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Evaluating Efficacy of Low and High Rates of Conventional and Biological Insecticides for Pecan Weevil Control in Oklahoma

Abstract

Pecan (*Carya illinoinensis* (Wangenh.) K. Koch is an economically important North American nut crop. In Oklahoma, native pecans account for 80 to 90% of total pecan production and Oklahoma ranks among the top three states for native production. The pecan weevil *Curculio caryae* (Horn) is a key pecan pest affecting yield and quality throughout the Southeastern United States, including portions of Texas and Oklahoma. Current management strategies for weevil control are broad-spectrum in nature and affect a wide range of insects including beneficials. The objective of this study was to evaluate efficacy of low and high rates of conventional and biological insecticides for *C. caryae* control in Oklahoma. Two conventional insecticides (Warrior® II, a.i.: lambda-cyhalothrin, and Minecto Pro®, a.i.: cyantraniliprole + abamectin), and Grandevo® WDG, with a soil bacterium (*Chromobacterium subtsugae)* as its active ingredient, were evaluated. There were no significant differences in the percentage of damaged nuts among nontreated trees and those treated with low or high rates of all products. Results from this experiment suggest the use of the microbial biopesticide Grandevo can be used as an alternative to chemical insecticides, in both organic and conventional systems, providing an additional option for *C. caryae* control in Oklahoma.

Introduction

Pecan (*Carya illinoinensis)* is an economically important North American nut crop (NPSA, 2023). Two types of pecans are produced in the U.S., native and improved. Native pecans are varieties that developed under natural conditions, while improved pecans are cultivars that have been genetically developed through breeding and grafting techniques to produce more pecans, and a higher percentage of kernel meat (Blayney and Gutierrez, 2017).

Native pecans account for 80 to 90% of Oklahoma's total pecan production. Oklahoma, along with Louisiana and Texas, are the top three states for native pecan production (Brus, 2017). In addition, Oklahoma ranks 5th or 6th nationwide for total production, producing an average of 17 million pounds of pecans each year, with an average wholesale value of $18 million (Carroll, 2017).

The pecan weevil *Curculio caryae* (Horn) is a key pecan pest affecting yield and quality throughout the southeastern United States, and in parts of Texas and Oklahoma (Dutcher and Payne, 1985). Once *C. caryae* is established, populations can increase rapidly. These insects require 2 or 3 years to complete one generation. Most adult weevils emerge from soil beneath trees in late August through October to feed, mate, and oviposit (lay) eggs in the developing fruit's kernel. Adult emergence is heavily dependent upon soil type and moisture. After emergence, 85% of weevils find the nearest tree and climb the trunk to reach its canopy. Optimum oviposition occurs when pecans are in the (dough stage) of development. Dough stage occurs in late August to mid-September, occasionally stretching into October. Dough stage is characterized by the absence of liquid or gelatinous material within the nut. Maturity soon follows with the splitting of the four sutures on the hull and exposure of the shell (Herrera and Lewis, 2000). Larvae develop within the kernel of the ripening nut while still attached to the tree. After 42 days of feeding, the final instar exits the kernel and drops to the ground, burrowing into the soil 10–31 cm to form an earthen cell in which it will over-winter. The following fall approximately 90% of larvae pupate and emerge as adults (Boethel and Eikenbary, 1979). The remaining 10% remain in the soil for an additional year and emerge as adults in the third year (Harp and VanCleave, 1976). Adult emergence can vary greatly, especially in years delayed by drought. Oviposition takes place approximately 6.5 days after emergence. This makes insecticide application timings crucial for optimum control. Many techniques have been developed and reviewed to monitor *C. caryae* emergence (Neel and Shepard, 1976; Mulder et al., 1997;, Mulder et al., 2003), allowing researchers to determine their utility for integrated pest management (IPM) of this perennial pest.

Control recommendations for *C. caryae* adults consist primarily of foliar applications of chemical insecticides (Harris, 1999). Pecan "Circle" traps (Mulder et al., 2012) are commonly used to monitor adult weevil emergence. The trap is economical, costing $20 or less, eliminating equipment and obstructions to cattle grazing in the orchard or grove. The number of traps needed varies depending on the number of trees, location, and cultivar; however, a general recommendation is 15 traps per 100 trees (Ree, et al., 2005). When *C. caryae* emergence is detected and tree nut phenology (dough stage) is suitable for egg laying, applications of chemical insecticides are recommended every 7–10 days during peak emergence. Although insecticide applications are effective in controlling *C. caryae*, they are broad-spectrum in nature, impacting a wide range of insects including beneficials (UC IPM, 2022). Therefore, development of alternative control strategies in both organic and conventional systems is justified.

Biopesticides are naturally occurring substances used to control pests (EPA, 2023). Microbial pesticides are a class of biopesticides consisting of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. The most widely used microbial pesticides are subspecies and strains of the bacteria *Bacillus thuringiensis*, or Bt (NPIC, 2023). Commercialized in 1938 (Ibrahim, 2010), its uses have expanded and proved effective in reducing use of chemical insecticides globally. Each strain of this bacterium produces a different mix of proteins and kills one or more related species of insect larvae. In recent years, increased interest in organic farming, pesticide applicator safety, and lessening the effects of harmful insecticides on the environment, has prompted development of new microbial pesticides. In 2015, an integrated approach using three microbial agents to control *C. caryae* was evaluated: the entomopathogenic nematode *Steinernema carpocapsae* (Weiser), the entomopathogenic fungus, *Beauveria bassiana* (Balsamo), and Grandevo (formulation that uses exudates of the soil bacterium *Chromobacterium subtsugae* (Martin) (Shapiro-Ilan et al., 2017).

One of the more promising agents from this approach, Grandevo, was first identified after isolating *C. subtsugae* from Maryland forest soil. This strain was subsequently found to be virulent to Colorado potato beetle larvae and other insects (Martin et al., 2007). The active ingredient, *C. subtsugae,* found in Grandevo contains several active compounds that repels, stops feeding, reduces reproduction, and induces mortality preventing the development of damaging populations of various insects and mites (ProFarm, 2023) The integrated approach using multiple microbial agents was successful in reducing damage caused by *C. caryae.* While effective, the cost of using full labeled rates of all three microbial pesticides in a combined strategy would not be economically feasible.

Given the need to find effective alternatives to current control strategies, the objective of this study was to evaluate efficacy of low and high rates of conventional and biological insecticides for *C. caryae* control in Oklahoma.

Methods

The experiment was conducted in a 25-yr-old pecan orchard planted with the cultivar ‘Kanza’ at the Cimarron Valley Research Station in Perkins, OK (Payne County). Low and high rates of two conventional insecticides (Warrior® II, a.i.: lambda-cyhalothrin and, Minecto Pro®, a.i.: cyantraniliprole + abamectin), and one biological insecticide, Grandevo® WDG, soil bacterium C*hromobacterium subtsugae*, were evaluated (Seuhs and Mulder, 2020). The test was arranged in a randomized complete block design with four replications of seven treatments (including a nontreated check). The tree spacing in the orchard was 12.2 m x 12.2 m. Each treatment utilized four trees, approximately 0.059 hectares. A total of 112 trees were utilized for the experiment (4 trees/treatment x 7 treatments x 4 reps). Two untreated buffer trees between treatments were maintained to prevent drift between treated plots. Insecticides were applied on 21 Aug 2019, when pecan kernels were in the dough stage and *C. caryae* emergence had begun. Applications were made using a Savage PTO-driven air-blast sprayer calibrated to deliver 100 gpa. A second application of each treatment was made 10 Sep after circle traps attached to four randomly selected trees confirmed continued weevil emergence. To help control aphids, the insecticide PQZ® (a.i., pyrifluquinazon), was applied as a tank mix to all test trees (including nontreated pecan trees) at 3.0 oz/acre during the second application. No additional applications were made.

Damage was evaluated at harvest on 23 Oct by filling a five-gallon bucket with pecans from the center two trees in each plot. Pecans were brought back to a lab, dried to 4.0%, then 200 random nuts from each sample were visually inspected, hand-cracked, and further inspected for pecan weevil damage. Damage from hickory shuckworm, *Cydia caryana* (Fitch) was also recorded. Data for each treatment were converted to percentage of nuts damaged by *C. caryae* and *C. caryana* and analyzed using an analysis of variance with mean separation determined using Fisher's Protected LSD.

Results

Pest pressure in this experiment was low, with *C. caryae* damage averaging 4.2% in the nontreated trees. There were no significant differences in the percentage of nuts with *C. caryae* or *C. caryana* damage among nontreated trees and those treated with low or high rates of Minecto Pro®, Warrior ® II, or Grandevo ® WDG (Table 1).

Table 1. Percentage of pecans damaged by the pecan weevil and hickory shuckworm at the Cimarron Valley Research Station, in Perkins, OK in 2019.

		% Damage	
Treatment	**Rate product/acre**	**Pecan weevil**[a]	**Hickory shuckworm**[a]
Nontreated check		4.2	3.0
Minecto Pro	8.0 fl oz	4.8	3.3
Warrior II w/zeon	1.28 fl oz	2.2	1.7
Grandevo WDG	2.0 lb	1.5	2.2
Minecto Pro	12.0 fl oz	2.2	2.1
Warrior II w/zeon	2.56 fl oz	2.8	3.2
Grandevo WDG	3.0 lb	1.8	1.3
***P*-value**		**0.4032**	**0.4519**

[a]Means within columns were not significantly different ($P \geq 0.05$).

Discussion

Results from this study (Table 1) suggest that the microbial biopesticide Grandevo is an effective alternative to chemical insecticides for *C. caryae* control. Damage by *C. caryae* was low in untreated trees (4.2%). Damage levels lower than 5% may be low enough to complicate our ability to detect a difference among treatments (Nayak, 2010). While numerically different, there were no statistical differences in the percentage of nuts with weevil damage among untreated trees and those treated with low or high rates of Minecto Pro®, Warrior ® II, or Grandevo ® WDG. A minimum of four applications of Grandevo has been recommended to achieve the best results throughout peak emergence. Due to lack of continued trap captures, only two applications were made during this experiment.

Evidence from this study supports similar observations (Shapiro-Ilan et al., 2017) that infestation caused by C. *caryae* were reduced and Grandevo provided similar levels of control compared with standard chemical insecticides. Unfortunately, while these studies demonstrate the efficacy of microbial pesticides, cost effectiveness remains uncertain. The highest rate per acre (3 pounds) of Grandevo, costs ($75 per acre), making this product's use cost prohibitive to most commercial growers, particularly considering multiple applications may be required in a given season. In comparison, conventional pyrethroids cost $2-5 per acre. However, given the recent rise in potential insecticide resistance to pyrethroids, environmental concerns, applicator safety, and regulatory issues, Grandevo may continue to develop into a rotational option. Other research has suggested, the use of entomopathogenic nematodes and fungi could be used to treat hot spots in an orchard, helping to reduce cost. However, given their sensitivity to environmental conditions, additional research is needed to optimize their use.

In 2021, pecan scientists in Georgia showed reduced rates of Grandevo (2 pounds) per acre significantly decreased the percentage of damaged nuts when compared to the nontreated checks; these results were similar to standard insecticides (Shapiro and Wells, 2022). Oklahoma experiments had similar results, with Grandevo efficacy occurring at the lower (2 pound) rate (Seuhs, 2022 unpublished data). Studies are ongoing to evaluate if a (1 pound) rate can be equally as effective.

Subsequent studies have found Grandevo to be virulent to the black pecan aphid, *Melanocallis caryaefoliae* (Davis) (Oliveira-Hofman et al., 2021), which is another serious pest of pecans (Shapiro-Ilan et al., 2013). Causing minimal impact on natural enemies, aphid control is perceived as another benefit of Grandevo verses conventional applications (Ray and Hoy, 2014).

Current management strategies consist of foliar applications to the tree canopy and rely heavily on broad-spectrum chemical insecticides (e.g., carbaryl and pyrethroids) to control *C. caryae.* While effective, these late season applications tend to flare aphid and spider mite pest populations, reducing beneficial insects (Wells, 2016). Outbreaks of aphids and mites have resulted from the destruction of natural enemies that were holding these secondary pests in check. This may prompt the need for additional insecticides targeting these pests, adding extra expense. If pyrethroids are used, it is recommended to limit their use to as late in the season as possible.

These findings support the use of Grandevo as a non-chemical alternative for C. caryae, black pecan aphid, and hickory shuckworm control. Unfortunately, cost continues to be a prohibitive factor. While preserving natural enemies, the use of Grandevo can potentially reduce the need for costly tank-mix additions related to aphid and mite management.

Conclusion

This study has identified that the microbial biopesticide Grandevo can be used as an alternative to chemical applications for *C. caryae* control in Oklahoma. Widespread incorporation into management programs, including organic production, will depend on cost effectiveness and determining how best to incorporate biological products into the *C. caryae* control rotation. Thus, additional research is needed to optimize a microbial biopesticide strategy using one or a mix of microbials for maximum control, while minimizing cost. Once the microbial approaches for controlling *C. caryae* are optimized, a full cost-benefit analysis can be conducted.

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Conflict of Interest

The author declares there are no conflicts of interest.

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