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Review

Protecting crops from non-persistently aphid-transmitted viruses: A review on the use of barrier plants as a management tool

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Abstract

Barrier plants are a management tool based on secondary plants used within or bordering a primary crop for the purpose of disease control. Aphid-transmitted viruses account for approximately 50% of the 600 known viruses with an invertebrate vector. Barrier plants may act as real natural sinks for non-persistent aphid-transmitted viruses and have proved in the past to be an effective crop management strategy to protect against virus infection. Increasing the knowledge on aphid host seeking and flying behaviour, and on how barrier plants may affect the behaviour of aphids and their natural enemies will allow further development of this environmentally-friendly habitat manipulation strategy. An ideal plant barrier should be a non-host for the virus and the vector, but appealing to aphid landing and attractive to their natural enemies and should allow sufficient residence time to allow aphid probing before taking-off occurs. In this review, we have addressed why aphids are manageable by barrier cropping, the mechanisms by which barrier plants affect the occurrence of non-persistently aphid-transmitted viruses and the limitations of using barrier plants as a virus control strategy. Finally, we have pointed out future directions of research that should be conducted to integrate barrier cropping with other disease management strategies, and optimise and extend the use of barrier plants as a strategy for managing aphid-transmitted virus diseases.

Keywords: Aphids; Disease management; Vegetables; Plant viruses

Contents

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1. Introduction

Aphids are among the most serious agricultural insect pests. They cause major economic losses in several crops worldwide, directly because of their feeding and indirectly by inflicting plant impairments (e.g., viruses, phytoxemias). However, their population threshold level as virus vectors is much lower than it is for them as direct pests (Satapathy, 1998). Aphids are the most common vectors of plant viruses, and aphid-borne non-persistently transmitted viral diseases (ABNPV) are of greatest economic importance in several annual cropping systems (Tomlinson, 1987). About 50% of the approximately 600 viruses with invertebrate vectors are transmitted by aphids and most of the roughly 290 known aphid borne viruses are non-persistent (NPV) (Hull, 2002). Non-persistent viruses are transmitted non-specifically by a large number of aphid species after very brief probes (1–2 min), are lost readily after probing on a healthy plant and have a short retention time in the vector (few hours). Conversely, persistent viruses are transmitted specifically by few aphid species that feed and colonise the crop, are retained in the vector for many days and transmitted after long inoculation access periods (optimum 24–48 h). Semipersistent transmission shares some of the properties of non-persistent and persistently transmitted viruses (for more information see reviews by Plumb and Callow, 2002; Ng and Perry, 2004).

Current control strategies for aphids regularly rely upon pesticide applications. However, many aphid species have and continue to become resistant to various classes of chemical compounds (Furk and Hines, 1993; Perring et al., 1999; Nebeshima et al., 2003; Li and Han, 2004). Additionally, insecticides are largely ineffective in managing ABNPVs (Raccah, 1986; Howell, 1993; Perring et al., 1999). Furthermore, insecticides may contribute to the spread of virus transmission by inducing greater vector activity (Budnik et al., 1996). Therefore, the development of non-chemical management strategies for controlling aphid vectors of NPVs is warranted.

It is well known that flora diversification can result in reduced pest population (references in reviews by Andow, 1991; Hooks and Johnson, 2003). It has also been established that the number of alatae and apterae aphids found on primary crops are consistently less in vegetational diverse than monoculture habitats (Smith, 1969, 1976; Horn, 1981; Costello and Altieri, 1995; Hooks et al., 1998; Showler and Greenberg, 2003). Thus, it is equitable to suppose that if an aphid population is recurrently found at lower numbers on host plants in vegetationally diverse habitats, this will provisionally result in decrease incidences of ABNPV. Still, there are few published studies where secondary crops or plants have been specifically used to reduce the occurrence of ABNPV. Secondary plants used within or bordering a primary crop for the purpose of disease suppression are often referred to as barrier crops (Deol and Rataul, 1978). This approach belongs to the wide array of habitat manipulation strategies that aims at making crops less favourable for pests and more attractive to beneficial insects. Barrier cropping is a cultural technique that perfectly fits under the philosophy of "Ecological Engineering for Pest Management" recently reviewed by Gurr et al., 2004. Among those studies in which barrier plants were investigated, many showed that barrier cropping lessens the incidence and/or hinders the spread of aphid-borne non-persistent viruses (Fereres, 2000, several references therein). Despite the potential success of using barrier plants for vector management, this tactic has received limited research attention compared with other management strategies. For example, the use of inert material such as reflective mulches and row covers (Perring et al., 1989; Webb and Linda, 1992; Brown et al., 1993; Stapleton and Summers, 2002) and mineral oils (Vanderveken and Semal, 1966; Webb and Linda, 1993; Wang and Pirone, 1996; Asjes, 2000) have been extensively investigated and many growers are familiar with these traditional management practices. Barrier cropping can also become a recognized component of integrated disease management (IDM). Presently, greater dissemination of information on this tactic for viral disease management is needed so that the agricultural community becomes better acquainted with this cultural management tool.

It is not our goal to conduct a thorough review of barrier cropping. We aim by reviewing the literature to: (1) alert readers that plant diversification in the form of barrier plants should receive greater recognition as a tenable management tactic for reducing the occurrence and spread of ABNPV, (2) give a holistic account of the mechanisms most responsible for the rate of spread of NPVs in florally diverse habitats and (3) suggest future direction of barrier cropping research. For the sake of simplicity, any form of plant diversification (e.g., mixed cropping, cover crops, border plants, intercrops, trap crops, flower strips, organic mulch, etc.) used to protect a primary crop from insect transmitted viral diseases will be referred to as barrier cropping regardless of its layout, composition or how it impacts vector behaviour.

2. Limitations of current control strategies

Insecticidal control of aphids that transmit plant viruses in a non-persistent manner may not reliably prevent the spread of disease within the field (Thackray et al., 2000). This is presumably due to the very short acquisition and inoculation times involved (Perring et al., 1999). Aphids are capable of transmitting NPVs prior to obtaining a lethal insecticide dose (Gibson and Rice, 1989). In some instances, insecticides may increase, rather than suppress the spread of virus transmission by destruc-