United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

Research Note
SE-355

April 1990

Field Tests of Pine Oil as a Repellent for Southern Pine Bark Beetles

J.C. Nord, F.L. Hastings, and A.S. Jones

ABSTRACT

An experimental mixture of terpene hydrocarbons derived from wood pulping, BBR-2, sprayed on the lower 6 m of widely separated southern pine trees did not protect nearby trees from southern pine beetle attacks. Whether treated trees were protected from southern pine beetle was inconclusive. The pine oil mixture did not repel *Ips* from treated trees or nearby untreated trees. Black turpentine beetles were attracted either by pine oil or by the resinosis and injury of the host caused by the pine oil. The pine oil was phytotoxic to treated trees, causing resinosis, mottling of the inner phloem and outer xylem tissue, and mortality. This is the first report of phytotoxicity to conifers.

Keywords: *Dendroctonus frontalis, D. terebrans, Ips grandicollis, Pinus taeda, P. echinata, P. virginiana,* BBR-2, phytotoxicity.

Nijholt (1980), Nijholt and McMullen (1980), and Nijholt and others (1981) reported that Norpine-65 (Northwest Petrochemical Corp., Anacortes, WA), a mixture of terpenes, terpene alcohols, and other minor constituents[1] derived as a byproduct of sulphate wood pulping of firs, hemlock, and pine, was active as a repellent of ambrosia beetles and three species of Dendroctonus bark beetles when sprayed undiluted on logs and living trees in British Columbia. Norpine-65 and an experimental mixture of terpene hydrocarbons selected for repellency to various species of bark beetles, BBR-2 (Safer Agro-Chem Ltd., Victoria, British Columbia, Canada), repelled mountain pine beetles, *D. ponderosae* Hopkins, (Richmond 1985, 1986; McMullen and Safranyik 1985) and spruce beetle, *D. rufipennis* (Kirby), (Werner and others 1986). Repelling of southern pine beetles (SPB), *D. frontalis* Zimmermann, was observed in a study by O'Donnell and others (1986) with Norpine-65 and in a study by Berisford and others (1986) with BBR-2. In the Berisford and others (1986) study, BBR-2 did not repel *Ips grandicollis* (Eichhoff) or black turpentine beetle (BTB), *D. terebrans* (Olivier).

In this Note we report attempts to determine whether BBR-2 repels SPB from treated trees located in the path of an advancing SPB spot head and from untreated adjacent trees. Results are inconclusive because spot expansion failed to occur in most cases, but potentially valuable observations are made on SPB, BTB, and *Ips* activity, and there was a strong indication that BBR-2 is phytotoxic to three southern pine species. Those results are reported here. A general description of the methods used is given; further details may be obtained from the authors.

Methods

Location and Stand Characteristics

Trees in the path of eight active SPB spots in the Piedmont of South Carolina were treated with pine oil in 1983. Table 1 gives locations and stand characteristics for each of these SPB spots. Spot selection criteria were: (1) 20 or more newly attacked green trees with apparently healthy SPB brood, (2) a minimum pine basal area of 18.4 m^2/ha, and (3) a spot head width and stand depth of 20 meters or more in the path of spot expansion.

The authors are, respectively, Research Entomologist, USDA Forest Service, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, GA, and Research Entomologist and Research Microbiologist, USDA Forest Service, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Research Triangle Park, NC.

[1] **Nijholt (1980) gives the gaschromatographic analysis of Norpine-65.**

Table 1 -Southern pine beetle spots in South Carolina where BBR-2 was sprayed onto pine boles for repellency, 1983

County and study area	Treatment date	Test trees: Number treated	Number controls	Spp.[a]	Average height	Average d.b.h.	Stand basal area	spot expansion[b]
					m	*cm*	*m²/ha*	
Oconee								
Oconee Point	July 20	2	2	SL	—[c]	—[c]	—[c]	
Reedy Fork	21	8	8	L	20.9	19.8	56.4	+
Route 488	26	4	0	SL, V	21.5	21.1	32.8	
Cherokee								
Route 50	Aug. 23	2	2	—[c]	—[c]	—[c]	—[c]	
I-85	24	2	2	SL	—[e]	19.3	31.7	
Spartanburg								
Chesnee	Sept. 14	5	0	SL, v	13.5	26.1	30.7	
Glenn Springs	20	10	0	SL, L	13.5	18.4	28.2	
Clifton	22	4	0	SL	23.3	21.9	34.0	

[a] SL = shortleaf pine; L = loblolly pine; V = Virginia pine.
[b] SPB spot salvaged before data taken.
[c] + = spot expanded; - = spot did not expand.
[d] One SL.
[e] Data not recorded.

Treatment

The trunks of test trees were sprayed to runoff with undiluted Safer BBR-2[2] from a height of 6 m (height marked with a band of marking tape) to the ground with a compressed-air garden sprayer. The trees were treated the same day the spot head was marked or early the next morning. Test trees were not baited with pheromone to induce attack.

Experimental Layout

The active head of each spot was carefully delineated by flagging newly infested trees after examining the trunks at ground level and up to 8 m for evidence of attack (pitch tubes, red and/or white boring dust expelled from entrance holes, or the presence of clerid adults running over the bark in search of bark beetle prey) using 8.5-m extension ladders. Trees were examined in this manner within 7 m of the apparent head to make sure the extent of spot expansion was known. Then pairs of trees receiving randomly assigned treatments (sprayed and unsprayed) were located 5 and 15 m beyond the head. Trees in each pair were separated from each other by a distance of 10 m (fig. 1). Of course, because these SPB spots were located in natural stands, the 10-m spacing between test trees was approximate and minimum. Trees were sometimes slightly more than 10 m apart. Test trees were dominants and codominants and apparently healthy.

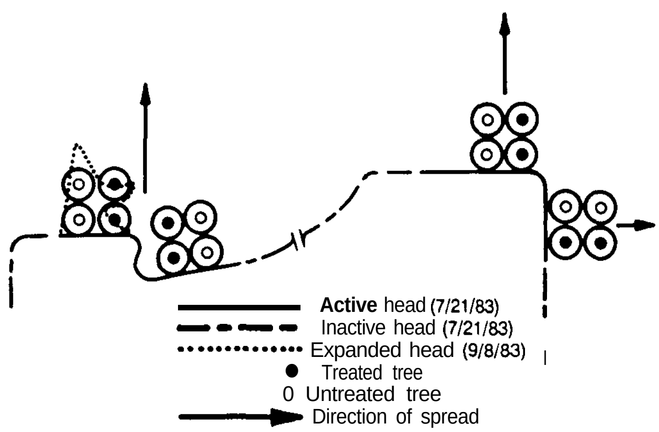

Figure 1 -Southern pine beetle spot with active heads at left and right, layout of test trees, and 5-m-radius circular plots. (BBR-2 test at Reedy Fork study area in South Carolina, 1983.)

[2]BBR-2 is generally described as a mixture of terpene hydrocarbons which varies somewhat from batch to batch because it is a byproduct of the wood pulping process. The repellent ingredient(s) is unknown. For more detailed information about composition, one should contact Safer Agro-Chem Ltd., Victoria, British Columbia.

Evaluation
When the head moved past the treated trees (4-6 weeks after treatment), the treated and control trees were examined to midboie and classified as "attacked" or "unattacked" by SPB and/or *Ips*. All trees within a 5-m radius of the test trees were recorded as to bearing and distance from each test tree, and each was classed by the above procedures as 'attacked" or "unattacked." Additional information was recorded for these trees: tree species, crown class, diameter at breast height (d.b.h.); i.e., 1.4 m above ground. Bark was peeled off trees to determine species of attacking beetles and their success. No bark was disturbed until the spot had moved past the treated trees or had died out, so no new attractive source was created before the end of the test.

Since SPB spot expansion occurred only in one area (Reedy Fork) and since it was limited on that area, statistical analyses were not done. If spots had expanded as anticipated, the study design would have permitted statistical comparisons between treatments in terms of incidence of attack on treated versus control trees using a contingency table (Steel and Torrie 1960). The analysis of the area effect of the repellent on trees adjacent to treated trees would have utilized a paired t-test if the number of trees within the 5-m radius was >15 and the percentage of attack was spread over a range; otherwise, a sign test would have been utilized (Snedecor and Cochran 1967). Pairs in which both test trees are unattacked, as well as all trees within a 5-m radius of both test trees, were not to be used in the analyses. Since the analysis had to be abandoned, the reported results are anecdotal.

Results and Discussion

SPB Responses
Repellency from treated trees. Only one sector (A) of the SPB spot head at Reedy Fork expanded into the area near the two treated test trees (fig.1). In that sector, both control trees (A-l and A-3) were mass attacked and killed by SPB and *Ips* within 4 weeks of plot installation. Both BBR-2-treated trees were attacked by *Ips* but not by SPB. One treated tree, A-4, was unsuccessfully attacked by *Ips* above the spray zone and it lived; the other, A-2, was attacked moderately by *I. grandicollis* and it died. Neither sprayed tree was attacked by SPB but both trees were on the edge of the spot expansion, as indicated by several unattacked trees within 5 m mostly in the northerly and westerly directions (fig. 1). Hence, the treated trees may have escaped attacks by chance, and we cannot say that the pine oil protected them from SPB attack.

Berisford and others (1986) baited treated loblolly pine (*Pinus taeda* L.) bolts with SPB attractant (Frontalure) to promote attack and found a reduction in beetle visits and no attacks on treated bolts for 2 months after treatment with BBR-2. They therefore concluded that BBR-2 was repellent to SPB. In another study in which treated loblolly and shortleaf (*P. echinata* Mill.) pines were baited with Frontalure, O'Donnell and others (1986) observed a reduction in beetle visits and attacks for only 1 week, and attacks increased thereafter. All treated trees eventually died from beetle attack, nine from SPB mass attack 2 weeks after treatment and six from SPB and *Ips* sometime later. So the repellent action did not last very long. It is possible that mass attacks would not have occurred if Frontalure had not been applied to bait the trees.

Frontalure was used in the above tests to make sure beetles came to treated trees, but it may produce an unfair test of a repellent. Nijholt (unpublished information obtained through telephone conversation with W.W. Nijholt, Safer Agro-Chem Ltd., Victoria, British Columbia) believes that on unbaited trees pine oil repels individual beetles or small numbers of pioneer beetles landing on the tree. Therefore, secondary attractants are never produced on the tree and mass attack does not occur. If secondary attractants are abundant on the tree, as when a treated tree is baited, the repellency may be overwhelmed and mass attack may occur. This is the reason we did not apply Frontalure to pine oil-treated trees in the path of SPB spot expansion.

Area effect. Most of the trees surrounding the two control trees in front of the spot expansion at Reedy Fork were attacked and killed by a mixed population of SPB and *Ips*. In fact, four trees within 5 m of one control tree were all that were unattacked, and these were the only survivors. More trees survived around the treated trees (36-38 percent), but the head seemed to expand up to the treated trees and stop (fig. 1). However, 12 trees within 5 m of BBR-2-treated trees were successfully attacked by SPB or SPB and *Ips*. Of those, two were within 2 to 3 m, and three were less than 2 m from the treated trees. Thus, even if there was a repellent effect of BBR-2 on a treated tree, there was little area effect, if any, on SPB attacking the adjacent trees.

Berisford (unpublished information obtained through telephone conversation with C.W. Berisford, Department of Entomology, University of Georgia, Athens, GA) found no evidence that BBR-2 had an area effect on SPB. Check bolts within 2 m of treated bolts were attacked, and all trees in which treated bolts were hung were attacked by SPB. O'Donnell and others

(1986) found SPB attacks in apparently untreated bark crevices on sprayed trees, suggesting that there was no area effect. Nijholt and others (1981) concluded that pine oil (Norpine-65) had at least a lo-m-radius area effect on Douglas-fir beetle, *D. pseudorsugae* Hopkins, mountain pine beetle, and spruce beetle. However, McMullen and Safranyik (1985) were unable to demonstrate an area effect for BBR-2 and Norpine-65 for mountain pine beetle in lodgepole pine, P. *contorta* Dougl. ex Loud.

Ips spp. Responses

Repellency from treated trees. In the Route 488 plot, two BBR-2-treated codominant Virginia pines (*P. virginiana* Mill.) (15.2 and 16.5 cm d.b.h.) in front of portions of the head containing an active *Ips* population were mass attacked by *I. grandicollis.* They died some time between the third and sixth week after treatment. Another sprayed Virginia pine located in front of the SPB head at Route 488 was also mass attacked by *I. grandicollis*, and it died. Several BBRZ-treated loblolly pines at Reedy Fork were moderately attacked by *I. grandicollis* and *I. avulsus* (Eichhoff). These treated trees were probably weakened by the BBR-2 prior to the mass attacks. In any case, 5 to 6 weeks after treatment, BBR-2 did not repel *Ips* from dying and perhaps weakened trees. Berisford and others (1986) found that BBR-2 did not prevent *I. grandicollis* attack on pine cut immediately after treatment. They observed *Ips* mass attacks 5 days after treatment.

Area effect. Two Virginia pines at Route 488 adjacent to a BBR-2-treated tree were attacked by *I. grandicollis* and *I. avulsus*. They were 2.0 and 2.6 m from the treated tree. If BBR-2 has a repellent effect on *Ips*, that effect does not extend from treated trees to adjacent trees.

BTB Responses

In the Reedy Fork area, where a large population of BTB occurred in SPB trees, all but one of the BBR-2-treated trees had been attacked by two to six BTB. Five of the six treated trees in front of sectors B, C, and D of the SPB head, which did not expand, were attacked by BTB (fig. 1). None of the control trees were attacked, and only 2 of the 162 trees within a 5-m radius of treated and control trees in sectors B, C, and D were attacked by BTB; both were near one control tree (D-i).

In the Route 488 plot treated *on* July 26, three of the four sprayed trees (two shortleaf and two Virginia pines) near the SPB head were attacked by BTB. One of them had nine attacks and the other two had two BTB attacks each. No BTB attacks occurred on the two trees sprayed at Oconee Point. Only 2 of 21 trees sprayed with BBR-2 after mid-August were attacked by BTB. In BBR-2-sprayed trees, success rate of the BTB attacks (as defined by the presence of live parent adults boring egg galleries and/or the presence of brood) was 47 percent at Reedy Fork and 67 percent at Route 488.

The high incidence of BTB attacks on BBR-2-treated trees 3 to 4 weeks after treatment in July together with a virtual absence of attacks on surrounding trees indicate that the pine oil might have attracted BTB. Another plausible possibility is that the phytotoxicity of the BBR-2 may have been responsible for the trees attracting BTB. Weakening of the trees and/or presence of copious quantities of resin under and on the bark may have attracted BTB just as paraquat-treated trees attract BTB (Nord and others 1985; Stubbs and others 1984). In any case, BBR-2 does not seem to repel BTB from injured trees and it does not appear to adversely affect success of those attacks.

Berisford and others (1986) found no evidence that BBR-2 was repellent to BTB, in fact the opposite may have been true.

Phytotoxicity of BBR-2

The first symptom of phytotoxicity that we noticed was resinosis-resin running down the trunks of trees that had been sprayed with BBR-2 in July. It was first noticed on August 17 at the Reedy Fork plot on loblolly pines, 4 weeks after treatment, and at the Route 488 plot on Virginia pines 3 weeks after treatment. The resin was usually clear and uncrystallized, but occasionally it was opaque, yellow, and crystallized. It emanated from one to several points on the trunk in the spray zone and ran down the trunk on the outer bark scales for several meters. A check of surrounding trees showed that resinosis occurred only on sprayed trees.

When the trees at Reedy Fork and Route 488 were checked again about 3 weeks later on September 7-8, we noticed boring dust coming from some of the sprayed trees. In checking for the identity of the insect involved, we discovered that some of the trees had been attacked by *Ips* and were already dead, as evidenced by the brown color of the inner phloem and outer xylem. After seeing this, we checked some sprayed trees that had no sign of beetle attack and found them to be alive but with brown mottling stains in the otherwise light-colored outer xylem and/or the inner phloem. We refrained from cutting the bark until this time, fearing that we would attract beetles to the test trees. Since the tests were essentially over, however, we decided to check every test tree for phytotoxicity.

Table 2 shows a summary of those observations made on September 7-8, 1983. Resinosis and mottling of the outer xylem and/or inner phloem was almost universal among sprayed trees; these symptoms did not occur in unsprayed trees, Mortality did not occur at Oconee Point where two shortleaf pines were treated. At Reedy Fork, however, mortality was 71 percent among the seven loblolly pines treated (the lone treated shortleaf pine survived). Except for the SPB-killed trees near the control trees in sector A, none of the 162 trees within 5 m of the other test trees had died as of December 7, 1983. At Route 488, three out of four of the BBR-2-sprayed Virginia pines died by September 7, but the two treated shortleaf pines survived. In checking these test trees at Reedy Fork and Route 488 by shaving bark with a machete, the following characteristics were noted:

- Resin had accumulated under the bark in pockets, and it was under such great pressure that resin hit the observer in the face when one of the pitch pockets was punctured. These pitch pockets were assumed to be the origin of the resin flow on the trunk.

- The origin of resin flow could not be readily associated with anatomical features on the trunk except in one shortleaf pine, on which it seemed to be coming from around adventitious buds. Flow was found only in the sprayed zone, which had been marked with a flagging band at 6 m.

- Mottling of the inner phloem and outer xylem seemed to be common throughout most of the sprayed zone. Sometimes it was absent at breast height but present at 5 to 6 m and vice versa. Mottling was absent above the spray zone.

- *Ips* attack on the loblolly pines that died at Reedy Fork did not look heavy enough to girdle the trees at least up to 6 to 7 m. Three treated Virginia pines at Route 488 were mass-attacked however. In some dying trees at Reedy Fork, cerambycid infestations were heavy.

Table 2-Phytotoxic symptoms and black turpentine beetle attack on three species of pine sprayed to 6 m with pine oil in late July 1983

Area and species	Treated trees	Dead trees	Trees with resinosis	Live trees showing mottling	BTB attack: Trees attacked	BTB attack: Success rate
	---- Number ----		*---------------- Percent*	*----------------*		
Oconee Point						
Shortleaf	2	0	_	100	0	_
Reedy Fork						
Shortleaf	1	0	--	100	0	_
Loblolly	7	5	71.4	100	85.7	39
Route 488						
Shortleaf	2	0	--	100	100	50
Virginia	4	3	100	100	25	100

Table 3-Phytotoxlc symptoms on three species of plnes sprayed to 6 m with pine oil from late August to late September 1963

Species and treatment date	Total trees	Dead trees	Spots of oozing pitch between O-6 m				Subcortical mottling at --			
							Breast height [a]		5-6 m	
			0	1	2-5	>5	Ph [b]	XY [b]	Ph [b]	Xy [b]
	- - Number - -		*- - - - - - - - - - Percent of trees - - - - - - - - - -*							
Shortleaf Aug. 24-Sept. 22	16	0	50	12	25	12	81	25	87	19
Virginia Sept. 14	3	0	0	0	0	100	100	67	100	67
Loblolly Sept. 20	2	0	50	0	50	0	100	50	100	50

[a] 1.4 m above ground.
[b] Ph = phloem; Xy = xylem.

Table 3 summarizes phytotoxicity data on trees treated after August 23. Similar symptoms were noted except that none of the trees had died as of December 6, 1983. Resinosis or oozing of pitch occurred only in the sprayed zone of trees treated with BBR-2. Incidence of resinosis was 50 percent in shortleaf (n = 16) and loblolly (n = 2) pines and 100 percent in Virginia pine (n = 3). Pitch oozed from more places on the trunks of Virginia pines than it did on shortleaf or loblolly pine. Incidence of mottling of the inner phloem in the spray zone was higher than that of the outer xylem in all species of pine. Shortleaf pine had less mottling of the outer xylem than did Virginia and loblolly pines. Mottling of both phloem and xylem tissues were equally common at breast height and at 5 to 6 m in all species. Mottling did not occur above the spray zone in any tree.

BBR-2 appears to have a phytotoxic effect on all three species of pine tested. Judging from the incidence of tree mortality and mottling of inner phloem and outer xylem, and the amount of resinosis, shortleaf pine seems to be less affected than loblolly or Virginia pine. Even when and where the phytotoxic reaction was most severe, none of the five treated shortleaf pines died, whereas 71 percent of the loblolly and 75 percent of the Virginia pine died. None of the pines treated from late August to late September died. However, most of the trees treated after mid-August were shortleaf pine, which seemed less sensitive earlier in the season.

Phytotoxicity of pine oil to treated trees was not repotted in other studies. Berisford and others (1986) treated loblolly pine in one test with undiluted BBR-2 to a height of 4 m, but the treatment was applied in mid-September (information obtained through telephone conversation with C.W. Berisford, Department of Entomology, University of Georgia, Athens, GA), so it may not be fatal at this time of year. In another test by Berisford and others (1986), slash pines (*P. elliottii* Engelm. var. *elliottii*) were sprayed with undiluted BBR-2 to 0.9 m above ground in mid-July. One day later they and control trees were partially girdled (1/3 circumference) and a 4-percent paraquat solution was applied to the wounds to stimulate attack by BTB. No phytotoxicity from BBR-2 to the treated pines was reported in that study, but it would be hard to distinguish phytotoxicity caused by BBR-2 from that normally caused by paraquat.

O'Donnell and others (1986) treated 15 loblolly and shortleaf pines with undiluted pine oil (Norpine-65) to a height of 10 m in May. All treated trees were attacked by bark beetles and succumbed within 35 days of treatment, so there was no chance to observe the phytotoxicity of the chemical at a macroscopic level.

Werner and others (1986) sprayed white spruce (*Picea glauca* (Moench) Voss) to a height of 3 m with undiluted BBR-2 and Norpine-65. A moderate number of treated trees survived for 13 months, and no phytotoxicity was evident.

Nijholt and others (1981) sprayed Norpine-65 to runoff on the lower 2.5 m of lodgepole pine, white spruce X Engelmann spruce hybrids (P. *glauca* x P. *engelmannii* Parry ex Engelm.) and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. They reported no phytotoxic symptoms on sprayed trees. Also, Nijholt and McMullen (1980) reported no phytotoxicity on lodgepole pine in a preliminary study. McMullen and Safranyik (1985) sprayed mature lodgepole pine in British Columbia to a height of 3.5 m with both Norpine-65 and BBR-2. They did not mention phytotoxicity. Richmond (1985) sprayed lodgepole pines in Colorado to a height of 5 m with Norpine-65 and BBR-2 but did not report any phytotoxicity.

In our study, BBR-2 was very phytotoxic to all broadleaf vegetation covered by the spray in the understory and on the ground. Leaves yellowed and desiccated overnight. Berisford and others (1986) also reported phytotoxicity of BBR-2 to nontarget plants. Because of this phytotoxicity to understory vegetation, it is doubtful that the BBR-2 would be useful in urban settings unless some sort of controlled-release dispenser or controlled-spray applicator could be developed.

Future Research on Pine Oil

Future research with pine oil should address the phytotoxicity of BBR-2 to southern pines and other vegetation. Diluted material and/or treatment of less of the bole could be tested. Effects of weather, environmental conditions, season of treatment, and tree growth and vigor on toxicity should be measured. Less adverse weather and better soil/water relations might have been important factors in the greater survival of the September-treated trees in our study. It would be helpful if the repellent component of the pine oil could be isolated so that it could be applied in a nonphytotoxic carrier or in a dispenser of some kind. Identification of the repellent component would also solve the quality-control problem associated with variations among batches of pine oil. Shea (1989) has reported results of field tests of different distillation tower refinements of Norpine-65P as repellents for mountain pine beetle on lodgepole pine.

Acknowledgments

We wish to acknowledge the help of Dr. Roy L. Hedden, Clemson University; Michael C. Remion, South Carolina Commission of Forestry; and Tom Coffey from the University of Georgia, in locating SPB spots. For permission to use their land for studies, we thank Buck A. Bearden, Gary Blanton, David Fort, H.P. Hines, Dorsey Jones, C.V. Stribling, Jr., Lloyd Trent, Dean Wall, Clemson University, and Oconee County Hospital. We also thank Ricky Couch, Gordon Moore, and Gretchen Waldbauer for their help with the field work.

Literature Cited

Berisford, C.W.; Brady, U.E.; Fatzinger, C.W. [and others] 1986. Evaluation of a repellent for prevention of attacks by three species of southern pine bark beetles (Coleoptera:Scolytidae). Journal of Entomological Science 21:316-318.

McMullen, L.H.; Safranyik, L 1985. Some effects of pine oil on mountain pine beetle (Coleoptera:Scolytidae) at different population levels. Journal of Entomological Society of British Columbia 82:29-30.

Nijholt, W.W. 1980. Pine oil and oleic acid delay and reduce attacks on logs by ambrosia beetles (Coleoptera:Scolytidae). Canadian Entomologist 112:199-204.

Nijholt, W.W.; L.H. McMullen. 1980. Pine oil prevents mountain pine beetle attack on living lodgepole pine trees. Bi-Monthly Research Notes. Ottawa, ON: Canadian Department of Environment, Canadian Forestry Service; 36:1-2.

Nijholt, W.W.; McMullen, L.H.; Safranyik, L 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera:Scolytidae). Canadian Entomologist 113:337-340.

Nord, John C.; Jones, Alice S.; Hastings, Felton L 1985. Field tests of insecticides for control of black turpentine beetle. In: Branham, Susan J.; Thatcher, Robert C., eds. Integrated pest management research symposium: The proceedings; 1985 April 15-18; Asheville, NC. Gen. Tech. Rep. SO-56. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 272-280.

O'Donnell, B.P.; Payne, T.L.; Walsh, K.D. 1986. Effect of pine oil on landing and attack by the southern pine beetle (Coleoptera:Scolytidae). Journal of Entomological Science 21:319-321.

Richmond, Charles E. 1985. Effectiveness of two pine oils for protecting lodgepole pine from attack by mountain pine beetle (Coleoptera: Scolytidae). Canadian Entomologist 117:1445-1446.

Richmond, Charles E. 1986. Effectiveness of Norpine-65 for protection of lodgepole pines from mountain pine beetle for two years. Insecticide and Acaricide Tests 11: 424-425.

Shea, Patrick J. 1989. Use of chemicals to protect trees from mountain pine beetle attack. In: Amman, Gene D. comp. Proceedings-Symposium on the management of lodgepole pine to minimize losses to the mountain pine beetle; 1988 July 12-14; Kalispell, MT. Gen. Tech. Rep. INT-262. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 114-l 17.

Snedecor, George W.; Cochran, William G. 1967. Statistical methods. 6th ed. Ames, IA: The Iowa State University Press. 593 pp.

Steel, Robert G.D.; Torrie, James H. 1960. Principles and procedures of statistics. New York: McGraw Hill. 481 pp.

Stubbs, Jack; Roberts, Donald R.; Outcalt, Kenneth W. 1984. Chemical stimulation of lightwood in southern pines. Gen. Tech. Rep. SE-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 51 pp.

Werner, R.A.; Holsten, E.H.; Hastings, F.L 1986. Evaluation of pine oil for protecting white spruce from spruce beetle (Coleoptera:Scolytidae) attack. Journal of Entomological Society of British Columbia 83:3-5.

Southeastern Forest Experiment Station, P.O. Box 2680, Asheville, North Carolina 28802