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was measured occasionally with a thermometer. The bolts in the unsprayed cage were debarked and examined after emergence ceased on 6 August, and those in the sprinkled cage on 17 September, 23 days after sprinkling had ceased.

Only 12 beetles emerged from the sprinkled bolts compared to 935 from the unsprinkled ones. All beetles found in the bolts at the time of examination were dead and the emerged beetles represented 1 and 71% of the total beetles originally in the sprinkled and unsprinkled bolts respectively. Two of the beetles emerging from the sprinkled bolts did so after the sprinkling had ceased.

Although air temperatures during the study were often 25 to 30° C, temperatures on the bark surface of the sprinkled bolts during these periods were about 20 to 21°C in the sun and 19°C in the shade.

The sprinkling was effective in reducing emergence of the young beetles. The factors relating sprinkling and mortality are uncertain. Under normal conditions, mountain pine beetle emerges at temperatures above 16°C (Reid, Can. Entomol. 94:531-538, 1962), but peak emergence is usually confined to periods when temperatures are above 20° C (Safranyik, pages 77-84 *in* Kibbee, ed., Theory and Practice of Mountain Pine Beetle Management in Lodgepole Pine Forests, Symp. Proc., 1978). Although bark surface temperatures in the study reported here met these requirements, subcortical temperatures may have been lower because of evaporation. The sprinkling described here was intense, keeping the bolts continuously wet and the bark soaked for more than 5½ wk and its action may have been similar to submergence in water. Bark of ponderosa pine (*P. ponderosa* Laws.) containing western pine beetle (*D. brevicomis* Lec.) (Miller and Keen, USDA Misc. Publ. 800, 1960) and spruce hybrids (*Picea glauca* [Moench] Voss - *P. engelmannii* Parry) containing spruce beetle (*D. rufipennis* [Kirby]) (Safranyik, pers. comm.) required about 5 wk submergence in water before mortality of the brood approached 100%.

This study illustrates that a sprinkling technique could reduce emergence of mountain pine beetle in infested logs in log storage areas. For practical use, further work needs to be done on intensity of sprinkling required and the deployment of sprinkling systems on or in log decks. — L.H. McMullen and R.E. Betts, Pacific Forest Research Centre, Victoria, B.C.

Field Testing Diesel Oil for Protecting Spruce Logs from Spruce Beetle Infestation. — The spruce beetle (*Dendroctonus rufipennis* [Kirby]) is the most destructive bark beetle of mature spruce (*Picea* spp.) forests. This beetle normally breeds in windthrown and felled trees and logging slash (cull-logs, tops, and stumps). Large populations accumulating in such host materials are precursors of outbreaks in living trees (Wygant and Lejeune, pages 93-95 *in* Davidson and Prentice, eds., Important Forest Insects and Diseases of Mutual Concern to Canada, the USA and Mexico. Can. Dep. For. Rural Dev., 1967).

A number of synthetic insecticides (e.g., chlorpyrifos, lindane, and carbaryl) and some natural products, such as pine oil (a derivative of sulphate pulp processing waste) and oleic acid, are effective in protecting trees, logs, and slash from attack by spruce beetles. These chemcials, however, are not always readily available. Some common mineral oils, such as creosote, kerosene, and No. 2 fuel oil, prevented elm bark beetles (*Scolytus multistriatus* Marsh. and *Hylurgopinus rufipes* Eichh.) from breeding (Becker, J. Econ. Entomol. 48:163-167, 1955). No. 2 fuel oil failed to provide satisfactory protection against the black turpentine beetle (*D. terebrans* [Oliv.]) on slash pine (*Pinus taeda* L.) stumps (Smith, South. Lumberman 189:155-157, 1954). Fuel oil is also the recommended carrier in formulations of penetrating sprays for controlling bark beetles and is highly toxic by itself to bark beetle broods in logs (Schmid, J. Econ. Entomol. 65:1520-1521, 1972; McMullen, Pac. Forest Res. Cent., pers. comm.).

This paper reports the effects of diesel oil on attack and on attack success by spruce beetles in spruce logs. The study was done in a mature spruce (*Picea glauca* [Moench] Voss - *P. engelmannii* Parry) hybrid population - subalpine fir (*Abies lasiocarpa* [Hook] Nutt.) forest, about 65 km southeast of Prince George, British Columbia. Two spruce trees, measuring 28.7 and 29.0 cm in diameter at 1.45 m, were felled, and six logs, each about 2.5 m long, were cut from each tree on 13 May 1980. Logs were numbered and consecutive pairs were placed on the ground in nearby shaded areas so that each pair was located at least 20 m distant from its nearest neighbors and the logs within the pairs were located 2-3 m from each other. One randomly selected log from each pair was uniformly sprayed to the run-off point with diesel oil from a gas-powered centrifugal pump equipped with a nozzle that delivered a dense, cone-shaped spray. Approximately 1.5 L of diesel oil was applied per m^2 of bark area. The unsprayed log in each pair served as control. The logs were sampled on 14 July, about 1 mo. after peak spruce beetle flight, which was monitored using lethal traps trees (Dyer, Can. J. Forest Res. 3:486-494, 1973) in an adjacent stand.

Three 30-cm-long bolts were cut from each log, one bolt 15 cm from each end and one from the middle, and the mid-circumference of each bolt was measured. All bolts were sampled for total and successful attacks and, on the middle bolts, egg gallery length and numbers of progeny by stage of development were also recorded. Attack was defined as any entrance hole visible at the cambium, and a successful attack was defined as an egg gallery that contained either a live female parent, eggs and/or larvae, or a combination of these life stages. Attacks were converted to numbers per 100 cm^2 and transformed ($x^1 = \sqrt{x+1}$) before analysis in a split plot design. Analysis of variance showed a significant difference ($p < 0.05$) in attack density between treatments, but not between trees, among log pairs or among bolts, and no interactions were significant. Mean attack density for the check and treated logs was 0.64 and

0.25 per 100 cm^2 respectively. Within each pair of logs, the attack density on the treated log was consistently lower than on the check log. On the untreated logs, all the attacks were judged as successful i.e., the egg galleries contained progeny and/or live female parent(s). On the treated logs, only 52.38% of the attacks were successful, the difference being highly significant ($X^2_{[1df]} = 32.48$, $p<0.01$). Exactly half of the unsuccessful galleries contained neither eggs nor live female parents; the rest had only dead female parents. The egg galleries in the treated logs were often crooked and branched, similar to atypical egg galleries produced in trees treated with systemic pesticides (Frye and Wygant, J. Econ. Entomol. 64:911-916, 1971). The average length of the egg galleries in the treated and check logs was 3.98 cm and 9.97 cm respectively ($t_{[97df]} = 13.84$, $p<0.01$).

Initial attacks and attack accumulation were not monitored, but periodic visual observations indicated that initial attacks were delayed on the treated logs by about 10–15 days. Therefore, delayed attacks could, in part, be responsible for the shorter mean egg gallery length in the treated logs. However, in these logs, there was no significant differences in the average lengths of successful and unsuccessful attacks (4.95 cm vs 3.29 cm).

Brood per attack averaged 23.70 and 2.44 (equal to 15.2 and 0.61 progeny per 100 cm^2) in the check and treated logs ($t_{[97df]} = 13.98$, $p<0.01$. At the time of sampling, 63.4% and 100% of the progeny, respectively, were in the egg stage. Delayed attacks on the treated logs could be responsible for this result. However, because the viability of the eggs was not investigated, we do not know what effect the treatment may have had on their ability to hatch.

In summary, the diesel oil treatment resulted in 61% reduction in attack density, 48% reduction in successful attack, 60% reduction in gallery length, 89% reduction in progeny per attack, and 96% reduction in progeny density. We conclude that diesel oil shows promise in preventing attacks and establishment of broods by spruce beetles on spruce logs. Further tests are needed to evaluate survival of established broods in treated logs and logging residue. — L. Safranyik and D.A. Linton, Pacific Forest Research Centre, Victoria, B.C.

Ambrosia Beetles in Alder. — Red alder (*Alnus rubra* Bong.) is one of the most important hardwoods in Pacific Coast forests. The wood is used for cabinet work, furniture, and core stock (Hosie, Native trees of Canada, 1969). Because red alder was believed to be less affected by ambrosia beetles, the industry suggested that it could be used as spacers in lumber packaged for export, thus replacing waste softwoods that often show severe beetle damage. Any evidence of ambrosia beetle damage on wood products can lead to quarantine problems on the export market. Hence reports of ambrosia beetle attacks on red alder were investigated as to their extent and circumstances.

During the spring and summer of 1980, ambrosia beetles attacked many red alder trees that had been treated with 2,4-D in the summer of 1979. The herbicide had been applied by the hack-and-squirt technique to red alder trees in a 100 ha stand of alder and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) near Caycuse, B.C., as a silvicultural treatment to release the Douglas-fir.

The ambrosia beetle attacks were mostly in trees killed or severely damaged by the herbicide. Entrance holes were usually found in areas where the sapwood was discolored by a dark-brown stain. Live beetles and their progeny identified by R.W. Duncan of the Pacific Forest Research Centre as *Trypodendron lineatum* (Oliv.) and *Gnathotrichus retusus* (Lec.), formerly known as *G. alni* Blackman (Bright, The insects and arachnids of Canada. Part II. 1976), were found in typical full-sized galleries in the attacked trees.

The production of host and secondary attraction to ambrosia beetles in coniferous trees is generally thought to be related to the abundance of terpenes in these trees. The fact that ambrosia beetles detected and successfully established broods in red alder trees that contain little or no terpenes (Von Rudloff, pers. comm.) indicates that the requirement for terpenes may not be essential.

The incidence of attacks by ambrosia beetles was less on felled alder that had not been treated with herbicides.

The significance of the relationship between felling date and incidence of ambrosia beetle attack in reducing insect damage has been shown for Douglas-fir (Dyer and Chapman, Can. Entomol. 97(1):42-57, 1965). The possibility of such a relationship for red alder has not been explored.

It is recommended that alder timber intended for packaging lumber for the export market be carefully examined for evidence of ambrosia beetle damage before processing. — W.W. Nijholt, Pacific Forest Research Centre, Victoria, B.C.

MISCELLANEOUS

The Use of Phyllotaxis in Estimating Defoliation of Individual Balsam Fir Shoots. — In studies of the relation of growth loss of balsam fir (*Abies balsamea* [*L.*] Mill.) trees to defoliation by the spruce budworm (*Choristoneura fumiferana* [Clem.]), it was necessary to accurately estimate defoliation at the individual shoot level and to assess variability within branches, whorls, and the entire tree. This note describes a method for determining accurate post-defoliation estimates of the original number of needles on a balsam fir shoot. The method was used to check the accuracy of visual estimates of defoliation made throughout the crowns of seven balsam fir trees.

The pattern of leaves on a stem, scales on a pine cone, or florets on a sunflower is generally a spiral. The study of these arrangements, called phyllotaxis or phyllotaxy, began in the 18th century (for a review of the history of phyllotaxis, see Adler [J. Theor. Biol. 45:1-79, 1974]). Because there is a definite pattern to the