SYPHONY FOR PREVENTING INFESTATION OF HIGH-VALUE LODGEPOLE PINE STANDS BY THE MOUNTAIN PINE BEETLE

Richard F. Schmidt

ABSTRACT: Results from experimental deployment of the mountain pine beetle (MPB) (Dendroctonus ponderosae Hopkins) semiochemical varnishes, an antiahesive pheromone component, suggest it may be useful for preventing or suppressing MPB infestations in high-value lodgepole pine stands (Pinus contorta var. latifolia Dougl.). Field measures of the response of MPB to conical traps baited with the standard MPB lure (trans-verbeinol, ecyd-brevicomin, and myrcene) in Utah showed a 90 percent reduction in MPB trapped when varnish was added. Then used experimentally to protect 1-ha lodgepole pine stands in Idaho from further MPB infestation, the treated stands had an average reduction of 48.6 percent in the number of infested trees. Comparable findings have resulted from similar tests conducted in Canada.

INTRODUCTION

There is an obvious need for environmentally acceptable suppression strategies that protect high-value lodgepole pine stands, such as those in travel influence zones, campgrounds, and riparian areas, from infestation by the mountain pine beetle (Dendroctonus ponderosa Hopkins) (MPB). This need has prompted investigations to determine how semiochemicals like verbenone might be used to suppress MPB populations. As a result, the effectiveness of suppression strategies utilizing synthetic semiochemicals to manipulate dispersing mountain pine beetle populations in being field tested to determine how these natural compounds should be deployed to prevent infestation of high-value stands (demon and others, in press; Borden and others 1983; 1987; Lindgren and others, in press). To that end, representatives of the U.S. Environmental Protection Agency (EPA) agree that semiochemicals may be preferable to conventional pesticides in the management of insect pests and encourage their development and use (Booth 1988).

Earliest efforts to exploit semiochemicals for suppression purposes centered on the attractive components that guide flying beetles to suitable hosts. As a result, most field tests were designed to evaluate the most effective deployment of these attractive elements to lure and concentrate beetles in stands targeted for harvesting. Results revealed that beetle populations attracted to treated stands often "spilled over" into surrounding untreated stands that land managers intended to protect (Purvis 1972). At the same time, field tests to evaluate the function of each newly isolated component in a specific pheromone bouquet revealed that bark beetle pheromone systems contained an antiaggregative component (Borden 1982). In general, these components appear to function as a mask that terminates response to the attractive elements, thereby ensuring that the density of attack does not exceed the threshold for optimum brood survival (Borden and others 1987).

SOURCE AND EFFECTIVENESS OF MOUNTAIN PINE BEETLE ANTIAGGREGATIVE COMPONENTS

Verbenone was identified and first isolated from the mountain pine beetle pheromone complex, using the hindwings of newly emerged and feeding female MPB, by Pitman and others (1969). It was also identified from air passed over emergent male/female pairs (Rudinsky and others 1970). The first evidence that verbenone had antiahesive properties resulted from laboratory and field bioassays that showed the (+)-verbenone inhibited MPB response to selected host- and beetle-produced volatiles (Byker and Tandell 1983). Additionally, four other pheromone components isolated from the MPB pheromone have at times exhibited antiaggregative properties. These include eno- and ecyd-brevicomin released by attacking males (Lishey and others 1985; Rudinsky and others 1974; Byker and Rudinsky 1985), frontalin produced by feeding males (Lishey and others 1985; Byker and Lishey 1982), and verbenone and pinocarvone produced by feeding beetles of both sexes (Lishey and others 1983).

Recent field tests in British Columbia (Borden and others 1987), using two reduced rates of eno-brevicomin, failed to confirm the concentration-dependent multifunctional attractive and antiahesive qualities reported by Byker and Rudinsky (1982). Similarly, field tests in Oregon (Lishey and others 1985) failed to substantiate the multifunctional properties of ecyd-brevicomin, confirming its antiahesive qualities at high
Relaxes rates but failing to demonstrate attractive properties at low rates. When used as a tree bait, it elicited a host-specific response. On western white pine, Pinus ponderosa, and other pines, D. Don, it inhibited MBF attack (McKnight 1971; Pitman and others 1970), but on lodgepole pine, P. contorta var. latifolia Doug., attraction was enhanced (Borden and others 1983; McKnight 1979). Field tests in Oregon revealed weak antitriggregatory effects at high concentration (Rodinsky and others 1973) but no marked attack on lodgepole pine in Idaho (Chotelan and Schenk 1984). Trapping experience in which pinecreevers was added to MBF lure reduced the catch by 50 percent (Libby and others 1985).

**ROLE OF VERBENONE IN HOST COLONIZATION**

Results to date suggest the primary antitriggregatory chemosensory that regulates MBF response to its host is C-verbenone. It has been recorded from three sources: (1) female beetles (Pitman and others 1969), (2) auto-oxidation of alpha-pinene to cis- and trans-verbenone, then to verbenone (Bordogna; and others 1968; Lindgren and Bordogna, these proceedings), and (3) oxidation of cis- and trans-verbenone by microorganisms (primarily yeasts) associated with the beetle (Hunt and others, in press; Lindgren and Bordogna, these proceedings).

A complete understanding of the interaction between chemosensory agents that regulates MBF host selection behavior requires all components to be identified and tested at appropriate concentrations in the field. To date, 33 chemosensory chemicals have been isolated from the beetle (Lindgren and Bordogna, these proceedings), and they often elicit conflicting responses from the beetle, depending on test concentrations and methods of deployment (Lindgren and Bordogna, these proceedings). The following conceptual model developed by Bordogna and others (1987) summarizes what is known about the sources of verbenone, the onset of production in relation to the period of attack, and a probable role in regulating the duration and density of attack.

At the onset of attack by female MBF, volatiles (including the host monoterpenes alpha-pinene and myrcene, together with female-produced trans-verbenone) attract additional beetles for the trees. As males reach the tree, they release cimbricinone, which stimulates the initial attraction of females, thereby increasing the level of attraction. As additional males colonize the tree, concentrations of sesquiterpenes 

**VERBENONE FIELD TESTS**

Reducing Response to Attractive Traps

**METHODS**

The MBF lure contained trans-verbenone, cimbricinone, and myrcene (mixed at 2 mg/24 h, 0.2 mg/24 h, and 10 mg/24 h, respectively). Verbenone was dissolved in the standard plastic bubble cap held at 5 mg/24 h/capulse at 25 °C. The test was conducted in naturally lodgepole pine stand surrounded by stands in which MBF populations were building to outbreak levels. The eight test blocks were 30 m square and were separated from one another by 20 m intervals. Funnel traps were hung at each of the four corners of a block. The four treatments—MBF lure, MBF lure with verbenone alone, verbenone alone, and empty traps—were randomly assigned to each of four positions. Effectiveness of verbenone as an antitriggregatory was assessed by the number of MBF caught by treatment. Results—A total of 1,150 MBF were trapped by the four treatments. Verbenone significantly reduced the catch in figure 1. The number and percentage caught by treatment is tabulated below:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBF lure alone</td>
<td>1,083</td>
<td>95.8</td>
</tr>
<tr>
<td>MBF lure with verbenone</td>
<td>7</td>
<td>0.6</td>
</tr>
<tr>
<td>Unbaited trap</td>
<td>22</td>
<td>1.9</td>
</tr>
<tr>
<td>Total</td>
<td>1,112</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The number of MBF responding to the MBF lure with verbenone was significantly less than to the MBF lure alone. Overall, the addition of verbenone to the synthetic MBF lure reduced the catch by 98 percent.

A field test of MBF response to synthetic verbenone in British Columbia indicated that when verbenone alone was added to several MBF funnel traps at 1 or 5 mg/24 h in the presence of the attractive synthetic lure (trans-verbenone, cimbricinone, and myrcene), it reduced the response of male MBF beetles. Although not statistically significant, the reduction in female MBF response followed a similar trend (Borden and others 1987).

Protecting Stands from Infestation

The encouraging results from the studies that used verbenone to suppress catch of MBF in traps prompted a second set of tests to determine the efficacy of verbenone for reducing MBF infestation in selected stands of lodgepole pine (Amman and others, in press). The test was conducted in the Southworth National Recreation Area, ID, while similar tests by Lindgren and others were being conducted in British Columbia (Dowd), during 1987.

The Southworth National Recreation Area was selected for the study because MBF populations in that area were rapidly increasing, providing an opportunity to test the effectiveness of verbenone for preventing infestation of high-value trees in campgrounds, near administrative sites, wildlife sites, and near summer homes. Lodgepole pine 15.2 cm in diameter at breast height (d.b.h.) averaged 20 cm d.b.h. and 144 years old. The stand consisted of 75 percent lodgepole pine; the remainder was mostly Douglas-fir (Pseudotsuga menziesii var. glauca [Balfour] Franco) and a few mixed species (Quinault and Malone Hills). The ratio of infested trees from 1985 to 1986 was 1:1. A survey through the main part of the infestation revealed 57 newly infested trees per hectare. Eighty percent of these were 20 cm and larger d.b.h., those sizes of trees in which MBF reproductive success is least (Cole and others 1976).

**METHODS**

Verbenone-treated blocks had 100 verbenone bubble caps dissolved from Permatex Inc., Vancouver, BC (chemical purity 98.6 percent; optical purity ca. 0-77 percent; 1:1,000), applied in a grid pattern approximately 10 m apart. The capsules were stapled to the north sides of stumps 3 m above ground (fig. 2b). In the blocks treated with MBF tree bait plus verbenone, baits and verbenone bubble caps were distributed as described for each alone. Check blocks were untreated.

All lodgepole pine larger than 15.2 cm d.b.h. were assayed in each block to determine the d.b.h. and number of MBF. Treatment effects were assessed by comparing the percentage of all lodgepole pine 15.2 cm d.b.h. and larger in each block that was infested by MBF in blocks treated with the chemical and control blocks. The number of MBF tree bait blocks was determined by the number of MBF larvae, adults, and egg mass characteristics shown to affect mountain pine beetle reproduction (Dowd and others 1985) and the number of MBF larvae, adults, and egg mass characteristics shown to affect mountain pine beetle reproduction (Dowd and others 1985). The results were analyzed by ANOVA for differences among treatments.

The cardboard containing the MBF lure was stapled 2 in above and level on the north side of a lodgepole pine 20 cm or larger d.b.h. (fig. 2a). MBF tree lures were distributed in the center of the block and at right-angle line direction from the center, approximately 20 m from the outside boundary of the block.
ROLE OF VERBENONE IN HOST COLONIZATION

Results to date suggest the primary antimaggregative neotenochelin that regulates NPB response to its host is (C)-verbenone. It has been recorded from three sources: (1) female beetles (Pitman and others 1983), (2) auto-oxidation of alpha pinene to cis- and trans-verbenol, then to verbenone (Lindgren and others 1984; Lindgren and Borden, these procedures), and (3) evaporation of C12- and trans-verbenol by our own spinners (primarily weevils) associated with the beetle (Hunt and Borden, in press; Lindgren and Borden, these procedures). A complete understanding of the interaction between pheromones that regulate host selection behavior requires all components be identified and tested at appropriate concentrations in the field. To date, 33 neotenochelins have been isolated from the beetle (Lindgren and Borden, these procedures), and they often elicit conflicting responses from the beetle, depending on test concentrations and methods of application (Lindgren and Borden, these procedures). The following conceptual model developed by Borden and others (1987) summarizes what is known about the sources of verbenone, the onset of production in relation to the stage of development and its probable role in regulating the duration and density of attack. At the onset of attack by female NPBs, volatiles (including the host monoterpenes alpha-pinene and myrcene together with female-produced trans-verbenol) attract additional beetles to the tree. As males reach the tree, they release verbenone, which initially attracts only males, thereby reducing the level of attraction. As additional males colonize the tree, concentrations of synthetic verbenone in the air are augmented by the male-produced antimaggregant, foraminol, and additional verbenone released from the female. This reduces the response of males to synthetic verbenone and verbenone, and the host monoterpene begins to decline. At this stage in colonization, it is believed verbenone levels produced by (1) auto-oxidation of the host monoterpene, alpha-pinene, to cis- and trans-verbenol and then to verbenone, and (2) by conversion of cis- and trans-verbenol to verbenone at such concentrations that deter additional beetles from attacking the focusing tree. The effect of these antimaggregants in the field is to determine the efficacy of verbenone for reducing NPB attack.

VERBENONE FIELD TESTS

Reducing Response to Attractive Traps

During the summer of 1986, entomologists from the Environmental Research Institute, in cooperation with personnel from Thoro Tech Inc., Vancouver, BC, conducted tests in the Watash National Forest to high to compare the number of NPB attracted to the standard NPB lure (trans-verbenol, exo-brevicomin, and myrcene) with the lure containing NPB (trans-verbenol, exo-brevicomin, and myrcene) with 80 mg of (C)-verbenone (Shonie and McGregor, in press).

Methods—The NPB lure contained Cis-verbenol, foraminol, and myrcene at 0.7/24 h, 5.2/24 h, and 18 mg/24 h, respectively. Verbenone was contained in the standard plastic bubble cap and released at 5 mg/24 h at 25°C. The test was conducted in a mature lodgepole pine stand surrounded by stands in which NPB populations were building to outbreak level. The light test blocks were 30 m square and were separated from one another by 20 m intervals. Funnel traps were hung at each of the four corners of a block. The four treatments—NPB lure, NPB lure + verbenone, NPB lure + verbenone + untrapped, and empty trap—were randomly assigned to each of four positions. Effectiveness of verbenone as an antimaggregant was assessed by the number of NPB caught by treatment.

Results—A total of 1,150 NPB were trapped by the four treatments. Reliable by block are given in Figure 1. The number and percentage caught by treatment are tabulated below:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPB lure alone</td>
<td>1063</td>
<td>92.8</td>
</tr>
<tr>
<td>NPB lure with verbenone</td>
<td>47</td>
<td>4.0</td>
</tr>
<tr>
<td>Verbenone alone</td>
<td>7</td>
<td>0.6</td>
</tr>
<tr>
<td>Unaffected trap</td>
<td>22</td>
<td>1.9</td>
</tr>
<tr>
<td>Total</td>
<td>1130</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The number of NPB responding to the NPB lure with verbenone was significantly less than that to the NPB lure alone. Overall, the addition of verbenone to the synthetic NPB lure reduced the catch by 95 percent.

A field test of NPB response to synthetic neotenochelin in British Columbia indicated that verbenone reduced the number of beetles attracted to the synthetic NPB lure at 1 or 5 mg/24 h in the presence of the attractive synthetic lure (trans-verbenol, exo-brevicomin, and myrcene), it reduced the response of males to synthetic verbenone, synthetic verbenone, and the host monoterpene began to decline. At this stage in colonization, it is believed verbenone levels produced by (1) auto-oxidation of the host monoterpene, alpha-pinene, to cis- and trans-verbenol and then to verbenone, and (2) by conversion of cis- and trans-verbenol to verbenone at such concentrations that deter additional beetles from attacking the focusing tree. The effect of these antimaggregants in the field is to determine the efficacy of verbenone for reducing NPB infection.

Figures 1a—Number of NPB in lodgepole pine in selected stands of lodgepole pine (Abies and others, in press). The test was conducted in the Watash National Recreation Area, BD, while similar tests by Lindgren and others were being conducted in British Columbia, during 1987.

The Watash National Recreation Area was selected for the study because NPB populations in that area were rapidly increasing, providing an opportunity to test the effectiveness of verbenone for preventing infestation of high-value trees in commercial, near residential sites, wildlife sites, and near summer homes, Lodgepole pines 15.2 cm in diameter and greater in height (d.b.h. herein) averaged 20 m d.b.h., and 144 years old. The stand consisted of 75 percent lodgepole pine; the remainder was Douglas-fir (Pseudotsuga menziesii var. glauca (Banks) Franco) and a few other species (Cupressus lusitanica Michx.). The ratio of infested trees from 1985 to 1986 was 1:1. A survey through the main part of the infestation revealed 57 newly infested trees per hectare. Eighty percent of those were 20 cm and larger d.b.h., those sizes of trees in which NPB reproductive success is least (Cole and others 1976).

Methods—Verbenone was added to the standard plastic bubble cap at 0.25 mg/24 h/encapsule at 25°C in the presence of the NPB control. The number of NPB in the control were the same as those used in the earlier traps (trans-verbenol, 2 mg/24 h; exo-brevicomin, 0.2 mg/24 h; and myrcene, 10 mg/24 h, at 20 m intervals). Treatment consisted of (1) NPB lure, (2) verbenone, (3) NPB lure and verbenone, and (4) blank. Each treatment was applied individually to 1-hectare blocks and replicated four times. Five NPB tree baits were used in each baited block.

The cardboard containing the NPB lure was stapled 2 in above ground level on the north side of a lodgepole pine 20 cm in diameter, d.b.h. (fig. 2a). NPB tree baits were distributed in the center of the block and at equidistant radial points in the center, approximately 10 m apart. The cages were stapled to the north side of each tree 3 m above ground (fig. 2b). In the blocks treated with NPB tree baits plus verbenone, baits and verbenone-hydrated baits were distributed as described for each alone. Check blocks were untreated.

All lodgepole pines larger than 15.2 cm d.b.h. were sampled in each block to determine the d.b.h. and number killed for 1986 and 1987. Treatment effects were assessed by comparing the number of all lodgepole pines larger than 15.2 cm d.b.h. and larger in each block that was infested by NPB. All plots were located on 10-factor basal area plots in each treatment block. Plots were positioned so overlap did not occur—ones at block center and one in each corner. All trees 12.7 cm d.b.h., regardless of species, were tallied. These data were used to calculate percentages of trees that were lodgepole pine, average heights of lodgepole pine, stand basal area, and crown competition. These were analyzed by ANOMA for differences among treatments.

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Results—A significant difference in percentages of infected trees among treatments was shown by ANOVA. Blocks having MBF baits only had a significantly more non-attached trees than other treatments. The effect of verbenone is apparent.

The average percent of lodgepole pine infected by mountain pine beetles in blocks treated with mountain pine beetle tree baits and verbenone is shown here:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MBF tree bait present</th>
<th>MBF tree bait absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbenone present</td>
<td>7.525</td>
<td>0.875</td>
</tr>
<tr>
<td>Verbenone absent</td>
<td>34.425</td>
<td>3.275</td>
</tr>
</tbody>
</table>

Verbenone in the presence of mountain pine beetle tree bait resulted in a 2.3-fold reduction in infested trees.

An examination of the percent change in numbers of MBF-infested trees between 1985 and 1987 for four treatments shows that only in verbenone-treated blocks did an average reduction occur (48.6 percent). However, despite the overall reduction, an increase occurred in three of the four blocks, with a large increase in the fourth block. However, the average increase was 48.7 percent from 1985 to 1987. Changes in infestation in verbenone-treated and check blocks were small when compared to baited blocks, which showed an average infestation increase of 2.75 percent. Blocks containing MBF baits and verbenone had an average infestation increase of 41.8 percent. The large difference in MBF infestation between MBF bait blocks and MBF bait plus verbenone blocks is considered due to the effect of verbenone. This suggests verbenone has considerable potential for reducing infestation of lodgepole pine stands, a conclusion also reached from tests by Lindsey and others (in press) in British Columbia.

Further, infestation differences probably were not related to differences in stand characteristics, since ANOVA failed to detect differences among treatments in percent of trees that were lodgepole pine, d.e.h. of lodgepole pine, basal area, and crown competition factors.

Discussion—Although verbenone-treated blocks had significantly fewer infested trees than blocks with MBF baits, the question remains: Would verbenone-treated stands have shown the significant reduction in MBF infestations without the accompanying source of attraction provided by MBF baits? MBF dispersal may have been altered by the presence of pheromone baits, thereby affecting distribution among the other treatments. At this population level (7.5 infested trees per hectare in 1980), beetles from surrounding stands were probably drawn into the study blocks as indicated by the large increase in infested trees in 1987 (28.5 trees per hectare), especially in blocks containing MBF baits, which had 80.3 infested trees per hectare in 1987. How beetles would respond at higher population levels, or in the absence of the synthetic attractants, could not be deduced from the study. The investigators suggest that MBF may be attracted to the general area of verbenone-treated trees or stands and then infest trees whose concentration and trend are low. Thus, while preventing infestation of treated trees and stands, infestation level of surrounding stands may be increased. Additional tests are under way to clarify this point.

OUTLOOK

The research results described here point to a growing understanding of the effects of pheromones, especially the antin ATTRACTANT compounds, on MBF host selection and aggregation BEHAVIOR, and how they may be used to integrate with existing suppression strategies once registered for operational use. Before these chemical messengers can be exploited to the fullest extent, it is likely several major gaps in our knowledge base regarding chemical deployment will need to be filled. These include (1) a knowledge of the structure of odor plumes and the effect topography and stand microenvironment have on their dispersion and transport, (2) an understanding of the inherent differences in response between individual beetles in a population and between different population levels, (3) knowledge of the effects of environmental dispersion patterns of emerging adults, and (4) responses of associated insects.

Even though this knowledge is lacking, test results obtained to date suggest that verbenone has the potential to prevent MBF infestations from reaching unacceptable levels in high-value lodgepole stands. Further, it is possible for preventing rather than limiting the spread of infestation to be enhanced if used in conjunction with synthetic pheromones deployed to attract the beetles to traps or stands away from the forest to be protected. At this point, test results suggest that verbenone has promise as an environmental dispersant that can be incorporated with other strategies for preventing or suppressing MBF infestations, and therefore warrants the continued need to determine how it can be deployed most effectively.

REFERENCES


Hunt, D. W. A.; Borden, J. R.; Lindsey, B. E.; Gries, G. 1988. The role of autodissociation of aliphatic alcohols in the production of pheromones of Dendroctonus ponderosae (Coleoptera: Curculionidae). unpublished paper on file at Simon Fraser University, Vancouver, BC.


Results—A significant difference in percentages of infected trees among treatments was shown by ANOVA. Blocks having MBP baits only had significantly more non-attacked trees than other treatments. The effect of verbenone is apparent. The average percent of lodgepole pine infected by mountain pine beetle in blocks treated with mountain pine beetle tree baits and verbenone is shown here:

<table>
<thead>
<tr>
<th>MBP tree bait</th>
<th>Verbenone present</th>
<th>Verbenone absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBP tree bait present</td>
<td>7.625</td>
<td>0.875</td>
</tr>
<tr>
<td>MBP tree bait absent</td>
<td>34.425</td>
<td>3.275</td>
</tr>
</tbody>
</table>

Verbenone in the presence of mountain pine beetle tree bait resulted in a 2.5-fold reduction in infected trees.

An examination of the percent change in numbers of MBP-infested trees between 1986 and 1987 for the four treatments shows that only in verbenone-treated blocks did an average reduction occur (-48.6 percent). However, despite the overall reduction, an increase occurred in three of the four blocks. Check stands showed either no change or a decline in three of the four blocks, with a large increase in the fourth block. However, the average increase was 64.7 percent from 1986 to 1987.

Discussion—Although verbenone-treated blocks had significantly fewer infested trees than blocks without the verbenone, the question remains whether verbenone-treated stands have shown the significant reduction in MBP infestation without the accompanying source of attraction provided by MBP baits. MBP dispersal may have been altered by the presence of pheromone baits, thereby affecting distribution among the other treatments. At this population level, 7.9 infested trees per hectare in 1986, beetles from surrounding stands were probably drawn into the study blocks as indicated by the large increase in infested trees in 1987 (27.5 trees per hectare), especially in blocks containing MBP baits, which had 80.3 infested trees per hectare in 1987. More beetles would respond as higher population levels, or in the absence of the synthetic attractants, could not be deduced from the study. The investigators suggest that MBP may be attracted to the general area of verbenone-treated trees or stands and then infests trees whose concentrations are low. Thus, while verbenone infestation of treated trees and stands, infestation level of surrounding stands may be increased. Additional tests are under way to clarify this point.

Outlook
The research results described here point to a growing understanding of the chemistry of pheromonal attractants, especially the antiegg aggregating component, on MBP host selection and aggregation behavior, and how they may best be integrated with existing suppression strategies once registered for operational use. Before these chemical messengers can be exploited to the fullest extent, it is likely several major gaps in our knowledge base regarding pheromonal deployment will need to be filled. These include (1) a knowledge of the structural chemistry of the pheromones and the effect topography and stand microenvironment have on their concentration and transport, (2) an understanding of the inherent differences in response between individual beetles in a population and between different population levels, (3) knowledge of the effects of environmental dispersion patterns of emerging adults, and (4) response of associated insects.

Even though this knowledge is lacking, test results obtained to date suggest that verbenone has the potential to prevent MBP infestations from reaching unacceptable levels in high-value lodgepole stands. Further, its potential for preventing rather than limiting the level of infestation would likely be enhanced if used in combination with synthetic pheromones deployed to attract the beetle to traps or stands away from the site to be protected. At this point, test results suggest that verbenone has promise as an environmental approach that can be incorporated with other strategies for preventing or suppressing MBP infestations, and therefore warrant the continued research needed to determine how it can be deployed most effectively.

References


Liddell, L. M.; Ryker, L. C.; Tendall, K. L., 1985, "Laboratory and field studies of volatiles released by Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae)," Forest Insects and Entomology, 100: 381-392.


MOUNTAIN PINE BEETLE POPULATION MANIPULATION: STRATEGIES—FIRE SUPPRESSION PRACTICES

Eugene L. Lessard

ABSTRACT. Suppression of mountain pine beetle is a viable strategy when implemented at the stand level in conjunction with ongoing vegetation management and is designed to protect a high value resource for a short period of time. There is a need to evaluate all management strategies for mountain pine beetle using an orderly process. Decision analysis is one such process that has demonstrated its utility in pest management.

Before I get into suppression, I would like to define a few terms. A mountain pine beetle EPIDEMIC occurs over an extensive area and consists of a matrix of INFESTATIONS at the stand level. At any one time in an epidemic, an INFESTATION in a stand may be in the epidemic, increasing, outbreak or declining phase. Stands themselves have varying levels of susceptibility which contribute both to the probability of an infestation occurring and to the expected level of infestation. Not all stands become infested and participate in an epidemic. In fact, not all highly susceptible stands participate in a given epidemic.

The history of mountain pine beetle suppression is marked by strategies that were directed at an epidemic and were applied too late in the epidemic cycle at great expense in both dollars and man power. Now often have we spent out the cry for action when massive amounts of tree mortality dented the landscape. Now, how often have we treated thousands of infested trees for three to five consecutive years only to see a general decline in populations in treated and untreated areas alike? Now, how often have we viewed this decline and said "the control worked"? The reality of mountain pine beetle suppression is that we are very effective at what I call the "Vigilance treatment." We can get the red out. Other than "getting the red out" what have we accomplished with mountain pine beetle suppression programs? I'm afraid that most of our accomplishments have a negative connotation. We've convinced a large portion of the public, ourselves included, that suppression is a viable way to manage expanses of forested acres. We've disrupted management plans and effectively delayed ongoing vegetation management that could have reduced stand susceptibility to infestation. We've neglected the resource management objectives of the land manager by implying that all infestations are "bad" and must be suppressed. A line is a say by Hart, Rhyolites best sums up our accomplishments. "Let's do something up here up there." Superficial? We doubt. Cheaper? Not in dollars and even manpower. Suppression costs have escalated from 91.50 per tree in the mid 1970's to $20.00 a tree in 1985. However, cheap in that we have effectively mitigated the land manager's and the public's concern - we got the red out! - without addressing the real and often controversial problem - and epidemic of mature trees.

Our accomplishments in insect suppression are akin to our accomplishments in fire suppression. We've had some real success in suppressing defoliant populations nationwide. The result has been an overall increase in the size of the forest, increase in offfire tree condition, increase in the progression of forest succession and increase in the overall susceptibility of the forest to insects and disease. We've also had real success in suppressing fires in the past. By doing so we've increased the average age of the forest, increased offfire maintenance, increased the progression of succession and increase the overall susceptibility of the forest to all insects and disease. Indirectly mountain pine beetle suppression has produced the same results by negatively impacting ongoing vegetation management. As a consequence, our ability to suppress insect epidemics and put fires out is declining rapidly even as our technology continues to advance.

There is a need to evaluate management strategies in an orderly process. By what process do you value the various alternative strategies? Using decision analysis, a procedure was developed to match management strategy to a land classification system (Freele and Frelew 1990). The procedure first developed a land classification system based on the following criteria:

1. Stand risk to mountain pine beetle infestation
   a. Moderate to high
   b. low

2. Land accessibility or operability
   a. accessible
   b. inaccessible
