may be reduced and infected plants may eventually die (Smith, 1972; DANR, 2016). ToRSV is readily transmissible through vegetative propagation, sap inoculation, seeds and pollen. (EPPO/CABI, 2005; CABI, 2018). The virus has also been transmitted occasionally through tomato seeds. However, species of *Xiphinema* and *Longidorus* vectors remain the most important transmitting agents of ToRSV in many susceptible host plants (Samuitiené *et al.,* 2003) and infected seeds may serve as a source of primary inoculum of virus in the soil (EPPO/CABI, 1996). *X. nigeriense* and *Longidorus* spp. have been reported to occur in pineapple fields in South East (Daramola and Afolami, 2014) and irrigated vegetable fields in North East (Abraham *et al.,* 2018) of Nigeria. Both adults and juvenile stages of nematodes vectors can transmit the virus after acquiring it within an hour and infecting healthy plants within 1 hour (EPPO/CABI, 1997). ToRSV causes significant economic yield losses in many ornamentals, perennial fruit crops and horticultural crops globally (Griesbach, 1995; Stace-Smith 1996; Bosso *et al.,* 2016). An integrated management approach of tomato ringspot virus is necessary: use of ToRSV free propagating plant materials, controlling the nematode vector species by fumigation/sterilization of soil and substrates before planting, removal of reservoir weed hosts of the nematode vectors (DANR, 2016; http://ipm.ucanr.edu/PMG/r105102811.html).

***Tomato Spotted Wilt Virus* (TSWV)**

Tomato Spotted Wilt Virus (TSWV; type species, family *Bunyaviridae*, genus *Tospovirus*) is the only member from this genus known to infect tomato crop (Sherwood *et al.,* 2003). It contains a membrane-bound quasi spherical particle 80–120 nm in diameter with surface projections 5–10 nm in length which is found in all parts of the infected host plant (Francki *et al.,* 1991; Hull, 2014). Three segments of ssRNA (the L segment is negative-sense 8.90 kb, the M and S segments are ambisense of 4.82 and 2.92 kb, respectively) constitute the virus genome (Kormelink, 2005; Pappu, 2008; Hull, 2014). Its thermal inactivation point is 45^0C; longevity in vitro is 0.2 days (5 hours), while dilution end point is 10-3 (Alegbejo, 2015). TSWV occurs in Nigeria and is distributed in the Northern and South-western regions (Thottappilly and Rossel 1992; Brunt *et al*., 1996; Alegbejo, 2015, Ayo-John and Odedara, 2017). It has the largest host range of any plant virus, infecting over a thousand species, in 279 genera from 84 botanical families of dicotyledons and monocotyledons such as tomato, amaranth, pepper, peanut, watermelon, sun flower, tobacco and cowpea (Best, 1966; Cho *et al*., 1987; Parella *et al.,* 2003; Alegbejo, 2015; http://www.oznet.ksu.edu/tospovirus/ hostlist.html). Symptoms expression due to infection by TSWV vary as reviewed by Scholthof *et al.* (2011) including conspicuous chlorotic or necrotic rings on foliage, stems and fruits during early infection resulting to stunted plant growth while reduced sized, malformed and unmarketable fruits with chlorotic or necrotic ringspots that are frequently expressed only when the fruits attend full red colour as later infections symptoms. In nature, TSWV is transmitted exclusively by a number of Thrips species (*Thysanoptera: Thripidae*) within which the virus replicates itself (Van *et al.,* 1992; Wijkamp *et al.,* 1993; Ullman *et al.,* 2002 Sin *et al.,* 2005; Whitfield *et al.,* 2005). The virus is also transmitted by mechanical inoculation and grafting (Moritz *et al.,* 2004; Jones, 2005). Infection often reduces the market value both in quantity and quality of fruits and significant reduction in potential yield hence low income for farmers (Sherwood *et al.,* 2003; Alegbejo, 2015). Cultural control practices are the major prophylactic measures against infection by TSWV as thrips have been reported to develop resistance to a wide range of synthetic insecticides (Chattopadhyay *et al.,* 2017). Exclusion by screening of plant materials for TSWV and infestation by thrips, rouging of infected plant stands and removal of TSWV reservoir weed hosts within and around greenhouse or fields, frequent monitoring for thrips infestation and management is necessary (Zitter and Daughtrey, 1989).

***Pepper Veinal Mottle Virus* (PVMV)**

Pepper veinal mottle virus (PVMV), genus *Potyvirus* is a single-stranded RNA virus with flexuous, 770 x 12 nm in size (ICTVdB, 2006a). It contains 6 and 94% nucleic acid and protein respectively with particles found in cytoplasm of all parts of the infected host plant. It has the thermal inactivation

point (TIP) of 55-60°C, longevity *in vitro* (LIV) of 7-8 days and the dilution end point of 10^{-3}-10^{-4} (ICTVdB, 2006a; Alegbejo, 2015). PVMV occurs mainly in Africa and has been reported on pepper and tomato in Western and Northern states of Nigeria (Lana *et al*., 1975; Ladipo and Roberts, 1977; Atiri, 1986; Alegbejo and Uvah, 1987; Alegbejo and Kashina, 2002; Fajinmi, 2006, 2010; Alegbejo, 2015, Ayo-John and Odedara, 2017). The strains of the virus are host of least 35 species in the family Solanaceae and 9 species of 5 other families (Aizoaceae, Amaranthaceae, Apocynaceae, Chenopodiaceae and Rutaceae) (Brunt *et al*., 1978; Prasada *et al.,* 1979; Alegbejo, 1999). Crops such as *Capsicum annuum, C. frutescens*, (*Solanum lycopersicom*), and *Solanum melongena* have been reported to the principal hosts of the virus (Nono-Womdim, 2003; Alegbejo, 2015). PVMV is known to be mainly transmitted by a minimum of five species of aphids *Aphis gossypii*, *A. crassivora*, *A. spiraecola*, *Myzus persicae*, and *Toxoptera citridus* in a non-persistent manner while non-vector transmission is by mechanical inoculation (Brunt *et al*., 1978; Alegbejo, 1986; Nono-Womdim, 2003). Host plant susceptibility, viral strain and environmental factors determine the nature and severity of symptoms expression due to PVMV. Common symptoms due to PVMV include vein-banding or vein-clearing which may be wrinkled, curling of the leaves, stunted growth and fruits distortion (Alegbejo, 1978; Sastry, 1982; Alegbejo, 2015). *Pepper veinal mottle virus* (PVMV), a potyvirus, is a major constrain to the cultivation of pepper and tomato in all parts of Nigeria (Alegbejo and Uvah, 1987; Fajinmi, 2006). Cultural control stands out to be the most effective management measures for PVMV. These include removal and destruction of early infected plants, use of resistant cultivars, keeping field free of weed and intercropping with tall cereals such as maize or sorghum and integrated management. Botanical oil spray can also be used to deter aphid vectors from feeding and synthetic chemicals (Alegbejo, 2002; Alegbejo and Abo, 2002; Alegbejo, 2015)

***Tomato black ring virus* (TBRV)**

Tomato black ring virus (TBRV; family *Secoviridae*, genus *Nepovirus*) is a positive ssRNA virus (CABI/EPPO, 1993) that has isometric particles c. 28 nm in diameter with hexagonal outlines. The virus particles in purified form exist as three sedimenting components termed as T, M and B with sedimentation coefficients ($S_{20,w}$) of c. 55S, 97S and 121S respectively. M and B particles constitute the linear ssRNA with 1.7 x 106 and 2.7 x 106 mw respectively while T particles are nucleic acid-free protein shells. All particles consist of 60 protein subunits each of c. 57 000 mw (Murant, 1970; Murant *et al.,* 1973). TBRV occurs worldwide and Chalam *et al.* (2008) reported the interception of *Tomato black ring virus* (TBRV) in three accessions of cowpea from IITA, Nigeria. There is however, limited information about its spread on tomato and other vegetables in different parts of Nigeria. TBRV is widespread in many crops species of global economic importance such as rosaceous species (currant, strawberry, blueberry and raspberry), solanaceous species (onions, cabbage, lettuce, potato, tomato, pepper and tobacco), some forest tree, weed ornamental species (Harrison, 1964; Lister and Murrant, 1967; Harrison and Murant, 1977; Brunt *et al.,* 1996; Edwardson and Christie, 1997; Šneideris *et al.,* 2012; Šneideris and Staniulis 2014). TBRV is naturally transmitted between plants by both the larvae and adults of *Longidorus elongatus* and *Longidorus attenuatus* in a non-circulative persistent manner (Harrison *et al.,* 1961; Murant, 1970; Taylor and Brown, 1997). The virus is also transmitted through infected seeds of crops, weeds, vegetative propagated planting materials and by transport of soil contaminated with TBRV-infected nematodes (Lister and Murant, 1967; CABI/EPPO, 1993; Chalam *et al.,* 2008). Disease symptoms expressed by TBRV infected plants include systemic chlorotic or necrotic rings and spot, leaf mottling and deformation; vein chlorosis, stunting and flecking (Brunt *et al.,* 1996; Šneideris *et al.,* 2012). TBRV causes severe disease in its crop hosts (CABI/EPPO, 1993) with no quantifiable records of their yield losses however, Harper *et al.* (2011) reported yield losses of up to 40% on artichoke (*Cynara carduncul*us L.) while Ephytia, (2018) documented up to 80% yield loss on potato due to attack by TBRV. Soil treatment with nematicides or solarization in nurseries and fields prior to planting, use of healthy propagating material, removal of alternative weed host both for the virus and the vector are effective management measures for TBRV (Murant and Taylor, 1965; Trudgill and Alphey, 1976).

Potato virus Y

Potato virus Y (PVY; type member, family *Potyviridae*, genus *Potyvirus*) particles are long flexible about 750 nm long and 11 nm wide in diameter (Brunt *et al.,* 1990). The genome is a unipartite single-stranded molecule of positive-sense ssRNA, about 9.7 kb, the 5' end of which has a VPg and the 3' end is polyadenylated. There is one sedimenting component with sedimentation coefficient of 145 S 20w found in purified preparations. The virus have the thermal inactivation point (TIP) of 50-62°C, longevity *in vitro* (LIV) of 7-50 days and dilution end point of usually around 2-6 (Brunt *et al.*, 1990; Jones *et al.,* 1991; Kerlan, 2006; Hull, 2014; Alegbejo, 2015). The virus occurs worldwide, but has a narrow host range in the tropics. PVY occurs in tomato and pepper in few African countries (Nono-Womdim, 2004). In Nigeria, PVY has been reported on tomato and pepper in Ogun, Osun and Oyo states (Arogundade *et al.,* 2012; Ayo-John and Odedara, 2017) and on potato in Plateau state (Miha *et al.,* 1993) of Nigeria. PVY has a wide host range, infecting 405 species from 72 genera of which *Capsicum* spp., *Solanum tuberosum*, and *Solanum lycopersicon* are principal host of the virus (ICTVdB, 1995-1999d; Nono-Wondim, 2003; Alegbejo, 2015). Vein-clearing and mottling are characteristic symptoms due to PVY infection. Clearing of veins develop 7 – 9 days after infection followed by the characteristic green-banding of the veins (Nono-Wondim, 2003; Burrows and Zitter, 2005; Hull, 2009). Mechanical inoculation, grafting and by several species of aphids (*Aphis fabae* Blanchard,

Macrosiphon sp., *Myzus* spp., *Myzus persicae* Sulzer, *Rhopalosiphum* sp.) in a non-persistent manner and a helper component is necessary for transmission by the vector (Kerlan and Moury, 2008; Alegbejo, 2015). The virus causes serious losses in many important crops worldwide, especially in solanaceous plants such as *Solanum tuberosum* L., *Solanum lycopersicon* Mill., *Capsicum annuum* L., and *Nicc tabacum* L., (Miha *et al.*, 1993; Alegbejo, 2015). Remov weeds in tomato crops is very important in managing (Nono-Womdim, 2003). Other effective cultural mea include destruction of virus infected plants, planting virus-free seeds, planting of resistant cultivars, planting of only tubers harvested from healthy plants and integration of the above measures (Alegbejo, 2015).

CONCLUSION

Many viruses are known to cause tomato diseases of economic importance worldwide. Ten viruses infecting tomato have been reported from Nigeria. The incurable nature and complexity of managing viral diseases make them of economic concern to the farmer. Generally, studies on tomato viruses in the country have been concentrated in the North western region and to a lesser extent the South western region. Therefore, the need to investigate tomato viruses in other geopolitical regions becomes important. Extensive studies have been carried out mainly on ToLCV, ToMV, PVY and PVMV with much focus in the North West and South West zones of the country. Other important tomato viruses (TYLCV, TAV, TBSV, ToRSV, TSWV and TBRV) reported to occur in Nigeria need to be explored in tomato growing areas with much attention on their occurrence, epidemiology, yield losses, management, molecular characterization and functional studies. Integrated preventive measures are the most effective strategy for the managing tomato viruses.

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