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

MARNIE A. DUTHIE-HOLT

BUGBUSTERS PEST MANAGEMENT INC., P.O. BOX 1750,
PRINCE GEORGE, BC V2L 4V7

JOHN H. BORDEN

CENTRE FOR ENVIRONMENTAL BIOLOGY,
DEPARTMENT OF BIOLOGICAL SCIENCES, SIMON FRASER UNIVERSITY,
8888 UNIVERSITY DRIVE, BURNABY, BC, V5A 1S6

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 insecticide (2,000 ppm azadirachtin in 10% emulsifiable concentrate in water) to the boles of attractant-baited lodgepole pines, *Pinus contorta* var. *latifolia* Engelmann, 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 $\geq$ 15 mg per cm of circumference into axe frills at the base of lodgepole pines, *Pinus contorta* var. *latifolia* Engelmann, 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 pini* 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 axe 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 (Blaney 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; untreated 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 1.3 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 *exo*-brevicomin and *trans*-verbenol (Borden *et al.* 1993) were then stapled 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 classed as mass attacked if there were ≥ 5 entrance holes in total in two 20 x 40 cm areas at eye level on the east and west faces of the tree (≥ 31.25 attacks per m^2) (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 ($\alpha = 0.05$) (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 m^2 (Table 1).

DISCUSSION

Neem-induced repellency and/or feeding deterrency occurs in six families of Coleoptera (Schmutterer 1995), including the Scolytidae (Sponagel 1993). However, no such effects were seen in our experiments with an emulsifiable-concentrate formulation sprayed on the bole.

Any possible repellency was surmounted, apparently within 3 h, by beetles orienting to and attacking attractant-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 cm^2 of bark. In comparison, if neem applied at a dose of 1.5 g per tree were to be systemically 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 cm^2 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 arsenical monosodium methane arsonate (Maclauchlan *et al.* 1988), making the

Table 1
Summary of mountain pine beetle attack characteristics on untreated lodgepole pines, trees sprayed to the run-off point with a formulation control (10% proprietary emulsifiable-concentrate formulation diluted with water), or trees sprayed with neem (2,000 ppm azadirachtin in a 10% emulsiable-concentrate formulation). Commander Road, near Princeton, BC, treated 25 July 1996, 15 trees per treatment. Data from bark samples taken on 8 and 20 October 1996.

	Criteria measured[a]			
Treatment	Attack density per m^2 ($\bar{x}$ ±SE)	Number of egg galleries per m^2 ($\bar{x}$ ±SE)	Length of egg gallery (cm) per m^2 ($\bar{x}$ ±SE)	Number of larvae per m^2 ($\bar{x}$ ±SE)
Untreated Control	127.5 ± 16.5	345.0 ± 30.0	4271.3 ± 463.5	1505.0 ± 347.1
Formulation Control	126.7 ± 11.3	348.3 ± 25.3	4298.8 ± 448.3	1895.0 ± 325.3
Neem	155.8 ± 13.6	336.7 ±24.9	4182.8 ±401.3	1866.7 ± 278.3

[a]No significant difference between means within any column, GLM test, $P>0.05$.

actual residual dose in the phloem of the lower bole much less than 0.015 mg per cm^2. 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 <1-50 ppm azadirachtin in Lepidoptera, 100-600 ppm in Coleoptera, Hemiptera and Homoptera, and 0.05-1000 ppm in Orthoptera (Modue 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 deterrency for the mountain pine beetle. Naumann and Rankin (1999) found high larval mortality just above the axe frill 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, Weyerhaeuser 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 Pissapio 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., Ainsworth Lumber Co. Ltd., Canadian Forest Products Inc., International Forest Products Inc., Lignum Ltd., Northwood Forest Industries Ltd., Pacific Forest Products Inc., Riverside Forest Products, TimberWest Forest Ltd., Tolko Industries Ltd., West Fraser Mills Ltd., Western Forest Products Ltd., and Weyerhaeuser Canada Ltd.

REFERENCES

Blaney, W. M. and M.S.J. Simmonds. 1995. Feeding behaviour. pp. 171-176. In: H. Schmutterer (Ed.) The neem tree. VCH Verlagsgesellschaft, New York.

Borden, J.H., L.J. Chong and M.C. Fuchs. 1983. Application of semiochemicals in post-logging manipulation of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Journal of Economic Entomology 76:1428-1432.

Borden, J.H., L.J. Chong, B.S. Lindgren, E.J. Begin, T.M. Ebata, L.E. Maclauchlan and R.S. Hodgkinson. 1993. A simplified tree bait for the mountain pine beetle. Canadian Journal of Forest Research 23: 1108-1113.

Duthie-Holt, M. A., J. H. Borden and L. J. Rankin. 1999. Translocation and efficacy of a neem-based insecticide in lodgepole pine using *Ips pini* (Coleoptera: Scolytidae) as an indicator species. Journal of Economic Entomology 92: 180-186

Isman, M. B., O. Koul, J. T. Arnason, J. Stewart and G.S. Salloum. 1991. Developing a neem-based insecticide for Canada. Memoirs of the Entomological Society of Canada 159: 39-47.

Maclauchlan, L. E., J. H. Borden and J. M. D'Auria 1988. Distribution of arsenic in lodgepole pines treated with MSMA. Western Journal of Applied Forestry 3: 37-40.

Mordue, J. and A. Blackwell. 1993. Azadirachtin: an update. Journal of Insect Physiology 39: 903-924.

Naumann, K., L. J. Rankin and M. B. Isman. 1994. Systemic action of neem seed extract on mountain pine beetle (Coleoptera: Scolytidae) in lodgepole pine. Journal of Economic Entomology 87: 1580-1585.

Naumann, K. and L. J. Rankin. 1999. Pre-attack systemic applications of a neem-based insecticide for control of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Journal of the Entomological Society of British Columbia 96:13-19.

SAS Institute 1988. User's Guide. SAS Institute, Cary, N.C.

Schmutterer, H. (Ed.) 1995. The neem tree. VCH Verlagsgesellschaft, New York.

Sponagel, K. W. 1993. Untersuchungen zu Aultreten and Bekampfung des Kaffeekirschenkafers *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae) an Rubusta-Kaffee *Coffea canephora* Pierre ex Froehner in Amazonastiefland von Ecuador. Doctor. Thesis, University Giessen, Germany.