Gene D. Amman

INTEGRATED CONTROL OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE FORESTS

Gene D. Amman, Principal Entomologist
U.S. Department of Agriculture, Forest Service
Intermountain Forest and Range Experiment Station
Ogden, Utah, U.S.A. 84401

SUMMARY

Regulation of mountain pine beetle (Dendroctonus ponderosae Hopkins) populations in lodgepole pine (Pinus contorta var. latifolia Engelmann) forests is based on insect-host interactions, and land-use objectives. The mountain pine beetle periodically kills most of the trees of large diameter in a stand. The beetle selects the largest trees where phloem, the food of the larvae, is usually thick and beetle survival is high. Periodicity of infestations is related to rapidity with which a stand of trees grows into diameter-phloem distributions conducive to population buildup.

Forest management practices consisting of clear or partial cuttings are recommended in commercial forests. Particularly susceptible stands can be converted to other tree species, or harvest rotations can be shortened so that trees of small diameter that meet certain product requirements can be cut before the trees reach sizes and phloem thickness susceptible to beetle attack. Regulation of the beetle is not recommended in recreational and noncommercial forests. In these forests, lodgepole pine will be succeeded by spruce and firs. These species will fulfill requirements of recreation, watershed, and other values as well as lodgepole pine. Chemical insecticides can be used to protect trees of high value from beetle infestation in campgrounds and around home sites.

Keywords: Dendroctonus ponderosae; Pinus contorta; integrated control.

INTRODUCTION

The mountain pine beetle, Dendroctonus ponderosae Hopkins, is the most aggressive bark beetle in western United States. Populations of the beetle periodically kill most of the large, vigorous lodgepole pines, Pinus contorta var. latifolia Engelmann, in a forest before the beetle population declines. Frequency of infestations on a given area of forest appears to range from 20 to 40 years (Roe and Amman 1970), depending upon how rapidly a stand grows into conditions conducive to buildup of beetle populations (trees of large diameter that have thick phloem).

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ECOLOGICAL BASIS FOR CONTROL RECOMMENDATIONS

Control methods presented here are based on ecological relationships of the beetle and its host. The four most important factors known to affect mountain pine beetle populations are stand structure, phloem thickness, moisture, and climate.

Stand Structure

The mountain pine beetle kills proportionately more large- than small-diameter trees. Hopping and Beale (1948) showed a 5 percent increase in mortality for each increase of 2.5 cm in diameter for stands in Alberta and Roe and Amman (1970) observed an increase of 8.8 percent in Wyoming and Idaho. Mortality ranged from about 1 percent of trees 10 cm d.b.h. to about 87 percent of trees 40 cm d.b.h. and larger; the beetle preferred the larger trees each year and over the life of the infestation (Cole and Amman 1969). However, mortality varies greatly with elevation and latitude.

Visual cues appear to play an important role in initial tree selection by the beetle. Shepherd (1966) showed in laboratory studies that the beetle is attracted to large dark objects (which simulated the large trees of the forest) against a light background. The evolution of such behavior is most likely related to the greater probability of encountering thick phloem (the food of developing larvae) in large rather than small trees (Amman 1975), and consequently greater beetle production per unit area of bark (Amman 1969; Cole and Amman 1969; Reid 1963). Measurements of phloem in one stand showed that thickness averaged about 1.5 mm in trees 10 cm d.b.h., whereas phloem averaged about 4.0 m thick in trees 40 cm and larger d.b.h. (fig. 1). Similar relationships of thin phloem in small trees and thick phloem in large trees have been established for all lodgepole pine stands that have been surveyed.

Phloem Thickness

Phloem thickness is the single most important factor that we have been able to isolate to account for the number of beetles that will emerge from a given area of bark where temperatures for beetle development are optimal. In laboratory studies, production per 30.4 cm^2 of bark surface ranged between an average of 30 beetles for phloem 2.3 mm thick to 80 beetles for phloem 5.8 mm thick (Amman 1972). The relation is also apparent in field studies involving life table studies; large trees in a given year consistently produce more beetles per unit area of bark than small trees (Cole et al., in press). Laboratory studies failed to demonstrate a qualitative difference between phloem of young and old trees. Drying appears to be one reason that beetle production is lower in small trees than in large trees of equal phloem thickness.

Moisture

Drying usually is more rapid in small than in large infested trees, particularly those that had been growing slowly, and probably accounts for some of the reduced beetle emergence (survival) observed between large and small trees having similar phloem thickness. Cole (1974; 1975) reported that cold winter temperatures followed by drying of the trees were important mortality factors of the mountain pine beetle.

Blue stain fungi introduced by parent bark beetles interfere with movement of water in the infested tree and, consequently, could play an important role in

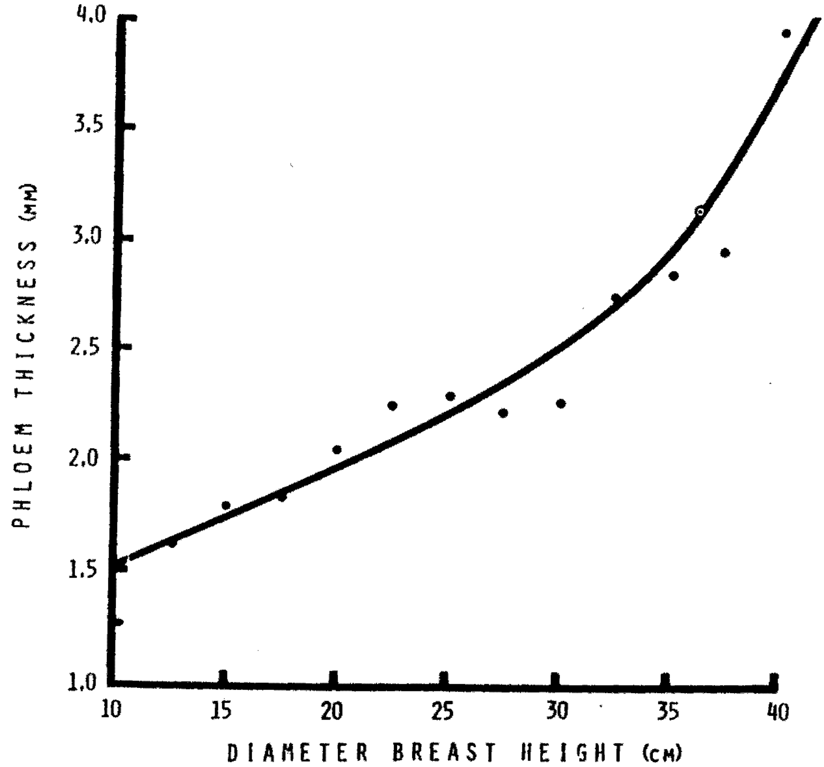

Figure 1.--Average phloem thickness for different diameters of lodgepole pine.

water regulation (Dixon and Osgood 1961). Usually, blue stain fungi uniformly discolor the entire sapwood in lodgepole pine trees that had been growing rapidly when killed by the beetles; these trees have thick sapwood. However, blue stain fungi usually do not uniformly discolor the entire sapwood in slow-growing trees (most of the small-diameter trees fall into this category); these trees usually have thin sapwood.

Reid (1961) observed that infested trees in which blue stain was well developed were drier the fall following attack than trees in which blue stain was not well developed. This relation also was observed in our studies. However, in early July, about 11 months following infestation, the opposite relation was observed. Trees having well-developed blue stain were more moist than trees in which blue stain did poorly. Survival of beetles was low in trees having poorly developed blue stain. Since the fungi clog the tracheids, and thus would slow transpiration, it seems plausible that the fungi were at least partially responsible for greater moisture retention.

Climate

Climate plays a major role as a limiting factor in dynamics of the mountain pine beetle at extreme northern latitudes and at high elevations in more southerly latitudes. Safranyik et al. (1974) outlined zones of infestation intensity for the mountain pine beetle in Canada, with the greatest intensity occurring at low elevations near the United States-Canada border. In Wyoming and Idaho, damage to lodgepole pine stands was found to be greatest below about 2,400 m at 43°N latitude, 110°W longitude (Amman and Baker 1972). When the beetle encounters the cooler climate of northern latitudes and high elevations, it requires more time to complete development. Consequently, the beetles often do not emerge early enough to construct much gallery and cold fall temperatures prevent embryogenesis and egg hatch. All eggs that enter the winter are killed and even small larvae suffer heavy mortality (Amman 1973). Above about 2,400 m, the beetles usually require 2 years to complete a generation. During these long developmental periods, survival is low, resulting in declining populations. Stands of lodgepole pine mixed with subalpine fir, Abies lasiocarpa (Hook.) Nutt., and Engelmann spruce, Picea engelmannii Parry, at high elevations contain a higher proportion of large-diameter trees than stands at low elevations because of the beetle's inability to build up and maintain large populations (Amman and Baker 1972; Amman et al. 1973).

CONTROL RECOMMENDATIONS

Ecological observations clearly indicate that Dendroctonus ponderosae shows a strong preference for large-diameter lodgepole pine trees, and that these trees are the most vigorous trees in the stand, based on silvicultural measures of radial growth, crown length, and phloem thickness (D. M. Cole 1973). The following control recommendations are based on these observations. Additionally, recommendations to regulate beetle populations must take into consideration land-use objectives. Consequently, cutting practices, use of chemical insecticides, and the age-old "do-nothing" policy are included in integrated control of the mountain pine beetle. Use of chemical insecticides to regulate beetle populations in large infestations has been ineffective (Amman and Baker 1972). Therefore, the use of insecticides is usually no longer considered in population suppression. However, insecticides appear to be both important and effective in preventing successful attacks on high-value trees in campgrounds, picnic areas, and summer home areas (Smith et al., in press).

Parasites and predators have not been included in the methodology for mountain pine beetle regulation outlined here. Cole (1974; 1975) evaluated mortality factors and found that parasites and predators were not effective in reducing mountain pine beetle populations. Occasional trees have high populations of parasites or predators that cause reductions in beetle survival. However, 14 years of life-table sampling show such instances to be clearly uncommon. Consequently, we have not attempted to fit parasites and predators into a scheme of integrated control of mountain pine beetle in lodgepole pine.

Prediction of Outbreaks

In most cases, successful control of mountain pine beetle populations in commercial forests will depend upon forest management practices. These practices require additional time for organized planning of tree harvest. Predictions of mountain pine beetle infestations based on diameter-phloem distributions are useful in dealing with stands that currently are approaching size and phloem thickness conducive to beetle outbreaks. Cole and Cahill[1] surveyed three stands in Colorado.

[1]Cole, Walter E., and Donn B. Cahill. Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine. Intermountain Forest and Range Experiment Station, Ogden, Utah (in preparation).

They considered the effect of various harvesting strategies, based on diameter-phloem cuts, on subsequent losses to the mountain pine beetle. These authors stated that by managing stands so that trees would not exceed 10 inches d.b.h. the probability of a beetle epidemic would be lower. They predicted that one of the stands under study, although infested, would not have a large buildup of beetles because only a few trees contained thick phloem. After 4 years, their prediction is still correct (Cahill, personal communication, December 1975).

By using a growth prognosis model (Stage 1973) and growth data for lodgepole pine (D. M. Cole and Stage 1972), it is possible to predict many years ahead when existing lodgepole pine stands will reach conditions conducive to beetle outbreak. Use of the model makes possible long-range management plans so that trees can be harvested before serious losses to the beetle occur.

Control Where Timber Values Are Primary

Several management strategies are available for use in commercial forests to minimize losses to the beetle (Roe and Amman 1970). On habitat types or at elevations where probability of loss is low, the manager can grow trees to large size, sawlogs for example. However, where the probability of loss is high, the manager can elect to grow small trees on as short rotation as possible that will yield sizes to meet product requirements, for example, poles.

Because the beetle concentrates heavily on trees of large diameter, continuous lodgepole forests at low elevations could be broken up into small blocks of different age and size classes, thereby reducing the area likely to be infested at any one time. Then, when a block is threatened by the beetle, all trees on the block could be harvested immediately.

At this time, our data suggest that rapid growth, thick phloem, and beetles go together. Therefore, the manager might employ controlled stocking to encourage a moderate growth rate and to assure that most trees would not develop thick phloem and trigger a large, beetle epidemic. A border planting of other tree species may be necessary; border trees usually grow more rapidly than trees within the stand and more quickly reach a stage conducive to mountain pine beetle infestation. It is usually among the edge trees that mountain pine beetle infestations have been observed to start.

Partial cuts can be used where only a small proportion of the trees are in diameter and phloem thickness categories conducive to beetle buildup, and where residual trees would be numerically adequate and vigorous to maintain stocking and productivity of the stand. For example, strategies of cutting to different diameter-phloem levels are being tested on the Gallatin National Forest in Montana. In one test, installed in 1974, all trees over 18 cm d.b.h. were cut. When remeasured in 1975, the stand had only 0.5 infested trees per hectare, in contrast to 7 trees per hectare in an adjacent check stand.[2]

Some problems must be anticipated when using partial cuts in the lodgepole pine type (Alexander 1975). Windfall can be of particular concern in stands opened up by a partial cut as specified by Alexander (1975). In addition, partial cutting creates ideal conditions for damage by dwarf mistletoe, Arceuthobium americanum

[2]Hamel, D. R., and M. D. McGregor. 1976. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana. USDA Forest Service, Northern Region, Forest Insect and Disease Control, Missoula, Montana. Progress Report, 11 pp.

Nutt., unless the stand is only lightly infected. Simulation procedures are available to help the manager predict yields from mistletoe-infected stands under various management alternatives (Myers et al. 1971).

Stands that are particularly susceptible to damage by the beetle (for example, those at low elevations) could be converted to such nonhost trees as Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco. In mixed-species forests, nonhost trees result in greater residual stocking should a beetle epidemic occur. However, the beetle appears to infest lodgepole in mixed-species forests just as readily as in pure forests (Roe and Amman 1970; Amman and Baker 1972). In addition, the manager must realize that in converting lodgepole pine stands to other tree species, he is merely exchanging insect problems. For example, the manager can expect depredations by the Douglas-fir beetle, Dendroctonus pseudotsugae Hopkins, should Douglas-fir be favored over lodgepole pine, and by the larch casebearer, Coleophora laricella (Hübner), should western larch be favored.

The natural conversion of noncommercial forest to nonhost tree species will eliminate the possibility of beetle populations building up and moving from noncommercial to commercial forest land. Conversion to nonhost species can be expected to occur naturally in the absence of fire since lodgepole pine is seral, being succeeded by Douglas-fir at lower elevations and subalpine fir and Engelmann spruce at higher elevations (Wellner 1971). If fire occurs prior to completion of succession, the stand would revert to a lodgepole pine forest.

Control Where Recreation Values Are Primary

Forests that are selected for recreation purposes such as National and State Parks, wilderness areas, and forested land not suitable for inclusion in the timber growing base outlined by Wikstrom and Hutchison (1971) do not require action against the beetle. In such forests, the proportion of other tree species can be expected to increase with each beetle infestation, until succession is complete and both lodgepole pine and the beetle have been eliminated from the stand in the absence of fire. Of course, this is not without its problems. For example, after an infestation, large numbers of dead trees fall across trails, fences, powerlines, and recreational facilities unless the trees are purposely felled and removed. In addition, there is potential danger from falling trees to the lives of hikers, campers, and others using the forests. Large numbers of dead trees will result in increased fuel buildup with greater probability of fire of high intensity (Brown 1975). However, since chemical means of controlling the beetle usually are not effective, and logging as a means of control cannot be used in these forests, a do-nothing policy seems justified with respect to the beetle.

Control Where Trees Have High Value

Trees in picnic areas, campgrounds, and around visitor centers and summer and permanent home sites have much higher value than trees in the forest situation. Preventive sprays using chemical insecticides offer promise for protection of such trees. A single application of lindane,[3] Dursban, or Sevin well before flight and attack by the beetles has been shown to be effective in preventing attacks

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[3]Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture of any commercial product or service. Pesticides are recommended contingent upon their registration for protective sprays against mountain pine beetle attack.

throughout the flight period and, in some areas, through a second year (Smith et al., in press). These authors stated that oil preparations generally are more effective than water preparations, but they recommend water emulsion sprays because of the phytotoxic effects of oil to host trees and surrounding vegetation.

The use of such chemicals will vary from State to State. Information on their availability can be obtained from the Pest Control Branch at any of the 10 Regional Offices or the Washington Office of the U.S. Forest Service.

Managers of high-use recreational areas should also consider periodically removing some of the large trees and replacing them with young trees of various species. Thus shade and esthetics will be preserved when some of the older, larger trees die or are killed.

CONCLUSIONS

The proposed system for regulation of mountain pine beetle populations in lodgepole pine is based on ecological relationships of the beetle and its host and considers land-use objectives. Forest management strategies are recommended where commercial timber values are important; essentially, a do-nothing policy is recommended where recreation values predominate or where noncommercial forest exists; and, preventive sprays (chemical insecticides) should provide protection for high-value trees in campgrounds, picnic areas, and around summer and permanent home sites.

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