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Evaluation of a novel host plant volatile-based attracticide for management of Colorado potato beetle, *Leptinotarsa decemlineata* (Say)

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Abstract

LT_{50} and LD_{50} values were established for three novel attract-and-kill formulations that were directed against *Leptinotarsa decemlineata* (Say) in a field trial. The "attracticide" is comprised of a synthetic blend of three naturally occurring potato plant volatiles ((*Z*)-3-hexenyl acetate, (±)-linalool and methyl salicylate) and a pyrethroid insecticide. Graphical and quantitative LT_{50} and LD_{50} estimates for formulations carrying 0.6%, 2%, or 6% active ingredient permethrin were determined by adult insect exposure time (0, 1, 3, or 10 s) and percent active ingredient. Following exposure for 10 s, the 2% and 6% formulation LT_{50} estimates were not significantly different despite the former representing a 66.7% reduction in active ingredient. However, only the 6% formulation produced ⩾50% mortality for exposure times below 10 s. Therefore, practical considerations suggest that this formulation would be the most appropriate for commercial use. In the field study, the attracticide proved effective only against small larvae (first and second instars). The 2% and 6% attracticide formulations deployed against small larvae provided control that was not significantly different from that of the commercial insecticide while using 92% less active ingredient.

Keywords: Semiochemicals; Attracticide; Colorado potato beetle; Plant volatiles

1. Introduction

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is considered to be one of the most destructive insect pests of cultivated potato, *Solanum tuberosum* L., in North America and Europe. It is known to have developed resistance to most insecticide classes (Forgash, 1985; Boiteau, 1988; Hare, 1990; Ioannidis et al., 1991; French et al., 1992; Olkowski et al., 1992; Kennedy and French, 1994; Stewart et al., 1997) as well as some biorational agents (Whalon et al., 1993; Rahardja and Whalon, 1995). Increased public awareness of the impact of conventional insecticide use on human and environmental health and the role they play in insecticide resistance development make it necessary to develop alternative strategies to more effectively manage this important pest (Casagrande, 1987; Shani, 1991; Smart et al., 1994, Ioriatti et al., 2000; Ioriatti and Bouvier, 2000).

One alternative to conventional pest control is incorporation of the semiochemicals utilized by insect herbivores in host selection with reduced rate insecticides into attract-and-kill products. Sex pheromone-based attract-and-kill products have been successfully deployed against orchard pests such as codling moth, *Cydia pomonella L.* (Charmillot et al., 2000; Ioriatti and Angeli, 2002) and light brown apple moth, *Epiphyas postvittana* (Walker) (Suckling and Brockerhoff, 1999).

Several studies have demonstrated that adult *L. decemlineata* are attracted to undamaged potato plants (McIndoo, 1926; Schanz, 1953; DeWilde, 1976; Visser and Avé 1978), while others (Bolter et al., 1997; Landolt et al., 1999) have shown that adult beetles are attracted to both artificially-damaged and insect-damaged potato plants. Dickens (1999, 2000, 2002) identified *S. tuberosum* (var. Kennebec) volatiles attractive to both larval and adult *L. decemlineata*

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and developed a synthetic host volatile attractant blend for this pest. In contrast to pheromone-based attract-and-kill formulations, much less is known regarding the efficacy of products based on synthetic host volatile kairomones. Such an "attracticide" might increase insecticide target specificity while decreasing the amount of insecticide necessary for economic control. In this study we established LD_{50} and LT_{50} values and conducted a field trial to evaluate several prototype attracticide formulations comprised of a synthetic blend of host volatiles (Dickens, 1999, 2000, 2002; Martel et al., 2005a, b) and permethrin insecticide.

2. Materials and methods

We conducted preliminary laboratory and field evaluations of a prototype host plant volatile-based attracticide formulation for *L. decemlineata* comprised of a synthetic blend of host volatiles (Dickens, 1999, 2000, 2002) and permethrin insecticide. Permethrin has been used in attract-and-kill formulations against *C. pomonella*, (Ioriatti and Angeli, 2002; Charmillot et al., 2000) and *E. postvittana* (Suckling and Brockerhoff, 1999). This insecticide was chosen by our industrial collaborator based on its previous deployment against *L. decemlineata*.

2.1. LT_{50} study

The objective of this study was to establish quantitative and graphical LT_{50} values for three attracticide formulations, determined by insect exposure time and percent active ingredient insecticide. The synthetic host volatile attractant discovered by Dickens (1999, 2000, 2002) was infused with 0.6%, 2%, or 6% active ingredient permethrin by Trécé Incorporated (Salinas, CA, USA). Based on the recommended field application rate, 0.25 ml of material was applied evenly to the bottom of 5.5 cm diameter glass Petri dishes. The Trécé formulation was a proprietary matrix comprised of 5% by weight of the three-attractant components: (*Z*)-3-hexenyl acetate, (±)-linalool and methyl salicylate. Under laboratory conditions, the derived release rates of the attractant components for 1 ml (ca. 1 g) of the attractant matrix were approximately: (*Z*)-3-hexenyl acetate 65.4 μg h^{-1}; (±)-linalool 75.0 μg h^{-1}; methyl salicylate 42.3 μg h^{-1}, or approximately 182.7 μg total volatile release per hour (Martel et al., 2005a). These release rates are only approximations and are for comparison purposes only. Actual release rates in a potato field are likely to vary based on the size of individual droplets, and prevailing temperature, humidity and wind conditions as well as other factors (Martel et al., 2005b).

Post-diapause adult *L. decemlineata* were collected in late June from the University of Maine Agricultural and Forest Experiment Station Rogers Farm, Stillwater, Maine, USA (20–25 d post-diapause; mean weight = 122 mg), maintained for seven days in rearing chambers at 25 °C and fed *S. tuberosum* (var. Kennebec) foliage until experimental work was initiated. Insects were divided into five groups of ten beetles per replicate per exposure time per attracticide formulation. Five replicates comprised of ten beetles each were either unexposed (0 s) or allowed to wander over attracticide formulations of 0.6%, 2%, or 6% permethrin in covered Petri dishes for one, three, or 10 s. Beetles were not fed following exposure and mortality was recorded at 10, 20, and 30 h post-exposure. LT_{50} values for each formulation were determined graphically where mean percent mortality crossed a 50% mortality threshold and quantitatively using SAS PROC LOGIT (SAS Institute, 1989).

2.2. LD_{50} study

Insect collection and maintenance methods were identical to those in the LT_{50} Study. Five replicates comprised of ten beetles each were exposed to 0%, 0.6%, 2%, or 6% attracticide formulations in the manner described above for 20 s, and mortality was recorded at 24 h post-exposure. LD_{50} was determined graphically where mean percent mortality percentage crossed a 50% mortality threshold and quantitatively using SAS PROC PROBIT (SAS Institute, 1989) adjusted for control mortality.

2.3. Field study

S. tuberosum (var. Russet Burbank) was planted 23 May 2002 in a 0.2 ha field (86.4 cm rows; 20.3 cm seed spacing). Four blocks (RCBD), each containing six randomized 3 × 3 m treatment plots, were established prior to insect emergence ($N_o = 0$ for all life stages). Treatments consisted of plots that were treated weekly with synthetic host attractant alone, 6%, 2%, or 0.6% permethrin-infused synthetic host attractant, Ambush® (24.6% active ingredient permethrin applied at commercial rate of 937 ml ha^{-1}; Syngenta Crop Protection, Greensboro, NC, USA), and untreated control. Plots were separated from both the field margin and each other by 1 m. The host attractant-only and attracticide formulations were applied using a tractor-mounted, CO_2-driven applicator (Trécé Incorporated, Salinas, CA, USA) that delivered 0.3 ml m^{-1} of row; the apparatus distributed 20 drops per row m with a volume median diameter (VMD) of 3 mm per droplet.

The objective was to compare insect density by treatment for post-diapause colonizing adults and first summer-generation larvae. The term *small larvae* refers to instars one and two, while *large larvae* refers to instars three and four. Plots were sampled biweekly from 10 June to 23 July 2002, with twelve plants sampled at random per plot in an X-shaped pattern. Total mean insect density by treatment was analyzed using SAS PROC GLM repeated measures Analysis of Variance (rmANOVA), with sampling days as the repeated measure and plot type as the treatment factor (SAS Institute, 1989). Square root data transformation was conducted to meet the condition of normality of $X = Y^{1/2}$. Mean separation was conducted using the Tukey's *w* Procedure (SAS Institute, 1989).