Biology of the black vine weevil *Otiorhynchus sulcatus* on hop in Idaho (Coleoptera: Curculionidae)[1]

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ABSTRACT

The black vine weevil, *Otiorhynchus sulcatus* (Fabricius), is an important pest of hop, *Humulus lupulus* L., in Idaho. Although some adults survived winter conditions, *O. sulcatus* overwintered primarily as developing larvae associated with hop root systems 5-50 cm deep in the soil. Primary damage occurred as nearly mature larvae girdled small roots and rhizomes during spring feeding. Pupation began in mid-April with soil temperatures of 15-17°C and concluded in mid- to late May. Adult emergence began in early May and was complete by late May to early June during 1986-1988. The preoviposition period averaged 26 days in the field. The mean number of eggs laid per adult female was 290 (22-1230). Eggs hatched in 12-22 days at 21°C.

INTRODUCTION

The black vine weevil, *Otiorhynchus sulcatus* (Fabricius), is an important pest of commercially grown hop (*Humulus lupulus* L.) in the Pacific Northwest. Nearly 1000 acres of infested hop have been removed from production in Idaho within the last 10 years because of this pest. Selective replanting of infested areas has enabled some yards to remain productive for several additional years. In Washington, *O. sulcatus* is also an important hop pest (Mayer and Cone 1985), although damage is not as extensive as in Idaho.

Nearly 200 plant species are listed as hosts of *O. sulcatus* (Smith 1927, Essig 1933, Warner and Negley 1976 and Masaki et al. 1984), yet this is the first published record of hop being infested at economically important levels in the United States. The biology of *O. sulcatus* on this perennial plant is poorly understood and no information is available in the literature on this host-pest relationship.

There are no natural agents effecting significant control in Idaho hop yards. Efforts have been directed at controlling adult weevils with foliar sprays after emergence but before oviposition (Baird and Nyberg 1987). More recently, several nematode parasites have demonstrated control in the field (Dorschner et al. 1989). This paper reports on a multi-year study of the biology of black vine weevil on hop in Idaho.

METHODS AND MATERIALS

Root weevil adults and larvae were collected in soil samples from hop yards in the Notus, Wilder and Greenleaf areas about 35 mi (55 km) W of Boise, near the Oregon border in Canyon County (Elev = 700 m), Idaho between 1977 and 1989. Larvae were reared to adults in 100 × 15 mm petri dishes containing slightly moistened soil. Adult identifications were confirmed by W.F. Barr, University of Idaho, and D.H. Whitehead, United States National Museum. Voucher specimens are deposited at each location.

Soil sampling consisted of removing soil from around hop roots and crowns to a depth of 18-50 cm, screening the soil through 4 mesh/cm metal screen, removing root weevil life stages, and replacing the soil around the hop root system. To determine developmental events in field populations, soil sampling was completed semi-weekly from March through September in infested hop yards (N = 50 BVW specimens). Soil temperatures were recorded at 10 cm depth at time of sampling, usually between 1000 and 1400 hr. Soil type was sandy with pH 7.5.

Internal egg development was monitored by dissecting newly emerged adults (20 per week) and examining them for reproductive tract condition and egg development. When newly emerged adults indicated egg maturity, close observations were begun on adult weevils in the field to observe oviposition behavior, sites and timing. Egg production was determined by placing newly emerged adults in petri dishes with slightly moistened filter paper and a new hop leaf daily for food (Penman & Scott 1976). Adults in petri dishes were maintained in shade at outdoor temperature and photoperiod.

To determine the sequence of developmental changes through the pupal stage, 100 mature larvae were collected in early March and placed in individual plastic cups (3 × 3 × 3 cm) filled with soil from the collection site. Sufficient moisture was provided to prevent desiccation. Cups were maintained at outdoor temperature (12–16°C) and photoperiod by placing them in shaded areas protected from severe weather. Specimens were observed daily while larvae, then twice daily after pupation. As rapid changes in pupal development occurred, hourly observations were made. Teneral adults were observed twice daily during the tanning period (17–19°C).

To determine the ability of adults to overwinter, 250 adults were placed in screened cages (91 × 61 × 61 cm) filled with soil and young, cutback hop plants. The cages were maintained outdoors under field conditions from September to April. Evaluations were then made by carefully screening the soil and counting the living adult weevils in each cage.

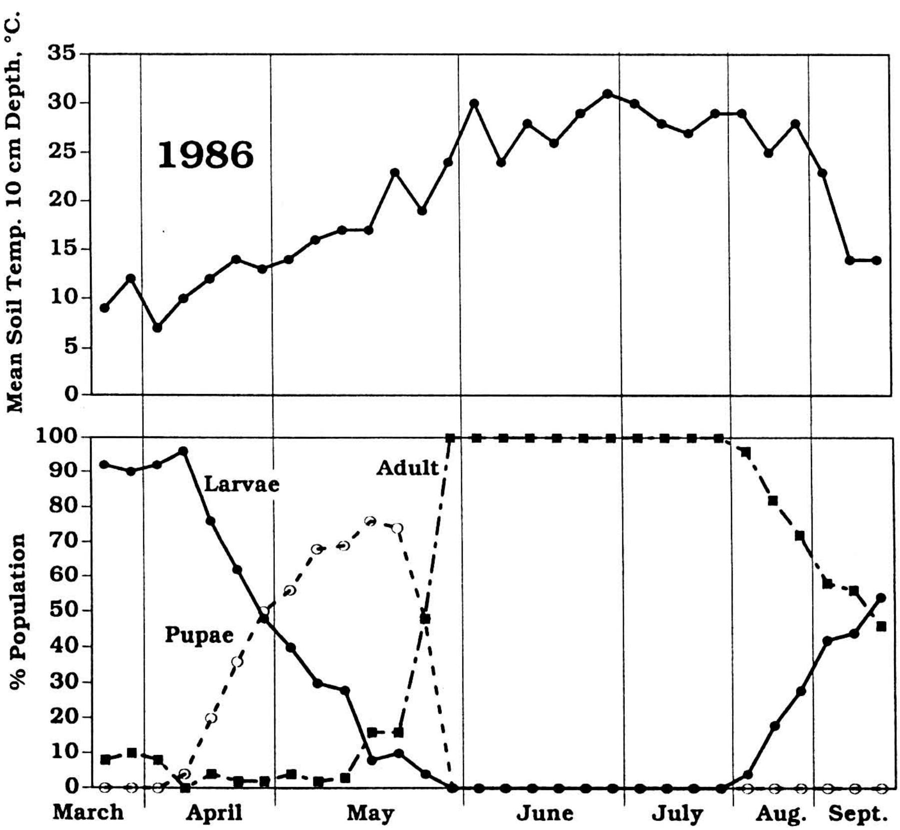

Figure 1. Percent larvae, pupae, adult black vine weevil and mean soil temperature in semi-weekly soil samples (1986).

RESULTS

Species of root weevils present. Soil and plant debris sampling of 36 hop yards in Canyon County, Idaho revealed low infestation levels overall. Certain varieties, i.e. Cascade and L-8, had high root weevil numbers in at least some portion of the yard whereas most other varieties were lightly-infested. Black vine weevil, *O. sulcatus*, was the dominant species found (94.2 %) with strawberry root weevil, *O. ovatus*, (4.8%), rough strawberry root weevil, *O. rugosostriatus*, (0.8%), and *O. meridionalis* (0.2%) occurring at lower levels. Two hop yards, var L-8 and Cascade, had *O. ovatus* as the dominant species (83%) and *O. sulcatus* (17%) during initial investigations during 1978, but the percentage reversed within two years and *O. sulcatus* remained the dominant species. No males of any *Otiorhynchus* species were found while examining over 1500 specimens.

General life history. Root weevils overwintered in the soil primarily in the larval stages, although a small percentage of adults also survived the winter in the soil. Overwintering larvae pupated beginning the second week of April, and the earliest adult emergence occurred in early May (Figs. 1,2,3). In most years, adults emerged by 27-30 May, but late emergence extended into mid-June. Oviposition by new adults began in late June, peaked by late July and concluded by early September (Fig. 4). Overwintered adults began oviposition in late May to early June and concluded by early July.

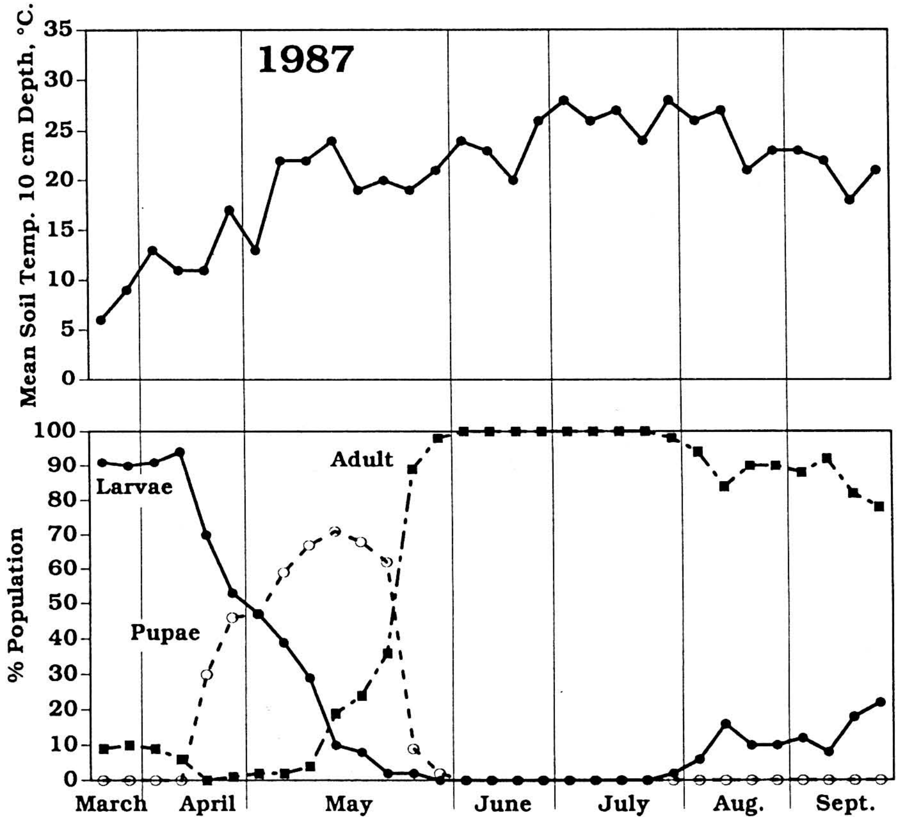

Figure 2. Percent larvae, pupae, adult black vine weevil and mean soil temperature in semi-weekly soil samples (1987).

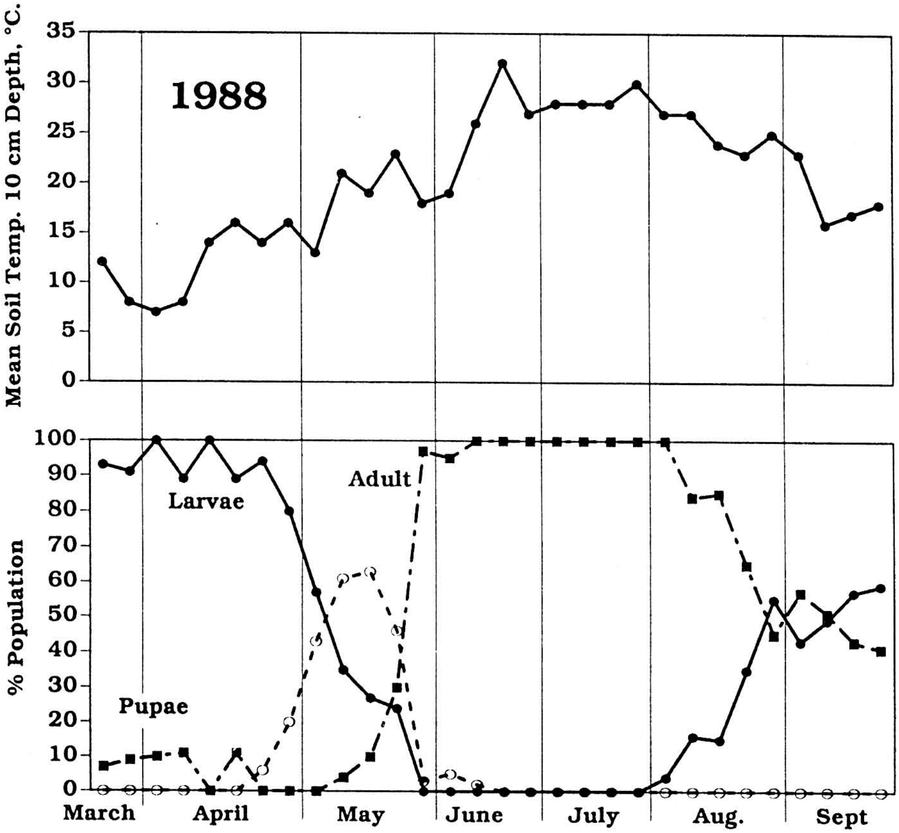

Figure 3. Percent larvae, pupae, adult black vine weevil and mean soil temperature in semi-weekly soil samples (1988).

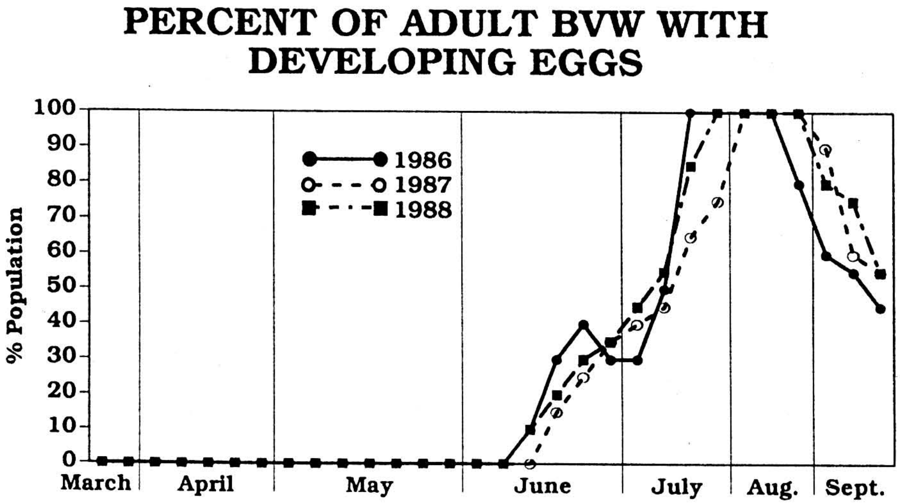

Figure 4. Percent of adult black vine weevil with developing eggs (1986-88).

Larval and adult feeding and damage. Larval feeding extended from late summer into the following spring with the primary damage being caused by larvae scoring and girdling 3-20 mm diameter hop roots. The most visible damage resulted from late instar feeding in early to late spring. During the coldest months, larvae were found 30-50 cm deep in the soil closely associated with the woody hop crown with little damage evident. Within a few hours after emerging from the soil, adults began feeding intermittently on hop leaves, but the defoliation was slight (<2%) and has not been demonstrated to be important. Adults were also observed feeding on several weed species including pigweed and lambsquarter and ornamental shrubs (lilacs) in the Ada and Canyon County areas.

Table 1
Developmental Changes During Black Vine Weevil Pupal Stage (12–16°C).

Elapsed Time	Developmental Events
0.0-1.0 days	Mature larva (prepupa). Feeding ceases, thoracic segments swell, integument splits along dorsal line; Pupa emerges.
1.0-2.0 days	Pupa translucent white, spine tips light brown.
4.0-6.0 days	Pupa milky white.
8.0-10.0 days	Pupa yellowish-white; compound eyes dark red top half, light red bottom half; antennae bases light brown; tarsal claws tan distally.
10.0-12.0 days	Dorsum of head medium brown; femora-tibiae joint medium brown; compound eye uniformly red; tarsal claws light brown; mandibles visible, dark brown; antennae bases dark brown.
12.0-13.0 days	Dorsum of head dark brown; snout dorsum dark brown; antennae bases black, other segments light brown; tarsal claws black; mandibles black; sclerite margins light brown; elytra separated slightly, tan lines visible.
13.0-13.5 days	First visible signs of molt, liquid droplets on pupal body. Ecdysis occurs. Cuticle splits at leg base, peels off distally; antennae cuticle splits at base, peels off distally; cuticle splits at vertex of head, peels off to snout, mandibles; elytra folds into position on dorsum; molt complete in 3-6 hr.

Developmental events in field populations. During 1986-88, five to ten percent of the *O. sulcatus* field population overwintered as adults in the soil. In separate tests of caged adults maintained outdoors during these same winters, 11 to 14 percent survived.

In early March, late instar larvae were found in close proximity to hop roots from 2 to 30 cm deep in the soil. Fresh girdling and scoring on roots indicated recent feeding. By mid March, most larvae were mature and had moved higher in the soil profile away from the root system. By late March, mature larvae in prepupal cells were found 2-6 cm deep in the soil.

During 1986 through 1988, the earliest pupae were found from 11-21 April reaching a peak of 62-70% in pupal stage by 15 May. The average pupal period was 18 days, however, this varied from 15 to 30 days. New, teneral adults were first found 2 May reaching a peak adult (98-100%) emergence by 27-30 May. Teneral adults were found in soil samples until 7 June (1986-87) and until 21 June in 1988.

Newly emerged adults taken in field samples showed little evidence of internal egg development until 21-26 June when 30% were gravid (Fig. 4). An increasing prevalence of gravid females occurred through early July reaching 100% of the weevil population by July 22-29. The earliest egg deposition in field populations was on 20 June 1986 and 24 June 1987. Most adult weevils were gravid and ovipositing by early July and had completed oviposition by mid August, however, a few eggs were laid in early September. Overwintered adults, being a very small portion of the population, were difficult to observe. However, limited observations indicate early onset of oviposition (late May) and completion by early July. In commercial hop yards, eggs hatched in 14-18 days.

Observations in laboratory populations. The sequence of morphological and color changes in pupae transforming to adults is described in Table 1. Adult tanning and color changes following eclosion are described in Table 2.

Feeding on hop leaves began within 24 hr of adult emergence from the soil. Caged adults fed readily on hop leaves usually notching the leaves but at times feeding on the inner leaf portions thus skeletonizing the leaf. As in the field observations, all feeding was at night.

The preoviposition period (eclosion to oviposition) averaged 26 days (14-75 days) for adults from field populations. Maximum egg production occurred in weevils with a preoviposition period of 17-23 days and dropped off sharply after 25 days. Weevils with onset of oviposition delayed beyond 30 days had very low egg counts.

Table 2
Tanning Sequence of Teneral Adult Black Vine Weevils (17–19°C).

Elapsed time	Developmental events
0–10 hr	Newly emerged adult; antennae and snout dorsum light brown; distal femora, proximal tibiae light brown; dorsal thorax, ventral snout, sternites light tan; mandibles and antennae bases black.
16–24 hr	Distal femora and proximal tibiae dark brown; remainder of legs light brown; snout dorsum anterior 2/3 black; elytra tan.
2–4 days	Distal femora and proximal tibiae black; snout dorsum anterior 3/4 black; snout venter anterior 1/2 black; coxae light brown.
4–8 days	Ventral and dorsal head and snout black; legs except coxae black; coxae reddish brown; elytra and thorax dorsum dark brown; thorax venter reddish brown.
8–10 days	Thoracic sternites dark brown; coxae dark brown; other head, thorax, abdomen areas black; yellow tufts visible on elytra.
10–21 days	All areas black except for yellow tufts on elytra.

During oviposition, the female lowered the terminal abdominal segment and extended the ovipositor about 1.5 mm. Individual eggs were then forced down the egg tube and deposited singly or in small, unevenly spaced groups. They were laid on the soil surface, in soil crevices, and on leaves. The mean number of eggs laid per day per ovipositing adult was 10 with a maximum of 45 (20–21°C). The mean oviposition period for 113 weevils was 33 days with oviposition being frequently interrupted by feeding intervals of 2-6 days. The average number of eggs laid by a single adult in one season was 290 (22-1230). Eggs laid under laboratory conditions hatched in 12-22 days (21°C).

DISCUSSION

Black vine weevil (*O. sulcatus*) was the most common root weevil species found in Idaho hop yards, although strawberry root weevil (*O. ovatus*) was found in dominant numbers in two yards and occasionally in other yards throughout the study. *Otiorhynchus rugosostriatus* and *O. meridionalis* were rare in collections from hop yards but were occasionally collected from ornamental hosts in the area. Essig (1933) reported *O. sulcatus* as a hop pest in Great Britain but not in the United States. He further indicated *O. sulcatus* is the most widely distributed *Otiorhynchus* species in North America but did not list hop among its host plants. Warner and Negley (1976) listed *O. ovatus* from hop in the United States but did not record *O. sulcatus* and *O. rugosostriatus* on hop as we found in this study. Cone (Pers. Comm. 1991) indicated *O. sulcatus* is a significant pest in Washington hop yards.

Based on specimens in museums (University of Idaho, Moscow and Albertson College of Idaho, Caldwell), the next most frequent collection site for *O. sulcatus* in Idaho is lilac and for *O. ovatus*, caneberries and as a transient pest in homes and yards. Interestingly, *O. ovatus* is rare in commercial peppermint in Idaho, even in fields adjacent to infested hop yards, yet it is an important pest of mint (*Mentha* spp.) in Oregon.

Black vine weevil not only has a wide host range but has adapted to widely differing conditions in the Pacific Northwest and elsewhere. Adult emergence in Idaho hop yards began earlier (2 May) than in western Washington strawberries (31 May) (Garth and Shanks 1978) or south central Washington grapes (17 June) (Cone 1963).

There was considerable variation in the preoviposition period observed in various locations and host plants. According to most authors, *O. sulcatus* oviposition is dependent upon the food source and quality resulting in a shorter preoviposition period and more eggs when adults fed on optimal host plant tissue (Cram and Pearson 1965). Shanks and Finnigan (1973) stated the preoviposition period for *O. sulcatus* on strawberries in western Washington to be 3-4 weeks. Garth and Shanks (1978) found the interval to be 7 weeks during a cooler than average season. Ambient temperature and water availability (plant succulence) also affect the length of the preoviposition period and egg production (Cram 1970, Shanks 1980). Our findings of 3-4 weeks on Idaho hop are within the range reported by other workers. The number of eggs laid per day and per season on hop was highly variable but within the range found on other crops (Cram 1970, 1980, Shanks 1980, Doss and Shanks, 1985).

Egg development time at 12-22 days was quite variable whether in the laboratory or under field conditions but was within the range reported by other workers (Smith 1927).

Changes in *O. sulcatus* pupae and teneral adults during the developmental processes have not been described by other workers. Although there was variation among the 200 weevils observed, the elapsed times recorded in Tables 1 and 2 represent the timing of most of the individuals observed and provide a reference for determining age and stage of development for future researchers.

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