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Management Methods of Hot Pepper (*Capsicum annuum L)* Viruses

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Abstract

Virus is one of the major constraints of pepper production. Increasing outbreaks of virus species infecting Hot Pepper (*Capsicum annuum L.*) is a major problem for pepper growers due to a combination of factors, including expansion of pepper cultivation and abundance of insect vectors. Many viruses have been identified to infect pepper crops causing economic loss in terms of reduced quality and marketable yield, sometimes up to 90%-100%. Potato Virus Y (PVY), Tobacco Etch Virus (TEV) and Cucumber Mosaic Virus (CMV) are the most severe pepper virus around the world. The management options for virus infection in *Capsicum annuum* is by the integration of several approaches. More significantly, removing of infected plants, cultivation of disease resistant varieties, improved cultural practices and using of insecticides especially when plants are young and easily colonized by vectors. However, integrated management measures are needful to reduce occurrence of virus diseases in *Capsicum annuum*.

Keywords: Hot pepper; Management option; Vectors; Viruses

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Introduction

Hot pepper (*Capsicums* spp.) is one of the main vegetable crops belonging to the family Solanaceae and grown as spice crop in different parts of the world [1]. The genus *Capsicum* is the second main vegetable crop of the family after tomato in the world [2,3].

Hot pepper production for dry pod has been low with a general average yield of 0.4 t/ha [4]. This may be due to the use of low yielding varieties, drought, insect pest, diseases, and poor cultural practices.

Arthropod pests, diseases caused by different fungi, bacteria and viruses are the most important biotic factors which reduce yield of pepper [5]. Viral diseases such as Potato Virus Y (PVY), Tobacco Etch Virus (TEV) and Cucumber Mosaic Virus (CMV) are emerged as severe threats to the crop in the pepper producing areas [6]. Viruses are reported to cause total crop failure in addition to lowering yields and reducing fruit quality [5].

More than 90% viral disease incidences and absolute crop failure have been reported from various places of world [7,8]. Relative importance of viruses on pepper is irregular across regions, where a few viruses are common to a particular region. Viral diseases such as Potato Virus Y (PVY), Tobacco Etch Virus (TEV) and Cucumber Mosaic Virus (CMV) occurring in diverse or single infection, is the most significant virus [7-9].

The epidemiology of virus differs with localities and time and a factor of local source of inoculum, vector complex involved, and how the pretenses of vectors harmonized with the phenology of the crop [10]. So, understanding the epidemiology of aphid-borne viruses is very essential for the development of appropriate management strategies. Barrier crops, mulches and nets are used to decrease virus infection and vector infestation in several non-persistently transmitted plant viruses. For example, netting of okra plants for up to 4-5 weeks reduced the number of jassids and whiteflies as well as virus infection when compared with that of un-netting plants [11].

Although spreading of non-persistent viruses by aphids has inadequate specificity with respect to individual aphid species, some aphid species are more efficient in transmitting certain virus species than other aphid species [12]. Sometimes a less efficient vector can be more important in spreading a virus than more efficient vectors if it occurs in larger quantity [13].

Literature Review

Origin and distribution of pepper

Capsicums species are originated from around Mexico in the North and Bolivia in the south of Latin America [14]. Spanish and Portuguese explorers distribute pepper across the world, i.e. first into Europe and then to Asia and Africa. Pepper is produced in all continents except Antarctica. Tropical Asia (India, Malaysia, Thailand, and Indonesia), and tropical Africa (North Africa, Senegal, Nigeria, Ghana and Kenya), and South America (Mexico) and Caribbean countries are the major producers [15].

Importance of pepper

Hot pepper (*Capsicum annuum* L.) is a vegetable crop at its green stage. Peppers are among the most heavily consumed spices all over the world. They are the most popular salad vegetables [16]. Dried ripe pods of many different varieties of *Capsicum* are utilized to prepare cayenne pepper, ground pepper and crushed red pepper. This is because it increases the receipted of the insipid basic nutrient foods. Both sweet and hot peppers are processed into many types of sauces, pickles, relishes and canned products. According to Bosland and Votava hot peppers, contains vitamins A and C and good sources of B2, potassium, phosphorus and calcium [17].

Hot pepper is a significant vegetable crop both economically and nutritionally because it is a good source of natural color and antioxidant compounds [18]. A wide spectrum of antioxidant vitamins, carotenoids, ascorbic acids, capsaicinoids and phenolic compounds are present in hot pepper fruits.

According to Bosland and Votava, pepper is the mainly recommended tropical medication for arthritis [17]. The pharmaceutical industry uses capsaicin as a counter-irritant cream, for external application of sore muscle [19]. Creams containing capsaicin have reduced pain associated with post-operative pain for mastectomy patients and for amputees suffering from phantom limb pain. Expanded use of the cream has also been found to help reduce the itching of dialysis patients, the pain from shingles and cluster headache. Peppers also motivate the flow of saliva and gastric juices that serve digestion [20].

Constraints of pepper production

The limited quantity and quality of pepper production in the world is largely attributed to biotic and a biotic stress [21,22]. Abiotic factors affecting pepper productions include various environmental factors such as temperature, soil, humidity, light intensity and moisture [23]. Temperature along with humidity is playing an important role in pepper production. Dorland stated that the maximum set of bell or sweet pepper occurs at temperatures of 18°C to 24°C, but temperatures below 16°C and high temperature above 32°C prevent fruit set. Temperature can also affect fruit quality; best fruit color is realized at temperatures from 18°C to 24°C [24]. Night temperatures above 22°C lead to poor fruit set. Low humidity and high temperatures will cause abscission of buds, flowers and small fruits. Irregular rainfall distribution during fruit development exposes pepper to blossom end rot disorder. During the same period water stress lead to fruit and flower abortion.

Biotic factors like fungal, bacterial, viral diseases, nematodes, mites and many insect pests can cause significant losses in pepper production [25]. The major limiting diseases of hot peppers are phyto pathogenic fungi, bacteria, and viruses. For example, 60 to 100% losses of marketable fruit have been reported from virus infection [5,8]. Bacterial spot caused by a seed borne bacterial pathogen (Xanthomonas campestris pv. vesicatoria) is also capable of causing severe defoliation of plants, resulting in reduced yield and loss of harvested fruit quality when severe damage occurs on enlarging fruits [26].

Peppers are also affected by different virus diseases such as pepper mottle virus, potato virus Y, tomato mosaic virus, tobacco mosaic virus, tobacco etch virus, and other virus like tomato spotted wilt virus, and cucumber mosaic virus [7,8]. These virus diseases are important factors contributing to low yields and reduced fruit quality of pepper [9]. Virus diseases cause serious losses in the pepper and the most limiting factor affecting pepper production [27]. Sometimes total crop failure due to viral diseases had occurred and farmers were forced to lose their production due to high infection of viruses in the field [8]. Potyvirus such as pepper mottle virus, potato virus Y, Tomato mosaic virus and tobacco mosaic virus are very important viral diseases in pepper field [6].

In additions, pepper crops can be affected by different pests like aphids, thrips, whiteflies and worms such as bollworms and cutworms that cause damage to agricultural production by feeding on crops and transmitting viral disease. For example, several species of aphids can be found on pepper plants and some of them can cause a significant problem. Green peach aphids (*Myzus persicae*), cotton melon aphid (*Aphis gossypii*), and *Rhopalosiphum maidis* (corn leaf aphid), *Macrosiphum euphorbiae* (*potato aphid*) can cause the most problem on peppers [28]. However, aphids are a vector of several important viruses on pepper, including cucumber mosaic virus, potato virus Y, tobacco etch virus, and pepper mottle virus [6]. Some vectors also produce sticky honeydew that is difficult to remove from fruit. Honeydew produced by vectors allows the development of sooty mold fungi, covering leaves and fruit with dark mold growth that reduce photosynthesis and lower fruit quality.

Viral disease of pepper

Viral disease belongs to genus potyvirus and the family potyviridae are occurred at rates up to 100% in pepper fields [29]. Pepper productions are strictly affected by virus diseases caused by aphid transmitted viruses, particularly Pepper Mottle Virus (PMV), Potato Virus Y (PVY), Tomato Mosaic Virus (TMV) and Tobacco Etch Virus (TEV) [8].

Potato Virus Y (PVY) is the most common potyvirus infecting pepper. It occurs worldwide although it appears to be more important in warmer areas [30]. Mosaic, mottle, dark green, vein banding, vein clearing and yellowing are typical symptoms of infection by PVY, other symptoms such as leaf crinkling, leaf distortion and stunted growth are also common, depending on the virulence of the strain and the host pathogen interaction [31]. PVY is easily transmitted by sap inoculation. PVY has flexuous thread-like (filamentous) particles ranging from 700nm-800nm in length [32].

Pepper mottle virus is one of the potyvirus genus, which causes mosaic disease of pepper cultivars [33]. The most common symptom of pepper mottle is mottling of leaves, but other symptoms such as green vein banding, vein clearing, leaf deformation, stunting or dwarfing and necrosis can also occur on *Solanaceous* species such as *Capsicum annuum L., Lycopersicon esculentum*, Nicotiana hybrid, *N. tabacum, Physalis floridana* and other Solanum species [34]. Pepper mottle virus is transmitted by aphids species such as green peach aphid (*Myzus persicae*), cotton melon aphid (*Aphis gossypii*), and cowpea aphid (*Aphis craccivora*) from infected host plants to health [35]. However, this virus is able to persist because vectors can carry the virus from infected peppers to native, perennial, solanaceous weeds such as *Datura stramonium* (jimson weed) and *Solanum elaeagnifolium* (silver leaf nightshade). Flexuous rod-shaped particles are found in crude extracts from pepper leaves infected with pepper mottle virus measuring between 729nm-745nm in length [35].

Pepper Veinal Mottle Virus (PVMV) is another member of potyvirus genus which infects pepper plants [36]. Leaves of PVMV infected plants commonly develop chlorosis of the veins followed by systemic interveinal chlorosis. Mottle, vein chlorosis and small distorted leaves also occur. Leaf abscission and fruit distortions have also been reported [37]. Alegbejo found that PVMV was transmitted by seven species of Aphids (*Myzus persicae; Hystero neurasetariae, Aphis gossypii, A. fabae, A. cracivora* and *Rhopalosiphum maidis*) [38]. Pepper veinal mottle virus had filamentous particles 700-750nm in length [7].

Tobacco Etch Virus (TEV) is a potyvirus; mainly important virus affecting pepper plants which has a filamentous particle which is 730 × 12nm in length [39]. The virus causes chlorotic mottle and necrosis of pepper [40]. Vein banding along the whole length of the veins is another typical symptom [41]. Agrios also reported that TEV infected pepper leaves showed mottling, mosaic and distortion; pepper fruit were distorted, and the entire plant may be stunted [42]. Tobacco Etch Virus (TEV) was easily transmitted mechanically. TEV is also transmitted in a non-persistent mode by aphids to over 150 plant species from more than 20 families [43]. Twelve species of aphids have been identified as vectors of TEV [44]. *Aphis gossypii Glover, Rhopalosiphum maidis, Lipaphis erysimi, Macrosiphum euphorbiae, Hyperomyzus lactucae* and *Myzus persicae* have been found in the pepper agro ecosystems [28].

Tomato Spotted Wilt Virus (TSWV) is known a member of genus tospovirus that infects pepper. It is known to cause chlorosis and yellow rings on pepper leaves and fruits. TSWV is transmitted persistently by thrips. This virus has a wide host range and it is very potentially damaging Solanaceae family [45].

Pepper crop is also strongly affected by other viruses like Cucumber Mosaic Virus (CMV) from cucumovirus genus and Alfalfa Mosaic Virus (AMV) from alfamovirus genus. These viruses are estimated to cause up to 50% loses in potential production of pepper varieties [46,47].

Transmission of vector borne viruses

Viral diseases are transmitted from infected plants to the uninfected plants through mechanical injuries on plant tissues by contaminated tools and insect vectors. Most of the pepper viruses are categorized under potyvirus genus. These viruses are transmitted in a non-persistent mode and epidemic levels of field spread often occur [48]. In addition, members of potyvirus genus are also sap transmissible and some of them are spread by seeds [49]. The rate and pattern increase of potyvirus within a pepper field is determined by the presence and behavior of its vectors, and the availability of a suitable source of virus inoculum [50]. Vectors are first probe on plants hosting viruses and then probe on uninfected pepper plants for the virus to spread within the crop. Aphids are ideal vectors of viruses because successful transmission of viruses requires penetration without excessive injury to plant cells and aphid probe plant cells without causing much disturbance [51].

Viruses transmitted by vectors have been classified into three groups based on how long they are retained by the vector and the mechanism by which they are transmitted [52]. These categories are: non-persistently transmitted, semi-persistently transmitted and persistently transmitted. The retention period by the vectors are strictly related to the mechanism of transmission. Therefore, non-persistently transmitted viruses are acquired within one minute, infectious directly after gaining and lost after the vectors probes a new host [53]. The gaining period for semi-persistently transmitted viruses requires minutes, although they can be transmitted shortly after they are acquired. Persistently transmitted viruses are acquired after minutes to hours of feeding, require a latent period before they are transmissible and retained in their vectors where they stay transmissible for weeks. Persistently transmitted viruses are reproducing within and retained during the life of their vectors [54].

Both non-persistent and semi-persistent viruses are accepted on the lining of the food canal formed by the stylets, fore gut, and lost as the vector molts [55]. Non-persistently transmitted viruses are likely to be detached from the stylets and foregut during long gaining periods and during long probes or feeding [53]. Such viruses show limited vector specificity within insect families. However, members from more than one insect family will not normally transmit similar viruses [51]. For example, potyvirus are non-persistently transmitted by different aphid species. *Myzus persicae* is most efficient in transmitting potyvirus in hot peppers [28]. *Myzus persicae* and *Aphis gossypii Glover* appears equally efficient in transmitting Pepper Mottle Virus (PMV) from pepper to pepper [56]. Alate and apterous aphids of the same species are equally able to transmit any one virus but alate contain the benefit of moving the virus greater distances [12]. The effectiveness of virus transmission by the vector is sometimes affected by the plant from which the virus is acquired [57].

Managements of vector born viruses

Understanding the epidemiology of vector borne virus is very important to develop suitable management strategies. Simon et al. found greater association between the incidence of pepper mottle virus in hot pepper gowning area and their vectors [28]. The vectors increased their populations on widespread weeds found in and around hot pepper farms.

Cultural practices: Cultural management of viral disease are a set of different practices including sanitation which leads to the destruction of alternate hosts which act as sources of infection, crop rotation, intercropping, managing planting date and harvesting time. Destruction of alternate habitats and hosts are intended to remove weeds and wild hosts [58]. These cultural practices can disturb the life cycle of the virus disease, thereby decreasing its vector population and sources of inoculum. These measures are aimed to eliminating the sources of inoculum within and outside the field and also in reducing the vector population or shifting their feeding behavior. These operations are reducing the numbers of viruliferous insects that reach the crop [59].

Using a good seed source is very important cultural management of plant viruses. Healthy plants are more tolerant to viruses. Crop rotation practices are also help in decreasing the virus disease spread. For example, new vegetables like tomato, pepper and other crops should not be grown nearby old fields having the same or another susceptible crop harboring virus disease. The incidence of Potato Virus Y (PVY) in green pepper is reduced when the crop is grown in fields isolated from other solanaceous crops [60].

Planting barrier crops on the edges of fields can help in delaying and/or reducing the increasing of non-persistently transmitted viruses in the field, particularly wherever the aphid vector tends to remain in the area where it first landed. The next viruliferous aphids would drop their virus inoculum to the barrier plants, which they are most likely to probe first. Barrier crops contain a supplementary advantage if they are taller than the field crop because aphids land on taller plants [61].

Physical management: Reflective/repelling surface aluminum or plastic mulches have effective primarily against aphid, whitefly and thrips vectors transmitting different viruses. Aphids are responding to various wavelengths of light, the use of attractive colors as traps or repellents to avoid landing of the vector on susceptible crops are important in minimizing the spread of virus diseases [62].

Summers et al. reported a comparison competence of spray mulches, film mulches and nets placed on soil surface used to protecting squash from non-persistently transmitted aphid borne viruses [63]. UV reflective aluminum mulches are used to successfully reduce the incidence of aphid borne virus diseases in squash and to delay colonization by *Bemisia argentifolii* [64]. These mulches reflect short-wave UV light, which confuses and repels incoming alate aphids and adult whiteflies, thus reducing their incidence of alighting on plants.

The uses of row cover during the vegetative growth stages of crops can helps to delays and reduces virus incidence. Vectors and viruses are completely barred from pepper with different types of synthetic row cover spending these covers are removed [65]. According to Espinoza and McLeod at the end of the growing season, the virus incidence in uncovered plant plots was much greater than in plots that were covered [66].

Chemical method: Insecticides are often effective against the spread of persistently vector transmitted viruses but not against the spread of non-persistently vector transmitted viruses. Some of the conventional insecticides even increase the incidence of the virus within the crop due to increased probing by agitated vector. Non-persistently vector transmitted viruses are transmitted quickly by the short duration probing less than a minute [67]. The effectiveness of insecticide in controlling non-persistently vectors transmitted viruses also depend on a climatic factor that affected the numbers and movement of the vectors [68].

Pyrethroid is one of the types of insecticides quickly knock down the insect vectors like whiteflies, aphids, leafhoppers and thrips. For example, controlling of aphid species likes *Macrosiphum euphorbiae* and *Myzus persicae* by using of pyrethroids are reduced Potato Virus Y (PVY) [69] have provided the evidence by managing the spread of TSWV in flue cured tobacco by application of acibenzolar-S-methyl and imidacloprid.

Mineral oils are also preventing the transmission of stylet borne viruses without killing the vector or destroying the virus [70]. Oils avoid aphids from retaining virus particles through gaining and inoculation [71]. DeWijs et al. reported that the higher viscosity of the oil, the greater its capacity to reduce transmission of stylet borne viruses [72]. An oil coat plant surfaces helps to build up depression between epidermal cells where aphids probe [73].

Host resistance: The most successful component of virus disease management is the use of virus resistant varieties. Genetic engineering has allowed for the fast introduction of resistant plant genes as well as virus genes to protect plants against virus infection [74]. The successful breeding high yielding varieties of *Capsicum species* including *Capsicum chinense*, which are resistant to Potato Virus Y (PVY), Tobacco Etch Virus (TEV), Tomato Mosaic Virus (TMV) and Pepper Mottle Virus (PMV). The performance of a resistant line is dependent on the strain of the virus to which it is exposed to weather, soil conditions and the type of farming practice employed [75].

Combining resistant crops to vector with some other control measures is very important. For instance, in field trials, rice tungro disease was successfully controlled by a combination of insecticide application and moderate resistance of rice cultivar to the leafhopper vectors [76]. Mung bean germplasm against *Bemisia tabaci* to manage Mungbean yellow mosaic virus spread. Intensive efforts were made for developing crops resistant against whitefly transmitted virus diseases [77]. Another example of vector resistance was observed in soybean genotype which are resistant to aphid species such as *Myzus persicae* and *Rhopalosiphum maidis* by which Soybean mosaic virus spread was reduced under field conditions [78].

Integrated management: Integrated virus disease management is developed by implementation of different control methods like destroying the sources of infections, using of pathogen-free planting material, using of net cover, mulching, using of tolerant cultivars and application of insecticides against vectors [79]. For example, management of sunflower necrosis disease caused by tomato spotted wilt virus transmitted by thrips was effectively minimized by bordering the sunflower crop with sorghum and sunflower seeds treated with imidacloprid along with spraying the sunflower crop with imidacloprid [80].

Tomato Spotted Wilt Virus (TSWV) in tomato is also successfully managed by the using resistant tomato cultivar and raising the crop in tunnels protected. The thrips vector population was less than the control and yield of tomato cultivar was significantly higher under tunnel cultivation than in open air [81].

Conclusion

Viruses are one of the primary constraints to production of high-quality *Capsicum annum.* In Ethiopia as well as worldwide, especially in the developing regions. Weeds are often hosting for vectors and virus species that attack pepper in the field. Mostly, virus species in the genus *Potyvirus*, *Cucumovirus*, *Begomovirus* and *Tobamovirus* are major factors for reduction of hot pepper yield. The severity of infection may be depending on environmental conditions, host varieties and availability of vectors. Virus infections cannot be totally controlled in many plantations where they occurred. However, rapid action against the damage caused by viruses is with the use of resistant varieties and ensuring adequate phyto-sanitary conditions within the field. Generally, awareness of local farmers on the impact of field sanitation must be improved as aid to using tolerant varieties. Additionally, screening of young seedlings for infection before they ever reach the field is critical to reduce virus occurrence.

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