Treatment of lodgepole pine bark with neem demonstrates lack of repellency or feeding deterreny to the mountain pine beetle, Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae)

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ABSTRACT
Recent research indicates that development of coniferophagous bark beetles can be severely disrupted by systemic applications of extracts from seeds of the neem tree, Azadirachta indica A. Jussieu. However, the potential for neem to repel or deter feeding has not been determined. Surface treatment to the run-off point with a neem-based aqueous (2,000 ppm azadirachtin in 10% emulsifiable concentrate in water) to the boles of attractant-based lodgepole pine, Pinus contorta var. latifolia Engelm man, was ineffective at repelling or deterring attack by the mountain pine beetle, Dendroctonus ponderosae Hopkins. Therefore, the activity of neem against the mountain pine beetle is limited to that of a systemically-applied insect growth regulator.

INTRODUCTION
Recent research on direct control of bark beetles (Coleoptera: Scolytidae) has focused on extracts from seeds of the neem tree, Azadirachta indica A. Jussieu (Meliaceae). When emulsifiable concentrates of neem seed extracts were applied at doses ≥ 15 mg per cm of circumference into axil frills at the base of lodgepole pine, Pinus contorta var. latifolia Engelm man, almost complete disruption of development to adults was achieved by systemic action for both the mountain pine beetle, Dendroctonus ponderosae Hopkins (Naumann et al. 1994, Naumann and Rankin 1999), and the pine engraver, Ips pinus Say (Duthie-Holt et al. 1999). Because both species freely attacked neem-treated trees, successfully established galleries, and produced brood larvae that appeared to be unaffected as early instars, it is unlikely that neem applied to axil frills had any repellent or antifeedant activity.

However, against many other insects, neem acts as a repellent and a feeding deterrent (Mordue and Blackwell 1993), rendering plants unattractive or unacceptable to insects. The feeding deterrent effect of neem is caused by the principal active ingredient azadirachtin (Gillani and Simmonds 1995), the most potent natural insect antifeedant discovered to date (Isman et al. 1991).

Our objective was to determine whether neem applied externally to the bark of lodgepole pines had any repellent or feeding deterrent activity against the mountain pine beetle.
MATERIALS AND METHODS

Forty-five uninfested lodgepole pines (mean diam. at 1.3 m = 27.3 ± 3.6 cm) were selected at 25 m intervals in a heavily-infested mature stand on Commander Road, in the Willis Creek drainage, ca. 26 km south of Princeton, BC. The trees were randomly assigned to one of three treatment groups, untrated control, formulation control (10% emulsifiable concentrate formulation in water, with no neem), and neem (2,000 ppm azadirachtin in 10% emulsifiable concentrate formulation in water). The proprietary control and neem formulations were supplied by Neem International Enterprises Inc., Surrey, BC. Two separate back pack sprayers, each with 1.5 m wand extensions and flat fan nozzles, were used to apply the control and neem treatments. On 25 July 1996 trees were sprayed to the run-off point with 1.0 to 1.2 L treatments from the root collar to approximately 5 m up the bole around the entire bole circumference. Tree baits (Phero Tech Inc, Delta, BC), releasing the aggregation pheromones eexo-brevicomin and trans-verbenol (Borden et al. 1993) were then applied approximately 1.5 m high on the north face of each of the 45 trees to challenge mountain pine beetles to attack the trees. On 26 July, 1 August, and 7 August 1996 all trees were examined, and classified as mass attacked if there were ≥ 5 entrance holes in total in 20 x 40 cm areas at eye level on the east and west faces of the tree (≥ 31.25 attacks per m²) (Borden et al. 1983). In October 1996, 20 x 20 cm bark samples were removed at eye level from the east and west faces of each tree. The exposed entrance holes, egg galleries, and larvae were counted, and the total length of egg galleries in each sample was measured. The data were analyzed by ANOVA using general linear models (α = 0.05) (SAS Institute Inc. 1988).

RESULTS

The neem formulation had no effect on mountain pine beetle attack when applied as a spray to the bole of lodgepole pines. When some of the treated trees were inspected at 1900 h on 25 July, ca. 3 h after treatment, most were already under attack, as evidenced by beetles walking on the bark surface and beginning to bore entrance holes. At that time the neem odor was very evident to the authors. All 45 trees were attacked within 1 day of treatment, and confirmed as mass attacked 1 week later. There were no differences between treatments in attack densities, lengths of egg galleries, or numbers larvae per m² (Table 1).

DISCUSSION

Neem-induced repellency and/or feeding deterrence occurred in six families of Coleoptera (Schnitterer 1995), including the Scaptiidae (Sponagel 1993). However, no such effects were seen in our experiments with an emulsifiable-concentrate formulation sprayed on the boles.

Any possible repellency was surmounted, apparently within 3 h, by beetles orienting to and attacking attractive-baited trees, regardless of the neem treatment. At a dose of 2000 ppm azadirachtin with 1.0-1.3 L applied to the lower 5 m of a perfectly cylindrical tree bole with a 27.3 cm diameter, there would be 2.0-2.6 g of active ingredient per tree, or 0.047-0.061 mg per cm² of bark. In comparison, if neem applied at a dose of 1.5 g per tree were to be systematically translocated evenly throughout the lower 10 m of the bole of a perfectly cylindrical tree with a 31.4 cm diameter (Naumann and Rankin 1999), there would be at most 0.015 mg of active ingredient per cm² of inner bark, 3-4 times lower than on the bark surface in our experiment. Because azadirachtin translocates rapidly in conifers (Naumann et al. 1994), it would probably lodge in the upper bole or foliage, as does the arachidonic-monoestradiol methyle araminate (Moshagen et al. 1988), making the

Table 1

<table>
<thead>
<tr>
<th>Criteria measured</th>
<th>Treatment</th>
<th>Attack density per m² (X ±SE)</th>
<th>Number of egg galleries per m² (X ±SE)</th>
<th>Length of egg gallary (cm) per m² (X ±SE)</th>
<th>Number of larvae per m² (X ±SE)</th>
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<tbody>
<tr>
<td></td>
<td>Untrated Control</td>
<td>127.5 ± 16.5</td>
<td>345.0 ± 30.0</td>
<td>4271.3 ± 463.5</td>
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<td>Formulation Control</td>
<td>126.7 ± 11.3</td>
<td>348.3 ± 25.3</td>
<td>4298.8 ± 448.3</td>
<td>1895.0 ± 325.3</td>
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<td></td>
<td>Neem</td>
<td>155.8 ± 13.6</td>
<td>336.7 ± 24.9</td>
<td>4182.8 ± 401.3</td>
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No significant difference between means within any column, G'M test, P>0.05.

actual residual dose in the phloem of the lower bole much less than 0.015 mg per cm². Mountain pine beetles characteristically walk extensively on the bark of lodgepole pines before beginning boring activity. Therefore they would be even more likely to experience a high dose of neem following a surface application to the bark than they would in the phloem of a systemically treated tree. Typically, feeding deterrent activity occurs at <1.5 ppm azadirachtin in Lepidoptera, 100-600 ppm in Coleoptera, Hemiptera and Homoptera, and 0.05-1000 ppm in Orthoptera (Modas and Blackwell 1993), in each case far lower doses than the 2000 ppm applied in our experiment.

Our results constitute strong evidence for the lack of neem-based repellency or feeding deterency for the mountain pine beetle. Naumann and Rankin (1999) found high larval mortality just above the axil of systemically-treated trees, suggesting some degree of acute toxicity at high doses of neem. However, the results of this study, as well as those of Naumann et al. (1994), Duthie-Holt et al. (1999) and Naumann and Rankin (1999) demonstrate that neem must act on the mountain pine beetle primarily as an insect growth regulator.

ACKNOWLEDGEMENTS

We thank Neem International Enterprises Inc. for providing the proprietary neem formulation used in this study. Veyerhansker Canada Ltd., Princeton, BC, for making the research site available, and K. Naumann for critical review of the manuscript. This work was supported by a BC Science Council GREAT Scholarship, a Pinuscop Scholarship, and a SFU Graduate Fellowship, the Natural Sciences and Engineering Research Council of Canada, the Interior Lumber Manufacturers Association, the Cariboo Lumber Manufacturers Association, Phero Tech Inc., Neem International Enterprises Inc., Akinsworth Lumber Co. Ltd., Canadian Forest Products Inc., International Forest Products Inc., Lignum Ltd., Northwood Forest Industries Ltd., Pacific Forest Products Inc,
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Riverside Forest Products, TimberWest Forest Ltd., Tolko Industries Ltd., West Fraser Mills Ltd., Western Forest Products Ltd., and Weyerhaeuser Canada Ltd.

REFERENCES


Laboratory rearing of the eastern hemlock looper (Lepidoptera: Geometridae) on artificial diet and grand fir foliage

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ABSTRACT

This paper describes a technique to rear the eastern hemlock looper, Lambdina fiscella/lasiella (Guen.) on a modified spruce budworm artificial diet and foliage of grand fir, Abies grandis (Doug. ex D. Don). Key words: Lambdina fiscella/lasiella, Abies, artificial diet, rearing.

DISCUSSION

The eastern hemlock looper, Lambdina fiscella/lasiella (Guen.), is distributed from Newfoundeland to Alberta in Canada, and in a serious forest pest at mature stands of balsam fir, Abies balsamea (L.), and eastern hemlock, Tsuga canadensis (L.) Carr. To ensure a continuous and qualitatively uniform supply of this insect for research, efficient and reliable laboratory rearing techniques are needed. Larvae can be successfully reared by feeding early larval instars CSIM (corn, soy flour and milk solids) artificial diet, and later instars foliage of balsam fir (Oridsdale 1975, 1985); however, the lack of availability of balsam fir in western Canada presents a major problem in the laboratory rearing of this species there. Here we describe rearing procedures for eastern hemlock looper, using a spruce budworm artificial diet (Robertson 1979) without formalin, for the first two instars, and foliage of grand fir, A. grandis (Doug. ex D. Don) for later instars. The modified artificial diet was used in this study because of its availability in our laboratory. The grand fir is in the same genus as the balsam fir, a primary host of eastern hemlock looper, and available near our laboratory.

Chesedifolds with eggs of eastern hemlock looper were placed inside of sealed plastic bags that were placed inside of paper bags. To satisfy diapause requirements, eggs on the Chesedifolds were stored in darkrooms at 2-4.0°C, 100% RH for a minimum of 3 months. After diapause, eggs were moved to an iced rearing room with conditions of 20 ± 2°C, 55-60% R.H., and 16:8 h (L:D). The Chesedifolds with eggs were sprayed with distilled water twice before larval hatching. Approximately 9 days after being moved to the rearing room, the eggs started hatching and most of them hatched over 2-4 day period. Over 90% of the eggs hatched.

Newly hatch larvae were transferred with a camel's hair brush into 20-mdiameter cups, at the rate of five larvae per cup. Each cup had previously been half-filled with the artificial diet (Table 1). Larvae in the cups were kept at the above rearing conditions for 2 weeks, and then transferred to rearing containers filled with one-year-old grand fir foliage. The survival of neonates on the artificial diet was greater than 90%, and cannibalism in the cups was lower.