Efficacy of verbenone in reducing lodgepole pine infestation by mountain pine beetles in Idaho

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Verbenone, a bark beetle antiaggregative pheromone, was deployed in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) stands in the Sawtooth National Forest, Idaho, U.S.A., to test its efficacy in reducing tree losses to mountain pine beetle (*Dendroctonus ponderosae* Hopkins). Treatments tested were verbenone, mountain pine beetle tree bait, verbenone plus mountain pine beetle tree bait, and a control. Each treatment was applied individually to 1-ha blocks and replicated four times. Treatment effects were measured by percentage of infested (i.e., mass-attacked) lodgepole pine. ANOVA showed a significant treatment effect ($P < 0.005$). Blocks treated with mountain pine beetle tree baits had significantly ($P < 0.002$) higher average percentages of infested trees (24.4%), whereas no significant difference occurred in percentages of infested trees among the other three treatments. Average percentages of infested trees were 0.9% for verbenone, 7.4% for verbenone plus mountain pine beetle tree bait, and 3.3% for the control. A 2.3-fold reduction in infested trees occurred when verbenone was applied to blocks treated with mountain pine beetle tree baits.

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La verbénone, une phéromone antiagrégative du Scolyte de l'écorce, a été répandu dans des peuplements de Pin tordu (*Pinus contorta* Dougl. var. *latifolia* Engelm.) de la Forêt nationale de Sawtooth en Idaho, U.S.A., en vue de vérifier son efficacité pour réduire les pertes en arbres causées par le dendroctone (*Dendroctonus ponderosae* Hopkins). Les traitements expérimentés étaient la verbénone, un leurre du dendroctone, la verbénone additionnée du leurre et un témoin. Chaque traitement était appliqué individuellement à des surfaces de 1 ha et répété quatre fois. Les effets des traitements ont été mesurés d'après la proportion de pins infestés (ayant subi une attaque massive). ANOVA a produit un effet significatif ($P < 0{,}005$). Les surfaces traitées avec les leurres avaient une proportion d'arbres infestés (24,4%) significativement plus élevée en moyenne ($P < 0{,}002$), alors qu'aucune différence significative n'était décelée dans la proportion des arbres infestés parmi les trois autres traitements. La proportion moyenne des arbres infestés était de 0,9% (verbénone), 7,4% (verbénone additionnée du leurre) et 3,3% (témoin). Une diminution de 2,3 fois dans le nombre d'arbres infestés a été réalisée lorsque la verbénone était appliquée aux surfaces traitées avec les leurres.
[Traduit par la revue]

Introduction

The presence of verbenone in the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) pheromone complex was first reported by Pitman et al. (1969). Since that discovery, verbenone has been determined to be one of five components in the complement of MPB pheromones that have at times exhibited antiaggregative properties. The other four include *endo*-brevicomin and *exo*-brevicomin released by attacking males (Rudinsky et al. 1974; Ryker and Rudinsky 1982; Libbey et al. 1985), frontalin produced by feeding males (Ryker and Libbey 1982; Libbey et al. 1985), and verbenone and pinocarvone produced by feeding beetles of both sexes (Libbey et al. 1985).

Field tests in British Columbia (Borden et al. 1987), using two release rates of *endo*-brevicomin, failed to confirm the concentration-dependent, multifunctional attractive and antiaggregative qualities reported by Ryker and Rudinsky (1982). Similarly, field tests in Oregon (Libbey et al. 1985) failed to substantiate the multifunctional properties of *exo*-brevicomin, confirming its antiaggregative qualities at high release rates but failing to demonstrate attractive properties at low rates. On western white pine (*Pinus monticola* Dougl.), *exo*-brevicomin inhibited MPB attack (McKnight 1979; Pitman et al. 1978), whereas on lodgepole pine (*P. contorta* Dougl.), attack was enhanced (McKnight 1979; Borden et al. 1983).

Field tests of frontalin in Oregon revealed that it had antiaggregative effects at high concentration. However, frontalin induced attack on lodgepole pine in Idaho (Chatelain and Schenk 1984). Trapping experiments in which pinocarvone was added to MPB lure reduced the catch by 50% (Libbey et al. 1985).

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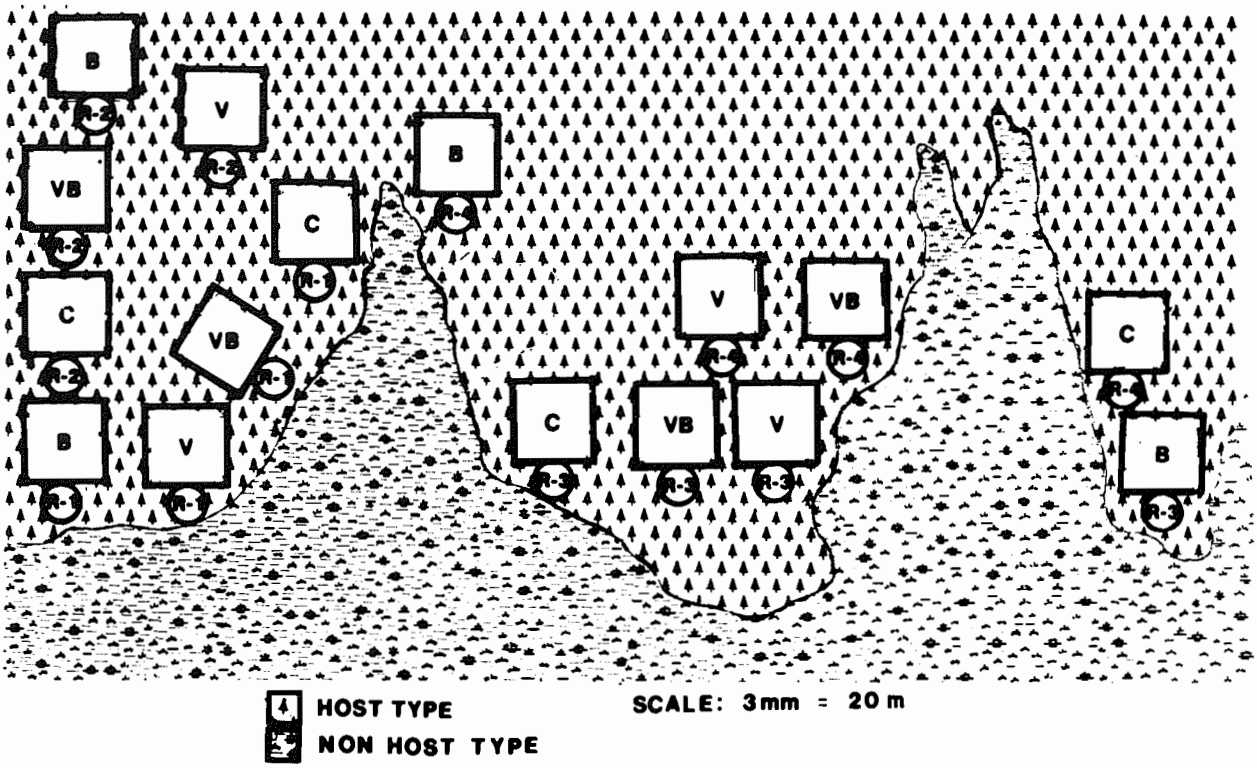

FIG. 1. Locations of blocks and replicates. Treatments are as follows: V, verbenone; B, mountain pine beetle bait; VB, verbenone plus mountain pine beetle bait; C, control. Numbers indicate replicate to which block belongs.

The primary antiaggregative semiochemical appears to be verbenone (4,6,6-trimethylbicyclo(3.1.1)-hept-3-en-2-one), which is derived from three sources: female beetles, autoxidation of α-pinene, and microorganisms (primarily yeasts) growing in established galleries (Borden et al. 1987). Field tests of MPB response in British Columbia revealed that verbenone, when released in funnel traps at 1 or 5 mg/24 h in the presence of the attractive synthetic MPB lure (*trans*-verbenol, *exo*-brevicomin, and myrcene), reduced the response of males by approximately 75%. Although not statistically significant, the reduction in female response followed a similar trend (Borden et al. 1987). In Utah, R.F. Schmitz and M.D. McGregor (unpublished results) observed a 97% reduction in catch in funnel traps baited with the MPB lure and verbenone, compared with catch in traps baited with MPB lure alone.

Based on the results of these studies using verbenone to suppress catch of MPB in traps, we began a field test of the efficacy of verbenone in the Sawtooth National Recreation Area, Idaho, U.S.A. in 1987, while similar tests were being conducted by Lindgren et al. (1989) in British Columbia, Canada. The objective of the tests was to determine the efficacy of verbenone in reducing MPB infestation in stands of lodgepole pine.

Study area

Sawtooth Valley in the Sawtooth National Recreation Area was selected for our study because the MPB population in that area was rapidly increasing, and verbenone offers the potential to prevent infestation of high-value trees in campgrounds, near administrative sites, in wildlife sites, and near summer homes. Elevation of the area is 2256 m above sea level. Lodgepole pines of 15.2 cm and larger diameter at breast height (dbh) averaged 20 cm dbh and 144 years old. The stand consisted of 75% lodgepole pine, the remainder being mostly Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and a few quaking aspen (*Populus tremuloides* Michx.). The ratio of infested to noninfested trees from 1985 to 1986 was 1:8. A survey through the main part of the infestation revealed 57 newly infested trees per hectare, 80% of which were 20 cm and larger dbh; these are sizes in which MPB reproductive success is greatest (Cole et al. 1976).

Methods

A 2 × 2 factorial design, replicated four times, was used to test verbenone (released at the rate of 5 mg/capsule per 24 h at 25°C) in the presence of the MPB tree bait. Constituents of the bait would release at 25°C at the following rates: *trans*-verbenol, 2 mg/24 h; *exo*-brevicomin, 0.2 mg/24 h; and myrcene, 18 mg/24 h. Treatments consisted of (*i*) MPB tree bait, (*ii*) verbenone, (*iii*) MPB tree bait and verbenone, and (*iv*) control. Each treatment was applied individually to 1-ha blocks and replicated four times. Blocks were generally 20–60 m apart, but up to 360 m apart where sagebrush meadows occurred (Fig. 1). All replicates were within the Beaver Creek drainage, in an area approximately 1 km wide and 1.5 km long on one sidehill ranging in elevation from 2200 to 2300 m.

The order of treatments within a replicate was determined randomly by drawing names of treatments out of a hat, and the same order was followed throughout all replicates to avoid giving the same treatment to adjacent blocks (Fig. 1). Five MPB tree baits were used in each baited block. The cardboard containing the bait was stapled 2 m above ground level on the north side of a lodgepole pine of 20 cm or larger dbh. Baits were distributed in the center of the block and at each cardinal direction from the center, approximately 20 m from the outside boundary of the block. Verbenone-treated blocks received 100 verbenone bubble capsules[1] (chemical

[1]Pheromone products were obtained from Phero Tech Inc., Vancouver, B.C., Canada. The use of trade or company names in this paper is for information only and does not imply endorsement by the USDA Forest Service.

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TABLE 1. ANOVA sums of squares partitioned among treatments

Source	df	Mean square	$P > F$
Replicates	3	0.0342	0.1884
MPB bait	1	0.3496	0.0015
Verbenone	1	0.0589	0.0982
Interaction	1	0.0483	0.1294
Error	9	0.0173	

TABLE 2. Average percentage of lodgepole pine infested by mountain pine beetle in blocks treated with mountain pine beetle tree baits and verbenone

	MPB tree bait	
	Present	Absent
Verbenone present	7.425	0.875
Verbenone absent	24.425	3.275

purity 98.6%, optical purity, enantiomeric excess = (−)72%), applied in a grid pattern, approximately 10 m apart. The capsules were stapled to the north side of the tree, 2 m above ground. In the blocks treated with MPB tree bait plus verbenone, baits and verbenone bubble capsules were distributed as described for each alone. Control blocks were untreated.

We made 100% surveys of the blocks to measure the diameter at breast height of all lodgepole pine 15.2 cm and larger, and to determine numbers of infested (i.e., killed) trees each year in 1986 and 1987. Because of unseasonably warm temperatures, which could have caused early MPB emergence, treatments were applied the 1st week in June 1987. All beetles were assumed to have flown by mid-August when the treatment effects were assessed.

Treatment effects were measured by the percentage of all lodgepole pine of 15.2 cm and larger dbh in each block that was infested by MPB in 1987. Percentages of infested trees were arc sine square root transformed and analyzed by ANOVA. Because of the importance of stand characteristics to mountain pine beetle infestation behavior (Cole and Amman 1980), stand measurements were made on five plots using a 10-BAF angle gauge in each treatment block, one in the center and one in each corner so that overlap did not occur. All trees of all species of 12.7 cm dbh were tallied. From these data, percentages of the trees that were lodgepole pine, average diameter at breast height of lodgepole pine, stand basal area, and crown competition (Krajicek et al. 1961) were calculated and analyzed by ANOVA for differences among treatments.

Results and discussion

A significant difference in percentages of infested trees among treatments was shown by ANOVA ($P < 0.005$). Blocks having MPB baits only had significantly more mass-attacked trees than did other treatments ($P < 0.002$) (Table 1). The other treatments did not differ significantly, but the $P > F$ for verbenone was less than 0.1. A larger test (more replicates) probably would have resulted in the effect of verbenone being significantly different from that of the other treatments. The effect of verbenone is more readily apparent in a table of means (Table 2). Verbenone in the presence of MPB tree bait resulted in a 2.3-fold reduction in infested trees.

An examination of the percent change in numbers of MPB-infested trees between 1986 and 1987 for the four treatments shows that only in verbenone-treated blocks did an average reduction occur (−48.6%) (Table 3). However, despite the overall reduction, an increase occurred in three of the four blocks. Control 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% from 1986 to 1987. Changes in infestation in verbenone-treated and control blocks were small compared with those in baited blocks, which showed an average infestation increase of 2575%. Blocks containing MPB baits and verbenone had an average infestation increase of 418.8%. The large difference in MPB infestation between MPB bait blocks and MPB bait plus verbenone blocks is considered to be due to the verbenone treatment. This suggests that verbenone has considerable potential for reducing infestation of lodgepole pine stands, a conclusion also reached by Lindgren et al. (1989) from tests in British Columbia.

Differences in infestation were probably not related to differences in stand characteristics, as ANOVA failed to detect differences among treatments in percentages of trees that were lodgepole pine ($P > 0.81$), diameter at breast height of lodgepole pine ($P > 0.65$), basal area ($P > 0.51$), and crown competition factor ($P > 0.53$) (Table 4). The lack of significant difference in percentages of infested trees among replicates suggests that there was no position effect among replicates (Table 1).

Although verbenone-treated blocks had significantly fewer infested trees than blocks with MPB baits, the question remains: Can verbenone significantly reduce MPB infestation without an accompanying source of attraction, such as that provided by MPB baits? In our test, MPB were apparently manipulated by the presence of pheromone baits, and this affected distribution among the other treatments. At this population level (3.7 infested trees/ha 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/ha), especially in blocks containing MPB baits, which had 80.3 infested trees/ha in 1987. How beetles would respond at higher population levels, or in the absence of the synthetic attractants, cannot be deduced from our study. MPB may be attracted to the general area of verbenone-treated trees or stands and then infest trees where verbenone concentrations are low. Thus, while infestation of treated trees and stands is prevented, infestation level of surrounding stands may be increased. Additional tests are needed to clarify this point.

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TABLE 3. Numbers of lodgepole pine killed per hectare by mountain pine beetles before and during a test of the efficacy of verbenone to prevent beetle infestation, Sawtooth National Forest, Idaho, U.S.A., 1987

	Replicate				
	1	2	3	4	Avg.
MPB bait					
Attacks (no./ha)					
Older	0	7	67	8	20.5
1986	6	2	3	1	3.0
1987	142	11	116	52	80.3
% change, 1986–1987	2266.7	450.0	3766.7	5100.0	2576.7
Verbenone					
Attacks (no./ha)					
Older	0	10	0	5	3.8
1986	0	14	0	0	3.5
1987	2	0	2	3	1.8
% change, 1986–1987	200.0	−1400.0	200.0	300.0	−48.6
MPB bait + verbenone					
Attacks (no./ha)					
Older	2	1	15	5	5.8
1986	0	2	14	0	4.0
1987	16	8	20	39	20.8
% change, 1986–1987	1600.0	300.0	42.9	3900.0	420.0
Control					
Attacks (no./ha)					
Older	7	0	4	2	3.3
1986	3	0	14	0	4.3
1987	0	0	0	28	7.0
% change, 1986–1987	−300.0	0.0	−1400.0	2800.0	62.8
Combined					
Attacks (no./ha)					
Older	2.3	4.5	21.5	5.0	8.3
1986	2.3	4.5	7.8	0.3	3.7
1987	40.0	4.8	34.5	30.5	27.5
% change, 1986–1987	1639.1	6.7	342.3	9166.7	643.2

TABLE 4. Characteristics of lodgepole pine stands receiving different mountain pine beetle pheromone treatments and percentages of trees mass attacked, Sawtooth National Forest, Idaho, U.S.A., 1987

	MPB bait		Verbenone		MPB bait + verbenone		Control	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
No. of lodgepole pine/ha[a]	312.3*b*	173.3	208.0*a*	45.0	293.5*a*	120.3	297.8*a*	114.7
% lodgepole pine in stands	76.3*a*	15.1	69.3*a*	24.9	80.5*a*	10.9	76.6*a*	14.6
% mass attacked (1987)	24.4*a*	16.9	0.9*b*	0.6	7.4*b*	4.5	3.3*b*	6.6
Diameter at breast height (cm)	18.7*a*	1.0	18.2*a*	1.1	19.4*a*	0.2	20.0*a*	2.1
Crown competition factor	124.8*a*	26.3	100.8*a*	36.3	97.9*a*	18.2	107.5*a*	28.8
Basal area (m^2/ha)	25.3*a*	5.9	19.1*a*	4.8	20.2*a*	4.3	22.0*a*	7.3

NOTE: within rows, values followed by the same letter are not significantly different ($P > 0.05$).
[a]Trees of 15.2 cm and larger dbh.

Sartwell, Pacific Northwest Forest and Range Experiment Station, Corvallis, OR; Dr. Hal Wieser, University of Calgary, Calgary, Alta.; and Ken Gibson, Forest Pest Management, Northern Region, Missoula, MT.

BORDEN, J.H., CONN, J.E., FRISKIE, L.M., SCOTT, B.E., CHONG, L.J., PIERCE, H.D., JR., and OEHLSCHLAGER, A.C. 1983. Semiochemicals for the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), in British Columbia: baited-tree studies. Can. J. For. Res. **13**: 325–333.

BORDEN, J.H., RYKER, L.C., CHONG, L.J., PIERCE, H.D., JR., JOHNSTON, B.D., and OEHLSCHLAGER, A.C. 1987. Response of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), to five semiochemicals in British Columbia lodgepole pine forests. Can. J. For. Res. **17**: 118–128.

CHATELAIN, M.P., and SCHENK, J.A. 1984. Evaluation of frontalin and *exo*-brevicomin as kairomones to control mountain pine beetle in lodgepole pine. Environ. Entomol. **13**: 1666–1674.

COLE, W.E., and AMMAN, G.D. 1980. Mountain pine beetle dynamics in lodgepole pine forests. Part I. Course of an infestation. USDA For. Serv. Gen. Tech. Rep. INT-89.

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COLE, W.E., AMMAN, G.D., and JENSEN, C.E. 1976. Mathematical models for the mountain pine beetle–lodgepole pine interaction. Environ. Entomol. **5**: 11–19.

KRAJICEK, J.E., BRINKMAN, K.A., and GINGRICH, S.F. 1961. Crown competition: a measure of density. For. Sci. **7**: 35–42.

LIBBEY, L.M., RYKER, L.C., and YANDELL, K.L. 1985. Laboratory and field studies of volatiles released by *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Z. Angew. Entomol. **100**: 381–392.

LINDGREN, B.S., BORDEN, J.H., CUSHON, G.H., CHONG, L.J., and HIGGINS, C.J. 1989. Reduction of mountain pine beetle (Coleoptera: Scolytidae) attacks by verbenone in lodgepole pine stands in British Columbia. Can. J. For. Res. **19**: 65–68.

MCKNIGHT, R.C. 1979. Differences in response among populations of *Dendroctonus ponderosae* Hopkins to its pheromone complex. M.Sc. thesis, University of Washington, Seattle.

PITMAN, G.B., VITÉ, J.P., KINZER, G.W., and FENTIMAN, A.F., JR. 1969. Specificity of population-aggregating pheromones in *Dendroctonus*. J. Insect Physiol. **15**: 363–366.

PITMAN, G.B., STOCK, M.W., and MCKNIGHT, R.C. 1978. Pheromone application in mountain pine beetle/lodgepole pine management: theory and practice. *In* Theory and Practice of Mountain Pine Beetle Management in Lodgepole Pine Forests: Symposium Proceedings, Washington State University, Pullman, 25–27 April 1978. *Edited by* A.A. Berryman, G.D. Amman, and R.W. Stark. Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. pp. 165–173.

RUDINSKY, J.A., MORGAN, M.E., LIBBEY, L.M., and PUTNAM, T.B. 1974. Antiaggregative-rivalry pheromone of the mountain pine beetle, and a new arrestant of the southern pine beetle. Environ. Entomol. **3**: 90–98.

RYKER, L.C., and LIBBEY, L.M. 1982. Frontalin in the male mountain pine beetle. J. Chem. Ecol. **8**: 1399–1409.

RYKER, L.C., and RUDINSKY, J.A. 1982. Field bioassay of *exo*- and *endo*-brevicomin as antiaggregation pheromones for *Dendroctonus ponderosae* in lodgepole pine. J. Chem. Ecol. **8**: 701–707.

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2. Christopher J. Fettig, Stephen R. McKelvey, Christopher P. Dabney, Dezene P. W. Huber, Cameron G. Lait, Donald L. Fowler, John H. Borden. 2012. Efficacy of "Verbenone Plus" for Protecting Ponderosa Pine Trees and Stands From <I>Dendroctonus brevicomis</I> (Coleoptera: Curculionidae) Attack in British Columbia and California. *Journal of Economic Entomology* **105**:5, 1668-1680. [CrossRef]
3. Carlos Alberto Hector Flechtmann, Vinicius Gomes Tabet, Ingrid Quintero. 2009. Influence of carrion smell and rebaiting time on the efficiency of pitfall traps to dung beetle sampling. *Entomologia Experimentalis et Applicata* **132**:3, 211-217. [CrossRef]
4. Andrew D. Graves, Edward H. Holsten, Mark E. Ascerno, Kenneth P. Zogas, John S. Hard, Dezene P.W. Huber, Robert A. Blanchette, Steven J. Seybold. 2008. Protection of spruce from colonization by the bark beetle, Ips perturbatus, in Alaska. *Forest Ecology and Management* **256**:11, 1825-1839. [CrossRef]
5. Nicholas C. Coops, Joleen A. Timko, Michael A. Wulder, Joanne C. White, Stephanie M. Ortlepp. 2008. Investigating the effectiveness of Mountain Pine Beetle mitigation strategies. *International Journal of Pest Management* **54**:2, 151-165. [CrossRef]
6. M.A. Wulder, J.C. White, B. Bentz, M.F. Alvarez, N.C. Coops. 2006. Estimating the probability of mountain pine beetle red-attack damage. *Remote Sensing of Environment* **101**:2, 150-166. [CrossRef]
7. B. Staffan Lindgren, Daniel R. Miller. 2002. Effect of Verbenone on Attraction of Predatory and Woodboring Beetles (Coleoptera) to Kairomones in Lodgepole Pine Forests. *Environmental Entomology* **31**:5, 766-773. [CrossRef]
8. B. Staffan Lindgren, Daniel R. Miller. 2002. Effect of Verbenone on Five Species of Bark Beetles (Coleoptera: Scolytidae) in Lodgepole Pine Forests. *Environmental Entomology* **31**:5, 759-765. [CrossRef]
9. I. M. Wilson, J. H. Borden, R. Gries, G. Gries. 1996. Green leaf volatiles as antiaggregants for the mountain pine beetle,Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae). *Journal of Chemical Ecology* **22**:10, 1861-1875. [CrossRef]
10. Jane Leslie Hayes, Brian L. Strom, Lary M. Roton, Leonard L. Ingram. 1994. Repellent properties of the host compound 4-allylanisole to the southern pine beetle. *Journal of Chemical Ecology* **20**:7, 1595-1615. [CrossRef]
11. T. L. Shore, L. Safranyak, B. S. Lindgren. 1992. The response of mountain pine beetle (Dendroctonus ponderosae) to lodgepole pine trees baited with verbenone and exo-brevicomin. *Journal of Chemical Ecology* **18**:4, 533-541. [CrossRef]
12. L. Safranyik, T. L. Shore, D. A. Linton, B. S. Lindgren. 1992. The effect of verbenone on dispersal and attack of the mountain pine beetle, Dendroctonus ponderosae Hopk. (Col., Scolytidae) in a lodgepole pine stand. *Journal of Applied Entomology* **113**:1-5, 391-397. [CrossRef]