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Eradicating *Bemisia tabaci* Q biotype on poinsettia plants in the UK

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ABSTRACT

The sweetpotato whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) continues to be a serious threat to crops worldwide. The UK holds Protected Zone status against this pest and, as a result, *B. tabaci* entering on plant material is subjected to a policy of eradication. Q biotype (Mediterranean species) is the predominant whitefly now being intercepted entering the UK. With increasing reports of neonicotinoid resistance in this biotype, it is becoming more problematic to control/eradicate. The current study evaluated sequential insecticide applications of a range of chemicals and two entomopathogenic fungi, *Beauveria bassiana* and *Lecanicillium muscarium*, applied within the first 21 days after potting poinsettia cuttings. All sequential treatment programmes tested eradicated Q biotype from poinsettia plants. The efficacy of chemicals and fungi against various Q biotype life-stages was also evaluated as individual treatments. Against the egg stage, abamectin (Dynamec), acetamiprid (Gazelle), refined petroleum spraying oil (Tri-Tek) and the physically acting product SB-Plant Invigorator all proved excellent. None of the products gave total control of second instar larvae. However, Agri-50E, *B. bassiana*, Tri-Tek and SB-Plant Invigorator all gave over 71% mortality. For adult control, *B. bassiana* and the oil based products (Addit, Tri-Tek and Spraying Oil) all produced 100% mortality. The work also demonstrated that *B. bassiana* offers better control of *B. tabaci* than *L. muscarium*. Investigating direct tank-mixing of the fungi with the chemical products proved that Majestic (physically acting product), spiromesifen (Oberon), Savona (physically acting product) and SB-Plant Invigorator significantly reduced germination of *B. bassiana* spores and so could not be recommended as mixes. Tri-Tek Oil, Spraying Oil, Addit, Dynamec and Gazelle showed best potential to be used as tank-mixes with over 90% *B. bassiana* spore germination following exposure to the test products for 24 h. A direct tank mix of *L. muscarium* with Tri-Tek allowed full fungal spore germination. The implications of the work in regards to continued protection of the UK horticultural industry from *B. tabaci* and overcoming insecticide resistance among biotypes are discussed.

1. Introduction

The tobacco whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae), continues to be a major pest of economically important crops worldwide (Gerling et al., 1980; Nomikou et al., 2000). Damage can be caused directly by feeding on phloem sap or indirectly by the large amounts of honeydew produced so lowering photosynthesis. *B. tabaci* is also a vector of many plant viruses (Alegbejo, 2000; Simón et al., 2003). Within the United Kingdom (UK), *B. tabaci* is a notifiable pest subject to a policy of eradication if found on propagators' premises or on plants moving in trade, and of containment/eradication if outbreaks occur at nurseries (Cuthbertson, 2005; Cuthbertson et al., 2011). The UK maintains Protected Zone status against *B. tabaci* and eradication generally involves use of chemical insecticides, though much research has shown the potential of entomopathogens to control *B. tabaci* populations (Cuthbertson et al., 2011). There are several active ingredients currently used in the UK for treating *B. tabaci* outbreaks (Cannon et al., 2005; Cuthbertson et al., 2011), but with increasing chemical resistance being shown by *B. tabaci* (Ahmad et al., 2002; Byrne et al., 2010; Luo et al., 2010; Schuster et al., 2010; Wang et al., 2010) an integrated strategy using both biological and chemical agents is required.

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Since 1987, *B. tabaci* has been intercepted at nurseries in the UK on a wide range of hosts, and in particular poinsettias. In 1987, there were 98 interceptions and outbreaks of *B. tabaci* at nurseries, all on poinsettias, predominantly from the Netherlands (Bartlett, 1992). The following year (1988), there were 87 interceptions and outbreaks on growing sites, again predominantly on poinsettias from the Netherlands. Over recent years, *B. tabaci* has continually been intercepted on poinsettia, with this host plant accounting for the majority of outbreaks in every year between 1998 and 2009 (Cuthbertson et al., 2011). Within the *Bemisia* intercepted entering the UK over this time period, there has been a gradual shift from *B. tabaci* B (Middle East-Asia Minor 1 species) to *B. tabaci* Q (Mediterranean species) biotype (Cuthbertson and Powell, 2012; Powell et al., 2012). The Q biotype characteristically shows strong resistance to novel insecticides (Nauen, 2005; McKenzie et al., 2009) and hence has become more difficult to eradicate within the UK by the use of conventional insecticides.

The aim of the current work was to evaluate sequential insecticide applications, applied within the first 21 days after potting poinsettia cuttings to eradicate *B. tabaci*. This is on the basis that early sprays, applied when the plants are small, are likely to achieve better spray coverage and pest control than applications made later when the crop canopy is well developed and under leaf coverage is difficult. The efficacy of the individual chemicals (deemed to be IPM compatible) and the entomopathogenic fungi *Beauveria bassiana* and *Lecanicillium muscarium* against various biotype Q life-stages was also evaluated, as was the potential of the fungi to be directly tank-mixed with the various chemicals.

2. Materials and methods

2.1. Insects and products used

Specimens of *B. tabaci* were collected from an outbreak at a commercial nursery during the growing season of 2009. The population had proved extremely difficult to eradicate. It was assumed to be insecticide resistant. The specimens were transported under the required conditions for moving non-indigenous insects (Marris et al., 2010) to the Plant Health Insect Quarantine Unit at the Food and Environment Research Agency, York. The *B. tabaci* were cultured under quarantine conditions in perspex cages (60 × 60 × 80 cm) on poinsettia (*Euphorbia pulcherrima* c.v. Freedom Red) plants at 23 ± 1 °C following the methods of Cuthbertson et al. (2005a,b, 2008a,b). Following this, DNA was extracted from individual adult *B. tabaci* according to Boonham et al. (2002) and real-time PCR based on TaqMan® chemistry was used to confirm biotype status as Q (Jones et al., 2008).

The entomopathogenic fungus *B. bassiana* was supplied as Naturalis from Intrachem and *L. muscarium* was supplied as Mycotal from Koppert. Table 1 lists the chemical products used and their application rates.

2.2. Leaf dipping to test efficacy of control agents against Q biotype

In order to test their efficacy, the different products were tested against three life stages of Q biotype; eggs, second instar larvae and adults. Poinsettia plants were infested following the method of Cuthbertson et al. (2003). Briefly, two male and five female whitefly were added to clip cages modelled on those described by MacGillivray and Anderson (1957) on individual poinsettia leaves and incubated for 48 h at 25 ± 1 °C, 65% relative humidity and 16:8 L:D to allow egg laying, after which adults were removed and infested leaves labelled. Cohorts at the desired life-stages were obtained using the methods and data of Butler et al. (1983), Bethke et al. (1991), Wang and Tsai (1996) and Cuthbertson et al. (2003, 2007). Then following the method of Cuthbertson et al. (2009) four separate insecticide dilutions (all UK recommended dose rates, Table 1) of each chemical and fungal product were prepared for replication purposes. Poinsettia leaves inoculated with eggs were dipped into each dilution for 10 s then allowed to air dry, before being placed within sealed Petri dishes for each individual dilution of each insecticide. This procedure was repeated with leaves infested with second instar larvae. For adult studies, leaves were dipped and then five adult whitefly were exposed to the leaf surface again using a clip cage while the leaves were still wet. The adults therefore had space not to sit on the leaf surface should they choose. However, to feed they had to settle on the leaf surface and so would come into contact with the product. These were maintained in sealed Petri dishes and replicated five times for each chemical. All Petri dishes were incubated at 20 °C, 14 h: 10 h Light: Dark for 48 h. Control samples for each life stage were also undertaken using water. Mortality of the individual *Bemisia* life-stages was assessed.

2.3. The effect of direct exposure of B. bassiana and L. muscarium to conventional insecticides

Following the protocol of Cuthbertson et al. (2005b), the effect of direct suspension of the fungal spores in insecticide solutions was investigated in order to determine the potential for direct tank-mixing. All products were tested for their direct compatibility with *B. bassiana*. Several selected products were also tested against *L. muscarium* to add to the knowledge base of direct compatibility of chemicals with this fungus for whitefly control (Cuthbertson et al., 2005b, 2008a). Briefly, *L. muscarium* and *B. bassiana* conidia were

Table 1
List of products tested for efficacy against Q biotype.

Product	Active ingredient	Rate of use (%) or ml or g/100 L water	Comments
Addit	Adjuvant	0.25%	Add to naturalis or mycotal in tank
Agri 50-E	Surfactant	300 ml (0.3%)	Physically acting product
Chess	Pymetrozine	60 g (0.06%)	Azomethine SOLA rate, tank mix with dynamec
Dynamec	Abamectin	50 ml (0.05%)	Macrocyclic lactone tank mix with chess
Gazelle	Acetamiprid	50 g (0.05%)	Neonicotinoid
Majestik	Starch based	2500 ml (2.5%)	Physically acting product
Naturalis	*Beauveria bassiana*	300 g (0.3%)	Insect pathogenic fungus
Mycotal	*Lecanicillim muscarium*	100 g (0.1%)	Insect pathogenic fungus
Oberon	Spiromesifen	50 ml (0.05%)	Lipid synthesis inhibitor
Savona	Surfactant	1000 ml (1%)	Physically acting product
SB plant invigorator	Surfactant	200 ml (0.2%)	Physically acting product
Tri-Tek	Refined petroleum oil	2000 ml (2%)	Physically acting product (awaiting UK registration)
Spraying oil	Refined petroleum oil	1000 ml (1%)	Physically acting product