IMPACT OF *n*C24 HORTICULTURAL MINERAL OIL DEPOSITS ON OVIPOSITION BY GREENHOUSE WHITEFLY *TRIALEURODES VAPORARIORUM* (WESTWOOD) (HEMIPTERA: ALEYRODIDAE)

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Summary

The impact of *n*C24 horticultural mineral oil deposits on oviposition by greenhouse whitefly on tomato leaves was determined in laboratory choice and no-choice tests. The deposits significantly suppressed oviposition. No eggs were laid on leaves treated with aqueous emulsions of 20 mL of oil/L of water in the choice test and on the leaves treated with 10 and 20 mL of oil/L in the no-choice test. The relationships between oviposition and oil concentration (0, 2.5, 5, 10 and 20 mL of oil/L) in sprays in the choice test suggested that deposits of sprays containing > 11 mL of oil/100 L of water would completely suppress oviposition for 2 d after the application of spray. In the no-choice test, deposits of sprays containing 5 mL of oil/L reduced oviposition by 97% over 2 d.

Keywords: greenhouse whitefly, horticultural mineral oil, behaviour, oviposition, repellency

INTRODUCTION

Greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) is a cosmopolitan pest of a range of vegetables, particularly beans, tomatoes, potatoes and cucurbits, and cotton and ornamentals. It can be serious in greenhouses. Weeds such as common sowthistle are alternative hosts. Damage is the result of feeding, honeydew production (Hely *et al*. 1982), and transmission of closteroviruses (Wisler *et al*. 1998; Berdiales *et al*. 1999). It was a particularly serious pest in Australia before the introduction of *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) in the 1930s (Hely *et al*. 1982). *E. formosa* is a parasitoid used worldwide in greenhouse whitefly integrated pest management programs (Hoddle *et al*. 1998).

Chemical control of greenhouse whitefly in Australia has relied on the use of synthetic pesticides (Hely *et al*. 1982; Hamilton and Toffolon 1987a,b; Brough *et al*. 1994; McMaugh 1996). Resistance to a range of these chemicals has been reported (Khodzhaev 1992; Omer *et al*. 1993a,b; 1995; de Cock *et al*. 1995). Until recently, the use of softer, non-resistance prone options such as petroleum-derived spray oils has been widely overlooked for commercial pest management (Beattie and Smith 1997). This is despite recommendations for the use of oils that extend back several decades (e.g. Pruthi and Mani 1945; Westcott 1946; Ebeling 1959). One reason for this may be a common human tendency to focus on using toxins to kill pests rather than use of non-toxic spray deposits to modify arthropod feeding and oviposition behaviour. The impact of biorational horticultural and agricultural mineral oils (HMOs and AMOs; see Beattie *et al*. 2002) on greenhouse whitefly oviposition was first reported in the late 1980s when Larew (1988; 1989) reported the effects of sprays of 2 mL/L aqueous emulsions of an *n*C21 HMO and an *n*C25 AMO on chrysanthemum. We report the effect of *n*C24 HMO deposits on greenhouse whitefly oviposition on tomato leaves during the 48 h after application of sprays of aqueous emulsions containing 2.5 to 20 mL oil/L.

MATERIALS AND METHODS

Horticultural mineral oil

The horticultural mineral oil used in the experiment was *n*C24 Ampol D-C-Tron Plus (Ampol Limited, now Caltex Australia Pty Ltd, Sydney). Its specifications are given by Rae *et al*. (1996).

Whiteflies and plants

Whiteflies were obtained from James Altmann, Biological Services, Loxton, South Australia. A culture was maintained at 25 ± 5°C on caged Grosse Lisse tomato seedlings in a laboratory at the University of Western Sydney.

Choice test

The design was partially based on that of Liu and Stansly (1995a). There were five treatments with six replicates: water and emulsions of 2.5, 5, 10 and 20 mL of oil/L of water. Each replicate used a pest-free, unsprayed penultimate leaf from pesticide-free glasshouse tomato plants. All leaves were similarly sized, and each leaf was trimmed to three terminal leaflets and the midvein inserted through a small hole in the lid of a 300 mL plastic food storage container, containing 230 mL of distilled water. Small quantities of plasticine were used to ensure that the leaves remained vertical. The height of each leaf above the lid of each container was about 20 cm. The experimental design was a completely randomised split-plot with two cages (50 x 35 x 30 cm) into which three replicates of each treatment were placed after leaves were sprayed. Sprays were applied with a paint airbrush sprayer (Paasche Airbrush Company, Harwood Heights, Illinois, United States of America) operating at 138 kPa from a distance of 10 cm. A fine nozzle was used to apply 2 mL of spray, half applied adaxially and half abaxially, to each leaf. Approximately 250 whitefly adults were released into each cage, after the spray deposits dried (approximately 2 h). The cages were then placed in a constant environment chamber (Thermoline Pty Ltd, South Melbourne, Victoria, Australia) at 23 ± 2ºC and 70% RH under a 14:10 L:D cycle. After 2 d, the number of eggs on each leaflet was counted and the area of each leaflet measured using a CI-202 leaf area meter (CID Inc., Vancouver, Washington, United States of America). Data were analysed using SPSS® for Windows® Version 9 (SPSS 1999). The dependent variable was eggs/cm^2 and the data were $\ln(x + 1)$ transformed to better approximate a normal distribution (visually assessed using normal probability plots). 'Cage' was a whole plot effect and was assumed to be a random factor.

No-choice test

There were five treatments with six replicates: water, and emulsions of 2.5, 5, 10 and 20 mL of oil/L of water. Unsprayed pest-free penultimate leaves were arranged vertically in the lids of plastic food containers using the methods described above for the choice-test experiment. Each leaf, which protruded 12 cm above the lid of each container, was sprayed as above, then covered with a 15 cm high, 300 mL disposable clear plastic cup to contain the insects. Ventilation was provided by a fine-mesh covered 20 mm hole punched in the base of each cup. Ten whitefly adults were released into each cup. Each replicate was then placed in a constant environment chamber under same conditions used in the choice test experiment and the number of eggs laid on each leaflet was counted after 2 d. Data were analysed using SPSS® for Windows® Version 9 (SPSS 1999). The dependent variable was eggs/10 adults and the data were √ transformed. Transformed data were approximately normally distributed (visual assessment of normal probability plots) and variances were homogeneous (Levene's test: $F_{2, 15}$ =1.332, p = 0.293). As no eggs were laid on leaves treated with 10 and 20 mL of oil/L of water emulsions, these treatments were not included in the analysis of data.

RESULTS

Choice test

HMO concentration significantly affected the number

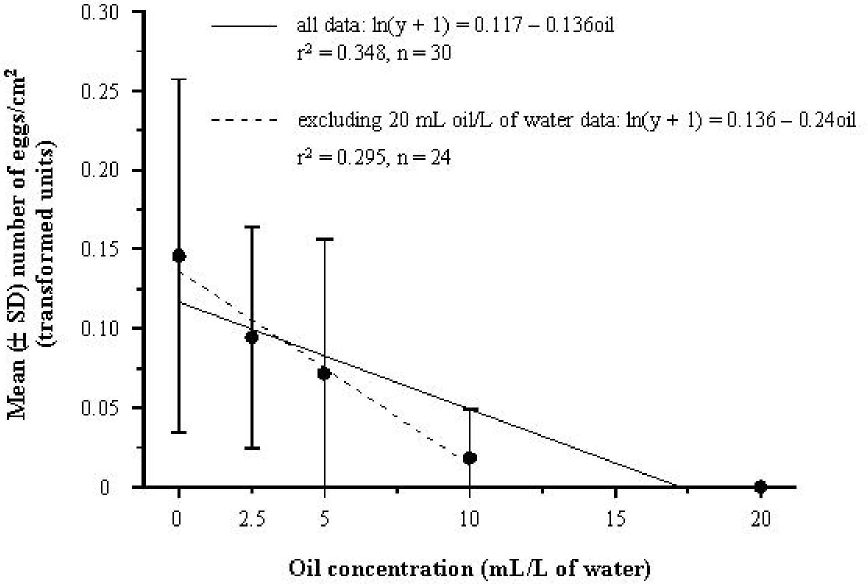

Figure 1. Relationship between the number of eggs/cm^2 laid by whiteflies in 2 d and oil concentration applied to tomato leaves in a choice test.

of eggs deposited on tomato leaves ($F_{4, 20} = 4.523$, $p = 0.009$) (Figure 1). The deviation from regression of treatment effects was not significant ($F_{3, 20} = 0.166$) while the linear regression of eggs/cm^2 [ln(y + 1) transformed] on oil concentration was highly significant ($F_{1, 23} = 15.243$, $p = 0.001$). No eggs were laid on leaves treated with 20 mL of oil/L of water, with the fitted regression line suggesting complete suppression at about 17 mL of oil/L of water. However, the data suggest complete suppression occurs at concentrations of about 11 mL of oil/L of water if the data obtained at 2 ml of oil/L of water were removed from the regression (Figure 1). No phytotoxicity was observed.

No-choice test

HMO concentration significantly reduced the number of eggs deposited on tomato leaves ($F_{2, 15} = 38.415$, $p < 0.001$) (Figure 2). The leaves treated with 0.5% oil had significantly fewer eggs than leaves treated with 0.25% oil ($p = 0.01$).

DISCUSSION

The results of our ‘choice’ test experiment indicated that deposits of sprays containing >11 mL *n*C24 HMO/L of water would completely suppress oviposition by greenhouse whitefly for 2 d after the application of sprays. In the no-choice test, deposits of sprays containing 5 mL of oil/L of water reduced oviposition by 97% over 2 d. In studies related to ours, Kallianpur *et al*. (2002) determined LD_{95} values of 103 and 131 µg oil cm^{-2} for *n*C23 and *n*C21 HMOs respectively in Potter spray tower anoxia bioassays. The HMO concentrations required for these deposits were 10.3 and 13.1 mL of oil/L of water respectively (Herron *et al*. 1995; Kallianpur *et al*. 2002). Although we did not measure oil deposits, a subsequent review of the spray application procedures suggested that similar deposits, possibly as high as 150 µg oil cm^{-2}, were required in our choice-test to completely suppress oviposition for 2 d after spray application (Nicetic, unpublished data, University of Western Sydney). In studies on greenhouse whitefly control on chrysanthemum reported by Larew (1988; 1989) 24 h old spray deposits of 20 mL/L of water of *n*C21 Sunspray 6E Plus and *n*C25 Ortho Volck Spray Oil suppressed oviposition by greater than 90%. In related studies, 10 mL and 20 mL/L sprays of the *n*C21 HMO reduced oviposition by greater than 99%, and 20 mL/L sprays caused greater than 99% mortality of young larvae and pupae. Egg hatch was not affected by 20 mL/L sprays but deposits of the 20 mL/L sprays repelled adults for up to 11 d, with greater than 96% of adults avoiding deposits (Larew and Locke 1990). Similar results have also been reported in more extensive studies with the same *n*C21 HMO against sweet-potato whitefly (*Bemisia tabaci* (Gennadius) B biotype = silverleaf whitefly, *B. argentifolia* Bellows and Perring) (Stansly and Liu 1995; 1997; Liu and

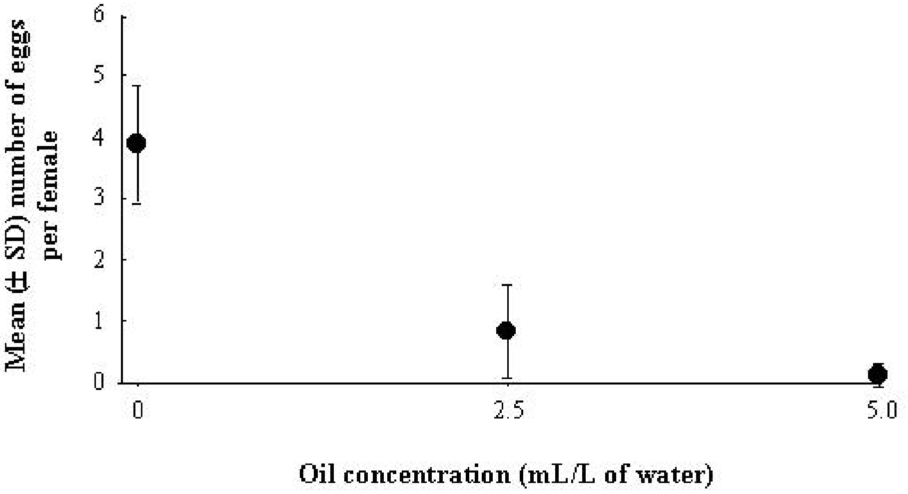

Figure 2. Relationship between mean number of eggs (√ transformed) laid/adult female whitefly over 2 d and oil concentration applied to tomato leaves in a no-choice test.

Stansly 1995a,b,c; Stansly *et al*. 2002). Even dried sprayed deposits caused adult mortality (Liu and Stansly 1995a) although, as with our study, oil deposition was not determined.

Use of HMOs and AMOs is generally considered to be compatible with natural enemies (Beattie and Smith 1997). However, adverse effects have been reported. Stansly and Liu (1997) reported that *n*C21 HMO residues caused high mortality of immature parasitoids and reduced parasitism against the sweet-potato whitefly parasitoid *Encarsia pergandiella* Howard. However, the effects were more severe on dipped surfaces than on sprayed surfaces and less severe than the synthetic pesticide bifenthrin. Adverse effects of D-C-Tron Plus have also been noticed on *E. formosa* in laboratory experiments and commercial crops (Paul De Barro, Commonweath Scientific and Industrial Research Organisation, pers. comm., March 2002). These adverse effects need to be assessed in the field and viewed in the context of integrated pest management programs in which HMOs and AMOs can be used simultaneously for control of a wide-range of pests and diseases (e.g., Nicetic *et al*. 1999; 2001; 2002a; Rae *et al*. 2000; Singh *et al*. 2000; Clift *et al*. 2002; Leong *et al*. 2002).

In field studies, Singh *et al*. (2000) reported that sprays of 1 L D-C-Tron Plus/100 L of water gave significantly better control of greenhouse whitefly than conventional synthetic pesticides in trellised fresh tomatoes. All treatments were applied at the same volumes but the volumes used (500 L to 2,800 L/ha from planting to crop maturity) were higher than those used commercially. In related studies, infestations of greenhouse whitefly in a commercial greenhouse were controlled by 10 mL/L sprays of D-C-Tron Plus (Nicetic, unpublished data). These greenhouse results indicated that control strategies should be prophylatic rather than curative, and that a synthetic pesticide spray should be used initially when infestations exceed economic thresholds. Spray volumes used in the study were also higher than those used commercially. In order to minimise spray volumes, dose-response relationships relating oil concentration in sprays, oil deposits, and outcome need to be determined. Oil concentrations higher than those used by Singh *et al*. (2000) and Nicetic (unpublished data) may be required for commercially acceptable control of whitefly. Phytotoxicity is unlikely to be a problem as tomatoes are quite tolerant to HMOs (Singh *et al*. 2000) and the deposits of oil required for control are unlikely to be greater than those that occurred in the studies conducted by Singh *et al*. (2000) and Nicetic (unpublished data). Our result and those of Singh *et al*. (2000), Nicetic *et al*. (2002a,b) and Nicetic (unpublished data) indicate considerable scope for the development of biorational IPDM programs based on the use of HMOs and AMOs, predators and parasitoids, and entomopathogens (Franssen 1990; Franssen and van Lenteren 1993; 1994) for control of greenhouse whitefly in tomatoes. Given results reported by Nicetic *et al*. (2002b) for control of tomato powdery mildew (*Leveillula taurica* (Lév.) Arnaud (Erysiphales: Erysiphaceae)) and for control of two-spotted mite (*Tetranychus urticae* Koch (Acari: Tetranychidae)) and rose powdery mildew (*Sphaerotheca pannosa* var *rosae* (Wallr. et Fr.) Lév.) (Nicetic *et al*. 1999; 2001; 2002a) it would seem logical that a HMO or AMO based program implemented for powdery mildew control in fresh field and greenhouse grown tomatoes could also prevent development of greenhouse whitefly infestations, providing infestations of the whitefly are below the economic threshold before application of the first spray.

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