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Involvement of Insects (Insecta: Artropoda) in Spreading of Plant Pathogens and Approaches for Pests Management

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Abstract

Everywhere on our planet, insects are the most common animals contributing variably in the environment and have a significant impact on the ecosystem. Most of insects are adapted to live with plants, important as predators and parasitoids, and some are important vectors of diseases that weaken or kill the hosts. In this article information is described on insect vectors of plant diseases and the basic requirements for insect and disease management for the plant scientists. The four basic types of plant pathogens transmitted by insects are fungi (most important plant pathogens), bacteria, viruses (second most important pathogens) and mycoplasma-like organisms, that can replicate within both their host and vector. Spread of plant pathogens by insects involves interactions of plant, pathogen, insect vector, environment, weather, cultural practices, farming operations and agro-ecosystem. The factors contributing to plant diseases spreading are new emerging and re-emerging environmental changes, microbial adaptation and change, human demographics and behavior, technology and economic development, international travel and commerce, and introduction of exotic or invasive species. Control of plant disease vectors is crucial to the reliable production of food, and it provides significant reductions in agricultural use of land, water, fuel and other inputs. The services to vector borne diseases control can be include plant disease identification and disease assessment, insect and insect injury identification along with their assessments, and nutritional and cultural problem assessment as well as Integrated Pest Management (IPM) program. Integrated pest management is an ecological approach to pathogens transmission control that focuses on prevention, observation, thoughtful assessment and careful intervention only when needed. In the IPM system, chemical pesticide is employed as a last defense option against the vectors and pests.

Keywords

Insect, Vector, Virus, Bacteria, Fungus, Mycoplasma, Toxaemia, Pathogen, Disease

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1. Introduction

The insects have greater roles as prey, predators, parasites, recyclers of dead matter, and many of higher plants, which are the main source of food for the majority of insects, can not exist without them due to their pollination. Most of plants in nature are highly prone to attack by various insect pests by their feeding and plant disease transmission, and therefore lead to know a scientist if a particular ecosystem is healthy or disturbed. Most of plant pathogens depend on vectors for their survival and spreading. Insects tend to transmit pathogens of diseases in the course of feeding on plants, and their movement between plants is influenced by plant quality and the distance between plants or how far they have to travel to get the next meal (Sarwar, 2012; 2014 a; 2014 b). Therefore, pest outbreaks and diseases must be identified

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accurately to enable their efficient management. The purpose of this article is to provide a strong system for the exclusion of insect vectors of plant diseases through regulation of movement and quarantines in infested areas to protect the forest, agricultural, horticultural, floricultural, and apiary industries, plants, shrubs and the environment of the state from the impact of pests.

The principal families of insect vectors which cause the most damage to agricultural crops through the spread of plant diseases are in the order Hemiptera, and include the aphids, leafhoppers, delphacid planthoppers and whiteflies. Another important group of insect vectors found worldwide is the order Thysanoptera, the thrips. Other insects also spread plant diseases; however, aphids alone are responsible for spreading the majority of known plant viral diseases, followed closely by the leafhoppers, whiteflies and thrips. The known number of plant disease vectors within these taxa is large, including Cicadellidae (leafhoppers, containing 49 known vector species), Aphididae (aphids with the majority of 192 vector species), Aleyrodidae (whiteflies with 3 vector species) and Thripidae (thrips with 8 known vector species) (Nault, 1997; Sarwar, 2015 a).

Many pathogens of insect-borne plant diseases are spread by homopterous insects, e.g., aphids, leaf and planthoppers, and whiteflies. At least 180 species of aphids transmit 164 viruses, and 151 species of leaf and planthoppers transmit 55 viruses and 40 other microorganisms. Of these, nine viruses and two mycoplasmas like organisms that cause rice diseases are transmitted by leaf and planthoppers. The rice diseases are distributed mostly in Asia, and two of nine rice virus diseases mentioned above have recently been discovered, such as ragged stunt and gall dwarf (Harris, 1987).

The insects are more likely to move shorter distances between better plants, interestingly, then the probability of disease being passed between two plants goes up if they are closer and better, which parallels the stronger gravity between closer and larger plantlets. The researchers tracked a fungal disease spread by bees and moths in the course of pollinating and feeding on nectar from flowers, and as predicted by the behavior of insects, the disease is more likely to spread shorter distances between plants that have many flowers. This implies that knowledge of insect behavior can lead to better prediction of where disease will spread (Matthew et al., 2006).

2. Insects Transmitting Plant Pathogens

Most of the damage and losses caused by plant diseases is due to the direct or indirect effects of transmission and facilitation of pathogens by insects. Almost all types of pathogens can be transmitted by insects, and the ability of piercing-sucking insects to transmit plant disease is closely linked to feeding mode of vector and target tissue of host.

2.1. Hemiptera

The Hemiptera is the largest exopterygote groups of insects and they may be recognized by the special structures of the mouthparts, which are modified into concentric stylets, the mandibular enclosing the maxillary ones and together forming the food and salivary channels. They are very diverse groups comprising scale insects, aphids, psyllids and whiteflies (Sternorrhyncha), true bugs (Heteroptera) and the Auchenorrhyncha (leafhoppers, planthoppers, treehoppers, spittle bugs and cicadas). Hemiptera feeding habits range from phytophagy (the majority of species) to predation, including ectoparasitism and haematophagy. Many of them are important pest species of cultivated crops and some are important vectors of plant diseases. The Auchenorrhyncha has been traditionally divided into two main groups, Cicadomorpha (leafhoppers, treehoppers, spittle bugs) and Fulgoromorpha (the planthopper families). They are all plant feeders, either from phloem, xylem vessels or mesophyll tissue. Some are important pests of crop plants either by direct feeding or by spreading virus and phytoplasma diseases. Many leafhoppers and planthoppers, and some psyllids, are important pests of crop plants, particularly because they are vectors of virus, bacteria and phytoplasma diseases.

Aphids of superfamily Aphidoidea are soft bodied insects and look like small green, white, yellow or black spots that can attack on all parts of a plant. Aphids can reproduce so quickly that their infestation can cover the entire plant in few days. Aphids are able to transmit over 300 plant viruses including cucumber mosaic virus and about 100 different members of the potato virus Y group, generically known as potyviruses. Cucumber mosaic virus can infect over 900 plant species, while most potyviruses have more limited host ranges. Usually the aphids are able to transmit these viruses almost immediately after feeding on infected plants, but unlike the tospovirus, thrips lose the ability to transmit the virus after just a few minutes or hours and must reacquire virus particles to continue for transmitting them. Tobacco mosaic virus is not classically vectored by any insect through feeding. However, it has been shown that this readily mechanically transmissible virus can be transmitted by aphids that walk on infected leaves and pick up virus particles on their legs, then fly to new plants and move around on the foliage, thus inoculating these plants with virus. Aphids are also known to transmit other different kinds of plant viruses, including beet mosaic, cabbage black ring spot, carnation latent, cauliflower mosaic, cherry ring spot, onion yellow dwarf, pea wilt, tobacco etch, tomato spotted wilt and turnip yellow mosaic. Outbreaks of large numbers of aphids are somewhat rare inside greenhouses, but field crops or outdoor nursery crops face more of threats from viruses transmitted by aphids. The green peach aphid, *Myzus persicae* is a vector for more than 110 plant viruses. Cotton aphids (*Aphis gossypii*) often infect sugarcane, papaya and peanuts with viruses. Aphids can contribute to the spread of late blight (*Phytophthora infestans*) among potatoes (Catherine, 2007).

Ash-gray leaf bugs in the genus *Piesma* of Family Piesmatidae are vectors of the beet leaf curl virus, the sugar beet savoy virus and beet latent rosette disease.

Leafhoppers in the family Cicadellidae transmit over 80 known types of plant disease, including that caused by viruses, mycoplasma-like organisms and spiroplasmas. The examples include aster yellows, beet curly top, blueberry stunt, dwarf disease of rice, phony peach and pierce's disease of grapes.

Planthoppers belonging to superfamily Fulgoroidea have been implicated as vectors in the transmission of about 20 plant diseases (viruses and mycoplasma-like organisms) including cereal tillering disease, maize mosaic, northern cereal mosaic, oat sterile dwarf, rice hoja blanca, rice stripe and sugarcane Fiji disease (Burrows and Sutton, 2013).

Treehoppers within family Membracidae, especially *Micrutalis malleifera*, transmit a viral pathogen that causes pseudo-curly top disease in eggplants and other Solanaceae plants.

Psyllids of family Psyllidae are the vectors of mycoplasma-like organisms responsible for pear decline and greening disease of citrus (Prudhomme, 2011).

Whiteflies within family Aleyrodidae are responsible for transmitting of yellow mosaic diseases in at least 20 plant species including cowpeas, roses, soybeans and tomatoes. Whiteflies also spread leaf curl viruses in cotton, potato, tomato, tobacco and other plants. Whiteflies are in addition very efficient vectors of about 115 plant viruses. Common vectors are greenhouse whitefly (*Trialeurodes vaporariorum*) and silver leaf whitefly (*Bemisia argentifolii*/ *Bemisia tabaci* B-biotype). Fortunately, most of these viruses affect mainly vegetable crops, but as it becomes more common to grow tomatoes and peppers alongside ornamental plants, there may start to see more problems of these in plants. Whitefly transmission varies with the insect species and the virus, but generally they are able to acquire the virus at the nymph and adult stages in as little as an hour, and then they can transmit the virus for days or weeks. As with thrips, the increase in pest infestations and the development of pesticide-resistant populations in recent years has made the role of whiteflies more important in virus transmission (Brown et al., 1995).

2.2. Homoptera

Mealy bugs belonging to family Pseudococcidae are small cottony white globules, usually attach to the plant at the stem joints, but they may also be found along the stems. They slowly feed on the plants by sucking sap. Plants infested with mealy bugs often look like as they are drying out, even when they have been watered. Mealy bugs are known vectors of several plant viruses including cocoa swollen shoot virus and cocoa mottle leaf virus (Mekuria et al., 2013).

The scale insects are small arthropods of the order Homoptera belonging to several families of the superfamily Coccoidea. Scale insects are a diverse group of insects, which attach themselves to the stem of a plant and cover themselves with a hard, oval shaped shell. Like mealy bugs, they slowly suck the sap from plants, leaving them too weak to sustain themselves and are known vectors of several plant viruses.

2.3. Thysanoptera

Flower thrips of family Thripidae are suspected of transmitting bacterial, fungal, and viral pathogens. Tomato spotted wilt virus, for example, is spread by onion thrips (*Thrips tabaci*) and tobacco thrips (*Frankliniella fusca*). Two of the most common virus diseases facing greenhouse operations today are members of a virus family collectively called the tospoviruses:- impatiens necrotic spot virus and tomato spotted wilt virus, the former is more prevalent in ornamentals, while later is more often found in vegetable crops. However, both viruses can infect hundreds of different plant species, and plants with mixed infections of both viruses are not uncommon. These tospoviruses are moved by vegetative propagation of plants and can be mechanically transmitted, but by far the most important mode of transmission is through thrips. The prevalence of western flower thrips, *Frankliniella occidentalis*, can help to an increase in the incidence of these viruses. The insect vector-virus relationship is quite complex in that only the juvenile larval stages of thrips can acquire the viruses (the first instar is primarily responsible, the second instar acquires rather inefficiently). Juvenile larval stages that acquire the disease must then undergo their non-feeding pupal stages and emerge as adults before they can transmit the viruses to new plants. The entire progression takes about 1 to 2 weeks from egg to adult, depending on temperature. Once acquired in this manner, the adults can transmit the viruses for the rest of their life span (about 30 to 35 days), although adults do not pass through the virus to their eggs. Interestingly, adults that have not acquired the virus, which feed on infected plants, cannot transmit the viruses to new plants, even though the virus may be detected within the insects themselves (Nault, 1997).

The prevention of virus transmission in plants depends greatly on thrips supervision, if thrips reproduction can be prevented, juveniles cannot be available for virus acquisition, and viruliferous adults (those able to transmit the virus) will not be produced. Fine mesh screening for thrips exclusion on greenhouse vents and other openings can prevent thrips that have obtained virus from weeds or field crops outside from entering the facility and inoculating plants. A good scouting and trapping routine for thrips detection and chemical application and rotation schedules for thrips control can round out an integrated management program. There are easy to use "dipstick" type detection systems available for viruses that take only 5 to 10 minutes to get a result. If these viruses are an ongoing problem in the vicinity, one may consider adding this type of early detection system so that infected plants may be identified and discarded before virus spread can occur.

2.4. Diptera

Cabbage maggot flies, *Delia radicum* in the family Anthomyiidae spread the fungal pathogen of blackleg (*Phoma lingam*).

Leaf miner flies of family Agromyzidae in the genus *Liriomyza* are capable of transmitting tobacco mosaic virus and sowbane mosaic virus (Spencer, 1987).

Apple maggot flies, *Rhagoletis pomonella* within family Tephritidae, are vectors of *Pseudomonas melophthora*, which is the pathogen of bacterial rot in apples (Merz, 1994). Tephritid female flies lay eggs in fruit or vegetable by puncturing the skin with their ovipositors and inject batches of eggs into the wounds. In this manner infected fruit flies may also serve as vectors of pathogens to fruits and vegetables through the wounds of host (Shah et al., 2014; Sarwar and Riaz, 2014 Sarwar et al., 2014; 2015).

2.5. Coleoptera

Leaf beetles of family Chrysomelidae spread more than 35 plant viruses including broad bean mottle, turnip yellow mosaic, southern bean mosaic and rice yellow mottle. Potato flea beetles (*Epitrix cucumeris*) spread the pathogen of potato scab (*Actinomyces scabies*) when the larvae enter a tuber. Corn flea beetles (*Chaetocnema pulicaria*) and corn rootworms (*Diabrotica* spp.), are responsible for spreading of *Bacterium stewarti*, which is the bacterial pathogen of Stewart's disease in corn.

Bark beetles of family Scolytidae are vectors of fungal pathogens in trees. The elm bark beetle (*Scolytus multistriatus*) infects elms with *Ceratocystis ulmi*, which is the pathogen of Dutch elm disease. A similar blue stain fungus (*Ceratocystis ips*) is spread among pine trees by the pine engraver (*Ips pini*) and other bark beetles. The pathogen for chestnut blight (*Endothia parasitica*) is also spread by the beetles of Scolytidae.

Plum curculio, *Conotrachelus nenuphar* belonging to family Curculionidae, inoculates fruits of peach cherry and plum with *Sclerotinia fructicola*, which is the fungal pathogen of brown rot.

2.6. Hymenoptera

Honey bees, *Apis mellifera* of family Apidae, and other pollinating insects spread the bacterial pathogen of fire blight (*Erwinia amylovora*) as they travel from tree to tree for collecting the nectar.

Ants within family Formicidae and bees spread the pathogen for mummy berry, which is a blueberry fungus, transmitted from stem lesions to fruit as the vectors forage for food.

3. Plant Pathogens Transmitted by Insects

3.1. Fungi

The majority of phytopathogenic fungi are belong to the Ascomycetes and the Basidiomycetes. The fungi reproduce both sexually and asexually via the production of spores and other structures. The spores may be spread to long distances by air or water, or they may be soil borne. They are normally transmitted by sap-sucking insects being transferred into the plants phloem where they reproduce. Certain parasitic fungi can also be transferred from a diseased plant to another plant by other vectors. Insects can disperse pathogens over short or long distances, as a result of chance contamination of insects visiting plants. In diseases such as fungal anthracnoses, insects moving on infected plants become contaminated with fungal spores or fragments of hyphae, which are then transported to the vector's next plant feeding sites. Bees and wasps visit diseased flowers, become contaminated with the pathogen and transmit it to other flowers. The anther smut fungus (*UstiLago uioLacea*) replaces the pollen in the anthers of carnation flowers. The petals are not affected and continue to attract insects, which become smeared with smut spores. When the insect visits other flowers, the spores are rubbed off and infect those flowers. The ergot fungi (*Claficeps* spp.), develop in grass and cereal flowers. They produce conidia in sticky and sugary liquid called honeydew, which attracts insects. The insects become contaminated with spores when they visit infected flowers exuding honeydew and carry the spores to other flowers, which become infected. Insects that bore into the stems or trunks of plants can carry pathogens attached to their bodies deep into the plant's tissues (Helen and Brown, 1997).

3.2. Phytoplasma

Phytoplasmas are specialized bacteria that are obligate parasites of plant phloem tissue and transmitted by insects (vectors). They are originally named mycoplasma-like organisms and are characterized by lack of their cell wall, a pleiomorphic or filamentous shape, normally with a diameter less than 1 micrometer, and their very small genomes. They cannot be cultured in vitro in cell-free media. Phytoplasmas are mainly spread by insects in the families Cicadellidae (leafhoppers), Fulgoroidae (planthoppers) and Psyllidae (jumping plant lice), which feed on the phloem tissues of infected plants, picking up the phytoplasmas and transmitting them to the next plant on which they feed. For this reason the host range of phytoplasmas is strongly dependent upon its insect vector. Phytoplasmas may overwinter either in insect vectors or perennial plants. Phytoplasmas enter the insect's body through the stylet, move through the intestine and are then absorbed into the haemolymph. From here they proceed to colonize the salivary glands, within a process that can take up to three weeks. Once established, phytoplasmas can be found in most major organs of an infected insect host. Phytoplasmas are pathogens of important crops, including coconuts and sugarcane, causing a wide variety of symptoms that range from mild yellowing to death of infected plants. They are most prevalent in tropical and sub-tropical regions of the world.

3.3. Viruses

Many plant viruses need to be transmitted by an insect vector. Often these vectors are aphids and whiteflies (Sternorrhyncha), but some very important plant diseases are transmitted by leafhoppers and delphacid planthoppers. A virus's host range may be determined by the host range of the vector and it can only infect plants on that the insect vector feeds upon. Plant viruses are divided into non-persistent, semi-persistent and persistent, depending on the way they are transmitted. In non-persistent transmission, viruses become attached to the distal tip of the insect's stylet and the next plant it feeds on is inoculated with the virus. Semi-persistent viral transmission involves the virus entering the foregut of the insect. Those viruses that manage to pass through the gut into the haemolymph and then to the salivary glands are known as persistent. There are two sub-classes of persistent viruses: propagative and circulative. Propagative viruses are able to replicate in both the plant and the insect, whereas circulative cannot achieve this.

3.4. Spiroplasma

The best-known species of spiroplasma are *Spiroplasma citri*, the causative agent of citrus stuborn disease, and *Spiroplasma kunkelii*, the causative agent of corn stunt disease. The *S. citri*, the type species of the genus Spiroplasma (Spiroplasmataceae, Mollicutes), is restricted to the phloem sieve tubes and is transmitted by phloem sap-feeding insects, as is characteristic of the phytopathogenic mollicutes.

3.5. Bacteria

Citrus greening, also called huanglongbing or yellow shoot/ dragon disease, is a plant disease caused by a bacterium *Candidatus liberibacter*. The bacterium is spread by the psyllid *Diaphorina citri* and carried by the psyllid from host plant to host plant, where it resides exclusively in the phloem tissues. The bacterium, *Xylella fastidiosa*, is the most important bacterial disease transmitted by Auchenorrhyncha, it is xylem-limited so that only xylem feeding species are able to transmit it from diseased to healthy plants. The *X. fastidiosa* causes a variety of plant diseases:- pierce's disease, oleander leaf scorch, phony peach disease, almond leaf scorch, alfalfa dwarf, citrus variegated chlorosis, bacterial leaf scorch of oak, leaf scorch disease in pear, bacterial leaf scorch of coffee, maple leaf scorch, mulberry leaf scorch, and bacterial leaf scorch of elm. The *X. fastidiosa* proliferates only in xylem vessels, in roots, stems and leaves. The vessels are ultimately blocked by bacterial aggregates and by tyloses and gums formed by the plant. The bacterium is efficiently acquired by vector insects, with no latent period and persists indefinitely in infective adult insects. A number of cicadelline leafhoppers species and some Cercopidae are known to be vectors of *X. fastidiosa*, and as a result pierce's disease has become a major problem for the grape industry (Wilson and Turner, 2010).

4. Insect Vector-Plant Pathogen Interactions

The insect feeding mechanisms that contribute to the ability of the insects to transmit plant diseases so efficiently is their piercing-sucking feeding style. Insects in the order Hemiptera (aphids, leafhoppers, whiteflies), and Thysanoptera (thrips) have similar basic morphologies of the head and body. All these insects have piercing-sucking mouthparts that allow them to feed on plants while causing minimal damage. This is important for virus transmission, as viruses require a living cell to reproduce. The insects use paired maxillary stylets to form a suction tube that is inserted into plant cells. In the Hemiptera, these stylets form two canals, the food canal and a smaller salivary canal where the saliva of the insect comes out during feeding. The Thysanoptera are unique in that the thrips stylets form a single canal used for both sucking up plant fluids and to secrete saliva. The insect salivary secretions have several functions. There are at least two types of saliva, one is liquid and aids in the digestion of plant cells and cell debris, so that they can be ingested and sucked up through the food canal. Another solidifies or hardens during feeding which functions to form a salivary sheath to help in preventing leakage around the inserted stylets, and to hold the stylets firmly in place during feeding.

There are two systems to describe the association and transmission of plant diseases by insect vectors, which feed in a piercing-sucking manner. One is based on how long the virus persists in the insect vector and the second is based on the route of virus movement through the insect vector. They can be combined as follows: - 1) the non-persistently transmitted, stylet-borne viruses; 2) the semi-persistently transmitted, foregut-borne viruses; 3) the persistently transmitted, circulative viruses; and 4) the persistently transmitted, propagative viruses. Using this expression, virus transmission is referred to as non-persistent, semi-persistent, or persistent. The way a virus moves through the insect vector can be described by the terms circulative or propagative. Circulative viruses pass into the insect hemolymph and circulate through the insects before being salivated back out during feeding. This involves the ability of the virus to pass several barriers within the insect, passing through the midgut membranes and then the salivary gland membranes, to be able to be released back out with the saliva. These types of viruses do not replicate inside their insect vectors, but merely pass through the insect. Viruses that reproduce inside the insect are considered propagative. Propagative viruses are able to enter the insect hemolymph, but they also replicate once they infect an insect. A virus that is circulative is retained in the insect for a longer period of time than a virus that is non-circulative and merely stuck to the insect's stylets (stylet-borne) or foregut (foregut-borne virus). Viruses that are propagative (replicating in the insect) are retained for the life of the insect. Non-persistently transmitted, stylet-borne viruses are transmitted into the plant during short durations of feeding. Virus acquisition (the ingestion of a virus that results in the insect's ability to transmit the virus to a plant), is brief and often just of a few seconds of feeding. There is no latent period (the time that passes between when the virus is acquired and when it can be transmitted to a plant). Since these types of viruses usually are binding to the insect's stylets for only a brief period of time, the insect does not retain the ability to transmit the virus for long periods. Usually, virus transmissibility is lost after a few minutes of feeding on a non-infected plant. Aphids transmit the majority of non-persistently transmitted viruses. The ability of viruses to bind to the insect's stylets is aided by a helper component (a virus encoded, non-structural protein produced only in infected plants). During subsequent periods of feeding the virus is released or washed from the stylets, thus depositing virus into the plant tissues. Semi-persistently transmitted, foregut-born viruses are transmitted into the plant during longer durations of feeding (minutes). Virus acquisition increases with increased time spent on feeding (minutes to hours), and the virus stays in association with the insect for several hours, being able to be transmitted into other plants. The virus is thought to be binding in the anterior areas of the alimentary tract, along the stylets to the foregut and a few virus particles are released during each act of feeding. There is no latent period, the virus does not replicate and the insect can lose the ability to transmit the virus during its life. Persistently transmitted, circulative viruses do not replicate in the insect vector. These types of viruses are acquired and transmitted during long periods of feeding (minutes to hours) and there is a latent period of hours to days before the virus can be transmitted to another plant. This makes sense as the virus must move through the insect body and get into the salivary glands to be salivated back out before transmission can occur. Virus retention is long, but is dependent upon the amount of virus acquired into the insect body and may last for the life of the insect, usually around 30 days. Persistently transmitted, propagative viruses do replicate inside the insect. Virus acquisition time takes hours to days of feeding by vector. The latent period can take weeks before an insect can transmit virus. The virus is retained for the life of the insect and often the virus is passed to the eggs (transovarial transmission) (Hunter and Backus, 1989; Hunter and Ullman, 1992).

5. Approaches for Management of Insect-borne Plant Pathogens

Countywide vectors control is a fundamental element for eliminating the pathogens transmission and the diseases that they carry. Good information can contribute to a better understanding of the pest's problem; as a result, it is important to gather the best plant samples and to record all pertinent background information for the diagnostician of disease. For collecting insect samples, a good insect sample must be consist of a range of the organism's life stages presented in well preserved and undamaged conditions (Nelson and Bushe, 2006).

There are always some disease problems on the plants that are a part of nature. The control trick is to catch the problems early, before they spread. Some problems may disappear with better weather and others need intervention on owner's part. If there are disease problems in the farm, usually consider the growing of disease-resistant varieties. Insect pests multiply very quickly indoors and outdoors, so one should have to be very diligent about checking for their symptoms. Always keep an eye view for leaves that become discolored or curled and for plants that look wilted even when they are watered. Find out hot spots of the common plant pests and also work out the natural predators to keep the insects under check (Sarwar, 2015 b).

The important approaches for management of insect-borne plant pathogens are host manipulation (isolation in space and time), reducing pathogens sources (inoculum identification and reduction), manipulating (controlling) vectors (alightment, landing, plant appearance), and blocking pathogens transfer between vector and plant (oils, insecticides, transgenics). Other solutions for managing vectors transmitted pathogens to some crops are preventing vectors from landing on crop, use of reflective mulches (e.g., pepper), row covers, interference with vector's ability to transmit virus, use of mineral and stylet oils (e.g., pepper and snap beans), manipulating immigrating vector populations using border crop or barrier crop, and separating crop from pathogen sources (Sarwar, 2015 c).

6. Integrated Pest Management (IPM) Programs

Integrated Pest Management (IPM) is a comprehensive, decision-making process for solving pest problems in both agricultural and nonagricultural settings. It is a sustainable approach providing economical control with the least possible hazard to people, property and the environment. Rather than simply trying to eradicate pests, IPM considers all available information and experience, accounts for multiple objectives, and considers every preventive and curative option. By combining information about pest's life cycles and their interaction with the environment, biological, cultural, physical and chemical tools can be implemented to achieve optimum results in ways that minimize economic, health and environmental risks. The IPM can be used wherever pest damage occurs and it can be applied to diverse situations such as houses, apartments, gardens, schools and farms. The IPM programs require that it is necessary to use some common options, identifying the problem and deciding if the problem is big enough to warrant a pesticide, by starting with the least toxic control and then move up to larger toxic only if needed, and keeping a close watch on plant so that small problems do not get out of control. Always keep an eye view on the beneficial invertebrates that are usually the pollinators including a variety of bees, butterflies, flies and even some beetles. These insects provide a vast, free public service because they visit flower to feed on pollen and nectar, and they fertilize the plants as well allow them to make fruit (Sarwar, 2013 a; 2013 b). These creatures need a good support to build up because their populations are declining.

7. Conclusion

The sucking insects that feed on plant's xylem and phloem vascular tissues are the most common vectors of plant pathogens. Within order Hemiptera, the greatest number of insect vectors of plant pathogens especially aphids transmit the greatest number of different plant viruses, followed by whiteflies, leafhoppers, plant hoppers and mealybugs. Thrips and chewing insects mostly beetles transmit a relatively small number, but varied types of plant viruses, which can be of great economic importance. Among the mites, the minute bud or gall mites are the most important virus vectors. The most noticeable initial step in controlling of diseases caused by insect-borne pathogens is the elimination of vectors with insecticides. Though insecticides are very effective in some situations, but they are typically not the best tools for control of most vector-borne pathogens of crops. The most effective control approaches combine multiple methods including sanitation to eliminate nearby sources of the pathogen, use of virus-free plants, heat therapy or antiviral chemical treatments to produce virus-free new plants and by crops planting after peak vector flight periods. Some viruses are transmitted via seeds from infected plants and control may be based on planting of virus-free seed.by breaking of the transmission cycle. Genetically based plant resistance to pathogens or tolerance of infection without loss of yield provides the basis for the most successful control programs for vector-borne plant pathogens. Finally, molecular methods of introducing novel genes for resistance to viruses directly into crop plants promises to provide resistance to virus diseases where no genetic resistance has yet been identified.

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