Biological Control of Insects and Weeds in Oregon

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Biological Control of Insects and Weeds in Oregon

PAUL O. RITCHER

In this age of emphasis on chemical control of pests, most people are unaware of the considerable amount of work and professional interest in biological control. Interest in biological control in Oregon began prior to 1913 (4). Since 1924, and continuing up to the present time, many attempts at biological control have been made, and in several cases spectacular success has resulted.

Biological control has many definitions. The biological control of insects and weeds may be defined as man's manipulation of their natural enemies in order to reduce the abundance of undesirable species. This works least well with native insects and weeds and has the best chance of success with pests of foreign origin.

Biological control agents can be of several types. They may be predaceous or parasitic insects, nematodes, fungi, bacteria, or viruses. In any case, they must be thoroughly investigated before their release, in order that no organisms are introduced which will later attack desirable species of insects or plants.

With the exception of California and Hawaii, most of the initial work on insects of promise for the control of noxious insects and weeds is carried on by entomologists of the United States Department of Agriculture, Entomology Research Division, Insect Identification and Parasite Introduction Research Branch. Since many of our worst pests came from foreign lands, this work first involves searching for parasites and predators in foreign countries and stringent screening and feeding experiments abroad. Later, promising insects are imported to this country for further tests under quarantine and for initial release (Figure 1). Centers for such work in the United States are located at Moorestown, New Jersey, and Albany, California.

Except for the earwig parasite work in the 1920's, the pattern for our work in Oregon is to secure insects for release only after they have been thoroughly tested by federal entomologists, Colonies are sent to us on request after federal entomologists have obtained enough for general distribution, either by multiplication abroad or from initial

1 Italic numbers in parentheses refer to Literature Cited, page 36.
test sites in this country. In all cases, our first releases are entirely experimental and we require that each release be made by an entomologist. Sites selected for the first tests are picked with the advice of county agents as being most typical of Oregon infested areas and/or most likely to result in establishment.

It may take three years or more for any indication that an introduced insect has become established. Once an insect has become well established in several localities, we can then move colonies to other counties and encourage their general distribution through county agents.

**Insect Parasites**

A parasite is an organism that lives at the expense of another organism. Insect parasites are usually much smaller than their insect hosts and parasites usually spend much of their lives on or in one host. The most common insect parasites are either wasps or flies.

Insect parasites usually attack their hosts while in the larval stage, and each species usually attacks only one stage of a given host. All stages—egg, larva, pupa, and adult—are susceptible to parasite attack. In a number of instances, the parasite adult lays its egg in the egg of the host, but the parasite larva does not develop until the host larva hatches or begins to grow.

![Figure 1. A shipping case for insect predators. (U. S. Forest Service.)](image-url)
Since 1924, 30 species of parasites have been introduced in an attempt to control 14 important insect pests of Oregon forage, seed, vegetable, and fruit crops. These pests included the vetch bruchid, pea aphid, Hessian fly, pea weevil, European earwig, woolly apple aphid, codling moth, oriental fruit moth, apple mealy bug, cherry fruit fly, omnivorous leaf tier, and alfalfa weevil (Table 1, pages 18-22). Of these introductions, made either by federal entomologists or by entomologists of the OSU entomology department, those for the control of the European earwig and the woolly apple aphid have been most successful.

Insect parasites may be external on their hosts or internal in their hosts. Internal wasp parasites often emerge when full grown and spin cocoons on or near the host. In some cases (Platygaster and Copidosoma, for example) a single parasite egg results in multiple embryos giving rise to numerous parasites from a single host. This is called polyembryony. (See Figure 2, center.)

Some insect parasites are themselves attacked by parasites. In such cases, these are called secondary or hyperparasites. Hyperparasites of course, have an adverse effect on parasites and must be eliminated before parasites are introduced from abroad.

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Figure 2. Larva of the sagebrush defoliator (Aroga websteri Clarke), on the left; larva parasitized by Copidosoma (note polyembryony), in the center; and parasitized larva with parasite adults emerging, on the right. (Robert Koontz.)
successful. Most of the parasites introduced were of foreign origin brought in to control pests which were also of foreign origin. Except for one parasite from India and several from eastern United States, the rest came from Europe.

Alfalfa weevil

The alfalfa weevil, *Hypera postica* (Gyllenhal), is a native of southern Europe which was probably introduced into the United States about 1900 (57). Injury was first noticed near Salt Lake City, Utah, in 1904 (36). The insect was first reported from California in 1923 (58) and now occurs in most of the alfalfa-producing states. It came into Oregon about 1919 (38) and has been a major pest of alfalfa in Oregon since about 1930.

*Bathyplectes curculionis* (Thompson), a small ichneumonid wasp, is an internal parasite of weevil larvae, commonly found in Europe wherever the alfalfa weevil occurs (12). Beginning in 1911, introductions of this parasite were made into the United States in Utah by federal entomologists; by 1919 it had spread rapidly as far west as Idaho (13). According to Chamberlin, the parasite reached eastern Oregon by natural dispersion from releases made in the east (13).

*Bathyplectes curculionis* was released in southern Oregon, near Medford, in 1934, by the USDA Bureau of Entomology and Plant Quarantine, and by 1938 was abundant throughout Jackson County (65). Little is known of the parasite's abundance in Oregon in recent years. Thousands of alfalfa weevil cocoons were examined in the Klamath Falls area in 1964 without finding a single parasite.

According to Chamberlin (11), even 90% parasitism by *Bathyplectes* did not result in much reduction in weevil population because of the weevil's large reproductive capacity. General experience has been that chemical control continued to be necessary in spite of persistence of this parasite.

Apple mealybug

The apple mealybug, *Phenacoccus aceris* Signoret, is another pest of European origin which has become established in the United States and Canada. According to Rau (67), it was first introduced into Maine before 1910 and by 1942 had spread into Nova Scotia and British Columbia where it was a serious pest of apples and cherries and also of some importance on currants. It was first found in Oregon in 1951, in the Joe Ryan orchard, north of Salem, infesting filberts. By 1958 it had spread to several other locations in the Willamette Valley (50).
**Allotropa utilis** Muesebeck is a parasite of the apple mealybug in Nova Scotia and was first reared in large numbers in 1933 (40). In 1961, we were able to obtain about 500 parasites from Nova Scotia through the efforts of L. B. Parker, USDA entomologist at Moores-town, New Jersey. These were released in July, part at Corvallis and part in a filbert orchard eight miles north of Salem, where the apple mealybug was first found in Oregon. Information is lacking on establishment of this parasite.

**Codling moth**

The codling moth, *Carpocapsa pomonella* (L.), often considered the most important pest of apples, is found throughout the world wherever apples are grown (57). It was the number one apple and pear pest in Oregon until the advent of DDT. Since about 1950, it has been of much less consequence, but careful spraying is still needed for satisfactory control.

*Ephialtes caudatus* (Ratz.), formerly called *Calliephialtes messor* Grav., is a small ichneumonid wasp which is a pupal parasite of the codling moth. It was brought from Spain to California in 1904 and 1905 by the State Commission of Horticulture. Although it became established and locally abundant, it did not persist (17).

According to an article in the *Oregon Agricultural College Press Bulletin* for September 15, 1913, entitled “Insect Enemies to the Codling Moth,” H. F. Wilson, then head of the Department of Entomology, had secured a supply of this parasite for propagation and release against the codling moth in Oregon. Whether or not any of these parasites were ever released is not known.

*Ascogaster carpocapsae* Viereck is a well-known braconid parasite of codling moth larvae which attacks its host in the egg stage. According to Cox (19), although described from specimens reared in Michigan, the parasite is probably of European origin and reached this country in the 1700's along with its host.

*Ascogaster* parasites were sent to Oregon by E. J. Newcomer, then federal entomologist at Yakima, Washington, on two occasions. Those sent in 1935 were released at Talent (near Medford) and those sent in 1941 were released near Elgin. No information is available as to their establishment.

**European earwig**

The European earwig, *Forficula auricularia* L., is a cosmopolitan, omnivorous insect, more commonly found in cities than in the country.
Its habits, the injury it inflicts, and its distribution were summarized by Fulton in 1924 (39). He stated that it had been in Oregon since at least 1909. By 1923, the earwig had spread to a number of Willamette Valley cities and was also known from Astoria, Roseburg, and Bledgett. In 1924 Portland had the major infestation (31).

One of Oregon’s two most ambitious biological control projects was begun in 1923 in an attempt to control the European earwig with parasites. Two parasitic tachinid flies, *Digonichaeta setipennis* Fall and *Rhacodineura antiqua* Meigen, were brought from Europe, and a large-scale rearing and release program was initiated (62). Of the two parasites, the first, *D. setipennis*, became widely established (Figure 3). Work with the other species stopped early in the program and none were ever recovered.

The Earwig Parasite Project was a cooperative endeavor between the Oregon Agricultural Experiment Station, the State Board of Horticulture, the City of Portland, Multnomah County, and the United States Bureau of Entomology. The project began in 1924 and terminated about 1936. The first rearing work was carried out at Corvallis by H. C. Stearns and at Forest Grove by L. P. Rockwood. After May of 1925, all parasite work was done at the Portland Earwig Parasite Laboratory located at Killingsworth and Interstate avenues (Figure 4).

With the help of L. O. Howard, then Chief of the USDA Bureau of Entomology, earwig parasites were shipped from England and France beginning in the fall of 1924 and the spring of 1925 (5). Importation of parasite material (parasite puparia or parasitized earwigs) was continued until 1929 and served as a nucleus for the rearing program in Portland (62).

As a result of new rearing techniques developed at the Portland Laboratory (25), production of parasites rose from an initial output of 1,185 in 1927 (6), to over 50,000 in 1932 (30). In the peak years of 1931-1934, 65,917 parasite adults and 169,750 parasitized earwigs were liberated. Releases in 1926 and 1928 were confined to Portland. In 1929 releases were made in both Portland and Corvallis. In 1932 large numbers of parasites (34,350) were released in Portland and Multnomah County.

As parasite production became larger, many parasitized earwigs were sold for one cent apiece to various individuals and civic organizations outside of Multnomah County, through county extension agents (30). This helped defray Portland’s cost of running the laboratory. During the period of 1932-1935, over 100,000 parasitized earwigs were distributed to some 38 Oregon communities in 15 counties (21).
Figure 3. Larvae of *Digonichaeta setipennis* Fall leaving a dead earwig. (From H. H. Crowell, 1937.)

Figure 4. The Portland Earwig Parasite Laboratory at Killingsworth and Interstate avenues. Insectary houses are in the foreground and the earwig mating shed in the background.
Information on the establishment and impact of earwig parasites is fragmentary. The rapid decline of earwigs in the Portland area in 1931 and 1932 was credited to the parasite (30 and 31), but there was little evidence to substantiate this claim.

The record shows that D. setipennis was first recovered in 1926 in Portland and found to be well established there in 1930 (62). The parasite was recovered at Corvallis in 1933 and 1934 (21) and has been reared from earwigs there on numerous occasions in more recent years. According to Crowell (21), who made a survey in Portland in 1936, the parasite was definitely established within the city in all localities checked. Percent of parasitism at nine points ranged from 1 to 38.4%. The life cycle of the earwig parasite is shown in Figure 5. The parasite has two generations a year, while its host has only one.

**Hessian fly**

The Hessian fly, Phytophaga destructor (Say), thought to have been introduced into the United States from Europe in the late 1700's, has been present in western Oregon for over 70 years. It has been found at Hood River but is not known to occur in eastern Oregon (70). In some years it causes severe damage to wheat, especially in years with early springs.

Rockwood and Reeher (71) discussed the natural control of the Hessian fly due to parasites in the Pacific Northwest. In 1918 parasitism averaged 34%, and in 1919 it was 48%, with Platygaster hiemalis Forbes appearing to be the most important parasite. Altogether, Rockwood and Reeher listed twelve species of parasites which had been reared. They did not give either the locality or state in which most of them occurred, except for Platygaster hiemalis which they mentioned as occurring in Oregon and having normally two generations a year. This same parasite (determined by the U. S. National Museum) was reared in 1965 from Hessian fly puparia found in nonvernalized wheat north of Albany. There was about 40% parasitism.

The eastern parasite, Platygaster zosine Wlk., which is an important parasite in Illinois, Indiana, Ohio, and southern Michigan (43) was not found in Oregon according to Rockwood (letter, 1948). Several thousands of this polyembryonic hymenopterous parasite were reared by M. M. Reeher at Forest Grove and released in 1932 and 1933 in wheat fields in Washington and Clackamas counties. Adult parasites were recovered in Washington County the following year, but it is not known whether they are established.

**Omnivorous leaf tier**

The omnivorous leaf tier, Cnephasia longana Haw., was first found in Oregon in 1929 (35). It has also been called the strawberry
Figure 5. The life cycle of the earwig parasite, *Digonichaeta setipennis*. (Drawn by H. H. Crowell.)
Since 1951, the USDA European Parasite Laboratory in France has sent shipments of parasites, representing nine species, for liberation in Oregon (see Table 1). Surveys and rearing work at Oregon State in 1955 indicate that three of the introduced parasites—*Bracon stabilis* Wesmael, *Bracon piger* Wesmael, and *Itoplectis maculator* (F.)—are now established (determined by the U. S. National Museum).

The omnivorous leaf tier was very abundant on vetch in 1956 and before and caused damage to ripening strawberries. At present, however, it is quite scarce. Whether or not this is due to biological control is not known.

**Oriental fruit moth**

The oriental fruit moth, *Grapholitha molesta* (Busck), is thought to have originated in eastern Asia since that is the homeland of the peach, its preferred host (1). This insect apparently was introduced into the United States from Japan about 1913 and by 1945 was present in Oregon, Washington, and Idaho (1). According to Jones (49), the oriental fruit moth was first found in Oregon near Nyssa in Malheur County and in 1949 was found infesting peaches in a home planting at The Dalles.

In more recent years, a number of oriental fruit moths have been trapped in an orchard near Salem by entomologists of the State Department of Agriculture, but to date the pest has not been important in Oregon. Injury thought to be caused by this pest is usually caused by the peach twig borer.

In the eastern United States, considerable control of the oriental fruit moth has been obtained utilizing *Macrocentrus ancylovorus* Rohwer, a native parasite originally reared from the strawberry leaf roller (17). This is said to be one of the few examples of a native parasite on a native species proving of any value for the control of an introduced species. A number of parasites (apparently 1,250) were furnished by H. W. Allen of the Moorestown, New Jersey, laboratory and released in The Dalles, Milton-Freewater, Nyssa, and Ontario, in 1946. These releases were made by Charles H. Martin who worked with this parasite in California before coming to Oregon State (53, 54, 55, 56). Unless the parasites were able to find an alternate host, such as the strawberry leaf roller, it is doubtful if they became established.
Pea aphid

The pea aphid, *Macrosiphum pisi* (Kaltenbach), is a European species first reported from the United States in 1878 (22). The insect is a common pest of alfalfa and of field and edible peas. In Oregon it may also injure vetch (18, 24). Severe damage is caused by direct feeding or by transmission of several serious virus diseases. Of these, bean yellow mosaic may be widespread on alfalfa and pea enation mosaic is commonly spread from alfalfa to peas (33).

Lady beetles, several small parasitic wasps, and fungus diseases often check the spread of pea aphids in various parts of the United States. In an attempt to augment the natural enemies already present in Oregon, four species of *Aphidius*, all small wasps, have been introduced (Table 1, pp. 18-22).

*Aphidius pisivorus* was recovered in 1963, near Corvallis, where parasites of this species from New Jersey were released in 1961. This same parasite, however, had been reared several times previously in Oregon. According to W. H. Anderson, (letter, 1963) the type series of *A. pisivorus* included specimens reared from pea aphids at Forest Grove in 1918. The OSU departmental insect collection contains specimens reared from two other species of aphids. It has been suggested that the eastern parasites may be of a different strain and thus more effective for control of pea aphid than the strain present on the west coast.

In 1961, three mixed lots totaling 645 adults of *Aphidius urticae* Hal. and *Aphidius avenae* Hal. were released in alfalfa plots at the OSU Hyslop Farm. To date we have no information on their establishment.

In California, *Aphidius smithi* Sharma and Rao, imported from India in 1958, has been largely responsible for control of the pea aphid, especially in coastal valleys (41). Releases of this parasite in Oregon have used material from California and from the USDA, Moorestown, New Jersey, Laboratory. The eastern material (595 wasps) was released west of Hermiston and the California material was released near Dayton. In 1965 parasitized pea aphids were very abundant in the latter area, but reared parasites have not yet been identified definitely as to species (Figure 6).

Pea weevil

The pea weevil, *Bruchus pisorum* L., once thought to be native, has been present in the eastern United States since at least 1748 (9). It has been an important pest of peas in Oregon and other western states for many years (14).
Several insect parasites of the pea weevil have been found in the United States, including *Eupteromalus leguminis* Gahan reared at Corvallis (51). A common European parasite of the pea weevil (and of the vetch bruchid), *Triaspis thoracica* (Curt.), was introduced into several western Oregon counties in 1940-41 by the U.S. Bureau of Entomology and Plant Quarantine (17). Over three thousand females
of this parasite were released on Austrian peas at Forest Grove between May 28 and June 4, 1940. Adult parasites were recovered from infested Austrian peas in August 1940, but they have not been recovered since then. This indicates that the attempted introduction was unsuccessful.

**Vetch bruchid**

The vetch bruchid, *Bruchus brachialis* Fahr. (Figure 7, A and B) another pest of European origin, was first found in the United States in New Jersey in 1930 (66). It reached Oregon in 1936 and by 1940 had begun reducing the quantity and quality of hairy vetch seed (71). This pest attacks seeds of woollypod vetch, purple vetch, hairy vetch, and smooth vetch (24).

In 1940 and 1941, USDA entomologists attempted to establish *Triaspis thoracica* (Curt.) in Oregon. Altogether 4,975 specimens from France and Austria were released in Washington, Clackamas, Linn, and Polk counties. These releases are mentioned by Clausen (17) but his figure of 17,200 specimens includes a large number which did not survive shipment from New Jersey. Another European parasite, a chalcid, *Dinarmus acutus* (Thompson), formerly called *Bruchoius mayri* (Masi.), has been recovered from vetch weevil in the eastern United States (66). Two lots of this species from France, totaling 645 specimens, were released in August 1963, on vetch 10 and 15 miles north of Corvallis. These releases were probably too late in the activity period of the host in Oregon for establishment.

In spite of the above introductions, recent studies of the vetch bruchid by Oregon State entomologists indicate that at present no parasites of the vetch bruchid occur in the Willamette Valley. This creates an opportunity at Corvallis to evaluate effects of introducing one or two species of foreign parasites. To date several releases in field cages have been made of *Tetrastichus bruchivorus* Gahan and *Dinarmus acutus* (Thompson). These will be studied in detail before field releases are made.

**Western cherry fruit fly**

The western cherry fruit fly, *Rhagoletis cingulata indifferens*, is a native American insect and Oregon's most serious cherry pest. Commercial growers must obtain 100% control for their crop to be marketable. In spite of highly effective new chemicals for fruit fly control, infestation of unsprayed and neglected cherry trees remains high.

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* *Dinarmus acutus* (Thompson) has been recently discovered attacking vetch bruchid near Yoncalla. (Figure 7, C and B.)*
Figure 7. A: A vetch seed showing the exit hole of a vetch bruchid; B: A vetch bruchid; C: The vetch bruchid parasite *Dinarmus acutus* (Thompson); and D: The exit hole of the parasite from a bruchid infected vetch seed. (Robert Koontz.)
In 1952 and 1953 shipments of two fruit fly parasites, *Opius formosanus* and *Opius compensans* (Silv.), were received from USDA entomologists in Hawaii. These were released in Corvallis under seedling sweet cherry trees infested with western cherry fruit flies. Whether or not they are now established is unknown.

In 1959, OSU entomologists were informed by the Parasite Introduction Section at Albany, California, that some European parasites of fruit flies (genus *Rhagoletis*) were available for release in Oregon. These had shown a great affinity for *R. cingulata* at Moores-town, New Jersey. In 1960, 194 parasites of *Opius muliebris* were released under wild bitter cherry trees at the Botany and Plant Pathology Farm, east of Corvallis.

**Woolly apple aphid**

The woolly apple aphid, *Eriosoma lanigerum* (Hausmann), is found throughout the world wherever apples are grown (74). Some writers suggest that the woolly apple aphid originated in North America and then spread to other regions (52). At any rate, it has been a common pest of apple trees in Europe and America for over 150 years. It seems to have become a more serious pest since the advent of DDT for orchard use in the 1940's.

Woolly aphid damage is of several types. Soil-inhabiting aphids cause undesirable galls on the roots of young trees and these affect their growth. The woolly aphid is also implicated in the spread and development of perennial canker, in wounds and in pruning scars. The causal relationship between the aphid and canker was worked out by Leroy Childs (15). Earlier Zeller and Childs discovered the causal organism.

*Aphelinus mali*, a wasp parasite of the woolly apple aphid in the eastern United States, was first introduced into Oregon in 1928 from Michigan. A later introduction was made near Monroe in 1935. Until the advent of DDT, this parasite was credited with control of woolly apple aphid in the Hood River and Willamette valleys.
<table>
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<th>Host</th>
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<th>Source of parasites</th>
<th>Present status</th>
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### Table 1. Biological Control of Insects With Parasites—Oregon (Continued)

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<td>Not established</td>
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<td></td>
</tr>
<tr>
<td>Vetch bruchid Dinormus acutus (Thompson)</td>
<td>1965</td>
<td>USDA Moorestown, N.J., Lab.</td>
<td>France</td>
<td>Corvallis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woolly apple aphid Aphelinus mali (Hald.)</td>
<td>1928</td>
<td>USDA Bureau of Entomology</td>
<td>Michigan, U.S.A. (native)</td>
<td>Well established</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woolly apple aphid Aphelinus mali (Hald.)</td>
<td>1935</td>
<td>USDA Bureau of Entomology</td>
<td>Yakima, Washington</td>
<td>Well established</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Insect Predators

Insect predators are usually much larger and more active than their insect prey. Each insect predator usually feeds on a number of host insects. Some common insect predators are ground beetles (Carabidae), tiger beetles, chequered beetles (Cleridae), lady beetles, lace wings (Neuroptera), and preying mantids.

Figure 8. Liberating the predator *Aphidoletes thompsoni* on Pacific silver fir infested with balsam woolly aphid, near Grande Ronde, Oregon. From the left: Scott Tunnock, former OSU graduate student in forest entomology; Russel G. Mitchell, United States Forest Service entomologist; and Julius A. Rudinsky, professor of forest entomology, Oregon State University. (U. S. Forest Service.)
Several attempts were made in 1933 to introduce insect predators into Oregon, but none seem to have been established. *Stagmomantis carolina*, a praying mantis from Pennsylvania, was released at Corvallis but none have been recovered. Also in 1933, United States forest entomologists released a colony of 110 adults of the predaceous ground beetle, *Calosoma sychophonta*, near Clatskanie, Oregon.

The most recent and extensive work with insect predators has been by entomologists of the Forest Service, from 1957 to the present, in an attempt to control the balsam woolly aphid (32, 10, 59). Up to 1963, 18 species of insect predators were liberated in Oregon, 11 from the Orient, one from Australia, and six from Europe (Figure 8). Of these, five species (all from Europe) are known to be established and may prove of significance in the control of the balsam woolly aphid. Two of these predators are small beetles of the families Derodontidae (Figure 9) and Coccinellidae and three are small flies of the families Itonididae (one species) and Chamaemyiidae (two species).

Figure 9. *Laricobius erichsonii*, a beetle predator introduced from Europe, feeding on balsam woolly aphid. (U. S. Forest Service.)
Insect Pathogens

Insect pathogens are organisms which cause diseases of insects. Some common pathogens are polyhedrosis viruses, bacteria, fungi, and protozoa.

One of the first attempts in Oregon to use insect pathogens to control insects was made in 1935 by L. P. Rockwood. He released cutworms near Coquille which had been coated with spores of the fungus *Spicaria rileyi*.

Since 1960, Clarence Thompson, of the Forest Service Laboratory at Corvallis, has worked extensively in the field of insect pathology and has worked on such insects as the hemlock looper, Douglas-fir tussock moth, and Great Basin tent caterpillar.

OSU entomologists are engaged in research on a fungus disease of symphyllans and on pathogenic bacteria and nematodes.

**Bacterial diseases**

There is extensive literature on *Bacillus thuringiensis* Berl., one of a number of bacteria which can be used to kill insects by the pro-

*Figure 10. Applying Bacillus thuringiensis against hemlock looper during an experimental control project in Pacific County, Washington, in 1963. The laboratory work was done at the Forest Science Laboratory in Corvallis, Oregon. (U. S. Forest Service.)*
duction of toxic protein crystals (23). Standardized, commercial preparations of this *Bacillus* are on the market and have been tested in Oregon in sprays or in irrigation water in an attempt to control both insects and symphylans.

OSU entomologists, in cooperation with extension and federal entomologists, tested *B. thuringiensis* in 1958 for the control of cabbage looper. Although a mortality of up to 80% was attained, this was inferior to the control secured with seven chemical pesticides. In other tests using *B. thuringiensis* against the variegated cutworm and symphylans, results were very poor.

U. S. Forest Service entomologists have used *B. thuringiensis* against several forest insects. Figure 10 shows application of this material by helicopter against the hemlock looper, in Washington in 1963.

**Virus diseases**

Many viruses are known which infect insects and cause their death. Most of these attack caterpillars of Lepidoptera and a large number are polyhedroses forming crystalline bodies in the infected host (23).

Figure 11 shows a Douglas-fir tussock moth larva dying of polyhedrosis disease following aerial application of virus in Oregon.

![Figure 11. A Douglas-fir tussock moth dying of polyhedrosis disease following aerial application of virus. (C. G. Thompson, U. S. Forest Service.)](image-url)
Pathogenic nematodes

An OSU entomologist, Knud Swenson, has been able to infect and kill symphyllans in the laboratory using the pathogenic nematode DD-136 developed by Dutky (34). (See Figure 12.) Apparently the nematode carries a bacteria into the symphylan which is the actual cause of death.

Insects to Control Weeds

The fact that insects feed on undesirable plants can be turned to man's advantage. In the case of weeds of foreign origin, many were accidentally introduced into this country and their insect enemies were left behind. By exploration abroad, usually in the native habitat of the weed, USDA entomologists have been able to find a number of insects which will feed and reproduce only on a specific weed.

The benefits of the destruction of a weed species must be weighed carefully against harmful effects to the total environment. In many cases, the decision of whether an insect should be introduced for control is easy if the weed has no desirable features.
We have been reluctant to introduce insects for the control of Scotch broom since it is grown extensively in home and highway plantings. Two insects, a stem miner \((Leucoptera spartifoliella)\) and a seed weevil \((Apion fuscirostre)\), have been established in California and have been offered to us for release in Oregon. These insects will not be released unless all affected interests, including the Oregon State Department of Agriculture, the Highway Department, Oregon garden clubs, nurserymen, and farmers are in agreement that it should be done.

With the cooperation of federal entomologists, insects have been introduced into Oregon in an attempt to control St. Johnswort (often called goatweed, or Klamath weed), gorse, tansy ragwort, and puncture vine (Table 2). The control of St. Johnswort has been spectacular, and pests of gorse and tansy ragwort are now well established.

**Tansy ragwort**

Tansy ragwort is a weed of foreign origin which is now widespread in western Oregon. The weed is toxic to cattle and horses and crowds out more desirable plants. In Europe, one of its insect pests is the cinnabar moth, a beautiful red and black moth (Figure 13) whose yellow and black banded larvae will feed only on tansy ragwort.

![Figure 13. A cinnabar moth on tansy ragwort. (Robert Koontz.)](image-url)
<table>
<thead>
<tr>
<th>Host</th>
<th>Insect introduced</th>
<th>Source of insects</th>
<th>Present status</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Johnswort (Klamath weed)</td>
<td><em>Chrysolinia quadrigenima</em> (Suffrian)</td>
<td>USDA, Albany, Calif.</td>
<td>Australia</td>
</tr>
<tr>
<td>St. Johnswort (Klamath weed)</td>
<td><em>C. hyperici</em> (Forst.)</td>
<td>USDA, Albany, Calif.</td>
<td>Australia</td>
</tr>
<tr>
<td>Tansy ragwort</td>
<td><em>Tantheria jacobaeae</em> (L.) cinanbar moth</td>
<td>USDA, Albany, Calif.</td>
<td>France</td>
</tr>
<tr>
<td>Gorse</td>
<td><em>Apion ulicis</em> (Forst.) gorse weevil</td>
<td>USDA, Albany, Calif.</td>
<td>France</td>
</tr>
<tr>
<td>Puncture vine</td>
<td><em>Microlarinus lareynii</em> (du V.) puncture vine seed weevil</td>
<td>USDA, Albany, Calif.</td>
<td>Italy</td>
</tr>
</tbody>
</table>
In 1960, federal entomologists at Moorestown, New Jersey, sent a shipment of 1,000 cinnabar moths for release in Oregon. Two releases were made, one near Scio and one near Valley Junction. Two further releases were made in 1964, using large larvae. One shipment of 1,000 larvae from Fort Bragg, California, sent by Robert Hawkes of the federal Insect Identification and Parasite Introduction Branch, was released near Broadbent in Coos County, Oregon. A second release of 100 larvae from our Scio site was made near Hoskins in 1964. Additional releases were made in 1965 in Polk and Benton counties and in Coos and Curry counties, using larvae from California (Figure 14). Releases in Coos County were made on 24 different sites and releases in Curry County on 4 sites.

Figure 14. County Extension Agent Fred Hagelstein releasing cinnabar moth larvae on tansy ragwort in Coos County, Oregon.
Results to date with the cinnabar moth show that we have establishment in only two areas, one in Coos County and the other at the Scio site. Larvae were present for several years at the Valley Junction site, but no evidence of cinnabar moth was found there either in 1964 or 1965. Also, no evidence of cinnabar moth was found on the Hoskins site when it was visited in early July of 1965.

A tremendous buildup in the cinnabar moth population in 1964 in the Fort Bragg area of California, gives hope that the insect may also build up in the coastal areas of Oregon. The habit of the larvae in destroying the bloom of tansy ragwort is also of interest. The greatest defect of the cinnabar moth as an important pest of tansy ragwort is the fact that it has only one generation a year.

**Puncture vine**

Puncture vine (*Tribulus terrestris* L.) is an herbaceous annual with hard, spiny pods which is found in the drier regions of many parts of the world (2). According to Johnson (48), it was brought into the United States from the Mediterranean region. It is now quite common in the Southeast, California, and some counties in eastern Oregon.

In 1957 and 1958 two weevils were found infesting puncture vine in India, Italy, and France. These were *Micolarinus lareynii* (du V.) a seed weevil (Figures 15 and 16) and *M. lypriformis* (Woll.) a stem weevil (2). From 1959 to 1961 screening tests with the seed weevil were made at the USDA Biological Control of Weeds laboratory in Rome, Italy, and with the stem weevil at the USDA European Parasite Laboratory at Nanterre, France. Since feeding tests showed that feeding on puncture vine or closely related plants was necessary for egg development, both species were cleared for introduction into the United States in 1961 (46). Introductions were made in California, Washington, Nevada, Arizona, Colorado, and Utah. In August 1963, in cooperation with the USDA Biological Control of Weeds Laboratory at Albany, California, two releases of the seed weevil were made in Umatilla County, Oregon, one near Pendleton and one near Hermiston. A further release of 653 seed weevils was made in 1964 in Wheeler County.

A recent survey (September 1965) indicates that the seed weevil did not become established.

**Gorse**

Gorse (*Ulex europaeus* L.) is a dense, spiny, yellow-flowered shrub of European origin which has become established along the Oregon coast. It forms impenetrable thickets and its oily wood burns very readily. A gorse fire is said to have started the blaze which destroyed Bandon, Oregon, in 1936.
Figure 15. A puncture vine weevil, *Microlarinus lareynii* (du V.), much enlarged. (Kenneth Middleham.)

Figure 16. Larva of a puncture vine weevil inside a bur. (Kenneth Middleham.)
In 1956 the gorse weevil, *Apion ulicis* (Forst) was first introduced into Oregon, at several points near Bandon, using weevils supplied by the Albany, California, Laboratory. By 1959 the population of weevils had increased greatly north of Bandon and it was estimated that the area infested covered about $1\frac{1}{2}$ square miles. Almost every gorse pod contained 3 to 10 beetles.

In 1959 additional releases of gorse weevils were made in Curry and Lane counties, using weevils from the Bandon area.

Although the gorse weevil can sometimes reduce seed production by 98% (23), it is doubtful if it will check the spread of gorse. In California adult weevils have caused injury to the tips of the branches by their feeding, but their feeding has not been observed to cause significant damage to gorse in Oregon.

**St. Johnswort**

St. Johnswort (*Hypericum perforatum* L.), also called Klamath weed or goatweed, is an undesirable, poisonous weed of foreign origin which at one time was very abundant in some parts of Oregon, before its control by biological means. The plant is unattractive to livestock and crowds out desirable grasses. Cattle feeding on the plant develop a hypersensitivity of the white skin areas to sunlight. Animals feeding on small amounts of the plant have sore mouths and are generally unthrifty.

Spectacular control of St. Johnswort in western Oregon has been achieved since the introduction in 1948-1950 of a French, chrysomelid leaf beetle, *Chrysolina quadrigemina* (Suffr.) (formerly called *C. gemellata*). A second species of leaf beetle, *Chrysolina hyperici* was also released, beginning in 1947, but has not been of any consequence in controlling St. Johnswort.

The early lots of beetles were secured from the federal entomology laboratory in Albany, California. The first colonies of *C. quadrigemina* were started in 1948 at Corvallis, Roseburg, and Glendale. In 1950, Charles Martin, OSU entomologist in charge of the Oregon project, collected 15 colonies in California which were released in Umatilla and Wallowa counties and at intervals in western Oregon from Medford to McMinnville. Robert Every, OSU Extension entomologist, and many county agents assisted with these releases and made many releases in other Oregon counties from 1951 on.

By 1952, remarkable control of St. Johnswort had become evident in southwest Oregon. In one area near the southern edge of Douglas County over 1,000 acres of almost solid St. Johnswort had been killed, due to a combination of beetles and dry weather. The beetle-infested area, started with one colony in 1948, extended for a distance of 14 miles in 1952.
In 1954, control in southern Oregon was unbelievable wherever there were dense stands of the weed. At Scio, beetles cleared several hundred acres. In eastern Oregon, control of St. Johnswort by beetles was good along the Snake River, but poor near Pendleton and above Wallowa. In more recent years, the beetles practically eliminated St. Johnswort in the Pendleton area.

As of 1965, St. Johnswort in western Oregon has been largely reduced from hundreds of thousands of acres of solid stands to scattered plants along roadsides and in shady areas. The introduced beetles are very widespread and continue to survive on the remaining plants. Thus they will probably continue to hold this noxious weed in check.

It is believed that the success of *C. quadrigemina* is due to its synchronization with both the climate and the growth of its host plant, St. Johnswort. The adult beetles strip the plants in the spring and early summer when they are beginning to flower (Figure 17) and the larvae feed in the fall and winter destroying the prostrate growth before the plants can recover from the summer damage (Figure 18).

Figure 17. *Chrysolina* beetles destroying St. Johnswort in southern Oregon.
Future Plans for Biological Control

Biological control studies of forage insects and of symphylans are receiving increased emphasis at Oregon State University. At Hood River and Medford, OSU entomologists have just begun work on a newly discovered parasite of the pear psylla. At Portland and at Corvallis, research on the biological control of forest insects has been greatly expanded recently by entomologists and insect pathologists of the United States Forest Service.

As other promising insects for biological control become available, they will be introduced into Oregon in carefully selected localities by OSU entomologists. Entomologists of the USDA, Insect Identification and Parasite Introduction Research Branch, have a number of insects under test in this country and abroad which will be available shortly for release. Some of these may be of value as insect parasites or predators to control introduced pests of tree and small fruits. Others show promise for control of various noxious weeds such as Mediterranean sage, alligator weed, Dalmatian toad flax, and halogeton. Additional species of insects will be brought in for the control of tansy ragwort and puncture vine.
In 1964 Oregon State entomologists were contacted by James F. Holloway, federal entomologist at Albany, California, about the availability of a European flea beetle, *Haltica carduorum*, which feeds on Canadian thistle. The insect has been cleared for release in North America, and releases have already been made in Canada. Material has been promised for release in Oregon in 1966.

Several people have shown an interest in the use of insects to control or eradicate such native Oregon plants as wild iris and sagebrush. Whether this can or should be done is questionable.

In the case of sagebrush, it has been suggested that *Aroga weberi* Clarke, a native moth responsible for widespread damage to sagebrush in 1964, might be spread to other areas of Oregon. A survey of *Aroga* infested areas (69) showed that this insect is heavily parasitized in some areas by a number of parasites including a polyembryonic larval parasite *Copidosoma* sp. and several parasites of *Aroga* pupae. Possibly these parasites are responsible for the cyclic appearance of *Aroga* outbreaks in Oregon. There is also a question in regard to sagebrush as to whether its wholesale destruction is wise because of its value as a food plant for deer, antelope, and game birds, and its value in the control of erosion.

### Summary and Conclusions

This account of biological control efforts in Oregon demonstrates that entomologists have not been unmindful of nonchemical control methods. Biological control of insects has been most successful against pests of foreign origin, but the level of control obtained is frequently unacceptable for modern agriculture and today’s consumer. In many cases, successful establishment of parasites at rather high levels has not resulted in a lessening of crop injury. The most successful instances of biological control with parasites, in Oregon, were against earwigs and the woolly apple aphid. The use of insect predators against the balsam woolly aphid and the use of pathogens to control other forest pests seem promising. Spectacular control of St. Johnswort was achieved through the introduction of the *Chrysolina* beetle. Attempts to control gorse, puncture vine, and tansy ragwort must await further evaluation.
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