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Distribution and Life History Of *Bathyplectes curculionis* (Thomson)
(Ichneumonidae: Hymenoptera)
In Northern Idaho

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ABSTRACT

Bathyplectes curculionis (Thomson) and *Hypera postica* (Gyllenhal) distributions were examined in a six county area of northern Idaho during 1968. Both species were found commonly in Latah, Benewah, Kootenai, and Bonner counties. Neither species was found in Shoshone or Boundary county. *H. postica* occurred in the absence of its parasite, while *B. curculionis* was restricted to its host, showing no affinity for the closely related species *Hypera zoilus* (Scopoli) and *Hypera nigrirostris* (Fabricius). Natural barriers were instrumental in deterring the spread of the alfalfa weevil in northern Idaho. Evidence suggesting weevil spread through importation was found.

B. curculionis effectively parasitized first, second, and third instar larvae of the alfalfa weevil, but was ineffective in parasitizing larvae of the fourth instar in the field. Oviposition occurred readily in all larval instars of the alfalfa weevil under laboratory conditions.

H. postica and *B. curculionis* populations were observed in both cut and uncut fields through their seasonal occurrence. Cutting sharply reduced both weevil and parasite populations. In uncut alfalfa the weevil larval population peaked on June 18; the parasite population was highest on June 5. Occurrence of the parasite was synchronized with the first and second host instars.

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David E. Foster and Guy W. Bishop

Bathyplectes curculionis (Thomson), a solitary endoparasite of the alfalfa weevil, *Hypera postica* (Gyllenhal), was introduced into the Great Basin region of the western United States about 60 years ago in an effort to control damage caused by the weevil. Though *B. curculionis* flourished in its new surroundings and spread rapidly, it failed to check weevil damage. Following its introduction, many augmentative procedures were undertaken to develop the parasite as an effective control agent. None of these was fully successful.

Interest in *B. curculionis* dwindled with the advent of synthetic organic insecticides that effectively controlled the alfalfa weevil. However, in recent years, interest in the parasite has been renewed because of weevil resistance to insecticides and growing concern over environmental contamination resulting from pesticide applications. Recent work with the parasite has included its release on the eastern strain of the alfalfa weevil (Coles and Puttler, 1963) and investigations into physiological defense mechanisms developing within the host (Puttler, 1967; Van Den Bosch, 1964; Salt and Van Den Bosch, 1967). Dysart and Puttler (1965) have investigated interspecific relationships involving *B. curculionis* and the alfalfa weevil.

The objectives of this study were to determine the distributional limits of *B. curculionis* under conditions of expanding host distributions, to ascertain the effectiveness of *B. curculionis* in parasitizing the various larval instars of the alfalfa weevil, and to study population densities of both species.

LITERATURE REVIEW

Occurrence of the alfalfa weevil, *H. postica,* in the United States was first reported in 1904 near Salt Lake City, Utah (Titus, 1909). The weevil spread rapidly from there into southern Idaho (Chamberlain, 1926). It reached Colorado in 1917 (Newton, 1933), Nevada in 1920 (Snow, 1925), and California in 1923 (Essig and Michelbacher, 1933).

More recently the weevil has invaded the province of Alberta (Hobbs et al., 1959), northern Idaho (Gittins, 1956), and western sectors of Kansas, Nebraska, and North and South Dakota (Hagen and Manglitz, 1967).

In addition to the widely disseminated western strain, a second, physiologically distinctive strain of the alfalfa weevil occurs in the eastern half of the United States (Blickenstaff, 1965; Davis, 1967). The eastern strain, first discovered in 1952 near Belaire, Md., apparently resulted from a separate introduction from Europe (Poos and Bissell, 1953).

No native parasites of the alfalfa weevil were found in Utah when the weevil was first reported (Titus, 1910). Several species of parasites, including *B. curculionis*, were discovered in the weevil's native range in Europe and exported to the United States in the early 1900's for use in biological control.

B. curculionis has spread with the alfalfa weevil throughout the western United States (Parks, 1913; Newton, 1933; Michelbacher, 1943). This parasite has also been introduced onto the eastern strain of the weevil and it now occurs in nearly all areas occupied by the weevil (Puttler et al., 1961).

Despite its close association with the alfalfa weevil, *B. curculionis* has never become a completely satisfactory biological control agent. Both eastern and western weevil strains have physiological mechanisms that encapsulate parasite eggs through a melanization process (Puttler, 1967; Van Den Bosch, 1964). Michelbacher (1940) pointed out that *B. curculionis* is ineffective during the latter part of the summer since it has disappeared from the field while a few alfalfa weevil larvae are still developing. The high reproductive potential of the weevil (Parks, 1914) makes it necessary to remove nearly 100 percent of the larval population to effect control the following year. Thus, defensive mechanisms in the weevil and low incidence of parasitism late in the season seriously impair the parasite's effectiveness. Another reason for its inefficiency is that parasitized weevil larvae die only after completing their normal feeding activities (Essig and Michelbacher, 1933). The parasite's effects, then, are passive, becoming manifest in autumn in the form of reduced numbers of overwintering weevil adults. Current season damage goes unchecked.

B. curculionis is the most effective parasite presently established. Several other parasites have recently been imported from Europe and are currently held in culture at Beltsville, Md., by the U. S. Department of Agriculture for future release against the alfalfa weevil (Brunson and Coles, 1968). *B. curculionis* and other introduced parasites may prove useful in an integrated control program (Stern, 1961).

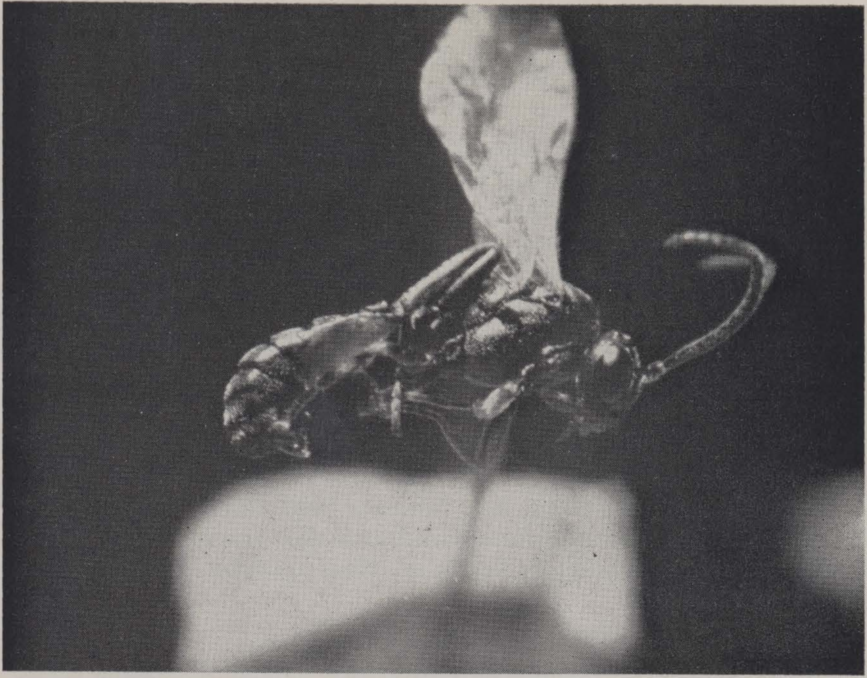


Fig. 1. **B. curculionis** male (15X).

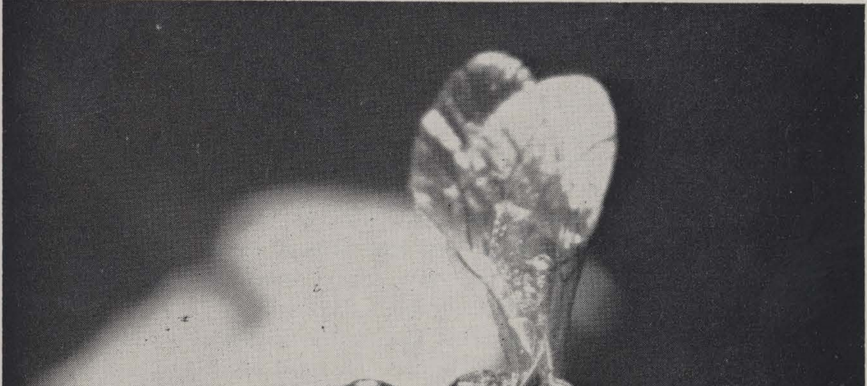


Fig. 2. **B. curculionis** female (15X).

METHODS AND MATERIALS

Distributional Study

B. curculionis and *H. postica* distributions in northern Idaho were surveyed during the summer of 1968. A 100-sweep sample, using a 15-inch sweep net, was taken at each stop, and the geographical location of each site was marked on a county map. A data sheet was started for each sample.

Each sample was returned to the laboratory and adult alfalfa weevils were counted. Adults and larvae of *Hypera zoilus* (Scopoli) and *Hypera nigrirostris* (Fabricius) were noted. Adult *B. curculionis* were sexed and counted. Female parasites were easily separated by the presence of the female ovipositor (Figs. 1 and 2). Alfalfa weevil larvae were separated into instar groups and counted. Head capsule measurements (Hamlin et al., 1949) were used at first to separate larvae. This proved to be a time-consuming procedure, so an alternate method was used for most of the investigation. The alternate method made use of a series of larvae, covering the entire range of sizes for each instar, held in shell vials of alcohol. Each time larvae from the field were sorted, the contents of the vials were emptied into petri dishes and used as standards for determining larval instars.

Larvae of each instar, from each sample, were reared to pupation in the laboratory to expose any parasites that might be present. Groups of up to 25 larvae were reared in clear, cylindrical plastic cages suspended over trays of water (Fig. 3). They were provided fresh terminal shoots of alfalfa, as needed, from a weevil-free supply maintained in the green-

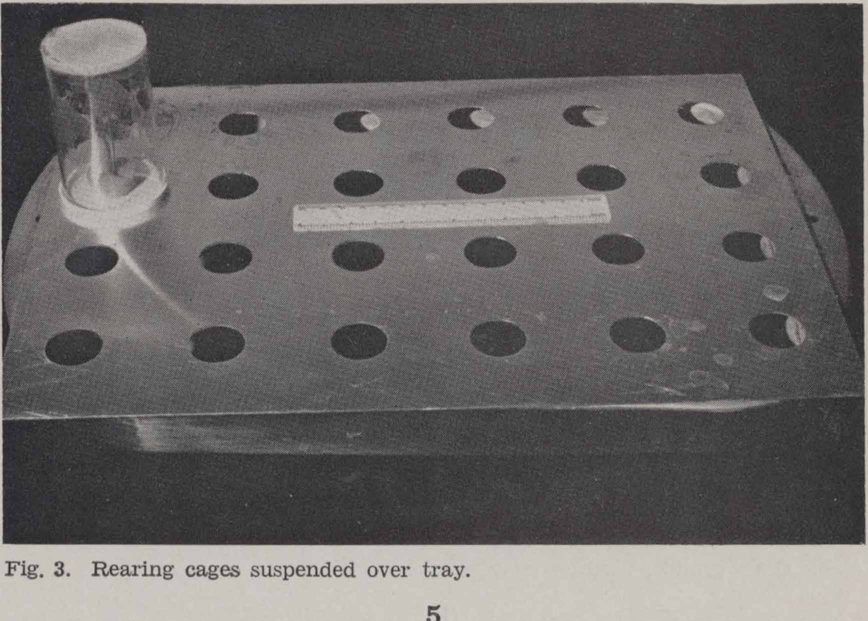


Fig. 3. Rearing cages suspended over tray.

house. After all weevil larvae had pupated, the numbers of weevil and parasite pupae and adults in each cage were recorded. The laboratory analysis of each sample was entered on the data sheet prepared for each site at the time of collection.

Instar Preference Study

Host instar preference by *B. curculionis* females was studied using field samples collected every third day.

Collected material was returned to the laboratory, sorted into instar groups, and reared on fresh alfalfa as described previously. Whenever possible, 200 larvae of each instar from each sample were reared. The contents of each rearing cage were sorted as soon as the last weevil larva had spun its cocoon. The numbers of weevil pupae and adults, male and female *B. curculionis*, and parasite cocoons were counted.

Observations determined which larval instars were attacked by *B. curculionis* in the laboratory, in which instars parasite larvae developed, and whether emerging (light brown) or overwintering (dark brown) parasite cocoons resulted. Parasite females used in the experiment were obtained from cocoons that formed during the distributional study. Upon emergence, each female parasite was placed with a male and allowed to mate. Weevil larvae for the experiment were obtained from female weevils cultured in the laboratory. In the experiment, a single larva of

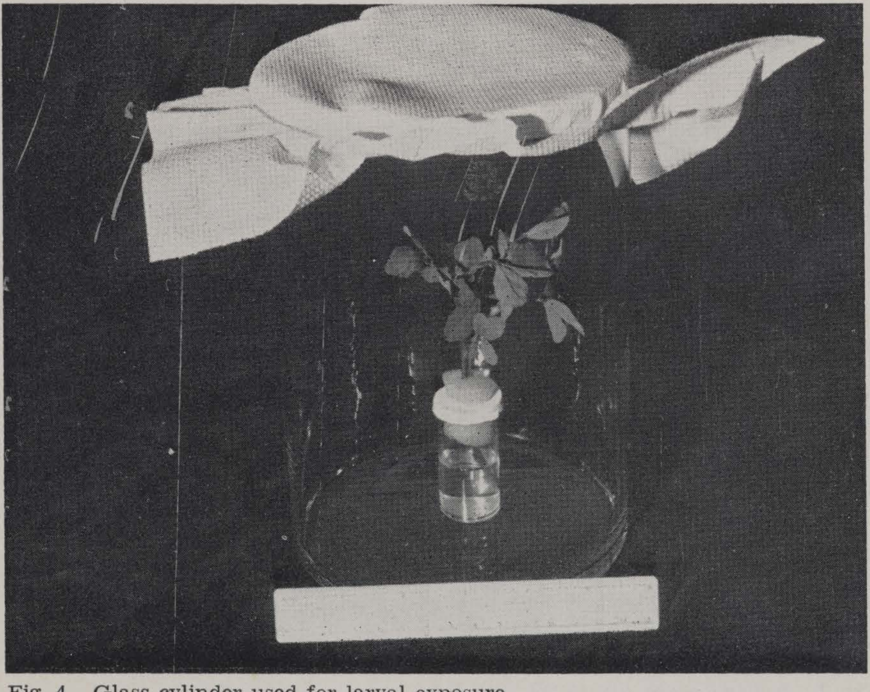


Fig. 4. Glass cylinder used for larval exposure.

a specific instar was placed on a terminal shoot of alfalfa held vertically in a stoppered plastic container and situated in the bottom of a cylindrical glass jar (Fig. 4). A mated parasite was then introduced. Each female was allowed to remain in the jar for 30 minutes while her behavior toward the host was observed. After the parasite was removed, the alfalfa shoot and larva were placed in a rearing cage until the larva pupated.

Population Study

Fluctuations in *H. postica* and *B. curculionis* populations were observed in two fields containing both cut and uncut areas. A uniform 50-sweep sample was taken from each field every three days throughout the summer. All samples were returned to the laboratory and examined as discussed for the instar preference study.

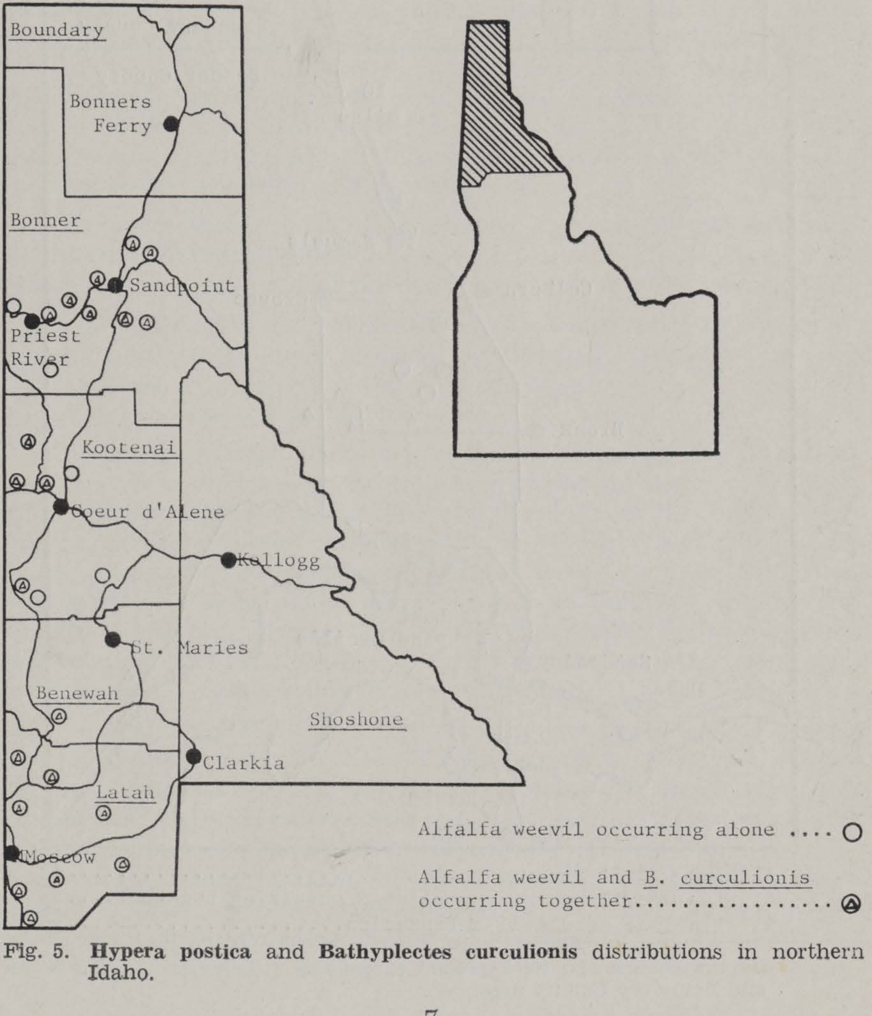
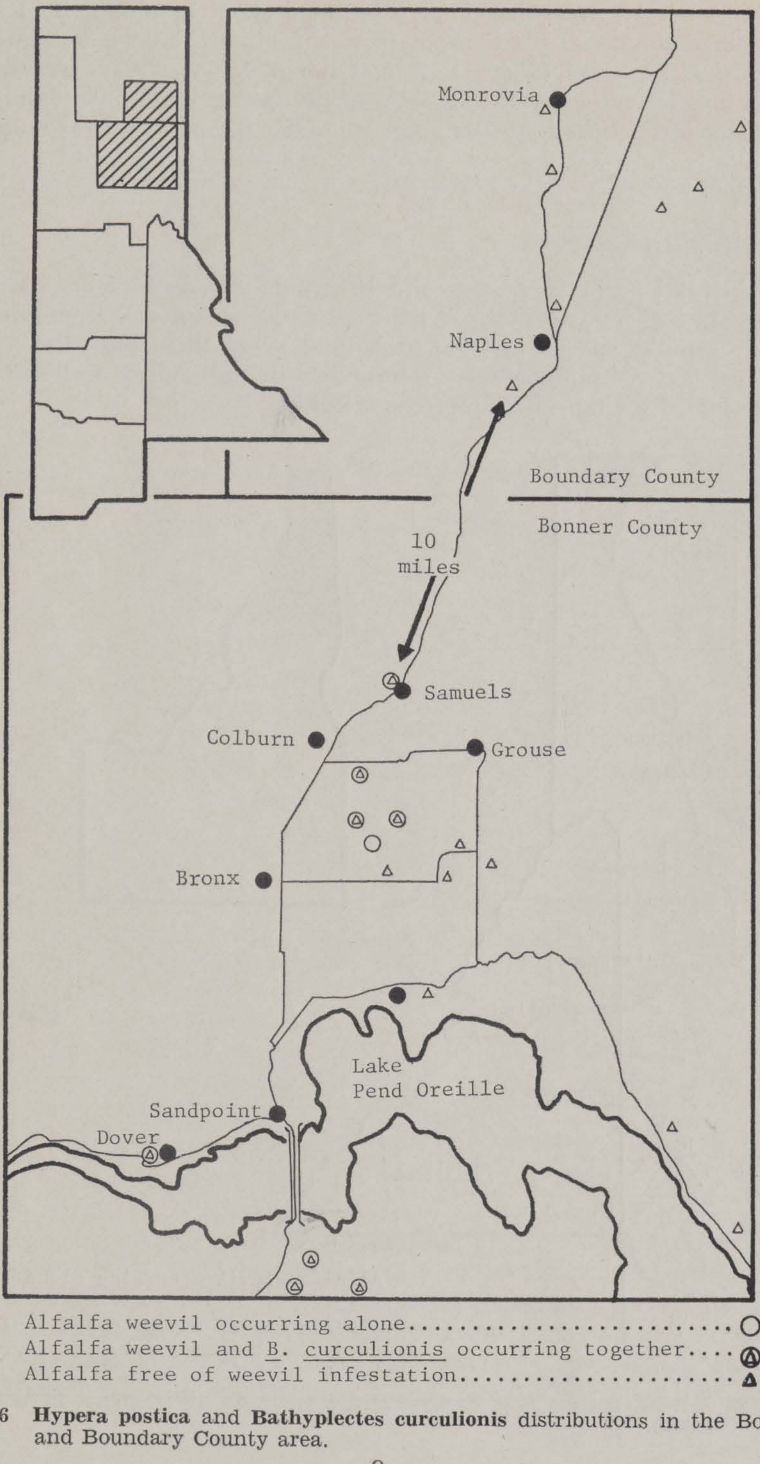


Fig. 5. **Hypera postica** and **Bathyplectes curculionis** distributions in northern Idaho.



Alfalfa weevil occurring alone........................ ○
Alfalfa weevil and B. curculionis occurring together.... △⃝
Alfalfa free of weevil infestation.................... △

Fig. 6 **Hypera postica** and **Bathyplectes curculionis** distributions in the Bonner and Boundary County area.

RESULTS AND DISCUSSION

Distributional Study

Locations where *H. postica* and *B. curculionis* were collected are shown in Fig. 5. Both weevil and parasite have been present in Latah county for several years. Their present distributions are consistent with alfalfa production in the county and seemingly represent a static condition that varies only with alfalfa production.

Weevil and parasite distributions in Benewah county are limited to the southwestern corner. Alfalfa in the St. Maries area remains uninfested. Evidently this area is sufficiently isolated to impair immigration of the alfalfa weevil.

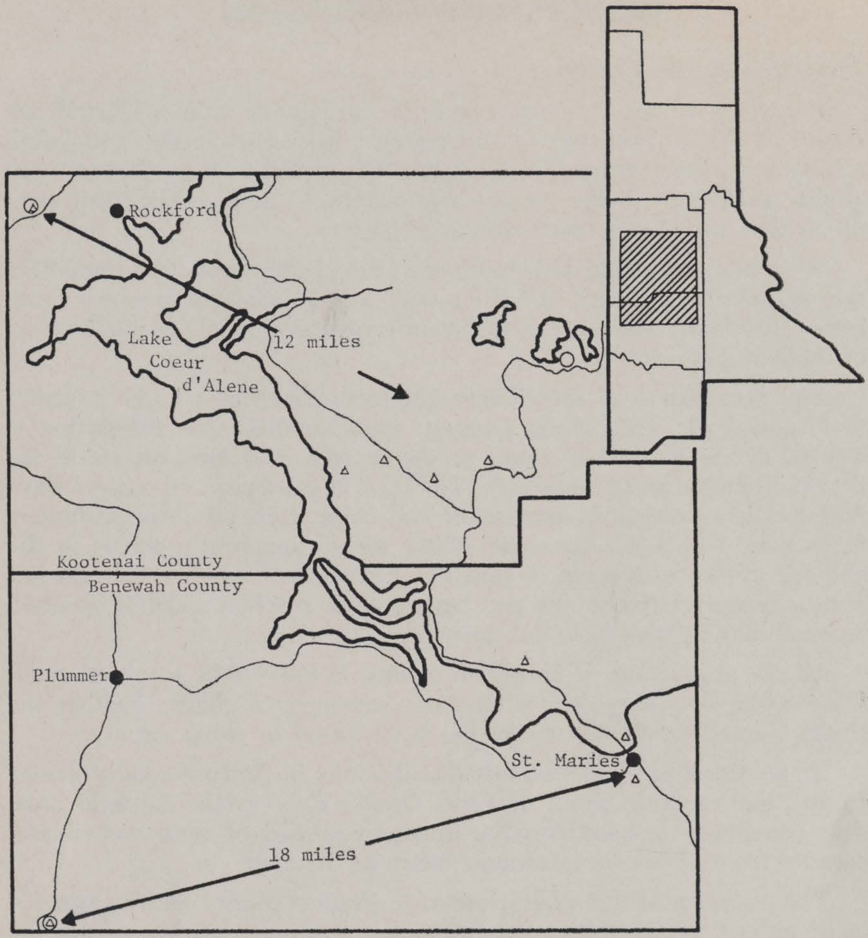
The distribution of weevil infestations in Kootenai county indicates that there have been three separate introductions. One infestation is located in the southwest corner of the county. A second occurs in the Post Falls-Rathdrum Prairie area. The third is a single field east of Cave lake in the southcentral portion of the county. In all three instances, fields were found in which the alfalfa weevil apparently occurs in the absence of *B. curculionis.* A possible explanation may be that the infestations are relatively new and have not yet reached a stable situation accommodating both host and parasite.

Alfalfa production in Shoshone county is limited to scattered small fields while Boundary county has large acreages of alfalfa. Neither the alfalfa weevil nor *B. curculionis* has been found in either county.

H. postica and *B. curculionis* distributions in Bonner county center around the northern shore of Pend Oreille river in the Laclede area. This conclusion is based on the apparent spread of both weevil and parasite from high concentration centers in the area.

The presence of the alfalfa weevil in Bonner county and its absence in Boundary county reflect the influence of natural barriers. From the center of its occurrence along the Pend Oreille river, the alfalfa weevil and parasite have spread northeastward only as far as Samuels, 11 miles north of Sandpoint. A 10-mile-wide band of forest separates the Samuels area from the nearest alfalfa growing region in Boundary county (Fig. 6). The weevil has not been able to cross the forested region into Boundary county. The fact that hay is exported from Boundary county and not imported almost certainly is a factor in this.

The absence of the weevil from the Harrison Flats region of southcentral Kootenai county and the St. Maries region of Benewah county (Fig. 7) indicates that the weevil is not successful in migrating long distances. The distances between these areas and the nearest established infestations are 12 and 18 miles respectively. A new infestation near Cave lake is located less than 10 miles from either of these areas. However, it is unlikely that this infestation has persisted long enough to serve as a source of dissemination since no other fields in the immediate area are infested.



Alfalfa weevil occurring alone............................ ○
Alfalfa weevil and *B. curculionis* occurring together....... ◬
Alfalfa free of weevil infestation........................ △

Fig. 7. **Hypera postica** and **Bathyplectes curculionis** distributions in the Benewah and Kootenai County area.

The Cave lake infestation is apparently the result of importation rather than natural spread of the weevil. The infestation is confined to one field adjacent to a barn lot, 17 miles away from the next closest known infestation. Alfalfa shipments into the immediate locality could not be substantiated, however.

Although *B. curculionis* is capable of rapid and extensive dissemination (Chamberlain, 1926), it was not found in the absence of *H. postica.* Evidently its distribution is completely dependent upon its host and it cannot parasitize species closely related to the alfalfa weevil. Two such species, *H. zoilus* and *H. nigrirostris,* occur in areas of northern Idaho where the alfalfa weevil was not found. *B. curculionis* was not directly associated with either species in the field.

In a few instances the alfalfa weevil was found without *B. curculionis,* suggesting that perhaps the weevil must reach a certain population level before the parasite can maintain itself. If this is the case, areas of expanding weevil distribution should be characterized by fields containing sparse populations of the weevil without the parasite. This situation seems to be occurring on the fringe areas of weevil distribution in Bonner and Kootenai counties. In Latah county, the weevil and parasite have been established for several years and blanket all alfalfa growing areas. Weevil and parasite distributions are concurrent throughout the county.

Instar Preference Study

Significant differences were found in parasitism levels among the first three instars (Table 1). Lack of significance between parasitism levels in the third and fourth instars suggests a reduction of parasitism during these stages of development.

In an effort to determine the degree of parasitism during the third and fourth instars, a series of controlled exposures was made in the laboratory. The larvae of each instar were exposed individually to separate parasite females. The results are listed in Table 2.

Each larva was exposed for 30 minutes during which time it was observed continuously. When the larva was introduced, the female para-

Table 1. Instar preference study, percent parasitism by instar.

Instar	Number weevil larvae parasitized	Total number weevil larvae	Percent parasitism[1]
First	30	237	12.6a
Second	183	747	24.4b
Third	369	947	39.0c
Fourth	378	1027	36.8c

[1] Items followed by different letter suffixes are significantly different at the 5 percent level.

site usually became excited and started maneuvering her antennae in search of the larva. The parasite usually made initial contact with her antennae. Upon locating the host, the female parasite characteristically positioned herself parallel with and above the host and inserted her ovipositor through the larva's dorsum. The parasite seemed to have no preference for anterior versus posterior insertion of ovipositor or front versus rear mounting of the host. Occasionally, parasites failed to align themselves parallel with the host. In such cases, ovipositional insertion was often made laterally.

When ovipositional contact was made, larvae frequently thrashed about violently, sometimes dropping to the floor of the container. This was true particularly with larger larvae. In most cases, the parasite was able to remain attached during larval thrashing. Ovipositional contact averaged about 30 seconds in duration. In several cases, the female revisited a previously parasitized larva and oviposited for a second time.

The laboratory experiments (Table 2) show that oviposition occurred during the third and fourth alfalfa weevil larval stadia, but that parasite development is impaired in some way. Field data (Table 1) indicate that oviposition apparently did not occur in the fourth stadium and may even be limited to the early portion of the third stadium.

Failure of parasites to develop following oviposition in late third and fourth instar larvae may be the result of either a physiological or a time factor. Salt and Van Den Bosch (1967) and Puttler (1967) have reported a melanization process in the alfalfa weevil larva that encapsulates the eggs of *B. curculionis.* Both reports indicate that parasite eggs are more readily encapsulated in large larvae than in small larvae. However, encapsulation has not been shown to prevent parasite development in third and fourth instars. Apparently some other factor is involved. Perhaps *B. curculionis* eggs inserted into late third and fourth instar weevil larvae do not have time to hatch and mature before the host pupates.

Parasitism may not occur uniformly throughout the first three stadia. Assuming that the first, second, and third stadia have average lengths

Table 2. Laboratory exposures of specific weevil instars to *Bathyplectes curculionis.*

	First instar	**Second instar**	**Third instar**	**Fourth instar**
Number larvae parasitized	10	10	10	10
Larval mortality	7	4	5	4
Larval pupation	3	6	5	6
Adult weevil emerging	1	1	4	6
Parasite cocoons formed	2	5	0	0
Weevil pupal mortality	0	0	1	0

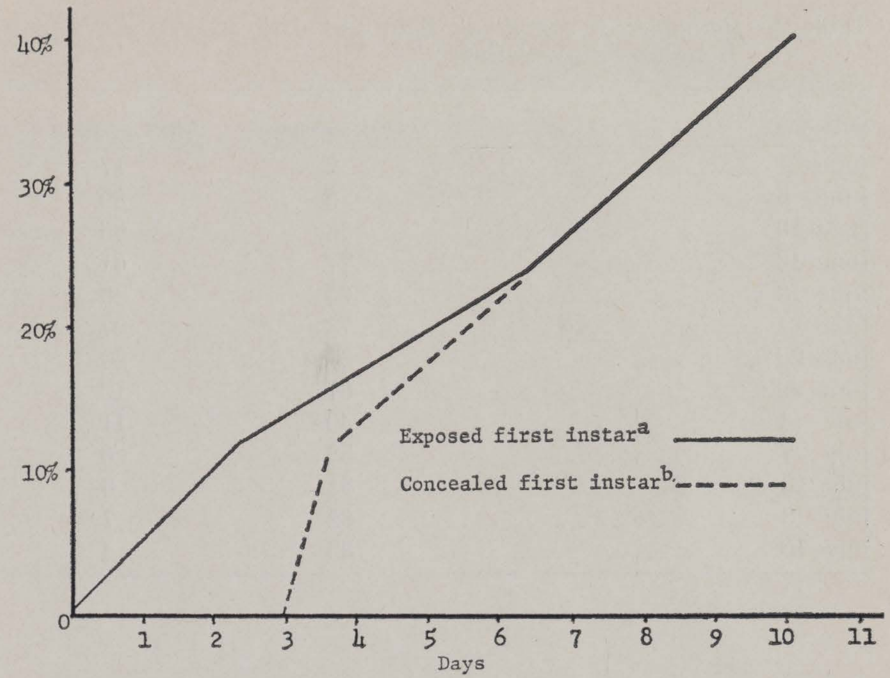


Fig. 8. Average frequency of parasitism during the first, second, and third stadia of the alfalfa weevil larvae. (Line "a" assumes that first instar larvae were exposed to parasitism from hatching; "b" assumes that first instar larvae were protected from parasitism during the first three days.)

of 4.6, 3.7, and 3.7 days respectively (Ben Saad, 1969), that sampling is random, and that parasitism occurs equally throughout each stadium, an estimate of parasitism frequency can be made (Fig. 8). The observed parasitism level of 12.6 percent for the first instar would represent the average amount of parasitism after 2.3 days, midway through the first stadium. The parasitism level would stand at 24.4 percent after 6.5 days and at 39.0 percent after 10.3 days, midway through the second and third stadia respectively.

Fluctuations in the parasitism rate during the first three instars can be best explained on the basis of larval behavior. Weevil oviposition occurs in the hollow stems of the alfalfa plant. When the larvae hatch, they must either locate the hole left by oviposition or eat their way out. As a result, larvae may not be accessible to the parasite during the early first instar. If such is the case, parasitism would not occur. Parasitism through the remainder of the first stadium may be depressed by the larvae's tendency to seclude themselves within terminal leaf and flower buds. Although parasites have been observed in the laboratory probing buds with their ovipositors, such activity might lack the efficiency of direct attack upon exposed larvae.

Table 3. *Bathyplectes curculionis* light and dark cocoons developing from laboratory rearings.

Date of field collection	Dark cocoons	Light cocoons
June 1	2	17
June 5	6	39
June 10	58	66
June 13	77	61
June 18	65	48
June 21	73	37
June 26	37	20
June 29	37	16
July 4	49	11
July 7	53	6
July 10	51	6
July 13	62	7
July 16	55	4

Table 4. Larval population figures, field 1*.

Date	First instar	Second instar	Third instar	Fourth instar
June 1	13	112	27	0
June 5	40	363	203	24
June 10	37	629	763	49
June 13	28	598	911	70
June 18	30	502	1104	104
June 21	24	406	1072	176
June 26	0	119	339	138
June 29	0	137	440	201
July 4	2	100	453	173
July 7	0	34	86	98
July 10	0	26	77	71
July 13	0	9	79	46
July 16	0	4	30	33
July 19	0	0	14	20
July 22	0	2	7	7
July 25	0	0	12	6
July 28	0	0	5	2

* Per 50-sweep sample.

Second instar larvae can also be found secluded within buds. As the larvae grow, it becomes increasingly difficult for them to remain hidden within the folds of the buds. Second instar larvae are also found feeding on exposed leaves. Assuming that early second instar larvae characteristically remain secluded within buds and that they feed on open leaves only after they grow larger, the variation in second instar parasitism (Fig. 8) can be explained.

Third instar larvae characteristically feed on exposed leaves, so they are not sheltered by the buds. Such continuous exposure results in a constant rate of parasitism throughout the third stadium. Because the length of time during which parasitism occurs in the third stadium has not been determined, it is arbitrarily depicted as lasting until the middle of that stadium (Fig. 8).

A consideration of oviposition and early first instar behavior indicates that the first instar portion of the graph in Fig. 8 may not be correct. If the assumption is made that larvae remain in the stem for three to four days (Michelbacher, 1940), the curve would rise more sharply during the first stadium as shown by the broken line. Either curve for the early first instar, or any intermediate between, shows a sharper rise than that of the late first and early second instar. This may be the result of exposure of weevil larvae as they migrate from stems to buds. In addition, the greatest number of previously unparasitized larvae are present in the early first instar.

The instar preference study led to some interesting observations not directly connected with preference. One observation concerned the changing ratio between emerging and overwintering parasite cocoons as the season progressed. Overwintering cocoons are characterized by a dark brown pupal case. Such cocoons remain in diapause until the following spring. Second generation cocoons are lighter brown in color, do not undergo diapause, and give rise to a partial second generation (Michelbacher, 1940). Table 3 indicates the occurrence of light and dark cocoons in rearings made during the experiment.

The partial second generation exists through most of the season. Second generation adult parasites emerge from their pupal cases a few days after the pupae form. Second generation adult parasites were found in laboratory rearings as early as June 10. Peak emergence of the partial second generation occurred during the second week of July.

An examination of individual instar populations indicated there are large differences (Table 4). Ben Saad (1969) found that the average stadia lengths of the alfalfa weevil larvae, under controlled conditions, are as follows:

First instar	4.6 days
Second instar	3.7 days
Third instar	3.7 days
Fourth instar	6.8 days

If these time periods could be applied to field situations, one would assume that more individuals of the first and fourth instars would be present in the population samples. Such was not the case. The data in Table 4 indicated that, most of the season, the third instar comprised the largest segment of the population in field 1.

The fact that no more first and fourth instars were present might be the result of inadequate sampling due to behavior patterns of the larval instars. Since weevil oviposition occurs within the hollow stems of the host plant, newly emerged larvae are commonly found feeding within the stems. These larvae then move to blossom and meristem buds where they seclude themselves while feeding. They were difficult to remove, even when the plant was shaken by hand. Evidently, many first instar larvae were missed during sweeping because they were in stems and tightly folded buds.

Second instar larvae are also associated with the buds although they can be observed feeding on fully opened leaves. No second instar larvae were found within the stems. Third instar larvae are active feeders and are usually found on fully opened leaves. Because of their size, they are seldom fully secluded by the buds and can be readily shaken from them.

Fourth instar larvae also feed actively, making use of the exposed foliage. They are poorly protected by buds. Feeding habits will not explain why the population samples included fewer fourth instar than third instar larvae. The explanation may lie in increased mortality during the fourth instar. The 2.2 percent decrease in parasitism during the fourth stadium shown in Table 1 suggests that weevil mortality may be occurring. There was no evidence found to link parasitism by *B. curculionis* with death prior to pupation, but it may be possible that parasitism weakens fourth instar larvae, making them more susceptible to attack by pathogenic agents.

Population Study

Population fluctuations were investigated in two University-owned fields in the Moscow area. During the second week of June, both fields were cut. Two corners of field 1 were left standing while all of field 2 was cut. This afforded an opportunity to observe the effects of cutting on weevil and parasite populations in addition to studying their seasonal fluctuations.

The number of adult alfalfa weevils in field 1 (Fig. 9) increased from 74 to 88 following adjacent cutting; no corresponding increase was evident in field 2 (Fig. 10). This suggests migration from the cut to the standing portion of field 1 following cutting. The decreasing number of adult weevils present as the summer progressed was probably the result of individuals entering estivation. Such an estivation period is typical of the alfalfa weevil (Prokopy et al, 1967).

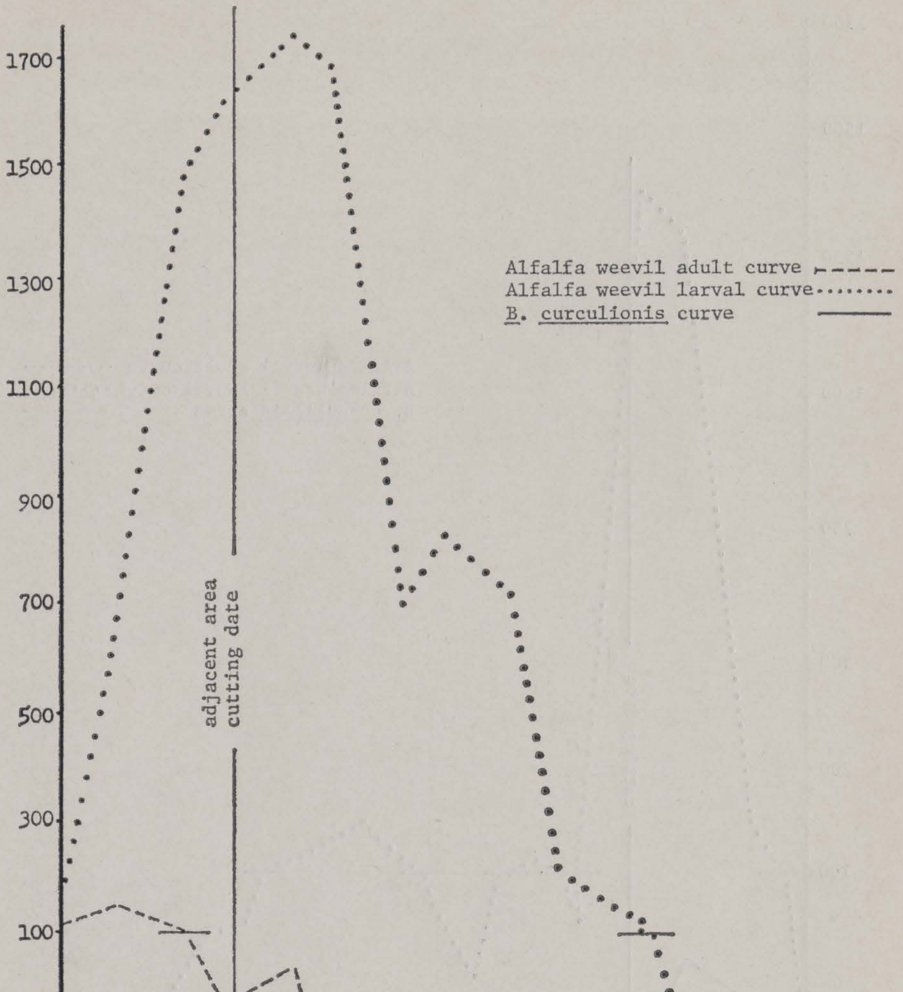


Fig. 9. Populations of **Hypera postica** adults and larvae and **Bathyplectes curculionis** adults in uncut portions of field 1 (populations per 50 sweep sample).

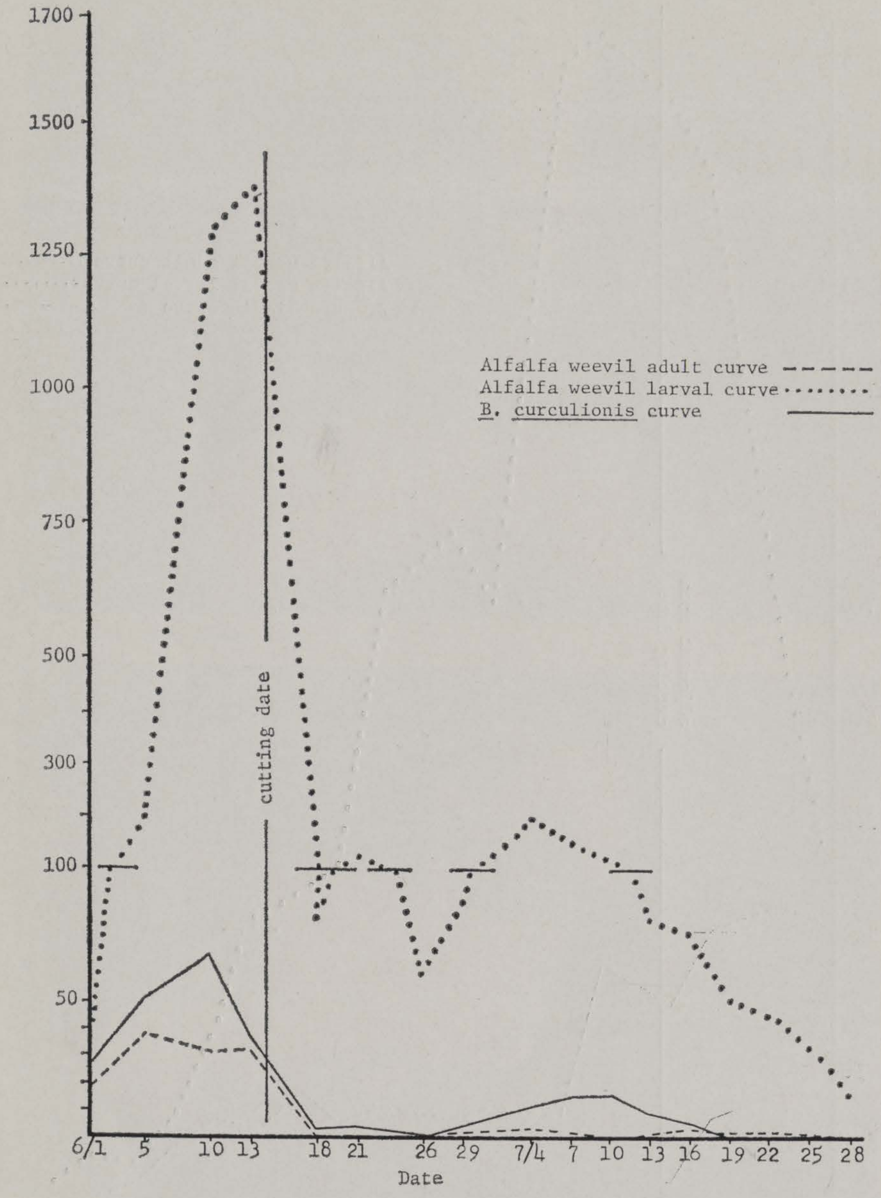


Fig. 10. Field 2 populations of **Hypera postica** adults and larvae and **Bathyplectes curculionis** adults (populations per 50 sweep sample).

The larval population in field 1 (Fig. 9) also continued to increase following cutting. Apparently no significant migration of weevil larvae occurred. Cutting resulted in a high level of larval mortality in field 2 (Fig. 10).

B. curculionis females in both fields had reached their peaks and started to decline prior to cutting. Adjacent cutting seemingly had no major effect on the parasite population in the standing portion of field 1 since no increase was noted following cutting (Fig. 9). However, there was a temporary dampening of the parasite population's established downward trend which may indicate that some immigration into the standing area did occur. Cutting effects were apparently of short duration since parasite numbers in both fields were comparable after June 18. The minor peaks occurring in both populations on July 10 represented the high point of the partial second generation.

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