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CONTENTS

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EFFECT OF BATHYPLECTES CURCULIONIS ON THE ALFALFA-WEEVIL POPULATION IN LOWLAND MIDDLE CALIFORNIA[1]

A. E. MICHELBACHER[2]

Bathyplectes curculionis (Thomson)
Canidia curculionis Thomson 1887
Canidia subcincta[3] Holmgren 1858
Canidiella curculionis (Thomson) Dalla Torre 1891

INTRODUCTION

Bathyplectes curculionis (Thoms.), a larval parasite of the alfalfa weevil, was introduced into Utah from southern Europe by the United States Department of Agriculture Bureau of Entomology during the years 1911 to 1913, inclusive. Chamberlin (1924)[4] has given a brief account of the introduction and establishment of this parasite, and in 1926 he published further data on this subject and called attention to the rapid spread and increase of the species.

After the discovery of the alfalfa weevil in the lowlands of middle California in May, 1932, the Bureau of Entomology,[5] in 1933 and 1934, introduced *Bathyplectes* (fig. 1) into this new area.

In 1933 all liberations were made at Pleasanton, Alameda County, but in 1934 parasites were colonized in the San Francisco Bay area, Pleas-

[1] Received for publication April 7, 1938, but withdrawn to add 1938 data. Resubmitted March 25, 1939.

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[3] Preoccupied by *Campoplex* (= *Canidia*) *subscinctus* Gravenhorst 1829.

[4] See "Literature Cited" for complete data on citations, which are referred to in the text by author and date of publication.

[5] The Bureau of Entomology of the United States Department of Agriculture was combined with the Bureau of Plant Quarantine and became the Bureau of Entomology and Plant Quarantine on July 1, 1934.

anton, and in the San Joaquin Valley. In all localities *Bathyplectes* became readily established, and at the present time it can be found over the entire region infested by the alfalfa weevil. The rate of spread and the build-up of the parasite has been so rapid that it seems to be of sufficient importance to be discussed at this time.

W. B. Cartright of the Bureau of Entomology made the first recovery

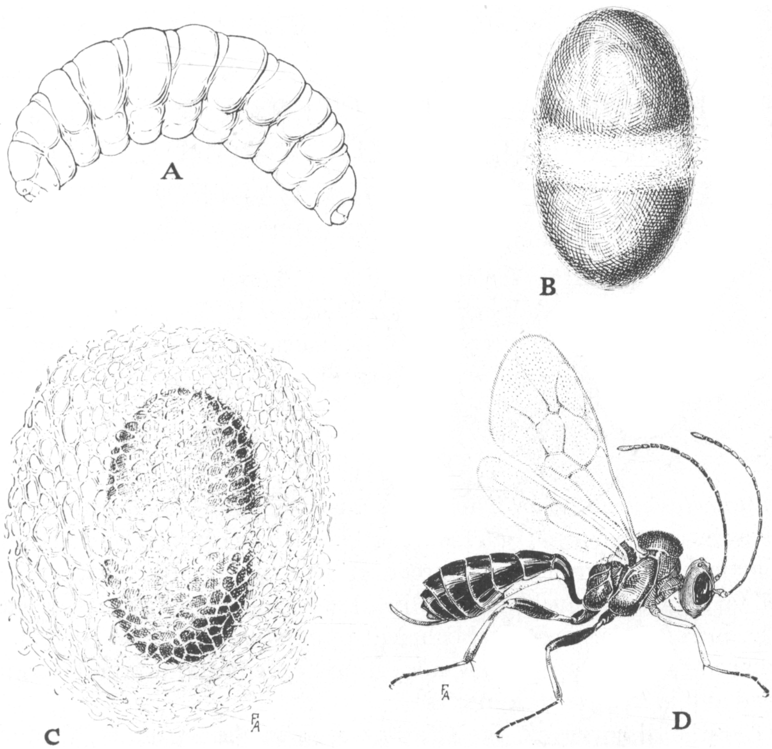

Fig. 1.—Life cycle of *Bathyplectes curculionis: A,* mature larva at time of leaving body of host; *B,* cocoon removed from within host cocoon; *C,* cocoon in normal position within cocoon of host; *D,* adult female parasite. (× 12.)

of the parasite on June 14, 1933, at Pleasanton, and on July 23, 1934, the author recovered the parasite for the first time in the San Francisco Bay area. No recoveries were made in the San Joaquin Valley until May 23, 1935, at which time about 30 per cent of the large alfalfa-weevil larvae were found to be parasitized.

While making a survey of the alfalfa fields at Pleasanton on May 15, 1935, a number of large alfalfa-weevil larvae were examined and most of them were found to be parasitized. It was decided then that if the population trends of the alfalfa weevil were to be completely understood, it would also be necessary to gather information on the corresponding population trends of *Bathyplectes*. This marked the beginning of that study.

AREAS IN LOWLAND MIDDLE CALIFORNIA INFESTED BY THE ALFALFA WEEVIL

The infestation of the alfalfa weevil, *Hypera postica* Gyll.[6] (fig. 2), in lowland middle California occurs in three climatic zones, in each of which it behaves differently. These zones are designated as the San Francisco Bay area, the Pleasanton area, and the San Joaquin Valley area. The San Francisco Bay area includes the towns of Niles, Centerville, and Irvington; the Pleasanton area includes the agricultural region surrounding the town of that name; and the San Joaquin Valley area includes a rather large section of the northwest portion of that Valley. In the San Joaquin Valley, fields were examined on Union Island and in areas about the following cities and towns: Tracy, Vernalis, Westley, and Patterson. This includes the area of heaviest infestation in the Valley.

The San Francisco Bay area has a cool, moderate climate, which is in marked contrast to that of the hot, dry San Joaquin Valley. In the Bay area the mean summer temperatures are lower, and the mean winter temperatures higher than those in the San Joaquin Valley. The climate of Pleasanton is intermediate between these two. The response of the alfalfa weevil to these different climatic conditions is partially discussed by Michelbacher and Essig (1934*a*, 1934*b*, 1935). *Bathyplectes* is also influenced in a marked and distinct way by these climatic differences, and this study indicates that its effectiveness is influenced by temperature.

The alfalfa weevil also occurs outside of lowland middle California in the following counties: Alpine, Lassen, Modoc, Mono, Plumas, Sierra, and Siskiyou. The climate in these counties where the alfalfa weevil exists is similar to that found in the intermountain region of western United States. Because these localities are far removed from Berkeley, it was not feasible to carry on an investigation of the alfalfa weevil in any of them.

[6] Up to the present time the alfalfa weevil has been called *Phytonomus variabilis* Hbst. at this experiment station. However, in a letter from L. L. Buchanan to Dr. E. C. Van Dyke, dated June 20, 1939, Mr. Buchanan stated:

"I have been assembling a few notes regarding the nomenclature of *Hypera*, which, as you doubtless know, was improperly suppressed as a synonym of *Phytonomus* by Schoenherr in 1823 (Isis von Oken, column 1133). To some extent I have also examined the nomenclature of the alfalfa weevil, and cannot find any reason to reject Titus' conclusion that *postica* Gyll. should be used for this species, *variabilis* Hbst. 1795 having been previously used in the same genus by Fabricius in 1777."

It therefore appears that the correct name of the alfalfa weevil is *Hypera postica* Gyll.

EXPERIMENTAL METHODS

The method used in studying parasitism is briefly as follows: From various fields in the localities studied large numbers of nearly mature, last-instar larvae were collected by sweeping the alfalfa with an insect net.[7]

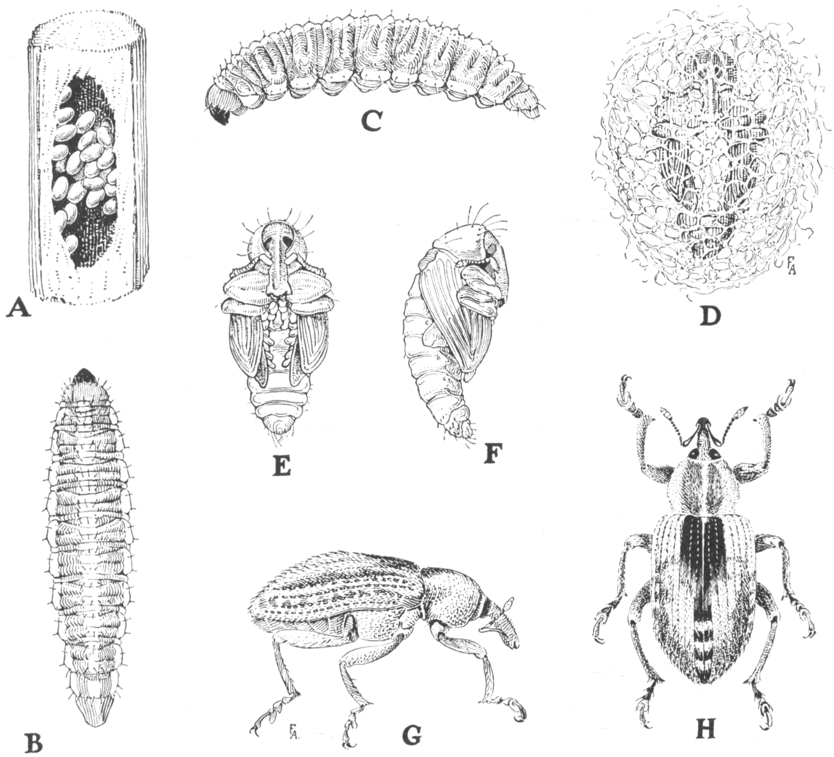

Fig. 2.—Life cycle of alfalfa weevil, *Hypera postica* Gyll.: *A,* alfalfa stem cut open showing a cluster of eggs; *B,* dorsal view of last-instar larva; *C,* lateral view of last-instar larva; *D,* pupa within lacelike cocoon; *E,* pupa removed from cocoon, ventral view; *F,* lateral view of pupa; *G,* lateral view of adult; *H,* dorsal view of adult. (× 6.)

These were taken into the laboratory where the parasites were reared. Frequently more than 500 host larvae were collected from a single field, and if possible not less than 100 were collected. Where the larval population was small, the larvae from several fields were sometimes grouped together. Often several thousand sweeps had to be made in order to obtain enough larvae for parasitism studies, and at times the larval popu-

[7] A number 5 "Harrimac" collapsing steel-frame landing net, manufactured by the Richardson Rod and Reel Company, Chicago, was used throughout this investigation.

lation dropped to such a low ebb that it was impossible to gather sufficient larvae for study.

It was decided to rear out the parasites rather than dissect them out because this less tedious and time-consuming method made it possible to study a larger number of fields and to base the percentage parasitized on a greater number of individuals. Early in the investigation these two methods were compared, with the result that the percentage parasitized obtained by rearing was slightly greater than that shown by dissection. However, no note was made of host larvae containing eggs of the parasite,

TABLE 1

PER CENT OF LAST-INSTAR ALFALFA-WEEVIL LARVAE PARASITIZED BY *Bathyplectes curculionis* AS DETERMINED BY DISSECTION AND BY REARING, 1935

Location	Date	Dissection			Rearing		
		Number of larvae dissected	Number para-sitized	Per cent para-sitized	Number of hosts	Number para-sitized	Per cent para-sitized
Pleasanton:							
Field 1	May 23	38	36	94.7	—*	—	—
Field 2	May 23	100	80	80.0	—	—	—
Field 3	May 23	200	165	82.5	157	155	98.7
Field 3	May 31	200	192	96.0	143	139	96.4
Field 3	June 3	100	94	94.0	80	75	93.7
Irvington	June 3	87	77	88.5	69	66	95.6

* Dashes indicate data not available.

and because of the possibility of overlooking some recently hatched parasites, it can be assumed that the two methods would give comparable data. The comparative results obtained are shown in table 1. Obviously, the rearing method has several disadvantages, among which are: (1) Some of the larvae collected do not spin their cocoons for from 1 day to several days, which means that the total time they would have been subject to an attack by the parasite is reduced by that number of days. This probably is not a serious objection to the method, for Reeves and Hamlin (1931*b*) stated that doubtless because of their tough skin, last-instar larvae are exceptionally free from attack by *Bathyplectes.* (2) Some of the weevil larvae die, and it is impossible to determine whether or not they were parasitized. For this reason dead individuals were discarded, and the percentage parasitized was based upon the number of parasites and hosts recovered.

Usually the examinations were made about 10 days after the collections were brought into the laboratory. By this time practically all the parasites had emerged from their hosts and spun cocoons within those made by the weevil larvae. The weevil larvae collected were placed in one section of a moisture dish with fresh alfalfa and covered with a cloth. The progress of the culture could be determined by looking through the bottom of the dish where many of the weevil larvae moved before spinning their cocoons.

ALFALFA-WEEVIL-POPULATION TRENDS

Before considering parasitism further the seasonal trends of the alfalfa weevil will be briefly discussed. This insect responds differently to environmental conditions in California and in the Great Basin.

In the Great Basin area most of the overwintering alfalfa-weevil adults lay their quota of eggs on the first crop of alfalfa, but according to Reeves and Hamlin (1931*a*) there are a few overwintering adults that survive to lay eggs on the second crop. They also state that the individuals arising from these eggs may be the important ones in carrying the weevil over to the following year. Not only do they escape parasitism, but their development is so rapid that a large percentage of the larvae that mature on the second crop of alfalfa pupate and emerge before cultural kill comes into play at the second cutting. They believe that these adults serve to maintain the weevil at an economically dangerous level. According to their investigations, the population that arises from the first crop is largely destroyed by parasitism and cultural kill. This was substantiated by Newton (1933), who further stated that there is some scattered egg laying throughout the season until winter. On the other hand, in a later paper Hamlin *et al.*[8] point out that when parasitism is low and cultural kill ineffective on account of adverse weather conditions at first harvest, the bulk of the new adults may be produced from the first-crop larvae.

Here in middle California egg laying takes place early, and maximum alfalfa-weevil-larval populations occur from the latter part of March to the first part of May, according to weather conditions. Typically, in individual fields the largest larval population occurs on the first crop, although there are numerous cases where the highest population occurs on the second crop, and sometimes even later than this. In nearly all cases there are surviving overwintering adults that lay eggs on the second crop, but the numbers that occur here largely depend on the time of cutting the first crop. If the first cutting is premature, a fairly large larval population can be expected on the following crop. A young vigor-

[8] According to correspondence by John C. Hamlin and Ralph W. Bunn to author, May 16, 1938, in which they summarize a part of a manuscript, "Bionomics of the alfalfa weevil" now in the course of preparation; the manuscript was not seen by the present author.

ous stand of alfalfa may reach maturity in a relatively short period and be cut long before the overwintering adults have depleted their egg supply. If cutting the first crop is greatly delayed, the overwintering adults will nearly finish egg laying before cutting. This relation of overwintering adults to the time of cutting the first crop must be more or less the same wherever the weevil occurs.

In California another complication is that current-season adults reach sexual maturity during late spring and summer. Because of this, a second build-up in the larval population may take place from the latter part of June throughout most of July. Prior to this rise, the larval population usually reaches a very low point. The second peak generally occurs on the third crop although it may be delayed until the fourth, and occasionally in individual fields it may exceed the peak that occurred on the first crop.

To what extent the current-season adults reach sexual maturity is probably largely dependent upon climatic conditions. Evidence which shows that current-season adults reach sexual maturity is reported on by Michelbacher and Essig (1935). Apparently the hot temperature that occurs as summer progresses either slows down or inhibits sexual development of the adult weevils, for otherwise higher larval peaks could be expected. That this should occur is not surprising because the alfalfa weevil is an insect that prefers cool weather, as is indicated by its stimulation to activity early in the year. Possibly high temperatures send the adults into semi-estivation, and this is more marked in the San Joaquin Valley than in the cooler San Francisco Bay area.

SEASONAL HISTORY OF BATHYPLECTES

Bathyplectes normally produces two generations a year, the short- and long-cycle cocoons. The long-cycle cocoons have thicker walls, are darker in color, and contain the overwintering forms. At about the time the alfalfa begins growing in winter or early spring, adult parasites emerge from these cocoons and oviposit in the alfalfa-weevil larvae that occur from an early hatching of eggs. The parasites complete their larval development in a short period, and upon emerging from their hosts spin the light-colored, short-cycle cocoons. The adults emerge from these cocoons very soon and oviposit in the weevil larvae, which have become abundant by this time. When these parasites complete their larval development, they emerge from their hosts and spin the dark, thick-walled, long-cycle cocoon.

The seasonal history as outlined above does not occur in lowland middle California.[9] Both types of cocoons are produced, but not at definite periods. *Bathyplectes* adults emerge during January and probably on through March, the duration of the emergence depending upon weather conditions. Large numbers of overwintering forms were reared at Berkeley in 1935 and were stored on a window sill having a north exposure. There was no heavy emergence from these until January, 1936. The overwintering forms reared in 1936 were kept in the same location, and adults did not emerge until late in January, 1937, the later emergence probably being due to the very cold weather that prevailed during the first part of that year. Emergence from this group lasted from January 11 to April 1.

The period of emergence coincides rather closely with the time that the weevil is stimulated to activity. The *Bathyplectes* adults from the overwintering cocoons oviposit in the early alfalfa-weevil larvae, but their progeny consists of both long- and short-cycle cocoons. Apparently the long-cycle individuals will not emerge until the following season. From collections of parasitized larvae made throughout the season, some cocoons of both cycles were usually obtained. The overwintering cocoons were present in fairly large numbers, but, as the season progressed, they appeared in smaller numbers until April, when the proportion of overwintering cocoons rapidly increased again, until by the end of May most of the parasites were overwintering forms.

The approximate trend in the production of overwintering forms in the San Francisco Bay area and in the San Joaquin Valley for 1937 is shown in figure 3. This information was obtained from the field collections of alfalfa-weevil larvae brought into the laboratory for parasitism studies, which are discussed in the next section. The points plotted are the average percentages of cocoons overwintering obtained from those collections. The term "approximate trend" is used because only those cocoons known definitely to be overwintering cocoons were used in calculating the percentage figures. Poorly formed cocoons or larvae that failed to spin cocoons were placed with the short-generation group. Therefore the percentage of cocoons overwintering should be slightly higher than that shown in the figure. The two curves are based on rearing records from last-instar-weevil larvae brought into the laboratory. The change to laboratory conditions might produce different results from those of field

[9] Hamlin *et al.* (see footnote 8, p. 86) call attention to the fact that there are not two complete generations of the parasite in the Great Basin—only a partial second generation. Their work has shown that all the overwintered individuals do not produce the short-cycle cocoons; some produce long-cycle cocoons immediately and thus have only one generation. They state that the percentages responding in these two ways are not known. The development as they have given it agrees rather closely, but not entirely, with that which occurs in lowland middle California.

conditions. In fact, some evidence was obtained which indicated that under the warmer conditions of the laboratory more overwintering forms are produced than would be expected under field conditions. Similar data were collected in 1936, but this material cannot be included, for early in the season no accurate count was made of the overwintering cocoons. The results, however, are similar to those obtained in 1937. In the

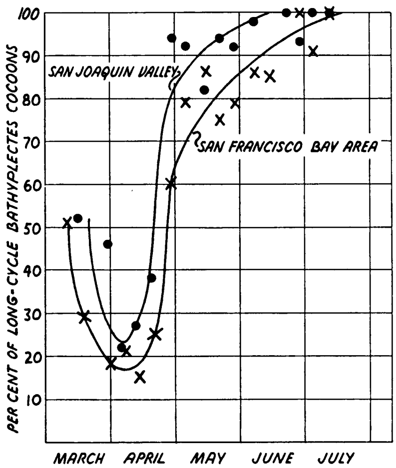

Fig. 3.—Production of long-cycle, or overwintering, *Bathyplectes curculionis* cocoons in the San Joaquin Valley and in the San Francisco Bay area in 1937.

San Joaquin Valley the activity of the parasite is more limited than in the San Francisco Bay area. Apparently the hotter climate of the Valley tends to cause the production of overwintering forms to a greater degree than the cooler climate found about the Bay area. This might account for the fact that the parasite is less effective in the San Joaquin Valley.

During the summer and fall of 1935 any large collection of alfalfa-weevil larvae in the San Francisco Bay area contained some that were parasitized. When the collection of parasitized larvae was large, some of these were almost certain to be short-cycle individuals. During the summer and fall it was not uncommon to collect adult *Bathyplectes* in the field. These same conditions were observed during 1936 but to a much smaller degree. For summer and fall activity of *Bathyplectes* to be noticeable, apparently two conditions are necessary, namely: a certain host density and a cool climate.

PARASITISM TRENDS IN THE DIFFERENT CLIMATIC ZONES

Bathyplectes curculionis, as has already been suggested, is apparently very much influenced by climate, and its reaction under one set of conditions cannot be taken as an indication of its behavior under different conditions.

A large mass of information has been collected on both parasitism and the trends of the alfalfa-weevil populations in the three climatic areas under consideration. The information obtained for the different areas is plotted by years and is shown in figures 4 to 6. Larvae and adults were collected at intervals during the growing season by sweeping the alfalfa with an insect net. Except during the growth of the first crop alfalfa fields were seldom swept before the alfalfa was one-fourth grown. In each of the fields studied two series of 100 sweeps each were made, and the average number of adults and larvae collected per 100 sweeps was used as a population index. On each graph the population figures (larvae and adults) are the averages for all fields in a given area, and the percentage of last-instar larvae parasitized is the average for several fields in the same area.[10] The population trends are plotted only through October, although in some seasons in the San Francisco Bay area and adjacent areas it was possible to collect adults and larvae of the alfalfa weevil by sweeping during all months of the year.

On the graphs only averages for all fields are shown, but frequently a wide range[11] in larval and adult populations was found while making the sweeps. In some fields very few larvae were collected, whereas in others the number collected was large. For example, in the San Joaquin Valley on March 20, 1934, only 2 larvae per 100 sweeps were collected in one field. In another field on that same day 1,194 larvae per 100 sweeps were collected. The average (six fields) shown on the graph was 302. In the San Francisco Bay area on March 21, 1934, the range was from 50 to 1,609 larvae per 100 sweeps, with an average (six fields) of 601. A few days before—March 15, 1934—in the Pleasanton area the range was 67 to 516 larvae per 100 sweeps, with an average (six fields) of 257.

[10] It is recognized that from a statistical standpoint average percentages as computed here, in which all fields are given equal weight, might in some cases give misleading results. In this particular case, however, average percentages determined in this way have been checked against those determined by grouping the larvae, total and parasitized, from all fields and then computing the average parasitism. The discrepancy is so slight as to have no significance.

[11] The data for low, high, and average larval and adult alfalfa-weevil populations and percentage of last-instar larvae parasitized by *Bathyplectes* were tabulated for the three infested areas for the period 1933–1938, but because the data duplicated the graphs in part, they have not been included. These tables have been included with the progress report and can be consulted in the files of the Division of Entomology and Parasitology, College of Agriculture, University of California, Berkeley.

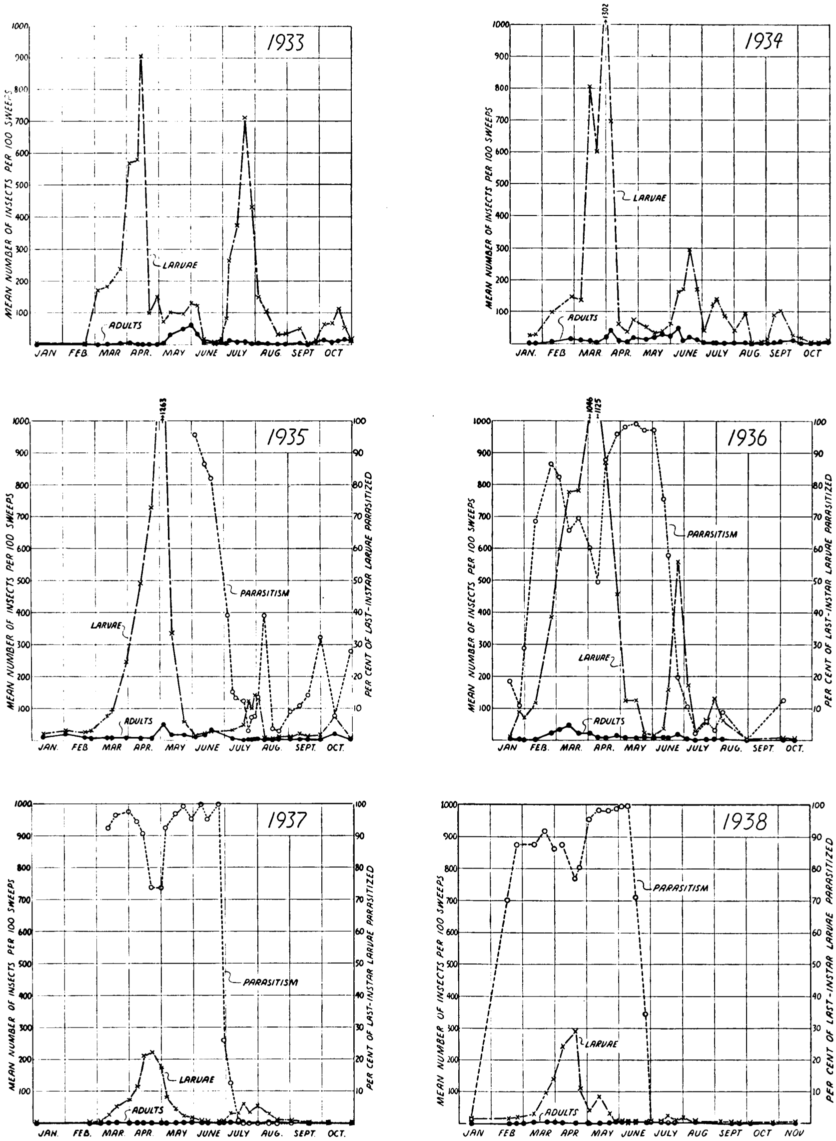

Fig. 4.—Alfalfa-weevil population and parasitism in the San Francisco Bay area, 1933–1938: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar-weevil larvae parasitized by *Bathyplectes curculionis*. Parasites were introduced in 1934.

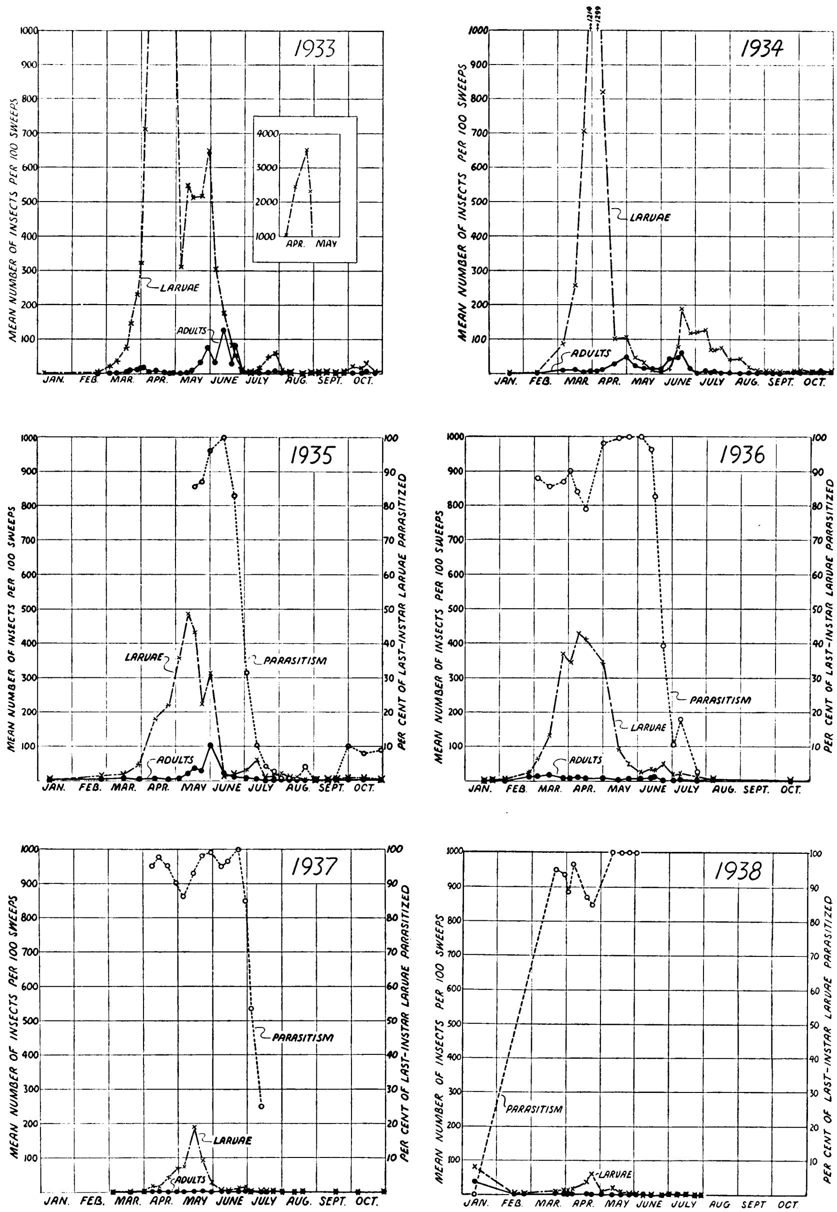

Fig. 5.—Alfalfa-weevil population and parasitism near Pleasanton, 1933–1938: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar-weevil larvae parasitized by *Bathyplectes curculionis*. Parasites were introduced in 1933.

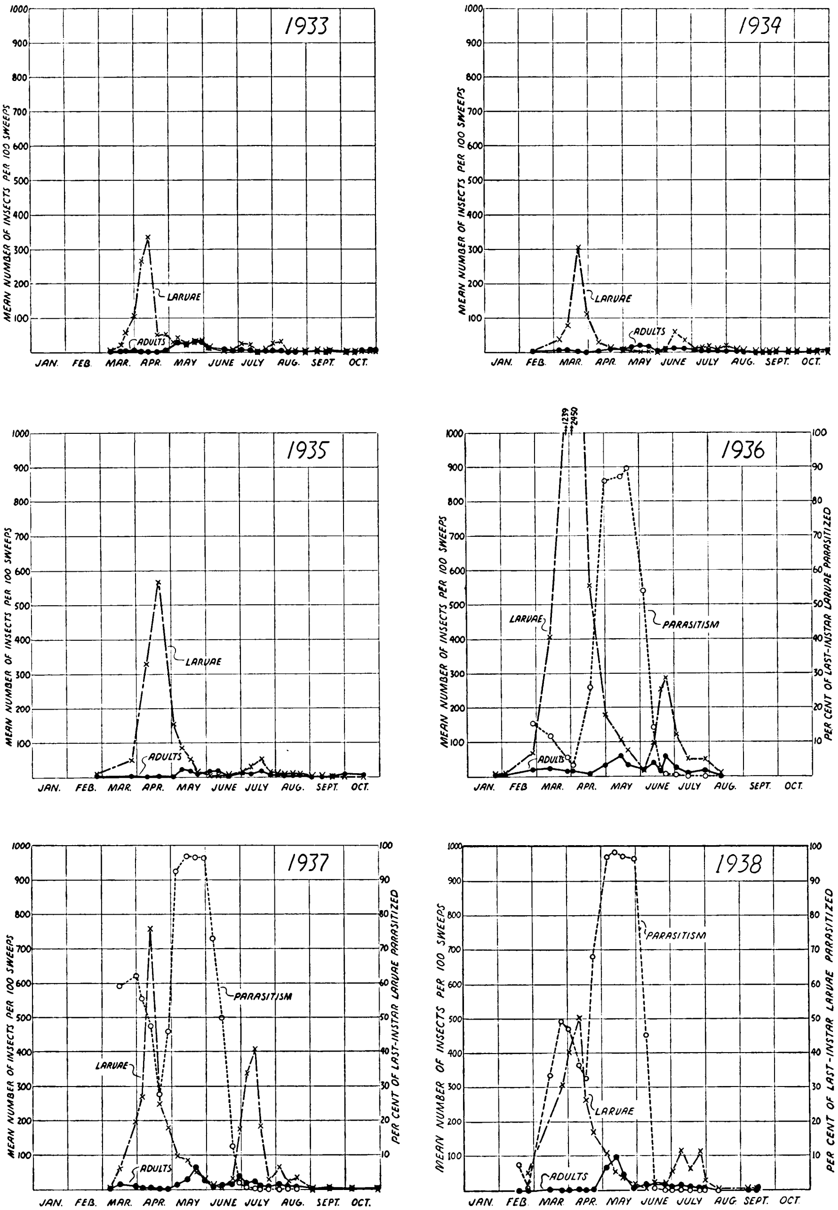

Fig. 6.—Alfalfa-weevil population and parasitism in the San Joaquin Valley, 1933–1938: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar-weevil larvae parasitized by *Bathyplectes curculionis*. Parasites were introduced in 1934.

An examination of the graphs shows that in the winter *Bathyplectes* begins to emerge and to lay eggs at about the same time that the weevil becomes active. In general the percentage parasitized increases at first, but after a given time, which coincides with the last period of rapid host increase, the curve turns downward. This downward trend is then arrested owing to either one or both of the following reasons: the cutting of the first crop or the emergence of the short-cycle parasite. The next rise is very abrupt and the percentage parasitized remains close to 100 per cent for a considerable time; then it drops off sharply and may even fall to zero. The extent of this fall depends largely upon climate and host abundance. The alfalfa-weevil larvae of the second crop are highly parasitized, which is just the reverse of what occurs in the Great Basin (Reeves and Hamlin, 1931*a*; Newton, 1933).

The year 1936 was one of the most favorable encountered for a build-up in the weevil population. There was a marked increase in the population in the San Joaquin Valley. In the San Francisco Bay area the population remained about constant, while at Pleasanton an actual decrease occurred. Possibly in the last two named areas *Bathyplectes* played an important rôle in holding down the weevil population. If this were the case, it would seem from a study of the graphs for 1936 that the parasite was most effective at Pleasanton, somewhat less so in the San Francisco Bay area, and of little importance in the San Joaquin Valley. In the Pleasanton area parasitism remained high during the entire period that alfalfa-weevil larvae could be easily found. In the San Francisco Bay area a considerable number of the first-crop alfalfa-weevil larvae escaped parasitism, and also later in the season after parasitism had dropped off abruptly, a considerable number of larvae were not parasitized. In the San Joaquin Valley most of the first-crop larvae escaped parasitism, and while those of the second crop were heavily parasitized, the large number of weevil larvae that came on later escaped parasitism altogether. Thus only a very small percentage of the total host population in the San Joaquin Valley was parasitized.

The 1937 season was not nearly so favorable for the weevil as was the preceding year, and there was a marked falling off of the weevil population throughout the three areas. With this decline in the weevil population, *Bathyplectes* appeared to play a more important rôle than it did in 1936. Early throughout the infested areas *Bathyplectes* adults were emerging in fairly large numbers before weevil larvae were plentiful. The adult parasites were most abundant in the San Francisco Bay area. On February 22, in one field the average number of *Bathyplectes* collected per 100 sweeps was 11½, while the average number of hosts was only $1\frac{1}{2}$. Eight days later the ratio was 42 to 14. In this area parasitism was heavy until nearly the first of July. After this period there was a slight build-up in the alfalfa-weevil-larval population, and these individuals for the most part escaped parasitism. At Pleasanton parasitism continued high until the first of July. This period included the entire time that the alfalfa-weevil larvae could be collected in any quantity. In the San Joaquin Valley the percentage parasitized was greater than in the preceding year but did not compare favorably with that at Pleasanton and in the San Francisco Bay area. Many of the first-crop larvae escaped parasitism, as did practically all of those occurring on the third and later crops. Parasitism began to fall off rapidly at a considerably earlier date in the San Joaquin Valley than in either of the other two areas.

There was one field at Patterson, in the San Joaquin Valley, in which the weevil population had built up to a point so that it greatly exceeded the populations in any of the surrounding fields in the same locality. For example, on April 5, 1937, the average larval count for this field was 963, while a field less than a quarter of a mile away had an average count of 215. Other fields only a few miles distant showed even a lower count. The highest count observed in this field in 1936 was 5,893 larvae to the 100 sweeps, as compared to 2,542, the larval count in the next most heavily infested field. In 1937 the maximum larval count obtained in the Patterson field was 2,072, while the next highest count was only 480. The Patterson field has been included in the graphs for the years 1936 and 1937. The inclusion of this field has not changed the shape of the curves to any great extent. It has tended to increase the height of the larval curve and to lower the parasitism curve. Further, if the field were excluded from the 1937 graph, the curves would be similar to those for 1933 and 1934 except for the high larval peak that occurred in July, 1937. This peak was the result of a high larval count in a single field, all other fields used in this investigation having been recently cut. Also the inclusion of the Patterson field tends to convey the idea that the average larval population in the San Joaquin Valley is larger than it really is. On the whole the larval count in the fields in the San Joaquin Valley is relatively small. Figure 7 shows graphs for the San Joaquin Valley with the Patterson field excluded.

In the San Francisco Bay area the weevil population remained rather constant until 1937 when there was a sharp drop. A portion of this decline was undoubtedly due to climatic conditions, although *Bathyplectes* was partly responsible.

In early January, 1938, alfalfa-weevil larvae were collected in the fields about the San Francisco Bay and at Pleasanton. At that time *Bathyplectes* adults were scarce and parasitism was very low. In one field at Pleasanton an average of 37 adult alfalfa weevils was collected to the 100 sweeps, and certainly this should have indicated a large larval population later on. However, shortly after the survey was made (January 11), there were heavy rains, and this particular area was flooded for weeks. This resulted in killing the alfalfa as well as the weevil. Apparently this was the only area where the weevil held any threat; for the entire year the weevil population encountered was the smallest since the investigation was started. The parasitism trend was similar to that encountered in 1936 and 1937. It is regretted that the field that showed the

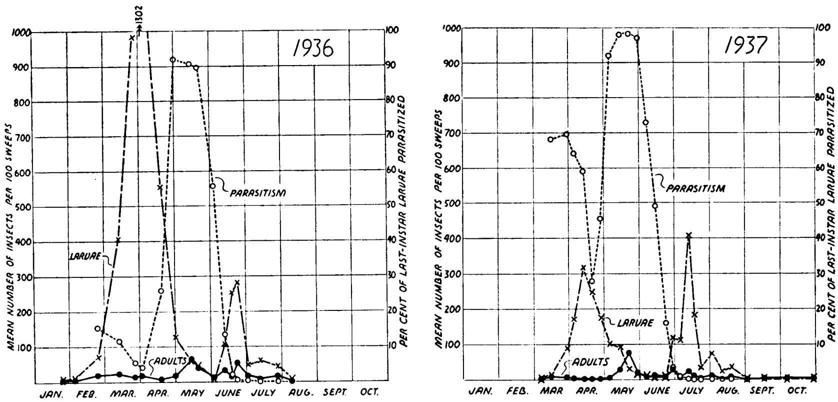

Fig. 7.—Alfalfa-weevil population and parasitism in the San Joaquin Valley, 1936–1937: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar-weevil larvae parasitized by *Bathyplectes curculionis.* The data on the heavily infested field at Patterson have been excluded.

heavy adult-weevil population was flooded. If this had not occurred, there would probably have been a rather heavily infested field in an area where the weevil has been relatively scarce for a number of years. This has led the author to believe that in the area about Pleasanton occasionally alfalfa fields will be found in which the weevil may be slightly destructive.

In the San Francisco Bay area and in the San Joaquin Valley the 1938 weevil-population trends and amount of parasitism were rather similar to those found in 1937. The evidence certainly indicates that *Bathyplectes* is playing an important rôle in limiting the alfalfa weevil in the San Francisco Bay area. On the other hand, although parasitism by *Bathyplectes* may be important in the San Joaquin Valley, it is certainly not as effective in controlling the weevil as it is in the cooler areas. In the San Joaquin Valley one field was rather severely injured by the alfalfa weevil, and rather high larval populations were encountered in one or two others fields.

In general, for the three years 1936 to 1938, the results of this study indicate that *Bathyplectes* will be most effective in the cooler weevil-infested areas. As with the alfalfa weevil, moderately cool temperatures seem to favor it more than warmer temperatures. For that reason its active period is of longer duration in the San Francisco Bay area than in the San Joaquin Valley.

EFFECTIVENESS OF PARASITISM

Bathyplectes curculionis has been present in lowland middle California for too short a time to make any definite prediction concerning its final effect upon the weevil population. Certainly at the present time (1938) it shows considerable promise, and if parasitism continues as high as in the past, *Bathyplectes* should prove to be an extremely valuable parasite. Frequently, however, an insect introduced into a new area builds up in tremendous numbers for a few years, then decreases in number and finally comes to equilibrium with the environment at a much lower level than that at the beginning. *Bathyplectes* may behave in this way. However, the following points are in favor of its becoming an effective parasite: the ease with which it finds its host, the percentage of hosts accessible to attack (that is, in the larval stage), the rapidity of its multiplication, and its facility for rapid dissemination.

At Pleasanton from 1932 to 1938 there has been a great decrease in the weevil population. Both adult and larval numbers have been reduced to a very low ebb. A portion of this decline has been due to better cultural care, some probably to climate, and a large part due to the establishment of *Bathyplectes*. If this area is compared with the others, *Bathyplectes* would appear to be the most important influence in bringing about the decline in the weevil population, but there is danger in reaching such a conclusion. During the same period that the weevil population was declining at Pleasanton it was increasing in the San Joaquin Valley, although a sharp decline occurred there in 1937. The build-up of the weevil in the San Joaquin Valley is believed by the author to be due to favorably climatic conditions and not the result of its being recently introduced into that area.

The alfalfa weevil has not been studied over a sufficiently long period in the infested area of lowland middle California to know the exact fluctuations that might occur in the weevil's population because of meteorological variation. For example, had the conditions in the San Joaquin Valley been reversed so that instead of low populations during the first years of this investigation there had been high ones, the decline in the population in the succeeding years might have been attributed to the introduction of *Bathyplectes,* which of course would have been false. Certainly, up to the present time all the data indicate that *Bathyplectes* will be least effective in that area. However, where parasitism has been as complete as it has been in the Bay area and at Pleasanton, the only reasonable belief is that some few individuals die as a result of parasitism that would otherwise escape death from other causes. If this is the case, and as evidence certainly indicates, *Bathyplectes curculionis* will be an important factor in reducing the alfalfa-weevil population in those areas where its activity is prolonged.

SUMMARY

Bathyplectes curculionis (Thoms.), a larval parasite of the alfalfa weevil, was introduced into lowland middle California by the United States Department of Agriculture Bureau of Entomology during the seasons of 1933 and 1934. It became readily established and was recovered at Pleasanton on June 14, 1933, and in the San Francisco Bay area on July 23, 1934. It was not found in the San Joaquin Valley until May 23, 1935, at which time about 30 per cent of the large alfalfa-weevil larvae were found to be parasitized.

Parasitism studies were conducted in three different climatic areas: the San Francisco Bay area, Pleasanton, and the northwest portion of the San Joaquin Valley.

Parasitism was determined by making field collections of last-instar alfalfa-weevil larvae and rearing through the parasites in the laboratory.

In each field two lots of 100 sweepings were made with an insect net, and the average number of larvae and adults collected per 100 sweeps was used as a population index for the alfalfa weevil.

The highest alfalfa-weevil-larval peak generally occurs on the first crop, but it may occur on the second or even later crops. Weevil activity begins early in the growing season, and a second generation generally makes its appearance during the latter part of June and through July.

Bathyplectes curculionis produces short- and long-cycle forms. Individuals of the latter form are produced at any time during the active period of the parasite. Climate apparently greatly influences the behavior of *Bathyplectes.* Its active period is limited by the hot climate of the San Joaquin Valley. In the cooler portions of the weevil-infested areas of lowland middle California the parasite is able to continue activity throughout the growing season. The most active period ranges from early season until about the first of July. For summer and fall activity to be noticeable two conditions are apparently necessary, namely: a certain host density and a cool climate.

The information gathered concerning parasitism and alfalfa-weevil-population trends is shown by graphs for the different regions studied. The graphs clearly indicate that the San Joaquin Valley is less suited to *Bathyplectes* than the cooler areas.

Definite predictions concerning the final effect of *Bathyplectes* upon the alfalfa-weevil population cannot be made as yet, but at the present time (1938) the parasite shows considerable promise. From all indications, it will certainly exert a marked controlling influence in the cooler weevil-infested areas.

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