OBSERVATIONS ON THE BIOLOGY OF *PRIONUS CALIFORNICUS* MOTS. ON HOPS, *HUMULUS LUPULUS* L, IN IDAHO[1]

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ABSTRACT

The damage potential, seasonal flight activity and larval development of *Prionus californicus* were investigated over five years in Idaho hop yards. Hop plants were not susceptible to oviposition and larval establishment until after their second year. Crowns of severely infested plants were reduced to masses of frass and rotted areas. Major roots were frequently tunneled and girdled. First foliar symptoms were loss of vigor and often one or more wilted and yellowing shoots. Some affected plants died within a few months while others became less vigorous over several years. Two kinds of damage occurred: the first was from larvae that developed within root systems in established yards; the second was root damage to new plantings from larvae left in the soil when the old yard was taken out and replanted to hops. Beetle flight occurred only during July with day-to-day variation at least partially related to minimum temperatures and to precipitation. Young larvae were found almost entirely in the vascular region of roots to a soil depth of about 200 mm. Older larvae were in both living and dead roots to a soil depth of about 500 mm. Based upon measurements of 243 larvae taken from 50 hop root systems, the life cycle of the species is usually 4 years.

INTRODUCTION

Prionus californicus Mots. is widely distributed in the Pacific slope of the United States and British Columbia (Doane *et al.*, 1936). Oak is the most common and apparently preferred host, but the species has been recorded from the roots of a variety of other broadleaved plants including poplar, alder, apricot, eucalyptus and grape, and from roots and stumps of several pines (*Pinus* spp.), Douglas fir (*Pseudotsuga menziesii*), *Sequoia*, *Abies* and butts of red-cedar (*Thuja* sp.) poles (Doane *et al.*, 1936; Keen, 1952). Essig (1926) reported that the larvae can feed on living roots and frequently kill fruit trees as well as native hosts. In New Mexico, Eyer (1942) found apple trees to be preferred over several other orchard fruits.

Hop growers in Idaho have noticed damage from *P. californicus* since at least the 1930's and their observations indicate that the longevity of a severely infested yard may be reduced by one half. The problem is compounded by the practices of concentrating production in certain favourable areas and planting new hops in old yards without several years' rotation of other crops.

Hop production in Idaho is centered in an area about 150 km^2 in the southwest part of the state, in 3 relatively distinct areas near the communities of Wilder, Greenleaf and Notus. The principal varieties are Talisman, Late Clusters and Galena.

Crawford and Eyer (1928) and Eyer (1942) studied the biology and control of *P. californicus* on apples in New Mexico. Little information is available on other crops and apparently there have been no studies on hops. The objectives of the present study were: 1. to assess damage potential of the species; 2. to obtain information on seasonal flight activity; and 3. on larval development; and 4. to assess control possibilities.

MATERIALS AND METHODS

General observations on larval development and damage were made from 1977 to 1982 by digging around individual plants to expose crowns and upper roots. Exposed parts were washed with water from a pressurized sprayer. When soil was replaced soon after examination the procedure had little effect on plant growth but was clumsy and time consuming. Detailed observations on size and location of larvae in root systems required sacrificing the plants in order to thoroughly clean and dissect crowns and roots.

To monitor flight periods of the beetles light traps were placed in 7 to 9 hop yards in each of 3 seasons. Traps were slightly modified from the Ellisco General Purpose "Black Light" Trap (Ellisco Inc., Philadelphia, PA). Traps were put out well in advance of anticipated emergence and maintained until no beetles were caught for at least 2 weeks. Traps were serviced every 2 to 3 days in 1980 and daily in 1981 and 1982. Weather records reported in relation to the number of beetles trapped were from the Southwest Idaho Research and Extension Center, Parma. The weather station was within 12 km and

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250 m elevation of all light trap sites. Each of the 3 periods of measurable precipitation was from general weather systems that affected the entire area.

Data on measurements of larval length were analyzed using the EM algorithm for normal populations as outlined by Everitt and Hand (1981).

RESULTS AND DISCUSSION

Damage

Two distinct kinds of damage were observed. The first was in yards older than about 7 years and was caused by long-term infestations which weakened and eventually killed plants. In severely infested plants, crowns were reduced to masses of frass and rotted areas, and major roots were frequently tunneled and girdled. Up to 20 larvae were found in single root systems. Early foliage symptoms were a lack of vigor, often with one or more wilted and yellowing shoots. Some plants observed to be affected in early summer died later in the season or the following spring. Others simply lost vigor over a period of years. Observations in several severely infected yards showed all plants to have some degree of damage. Although individual plants were sometimes replaced, growers typically removed entire yards when infestations became sufficiently extensive to seriously depress yields.

Observations on several new plantings showed that plants were not infested in the first or second year. This apparent immunity could result because crown areas of young plants are too smooth to be attractive for oviposition. Doane *et al.* (1936) reported that eggs are deposited in crevices near the soil level. It is also possible that larvae cannot become established because of the intense vigor of young plants. Eyer (1942) found that vigorously growing young apple trees were not frequently infested.

The second type of damage occurred when old yard sites were replanted to hops. New plants are usually placed in the same locations as those previously removed to avoid changing the location of trellises. Roots and crowns, therefore, are subject to damage from *P. californicus* larvae left in the soil. Young plants were sometimes completely cut off and died before the end of the first season. In yards examined the second and third year after planting, up to 20% of the root systems were damaged. Potential for damage remains even if another crop is in rotation for one year between hop plantings. In one case where the interim crop was potatoes, several larvae were found feeding on the tubers, one on a cedar stake, and others on pieces of hop roots left in the soil.

Flight period and Activity of Adults

Light trap catches during 3 years showed the flight period of *P. californicus* to be essentially restricted to the month of July (Fig. 1). Day-to-day variation in numbers caught during 1981 and 1982 was generally related to warm night temperatures as indicated by daily minimum temperatures (Fig. 1). The only other factor identified was precipitation which apparently had an influence exclusive of temperature during the July 4-8 period, 1981 and on July 28, 1982. Peak numbers were trapped about halfway through the annual flight period each year. This was evidently after most beetles had emerged but little mortality had occurred. Annual numbers of beetles per trap site varied from 0 to 174 over the 3 years. No beetles were caught in traps in the Greenleaf area but beetles were caught in every trap in the Wilder and Notus areas each year.

During daylight hours beetles were found in the duff at the base of hop plants where dense growth may provide required shade and protection. Beetles confined to plant bases in cages lived for about 10 days.

A series of dissected gravid beetles contained from 150 to 210 eggs. Eggs were not found in the field where they are difficult to detect since they are sticky and become covered with fine soil particles. Eyer (1942), however, found eggs were deposited from about 12 to 37 mm below the soil surface near the bases of apple trees in cage experiments.

Larval Development

P. californicus larvae were removed from 50 root systems collected in April, 1982, from an 8-year-old moderately infested hop yard. Size distribution of the 243 larvae recovered (Fig. 1) suggested that they represented 4 groups. The first two with boundaries of 3 to 10 mm and 14-21 mm respectively appeared distinct, whereas the third with boundaries of 23 to 35 mm and the fourth made up of larvae larger than 35 mm, were less distinct. To test the hypothesis that these size distributions represented 4 populations we used the EM algorithm for normal populations (Everitt and Hand, 1981).

For each of the four populations initial values of the proportion of that particular population to all populations, ρ_i, the variance, σ_i^2, and the mean, μ_i, were estimated. Assuming normal distributions, probabilities for each of the individual 243 observations coming from each of the four hypothesized populations were computed, and new estimates of ρ_i, σ_i^2, and μ_i were chosen by the algorithm to maximize the probabilities of belonging to the specified groups. This process was iterated until a reasonable convergence was achieved. Equations for the curves depicting the 4 hypothetical normal populations (Fig. 2) were based on the sixth and final iteration.

The appropriate Z or t values were next calculated for each of the four populations with population boundaries set at 12.5, 21.5, and 37.5 mm respectively. Then the expected number of larvae in each of these intervals from each of the four populations was computed. For example for the first population (.607) (243) = 148 expected from the EM algorithm.

The gains and losses from the hypothesized populations along with their observed values are shown in Table 1. A simple chi-square calculation with three degrees of freedom, yields a calculated χ^2

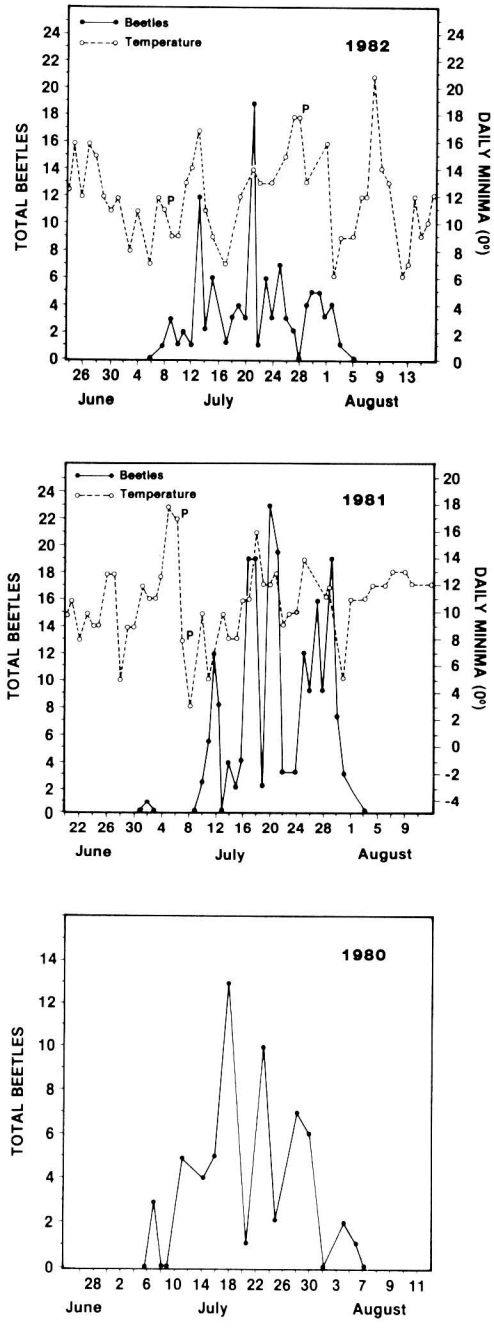

Fig. 1. Relationship between temperature (daily minima) and precipitation (p) and light trap catches of *Prionus californicus* in Idaho hop yards.

= .15, (p = .98) which is much less than 9.49 which would be needed to reject the null hypothesis at the .05 level of significance.

The close correspondence of the hypothesized 4 populations to observed size groups (Fig. 2) apparently supports the contention of Eyer (1942) that the species usually matures in the fourth year. It seems probable that larvae represented by the distinctive populations 1 and 2 were essentially 1 and 2 years old respectively. The size range of a third distinct group, the mature larvae, can be generally approximated as between 60 and 76 mm, based on a maximum larval size of 76 mm and about a 25% size variation observed among trapped adults. Actual numbers in the 3 groups of 151, 39 and 22 seem to represent a reasonable decline in numbers through the development period. But even under the relatively uniform environmental condition of cultivation some variation in development time would be expected. Some larvae between 20 and 60 mm in length, therefore, could be destined for 5 years or longer in the larval stage, even though the group designated as the third population probably consisted mainly of 3-year-old larvae.

All larvae smaller than about 10 mm were found in vertical tunnels in the vascular region to a soil depth of about 200 mm. None were found in dead tissues. Many larvae 10-15 mm in length were also associated with vascular tissues, but larger larvae exhibited little preference for particular areas of roots or crowns. Those longer than about 40 mm were sometimes associated with essentially un-

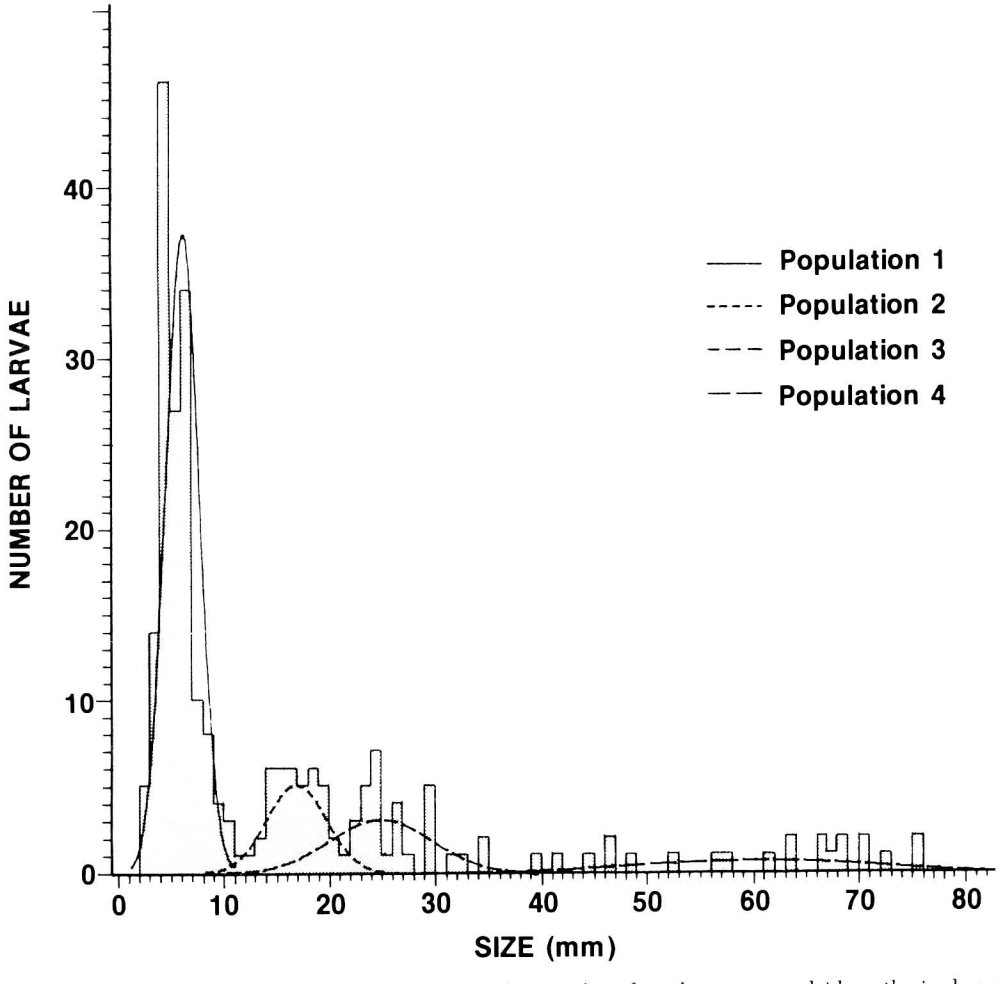

Fig. 2. Actual numbers (bars) of *Prionus californicus* by size class, from hop roots, and 4 hypothesized normal populations based upon the same data using the EM algorithm for normal populations (curves).

TABLE 1. Expected and observed numbers of *Prionus californicus* Mots. larvae in 4 hypothetical populations calculated by the EM algorithm.

Population	Number in Population	Loss	Gain	Expected Number in Interval	Observed Number in Interval
1	148	0	2	150	151
2	36	2 + 2	9	41	39
3	37	9	2 + 1	31	31
4	22	1		21	22
	243			243	243

damaged roots showing they can move from one part of a root system to another. These larger larvae were occasionally found at depths to 50 cm.

Control Considerations

The presence of uninfected hops at a locality within 6 km of infected yards suggests that spread of *P. californicus* may be limited when occurrence of the host is not continuous, and that rotation of production between areas even relatively close together would be an effective control. Under those circumstances it is highly unlikely that a serious infestation would develop in the 15 to 20 year life expectancy of a yard. Losses could also be reduced by allowing at least three years between hop plantings.

Eyer (1942) found eggs to a maximum depth of 37 mm. In the present study essentially all larvae were found well below this level. Therefore applications of effective soil insecticides at plant bases as suggested by Eyer (1942) could provide control since newly hatched larvae would be exposed as they migrated through the soil before entering the crown or a root. Under Idaho conditions an insecticide application could be made beginning with 2-year-old hops on about July 15 and repeated annually.

Eyer (1942) reported that *P. californicus* in New Mexico was most prevalent in light loam and sandy soils. These soil types are typical of the western Idaho hop producing area and may have contributed to the development of *P. californicus* as a serious problem.

No natural enemies were observed to attack *P. californicus* in this study, but Leech (1947) has reported parasitism of an adult female by the dipteran, *Sarcophaga rapax* Walk.

ACKNOWLEDGEMENTS

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ERRATUM

In Vol. 80, 1983, in the article by Vernon and Houtman entitled, 'Evaluation of sprayed and granular aphicides against the European asparagus aphid . . .', the graphs from Figure 2 should appear above the caption of Figure 3 and *vice versa*.