Global Journal of Plant Ecophysiology, 3(2): 74-82, 2013
ISSN 2074-0891
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Avoidance of Black bean Aphids, the Vector of Necrotic Yellow Virus (FBNYV) to Faba bean Plants - Middle Egypt: An Overview

Soliman, M.M.

Legume Research Department, Field Crops Research Institute, Agric. Res. Center, Egypt

ABSTRACT

In Egypt and since the early 1990's, there was a problem in the fields of faba bean when planted early in September they often severely attacked by black bean aphids, lead to 100% infection with faba bean necrotic yellow virus **(FBNYV)**, cause of destroying faba bean plants. In such circumstances, farmers ploughed the crop and replanted another crop. It was found that delaying sowing faba bean until November has resulted in lower levels of virus infection, most probably due to lower population densities and reduced activities of the vector aphids. However, more studies were required to establish the most effective ways to avoid aphid infestation in faba bean fields without using harmful insecticides that kill natural enemies (long term control). This overview is to reveal the roles of faba bean plants, natural enemies and natural repellents to avoid the infection with black bean aphids. It is also including the modern methods to control virus diseases in plants. It is also including the photoperiodic effect on black bean aphids in Egypt. It was found that spraying vinegar over faba bean plants at the concentration of 2 litre/20 liter of water per feddan no later than 20 days after sowing prevent aphids from causing infestation for a period enough for faba bean plants to escape from the infestation. In case of the existence of little infestation with aphids, it is rather smash aphids as a repellent approach than spraying harmful insecticides because smashing aphids releases warning chemicals threaten the rest aphids in the field and the upcoming ones.

Key words:

Introduction

Faba bean crop in the Mediterranean region is liable to attack by several insect pests in the field and during storage. Some of them cause extensive damage and require the development of control methods. The most important field insects are the black aphids, *Aphis fabae.* Besides studies on chemical control, a laboratory screening of faba bean lines is conducted in Egypt as a part of a network and lines showing some degree of resistance have been identified.

The black bean aphid, ***Aphis fabae***, responds behaviorally to the odor of its host plant faba bean (***Vicia faba***) in olfactometer bioassays by spending more time in the treated than control regions. It has been shown that a blend of fifteen volatile compounds emitted by *V. faba* elicits the same response as a headspace sample of an intact *V. faba* plant. It was report that no single compound within this blend fully accounts for the behavioral response and that the responses to individual compounds are different when in the context of the blend. As none of the compounds are specific to the host, it has been hypothesized that *A. fabae* responds preferentially to the blend of compounds when presented in a species-specific combination of volatiles or in ratios specific to *V. faba*. Future plans to test which of these two hypotheses pertains to host-seeking *Aphis fabae* were discussed.

Black bean aphids have many natural enemies. There are several parasitic wasps, which control aphids populations in celery, most notably species in the genera Diaeretiella and Lysiphlebus. In some cases, these parasites can eliminate high densities of aphids over a few weeks period. Other predators include ladybeetles, syrphid flies and lacewing.

In Egypt, black bean aphid, ***Aphis fabae*** has no regular life cycle because of the photoperiodic and circadian effects on aphids where the insect spend its life as a parthenogenic female and there is no existence of males throughout the seasons of the year. It was found in Middle Egypt that aphids continued on faba bean plant until late of January and that may give the opportunity to trace this dangerous insect and control or even avoid it without using harmful insecticides.

The role of faba bean plants via identification of Volatile Compounds Used in Host Location by the Black Bean Aphid, Aphis fabae:

Corresponding Author: Soliman, M. M. Legume Research Department, Field Crops Research Institute, Agric. Res. Center, Egypt

Behavioral and electrophysiological responses of winged Aphis fabae to volatiles of faba bean, Vicia faba (var. Sutton dwarf), plants were studied by Ben Webster et al (2008) and semiochemicals used in host location were identified. In olfactometer bioassays, aphids spent significantly more time in the region of the olfactometer where V. faba volatiles from an intact plant were present than in control regions with clean air. This response also occurred when an air entrainment sample of a V. faba plant was used as the odor source. Coupled gas chromatography–electroantennography revealed the presence of 16 electrophysiologically active compounds in the air entrainment sample. Fifteen of these were identified as (Z)-3-hexen-1-ol, 1-hexanol, (E)-2-hexenal, benzaldehyde, 6-methyl-5-hepten-2-one, octanal, (Z)-3-hexen-1-yl acetate, (R)-(−)-linalool, methyl salicylate, decanal, undecanal, (E)- caryophyllene, (E)-β-farnesene, (S)-(−) germacrene D, and (E,E,)-4,8,12-trimethyl-1,3,7,11-tridecatetraene. An olfactometer response was observed to a 15-component synthetic blend that comprised all identified compounds at the same concentration and ratio as in the natural sample, with the aphids spending significantly more time in the treated regions of the olfactometer where volatiles were present than in the control regions. These data are discussed in the context of insect host location and crop protection. Ben Webster et al (2010) also studied the Between plant and diurnal variation in quantities and ratios of volatile compounds emitted by *Vicia faba* plants and they stated that ratios of volatile phytochemicals potentially offer a means for insects to recognise their host-plant species. However, for this to occur ratios of volatiles would need to be sufficiently consistent between plants and over time to constitute a host-characteristic cue. In this context we collected headspace samples from *Vicia faba* plants to determine how consistent ratios of key volatile phytochemicals used in host location by one of its insect pests, the black bean aphid, *Aphis fabae*, were. These were (*E*)-2-hexenal, (*Z*)-3-hexen-1-ol, 1-hexanol, benzaldehyde, 6-methyl-5-hepten-2-one, octanal, (*Z*)-3-hexen-1-yl acetate, (*R*)-linalool, methyl salicylate, decanal, undecanal, (*E*)-caryophyllene, (*E*)-β-farnesene, (*S*)-germacrene D, and (*E*, *E*)-4,8,12-trimethyl-1,3,7,11-tridecatetraene, which had previously been found to be electrophysiologically and behaviourally active to *A. fabae*. Although the quantities of volatiles produced by *V. faba* showed large between plant and diurnal variation, correlations between quantities of compounds indicated that the ratios of certain pairs of volatiles were very consistent. This suggests that there is a host-characteristic cue available to *A. fabae* in the form of ratios of volatiles.

The information obtained gave the opportunity to use repellents on faba bean plants instead of using the harmful insecticides before the infestation of aphids. It was found in Middle Egypt that faba bean plants start to release the volatiles that make aphids recognize and locate them at the age of no more than 22 days from sowing at the average age of (20-25) days after sowing. spraying vinegar over faba bean plants at the concentration of 2 litre/20 liter of water per feddan no later than 20 days after sowing and smashing aphids that may exist in small number after the previous treatment was found to be better approach than spraying harmful insecticides.

The role of insect repellants:

Insect pest management that is safe and effective. Learn more!

An insect repellant of biodegradable ingredients, primarily food products or food stuff derivatives, that is safe and effective over long periods on animals and humans, wherein the insect repellant comprises two basic ingredients which are small amounts of a garlic extract component and a hot pepper extract component in a surfactant and carrier solution, preferably employing vinegar. It requires no petroleum-based materials. A method for repelling insects is also described.

Natural Aphid Pesticides: 10 Eco-Friendly Ways to Repel Aphids:

How do you get rid of these aphids without dousing the poor plants with harmful chemicals? Below are 10 eco-friendly ways to rid, reduce, and prevent aphids, also called plant lice.

1: Neem Oil:

Pure neem oil, an oil derived from the neem tree, has long been used in many natural remedies, including pest control. The oil, or Azadirachtin, acts as a repellent and growth regulator. To the insects, the neem oil has a bitter taste, so they will not eat the leaves treated with it. Also, if the insects do come in contact with the Azadirachtin, it prevents the larvae from growing into adults. Neem oil can be purchased at various online stores or made from neem trees.

2: Homemade Lemon Spray:

This natural aphid pesticide works as an instant remedy, killing the aphids on contact. To make this natural pesticide, grate the rind of a large lemon. Boil it in enough water to fill a garden spray bottle. Let the mixture sit

overnight. Drain the liquid into the garden spray bottle. Spray the aphids and larvae directly. It will cause them to convulse.

3: Homemade Vinegar Spray:

Get out a spray bottle and fill it 1/3 of the way with distilled white vinegar and the rest of the way with water. This will kill the aphids and larvae on contact.

4: Aluminum Foil:

Place a square of aluminum foil around the base of plants affected by aphids. This causes light to bounce around to the underside of the leaves, which repels the aphids. It is also good for the plants, as it brings them more natural sunlight.

5: Calcium Powder:

Sprinkling calcium powder around the base of the plants is another natural aphid repellent. The aphids do not like the calcium and will generally stay away from it.

6: Yellow Plastic Bowl:

Aphids are naturally attracted to the color yellow. Place a yellow plastic bowl filled about 1/3 of the way with water in the center of the infested area. Many of the aphids will be drawn to the bowl and will go into the water and die.

7: Banana Peels:

Burying shredded banana peels around the base of plants is an odd, but effective remedy. It has been around for ages and many gardeners will swear by it.

8: Smash Their Buddies:

Squashing a few aphids near the infested area will signify to the other aphids that it is time to go. It's a chemical reaction.

9: Ladybugs:

Ladybugs can be purchased at garden and home improvement centers. The ladybugs feed on the aphids and if you purchase enough, the aphids will be gone in no time. Ladybugs are also good for the garden in other ways.

10: Garlic or Onions:

Planting garlic or onions is another natural aphid deterrent. They do not like garlic or onion and will not likely come near an area they are in.

The role of Faba bean Natural Enemies of Aphids:

Aphids have many natural enemies. Use the photos below to identify predators and natural enemies of aphids. Names link to more information on identification and biology.

Glob. J. Plant Ecophysiol., 3(2): 74-82, 2013

Convergent lady beetle (larva)

Identification tip: Larvae are elongate with long legs and resemble tiny alligators.

Convergent lady beetle (adult)

Identification tip: Adults are mostly orange with black spots and converging white marks on the thorax. Some individuals have fewer spots, and some, no spots.

Sevenspotted lady beetle (larva)

Identification tip: Larvae are elongate, grayish, yellow- spotted, and alligator shaped.

Sevenspotted lady beetle (adult)

Identification tip: Adults have a black thorax with white along the front margin. Seven black spots are on the red or orangish wing covers, which may have 2 white areas near the front.

Parasitic wasp

Identification tip: Parasitic wasps such as this *Aphidius* sp. lay their eggs in aphids.

Parasitic wasp (aphid mummy)

Identification tip: The cuticle of aphids killed by parasitic wasps turn bronze (or black) and crusty and are called mummies. The exit hole is evidence that the parasitic wasp has emerged.

Bigeyed bug

Identification tip: Adults and nymphs are oval, somewhat flattened, about 1/4 of an inch long, with a wide head and prominent bulging eyes.

Damsel bugs

Identification tip: Adults are slender insects that are mostly yellowish, gray, or dull brown, measuring about 2/5 of an inch long, and have elongated heads and long antennae.

Minute pirate bugs

Identification tip: Adults are small, 1/12 to 1/5 of an inch long, oval, black or purplish with white markings, and have a triangular head.

Syrphid fly

Identification tip: Larvae are legless, maggot shaped, and opaque with tapered heads.

Fungal diseases

Identification tip: *Entomopthora* fungi first turn aphids pink and brown, later causing them to shrivel up and die.

The role of black bean aphids as the vector of FBNYV and modern technology to solve the problem:

The black bean aphid, ***Aphis fabae*** is the responsible for transmitting faba bean necrotic yellow virus (***FBNYV***) to faba bean and other legume plants. ***FBNYV*** caused economically important diseases of faba bean, lentil and pasture legumes in western Asia, north Africa, Sudan and Ethiopia (Makkouk *et al.,* 1994; Katul *et al.,* 1993; Shamloul *et al.,* 1999). Since the beginning of the 1990s this virus has been causing serious economic losses to faba bean in Egypt (Abdel-Salam and El-Sharkawy, 1996; Abdel-Salam, *et al.,* 1997). *FBNYV* is a

member of the family *Nanoviridae* which has two genera, viz. *Nanovirus* circumventing *FBNYV* and *Babuvirus* containing *BBTV* (Randels *et al.,* 2002). *FBNYV* shares vector-transmission (i.e. aphids) and particle properties, as well as genome composition and organization with *BBTV* (Harding *et al.,* 1991, 1993; Burns *et al.,* 1995; Franz *et al.,* 1998). *FBNYV* is persistently transmitted by various aphids of which *Aphis craccivora* is the most significant natural vector (Franz *et al.,* 1998). Seed-transmission of an Egyptian isolate of *FBNYV* has been reported (Abdel-Salam and El-Sharkawy, 1996). *FBNYV* has small isometric virus particles that are 18 nm in diameter made up of a single capsid protein of about 22 kDa (Katul *et al.,* 1993) engulfing ten circular ssDNA (Katul *et al.,* 1998).

Faba bean necrotic yellows virus (FBNYV; genus *Nanovirus*) causes severe yield losses and crop failure in important food and fodder legumes in African and Asian countries (Makkouk *et al.,* 1994; Franz *et al.,* 1995). The virus has a wide host range, and so far more than 50 plant species, mainly belonging to the *Fabaceae*, have been identified as hosts for the virus (Katul *et al.,* 1993, Franz *et al.,* 1997). All nanoviruses except coconut foliar decay virus (a tentative species in the genus *Nanovirus*; Pringle, 1998) are persistently transmitted in a circulative nonpropagative manner by aphids; coconut foliar decay virus is transmitted by planthoppers (Randles *et al.,* 1986). Efficient vectors of FBNYV are *Aphis craccivora* and *Acyrthosiphon pisum* (Franz *et al.,* 1998). Nanoviruses are phloem limited and not mechanically transmissible from plant to plant using abrasive agents or by seed (Chu and Helms, 1988; Harding *et al.,* 1991; Katul *et al.,* 1993). They consist of small icosahedral particles, 17±20 nm in diameter, that contain circular single-stranded DNA molecules each of about 1 kb in size (Chu and Helms, 1988; Harding *et al.,* 1991; Katul *et al.,* 1993). The viral capsid is composed of a single protein of about 20 kDa.

Alexander et al (1999) have shown that the genomes of two FBNYV isolates as well as that of milk vetch dwarf virus (MDV) consist of 10 different DNA molecules, with each containing one major open reading frame (ORF) coding for a protein (Katul *et al.,* 1998; Sano *et al.,* 1998). Both viruses show striking similarities in their genomic nucleotide sequences. For the other two definite *Nanovirus* species, subterranean clover stunt virus (SCSV) and banana bunchy top virus (BBTV), seven and six different DNA components have been identified, respectively (Boevink *et al.,* 1995; Burns *et al.,* 1995). Karan *et al.* (1997) detected the six different DNA components of BBTV in a number of virus isolates originating from various countries, which led to the suggestion that they represent the integral genome of the virus. Because one DNA component of BBTV does not have a matching counterpart among the other nanoviruses, it is believed that the complete genomes of SCSV, as well as those of FBNYV and MDV, might consist of more DNA components than have been identified. It has been reported that the DNA molecules are separately encapsidated, thus forming the multicomponent structure of the nanoviruses (Chu and Helms, 1988; Katul *et al.,* 1998). The relatively strong similarity between FBNYV and MDV at the genomic level is also serologically manifested (Franz *et al.,* 1996). Using monoclonal antibodies (MAbs) in ELISA, it was shown that the capsid proteins of FBNYV and MDV have several epitopes in common and that the epitope profiles of FBNYV isolates from different geographical regions vary considerably (Franz *et al.,* 1996). So far, all attempts to demonstrate aphid transmissibility of a purified nanovirus acquired from either artificial diets or sucrose suspensions have failed (Chu and Helms, 1988; Thomas and Dietzgen, 1991; Katul *et al.,* 1993). Chu *et al.* (1993) showed that purified SCSV replicated in protoplasts, leading to *de novo* synthesis of capsid protein. These observations led to the suggestion that the defect in aphid transmissibility might be caused by the lack of a helper factor (HF) of viral origin or a helper virus in the purified virus suspensions (Chu *et al.,* 1993; Katul *et al.,*1993). Here, we report that purified FBNYV is infectious to *Vicia faba* but lacks a HF for its transmission by aphids. The requirement of the HF in aphid transmission of the virus was demonstrated in a similar fashion as was instrumental in identifying the helper component (HC) and aphid transmission factor-dependent transmission of potyviruses and caulimoviruses (Govier and Kassanis, 1974, Lung and Pirone, 1974). Moreover, evidence is presented that one of the functions of the HF is to mediate the transport of FBNYV particles across the hemocoel±salivary gland interface of the aphid.

When Alexander et al (1999) purified faba bean necrotic yellows virus (FBNYV; genus *Nanovirus*) alone, they found that is not transmissible by its aphid vector, *Acyrthosiphon pisum*, regardless of whether it is acquired from artificial diets or directly microinjected into the aphid's hemocoel. The purified virus contains all of the genetic information required for its infection cycle as it readily replicated in cowpea protoplasts and systemically infected *Vicia faba* seedlings that were biolistically inoculated using gold particles coated with intact virions or viral DNA. The bombarded plants not only developed the typical disease syndrome, thus indicating that FBNYV is the sole causal agent of the disease, but also served as a source from which the virus was readily acquired and transmitted by *A. pisum*. The defect of the purified virus in aphid transmissibility suggests that FBNYV requires a helper factor (HF) for its vector transmission that is either nonfunctional or absent in purified virus suspensions. The requirement for an HF was confirmed in complementation experiments using two distinct isolates of the virus. These experiments revealed that aphids transmitted the purified virus isolate from artificial diets only when they had fed previously on plants infected with the other FBNYV isolate. Also, microinjected FBNYV, which persisted to the same extent in *A. pisum* as naturally acquired virus, was

transmissible when aphids had acquired the HF from infected plants. This suggests that one of the functions of the HF in the transmission process is to facilitate virus transport across the hemocoel±salivary gland interface.

The work of Alexander et al (1999) can be used to prevent the transmission FBNYV virus through genetic engineering on the help factor or using the following approaches.

Biotechnological Approaches for Plant Viruses Resistance:

Silas Pessini et al (2009) stated that virus diseases are significant threats to modern agriculture and their control remains a challenge to the management of cultivation. The main virus resistance strategies are based on either natural resistance or engineered virus-resistant plants. Recent progress in understanding the molecular mechanisms underlying the roles of resistance genes has promoted the development of new anti-virus strategies. Engineered plants, in particular plants expressing RNA-silencing nucleotides, are becoming increasingly important and are likely to provide more effective strategies in future. A general discussion on the biotechnology of plant responses to virus infection is followed by recent advances in engineered plant resistance.

Plant viruses are among the most important of plant pathogens. Virus infestation of cultivated areas results in a range of effects, from reduced crop quality to complete plant devastation. Virus specificity varies greatly, with some viruses able to colonize different hosts, whereas others can only infect one defined species due to specific intricate interactions with the plant cell machinery. As a result of mutation in the viral genome, new virus varieties emerge, while others are excluded (Mangrauthia et al, 2008; Jones 2009). The appearance of pathogenic strains is especially important to agriculture. Disease management strategies need extensive knowledge of virus infection and its effect on host plants to allow the correct control procedures to be implemented. Reduction of crop loss is based on controlling the pathogen dissemination rather than the treatment of infected plants, as usually done with fungal or bacterial diseases (Ventura et al, 2004). Different approaches have been used to diminish the virusspread throughout the plant, and/or the plantation. Results from epidemiological studies might indicate the main route by which the virus would reach its host and the mechanism(s) of inoculation (Gilligan and van den Bosch 2008, Rodrigues et al, 2009 a & b). Virus may be transmitted by contaminated seed, by vectors or during culture by normal agricultural practices (Fereres and Moreno 2009; Dieryck et al, 2009). The use of certified seeds may significantly reduce the occurrence of certain viruses (Novy et al, 2008). Furthermore, vector population control and the implementation of "clean" agricultural practices can considerably limit the virus spread (Fereresa and Moreno 2009; Castle et al, 2009). In general, damage to the barrier composed of the cell wall and plasma membrane allows virus delivery into a viable plant cell, a process known as inoculation (Rodrigues et al, 2009). Thereafter, should a compatible interaction occur between the virus and the plant cell, virus particles will replicate and spread within the host through plasmodesmata and vascular bundles (Taliansky et al, 2008). The intensity of these processes will depend on the relationship between the virus and the plant host. The set of plant resistance responses aims to reduce virus replication (Ascencio-Ibáñez et al, 2008). In some cases, breeding cultivars with elevated resistance levels represents a viable strategy to reduce the virus-induced crop loss (Ma et al, 2004). Another option is the use of attenuated virus strains to increase the resistance responses (Ichiki et al, 2005). Advances in the understanding the biochemistry of virus infection, such as RNA silencing, have resulted in potential new methods to efficiently limit the viral diseases (Tenllado et al, 2004). In this review, a general discussion on plant responses to virus infection is followed by an overview of recent advances in engineered plant resistance, the major antiviral strategy used for crop protection.

Francisco Tenllado et al (2003) used Crude extracts of bacterially expressed dsRNA can be used to protect plants against virus infections. They stated that Double-stranded RNA (dsRNA) is a potent initiator of gene silencing in a diverse group of organisms that includes plants, *Caenorhabditis elegans, Drosophila* and mammals. They have previously shown and patented that mechanical inoculation of *in vitro*-transcribed dsRNA derived from viral sequences specifically prevents virus infection in plants. The approach required the *in vitro* synthesis of large amounts of RNA involving high cost and considerable labour. They have developed an *in vivo* expression system to produce large amounts of virus derived dsRNAs in bacteria, with a view to providing a practical control of virus diseases in plants. Partially purified bacterial dsRNAs promoted specific interference with the infection in plants by two viruses belonging to the tobamovirus and potyvirus groups. Furthermore, we have demonstrated that easy to obtain, crude extracts of bacterially expressed dsRNAs are equally effective protecting plants against virus infections when sprayed onto plant surfaces by a simple procedure. Virus infectivity was significantly abolished when plants were sprayed with French Press lysates several days before virus inoculation.

Their approach provides an alternative to genetic transformation of plant species with dsRNA-expressing constructs capable to interfere with plant viruses. The main advantage of this mode of dsRNA production is its simplicity and its extremely low cost compared with the requirements for regenerating transgenic plants. This

approach provides a reliable and potential tool, not only for plant protection against virus diseases, but also for the study of gene silencing mechanisms in plant virus infections.

Photoperiodism (the biological calendar) in Insects: Aphid Polyphenism:

This subject discusses the complicated role of photoperiod in regulating life history traits in aphids. As for all organisms responding to day length, aphids require a photoreceptor system that can distinguish light from dark, a clock mechanism that can measure the duration of the light (or in most cases the dark period), a counter or photoperiodic memory that accumulates the number of long or short days, and an endocrine/neuroendocrine effector system that modifies the developmental processes associated with either long- or short-day development. The photoperiodic effect is reason of the absence of male aphids in Egypt and the continuing of the parthenogenesis in aphid females.

References

Abdel-Salam, A.M. and A.M. El-Sharkawy, 1996. The use of monoclonal and polyclonal antibodies for the detection of an Egyptian isolate of faba bean necrotic yellows virus (FBNYV) in faba bean tissues. Bull. Fac. Agric., Univ. Cairo., 47: 355-368.

Abdel-Salam, A.M., A.M. El-Sharkawy and S. Youseff, Sawsan 1997. Detection of three isolates of faba bean necrotic yellows virus (FBNYV) infecting different genotypes of *Vicia faba* in Giza. Egypt. The 8 th Cong. Phytopathology, Giza, Egypt.

Alexander, W.E. Franz, Frank van der Wilk, Martin Verbeek, Annette M. Dullemans, and Johannes F.J.M. van den Heuvel1, 2009. Faba Bean Necrotic Yellows Virus (Genus *Nanovirus*) Requires a Helper Factor for Its Aphid Transmission. Virology, 262: 210±219.

Ascencio-Ibáñez, J.T., R. Sozzani, T.J. Lee, T.M. Chu, R.D. Wolfinger, R. Cella, L. Hanley-Bowdoin, 2008. Global analysis of Arabidopsis gene expression uncovers a complex array of changes impacting pathogen response and cell cycle during geminivirus infection. *Plant Physiol.*, 148: 436-454.

Boevink, P., P.W.G. Chu and P. Keese, 1995. Sequence of subterranean clover stunt virus DNA: Affinities with the geminiviruses. *Virology,* 207: 354±361.

Ben Webster, Toby Bruce, Samuel Dufour, Claudia Birkemeyer, Michael Birkett, Jim Hardie, and John Pickett, 2008. Identification of Volatile Compounds Used in Host Location by the Black Bean Aphid,*Aphis fabae*. Journal of Chemical Ecology, 34(9): 1153-1161.

Ben Webster[a], Salvador Gezan[a], Toby Bruce[a,] , Jim Hardie[b] and John Pickett[aa] , 2010. Between plant and diurnal variation in quantities and ratios of volatile compounds emitted by *Vicia faba* plants**.** Phytochemistry, 71(1): 81-90.

Burns, T.M., R.M. Harding and J.L. Dale, 1995. Genome organization of banana bunchy top virus. *J. Gen. Virol.,* 76: 1471±1482.

Castle, S., J. Palumbo, N. Prabhaker, 2009. Newer insecticides for plant virus disease management. *Virus Res.*, doi:10.1016/j.virusres.

Chu, P.W.G., and K. Helms, 1988. Novel virus-like particles containing circular single-stranded DNA associated with subterranean clover stunt disease. *Virology,* 167: 38±49.

Chu, P.W.G., B.-S. Qui, Z.-Y. Li and P. Larkin, 1993. Replication of subterranean clover stunt virus in pea and subterranean clover protoplasts. *Virus Res.,* 27: 173±183.

Dieryck, B., G. Otto, D. Doucet, A. Legrève, P. Delfosse, C. Bragard, 2009. Seed, soil and vegetative transmission contribute to the spread of pecluviruses in Western Africa and the Indian sub-continent. *Virus Res.,* doi:10.1016/j.virusres. 2008.08.017.

Fereres, A. and A. Moreno, 2009. Behavioural aspects influencing plant virus transmission by homopteran insects. *Virus Res.*, doi:10.1016/j.virusres.2008.10.020.

Francisco Tenllado, Belén Martínez-García, Marisol Vargas and José Ramón Díaz-Ruíz, 2003. Crude extracts of bacterially expressed dsRNA can be used to protect plants against virus infections. BMC Biotechnology, (3): 1-11.

Franz, A., K.M. Makkouk, L. Katul and H.J. Vetten, 1996. Monoclonal antibodies for the detection and differentiation of faba bean necrotic yellows virus isolates. Ann. Appl. Biol., 128: 255±268.

Franz, A., K.M. Makkouk and H.J. Vetten, 1995. Faba bean necrotic yellows virus naturally infects *Phaseolus* bean and cowpea in the coastal area of Syria. *J. Phytopathol.,* 143: 319±320.

Franz, A., K.M. Makkouk and H.J. Vetten, 1997. Host range of faba bean necrotic yellows virus and potential yield loss in infected faba bean. *Phytopathol. Med.,* 36: 94±103.

Franz, A., K.M. Makkouk and H.J. Vetten, 1998. Acquisition, retention and transmission of faba bean necrotic yellows virus by two of its aphid vectors, *Aphis craccivora* (Koch) and *Acyrthosiphon pisum* (Harris). *J. Phytopathol.,* 146: 347±355.

Gilligan, C.A., van den F. Bosch, 2008. Epidemiological models for invasion and persistence of pathogens. *Annu Rev Phytopathol.*, 46: 385-418.

Govier, D.A. and B. Kassanis, 1974. A virus-induced component of plant sap is needed when aphids acquire potato virus Y from purified preparations. *Virology,* 61: 420±426.

Harding, R.M., T.M. Burns and J.L. Dale, 1991. Virus-like particles associated with banana bunchy top disease contain small singlestranded DNA. *J. Gen. Virol.,* 72: 225±230.

Harding, R.M., T.M. Burns, G. Hafner, R.G. Dietzgen and J.L. Dale, 1993. Nucleotide sequence of one component of the banana bunchy top virus genome contains a putative replicase gene. J. Gen. Virology, 74: 323-328.

Ichiki, T.U., E.N. Nagaoka, K. Hagiwara, K. Uchikawa, S. Tsuda, T. Omura, 2005. Integration of mutations responsible for the attenuated phenotype of Pepper mild mottle virus strains results in a symptomless cross-protecting strain. *Arch Virol.*, 150: 2009-2020.

Jones, R.A., 2009. Plant virus emergence and evolution: Origins, new encounter scenarios, factors driving emergence, effects of changing world conditions, and prospects for control. *Virus Res.*, doi:10.1016/j.virusres.2008.07.028.

Karan, M., R.M. Harding and J.L. Dale, 1997. Evidence for two groups of banana top virus DNA components 2 to 6 with bunchy top disease. *Mol. Plant Pathol.* On-Line: http:\\www.bspp.org.uk-mppol.

Katul, L., E. Maiss, S.Y. Morozov and H.J. Vetten, 1997. Analysis of six DNA components of the faba bean necrotic yellows virus genome and their structural affinity to related plant virus genomes. *Virology,* 233: 247±259.

Katul, L., T. Timchenko, B. Gronenborn and H.J. Vetten, 1998. Ten distinct circular ssDNA components, four of which encode putative replication-associated proteins, are associated with the faba bean necrotic yellows virus genome. *J. Gen. Virol.,* 79: 3101±3109.

Katul, L., H.J. Vetten, E. Maiss, K.M. Makkouk, D.-E. Lesemann and R. Casper, 1993. Characterisation and serology of virus-like particles associated with faba bean necrotic yellows. *Ann. Appl. Biol.,* 123: 629±647.

Lung, M.C.Y. and T.P. Pirone, 1974. Acquisition factor required for aphid transmission of purified cauliflower mosaic virus. *Virology,* 60: 260±264.

Ma, G., P. Chen, G.R. Buss, S.A. Tolin, 2004. Genetics of resistance to two strains of soybean mosaic virus in differential soybean genotypes. *J Hered.*, 95: 322-326.

Makkouk, K.M., L. Rizkallah, M. Madkour, M. El-Sherbeeny, S.G. Kumari, A.W. Amriti and M.B. Solh, 1994. Survey of faba bean (*Vicia faba* L.) for viruses in Egypt. *Phytopathol. Medit.,* 33: 207±211.

Mangrauthia, S.K., B. Parameswari, R.K. Jain, S. Praveen, 2008. Role of genetic recombination in the molecular architecture of Papaya ringspot virus. *Biochem Genet.*, 46: 835-846.

Novy, R.G., A.M. Gillen, J.L. Whitworth, 2008. Characterization of the expression and inheritance of potato leafroll virus (PLRV) and potato virus Y (PVY) resistance in three generations of germplasm derived from Solanum etuberosum. *Theor Appl Genet.*, 114: 1161-1172.

Pringle, C.R., 1998. Virus taxonomy: San Diego 1998. *Arch. Virol.,* 143: 1449±1459.

Randels, J.W., P.W.G. Chu, J.L. Dale, R. Harding, J. Hu, L. Katul, M. Kojima, K.M. Makkouk, Y. Sano, J.E. Thomas and H.J. Vetten, 2002. Nanovirus. www.ncbi.nlm.nih.gov/ICTVdb/Ictv/fsnanov .htm.

Rodrigues, S.P., J.S. Andrade, J.A. Ventura, G.G. Lindsey, P.M.B. Fernandes, 2009a. Papaya meleira virus is neither transmitted by infection at wound sites nor by the whitefly Trialeurodes variabilis. *J Plant Pathol.,* 91: 87-91.

Rodrigues, S.P., J.A. Ventura, M. Da Cunha, P.M.B. Fernandes, 2009b. Effects of Papaya meleira virus on papaya latex structure and composition. *Plant Cell Rep.*, DOI 10.1007/s00299- 009-0673-7.

Sano, Y., M. Wada, Y. Hashimoto, T. Matsumoto and M. Kojima, 1998. Sequence of ten circular ssDNA components associated with the milk vetch dwarf virus genome. *J. Gen. Virol.,* 79: 3111±3118.

Shamloul, A.M., A.F. Hadidi, M.A. Madkour and K.M. Makkouk, 1999. Sensitive detection of banana bunch top and faba bean necrotic yellows viruses from infected leaves, in vitro tissue cultures and viruliferous aphids. http://www.nal.usda.gov/ttic/ tektran/data/000010/28/0000102887. html.

Silas Pessini Rodrigues1, George G. Lindsey2 and Patricia Machado Bueno Fernandes1, 2009. Biotechnological Approaches for Plant Viruses Resistance: From General to the Modern RNA Silencing Pathway. Braz. Arch. Biol. Technol., 52(4): 795-808.

Taliansky, M., L. Torrance, N.O. Kalinina, 2008. Role of plant virus movement proteins. *Methods Mol Biol.*, 451: 33-54

Tenllado, F., B. Martínez-Gracia, M. Vargas, J.R. Díaz-Ruíz, 2003. Crude extracts of bacterially expressed dsRNA can be used to protect plants against virus infections. *BMC Biotechnol.*, 3: 1-11.

Tenllado, F., C. Llave, J.R. Díaz-Ruíz, 2004. RNA interference as a new biotechnological tool for the control of virus diseases in plants. *Virus Res.*, 102: 85-96.

Thomas, J.E. and R.G. Dietzgen, 1991. Purification, characterization and serological detection of virus-like particles associated with banana bunchy top disease in Australia. *J. Gen. Virol.,* 72: 217±224.

Ventura, J.A., H. Costa, J. Tatagiba, 2004. Papaya diseases and integrated control. In: Naqvi, S.A.H. (ed) Diseases of fruits and vegetables: diagnosis and management. Kluwer, London