Christmas Tree Promotion Board

CTPB Project Number: # 21-01-CAES

Project Title: Integrating Biological Control of Armored Scale Pests of Christmas Trees

Principal Investigator: Richard Cowles

Institution: The Connecticut Agricultural Experiment Station

Estimated Project Completion Date: July 31, 2022

Final Report

1. Technical Report

Objective 1. To determine the most effective single-spray program for selectively reducing populations of armored scales.

Background: In a previous report to the CTPB (Cowles and Li 2020), I identified three insecticides with properties that should be studied further for management of armored scales: pyriproxyfen, afidopyropen, and spirotetramat. All three products have low toxicity to pollinators, based upon U.S. EPA documents for registration of these active ingredients, suggesting that they could be substituted as pollinator-friendly alternatives to dinotefuran, the current industry standard. That report also identified acetamiprid (a neonicotinoid with less toxicity to honey bees than dinotefuran) as being more active than dinotefuran. The challenge with these alternative insecticides is that they must be applied as full foliar sprays, whereas dinotefuran can be effective on smaller trees when applied as a basal bark spray. Generally, foliar sprays for scale management requires two sprays about 10 – 14 days apart at the time that crawlers are active. The objective of this experiment was to determine whether oil could be combined with a systemic insecticide to provide an effective one-spray management program for elongate hemlock scale, *Fiorinia externa*. The rationale was that both the horticultural oil and the insecticide it is being mixed with would be compatible with the activity of natural enemies. Secondly, the oil acts through the physical mechanism of suffocation, for which no genetic variation among scales for susceptibility is likely. Therefore, combining oil with other insecticides that have specific, non-physical modes of action should prevent insecticide resistance.

Methods: A 2 × 6 factorial completely randomized experiment was designed, with the two-level factor being absence or presence of horticultural oil, and the six-level factor being a comparison of no insecticide, dinotefuran, acetamiprid, afidopyropen, pyriproxyfen, or spirotetramat. A cooperating farm in Suffield, CT, was chosen for this trial. The grower had not previously applied insecticides to manage scales. These moderate populations of scales were dominated by elongate hemlock scale, with small populations of cryptomeria scale. Forty-eight Fraser fir trees (6 – 10 feet in height) were chosen for the study, with at least one buffer tree between any two study trees. Individual trees constituted the experimental unit. Trees were chosen in June, based upon some evidence of scale activity. Insecticides were applied with a surfactant (Silwet L-77) with a backpack mist blower sprayer on August 16, 2021, with a liquid application rate of 70 gallons per acre.

To evaluate this experiment, four 6” shoot samples were collected from each tree in early October and held in the refrigerator until scales were counted. Twenty-five needles from current season’s growth were removed from each sample. Each scale found on the needles was examined by flipping the scale with an insect pin to determine whether the scale was alive or dead. The total count of live scales and the proportion of live and dead scales on new growth were assessed from combined counts from the four samples from each tree. Factorial analysis of variance was conducted on proportion of live scales and log-transformed (log (*x*+1)) counts of live scales per 100 needles.

Results: There was no statistically significant interaction between the horticultural oil and the insecticide effects, and so the degrees of freedom and sums of squares for the interaction were pooled with the experimental error. The insecticide treatment main effect was statistically significant for the number of live scales ($F_{(5,41)} = 2.58$, $P = 0.04$) and marginally significant for the proportion of live scales ($F_{(5,41)} = 2.15$, $P = 0.08$). The oil application main effect was not statistically significant ($F_{(1,41)} = 0.15$ and 0.56, respectively). The only treatment statistically significantly different from the untreated check was application of acetamiprid (Tristar), but two other treatments, pyriproxyfen (Distance) and dinotefuran (Safari) did not differ statistically from the Tristar treatment and were considered partially effective (Fig. 1). There was no evidence for insecticide effectiveness for afidopyropen (Ventigra) or spirotetramat (Movento) in a one-spray program.

Conclusions: The application timing for this experiment was later than optimal, to avoid phytotoxicity from applying oil to new growth prior to it hardening off. Since the addition of oil at this timing for application did not significantly improve the control of scales, we can conclude that combining horticultural oil with these systemic insecticides was not justified, based upon either cost or efficacy. The modest degree of suppression of scales with these insecticides applied in a one-spray program with delayed timing (relative to targeting peak crawler activity, which generally is about July 1 in CT) suggests that either (1) a more effective timing for the single spray is needed, or (2) a two-spray program with these insecticides may be necessary. Considering that the cooperating grower found the population of scales tolerable in the unsprayed trees, moderate suppression of elongate hemlock scales with a highly selective insecticide (pyriproxyfen) could allow a properly timed one-spray program to be integrated with naturally occurring biological control with parasitoid wasps. Farms with a lower tolerance for armored scales would have to resort to the more aggressive two-spray program using either acetamiprid, afidopyropen, or pyriproxyfen, if targeting scale management during the summer. An alternative is to implement a one-spray program with acetamiprid at the optimal timing, which is close to bud break (Cowles 2010). Subsequent implementation by growers of the bud break timing for using a foliar spray of acetamiprid at 0.15 lb active ingredient per acre has been extremely effective for managing scales and appears to be compatible with biological control – probably because this spray timing is earlier in the season than when these insects are active. To achieve compatibility of a spray program with natural enemies of scales, use of broad-spectrum insecticides (e.g., bifenthrin) must be avoided.

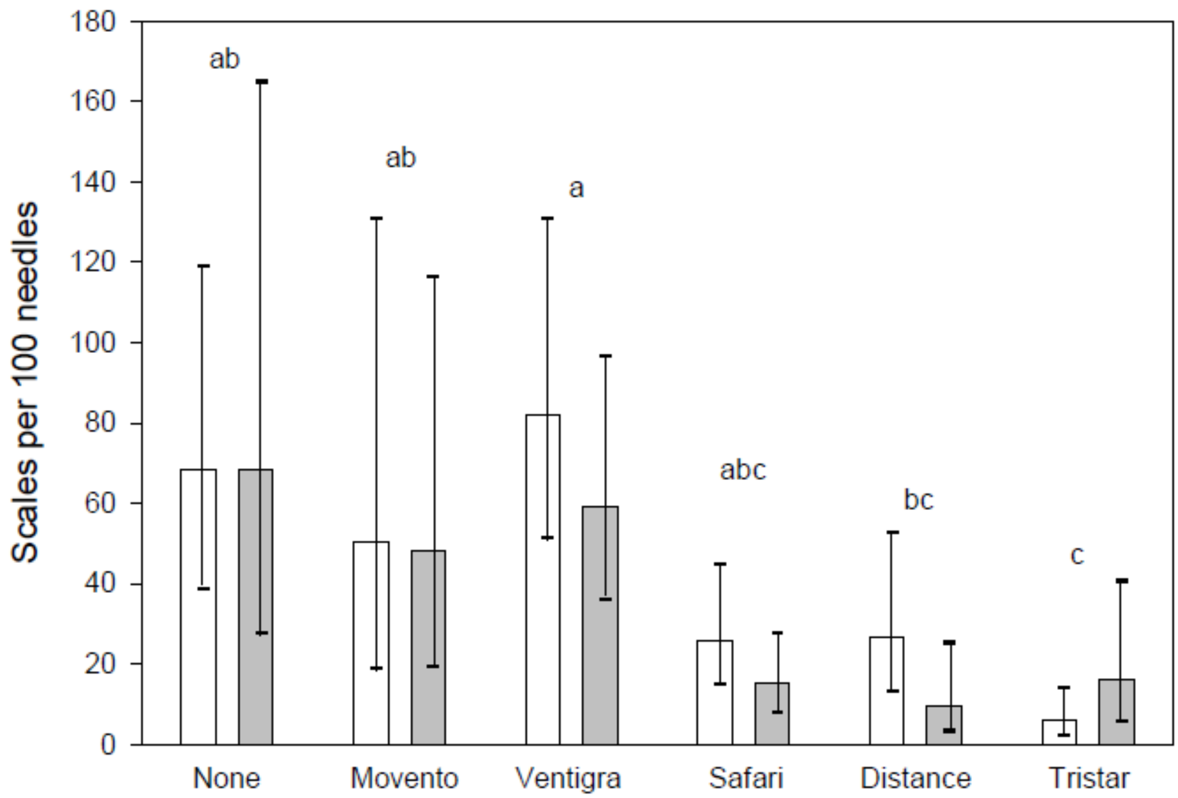

Fig. 1. Effectiveness of insecticides to suppress elongate hemlock scales on Fraser fir with a single foliar spray applied in mid-August. White bars, no horticultural oil; gray bars, insecticide applied with 2% horticultural oil. Bars present back-transformed means. Error bars display the standard error of the means and are asymmetric around the mean due to back-transformation of log-transformed values. Groups of bars with the same letters are not significantly different; mean separations were conducted with Fisher’s protected LSD test (*P* = 0.05).

Objective 2. To test the acceptance and development of *Aphytis melinus* on elongate hemlock, hemlock, and cryptomeria scale.

The ability of *Aphytis melinus* to attack and develop on elongate hemlock scale, cryptomeria scale, and/or hemlock scale, was evaluated by releasing commercially obtained parasitoids into sleeve cages surrounding branches heavily infested with scales at cooperating farms on Fraser fir in Broad Brook, Black Hills white spruce in Hamden, and concolor fir in Hamden, respectively. Fine mesh bags were used to enclose 500 – 1,000 live *Aphytis melinus* on each of four branches on each tree on August 19, 2021. Individual bags were cut from the trees between September and late November. They were transported to the laboratory, where the foliage was removed from the mesh bag and enclosed in emergence cages to monitor for emergence of parasitic wasps.

Results: *Aphytis melinus* was not recovered from sleeve cages in the field, and so they did not propagate on these scale populations. There were numerous *Encarsia citrina* captured on exposed adhesive tape within the emergence cages (Fig. 2) containing elongate hemlock and cryptomeria scales. *Cybocephalus nipponicus*, a predatory beetle imported from Korea for biological control of euonymus scale, were found with all three species of scale, but were especially abundant in association with hemlock scale. Hemlock scale was also heavily colonized by *Metarhiziopsis microspora*, an insect pathogenic fungus.

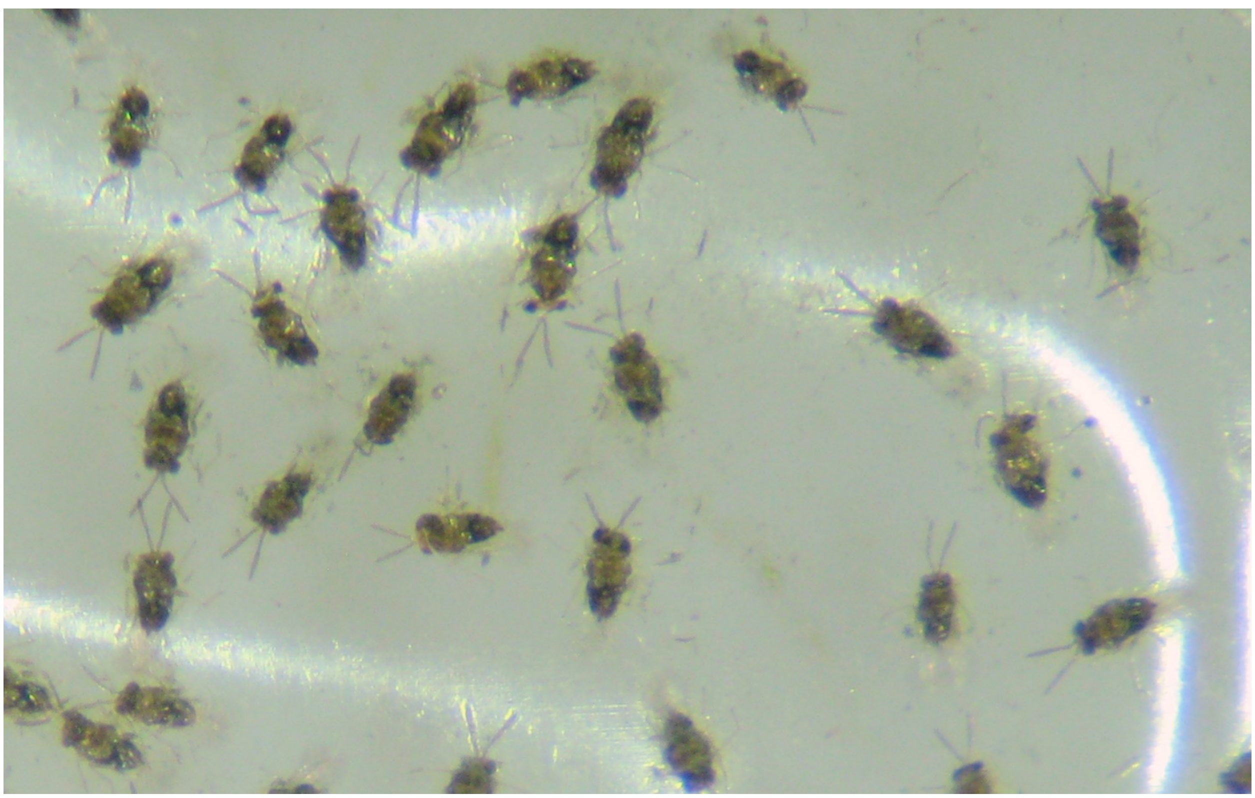

Fig. 2. *Encarsia citrina* wasps were captured in great abundance in emergence cages. Encarsia wasps have a dark abdomen, whereas Aphytis have golden-colored head, thorax, and abdomen. Only *Encarsia* were recovered from emergence cages.

Conclusion: Conditions inside the mesh bags should have allowed propagation of the scale parasitoids, as is evident from the abundance of *Encarsia* wasps. The commercially available *Aphytis melinus* probably will have no value for targeting any of the three common species of armored scales found infesting Christmas trees along the east coast.

Objective 3. To test insectary methods currently used for rearing *Aphytis melinus* for the production of *Aphytis proclia*.

Foliage infested with the three scale species of interest were placed onto organically grown butternut squash in the laboratory. Hatching scales did not settle and feed on butternut squash, and so could not serve as hosts for parasitoids.

This objective was modified. Fraser fir Christmas trees heavily infested with cryptomeria scale were brought into the greenhouse in January, 2022, and provided ample water. In addition, boughs containing scale parasitized by *A. proclea* were also introduced into the greenhouse (these were from the field site in Suffield used for the insecticide test). Every three weeks, a new scale-infested Christmas tree was introduced to the greenhouse. The intent was to allow emergence of parasitoids to take place in the greenhouse, and to have ample scales made available for continual reproduction.

On further evaluation of scale-infested foliage in the field, ample parasitoids of both species were routinely found, though *A. proclea* is found at much lower numbers than *E. citrina*. It is a “if you build it, they will come” situation: if there are armored scales, then the parasitoids will establish themselves without having to make releases, as long as pyrethroids have not been sprayed. Therefore, the goal for establishing and maintaining armored scale parasitoids simply needs to be to conserve the naturally occurring populations already present on farms.

2. Summary of Research Report for Public Release by CTPB

Armored scales are now more manageable in Christmas tree plantings, because of this and prior research, some of which was funded by the RCTB. Three insecticides were found to be effective as a two-spray program (acetamiprid, afidopyropen, and pyriproxyfen) for targeting crawler activity during the summer. All of these insecticides have reduced pollinator toxicity, relative to the dinotefuran standard, and so are more appropriate for use in summer foliar sprays. These active ingredients were found to be mediocre at suppressing scale populations when used in a single spray application in mid-August with or without horticultural oil, and horticultural oil was not found to be effective (at a 70 gallon per acre spray volume containing 2% oil). Acetamiprid is more effective against scales but is a less selective insecticide than pyriproxyfen, which is known to be compatible with parasitoid wasps, or afidopyropen, which should be compatible with predatory beetles. An effective strategy to make the best use of acetamiprid was trialed by growers in 2022 and 2023 by applying a full foliar spray about the time of bud break, based upon the superior timing effectiveness identified through previous work. The result was extraordinarily effective suppression of scale populations, while still permitting survival and effective parasitization of remnant patches of scales (possibly surviving due to inadequate spray coverage) later in the season. Manipulation of parasitoid populations via mass rearing and making field releases was not found to be feasible or cost effective. However, parasitoid wasps readily colonize scale infestations on commercial farms and can be used in an integrated pest management program, as long as use of broad-spectrum insecticides like bifenthrin are curtailed. Therefore, the most effective strategy for managing armored scales, as observed from large-scale grower experience, combines the most active insecticide, acetamiprid, applied at the most effective timing, which is close to bud break. For most fields, this one-spray program provides exceptional control of armored scales. Furthermore, acetamiprid is much less toxic to pollinators than the alternative scale insecticide dinotefuran, and at this spray timing acetamiprid replaces the use of the bee-toxic imidacloprid for managing balsam twig aphids. To avoid insecticide resistance to acetamiprid, growers should carefully monitor fields where this strategy is used and should plan to follow-up with two thorough applications of pyriproxyfen during periods of crawler activity to spot-treat areas where scale populations persist.

3. List of Publications

Cowles, R. S. 2023. Updates from Rich Cowles. The Real Tree Line (Newsletter of the Connecticut Christmas Tree Growers' Association). In press.

Reference

Cowles, R. S. 2010. Optimizing a basal bark spray of dinotefuran to manage armored scales (Hemiptera: Diaspididae) in Christmas tree plantations. J. Econ. Entomol. 103(5): 1735 – 1743. DOI: 10.1603/EC10077