

Christmas Tree Promotion Board

Final Research Report

CTPB Project Number: 21-04-NCSU

Project Title: Improving Management of Elongate Hemlock Scale in Fraser Fir Christmas Trees

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Institution: NC State University

Final Report

1. Technical Report

Introduction

Fraser fir (*Abies fraseri* [Pursch] Poir.) is one of North America's premier Christmas trees species. In North Carolina alone, the Christmas tree industry generates annual revenues exceeding \$125 million from sales of Fraser fir trees and greenery. With 1,300 growers producing trees on approximately 40,000 acres in 24 western counties, North Carolina ranks second in the nation in trees harvested and cash receipts, shipping trees to all 50 states, Canada, Mexico, Japan, Bermuda, the Caribbean Islands, and other places around the globe. Like other forestry and agriculture crops, Fraser fir Christmas trees have issues with a number of insect and disease pests. The North Carolina Cooperative Extension Service lists 14 insects and 5 pathogens that regularly cause problems for Fraser fir production in the state. They range in severity from those that cause significant tree decline and mortality, to those that cause aesthetic damage and reduce tree marketability, to those that become a nuisance post-harvest by infesting peoples' homes or hitching a ride to new areas on trees shipped long distances. Fortunately, for many of these pests well-developed integrated pest management systems exist that when properly implemented mitigate their potential impacts.

The elongate hemlock scale (*Fiorinia externa* Ferris, EHS) is an exotic insect that is considered the most difficult pest to control on Fraser fir. Recently, this insect has become an important regulatory issue for Christmas tree growers. Detections of scale-infested trees and greenery from North Carolina in states where EHS is not yet present has been on the rise in recent years. Inspectors with the Florida Department of Agriculture and Consumer Services Division of Plant Industry have intercepted scale-infested trees every year since 2012. The 2018 Christmas season was particularly problematic with detections reported from Wisconsin, Minnesota, Oregon, California and Utah.

Support for research to improve management of EHS has been extensive in recent years. Both the North Carolina Christmas Tree Association and Christmas Tree Promotion Board list the scale as a top priority in annual RFPs and have provided funds to address critical research questions. Progress has been made, but EHS remains a challenge for growers to effectively manage and the risk for Fraser fir to serve as pathway for introduction of the scale to new areas remains high. Research effort is needed to improve our understanding of EHS on Fraser fir, how it can potentially move in cut Christmas trees and greenery, and how to more effectively manage this pest

The purpose of this project was to improve understanding and management of the elongate hemlock scale on Fraser fir Christmas trees through field-based research. The objectives were to better document the phenology and life history of EHS and conduct a grower survey to evaluate the correlation between farm management practices, environments surrounding farms, and the severity of scale infestations.

Methods

Phenology of the Elongate Hemlock Scale: This study was conducted at three sites in the Christmas tree production region of western North Carolina. Two sites, the NCDA&CS Upper Mountain Research Station in Laurel Springs and Vannoy Seed Orchard in Jefferson, were located in Ashe County. The third site was located in Haywood County on the NCDA&CS Mountain Research Station near Waynesville. Samples were collected bi-monthly (every two weeks) between May 2021 and May 2023. During each collection period, samples were collected from five randomly selected trees in each of the three sites, consisting of two branchlets per tree including three needle age classes that were placed on ice and transported to the NC State University Forest Health Lab for microscopic analysis. For each sampling period, we aimed to collect data on at least 100 live scale per tree. To confirm an insect was alive, in the absence of fluorescent yellow color, the scale's armor was punctured and observed for active bleeding (Dale et al 2020). The number of 1st instar crawlers, 2nd instar nymphs, 3rd/4th instar males (prepupa and pupal stage) as well as adult females and the number of eggs were recorded. We also counted scale exuviae for each needle and recorded if scales were parasitized by insects or infected with fungi. All observations were recorded for three needle age classes where 0 = needles produced the year of sampling, 1 = needles produced the year prior and 2 = needles produced two years prior.

Grower Survey: Between Fall 2020 and Spring 2023, 56 Christmas tree fields were scouted across western North Carolina, with the number of fields per county weighed by the number of farms present in the respective county. An approximately 1 ac area within each field was assessed for the presence of EHS as follows. Within a selected field, every third tree in every third row was scouted. This roughly equates to ~10% or 170 trees per acre. The scouting method utilized a binomial approach where each selected tree is visually split into vertical halves and cardinal quadrants. Five branchlets were randomly selected from each half and quadrant, turned over and three years of growth were evaluated for scale presence. Scale presence was noted as "1" and absence was noted as "0". If a tree was small or did not have sufficient branches, the space for each missing branch was left blank. This resulted in up to 40 data points per tree. Following scouting, growers responsible for the management of each field were surveyed to document the management history of the site. Data gathered during the survey phase included season, application rate, and mode of application for insecticides, herbicides, fertilization, and mechanical ground management. All survey data was collected and is being managed in accordance with Institutional Review Board (IRB) guidelines.

Results and Discussion

Phenology of the Elongate Hemlock Scale: EHS is difficult to control because it has multiple, overlapping generations throughout the year that provide a continuous supply of first instar crawlers capable of producing new infestation centers. However, the timing of these generations is not well understood, complicating the timing of management activities. This study compared the phenology of EHS life stages across three locations in North Carolina to better document the timing of EHS life stages. Improving our understanding of scale phenology and ultimately crawler production will allow us to further refine the use and efficacy of management strategies (such as biological control and chemical insecticides) that target specific EHS life stages.

This study is complete and a manuscript for journal submission has been prepared for submission to a peer reviewed journal following the dissertation defense of the PhD student leading the project. Key data figures and their implications are provided below. **Figures are not to be reproduced without written permission from Dr. Robert Jetton and NC State University.**

Data from the phenology study reveals that all EHS life stages are present year round, indicating the presence of multiple overlapping generations of EHS in the North Carolina Fraser fir production region (Figure 4). This complicates management of this pest because while insecticides can offer effective

control of more susceptible crawler and second instar nymph life stages, less susceptible later nymph instar and adult life stages will persist in trees to perpetuate infestations. Given the zero-tolerance policy many states have in place for EHS on trees shipped from North Carolina, new research is needed on insecticide products that effectively target all life stages of the insect.

This study also revealed that all EHS life stages are present on multiple needle age classes, including those that are protected in the interior of the dense Fraser fir crown (Figure 7). This indicates that commonly used mist blower insecticide applications are probably not sufficient to ensure sufficient coverage and effective EHS controls on all trees, and that high pressure insecticide applications on an individual tree basis are likely required.

Data on EHS natural enemies revealed that the parasitoid *Encarsia citrina* and entomopathogenic fungus *Conoideocrella superstrata* were the most commonly observed in the North Carolina growing region, but percent parasitism and infection were very low (1.5% and 2.2%, respectively). Peak parasitism occurred during the spring each year of the study while peak infection occurred during late summer and early fall.

Although not a stated objective of this project, the EHS phenology study also reveal a better understanding of the risk of moving the pest to new areas on cut trees from North Carolina. Except for a lull during the winter months, EHS produces a steady year-round supply of eggs on Fraser fir in NC, with a peak in egg laying occurring in September and October just as the tree harvest and shipment season is starting. This means there is high probability of large numbers of crawlers hatching and dispersing from trees as they arrive on tree lots and in homes around the country.

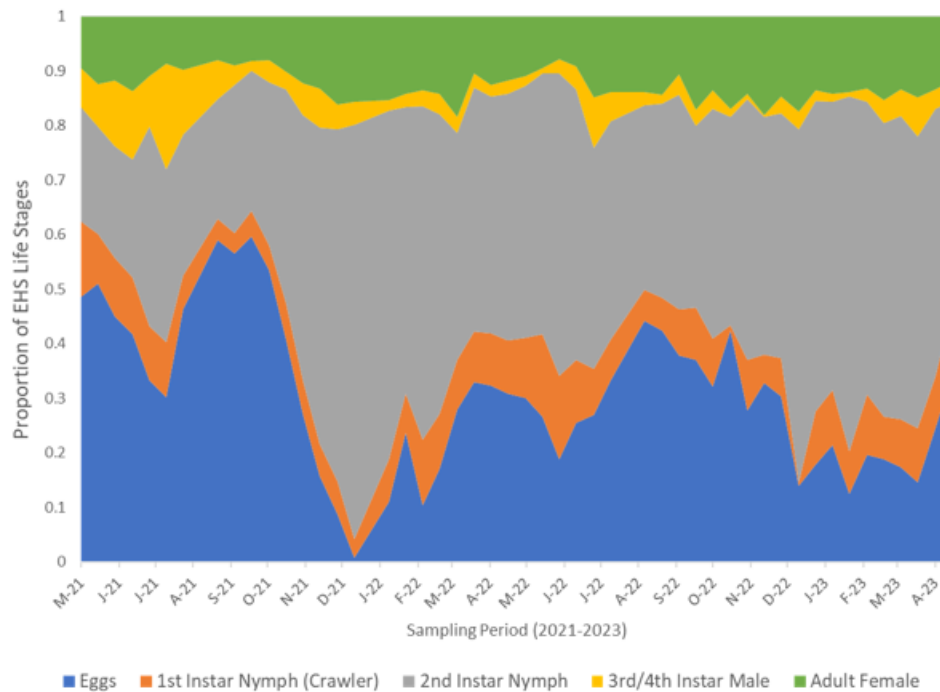


Figure 4: Average proportions of elongate hemlock scale (EHS) life stages recorded across three locations in western North Carolina (Upper Mountain Research station, Mount Jefferson State Park, Mountain Research Station), over 2 years between May 2021 and May 2023.

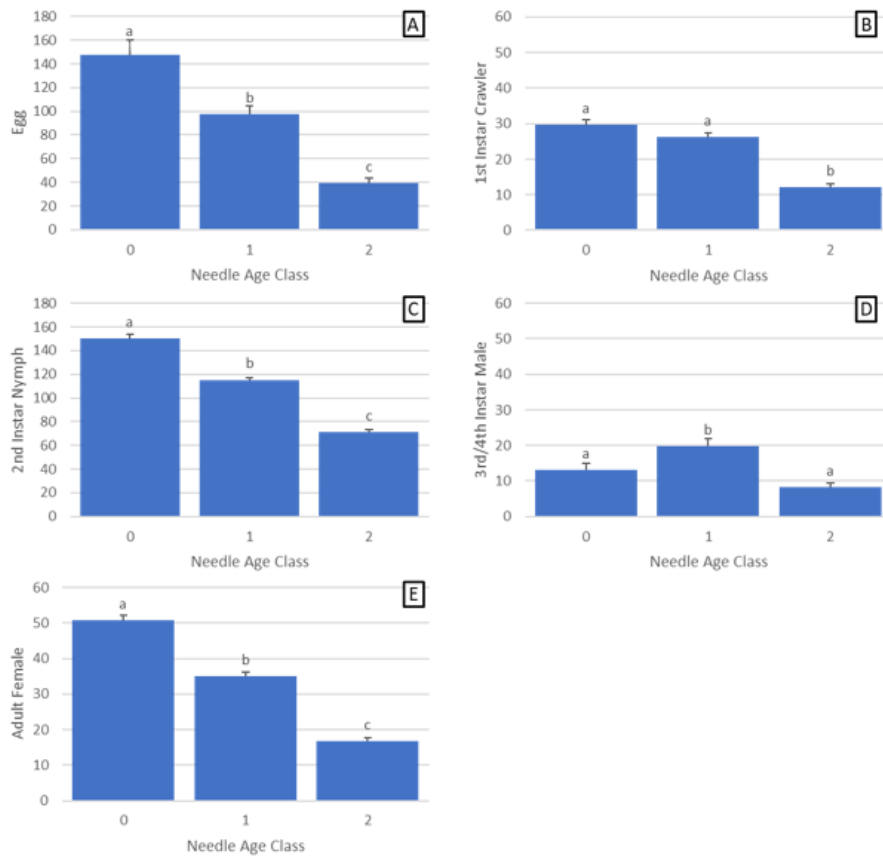


Figure 7: The Series shows the average abundance and standard error of the mean of each of the 3 years' branch segment across all locations sampled over the 2-year study period. A) is the average egg abundance, B) is the average abundance of the 1st instar crawler stage C) average abundance of the 2nd instar nymphal stage, D) average abundance of the 3rd/4th instar male stage and E) average abundance of the adult female stage.

Grower Survey: This combined field assessment and grower survey seeks to determine what areas within the North Carolina Fraser fir production region have the highest incidence and severity of EHS infestations and what site and management factors are most associated with increased EHS incidence and severity on Christmas tree farms. All field scouting and grower survey data has been collected. We are currently in the process of standardizing grower field management practices into a consistent format that can be utilized in the data analysis. Analysis and manuscript writing will be completed by 12/31/2024 by which date the PhD student leading the project will have successfully defended their dissertation.

2. Summary of Research Report for Public Release by CTPB- Summary should be suitable for non-scientific audience and should not exceed one page.

Ongoing research led by Dr. Robert Jetton and his PhD student Dominic Manz in the NC State University Forest Health Lab (Department of Forestry and Environmental Resources) is shedding new light on elongate hemlock scale (EHS) biology and management. They recently completed a study that evaluated the phenology (timing of the insect's life stages throughout the year) of the pest across the North Carolina Fraser fir production region. The data shows that EHS has multiple overlapping generations with all life stages occurring year-round. This means that with even good control of insecticide susceptible life stages, less susceptible life stages will survive to perpetuate infestations. The study also revealed that EHS infestations occur on older needle age classes deep within the dense Fraser fir crown where good insecticide coverage is difficult to achieve. Also evident in the phenology data is that peak EHS egg production each year occurs at the beginning of the annual fall harvest season, adding further evidence to the risk of moving this pest to new areas on tree shipments. All of these outcomes indicate the importance of continuing to test new products that are effective against all EHS life stages and the need to remain focused on true IPM approaches that combine insecticides applications with biological and cultural controls as well as new genetic approaches like those being developed by Dr. Justin Whitehill and the NC State Christmas Tree Genetics Program. Additional ongoing projects are assessing the influence of on-farm management practices (insecticide, fertilization, herbicides application timing, rates, methods) on EHS infestation patterns in Christmas tree fields and the risk of EHS crawler emergence from cut trees during the transport, retail, in-home display, and disposal phases of the tree life cycle. Final data and conclusions from these studies will be shared by the end of 2024.

3. List of all Publications related to this Research Grant

- Published papers (include citation or journal/date of submission)

None yet, see in preparation manuscripts below

- Published and projected abstracts (include meeting name(s) and date(s))

Rajarapu, S.R., R. Jetton, and J. Whitehill. 2024. Elongate hemlock scale and current IPM strategies. Real Christmas Tree Board Webinar Series, 30 January 2024. (Virtual)

Manz, D.* and R. Jetton. 2023. Post-harvest emergence of elongate hemlock scale on Fraser fir Christmas trees preliminary results. 32nd Southern Appalachian Forest Entomology and Pathology Seminar, 3 March 2023, Crossnore, NC.

Manz, D.*, R. Jetton, J. Owen, and A. Whittier. 2022. Phenology of elongate hemlock scale on Fraser fir Christmas Trees in NC. 61st Southern Forest Insect Work Conference, June 21-23, 2022, Lexington, KY.

Manz, D.*, R. Jetton, J. Owen, and A. Whittier. 2022. Phenology of elongate hemlock scale on Fraser fir Christmas Trees in NC. Appalachian Society of American Foresters, January 26-28, 2022, Asheville, NC.

Manz, D.*, R. Jetton, J. Sidebottom, and J. Owen. 2021. Elongate hemlock scale on Fraser fir. North Carolina Christmas Tree Association Winter Meeting, 4 March 2021. (Virtual)

- Projected manuscripts (include target journal name and estimated submission date)

Manz, D., K.L.F. Oten, C.E. Sorenson, and R.M. Jetton. Phenology of the elongate hemlock scale (Hemiptera: Diaspididae) on Fraser fir Christmas trees in western North Carolina. Target Journal: Journal of Economic Entomology.

Manz, D., K.L.F. Oten, C.E. Sorenson, and R.M. Jetton. Evaluating the post-harvest survival and emergence of elongate hemlock scale (Hemiptera: Diaspididae) from Fraser fir Christmas trees. Target Journal: Journal of Economic Entomology.

- Extension publications

None yet