Biological Control 94 (2016) 33–36

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Efficacy of *Steinernema carpocapsae* plus fire gel applied as a single spray for control of the lesser peachtree borer, *Synanthedon pictipes*

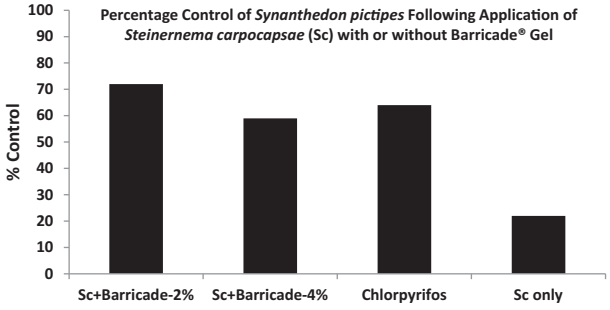
David I. Shapiro-Ilan [a,*], Ted E. Cottrell [a], Russell F. Mizell III [b], Dan L. Horton [c]

[a] USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory, Byron, GA 31008, USA
[b] Department of Entomology, University of Florida, Quincy, FL, USA
[c] Department of Entomology, University of Georgia, Athens, GA, USA

HIGHLIGHTS

- The ability of *Steinernema carpocapsae* to control *Synanthedon pictipes* was assessed.
- Aboveground applications of *S. carpocapsae* were enhanced using Barricade® gel.
- The gel can be applied in a single spray mixed with nematodes or separately.
- The nematode + gel combination controlled the pest as well as the standard chemical.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 August 2015
Revised 8 December 2015
Accepted 11 December 2015
Available online 12 December 2015

Keywords:
Biological control
Entomopathogenic nematode
Formulation
Gel
Peach
Steinernema carpocapsae
Synanthedon pictipes

ABSTRACT

The efficacy of aboveground applications of entomopathogenic nematodes (*Heterorhabditis* spp. and *Steinernema* spp.) can be severely limited by the nematode's susceptibility to UV radiation and desiccation. The lesser peachtree borer, *Synanthedon pictipes*, is a major pest of stone fruit; larvae attack trees aboveground by tunneling into the trunk and scaffold limbs. In previous research, *Steinernema carpocapsae*, caused high levels of *S. pictipes* mortality when a sprayable fire gel (Barricade®) was applied on top of the nematode application as a protectant. One drawback to the approach is that two applications must be made (first nematodes are applied followed by the fire gel); furthermore, the previous experiments did not compare nematode application to the existing standard chemical insecticide. Therefore, the objectives of this study were to (1) determine if a diluted rate of fire gel can protect nematodes when applied as a single spray, and (2) compare the efficacy of nematode applications with the chemical insecticide, chlorpyrifos. The experiment was conducted in a peach orchard in Quincy, Florida in 2013 and 2014. Treatments included: (1) chlorpyrifos, (2) *S. carpocapsae* applied in aqueous suspension only or (3) with a full rate (approximately 4% applied separately) or (4) 2% Barricade® (applied with nematodes in a single spray), and (5) a non-treated control. The treatments were applied post-harvest (in the fall) to *S. pictipes*-infested bark wounds; *S. pictipes* survival was assessed 8 (2013) or 14 (2014) d post-application. In 2013, chlorpyrifos and nematodes with Barricade® at 2% or the full rate reduced *S. pictipes* survival relative to the non-treated control and nematodes without Barricade®. In 2014, nematodes applied with 2% Barricade® was the only treatment that reduced *S. pictipes* survival. We conclude that *S. carpocapsae* and Barricade® can be applied as a single spray, and in our experiments the treatment was at least as effective as the chemical standard.

Published by Elsevier Inc.

* Corresponding author at: USDA-ARS SE Fruit & Tree Nut Research Lab, 21 Dunbar Road, Byron, GA 31008, USA.
E-mail address: David.Shapiro@ars.usda.gov (D.I. Shapiro-Ilan).

http://dx.doi.org/10.1016/j.biocontrol.2015.12.006
1049-9644/Published by Elsevier Inc.

1. Introduction

Entomopathogenic nematodes (EPNs) in the genera *Steinernema* and *Heterorhabditis* are biological control agents that can be used to control a variety of economically important insect pests (Shapiro-Ilan et al., 2002; Grewal et al., 2005). However, the efficacy of aboveground applications using EPNs can be limited due to harmful effects of ultraviolet radiation or desiccation (Shapiro-Ilan et al., 2002). Conceivably, improved formulations may improve efficacy of aboveground applications of EPNs by protecting the nematodes from harmful environmental conditions (Glazer et al., 1992; Baur et al., 1997; Head et al., 2004; Schroer and Ehlers, 2005; Shapiro-Ilan et al., 2006). We have been studying improved use of EPNs for aboveground applications against the lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson) (Lepidoptera: Sesiidae).

S. pictipes is an important pest of peach, *Prunus persica* (L.) Batsch, and other *Prunus* spp. in the eastern United States (Johnson et al., 2005). In general, two generations of *S. pictipes* occur per year. In the southeastern US, adult emergence typically begins in March and peaks in April and May, and a second adult emergence peak occurs between July and September. Adult moths lay eggs on the trunk and scaffold limbs usually in cracks in the tree's bark or near injured areas (Johnson et al., 2005; Cottrell et al., 2008). Larvae bore into the inner bark and cambium where they feed and develop. Larvae, including most instars, overwinter in the tunnels. Damage from larval feeding reduces tree vigor and in heavy infestations frequently leads to loss of scaffold limbs and/or premature loss of trees and orchard productivity (Johnson et al., 2005).

Current control recommendations for *S. pictipes* depend on intensive use of chemical insecticides. For instance, recommendations in Georgia and South Carolina, the key peach producing states in the southeastern US, call for multiple applications annually that specifically target *S. pictipes* at different stages of the crop's phenology; chlorpyrifos is recommended as the most effective chemical of choice (Johnson et al., 2005; Horton et al., 2015). Thus, due to costs, along with regulatory and environmental concerns associated with such chemical usage (Coppel and Mertins, 1977; National Research Council, 1989; Cohen, 2000), development of alternative strategies is warranted. EPNs are one possible alternative tactic for *S. pictipes* control (Shapiro-Ilan and Cottrell, 2006; Lacey and Shapiro-Ilan, 2008).

Laboratory studies indicate that several EPN species are highly virulent to *S. pictipes*, especially *Steinernema carpocapsae* (Weiser) (Shapiro-Ilan and Cottrell, 2006). Nevertheless, field studies indicate that aboveground applications with *S. carpocapsae* fail to cause significant *S. pictipes* mortality, presumably due to UV radiation or desiccation effects on the nematodes (Shapiro-Ilan et al., 2010). However, in earlier research we discovered that, *S. carpocapsae*, can cause high levels of *S. pictipes* mortality when a sprayable fire gel (Barricade®) is applied as a protectant on top of the nematode application. One drawback to the approach is that two applications must be made (first the nematodes then the fire gel on top); the Barricade®, when applied at its full rate (approximately 4%) is too viscous to go through normal agricultural spray equipment and therefore requires that the nematodes be applied separately. The requirement of a dual application reduces the ease-of-handling and attractiveness of the approach to growers. We hypothesized that a lower concentration of Barricade®, when combined with EPNs, could be applied as a single application using standard spray equipment, and the combination would still be effective for control of *S. pictipes*. Thus, our first objective was to test this hypothesis. Additionally, in prior research we did not compare nematode applications to chemical insecticide treatments. Therefore, the second objective of this study was to compare the efficacy of nematode applications with chlorpyrifos.

2. Materials and methods

2.1. Field site and nematode cultures

The experiments were conducted in Quincy, Florida, at the University of Florida, North Florida Research and Education Center. Peaches (16-year-old University of Florida test variety M2-6 trees) were planted with a 4.5 × 6 m spacing in a fine sandy loam soil. The experiment was conducted in 2013 and repeated in 2014.

Commercially produced nematodes, *S. carpocapsae* (All strain) were used in experiments. In 2013, nematodes were obtained from Becker Underwood (Ames, IA) and in 2014 from E-Nema (Schwentinental, Germany). Infective juvenile nematodes (IJs) were stored at 13 °C for <2 weeks before use. Nematode viability was ⩾95% in all experiments.

2.2. Field experiments

Four treatments and a non-treated control were included in the experiments. Three nematodes treatments, which were applied in aqueous suspension, included nematodes with a full rate of Barricade® (approximately 4%), nematodes with 2% Barricade®, and nematodes without Barricade®. The chemical standard, chlorpyrifos was also applied as Nufos® 4E (44.9% a.i. Cheminova, Inc., Research Triangle Park, NC) in 2013, and Lorsban® Advanced Insecticide (40.2% a.i., Dow Agrosciences, Indianapolis, IN) in 2014. A non-treated control was included. In our previous research (Shapiro-Ilan et al., 2010), we observed that Barricade® applied alone, or an application of water only, did not produce significant effects on *S. pictipes* survival; therefore we did not include these additional controls (water-only or Barricade®-only) in the current experiments.

Treatments were applied to wounds infested with *S. pictipes*. Infested wounds were identified and marked prior to treatment application (Johnson et al., 2005). Approximately 20 ml of suspension was applied to each wound. For nematode applications, one million IJs were applied to each wound (in a suspension of 50,000 IJs per ml). Chlorpyrifos was applied at a recommended field rate (approximately 7015 ml per hectare). All treatments were applied as a single spray using a 7.6 L handheld pump sprayer (Ortho/Scotts Company, Marysville, OH), except the Barricade® full rate was applied separately from the nematode suspension (applied immediately after as a cover spray) using a 94.6 L electric sprayer ("Dependable 12-Volt Standard 25 gal Sprayer," Fimco Industries, Dakota Dunes, SD).

Treatments were applied on November 5, 2013 and October 14, 2014. Experiments were arranged in randomized complete block designs. In 2013 there were 4 blocks of 3 wounds per treatment, and in 2014 there were 6 blocks of 6 wounds per treatment. All wounds were either on the same tree or two adjacent trees, and there was a minimum of a two-tree buffer between each treatment. Treatment effects were determined by assessing the number of surviving *S. pictipes* in wounds (Shapiro-Ilan et al., 2010) 8 or 14 d post-application in 2013 and 2014, respectively; the bark over each wound was peeled back, the wound was searched, and the number of live or dead larvae was recorded.

Weather data were recorded for the period of nematode application until assessment of *S. pictipes* survival. Specifically, average daily mean, minimum, and maximum temperatures were recorded as well as relative humidity and precipitation. The weather station (from which data were obtained) is located on the University of