



Review on Citrus Tristeza Virus

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Abstract: The genus Citrus are commercially important fruit crop belongs to Rue family. They are mainly cultivated in the subtropical and tropical regions of the world between 40^o north and south latitude in over 137 countries. However, citrus production has been delayed with biotic and abiotic factors. Mainly, plant viruses are highly prevalent and serious threat to cultivated plants and agricultural production in plants like vegetables and fruits worldwide. Citrus tristeza virus (CTV), is the largest and most complex member of the genus Closterovirus (family Closteroviridae) that induce the most destructive disease of cultivars and hybrids of citrus worldwide. The only natural non-citrus host that has been reported is Passiflora. Natural hosts of CTV remain essentially symptomless when infected by most CTV isolates. To establish a productive infection in a host plant virus needs to be able to move throughout the plant from an initially infected cell. The spatial and temporal spread of CTV in citrus orchards has been studied in different parts of the world. The most common diagnostic symptoms of CTV include Quick Decline, Seedling Yellows and Stem Pitting Disease. The disease is economically most important constraints of Citrus production widely, little emphasis has been given especially in Ethiopia. Exclusion and Quarantine, Resistant/tolerant rootstocks and Vector control are the most common means of CTV management today. Therefore, if we need to use citrus as one income source for the country, future research should give great focus on those viral diseases like CTV as of other economical diseases as a whole.

Keywords: Virus, Vector, Host, Management

1. INTRODUCTION

The genus Citrus belongs to the Rutaceae or Rue family, sub-family Aurantoideae. The 5 commercially important fruit crops (sweet orange (*C. sinensis* L.), tangerine (*C. reticulata* B.), grapefruit (*C. paradisi* M.), lemon (*C. limon* F) and lime (*C. aurantifolia* L.) are recognized as single species within Citrus. They are mainly cultivated in the subtropical and tropical regions of the world between 40^o north and south latitude in over 137 countries on six continents (Ismail and Zhang, 2004).

Plant viruses are highly prevalent and serious threat to cultivated plants and agricultural production in plants like vegetables and fruits worldwide. Viruses have evolved as combinations of genes whose products interact with cellular components to produce progeny throughout the plants and in most cases, to interact with a vector to be moved to other plants. These processes require several layers of precise interactions with the host. In general, the more conserved genes tend to be those whose products interact within the cell to replicate the viral genome (Fanny et al., 2015). This process appears to be somewhat generic because many viruses have been found to be capable of multiplying in individual cells (protoplasts) but cannot move throughout the intact plant. The less conserved genes tend to be those that have evolved for interactions with the specific host for movement and to counter host defense systems (Dung, 2006; Lucas, 2006).

Viruses that infect higher plants share a number of common principles with animal viruses. These include virion morphology and strategies for replication and expression of their genomes. Though, to establish a productive infection in the host, plant virus need to be able to move throughout a plant from an initially infected cell (Yokomi et al., 2017). Success depends upon compatible interactions between viral and host factors. Generally, systemic movement is thought to involve two distinct processes: cell-to-cell movement which indicates the process that allows the virus to transverse the

cell wall between adjacent cells and long-distance movement, which is a process that allows the virus to enter the sieve element from an adjacent nucleated cell and rapidly move through the connected sieve elements, followed by its exit into another adjacent phloem-associated cell at a distal region of the plant (Waigmann et al., 2004; Scholthof, 2005).

Citrus tristeza virus (CTV), a member of the genus *Closterovirus* (family *Closteroviridae*) is the causal agent of serious diseases of citrus that is has widely i.e. Almost in all citrus production areas of the world (Moreno et al., 2008). It is the largest identified RNA virus infecting plants and the second largest worldwide. The virus is phloem limited and it is transmitted by aphids (*Hemipteraaphididae*) and mechanically by graft propagation of virus-infected plant tissues. CTV isolates from different hosts and areas display great variability either biologically or genetically (Albiach, 2012). This Virus possess the potential to disrupt host physiology either by usurpation of substantial amount of plant metabolic resources or by the interaction of a specific viral product with the host components and CTV induces three hallmark syndromes plus a myriad different symptom patterns in indexing plants (Culver and Padmanabhan, 2007).

CTV is assumed to have originated in China quite a long time ago. Tristeza, known as 'quick decline' in the United States, is the most destructive disease of citrus in the western hemisphere and has a worldwide distribution (Yokomi et al., 2017). It is the causal agent of devastating epidemics that changed the course of the citrus industry. Adapted to replicate in phloem cells of a few species within the family *Rutaceae* and to transmission by a few aphid species, CTV and citrus probably coevolved for centuries at the site of origin of citrus plants. CTV is a member of the closterovirus group which have thread-like, flexuous virions, insect vectors, cause characteristic cytopathological structures (inclusion bodies) in infected phloem tissues, and have a positive sense, single-stranded RNA genome of up to 20 kb (Marti, 2013). However, the information on the impact and distribution of this virus is quite limited in our country. Therefore, the present review can provide some highlights on the overall status of Citrus Tristeza virus.

Objective

- To review on the overall status of Citrus Tristeza virus in potential citrus production areas including Ethiop

2. LITERATURE REVIEW

2.1. Taxonomic Position

Citrus Tristeza Virus is the largest and most complex member of the genus *Closterovirus* this member of the closterovirus group (Family: *Closteroviridae*) have thread-like, lexuousvirions, insect vectors, cause characteristic cytopathological structures (inclusion bodies) in infected phloem tissues, and have a positive sense, single-stranded RNA genome of up to 20 kb. Based on molecular characterization of CTV and other members of the closterovirus group, enough genetic diversity occurs among members to propose that the closteroviruses which contains homologues of cellular heat-shock proteins (Moreno et al., 2008).

The *Closteroviridae* are composed of three genera: *Citrovirus* (CTV type member) which has one 19.3 kb genome component and 12 open reading frames (ORFs); *Closterovirus* (beet yellows virus type member) which has one 15.4 kb genome and 9 ORFs; and *Biclovirus* (lettuce infectious yellows type member) which has two genome components of 8.1 and 7.1 kb and 9 ORFs (D'onghia et al., 2009).

Genotypes have diverged from the ancestral population or have arisen through recombination with previously described strains (Harper et al., 2008). CTV populations in citrus trees are quasispecies in nature, so complex mixtures of viral genotypes and defective viral RNAs developed during the long-term vegetative propagation of virus isolates through grafting and the mixing of such isolates with aphid-vectorized isolates. This results in CTV isolates containing a population of sequence variants, with one usually being predominant (Moreno et al., 2008)

2.2. Hosts

CTV infects all species, cultivars and hybrids of citrus. It also infects some citrus relatives such as *Aeglopsis*, *Afraegle*, *Fortunella* and *Pamburus* and some intergeneric hybrids. Species of *Passiflora* have been infected experimentally (but not naturally) and are the only non-rutaceous experimental hosts (Barjoseph, et al., 2008)

The only natural non-citrus host that has been reported is *Passiflora* (Kitajima et al. 1974). Some of the more important economic hosts are: sweet orange (*Citrus sinensis* (L.)), grapefruit (*C. paradisi* Macf.), mandarins (*C. reticulata*), Blimes (*C. aurantifolia* (Christm.) Swing.) And *C. latifolia* Tan.), lemons (*C. limon* (L.)), pummelo [*C. grandis* (L.) Osb.], tangelos [*C. reticulata* x *C. paradise*], tangors (*C. reticulata* x *C. sinensis*), calamondin (*C. madurensis* Lour.), and kumquat (*Fortunella margarita* (Lour.) Swing) (Moreno et al., 2008).

Many natural hosts of CTV remain essentially symptomless when infected by most CTV isolates. Mandarins, sweet oranges and rough lemon are among common tolerant hosts. Some citrus species show a selective susceptibility and are readily infected by some CTV isolates and not by others (Martelli et al., 2000). *Poncirus trifoliata* (L.), citrus relative commonly used as a rootstock, is highly resistant to nearly all isolates of CTV and this resistance is also found in some trifoliate orange hybrids (Navaset al., 1995).

2.3. Citrus Tristeza Virus Genetics and Plant-Host Interactions

In order to infect a plant, CTV needs to enter in the cell, and to overcome the constitutive and/or inducible plant defences, to re-program the plant cellular machinery for its viral multiplication. The infection process will continue with the assembly of new viral particles that will move cell to cell through the plasmodesmata to colonize the plant systemically. Each CTV gene product seems to have a primary genetic function required for the survival of the virus. However, there are secondary genetic interactions, which cause or trigger resistance or pathogenic responses in the citrus host (Culver *et al.*, 2007; Voinnet, 2005). The genus *Citrus* contains multitude of species, cultivars and intergenic hybrids, with which CTV could interact causing a range of physiological and biochemical responses. These could be from either pathogenic or asymptomatic phenotypes to limited or complete plant resistance (Moreno *et al.*, 2008). Although most of these mechanisms are The complex genetics of *Citrus tristeza* virus still a mystery, new discoveries towards the understanding of the genetics of CTV movement in the plant, host-range, host resistance and pathogenicity have been reported recently (Albiach *et al.*, 2010).

2.3.1. Virus, Vector and Plant Interactions

Efficiency of CTV transmissibility is affected by the species of aphid, by the source plant at acquisition feeding and the CTV isolate. For instance, cultivars of sweet orange are more suitable for acquisition and more sensitive to infection than grapefruit or lemon seedlings. Grapefruit groves do not tend to undergo decline on sour orange rootstock where there is widespread decline of sweet orange on sour orange root stock. Citrus aphids have a preference only for young lemon seedlings above sweet orange or young grapefruit seedlings. There is also a recognized decrease in transmission from plants kept at higher temperatures compared with a marked decrease in virus concentration in controlled experiments (Bhandari and Sharma, 2018). Red grapefruit varieties present problems with cross protection due in part to the slow distribution of protecting CTV isolates throughout the plant (Broadent, 1995; Ng, 2006). Pigmented grapefruits are more sensitive to stem pitting symptoms than 14 non-pigmented grapefruit (and grapefruit also have been shown to influence the strain composition of CTV isolates (Van Vuuren and Van der Vyver, 2000)

2.4. Movement in Host and Systemic Infection

To establish a productive infection in a host a plant virus needs to be able to move throughout a plant from an initially infected cell. Success depends upon compatible interactions between viral and host factors. Generally, systemic movement is thought to involve two distinct processes: cell-to-cell movement, which is a process that allows the virus to transverse the cell wall between adjacent cells, and long-distance movement, which is a process that allows the virus to enter the sieve element from an adjacent nucleated cell and rapidly move through the connected sieve elements, followed by its exit into another adjacent phloem-associated cell at a distal region of the plant (Ilharco *et al.*, 2005). A major obstacle for the spreading virus is to cross the boundaries represented by the cell wall. For this purpose most viruses utilize specific virus-encoded movement proteins as well as some host proteins that facilitate their translocation through plasmodesmata channels. The viral proteins and their interactions with the host during cell-to-cell movement are fairly well-known (Waigmann *et al.*, 2004; Scholthof, 2005; Lucas, 2006).

Despite the fact, CTV dispersal between new areas or countries occurs by graft propagation of virus

infected plant tissues; aphid transmission is responsible of local spread. Viruliferous aphids of *Toxoptercitricida* (Kirkaldy) and *Aphis gossypii* (Glover) species are able to transmit CTV in a semi-persistent manner. The aphid *T. citricidais* the most effective transmitting CTV and the most efficient and fast in the spatial and temporal viral spreading in citrus orchards (Moreno *et al.*, 2008).

Factors affecting aphid transmission include isolate or strain differences of the virus, the aphid species, plant donor and receptor varieties, the environmental conditions, and the number of aphid's involved. In addition, specific isolates or strains of CTV in mixtures may not be equally distributed throughout the source plant, further reducing the likelihood of successful transmission. Finally, aphids show a marked preference for some citrus species over others, for example it has been observed in feeding choice experiments that *Aphis gossypii* preferentially infests mandarins or sweet oranges over lemons (D'Urso *et al.*, 2000).

2.5. Citrus Tristeza Virus Suppressing Genes of Plant Silencing Mechanism

Plants constitutive defense consists of the RNA mediated post-transcriptional silencing mechanism (PTGS) that implies the specific degradation of the viral dsRNA in small interfering RNAs (siRNAs), which guides a specific plant ribonuclease to disintegrate the viral genomes in the cytoplasm. Besides the antiviral role, the plant silencing mechanism has important functions in regulating plant gene expression (miRNA metabolism). In order to infect plants, viruses developed a strategy to block this silencing mechanism: the suppressing genes. This strategy allows viral replication but interfere with host gene expression, thus inducing disease (Qu, & Morris, 2005). As indicated previously, CTV evolved ending up with three proteins that are 12 Current Issues in Molecular Virology. Viral genetics and BiotechnolViruses possess the potential to disrupt host physiology either by usurpation of substantial amount of plant metabolic resources or by the interaction of a specific viral product with the host components. Therefore, the degree of severity of a specific CTV isolate, strain or genotype usually is assessed by using indexing plants (Culver *et al.*, 2007). In this case, the degree of CTV symptomology ranges from the mild phenotypes, which are almost asymptomatic, to highly virulent CTV isolates that could generate vein clearing, leaf cupping, dwarfing, stem pitting and the plant death (Moreno *et al.*, 2016). This diversity and grade of symptom responses to CTV infection suggests the possible presence of more than one mechanism of pathogen city taking place during the CTV *Citrus* interactions (Moren *et al.*, 2008).

2.6. Epidemiology, Transmission and Spread

The spatial and temporal spread of CTV in citrus orchards has been studied in different parts of the world. These studies provide evidence for the fact that a long period of time may elapse between the introduction of a primary source of CTV inoculum and the development of a tristeza disease epidemic (Gottwald *et al.*, 2002)

Tristeza apparently originated in Asia and existed there for many years in tolerant cultivars which were either propagated vegetatively as cuttings or by seed. New areas of citri culture in other continents were first established from seed and were free of CTV infection. Subsequently, CTV has been introduced into nearly all citrus-growing areas via virus-infected budwood or plants. In many areas infections have become wide spread due to propagation and secondary spread by aphids. In some areas little or no secondary spread has occurred from the few existing infected trees (Timmer *et al.*, 2000)

Primary infections of CTV are usually established via propagation of infected plants and propagation of virus infected buds is the cause of dispersal of CTV into new areas, while the aphid vector is responsible for local spread. Epidemics of CTV decline observed in many countries began with importation and propagation of infected plants in areas heavily planted with CTV-free trees on sour orange (Bhandari and Sharma, 2018). When efficient vectors were present epidemics of decline often followed. Although CTV epidemiology is significantly affected by the citrus cultivar and horticultural practices, the most important factors are the CTV isolate and the aphid vector. When *T. citricidais* present, temporal and spatial spread of CTV spread is increased (Garnsey *et al.*, 1996). This aphid has a narrow host range and migrants move from citrus to citrus to start new aphid colonies and, in this process, can transmit CTV if they are viruliferous. High aphid populations also coincide with new lush who is favorable for virus acquisition and inoculation. The other vectors are much less efficient than *T. citricida* and also have a wider host range. Migrants may originate in other crops prior to feeding on citrus and may feed on a different plant species after leaving citrus (Moreno *et al.*, 2016).

Therefore, aphid host range and feeding behavior likely affect pattern and rate of spread (Gottwald *et al.*, 1996). It is assumed that aphid population levels may be correlated with rates of spread, but threshold levels for minimum and maximum levels of transmission have not been established. Natural spread is generally slow in desert regions where natural thermotherapy may keep inoculum at lower levels in plants and may vary seasonally in temperate areas as well. CTV spread rate in sweet oranges is generally higher than that observed in grapefruit (Folimonovet, 2007). CTV isolates in Meyer lemon and some mandarins have not spread appreciably from these hosts unless *T. citricidais* present. The latent periods between inoculation and systemic infection and between Citrus Tristeza Virus and *Toxoptera citricidus*: a serious threat to the Mediterranean citrus industry 27 infections and symptom expression also affect evaluation of disease development. Presence of other strains may also influence rate of virus movement (Tatineni *et al.*, 2008)

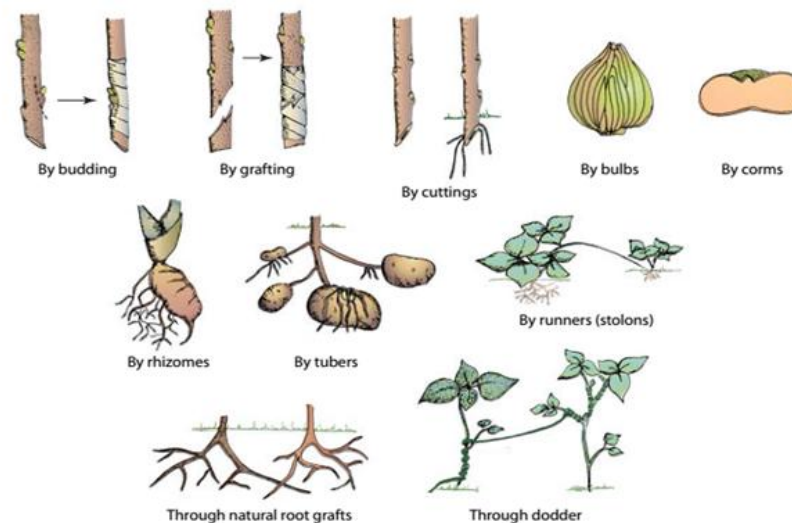


Figure1. General means of transmissions of viruses among different hosts

2.7. Diagnostic Symptoms of CTV

Citrus Tristeza virus (CTV) particles occur in large numbers in phloem cells of *Citrus* and other members of the *Rutaceae*, *Passiflora* species being the only non-rutaceous hosts. CTV is generally reported as limited to the phloem cytoplasm and also to the young cortex shoot tissue of plants. When tissue preparations are stained, aggregates of virus particles or inclusion bodies are often found as purple stained, cross-banded 'chromatic cells' in the parenchyma-like cells adjacent to the sieve tubes in pollen. Such inclusions have also been associated with the cambium of newly developing stem cells in the ground meristems (Moreno *et al.*, 2016). Where this association is known to occur, xylem and phloem mother cells are not initiated that are the regions of the 'pits which later develop in the stems of infected trees. Necrosis at the bud union is a result of destruction of the phloem tissues in scions grafted onto sour orange rootstock which are undergoing 'quick decline' (Yokomi *et al.*, 2017; Bhandari and Sharma, 2018).

CTV causes different symptoms on citrus plants depending on the virus strain (Fig 2), the variety of citrus, and the scion-rootstock combination. In Asia, various strains of CTV, generally referred to as seedling yellows (CTV-SY), tristeza (CTV-T), stem pitting (CTV-SP), and a mild type, have been widespread for many years. Any of these strains may exist in a citrus plant, or they may occur together, as a complex. The virus is phloem limited and can be detected in leaves, stems, fruits, and roots. Greatest concentrations of virions are found in young growth under relatively mild temperature conditions (Albiach, 2012).

The tristeza syndrome, induced by CTV, has devastated entire commercial citrus industries around the world, since it has caused the death of hundred million trees worldwide. In point of fact, this virus is present in most of the citrus producing areas infecting nearly all species, cultivars and hybrids of *Citrus* spp. and related genera. Phenotypically, CTV induces different grades and wide range of symptoms in *Citrus* species (Moreno, 2008).

Trees grafted on sour orange root stocks usually show die back and defoliation, stunting and in many cases complete decline. This symptomatology is caused by the starvation of the roots as a

consequence of sieve-tube necrosis induced by the virus below the bud union. Cells of the modularly rays of the wood become lignified in this area and produce the symptom called inverse pitting, honey combing or pinholing. However, this symptom is not specific to tristeza and can also be induced by *Spiroplasma citric* (stubborn disease) (Yokomi *et al.*, 2017; Bhandari and Sharma, 2018)

2.7.1. Quick Decline, or Tristeza Disease

Symptoms appear a year or more after infection and may occur gradually over several years or very suddenly (QD). Canopy symptoms are wilting, chlorosis and an abnormal crop of small fruit which may persist after tree death in trees affected by QD (Fig. 2A). Clinical symptoms can often be seen by removing a patch of bark across the bud union. Trees which decline slowly usually will have thicker bark immediately below the union and the face of the bark surface below the union will have many small conical pits (honeycombing) corresponding to bristle-like protuberances from the wood (Schneider, 1954). Tristeza disease or QD syndrome consists in overgrowth of the scion at the bud union, loss of root mass, and therefore death of citrus commercial varieties grafted on sour orange rootstock (Moreno *et al.*, 2008; Yokomi *et al.*, 2017).

2.7.2. Seedling Yellows

The SY syndrome is characterized by stunting (Fig. 2F), leaf chlorosis and sometimes a complete cessation of growth on sour orange, grapefruit or lemon seedlings. Although, SY syndrome might be found at the field in top-grafted plants and it is not economically valuable, it could be examined in the greenhouse in a timely manner and has a substantial diagnostic value for CTV pathotype differentiation. Self-rooted trees of sour orange, Natsudaidai, lemon and buntan are affected by this disease after being infected with CTV-SY. These trees become yellow and die back. If the affected trees are grafted onto a resistant rootstock, they soon recover (Bhandari and Sharma, 2018).

2.7.3. Stem Pitting Disease

CTV may also induce stem pitting, stunting and low yields on susceptible cultivars (mainly limes, grapefruits and some sweet oranges) even if they are grafted on tristeza tolerant rootstocks (Fig 2C and E). The cultivars affected and the intensity of the symptoms depends on the virus strain. Some severe strains may induce stem pitting in most citrus cultivars. Stem pitting does not kill trees, but affected trees may have thin canopies and produce fewer fruit of reduced size and quality (Marais *et al.* 1996). Dieback occurs in severely affected limes. Chronically infected trees sometimes show a bumpy or ropy appearance of trunks and limbs on larger trees. The twigs and limbs are brittle and easily broken (Albiach *et al.*, 2012).



Figure 2. Symptoms of citrus tristeza virus (CTV) infection: (A) tristeza syndrome or decline of sweet orange grafted on sour orange infected with CTV (left) and symptoms less tree (right); (B) collapse or quick decline grafted grapefruit on sour orange; (C) stem pitting on the trunk of grape fruit grafted on Troyer citrange caused by an aggressive CTV strain; (D) sever stem pitting on the branches of grape fruit; (E) stem pitting on the trunk of sweet orange grafted on Cleopatra mandarin and (F) pronounced stunting of CTV infected sweet orange trees grafted on Carrizo citrange (right) compared with a healthy tree (left) (Moreno *et al.*, 2016).

2.8. Economic Importance

CTV is the most economically important virus pathogen of citrus worldwide. It is estimated that worldwide there are over 200 million trees on sour orange rootstock which are at risk to this disease. Sour orange is popular because it produces a vigorous tree with high quality fruit, is adaptable to many soil conditions including high lime and salt content and has tolerance to many other viruses, viroids, and virus-like pathogens and *Phytophthora*. Use of tristeza-tolerant rootstocks often risks losses from other factors (Yokomi *et al.*, 2017; Bhandari and Sharma, 2018). In addition to decline, many severe CTV isolates cause stem pitting diseases of susceptible scions/cultivars and these occur even when tolerant rootstocks are used. Stem pitting weakens trees and eventually reduces fruit size, quality, and quantity (Yokomi *et al.*, 2017; Bhandari and Sharma, 2018). Grapefruit and lime are very sensitive to stem pitting. Sweet orange is more tolerant but can be severely affected by some isolates.

2.9. Management Options of CTV

Management/Control strategies for CTV differ according to the incidence and severity of the CTV isolates in an area and with the cultivars and rootstocks used. No single control strategy is applicable in all situations (Garnsey *et al.*, 1996; Lee *et al.*, 1994).

2.9.1. Exclusion and Quarantine

Effective quarantine and budwood certification programmes are the best measures to avoid CTV introduction or dispersal in CTV-free areas where citrus are still propagated on sour orange rootstock (Navarro *et al.*, 2002). Elimination of infected trees is the best means to avoid or delay an epidemic. When CTV is absent or rare, preventive efforts should be made to avoid introduction of CTV into the growing area by having quarantines on importation of live citrus tissue. A practical and safe method to legally introduce cultivars from other regions and to free these of infection is necessary and reduces industry pressure to illegally introduce new cultivars or germplasm resources. Procedures for safe international movement of citrus germplasm have been devised. Careful control of propagating material remains the single most effective means to avoid rapid and extensive CTV epidemics. If a few trees become infected in a CTV-free area and indigenous aphids are poor vectors, natural spread can be slowed appreciably by a vigilant eradication and suppression program. However, an effective survey program is essential and when CTV is detected, infected trees must be removed immediately and surveillance maintained (Garnsey *et al.*, 1996; Gottwald *et al.*, 2002).

2.9.2. Resistant/Tolerant Rootstocks

There are different *Citrus* species and relatives that exhibit total or limited resistance to CTV infection. Pummelos, sour orange and the rootstock Swinglecitrumelo display a differential degree of resistance depending on the CTV strain (Moreno *et al.*, 2008). Resistance of plants to viruses' results from blockage of a basic step in the virus life cycle. This blockage can result from the lack of a factor(s) in the plant that is necessary for virus multiplication and movement (passive resistance) or activation of a defense mechanism (active resistance) (Culver and Padmanabhan, 2007).

Numerous rootstocks are tolerant or resistant to CTV decline and use of these is essential for economic production of citrus in many areas. Some examples are Cleopatra and Sunki mandarins, rough lemon, Rangpur lime, trifoliolate orange and trifoliolate orange hybrids such as Troyer and Carrizo citranges and Swinglecitrumelo. CTV resistant/tolerant rootstocks are often susceptible to other problems such as citrus blight, viroids, nematodes, or poor soil conditions (Yokomi *et al.*, 2017).

Breeding to incorporate resistance genes in commercial cultivars is considered the best approach to avoid crop losses due to pathogens. However, different features of citrus biology, particularly their complex genetics and reproductive biology, together with their large plant size have greatly impaired genetic improvement through conventional breeding (Bhandari and Sharma, 2018).

2.9.3. Vector Control

Vector suppression is an unproven strategy or CTV control. In the case of semi-persistently transmitted viruses, viruliferous winged aphids may inoculate citrus trees several kilometers from the donor tree. It is not clear what level of vector control is necessary to reduce spread of CTV. However, vector control may have potential to reduce secondary spread (Gourmet *et al.*, 1994). Biological controls to restrict build up of citrus aphids, especially *T. citricida*, may be feasible (Tang and Yokomi, 1996). Although insecticides may not act quickly enough to prevent primary infection by viruliferous aphids, they could reduce local aphid populations and decrease rate of secondary spread.

Plants have evolved an RNA silencing process, one function of which is to protect them against viruses (Dunoyer and Voinnet, 2005; Wang and Metzloff, 2005).

2.10. Tristeza Diseases in Ethiopia

Citrus (*Citrus* spp.) is one of the most economically important fruit crops grown by smallholders and commercial farmers in Ethiopia (Kassahun *et.al.*, 2006; Mohammed, 2007). The total area coverage and the annual production of citrus were estimated 5,947 ha and 77,087 tons, respectively (CSA, 2011 and 2012). Citrus farming in Ethiopia is a mixed agriculture in which, many horticultural, field and forage crops, and shade trees are grown with and around citrus plantings. However, citrus production and productivity in Ethiopia is seriously threatened by various diseases including leaf and fruit spot disease (Mohammed, 2007; Sisay, 2007), which is caused by the fungus *Pseudocercospora angolensis* (Pretorius *et al.*, 2003).

The land holdings of citrus orchards surveyed varied from 0.15 ha by the smallholder farmer's to 10,030 ha for Bebeke Coffee Estate farm. The area coverage of citrus plantation for these orchards ranged from a few citrus trees in the backyards of smallholders to 1,000 ha at Nura Era citrus farm. Different citrus species and varieties are cultivated in the country. The information obtained from the surveys showed that sweet orange, mandarin, lime, lemon, grapefruit, citrus hybrids, sour orange and citron were produced (Tsedeke, 2008).

According to Sisay (2007) report, Citrus trees that were grown by smallholder farmers were directly from seeds and were not grafted. However, citrus trees in state and private owned orchards, government nurseries and research foundation blocks were grafted. The original sources of scions and rootstocks of most old orchards were unknown, but 33.3% of the respondents did not have available information. The lack of information in this regard could complicate management and breeding programs aimed at improving citrus production. However, the major sources of the recent citrus plantations included University of California at Riverside, MelkaSedi Farm in the Middle Awash, Upper Awash Agro Industry Enterprise, Research Centers, ICRISAT, and local growers. The most commonly used rootstocks were Sour orange, Volkameriana and Troyer Citrange.

In Ethiopia, citrus trees have been afflicted due to different diseases incited by many fungi, bacteria, viruses and virus-like organisms. Viruses and virus-like diseases including psorosis, tristeza and greening were reported to be of great economic importance and thought to play a significant role in the decline of citrus plantation in the country. Canker, caused by a bacterium, is a serious disease of most commercial citrus cultivars and some citrus relatives. Based on field observations citrus producers had reported 13.6% of citrus trees dieback due to virus problems and over 35% citrus attack by other plant pathogens in the major citrus farms across Ethiopia (Schubert and Miller, 2000; Sisay, 2007).

According to Tsedeke(2008) Tristeza and greening are among the most important and widely distributed diseases of citrus in many citrus growing regions of Ethiopia. His survey result showed that three aphid species, viz. *A. gossypii*, *T. aurantii*, *T. citricidus* and the citrus psyllid *erytraeae* are the only insects that occur as vectors of citrus diseases in Ethiopia. Their geographic distribution and population densities (Table 1). Among the aphids recorded *A. gossypii* was the least common species on citrus. It was observed at Arba Minch, Dire Dawa, ErerGota, MelkaWerer and Gibe; it was not recorded above 1250m. On the other hand, *T. aurantii*, is the common and most widely distributed aphid species in the country. It was found in large numbers almost in all altitudes covered in the survey. *T. citricidus*, which is known to be the more efficient vector of tristeza virus was restricted to the middle and upper Awash valley, almost all of which lies below 1500m. In these areas both species of *Toxoptera* may occur in the same orchard or even on the same tree, but *T. aurantii* was by far the more dominant species.

Table 1. The distribution and population density of insect vectors of citrus diseases in Ethiopia

Locality	Altitude (m)	Aphids-gossypii	Toxomtraaurantii	Toxoptera-citricidus	Triozaertreae
Addis Ababa	2280-2400	-	-	-	+++
Ambo area	2130-2400	-	-	-	+++
Gonder (aba Samuel)	2040	-	++	-	+++
Indibr	2040	-	-	-	+++
Metekesha	2000	-	-	-	+++

Debre- Zeiy	1900-1940	-	++	-	++
Shashemene	1900	-	-	-	++
Bahir-Dar	1850	-	-	-	+
Aleta-wendo area	1800-1880	-	+	-	++
Debeka	1750	-	+	-	+++
Jimma	1750	-	+++	-	++
Bako	1720	-	++	-	+++
Melghe-Wendo	1720	-	+	-	+++
Awassa	1700	-	+	-	+++
Koka	1700	-	++	-	++
Ziway	1650	-	+	-	+
Nazret	1625	-	++	-	++
Melka-Hinda	1570	-	-	-	+++
Table 1. Continued.....					
Metu	1570	-	+	-	+
Kobo	1530	-	+	+	-
Wenji area	1500-1550	-	++	+	+++
Elien farm	1500	-	-	++	+
Horo Degaga	1500	-	+	-	-
Degage	1400	-	++	++	-
Elabre	1400	-	+	-	-
Tibila	1360	-	++	++	-
Bilate	1350	-	-	-	+
Didessa	1300	-	++	-	-
Arba-Minch	1250	+	++	-	-
Nura-Era	1180	-	+++	+	-
Dire Dawa	1160	+++	-	-	-
ErerGota	1150	++	-	-	-
Gibe	1080	+	-	-	+
Abdir	1050	-	++	+	-
Ghinda	950	-	++	-	+++
Awara –Melka	750	-	++	+	-
MelkaWerer	750	++	+++	++	-

NB: (-) = none, += light, ++ moderate, +++ = heavy (Tsedeke, 2008)

Table2. The host range of in sect vectors of Citrus in Ethiopia

Host	Family	Aphids gossypii	Toxomtraaurantii	Toxomptarcitricidus	Triozaertreae
Abutionlongicuspe	Malvaceae	+	-	-	-
Bougainvilleaglabra	Nyctaginaceae	+	-	-	-
Capcicumfrutescens	Soanaceae	+	-	-	-
Carissa edulis	Apocynaceae	+	-	-	-
Citrullus vulgaris	Cucurbitaceae	+	-	-	-
Citrus	Rutaceae	+	+	+	+
Clausenaanisata	Rutaceae	-	-	-	+
Coffea arabica	Rubaiaceae	-	+	-	-
Coffea canephora	Rubaiaceae	-	+	-	-
Cucumismelo	Cucurbitaceae	+	-	-	-
Cucurbita pepo	Cucurbitaceae	+	-	-	-
Dovyalisabissinica	Flacuourtiaceae	-	+	-	-
D.caffra	Flacuourtiaceae	-	+	-	-
Ficussycomorus	Moraceae	+	-	-	+
Gossypiumhirsutum	Malvaceae	+	-	-	-
Hibiscus escufentus	Malvaceae	+	-	-	-
Magnifera indica	Anacardiaceae	+	+	-	-
Punicagrantum	punicaceae	+	-	-	-
Pygeumafricanum	Rosaceae	-	-	-	+

Solanum melongena	Solanaceae	+	-	-	-
S. tuberosum	Solanaceae	+	-	-	-
Stephania abyssinica	Menispermaceae	-	-	-	+
Thea sinensis	Theaceae	-	+	-	-

NB: (-) = none, + = light, ++ moderate, +++ = heavy (Tsedeke, 2008)

3. SUMMARY AND CONCLUSION

Citrus Tristeza virus (CTV) is globally devastating disease of citrus caused by an infectious filamentous closterovirus which is phloem limited; aphid vectored and can be harbored asymptotically in many citrus species. The virus has a very large single-stranded RNA genome, is not mechanically transmitted and has been inadvertently spread to most citrus growing areas through the historical movement of propagative material.

There are three major economically devastating symptoms caused by CTV. The first is a rapid decline and death of trees on sour orange (*Citrus aurantium* L.) rootstock. The second is stem pitting of scions regardless of rootstock causing reduced fruit production. Many species of aphid transmit CTV in a semi persistent manner, and this is important in the temporal and spatial spread of the virus within regions and the third one is seedling yellows (SY) syndrome is characterized by stunting, leaf chlorosis and sometimes a complete cessation of growth on sour orange. *Toxoptera citricida* Kirkaldy, the Brown citrus aphid (BrCA), feeds and breeds mainly on citrus, is considered the most efficient vector of CTV. It is economically important virus that challenges citrus production in all citrus producing counties including Ethiopia. However, its identity, economic importance and diagnostic procedures is not well studied in Ethiopia.

Management strategies for CTV usually involve shoot-tip grafting and thermotherapy, certification and eradication programs, deployment of tolerant cultivars or mild strain cross-protection. Vector control is the main strategy of to eliminate the devastating of effects of CTV because the most efficient infection of the virus is viz vectors.

Generally, in Ethiopia citrus production is economical but production and quality deminutionig time to time especially due to these biotic agents like virus. Moreover, no research information regarding these pathogens especially viruses like CTV which implies that little concern is given to viral disease i.e knowledge and proper (scientific) identification of diseases and disorders is very limited in Ethiopia concerning to those viral pathoges causing those viral diseases. So, if we want to boost citrus production in our country, the future research focus must be towards theses potential viral diseases caused by viral pathogens.

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