Improved laboratory production of eggs of *Coccinella septempunctata*. Ibid. 63: 315–7.
Shands, W. A., G. W. Simpson, and M. H. Brunson. 1972a. Insect predators for controlling aphids on potatoes. 1. In small plots. Ibid. 65: 511–4.
Shands, W. A., G. W. Simpson, and R. H. Storch. 1972b. Insect predators for controlling aphids on potatoes. 3. In small plots separated by aluminum flashing strip-coated with a chemical barrier and in small fields. Ibid. 65: 799–805.
Shands, W. A., G. W. Simpson, and C. G. Gordon. 1972c. Insect predators for controlling aphids on potatoes. 5. Numbers of eggs and schedules for applying them in large field cages. Ibid. 65: 810–7.
Sundby, R. A. 1966. A comparative study of the efficiency of three predatory insects, *Coccinella septempunctata* L. (Col. Coccinellidae), *Chrysopa carnea* St. (Neuroptera, Chrysopidae), and *Syrphus ribessii* L. (Dipt., Syrphidae) at two different temperatures. Entomophaga 11: 395–404.
Szumkowski, W. 1955. Observations on the biology of some coccinellids (Coleoptera). Biol. Entomol. Venez. 11: 77–96.
Wadley, F. M. 1931. Ecology of *Toxoptera graminum*, especially as to factors affecting importance in the northern United States. Ann. Entomol. Soc. Am. 24: 325–95.

Insect Predators[1] for Controlling Aphids[2] on Potatoes. 9. Winter Survival of *Coccinella* Species in Field Cages Over Grassland in Northeastern Maine[3]

W. A. SHANDS,[4] GEDDES W. SIMPSON,[5] and R. H. STORCH[6]

ABSTRACT

Over a 5-year period at Presque Isle, Maine, winter survival of *Coccinella septempunctata* L. in cages over undisturbed grassland averaged from 6.3 to 79.5% and probably depended upon age and condition of the beetles when placed in the cages. Minimum winter temperatures and precipitation did not appear to influence winter survival. In a similar test, 19% of the beetles survived a 2nd winter in the cages. Winter survival for 3 native species was 76.9 and 19.4% during 2 winters for the transverse lady beetle, *C. transversoguttata* Faldermann; 0.5% during 1 winter for the thirteenspotted lady beetle, *Hippodamia tredecimpunctata tibialis* (Say); and 0% during 1 winter for the convergent lady beetle, *H. convergens* Guérin-Méneville. There are no data to suggest that *C. septempunctata* has become established at Presque Isle following 5 years of release of eggs and larvae in experimental plantings of potatoes.

In 1964, studies were begun at Presque Isle, Maine, to determine the feasibility of supplementing naturally occurring populations of arthropod predators in potato fields to obtain control of aphids on potatoes. One of the insect predators under investigation since the outset, not native to the area, was a lady beetle, *Coccinella septempunctata* L. The breeding stock used in our studies was imported from the vicinity of Paris, France, by the Entomology Research Division, Agric. Res. Serv., USDA. We continually have maintained and mass produced populations of this beetle at the Presque Isle laboratory since receiving an initial shipment from the Entomology Research Division laboratory at Moorestown, N. J. From the outset, studies were made to determine how well the beetle can withstand the rigorous Maine winters, although its success or failure for supplementing the natural agents in controlling aphids on potatoes in northeastern Maine is not dependent upon its establishment in the new environment. Reported herein are results of the study during the period 1964–69 with results from similar, but less extensive, tests with the native transverse lady beetle, *Coccinella transversoguttata* Faldermann; thirteenspotted lady beetle, *Hippodamia tredecimpunctata tibialis* (Say); and convergent lady beetle *Hippodamia convergens* Guérin-Méneville. Since 1941, *H. convergens* has occurred in trace numbers and only occasionally in Aroostook County, Maine, except in 1965 and 1966 when it was one of the 3 most common coccinellids on potatoes at Presque Isle.

Grassland is one of the more important overwintering environments of *C. septempunctata* in Central Asia (Savoiskaya 1965), whereas in Middle- and East-Europe it is typically found in cultivated areas (Hodek 1960).

METHODS AND MATERIALS.—The hibernation cages were 76×61×76 cm high. The wooden frames were covered with a combination of copper screening with 24 strands/cm and clear-plastic film on the sides and on top with two 20-cm strips of copper screen with a 20-cm strip of cotton ducking between, which was fitted with a zippered slit opening. The cages were placed in well-drained grassland. The 23-cm wooden baseboard siding around the bottom of the cage was sunk into the soil 10–12 cm after removing a strip of sod and soil ca. 5 cm wide. Soil was packed around the inside and outside of the baseboard to ground level to prevent escape of the beetles. Practically all snow was excluded except for small amounts blown through the fine screening on the side of the cages during driving snowstorms.

The beetles were reared during the summer in an insectary in field cages covered with Saran® screen with 13 strands/cm or in plastic-covered greenhouses in which potato plants were growing, or they were collected from potato fields in September. They were fed one or more species of the potato-infesting aphids, including the green peach aphid, *Myzus persicae* (Sulzer); the potato aphid, *Macrosiphum euphorbiae* (Thomas); the buckthorn aphid, *Aphis*

[1] Coleoptera: Coccinellidae.
[2] Hemiptera: Aphididae.
[3] In cooperation with the Entomology Research Division, Agric. Res. Serv., USDA. Received for publication Oct. 26, 1971.
[4] Visiting Professor of Entomology, University of Maine, Orono 04473; formerly, Research Entomologist, Entomology Research Division, Agric. Res. Serv., USDA.
[5] Professor of Entomology, University of Maine, Orono 04473.
[6] Associate Professor of Entomology, University of Maine, Orono 04473.

nasturtii Kaltenbach, or the foxglove aphid, *Acyrthosiphon solani* (Kaltenbach).

The beetles were collected by gently disturbing them on the foliage or other surfaces on which they were situated until they fell into glass test tubes or 450-ml pasteboard ice cream cartons. Fifty beetles were usually collected in a container and were released in the hibernation cages soon afterward, typically within 30 min. The beetles were collected and placed in the hibernation cages from ca. Sept. 10 to 30, but in 1968 a few were introduced as late as Oct. 15. At the time of introduction, the cages were provisioned with collards, *Brassica oleraceae* L. var. *acephala* De Candole, in flats or pots that were heavily infested with green peach aphids. These plants were replaced with other aphid-infested plants as frequently as needed to maintain a continuing, adequate food supply for the introduced beetles until all of them became inactive; usually this was by late October.

Added protection for the beetles in the cages in the grassland was provided in 3 cages in the fall of 1964 and in 9 cages in the fall of 1965. In 1964, 8 layers of 170-g burlap were spread over the grassland after the beetles became dormant, while in 1965, 8 layers of the 170-g burlap were topped with a layer of 0.01-cm, waterproof clear-plastic film. The burlap was removed Apr. 19, 1965, 1 day before the 1st active beetles were seen in the cages, but the covering was not removed until May 6, 1966, 22 days after the 1st active beetles were seen and removed.

Winter survival of the beetles was determined by removing, at each observation, all living beetles that were active or had become active enough to appear since the preceding examination. The cages were examined in mid-afternoon for removal of visible living beetles from about mid-April to mid-June of each year. During that period in 1966 and in 1967, after the start of emergence, examinations were made at intervals of 7–10 days; in 1965, 1968, and 1969, they were made each day that the temperature in the shade reached 14.5°C at a height of 1.2 m. (This was the approximate temperature at which we initially found beetle activity. Bonnemaison (1964) found some activity at 13°C, but Yakhontov (1965) found none below 12°C, and at 13–14°C the beetles were still in massive aggregations). At the final examination each year, the dead grass in each cage was combed, closely clipped, and removed. This litter and the soil surface inside each cage were examined for any living beetles remaining.

RESULTS AND DISCUSSION.—Winter survival of adults of *C. septempunctata* in caged grassland during the 5-year study varied from 6.3 to 79.5% and depended largely upon the age and source of the beetles placed in the cages (Table 1). Comparable percentages for *C. transversoguttata* ranged from 76.9 in 1965 to 19.4 in 1969. *H. convergens* did not survive in the winter of 1965–66 in the same kind of hibernation environment, but during that winter there was a 0.5%-survival rate of *H. tredecimpunctata tibialis* in 1 hibernation cage.

Emergence of *C. septempunctata* in hibernation cages began as early as Apr. 14 in 1966. However, in the 3 years when the examinations were started at the same time and were made more frequently, the earliest date was Apr. 17 (Fig. 1). Beetles occasionally were seen on the walls of the cages on days when maximum temperature in shade did not exceed 11°C at a height of 1.2 m. This apparent activity could have resulted from movement upward on a previous day when observations were not made because the threshold temperature for activity was barely exceeded, or because of beetles becoming active on a previous day after the observations had been made. Greatest emergence generally occurred on days when the maximum reached or exceeded 18°C. A major portion of the emergence in all years occurred May 9 to 15 (Fig. 1). The percentages of total-season emergence during this period were 63, 44, and 37 in 1965, 1968, and 1969, respectively. Emergence was complete by about June 10. The large percentage of total-season emergence recorded on June 10, 1969, appeared to be associated with the rain on June 7, followed by 3 successive days of maximum temperatures of 21.1°C or above. This is similar to the response to moisture observed with the Mexican bean beetle, *Epilachna varivestis* Mulsant (Douglass 1933b).

Variability, within and among years in percent of *C. septempunctata* surviving, apparently was due chiefly to differences in age and source of the adults with respect to the duration of the feeding period prior to the onset of diapause or dormancy. Minimum winter temperature, which during the 3 coldest months in each of the years of the 5-year study ranged from −30.0 to −33.5°C, appeared to exert little or no influence on winter survival. Likewise, precipitation during hibernation had no meaningful effect on survival since there was practically no snow cover inside the cages. Survival of 59–80% was recorded among beetles that matured chiefly during July and August. With the assumption of Oct. 15 as the approximate date of onset of inactivity, beetles in this grouping had feeding periods ranging from about 45 to 105 days. From 41 to 44% of the beetles survived when maturation in the large field cages ranged from mid-August to mid-September, with resulting feeding periods of 30–60 days. Survival of only 6–29% was recorded when imagos had feeding periods of 1–10 days in plastic greenhouses before being put into the hibernation cages, followed by additional feeding periods of 15–30 days or less.

Covering the grassland in the cages with burlap or burlap topped with a waterproof plastic film probably had little, if any, influence upon winter survival of *C. septempunctata* (Table 1). The lower survival in the spring of 1966 in cages with the protective covering of burlap plus plastic compared with that in cages without it appeared to be due largely to drowning of beetles that emerged and became trapped in water-filled depressions in the plastic film.

The survival of 19% of the adults of *C. septempunctata* during a 2nd winter of hibernation in cages over grassland was surprisingly high (Table 1). These beetles obviously were in suitable condition for successfully enduring hibernation in the winter of 1967–68 as well as in that of 1968–69 (see footnote c, Table 1).

Winter survival of the native *C. transversoguttata* probably was not substantially different from that of *C. septempunctata*, and probably was influenced similarly by length of the feeding period prior to dormancy. The field-collected adults, showing 77% survival in 1965, most likely matured during July and August and had 105–45 days for feeding (Table

Table 1.—Winter survival of adults of some coccinellids in hibernation cages over grassland[a] at Presque Isle, Maine, during 5 winters.

Age and source of beetles	Introduction in fall			Survival in spring	
	Year	No. cages	No. beetles	Year	%
		Coccinella septempunctata			
Emerged chiefly in July and August					
In large field cages[b]	1964	3[a]	156	1965	69.9
	1965	9[a]	954	1966	43.1
	1965	9	976	1966	66.3
	1966	6	561	1967	79.5
	1967	7	1085	1968	59.3
Emerged chiefly mid-August to mid-September					
In large field cages[c]	1967	10	1810	1968	43.5
	1968	9	1100	1969	41.2
In plastic greenhouses[d]	1967	22	3618[e]	1968	6.3
	1968	9	854	1969	29.0
2nd year of overwintering[f]	1968	3	300	1969	19.0
		C. transversoguttata			
Collected from potatoes in the field in September	1964	1	13	1965	76.9
Emerged in field cages, chiefly in September	1968	5	867	1969	19.4
		Hippodamia tredecimpunctata tibialis			
Emerged in large field cages, chiefly in late August and September	1965	1	200	1966	0.5
		H. convergens			
Collected from potatoes in the field in September	1965	1	71	1966	0

[a] Without added protection except in the winters of 1964–65, when 8 layers of 170-g burlap were spread over the caged grassland, and of 1965–66, when a similar cover in 9 of the cages was topped with a layer of 0.01-cm waterproof clear plastic. These coverings were installed in late fall after the beetles were inactive; they were removed in early spring before beetle activity resumed in 1965, but not until May 6, 1966, or until 3 weeks after 1st beetle activity was observed.
[b] Kept for at least 3 weeks in the large field cages before being transferred to the hibernation cages.
[c] Kept 1–3 weeks in the large field cages before being transferred to the hibernation cages.
[d] Transferred directly to the hibernation cages from the plastic greenhouses. These adult beetles were mostly 1–10 days old at the time of transfer.
[e] Inadequately fed, both as larvae and as adults in the glasshouse insectary.
[f] After the 1st winter's survival, these beetles were used in oviposition studies for part of the summer, then stored at 7.5° to 9°C until mid-August, then they were kept in a large field cage containing potatoes infested with green peach aphids until the beetles were placed again in hibernation cages.

1). The feeding period was much shorter than this for the adults maturing in field cages in late summer 1968 and having 19% winter survival in the hibernation cages in spring 1969.

No winter survival of *C. septempunctata* occurred when 7-day-old imagos were put into screen cages and placed in a hole 10.2 cm beneath the soil surface.

C. septempunctata survived the winters exceptionally well in cages over grassland. Recoveries in spring of 6.3–79.5% were above those usually found for the Mexican bean beetle, a coccinellid with somewhat similar hibernation habits in some areas. During a 4-year study in western South Carolina, Eddy and Clarke (1929) observed winter survivals of 12.9–22.9% for the Mexican bean beetle in cages over grassland; in cages over litter on an oak-pine forest floor, survival ranged from 4.9 to 32.9%. In a similar 6-year study in the Estancia Valley, N. Mex., where minimum winter temperatures were not markedly different from those at Presque Isle during our study, Douglass (1933b) reported winter survivals of *E. varivestis* ranging from 0 to 58%, depending upon location and amount and distribution of rainfall.

Two aspects of our procedure may have resulted in higher estimates of winter survival of *C. septempunctata* in cages than might have occurred in a naturally occurring population of the beetle in the same locale. The generally abundant and continuing supply of aphids provided to the beetles, both before and after they were placed in the hibernation cages, possibly permitted the body buildup of levels of fats and glycogen adequate for winter survival (Hodek and Cerkasov 1961; Hagen 1962; Bonnemaison 1964; El-Hariri 1966; Hodek 1962, 1967). The removal of living beetles from the cages, when first found to be active in spring, could have resulted in counting as surviving some beetles which later may have died before "emerging." We found that some of the beetles that had become active, if not collected, would reenter the stand of dead grass and again become inactive at the base of the grass stems when temperatures dropped sufficiently following short periods of warm weather. Douglass (1933a) also found this in *E. varivestis*; in fact, he found that greatest mortality of these beetles occurred after they had become intermittently active in the cages in spring. Because of this, Eddy and Clarke (1929) and Douglass (1933a) waited for about 1 month (or until naturally surviving beetles were found moving into bean fields) before they began to remove and to count living beetles as having survived the winter in their cages.

There are no data to suggest that *C. septempunctata* has become established at Presque Isle after 5 years of introductions of eggs and larvae in our experimental plantings of potatoes. A few overwintered specimens were found in early spring of at least 1 year near the plastic greenhouses and the glasshouse insectary where the beetle was bred in large numbers

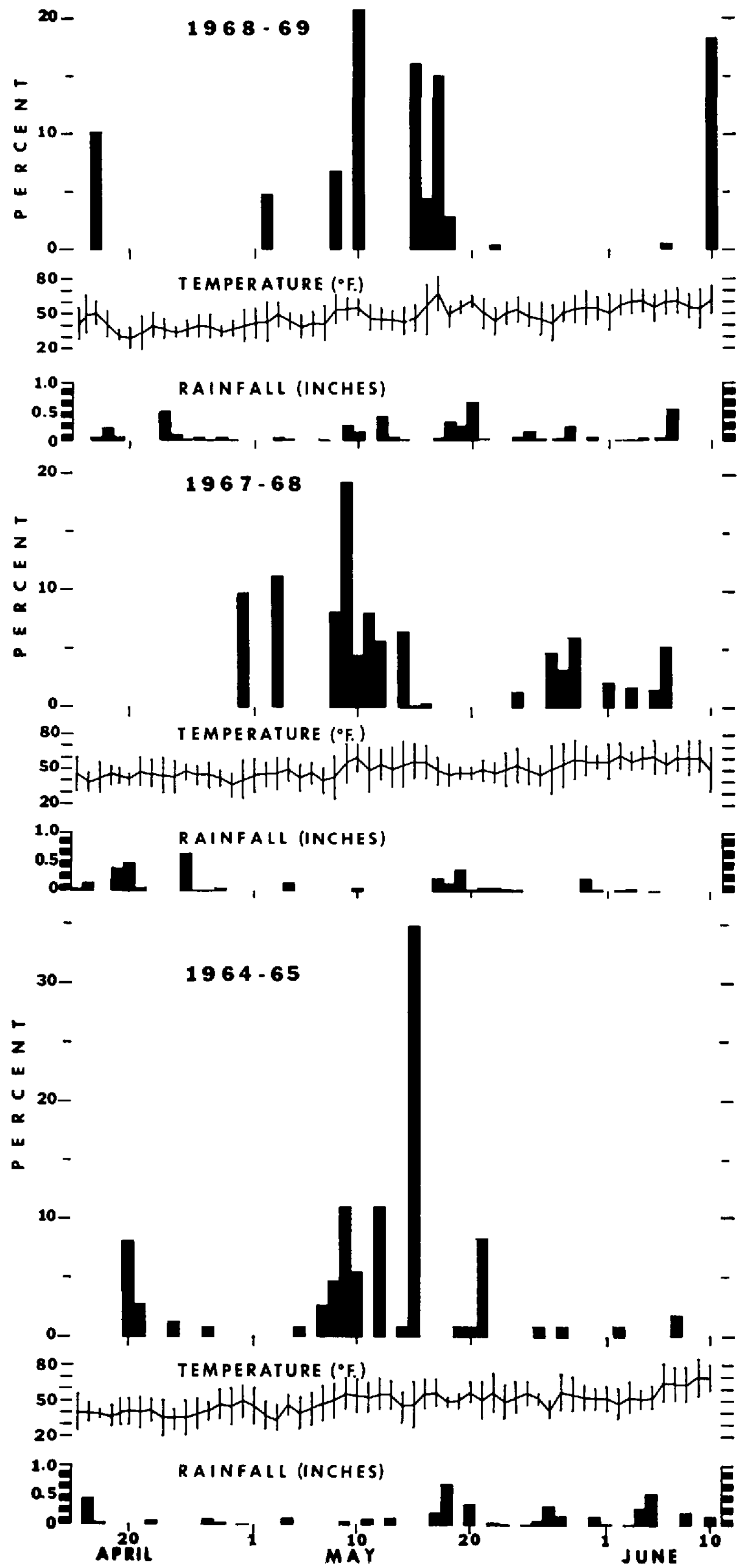

FIG. 1.—Percentages of adults of *C. septempunctata* recovered daily from hibernation cages in relation to temperature and rainfall during 3 years at Presque Isle, Maine.

the preceding year. They have not been found in any plantings of potatoes, before introductions were started, in each of the years 1964 to 1969, inclusive. However, results of our hibernation cage studies suggest that this introduced coccinellid may be capable of surviving the winter in grassland, in cages, at Presque Isle, at least as well as the native *C. transversoguttata*, and possibly better that *H. tredecimpunctata*. Considering the results in Table 1, grassland may not be the most suitable hibernation habitat for *H. tredecimpunctata* (and *H. convergens*, possibly). However, it and *C. transversoguttata* are ordinarily the most abundant of the coccinellids occurring there on potatoes. Apparently, minimum winter temperature at Presque Isle will not be a deterrent to successful establishment of *C. septempuctata*, as the range of −30.0 to −33.5°C occurring there during our cage studies does not differ markedly from that of −41°C in southeastern Kazakstan where the beetle occurs naturally (Savoiskya 1965).

According to Bonnemaison (1964) and Hodek (1965), our population of *C. septempunctata*, which was obtained from the Paris district, is rather heterogeneous in that it contains univoltine individuals, polyvoltine individuals, and crosses of the 2 races. Our observations lead us to think that if or when *C. septempunctata* becomes established in northeastern Maine, it probably will have 1 generation/year and a partial 2nd one, as does the native *C. transversoguttata*. Adults of the 2nd generation may survive the winter poorly because of inadequate food and length of feeding periods for developing the necessary reserves of fats and glycogen before entering hibernation.

ACKNOWLEDGMENT.—We appreciate the assistance of R. L. Holmes and S. H. Clockedile, Biological Aids, Entomology Research Division, Agr. Res. Serv., USDA, with the introduction and subsequent recovery of the beetles from the hibernation cages during the last 3 years of the study.

REFERENCES CITED

Bonnemaison, L. 1964. Observations ecologiques sur la Coccinella a 7 points (*Coccinella septempunctata* L.) dans region parisienne (Col.). Bull. Soc. Entomol. France 69: 64–83.

Douglass, J. R. 1933a. Hibernation of the Mexican bean beetle in the Estancia Valley, New Mexico. J. Agric. Res. 46: 579–605.

1933b. Habits, life history, and control of the Mexican bean beetle in New Mexico. USDA Tech. Bull. 376. 45 p.

Eddy, C. O., and W. H. Clarke. 1929. The Mexican bean beetle, 1927–1928. S. C. Agric. Exp. Stn. Bull. 258. 42 p.

El-Hariri, G. 1966. Changes in metabolic reserves of three species of aphidophagous coccinellidae (Coleoptera) during metamorphosis. Entomol. Exp. Appl. 9: 349–58.

Hagan, K. S. 1962. Biology and ecology of predaceous coccinellidae. Annu. Rev. Entomol. 7: 289–326.

Hodek, I. 1960. The influence of various aphid species as food for ladybirds *Coccinella 7-punctata* L. and *Adalia bipunctata* L., p. 314–6. *In* I. Hrdy [ed.] The Ontogeny of Insects. 405 p. Publishing House, Czechoslovak Acad. Sci.

1962. Migration of coccinellids to their hibernation quarters. 11th Int. Congr. Entomol. 3: 39.

1965. Voltinism and diapause in aphidophagous insects, p. 97–102. *In* I. Hodek [ed.] Ecology of Aphidophagous Insects. W. Junk, The Hague, The Netherlands. 360 p.

1967. Bionomics and ecology of predaceous coccinellidae. Annu. Rev. of Entomol. 12: 79–104.

Hodek, I., and J. Cerkasov. 1961. Experimental influencing of the imaginal diapause in *Coccinella septempunctata* L. (Coccinellidae, Coll.) 7th contribution to the ecology of Coccinellidae. Acta Soc. Zool. Bohemoslov. 25: 70–90.

Savoiskaya, G. I. 1965. Hiberation and migration of coccinellids in South-Eastern Kazakhstan, p. 139–42. *In* I. Hodek [ed.] Ecology of Aphidophagous Insects. W. Junk, The Hague, The Netherlands. 360 p.

Yakhontov, V. V. 1965. Diapause in coccinellidae of Central Asia, p. 107–8. Ibid.

Attraction of Mountain Pine Beetles[1] to Small-Diameter Lodgepole Pines Baited with *Trans*-Verbenol and Alpha-Pinene[2,3]

LYNN A. RASMUSSEN[4]

USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah 84401

ABSTRACT

Lodgepole pines, *Pinus contorta* Douglas, 8.9 in. diameter at breast height (DBH) or less, were baited with the pheromone *trans*-verbenol and the terpene alpha-pinene to determine if populations of *Dendroctonus ponderosae* Hopkins could be attracted to these trees of small diameter. Even though the beetles in most cases did not successfully attack baited trees, such trees were usually the first to be attacked. This phenomenon indicated that these chemicals might be used to attract beetles into areas with baited trees but not to baited trees exclusively. This indication was supported by the fact that the beetles successfully attacked larger unbaited trees.

Infestations of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in lodgepole pine, *Pinus contorta* Douglas, have occurred in Idaho, Montana, and Utah at rather frequent intervals. The mountain pine beetle kills most of the large lodgepole pine trees in a forest before the beetle population subsides, and it probably is the most aggressive *Dendroctonus* bark beetle in the western United States.

Amman (1969) reported that brood survival, as measured by emergence holes, was correlated closely with bark depth but varied with stand density and plot elevation. The greatest proportion of thick-barked trees was in the large-diameter classes. He hypothesized that phloem thickness was the critical

[1] Coleoptera: Scolytidae.

[2] Received for publication Oct. 13, 1971.

[3] Mr. Walter E. Cole endorses and communicates.

[4] Biological Technician.