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ABSTRACT: Success--defined as oviposition or tree-killing--was obtained by attracting western pine beetles to groups of pines with natural attractants and by en-massed forced attacks on individual trees combined with either physical or biological stress. Preliminary results show considerable agreement with laboratory tests of vapor toxicity.

Forcing Attacks of Western Pine Beetles to Test Resistance of Pines

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Why is one ponderosa pine (*Pinus ponderosa* Laws.) tree more resistant than another to attack by the western pine beetle (*Dendroctonus brevicomis* Lec.)? Laboratory tests suggest that certain components of resin may be important factors in resistance. However, these results need to be verified in field tests using naturally growing trees. The most formidable barrier in such tests is the development of suitable means of forcing successful attacks. The problem is especially difficult because the western pine beetle is not known to be partially successful in attacking ponderosa pine. That is, either it successfully establishes an F_1 generation and kills the tree, or the insect does not oviposit--it dies or cannot reproduce--and the tree lives. Therefore, to isolate the mechanisms of resistance, it is necessary to regulate forced attacks and to vary the suspected tree factors so that some trees live while others die.

At Placerville, Calif., we attempted to force the western pine beetle to attack pines--both successfully and unsuccessfully--to test the resistance of trees of differing resin characteristics to forced beetle attacks. From the somewhat preliminary results of this study, we concluded that they seem to substantiate laboratory results and to support the hypothesis that host specificity is closely aligned with resin quality.

EARLY STUDIES

Previous attempts by other investigators to use controlled forced attacks of the western pine beetle to kill ponderosa pine were not successful.[1,2] Several reasons could be advanced for these failures. The most obvious ones are lack of tree suitability, insufficient number of beetles, and the inappropriate time, location, and distribution of the beetle attack.

Person[3] was able to kill a few trees, located in an area where an intensive bark beetle epidemic was in progress, by using large numbers of beetles. There was no control of the number of beetles, and the natural beetle population usually attacked the tree outside the caged portion.

From laboratory tests and field observations, some preliminary and

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[1]Miller, J. M. *Studies of resistance of pine hybrids to insect attack at Institute of Forest Genetics*. 1950. (Unpublished report on file at Pacific SW. Forest and Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

[2]Callaham, R. Z., and Miller, J. M. *Studies of the resistance of pine hybrids to bark beetle attack, season of 1951*. 1952. (Unpublished report on file at Pacific SW. Forest and Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

[3]Person, H. L. *Report on western pine beetle studies of 1927, Cascadel Unit, Northfork, California*. 1928. (Unpublished report on file at Pacific SW. Forest and Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

tentative conclusions have been drawn about the role of resin quality in the resistance of ponderosa pine to beetle attack. Stark (1965) has reviewed other aspects of the relationship of resin and resistance. Laboratory tests have suggested that the specificity of attacks by bark beetles to their hard pine host might be based on the insect's tolerance to the particular resin vapor (Smith 1963). Vapors of the individual monoterpene components of ponderosa pine were differentially toxic to adult beetles (Smith 1965). The order of toxicity was limonene >3-carene > myrcene > β-pinene ≅ α-pinene > untreated. Heptane, a highly volatile but nonterpene component of some pine resins, was more toxic than limonene. This ranking suggested that variations in these components might be a factor in resistance. Large variations have been found in ponderosa pine (Smith 1964.).

In comparing fatally attacked and unattacked trees in the same area, it was found that fatally attacked trees had a much lower percent of limonene plus myrcene (Smith 1966). The monoterpene composition of the fatally attacked trees was determined by the corrected analysis of fresh pitch tubes.

These results and observations pointed to the need for development of an adequate field procedure to test the resistance of trees of differing resin characteristics to forced beetle attacks.

GENERAL PROCEDURE

The monoterpene composition of the wood resin of all trees used in these studies was determined by gas chromatographic analysis of either the pentane preparation of the fresh resin, or the Hickman still distillate of fresh resin (Smith 1964).

Beetles were obtained from brood material gathered from naturally infested trees in the Eldorado National Forest, near Placerville, Calif. The bark was removed when the brood had reached the late larval or pupal stage. The brood was allowed to continue development and to emerge in a screened outdoor insectary under the prevailing summer weather at Placerville. Emerged beetles were collected daily in individual #000 gelatin capsules and were held at 35°F. for no more than 2 days in order to collect enough for a test. Beetles were randomly distributed among the segments of a test. Therefore, they were comparable within a test, but were not comparable between tests. Beetles were placed in the cages on the trees of the various tests after the daily high temperature of the test site had been reached.

INDIVIDUAL PAIRS OF BEETLES

The first attempts to use forced attacks were with individual pairs of beetles in small gelatin capsule cages placed against the bark at the base of trees 10 to 12 inches d.b.h. Varying spacings of attacks, area of bark, and number and sequence of attacks were used. The heaviest planted attack on a single tree was 200 pairs of beetles on 8 square feet of bark. Both circumferential and strip areas were used at a height of 5 to 12 feet.

On the basis of occurrence of oviposition, no successful attacks were made in a large series of tests.[4] Most beetles were able to bore through the corky bark and all or part way through the phloem. They rarely extended galleries for even 1 inch, however, and usually considerably less than this.

The lack of a successful attack may be attributed to a condition of the tree, not enough bark area under

[4]Smith, R. H. *Studies on toxicity of resins, forced attacks, and analysis of ponderosa pine terpenes, 1962.* 1963. (Unpublished rep. on file at Pacific SW. Forest & Range Exp. Sta., U.S. Forest Serv., Berkeley, Calif.)

attack, or too few beetles. This last possibility can be classed within the theory of minimum numbers; i.e., a certain number of insects--more than one pair--is needed for survival. Adequate breeding possibilities and proper host conditioning are two of the commonly accepted reasons for a minimum number. The latter reason would be applicable for the case cited. Several investigators, including Miller and Keen (1960), have recognized this requirement of the western pine beetle.

ATTRACTED ATTACKS

Next, ponderosa pine trees were subjected to attack by attracting the indigenous population of western pine beetles to certain trees. Freshly infested bolts of ponderosa pine were the attractant. Vité and Gara (1962) used similar material to attract this beetle to field olfactometers. The bolts, 4 to 5 inches long and 3 to 6 inches in diameter, were artificially infested 2 to 4 days before use in the field. They were hung on trees at a height of 15 feet, which placed the bolts just below the crown. Each tree had four to six bolts and each group consisted of five to six trees. The trees stood next to each other rather than being interspersed throughout a stand. During the course of the summer five plots were used within a 3-mile radius (fig. 1).

The plots were observed regularly for the number and location of attacks on the baited trees as well as on nearby trees. Attacks were determined on the basis of the number of pitch tubes visible on the bark. Tree killing was the criterion of successful attack. If no successful attacks were made in a plot, it was rebaited later in the summer.

The insects quickly made numerous attacks in plot A, and killed some trees. They made few attacks (a maximum of 20) in the other four plots during either period of baiting. The first attacks in each plot were made on the baited trees within a few inches of the bolts. Subsequent attacks in the first plot were made upward and downward from the bolts, apparently by the indigenous population of beetles. In a few days nearby nonbaited trees were also attacked (fig. 2). By the end of the attack period 21 trees had been attacked in this plot: 6 were killed; 2 were heavily attacked, receiving more than 100 visible attacks, but surviving; and 13 received less than 50 visible attacks, but survived. Three other trees within the attack area were not attacked. No attacks on trees which survived were successful in establishing a brood.

Although the limited scope of the experiment may not merit conclusions of cause, a few points are worth noting. Western pine beetles can be attracted to ponderosa pines by freshly infested bolts of wood. This procedure is suitable for use in resistance studies because their attacks may or may not be enough to kill trees. The monoterpene composition of the plot trees varied considerably; no consistent pattern could be associated with the fate of the tree. The lightly attacked and unattacked trees tended to have a higher percentage of myrcene and limonene. One of the two heavily attacked but surviving trees had a high percentage of 3-carene, while the other was high in myrcene and limonene.

FORCED ATTACKS EN MASSE

Studies with individual pairs of beetles suggested the need for many beetles and large areas of bark before any attacks would be successful in attaining oviposition. Because previous attempts using beetles in caged massed attacks were not successful, additional measures seemed necessary. Stress, was the measure selected; it was applied to the tree in two ways: physical and biological. For physical stress the crowns of trees were removed just before caging the residual stump with beetles.

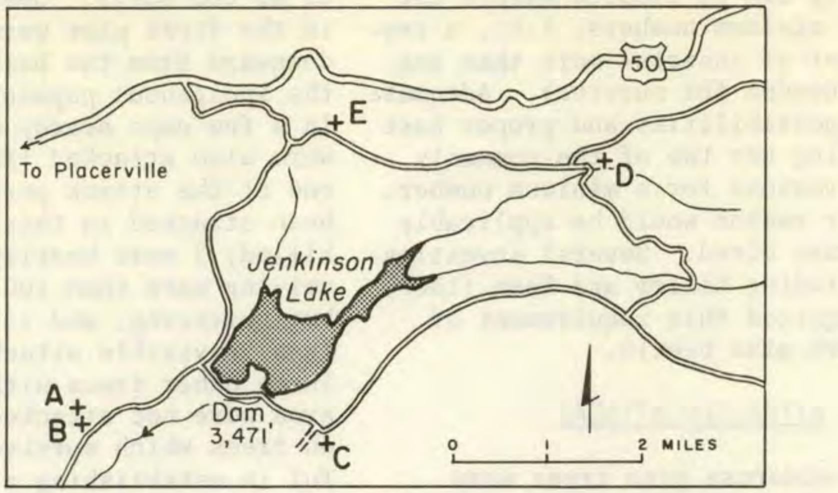


Figure 1.--Location of attracted forced-attack plots around Jenkinson Lake, Eldorado National Forest.

Biological stress was applied by the beetles; that is, through control of the sequence and location of their attacks on intact trees.

STUMPS

Two sets of experiments were conducted in which the tree crown was cut off. In one set the ponderosa pines were first cut to a 4-foot stump; in the other set the trees were cut to a 12-foot stump. These two types of stumps will be referred to as short and long stumps, respectively.

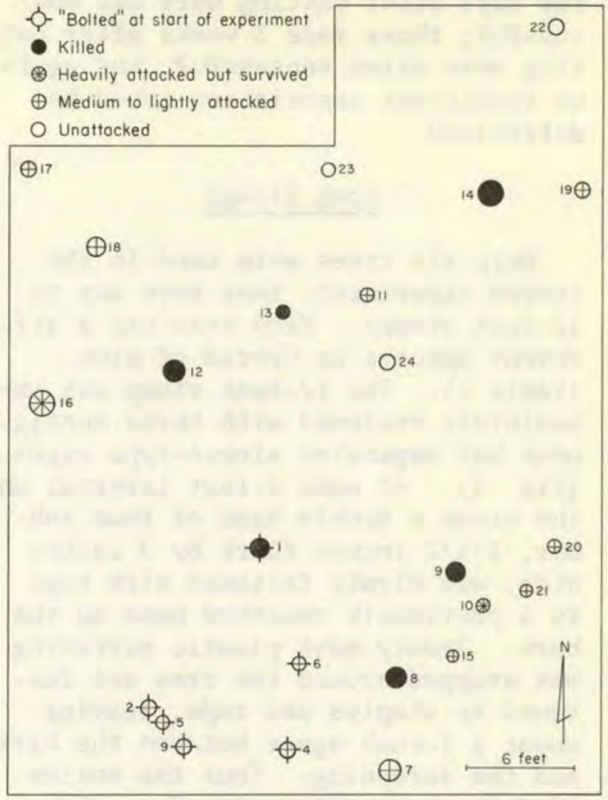
Short Stumps

Each short stump eventually was recut one or more times to a 45-inch height. The trees ranged from 4 to 6 inches in diameter to give a range in bark area of 4 to 5 square feet. The stumps were enclosed by a cylindrical cage of 20-mesh bronze screening with one end closed by a wood disc. To exclude other insects from the stump before and during the attack of western pine beetle, the cage was placed over the stump as soon as the initial cut was made. The forest debris on the ground around the stump was replaced by a layer of sand. The lower edge of the cage was made insect-proof by forcing it into the layer of sand. Beetles were introduced through a hole in the top of the cage.

During the month of June, 26 of these short stumps were used in an effort to determine suitable conditions for enabling the beetles to establish successful attacks. No completely factorial test was made. Conditions were simply varied from 5 to 75 beetles per square foot of bark area and from zero to three recuts of the stump. With each recut the flow of resin from the cross section of the stump diminished. But some resin pressure was present in all stumps at the time they were subjected to attack.

Successful attacks were made on 12 of the 26 short stumps, but no consistency could be discerned between resin composition and success. However, periods of cold rainy weather during the month may have strongly influenced the results. Nevertheless, the attainment of both successful and nonsuccessful attacks warrants further consideration of the procedure. Most attacks which were started within a

Figure 2.--Location and fate of trees in plot A of attracted forced-attack study. Numerical order shows order of occurrence of initial attacks. Size of circle proportional to tree diameter; No. 21 = 5 inches, No. 16 = 11 inches.



A-1 A-2 A-3 B C

Figure 3.--Sectional caging of trees for massed forced-attack studies with application of biological stress. A-1 = rings of bark smoothed; A-2 = foam-rubber bands attached; A-3 = screening fastened and heat-reflecting white bands applied over the tape; B = four sections with foam-rubber bands attached; C = four sections with screening in place without heat-reflecting white bands over tape.

few days after cutting were not successful; those made 3 weeks after cutting were often successful, but again no consistent association could be determined.

Long Stumps

Only six trees were used in the second experiment; they were cut to 12-foot stumps. Each tree was a different species or hybrid of pine (table 1). The 12-foot stump was immediately enclosed with three contiguous but separated sleeve-type cages (fig. 3). At each 4-foot interval on the stump a double band of foam rubber, 1-1/2 inches thick by 3 inches wide, was firmly fastened with tape to a previously smoothed band on the bark. Twenty-mesh plastic screening was wrapped around the tree and fastened by staples and tape, leaving about a 1-inch space between the bark and the screening. Thus the entire 12-foot stump was enclosed so that beetles could be introduced into or excluded from any section. The caged portion had to be shaded because the living crown of the tree had been removed.

Beetles were introduced into the top section of each stump the day after the trees were cut and caged. The cage was removed 10 days later, and the section was cut from the stump and examined. The umbrella was then reestablished, and beetles were introduced into the middle 4-foot section. This section and the basal section were handled similarly to the top section, except that the basal sections were allowed to remain for 6 weeks before they were cut and examined. With each cutting a comparative rating was made of the resin flow from the cross section.

In each section 144 beetles per square foot of bark area were placed, except in the middle section of ponderosa and ponderosa X Apache, where the number was halved because attacks in the top section had been successful.

An additional test was made with fresh-cut wood from these same trees to determine the boring and ovipositional capability of beetles when unencumbered by a flow of resin. Short (4 to 5-inch) bolts were cut

Table 1.--*Size and monoterpene composition of pines used with en masse forced attacks with application of physical stress*

Species[1] ♀ ♂	Circumference, midsection	Monoterpene composition[2]										
		Heptane	Nonane	α-pinene	Undecane	Camphene	β-pinene	3-carene	Myrcene	Limonene	β-phellandrene	Unknown
	Feet	*Percent*										
Ponderosa X wind[3]	1.65	0	0	13.1	0	0	30.2	43.3	5.0	6.1	1.4	0.8
Jeffrey X wind	1.48	92.9	.7	1.1	0	0	0	2.0	2.2	0	0	0
Coulter X wind	1.60	.6	1.0	40.1	2.4	.6	2.8	.1	15.2	2.5	34.0	0
Jeffrey X ponderosa	1.47	17.9	1.3	14.9	3.0	0	23.3	27.0	3.0	.9	7.5	1.1
Jeffrey X Coulter X wind	1.62	64.9	2.0	4.4	3.2	.2	1.4	2.4	6.3	.8	14.2	0
Ponderosa X Apache	1.71	0	0	38.9	0	.7	16.9	30.9	3.2	6.8	1.2	1.4

[1]*Pinus ponderosa*, *P. jeffreyi* Grev. & Balf., *P. coulteri* D. Don, *P. engelmannii* Carr. (Apache).

[2]Normalized: trace amounts not recorded.

[3]Wind pollinated.

from the severed portion of the crown. To enable beetles to bore into the phloem through the cross section, they were restricted to that area by barriers. The bolts were prepared the day the top was cut, and 25 freshly collected beetles were added to each of five bolts from each tree. Five days later the bark was carefully removed, and measurements were made of gallery length and oviposition.

Examination of each of the three 4-foot sections from the intact 12-foot stump of each tree showed a host suitability rating based on oviposition, gallery length, and gallery form, as follows: ponderosa > Coulter > Jeffrey X ponderosa > ponderosa X Apache > Jeffrey X Coulter > Jeffrey (table 2). If resin quantity strongly influences interspecific resistance, suitability should be inversely related to quantity. However, the generalized quantitative yield of resin from the six trees during the course of the experiments was Jeffrey X ponderosa < Jeffrey < ponderosa < Jeffrey X Coulter < ponderosa X Apache < Coulter. The lack of a general association between the two ratings could lead to the assumption that factors other than the amount of resin are important in interspecific resistance.

The extensive galleries and oviposition in the short cut bolts (table 2) suggested that the phloem tissue of these trees was suitable for feeding and oviposition. Therefore, an inspection of resin quality seems warranted. The most resistant trees (i.e., least suitable for the beetle)--Jeffrey and Jeffrey X Coulter--had > 60 percent heptane. The Jeffrey X ponderosa hybrid had only about 18 percent heptane. It would appear that the heptane concentration was not enough in this hybrid, which always had the poorest flow of resin. With a flow of resin comparable to that of Jeffrey X Coulter it might have decreased its suitability rating. Both ponderosa and Coulter had > 40 percent α-pinene plus β-pinene, the least toxic of the terpenes in the vapor toxicity tests; neither had heptane except for a trace in Coulter. Ponderosa X Apache was not too unlike ponderosa except that it did have a much greater flow of resin. Thus it would appear that amount of resin may contribute to or detract from the effect of resin quality.

The resin of the ponderosa X Apache hybrid crystallized much more rapidly than the others. This phenomenon appeared to prevent the beetle from extending its gallery very far in the phloem. The unsuccessful galleries usually contained a dead beetle enmeshed in a conglomerate of crystals. There was continued but no copious flow of resin at this time. The large distinct crystals were not at all like beetle pitch tubes in texture. The question of the role of resin crystallization has not been explored as to bark beetle activity, though Stark (1965) speculated on it briefly. He reached the opposite conclusions, however; i.e., that rapid crystallization could be helpful to the beetle. Apparently more study is needed.

INTACT TREES

Beetles were introduced into different caged portions of the trunk of pines at different times so that their action in one section could affect the ability of other beetles subsequently introduced into another section. Thus the beetles applied the stress. To give three or four contiguous but separate 4-foot sections, the basal 12 to 16 feet of a tree was caged similarly to the method used for long stumps (fig. 3). Only a single band of foam rubber was necessary at each interval since the tree was not cut until the end of the experiment. A foam-rubber band was placed a few inches above the root crown to alleviate problems associated with the flaring of the root crown and to prevent beetles from going into the ground.

Table 2.--*Beetle activity in the three sections of the long stump of each tree after caged forced attack by western pine beetle and in the 3-inch cut bolts*

Species	Average oviposition and boring in a cut bolt		Resin flow rating[1]	Beetle activity in 12-ft. stump						Host suitability
				Oviposition[2]			Gallery length			
	Eggs	Gallery length		Top	Mid	Base	Top	Mid	Base	
	No.	*Inches*					*Inches*			
Ponderosa	61	29	4	X	X	X	>6	>6	>8	Excellent
Coulter	68	25	1	O	X	X	<2.5	>6	>8	Good
Jeffrey X ponderosa	96	24	6	O	X	X	< .5	>6	>6	Fair
Ponderosa X Apache	79	24	2	X	O	O	>6	<2	<2	Poor
Jeffrey X Coulter	86	26	3	O	O	O	0	<1	<1	None
Jeffrey	92	31	5	O	O	O	0	0	0	None

[1]Average relative rating from greatest (1) to least (6) for all three sections.
[2]X = oviposition; O = no oviposition.

Beetles were introduced into successive sections, working upward or downward, at 5- to 7-day intervals. The whole tree was cut and examined about 2 months after beetles had been placed in the last section.

Three separate tests were made (table 3). The trees in each test were quite comparable in size. Test No. 1 compared an upward sequence of attacks with a downward sequence. Test No. 2 compared five pine species or hybrids with varying monoterpene composition. Test No. 3 sought to determine the minimum number of beetles necessary to establish a successful attack.

Results

In test No. 1 (table 3) both sequences of attacks were successful in killing the tree and producing progeny. But a cursory examination of a few attacks made after beetles had been placed in the first two sections showed that beetles in the bottom-to-top sequence were making better progress towards oviposition than those in the top-to-bottom sequence. If the test had been stopped after two sections, perhaps successful attack would have resulted with the bottom-to-top sequence but not the top-to-bottom. The early indication of success in this test prompted the establishment of test No. 2, using the bottom-to-top sequence.

Only three of the trees in test No. 2 were cut and examined, since a cursory examination of Jeffrey and Jeffrey X (Jeffrey X Coulter) showed not the slightest signs of success (table 4). Beetle boring activity was too slight to cause the formation of pitch tubes. A spot check of attacks failed to reveal even the penetration of the phloem tissue. Results with the other three trees were quite indicative. Attacks on Jeffrey X Coulter did not produce measurable galleries. The beetles barely penetrated the phloem; most of them did not get this far. Attacks on the ponderosa X Apache were not successful, but short galleries were made in the phloem. Subjectively, the beetles appeared to be nearer success in this hybrid than in the Jeffrey X Coulter hybrid. The use of another section or more beetles might have resulted in a successful attack. It should be noted that the α-pinene plus β-pinene content in this hybrid was about 23 percent--far less than with the Washoe X ponderosa and the two ponderosa pines in test No. 1. The factor of rapid crystallization was apparent in the ponderosa X Apache again, as discussed in the long-stump test.

Table 3.--*Monoterpene composition of trees used in tests with biologically applied stress*

Test number	Species	4-ft. sections	Sequence of attack[1]	Date of first attack	Days between attacks	Beetles per sq. ft.	Circumference of mid-section	Monoterpene Composition						
								Heptane	α-pinene	β-pinene	3-carene	Myrcene	Limonene	Remainder
		No.			*No.*	*No.*	*Feet*	*Percent*						
1	Ponderosa #1	4	Up	Jul.30	6	144	1.76	0	9.6	30.5	35.5	20.3	0.5	3.5
	Ponderosa #2	4	Down		6	144	1.79	0	5.6	26.3	26.3	15.5	23.6	2.8
2	Washoe[2] X ponderosa	3	Up	Aug.14	6	144	1.61	0	7.2	25.5	48.6	9.0	6.4	2.4
	Ponderosa X Apache	3	Up		6	144	1.71	0	11.3	12.2	57.5	5.5	9.4	2.9
	Jeffrey X Coulter	3	Up		6	144	1.61	44.7	16.8	1.5	1.5	5.6	11.9	4.2
	Jeffrey X (J X Cl)	3	Up		6	144	1.79	78.2	4.3	.6	3.7	3.7	(3/)	3.4
	Jeffrey	3	Up		6	144	1.37	95.2	1.5	.7	.8	.9	(3/)	.9
3	Ponderosa #3	4	Up	Aug.25	4-5	72	2.05	0	11.0	29.9	40.1	9.5	9.5	(3/)
	Ponderosa #4	4	Up		4-5	36	2.30	0	10.5	38.6	30.4	12.3	8.2	(3/)

1 Down, up = beetles introduced into sections successively from top to bottom or bottom to top, respectively.

2 *Pinus washoensis* Mason & Stockwell.

3 Trace.

Table 4.--*Gallery and brood development in three sections of each pine, following a bottom-to-top succession of western pine beetle attacks*

Tree	Section[1]	Resin flow rating[2]	Gallery	Oviposition[3]	Emergence[4]
			Inches		
Washoe X ponderosa	1	4	>6	X	X
	2		>6	X	X
	3		>6	X	X
Ponderosa X Apache	1	2	<2	O	O
	2		<2	O	O
	3		<2	O	O
Jeffrey X Coulter	1	1	O	O	O
	2		O	O	O
	3		O	O	O
Jeffrey X (Jeffrey X Coulter)	1-3	5	O	O	O
Jeffrey	1-3	3	O	O	O

[1]1, 2, and 3 = bottom, middle, top, respectively.
[2]Relative: (1) best to (5) poorest.
[3]X = yes; O = none.
[4]X = emergence; O = none.

Table 5.--*Gallery and brood development with two intensities of western pine beetle attack in 4 sections of 2 ponderosa pines*

Tree No.	Beetles per sq. ft.	Gallery development				Brood development[1]			
		Bottom	Mid-bottom	Mid-top	Top	Bottom	Mid-bottom	Mid-top	Top
	Number	*Inches*							
3	72	>8	>8	>8	>8	[2] X	X	X	X
4	36	<3	<4	<4	[3] <5	O	O	O	O

[1]X = oviposition and F_1 emergence; O = no oviposition.
[2]Brood development in this section was behind that of the upper sections in which beetles were placed at a later date.
[3]Galleries in this section appeared to be nearer the point of oviposition, and one more attack section above might have applied the necessary stress to enable oviposition.

The attacks on the Washoe X ponderosa hybrid were successful. The merits of the use of a succession of attacks were apparent with this tree. A spot check of attacks in the first two sections indicated that the beetles were having much difficulty in lengthening their galleries, though after 5 days many of the attacks were still active. It is possible that the attacks might have failed if the test had been stopped at this stage. However, the stress of the beetles in the third section seems to have tipped the balance in favor of the beetles in the lower two sections; likewise, the stress of the beetles in the lower two sections probably aided beetles in the top section. The tree was killed, and progenies were produced.

The third test was successful in determining ~~more closely the minimum~~ number of beetles required. Both trees were quite comparable, having > 40 percent α-pinene plus β-pinene. Tree No. 3, with an attack intensity of 72 beetles per square foot, was killed; tree

No. 4, with an attack intensity of 36 beetles per square foot, survived (table 5). The rate of brood development in tree No. 3 apparently did not parallel the sequence of beetle introduction. Beetles were emerging from the upper sections when they had only reached the pupal stage in the basal section. As in the Washoe X ponderosa hybrid, the success of the basal-section attacks depended on subsequent attacks in the upper sections. It is worth noting that the α-pinene plus β-pinene content of these two trees, the two trees in test No. 1, and the Washoe X ponderosa in test No. 3 was > 32 percent.

DISCUSSION

The results of tests that used biological stress were particularly promising, though much more research is required to define the parameters more adequately. The use of attractive bolts merits further consideration--particularly the location of plots and the time of the placement of the attractive bolts.

Though quite preliminary and limited the results do seem to substantiate the results of laboratory experiments and to add weight to Callaham's[5] hypothesis that host specificity is closely aligned with resin quality. Ponderosa and Coulter pine proved to be suitable hosts in these field tests; the laboratory tests showed their resin vapors to be the least toxic to the beetle. Hybrids of Coulter with Jeffrey were unsuitable hosts in the field tests; the laboratory tests showed the vapors of such hybrids to be quite toxic. The hybrid of ponderosa with Jeffrey showed only fair host suitability in field tests, laboratory test showed the vapors to be less toxic than Jeffrey X Coulter but more toxic than ponderosa. The very poor rating of this hybrid in resin flow capacity could have altered its field performance. With other hybrids, host suitability seemed to be linked with the resemblance of the resin to ponderosa. Those having close resemblance were more suitable than those having poor resemblance.

Resin quantity may be a factor to consider more seriously, as Callaham[6] has suggested. Quantity may enhance or detract from the qualitative performance of a resin, as indicated by the field test with the Jeffrey X ponderosa hybrid. Other physical properties of resin should be considered as possible factors in resistance. The question of rate of crystallization has been raised, and a similar case may be advanced for viscosity.

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