

# Characteristics of Mountain Pine Beetles Reared in Four Pine Hosts<sup>1</sup>

GENE D. AMMAN

Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah 84401

## ABSTRACT

Environ. Entomol. 11: 590-593 (1982)

Mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), obtained from naturally infested lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were reared in four common hosts: ponderosa pine, *P. ponderosa* Lawson; western white pine, *P. monticola* Douglas; whitebark pine, *P. albicaulis* Engelmann; and lodgepole pine. Emerging beetles were collected daily, counted, and sexed, and pronotal width was measured.

Significant differences in brood production, size of female beetles, and developmental rate, but not sex ratio, occurred among hosts. Differences were not all associated with the same species of tree. However, the results indicate that, overall, lodgepole pine is the poorest, and ponderosa pine is the best, of the four hosts for mountain pine beetles.

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), infests 13 species of pine native to North America (Wood 1963) and several exotics (Furniss and Schenk 1969, McCambridge 1975). In addition, it infests several nonpine hosts from which little or no brood is produced (Beal 1939, Evenden et al. 1943, Furniss and Schenk 1969). The phenomenon of mountain pine beetles infesting one host species and their brood then infesting a different host species is of interest to entomologists and of great concern to land managers.

Hopkins' host selection principle states that insects tend to infest the same species of plant as the one on which they completed development (Allee et al. 1949). Richmond (1933) observed mountain pine beetles believed to have come from lodgepole pine, *Pinus contorta* Douglas, infest ponderosa pine, *P. ponderosa* Lawson. Field observations and experiments by Evenden<sup>2</sup> suggest that, when a shortage of the preferred host exists as a result of epidemic conditions, other hosts may be attacked successfully. Baker et al. (1971) thought that Hopkins' principle applied to low mountain pine beetle populations both in mixed stands of whitebark pine, *P. albicaulis* Engelmann, and lodgepole pine and in adjacent pure stands of these pines. The study by Baker et al. (1971) showed considerable differential tree mortality in the two host types, thus demonstrating beetle preference. Stock and Guenther (1979) and Stock et al. (1978) found little genetic difference between mountain pine beetle populations in pure stands of adjacent but different hosts, and suggested that considerable gene flow occurs between beetle populations in different hosts, probably during epidemic phases. Wood (1963) summed up present thinking on the subject. He stated that, under endemic conditions, populations may exhibit a strong preference for one host species even when intermixed with other acceptable species. However, during epidemic

conditions, any acceptable host and sometimes any conifer may be attacked.

Another interesting aspect of host switching by the mountain pine beetle, and one which this study addresses, is the effect on the first-generation progeny when parents from lodgepole pine are introduced into other pine hosts. Host effects were evaluated by using four mountain pine beetle characteristics—brood production, female size, sex ratio, and developmental rate. The most suitable host for the mountain pine beetle was hypothesized to yield the most beetles per unit area of bark, the largest beetles, the most even sex ratio, and the most rapid beetle development. It also was hypothesized that the beetles would do somewhat better in lodgepole pine than in the other host trees because parent beetles were obtained from lodgepole pine.

## Materials and Methods

One green tree with phloem exceeding 2.5 mm thick from each of four pine hosts of the mountain pine beetle was selected. Thick phloem was specified, because thin phloem in lodgepole pine yielded low brood production, small brood size, and sex ratios strongly in favor of females (Amman and Pace 1976). Trees used in this study were lodgepole pine and whitebark pine from northwest Wyoming, ponderosa pine from southwest Idaho, and western white pine, *P. monticola* Douglas, from northern Idaho. These trees were felled in late June and early July, and billets 36 cm long were cut from the lower trunks. The billets then were transported to Ogden, Utah. Twenty slabs 15 by 36 cm were cut from the billets of each species, thus providing a total of 80 slabs for the study. Thickness of exposed phloem was measured in the center of each cut edge of the slabs. Exposed edges of bark and all exposed wood surfaces were then coated with hot paraffin to slow the rate of drying.

Mountain pine beetles were obtained by cutting infested lodgepole pine in northwest Wyoming in June and transporting infested billets to Ogden. These billets were held at 22°C for beetles to complete development and emerge. Emerged beetles

<sup>1</sup>Received for publication 15 May 1981.

<sup>2</sup>James C. Evenden. 1933. Host selection in relation to the control of bark beetles. USDA, Bureau of Entomology, Coeur d'Alene, Idaho. Unpublished report. 13 pp.

were collected daily and sexed, using characteristics of the seventh abdominal tergum (Hopkins 1909, Lyon 1958).

Six pairs of beetles selected at random were introduced into 4.5-mm-diameter holes spaced 2.5 cm apart within the phloem across one end of each slab. Not all of the slabs could be infested in a single day because of time constraints. Therefore, equal numbers of slabs from each host were infested each day. The order of slab infestation within each host was determined randomly. Beetles were placed in the holes, and a piece of aluminum window screen was stapled over the holes to prevent beetles from escaping. Slabs were placed in a vertical position with beetles at the base, thus simulating field conditions where beetles bore vertically, parallel with the grain of the wood. The infested slabs were kept uncaged until the mature adults started to expel boring frass from the bark during maturation feeding before emergence. Slabs then were placed in individual cages. Emerging beetles were collected daily from the cages, their pronotal width was measured, and their sex was determined. After emergence was complete, bark was peeled from each slab, and the length of egg galleries was measured.

Data were subjected to analysis of variance (ANOVA) to determine if brood characteristics differed significantly among hosts. The Hartley multiple range test was used to determine significant differences among means (Snedecor 1956).

**Results and Discussion**

**Brood Production**

Brood production differed significantly ( $0.025 > P > 0.010$ ) among hosts, with the greatest production occurring in the five-needle pines, western white followed by whitebark, and least in the three- and two-needle pines, ponderosa followed by lodgepole. However, only the means of lodgepole and western white differed significantly (Table 1). Phloem thickness was significantly different ( $0.05 > P > 0.025$ ) among hosts and shown to be strongly related to brood production in lodgepole pine (Amman 1972a, Amman and Pace 1976). This, however, did not account for differences in brood production, since phloem thickness of lodgepole and western white did not differ significantly. Both ponderosa and western white had phloem significantly

thinner than whitebark, but brood production did not differ significantly among these three hosts. Egg gallery density ( $m/930\text{ cm}^2$ ) did not account for the difference in beetle production between lodgepole and western white either, since a significant difference in total length of egg galleries was not demonstrated between these two pines. A significant difference in egg gallery density occurred only between whitebark and western white. These results suggest differences in nutritional quality among hosts for mountain pine beetle production, with lodgepole apparently being the poorest and western white being the best of the group, although beetle production from neither of these was significantly different from the intermediate beetle production in ponderosa and whitebark pines.

**Female Size**

Pronotal width of female beetles differed significantly among hosts ( $0.025 > P > 0.01$ ). However, only the means of lodgepole and ponderosa pines differed significantly, with ponderosa yielding the largest beetles (Table 1). The larger size of field-collected beetles from ponderosa pine was noted previously (Hay 1956, Wood 1963), and Wood suggested that the difference is at least partly environmental rather than genetic. The results of this study support that statement. Whether there is any advantage conveyed to a specific beetle size has not been demonstrated. However, large Douglas-fir beetles, *D. pseudotsugae* Hopkins, contained a greater quantity of lipids than small beetles (Atkins 1967). Because of the greater lipid content, such beetles may be able to disperse farther and, hence, be better able to find suitable host trees. Also, large mountain pine beetles oviposit more eggs than small ones (Amman 1972b, McGhehey 1971, Reid 1962).

**Sex ratio**

No difference in the proportion of females in emerging brood adults was observed. However, brood adults from lodgepole departed greatest from a 1:1 sex ratio, with 66.5% female. Broods from the other three hosts ranged between 57.4% female in whitebark to 62.3% in western white. The sex ratio for field populations of mountain pine beetles emerging from lodgepole pine was given as 2 ♀♀:1 ♂ (Reid 1962), about the same as found in this

Table 1.—Some characteristics of mountain pine beetle brood adults reared in four pine hosts of specified phloem thickness

Item	Host											
	Lodgepole			Ponderosa			Whitebark			Western white		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
No. of brood/930 cm <sup>2</sup>	34.3a <sup>a</sup>	16.86	20	43.7	17.88	20	45.5	17.85	20	56.9a	21.88	20
Width of female pronotum (mm)	1.98a	0.16	176	2.09a	0.17	225	2.03	0.15	217	2.00	0.15	254
% Females in brood <sup>b</sup>	66.5	—	—	61.3	—	—	57.4	—	—	62.3	—	—
Days for 50% of brood to emerge	64a	7.46	20	56abc	6.02	20	64b	5.95	20	69c	5.49	20
Length (m) of egg gallery/930 cm <sup>2</sup>	2.32	0.85	20	2.41	0.72	20	2.68a	1.08	20	1.71a	0.96	20
Phloem thickness (mm)	3.25	0.06	20	2.92a	0.06	20	3.45ab	0.07	20	3.00b	0.08	20

<sup>a</sup>Figures marked by the same letter are significantly different at a maximum of the 0.05 level of probability.  
<sup>b</sup>Samples were combined for a single estimate from each host.

study. Cole et al. (1976) reported that sex ratios of emerging beetles varied by diameter of lodgepole pine, ranging from ca. 80% female for trees 20 cm in diameter at breast height (dbh) to ca. 60% for trees 51 cm dbh. They suggested that thin phloem and greater rate of drying in small than large trees were responsible. The sex ratio differed among phloem thicknesses in a laboratory study where drying did not occur. Females ranged from 61.1 to 71.9% of the brood from four phloem thicknesses, with thin phloem yielding the highest percent (Amman and Pace 1976). The lower proportion of males in brood from lodgepole, although not significantly different from those in other hosts, suggests that nutrition for male survival may not be quite as good in lodgepole pine. Gene frequencies at specific loci differ in beetles from trees having thin and thick phloem (Stock and Amman 1980).

#### Developmental Rate

Rate of brood emergence, which probably is related directly to rate of larval development, differed significantly ( $P < 0.005$ ) among the pine hosts (Table 1). Rate of emergence was significantly faster from ponderosa pine than any of the other hosts (Fig. 1). Rates of emergence from lodgepole, whitebark, and western white did not differ significantly. For example, 50% of the female beetles emerged from ponderosa pine after 56 days, compared with 64 days for lodgepole and whitebark pines, and 69 days for western white pine. The significantly faster rate of larval development and hence adult emergence from ponderosa pine again suggests that nutrition for the mountain pine beetle is probably best in this host.

Although mountain pine beetles may infest hosts other than the one in which they developed, the selected host will have considerable effect on the resulting brood. No single host proved to be best or worst in all four criteria used to evaluate host influence on beetle quality in this study. However, overall, beetles tended to do best in ponderosa pine and poorest in lodgepole pine even though the parents came from lodgepole.

#### Acknowledgment

I thank W. F. McCambridge, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., M. D. McGregor, U.S. Forest Service, Missoula, Mont., and M. W. Stock, University of Idaho, for their helpful review of this manuscript.

#### REFERENCES CITED

- Allee, W. C., A. E. Emerson, O. Park, T. Park, and K. P. Schmidt. 1949. Principles of animal ecology. W. B. Saunders Co., Philadelphia. 837 pp.
- Amman, Gene D. 1972a. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. *J. Econ. Entomol.* 65: 138-140.
- 1972b. Some factors affecting oviposition behavior of the mountain pine beetle. *Environ. Entomol.* 1: 691-695.
- Amman, Gene D., and V. E. Pace. 1976. Optimum egg gallery densities for the mountain pine beetle in relation to lodgepole pine phloem thickness. U.S. Dep. Agric. For. Serv. Res. Note INT-209. 8 pp.
- Atkins, Michael D. 1967. The effect of rearing temperature on the size and fat content of the Douglas-fir beetle. *Can. Entomol.* 99: 181-187.
- Baker, B. H., G. D. Amman, and G. C. Trostle. 1971. Does the mountain pine beetle change hosts in mixed lodgepole and whitebark pine stands? U.S. Dep. Agric. For. Serv. Res. Note INT-151. 7 pp.

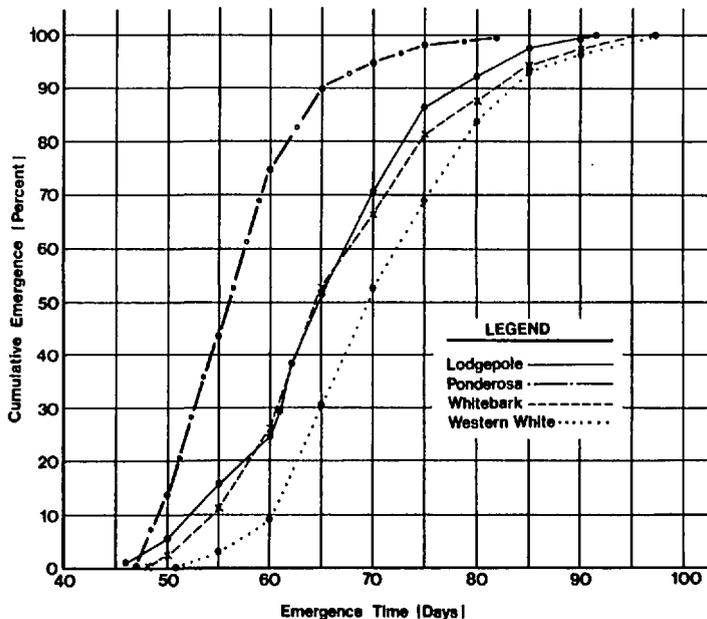


FIG. 1.—Rate of brood emergence. Time started when parent beetles were placed into the bark.

- Beal, J. A. 1939.** The Black Hills beetle, a serious enemy of Rocky Mountain pines. U. S. Dep. Agric. Farmers Bull. 1824. 22 pp.
- Cole, W. E., G. D. Amman, and C. E. Jensen. 1976.** Mathematical models for the mountain pine beetle- lodgepole pine interaction. Environ. Entomol. 5: 11-19.
- Evenden, J. C., W. D. Bedard, and G. R. Struble. 1943.** The mountain pine beetle, an important enemy of western pines. U.S. Dep. Agric. Circ. 664. 25 pp.
- Furniss, M. M., and J. A. Schenk. 1969.** Sustained natural infestation by the mountain pine beetle in seven new *Pinus* and *Picea* hosts. J. Econ. Entomol. 62: 518-519.
- Hay, C. J. 1956.** Experimental crossing of mountain pine beetle with Black Hills beetle. Ann. Entomol. Soc. Am. 49: 567-571.
- Hopkins, A. D. 1909.** Contributions toward a monograph of the scolytid beetles. I. The genus *Dendroctonus*. U.S. Dep. Agric. Tech. Ser. No. 17, Part I. pp. 1-164.
- Lyon, R. L. 1958.** A useful secondary sex character in *Dendroctonus* bark beetles. Can. Entomol. 90: 582-584.
- McCambridge, W. F. 1975.** Scotch pine and mountain pine beetles. Green Thumb 32: 87.
- McGhehey, J. H. 1971.** Female size and egg production of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Can. For. Serv. Northern For. Res. Centre, Inf. Rep. NOR-X-9. 18 pp.
- Reid, R. W. 1962.** Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootenay region of British Columbia. II. Behaviour in the host, fecundity, and internal changes in the female. Can. Entomol. 94:605-613.
- Richmond, H. A. 1933.** Host selection studies of *Dendroctonus monticolae* Hopkins in southern British Columbia. For. Chron. 9: 60-61.
- Snedecor, G. W. 1956.** Statistical methods. Iowa State College Press, Ames. 534 pp.
- Stock, M. W., and G. D. Amman. 1980.** Genetic differentiation among mountain pine beetle populations from lodgepole pine and ponderosa pine in northeast Utah. Ann. Entomol. Soc. Am. 73: 472-478.
- Stock, M. W., and J. D. Guenther. 1979.** Isozyme variation among mountain pine beetle (*Dendroctonus ponderosae*) populations in the Pacific Northwest. Environ. Entomol. 8: 889-893.
- Stock, J. W., J. D. Guenther, and G. B. Pitman. 1978.** Implications of genetic differences between mountain pine beetle populations to integrated pest management, pp. 197-201. In A. A. Berryman, G. D. Amman, and R. W. Stark, [eds.], Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc. College of Forestry, Wildlife, and Range Science, University of Idaho, Moscow.
- Wood, S. L. 1963.** A revision of the bark beetle genus *Dendroctonus* Erichson (Coleoptera: Scolytidae). Great Basin Nat. 23: 1-117.
-