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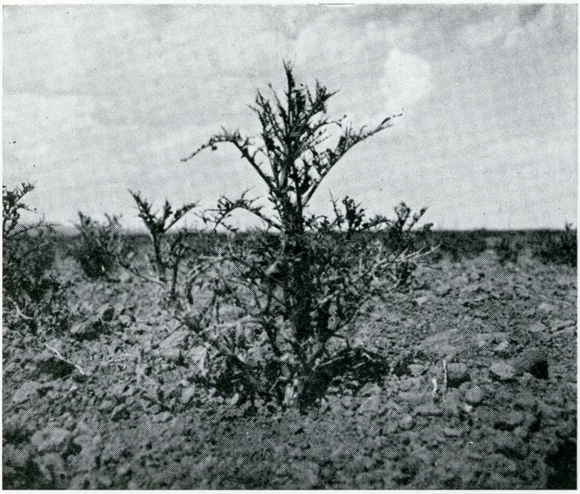

Potato Field Heavily Damaged by Immaculate Blister Beetle.

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Blister Beetles and Their Control

By George I. Gilbertson[1] and William R. Horsfall[2]

The purpose of this bulletin is to present a non-technical account of the life histories, descriptions, damage done and control of several blister beetles common to South Dakota. Most of the printed information dealing with the life histories and habits of blister beetles is old and observational in character (Riley 1878 and 1883 and Milliken 1921), or deals with species not present in this state (Ingram and Douglas 1932).

Blister beetles comprise one of the important economic groups of insects in South Dakota. They are important, first, because of their destructiveness to a wide range of hosts among field, garden and ornamental plants; secondly, they claim attention because of the large number of species; and lastly, this group of beetles deserves consideration because it is represented by certain species which often occur in great hordes over-running vast acreages. Many species have a wide variety of host plants and are often scattered more or less uniformly over whole sections of the state, while others are limited or have preferred hosts and therefore are concentrated or localized.

Apparently these beetles always have been present on the Great Plains, as well as in other sections of the United States. However, with the advent of the white man to the Plains came a certain amount of diversified agriculture and attendant insect depredations. Certain of the introduced plants proved to be susceptible to attack, and some became favored hosts of the beetles. Hence blister beetles became increasingly important as the human population became more dense.

An associated cause for the recent outbreaks of blister beetles is the interrelation between these insects and grasshoppers. A rise in grasshopper abundance is followed by a similar rise in blister beetle abundance. This relation is more than coincidental because the immature or larval stages of common blister beetles are predacious on eggs of many species of grasshoppers. Therefore, the more grasshopper eggs, the more food for the blister beetles the following year. Because agricultural conditions already favored grasshoppers and because certain climatic conditions beginning with 1929 also favored these pests, grasshoppers increased alarmingly and along with them developed hordes of blister beetles. The end result has been that some sections of the state have experienced not only a loss of all grain and grass crops from grasshoppers but a loss of other crops attractive to blister beetles but normally unattractive to grasshoppers. Fortunately, however, destructive outbreaks of blister beetles are less extensive than the accompanying grasshopper scourge.

The question often arises whether the beneficial effect of the egg-eating habits of blister beetle larvae offsets the injury caused by the beetles. In truly great range areas where cultivated crops are at a minimum, the damage done

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by the beetles may be wholly or in part relieved by the reduction in numbers of grasshoppers. On the other hand, in primarily cultivated areas, clearly the reverse is the case, and the beetles are classified distinctly as pests, even though they reduce the grasshopper scourge somewhat.

Blister beetles are unusual in several respects, two of which are outstanding. First, the common name comes from the fact that the human skin is subject to blistering when secretions or extracts from the beetles are rubbed on the skin. The blistering agent is a volatile crystalline substance known as cantharidin which is used in various ways in certain pharmaceutical preparations. A second is the unusual change from a predatory habit in the immature stage to a plant-feeding one in the adult stage. Associated with this change in habits are certain secondary peculiarities which will be discussed hereafter.

Approximately 35 species of blister beetles occur in South Dakota. Carruth (1931) has summarized the earlier collecting records including localities, dates of collecting, and collector. His records, together with subsequent collections, show several species to be among the more important and more widely destructive. Among these are the immaculate blister beetle, *Macrobasis immaculata* (Say)[1]; the striped blister beetle, *Epicauta lemniscata* Fab.[1]; the ash-gray blister beetle, *M. unicolor* (Kirby)[1]; the shiny black blister beetle, *M. murina Lec.*[1] ;the spotted blister beetle, *E. maculata* Say[2]; the white-banded blister beetle, *M. segmentata* (Say)[1]; the sunflower blister beetle, *E. callosa* Lec.[1]; and the squash blister beetle, *Henous confertus* (Say)[1]. All of these, excepting the squash blister beetle have been collected widely over the state. The spotted shiny-black and sunflower species are evenly distributed for they occur not only in all sections over the state but are uniformly abundant. The other four species are always concentrated and seem to move in armies in localities where they are found. It is the latter group which causes the more obvious losses.

General Biology

Blister beetles have a different developmental history or metamorphosis from that common for beetles, in that the larval instars differ widely. The same four stages, namely, egg, larva, pupa and adult are encountered, but deviation from normal complete metamorphosis occurs in the larval stage in which several dissimilar instars or stages of development occur in sequence. The complexities of the life cycle have occasioned the name hypermetamorphosis for this type of development.

In general, all eight of these species have a similar developmental history. The female selects a place for oviposition, and deposits fifty to three hundred eggs in a compact mass. These eggs hatch within an average period of 9 to 37 days, depending on the species. Usually most of the eggs of a single mass hatch within a few hours, and the young larvae ordinarily remain from one to three days in the egg cavity. Upon emerging from the soil, they run actively about often for a week or more searching for an entrance to a grasshopper

1. Determined by E. C. Van Dyke.
2. Determined by H. C. Severin.

egg mass. If a larva is successful in finding an egg mass, it begins feeding as soon as it enters. Within a few days, it molts and there emerges from the skin a white, rather helpless grub, which may still move about readily, but would die if exposed to conditions such as the first larval form survived. Each day or two during its developmental period the larva sheds its skin and gradually changes into a fat, almost legless grub which can move only by burrowing. Larvae of the fifth instar burrow into the soil one or more inches after they have finished feeding. Here they fashion an elongate, oval hibernating chamber in which the larva normally molts into the sixth instar, a helpless, inactive, resting or coarctate larva. The remainder of the year and often two or more years are passed in this quiescent state. In the spring or summer, the resting larva molts into an active, non-feeding seventh instar, and it, in turn, is followed by the pupa. In the case of certain species, the fifth instar is sometimes followed directly by the pupal stage and thereby the sixth and seventh instars are omitted.

Therefore, the larval stage may be considered to have three distinct divisions on the basis of the activity of the larva. The first of these is the feeding period in which the larva grows and gradually changes form throughout five instars of short duration. The second is a resting period of one instar in which the larva remains dormant for a varying length of time. Finally, a third period consists of one instar which is active and burrows about for a time before it constructs a pupal chamber.

The foregoing account of a generalized biology varies in detail according to the species. Therefore, in the following pages each species is considerd individually.

Immaculate Blister Beetle

Macrobasis immaculata (Say)

Economic Importance. This beetle was most abundant and injurious in gardens and caused especial damage to Irish potatoes in the central and south central parts of the state during the years 1934 to 1938. During these years, plants attacked made little recovery so that damage in many areas was total.

Although potatoes appear to be a preferred host,many other plants may be attacked. Among these are sweet clover, alfalfa, tomato, bean, pea, onion, radish, cabbage, matrimony bush, caragana, sugar beet, garden beet, squash, pumpkin, hollyhock, moss rose, gaillardia and marigold. The beetles also feed on such native vegetation as sunflower, cactus blossoms, various wild legumes, wild lettuce, young Russian thistle and Mullein. This array of host plants enables the beetles to have food enough to carry them over even the most adverse years. Consequently they are able to survive in any locality in which they are know to occur.

Observations made in 1933 and 1934 showed that the dwarf bush lima bean previous to blossoming was toxic to the beetles. After blossoming, the plant apparently lost its toxicity and the beetles fed on it without harmful results.

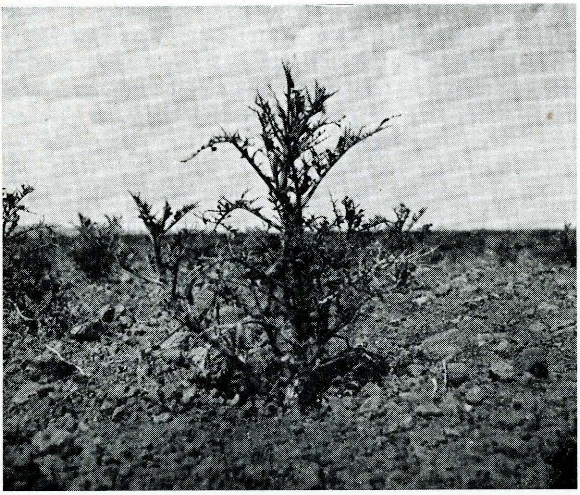

Fig. 1. Potato Field Heavily Damaged by Immaculate Blister Beetle.

Life Stages. The young or larval stages of the immaculate blister beetle live on eggs of several species of grasshoppers, chief of which are the two-striped, *Melanoplus bivittatus* (Say) and the differential or yellow, *M. differentialis* Thos.

Description. The adult is a uniform yellowish gray beetle about one inch long. The color may vary from gray to tan and even to reddish brown. The body surface is black and is so completely covered by microscopic hairs that the overall color is as above. Males and females differ but slightly, the basal antennal segments of the female are more slender than they are in the male. (Fig. 2A.)

The egg is translucent, yellowish-white when first laid, and becomes darker yellow as the embryo develops. Conspicuous features of the embryo are easily visible within the transparent shell. In shape, the eggs are an elongate oval, tapering toward the posterior end. They are about one twentieth inch long and about one sixtieth inch in diameter. (Fig. 2B.) (Fig. 3.)

The larva changes in appearance as it grows older. The change is so complete that it is difficult to recognize the relationship between the forms. The primary larva is a tiny active creature about one-tenth inch long and about one-fiftieth inch wide at the head, the place of maximum width. The body tapers gradually toward the rear and bears two conspicuous long hairs which extend backward. The whole upper surface is light yellow except the last segment which is brownish. In this stage the insect has conspicuous slender legs which enable it to run actively about. (Fig. 2C). After the larva begins to feed, it molts and changes its appearance, becoming a sluggish, creamy white grub with a conspicuous brown head. It feeds and grows rapidly through four dis-

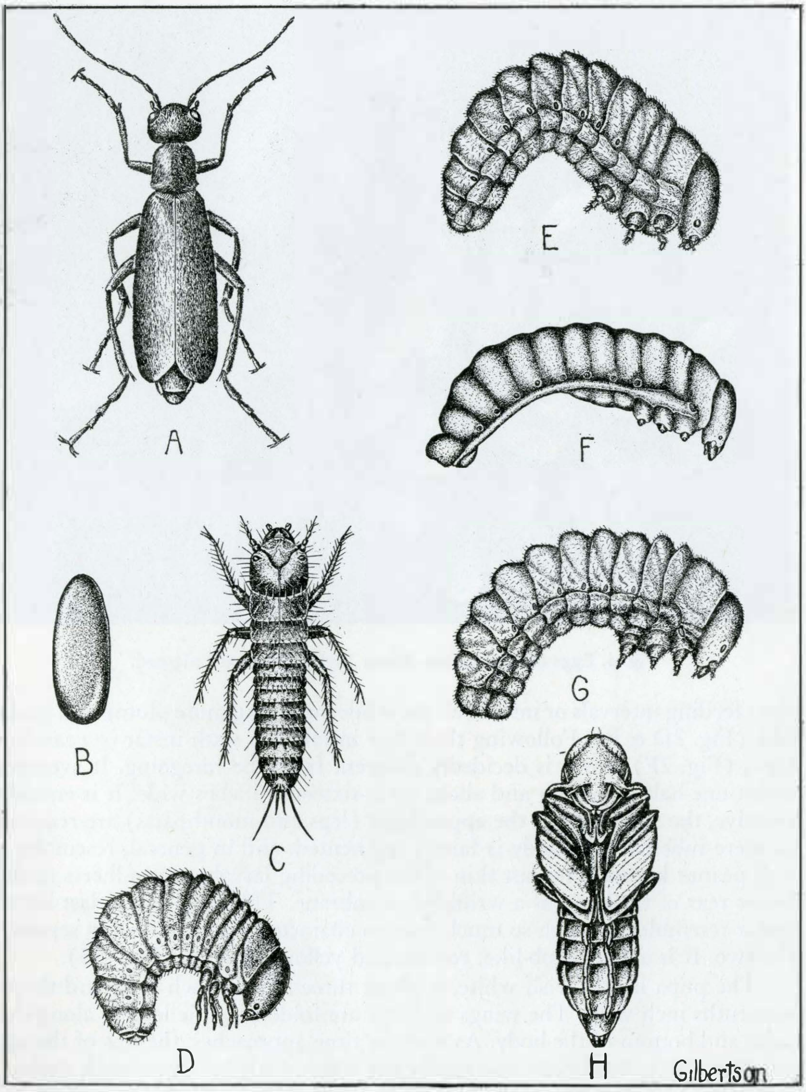

Fig. 2. Developmental Stages in the Life Cycle of the Immaculate Blister Beetle [*Macrobasis immaculata* (Say)] A.—Beetle. B—Egg. C—First instar larva. D and E—Larval feeding instars. F—Coarctate or overwintering larva. G—Last larval instar. H—Pupa. All enlarged Original.

Fig. 3. Eggs of Immaculate Blister Beetle, Original Enlarged.

tinct feeding intervals or instars, all the while becoming more plump and grub-like (Fig. 2D & E). Following these five instars is a sixth instar or *coarctate* larva (Fig. 2F) which is decidedly different from the foregoing. It averages about one-half inch long and about three-sixteenth inches wide. It is entirely inactive, the skin is rigid, the appendages (legs and mouthparts) are reduced to mere tubercles, the body is faintly segmented, and in general, resembles a half peanut kernel. The cast skin of the preceding larval instar adheres to the lower rear of the body as a wrinkled membrane. The seventh and last larval instar resembles the fifth so much that no characteristics will readily separate the two. It is active, grub-like, robust, and yellowish-white (Fig. 2G).

The pupa is yellowish white, is about three-fourths inch long and three-sixteenths inch wide. The wings and legs are folded and lie loosely along the sides and bottom of the body. As molting time approaches, the tips of the appendages begin to darken and finally the whole body becomes much darker. Several days before the molt the legs begin to twitch, a behavior which becomes more noticeable as time for the molt approaches (Fig. 2H).

Habits. Adult beetles of this species usually appear about the middle of June, and some adults have been collected during late August. The season of greatest abundance is during July. Beetles of this species seem to be gregarious and often appear in swarms over vast acreages and move in hordes from one feeding place to another. When disturbed, the beetles tend to seek the cover of leaves, clods or debris. Another peculiarity of the beetles which has been observed in cages is a periodicity of feeding. All would eat ravenously for a period of five or six days, and then they would nearly cease feeding for an equal interval, during which time the beetles sought to escape from the cages. After a time, all gravid (heavy with eggs) females would deposit their eggs and the feeding cycle would commence again followed by another period of egg laying.

Life History. As soon as the adult beetles appear, they feed voraciously for a week or 10 days before mating, and then follows a period of minimum feeding during which mating and development of eggs take place. About 15 or 21 days later the females lay their first batch of eggs at the bottom of a tubular cavity, the diameter of which is slightly greater than that of a gravid female. A female digs an egg cavity in any place where the soil is somewhat packed and slightly moist. The eggs are laid in the bottom of the cavity, the shaft is plugged tightly with soil, and finally the female abandons them. The number of eggs in each of 10 masses has been found to vary from 25 to 306, with an average of 85 eggs per mass. One female laid a total of 490 eggs in four successive batches which contained in order 172, 170, 47 and 101 eggs. Other females laid from three to six masses before they died.

Eggs normally are found from early July until mid-August with the peak hatching period during early August. Eggs have been kept in both the laboratory and in the field for comparisons on the duration of the stage. In the laboratory where the temperature was fairly constant about a mean of 85 degrees Fahrenheit, a total of 1,259 eggs hatched. The first began hatching on the eleventh day and the last hatched on the fifteenth day. The mean interval was 12.4 days. On the other hand, in the field where daily fluctuations in temperature were often great and where the mean temperature was about 80 degrees Fahrenheit, 2,903 eggs were hatched. These hatched in an interval from 11 to 18 days with a mean of 13.3 days.

Upon hatching, the tiny larvae remain for a day or two in the egg cavity before they burrow to the surface of the soil and disperse. Once at the surface, each larva goes its own way in search of egg pods of certain grasshoppers, chiefly those of the two-striped, and the differential or yellow species. When a pod is located the larva enters and begins shortly to feed on the enclosed eggs. After an interval of three to five days from the time the larva enters the egg pod, the first skin is molted and the second instar begins. Four other instars follow in short succession, with the second, third and fourth requiring from one to four days each. The fifth is somewhat longer, requiring from 7 to 13 days. The mean duration of these five feeding instars was 17.9 days in the laboratory. After feeding to repletion, the fifth instar larva burrows away from the egg pod and downward three to six inches, constructs an oval cell and molts its skin. The sixth instar or *coarctate* larva is incapable of motion, hard-shelled, and serves as a resting stage. It is resistant to drying caused from heat and cold. Consequently, this form is well adapted to survive the rigors of winter in this latitude. A larva may remain in this dormant instar a few days or one or more years, according to conditions not clearly understood.

Under field conditions, at least the greater part of a year is spent in this form. With the advent of warm weather in late spring, the larva molts again and an active seventh instar emerges. In this stage, the larva burrows upwards and forms a chamber usually an inch or two below the surface of the soil, but it does not feed. After an interval of 8 to 15 days, this last instar molts and the pupa is formed.

The pupal stage is brief, requiring only 10 to 14 days, and under no conditions has it been found to act as a hibernating stage. The whole life cycle then ordinarily requires a year under field conditions in this latitude. However, in the laboratory, a partial second generation has been observed.

Considerable variation and adaptation to local climatic conditions are shown by nearly all stages of this beetle. The first instar may live three weeks or longer while searching for suitable grasshopper eggs. The intermediate feeding instars may require a longer time than that stated above in the absence of suitable food. Coarctate larvae have been kept in the laboratory three years without changing. Under some conditions, larvae in the last instar have been induced to revert to the coarctate form. These adaptations undoubtedly are advantageous under soil conditions typical of the semi-arid Great Plains where there are wide fluctuations of temperature and moisture.

Striped Blister Beetle

Epicauta lemniscata Fab.

Economic Importance. This beetle is found most abundantly in the southeastern quarter of the state and in most of the Sioux River Valley. In 1937 and 1938, an area near Canton in Lincoln county reported serious infestations in potato fields. Wherever this species occurs in large numbers the damage is often total, as is the case with the immaculate blister beetle. Flowers of several composites, notably Calendula, which bloom during July and August are susceptible to damage, but the host plants are limited in number. Since the area inhabited in South Dakota by this species of blister beetle is the northern limits of its range, and since the food plants of the beetle are limited, the species is generally not so numerous as the immaculate blister beetle.

Description. The adult or beetle is longitudinally striped with alternate orange and black stripes along the wing covers. The orange-colored head is beset with two black eyes; and two small, indistinct black spots mark the head near the mid-line just above the eyes. In general the larger of these beetles are about the same length as the foregoing species but they are narrower. Commonly the adults are much smaller than usual, an adaptation to reduced rations during the immature stages.

For the most part, the larvae resemble superficially those of the immaculate blister beetle.

Habits. This species has several peculiar habits which distinguish it from the other seven studied. One of the most characteristic is its response to a disturbance. Any irregularity such as a noisy, sudden approach of a person causes the beetles to fall to the ground and scurry away in apparent confusion, with each seeking a hiding place such as clods or debris. Another peculiarity is the tendency for the beetles to migrate afoot from field to field. Often they suddenly appear in a field and as suddenly disappear, or at other times, they remain until the whole of a planting is destroyed. A third distinguishing habit is that of secreting themselves during the heat of the day beneath clods, debris, or in shade. They are very active beetles and feed voraciously early in the morning and late in the afternoon. During the middle of the day they hide.

Oviposition. The caged females varied widely in the number of masses and total number of eggs laid. The largest number of eggs recorded from any female was 769 and these were laid in five different masses. Records on fourteen caged females show that the average number of egg masses laid per female was 3.2 and that the greatest number laid by any one was six. From the field and laboratory cages, a total of 49 egg masses were removed from the soil and the number of eggs per mass varied from 44 to 218 per mass with an average of 110. The larger masses and larger eggs were laid by the females earlier in their lives and the masses tended to grow progressively smaller as the adults became older.

The eggs are laid at the bottom of a tubular cavity that is about one-fourth inch in diameter and about one or one and one-half inches deep. After the eggs have been laid, the cavity is plugged with moist soil and a ring of dried pellets of soil is left about the surface where the hole was dug (Fig. 4).

Fig. 4. Completed Egg Cavity of Striped Blister Beetle Containing Eggs and Plug of Soil.

Longevity. It is apparent that the adults of this species may live for several weeks although exact records are not available. On July 13, 1938, about 200 adults were collected from a potato field near Canton. From these, 14 mating pairs were isolated in individual oviposition cages and longevity records were kept. Table I gives some indication of the longevity.

Table 1.

Longevity of Striped Beetle Collected in Field.

Days	Male	Female
21	1	1
22	1	
23	1	
27	1	
29	1	
33	3	2
34	1	
36	1	2
40	1	2
43		1
45		1
47	2	3
48		1
51	1	1

Duration of Egg. A comparison was made between the duration of the egg stage in both the field and laboratory. In the former case, 3,614 eggs were placed in tin boxes and buried in the soil adjacent to and at the same depth as the device for recording soil temperature. In the latter, 3,753 eggs were kept in similar tin boxes in the laboratory. Those eggs in the soil were subject to wide ranges of temperature daily whereas those in the laboratory were subject to a narrow range. On the whole, the temperature averaged higher in the laboratory than in the soil. In the laboratory the duration of the egg stage varied from 6 to 15 days with a mean of 9.5 days, whereas in the field, the range was between 10 and 14 days with a mean of 11.2 days. These extremes represent the greatest variation between the beginning and ending of the hatching period for all the masses. However, it required from one to three days for each mass to hatch.

Duration of Larva. Like the egg stage the larval feeding period is short. For 88 larvae, the average period was 16.0 days from the time the first instar larvae were placed in the vials containing grasshopper eggs until they had transformed to resting larvae. The fifth instar was the longest, requiring from 5 to18 days and 8.4 days on the average. The first instar was the next longest in duration, lasting from two to seven days and 3.8 days on the average. This instar may last much longer under field conditions where the larva must seek out the egg masses. The second, third, and fourth instars were much shorter, lasting on the average 1.2., 1.2 and 1.7 days respectively. Some unusual individuals went through the second and third instars within one day. In no case, did any individual exceed three days in either the second, third, or fourth instar. The coarctate larva (Fig. 5B) in a few cases, transformed with-

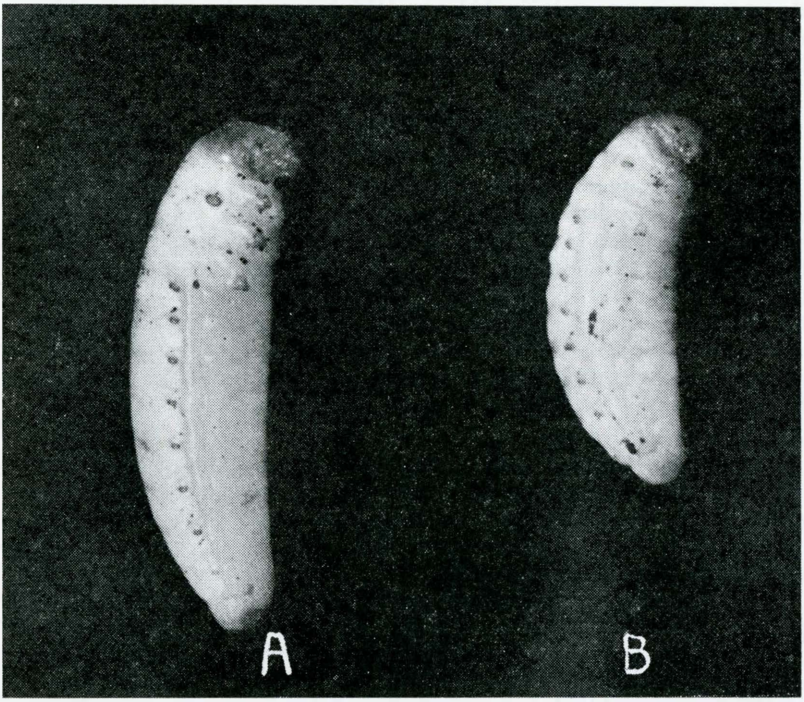

Fig. 5. A. *Coarctate* Larva of Squash Blister Beetle [*H. Confertus* (Say)].
B. *Coarctate* Larva of Striped Blister Beetle (*E. lemniscata* Fab.).

in a few days to the seventh instar but the majority remained in this stage throughout the entire winter, transforming the following spring to the seventh instar. The seventh instar required from five to eight days to transform to the pupa under laboratory conditions. Again, this instar is much longer in the field where the temperatures are lower.

The striped blister beetle is one of four species in which a tendency existed for certain larvae to pass from the fifth instar directly into the pupal period, thus omitting the sixth and seventh instars. In all, 84 larvae were reared through the fifth instar. Of these, 82 molted normally into the resting instar. The other two transformed to pupae directly from the fifth instar.

Like the immaculate species the pupal period was short, requiring from nine to twelve days. Throughout, with the exception of the sixth instar, this species required less time to develop than did the immaculate species.

In the course of some mass rearing work, eight adults emerged, and were kept in the laboratory in a small oviposition cage where they were fed Calendula flowers and potato leaves. Their longevity ranged from 9 to 46 days and averaged 24.4 days. They laid 15 masses with a range of 84 to 127 eggs, with the average mass containing 103 eggs. While the variations in number of eggs were not so great as with those laid in the field cages, the average number per mass was nearly the same.

Spotted Blister Beetle

Epicauta maculata Say

Economic Importance. The spotted blister beetle occurs throughout the state and has been destructive during the years of general outbreaks of grasshoppers. Particularly is this beetle of importance east of the Missouri River, because its preferred host is the Irish potato. Other hosts are soybeans, alfalfa and sweet clover, on which feeding is largely confined to the flowers. While the injury to the potato is less striking than that caused by the two preceding species, it is persistent and widespread, resulting more in reduced yields than in total loss. The general abundance of the beetle and the consequent general feeding causes this beetle to be considered almost as important as the two foregoing species.

Description. The adult has a background color of light brown dotted here and there with minute round black spots (Fig. 6). All parts of the body even to the legs are so marked. The length is from three-eighths to five-eighths inch and the width is about one-eighth inch. This is one of the smaller blister beetles attacking cultivated plants.

The first-instar larvae are much smaller than the preceding species with a general color of lemon yellow (Fig. 7). There are no dark bandings as are present on the two species described heretofore. In other regards, this instar resembles the preceding species. Superficially, larvae in subsequent stages of development resemble those previously described except they are smaller.

Habits. Adults begin to appear early in June and continue to emerge throughout June and July. A few records show the beetles are occasionally collected during August. Unlike the foregoing species, this one is not gregarious but instead is more or less uniformly distributed. Preference is given potatoes when such plants are available, but the wild hosts seem to be sufficient in the absence of cultivated ones. Usually the beetles are found near the tops of the plants, feeding on the tender growth or flowers, and there they may be found even during the hottest part of the day. When they are disturbed, they feign death and fall to the ground where they may remain quiet for several minutes.

Oviposition. Under conditions in the laboratory, no female laid more than one mass of eggs, and she usually died within a few days after depositing it. However, conditions in the laboratory were unlike those in the field in that there was no direct sunlight and the temperature did not rise so high during the heat of the day. Based upon subsequent field observations, the soil in the oviposition cages was too moist in these experiments.

On July 25 on the farm at the Experiment Station at Brookings, an examination of the soil in an alfalfa field yielded eight masses of eggs, which seemed to have been placed at random. In every respect, the cavities were similar to those laid in the field cages and in the laboratory. In a patch of

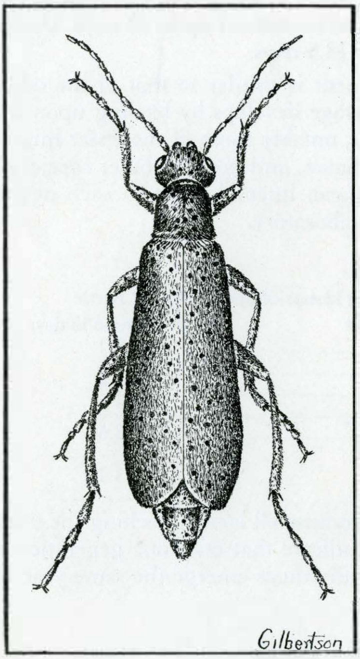

Fig. 6. The Spotted Blister Beetle (*Epicauta maculata* Say)

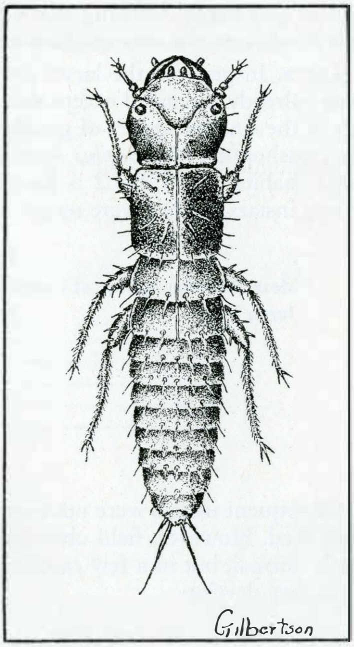

Fig. 7. First-instar Larva of Spotted Blister Beetle. Greatly enlarged.

soybeans adjacent to the alfalfa, one mass of eggs was laid on the surface of the soil between two rows and no cavity was near. They hatched normally upon removal to the laboratory but in the field, such undoubtedly would dry up before they would have time to hatch.

Number of eggs per mass. Nine egg masses contained from 40 to 93 eggs each, with an average of 71. In this respect, this beetle lags behind the others, for these laid a much larger number on the average. The small number of eggs per mass together with only one mass per female would appear to indicate a small number of these beetles. However, this is one of the most numerous and uniformly distributed of our South Dakota species. The low fecundity is possibly compensated for in that the larvae develop generally in egg pods of the lesser migratory grasshopper, a species which is present in great numbers throughout the state.

Duration of Egg. As in the case of the preceding species, a comparison was made between the duration of the egg stage in the field and in the laboratory. In the insectary, 459 eggs were placed in tin boxes on moist soil and observed daily for hatching. Under these conditions, the minimum period was ten days and the maximum was seventeen days with an average period of 12.8

days. A total of 1,629 eggs were placed in boxes at a depth of one inch in the soil and they began hatching in six days and continued up to 20 days. Under these conditions, the average duration was 13.5 days.

Larva. In general, the larval development is similar to that of the other species already discussed except that this stage develops by feeding upon the eggs of the smaller species of grasshoppers, notably those of the lesser migratory grasshopper, *Melanoplus mexicanus* Sauss, and possibly other species of similar habits. In Table 2 is listed the mean interval spent in each of the feeding instars, as they were reared in the laboratory.

Table 2

Mean Duration in Days of Larval Feeding Instars of Spotted Blister Beetle

Instar No.	No. larvae	Mean duration in days
1	23	4.1
2	22	1.6
3	20	1.5
4	20	2.0
5	5	13.6
	Total	23.4

Subsequent instars were not recorded because all larvae reaching the sixth instar died. However, field observations indicate that only one generation a year is normal, but in a few cases, some individuals emerge the same year in which they develop.

Ash-Gray Blister Beetle

Macrobasis unicolor (Kirby)

Economic Importance. This species like the spotted one is uniformly distributed over the state and has been generally destructive in much the same fashion as that species. Like the spotted beetle, it also is more important in the potato growing regions, although potato plants do not seem to be the preferred hosts. Apparently the flowers of sweet clover and alfalfa are preferred and flowers of other legumes are often eaten. However, extensive general feeding on potato leaves is common. Since these beetles are not gregarious and feed independently, the observed damage may be small but the reduced yields are evidence of their presence.

Description. As the common name implies, the beetles are an ash-gray color over all of the body, including legs and head. The underlying color is black with a covering of minute whitish hairs (Fig. 8). There are no marks such as lines or spots. In size, this species is similar to the spotted beetle.

Habits. At Brookings, this is the earliest species to emerge from the soil in the spring. Adults begin to appear in late May and early June and reach their peak about mid-June. Some stragglers or individuals of a partial second generation may be collected in August.

Oviposition. This and the spotted beetles are similar also in that one female apparently deposits only one relatively small mass of eggs. Only incomplete records on this point are available, but all cage records are in agree-

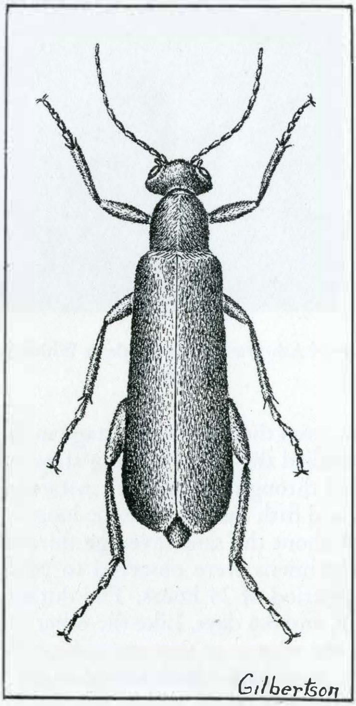

Fig. 8. Ash-gray Blister Beetle [(*Macrobasis unicolor* (Kirby)].

ment. Only three masses were separated and the eggs counted, and they had an average of 98 eggs per mass. (Fig. 9.) Other masses taken from the field cages were within narrow limits nearly the same. Under natural conditions, the low reproductive rate of this species is offset by its wide distribution, and because it will develop on the eggs of any species of grasshopper, the normal food in nature being the eggs of the lesser migratory grasshopper and possibly some of the range species as well.

Duration of Egg. In this regard, this species is unrivalled among the eight reared. A total of 273 eggs was placed in tin boxes and kept in the insectary under conditions similar to those for the other species. None of these hatched before the twenty-fifth day and some required 58 days to hatch. For the whole lot, a mean of 36.8 days was required, while eggs of other species required nearer 12 to 14 days on the average. Not only is the hatching period delayed, but it is prolonged as well. Only a few eggs hatch each day and two or three weeks may pass between the beginning and the end of the hatching of a whole mass of eggs. This is an admirable adaptation, for this species often lays its eggs several weeks before eggs of its host are available as food for the larvae.

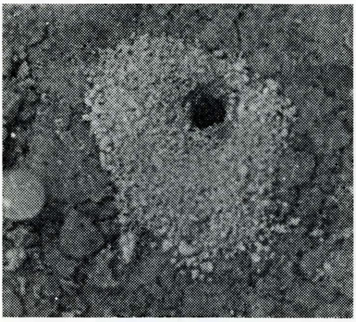

Fig. 9. Completed Cavity of Ash-gray Blister Beetle in Which Eggs Have Not Been Laid. Original.

Duration of Larva. Even though the egg stage in this species is longer than in any other species studied the larval feeding stage is one of the shortest. A total of 61 larvae passed through the first five instars in an average of 15 days. Here, again, the first and fifth instars were the longer. The second, third and fourth instars were of about the same average duration as several foregoing species and several specimens were observed to pass through two of these three instars within a period of 24 hours. The duration of the respective instars is 4.8, 1.5, 1.3, 1.6, and 8.6 days. Like the other species the sixth instar or coarctate larva passes the winter, so that normally only one generation a year occurs. Upon occasion, some individuals reared in the laboratory omit this instar and go directly into the pupal stage. The seventh instar is somewhat shorter than the fifth, lasting from five to seven days under laboratory conditions. Upon molting, this larva produces the pupa, which lasts from six to eight days under laboratory conditions. In the field, both the seventh instar larva and pupa require a longer time to develop because they begin development early in the spring while the temperature is low.

Shiny Black Blister Beetle

Macrobasis murina Lec.

Economic Importance. This species is similar to the ash-gray blister beetle so far as its injuriousness is concerned.

Description. The adults are about three-eighths to five-eighths inch long by a scant one-eighth inch wide. The whole body surface, including the appendages, is shiny-black like tar.

Habits. The habits of the adults are similar to those of the ash-gray species with the exception of the time of the occurrence of the beetles. The shiny black blister beetle emerges slightly later than the ash-gray and reaches a peak of abundance a week or ten days later.

Oviposition. Females kept in field cages laid only one mass of eggs each and died within a few days as is also the case of the ash-gray species. On the whole, the number of eggs laid by each female was greater than that laid by the ash-gray beetle, with the number known to vary from 77 to 215 eggs, with an average of 129 eggs per female. If this obtains in the field, the adults live a short time and lay all of their eggs largely before eggs of the common grasshoppers have been laid.

Life History. The site chosen by a female for an egg cavity is any packed, moist, soil wherever such soil is to be found. Since the bulk of eggs are laid before the host grasshoppers begin to insert their eggs into the soil, there is no relation between the location of the beetle eggs and that of the host eggs. Under field conditions, eggs of this species hatch between ten and eighteen days, and the larvae are often seeking food before the host eggs have been laid in any numbers. In the case of the ash-gray species, the egg stage lasted a long time and larvae were not out before food was available, but eggs of this species hatch in a short time, which obligates the larva to survive a longer time. Larvae in the first instar have been observed to live as long as 46 days without feeding. This ability to go without food for a long period allows sufficient time for the host to pass even the period of peak oviposition and thereby provide sufficient food.

Once a larva begins feeding, it develops very rapidly. Twenty-eight larvae have been observed to complete the feeding period in an average of 12.4 days, the shortest average of all reared species. The mean duration of the instars was 3.5,1.5, 1.1, 1.1 and 6.2 days for the first five respectively. The sixth instar required about 10 months, and in none of the reared material was it omitted. In late April the resting larvae shed their skins and become seventh instar larvae. Without feeding, these molt to pupae within a minimum of six days but if the soil is cold, two weeks or longer may be required. After this molting, a pupa is produced. This stage requires 10 to 20 days under field conditions and finally the adults begin emerging during June.

Squash Blister Beetle

Henous confertus (Say)

Economic Importance. Because of its limited range in the state, this species is of little importance. Possibly the Missouri River valley along the southern edge of the state is the northern limit of its range. In this state, no damage from this species is known to have occurred but farther south the junior author has observed it commonly feeding on the fruit and flowers of the bush squash.

Description. Fully-fed adults of this species are dull black with a large orange spot on each side of the abdomen. They are about five-eighths of an inch long and about three-sixteenths of an inch wide near the middle of the abdomen, and the body tapers toward the head. The wing covers are shorter than the abdomen.

Larvae in the first instar are characteristically larger than any of the others reared. The head is wide in proportion, and the body tapers sharply toward the rear. Little is known of the life history and habits of this species, aside from the fact that the larvae fed on eggs of the yellow, and two-striped grasshoppers in the laboratory. (Fig. 5A.)

White-Segmented Blister Beetle

Macrobasis segmentata (Say)

Economic Importance. This species has been reported destructive in dry seasons in the state doing some damage to gardens, chiefly to potatoes. Russian thistle is the principal host, and in normal seasons undoubtedly this host is sufficient to maintain this species (Fig. 10).

Little is known of the biology and habits of this species except that it will develop on eggs of the lesser migratory, the two-striped and the differential grasshoppers.

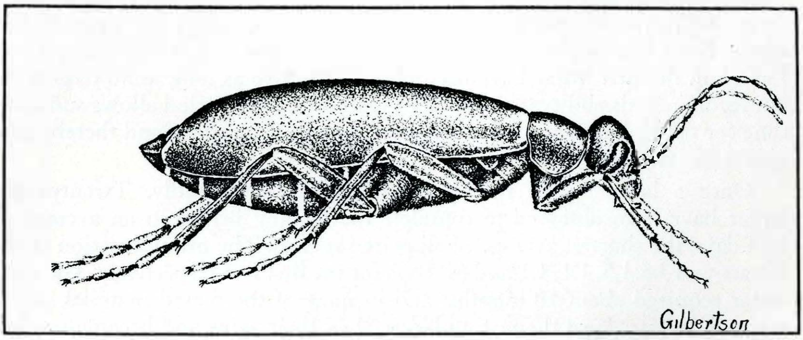

Fig. 10. White Segmented Blister Beetle [*Macrobasis segmentata* (Say)].

Sunflower Blister Beetle

Epicauta callosa Lec.

Economic Importance. So far as known this species does no damage to cultivated crops and the only observed host are the sunflowers which grow so abundantly in idle land. Since the larvae develop on eggs of the lesser migratory grasshopper and certain range species, in a small way, they aid in reducing the plague of these insects.

Survey of Insect Enemies Attacking Grasshopper Egg Pods In A Local Area In 1938

An attempt was made on August 27, 1938, to discover the percentage of grasshopper egg masses that were attacked by one species of blister beetle under field conditions. The area selected was an 80 acre field located in Hand county, 12 miles north of Miller. The cover was wheat stubble with scattered patches of Russian thistle. The field was generally flat with a slight rise toward the northwest selected because of its uniform distribution of egg masses of *Melanoplus mexicanus* Sauss.

Methods. At each of 10 stations 10 square feet of the soil were examined minutely. The stations were chosen at random and marked with a flag before any one was examined. A frame 10 feet by 1 foot, inside measurements, was used to lay out the space at each station. Since the drill rows ran along a north-south line and the shock rows ran on an east-west axis the frame was consistently placed on a line crossing these at an angle of about 45 degrees. The stations were fairly well distributed over the entire field.

Successive thin layers of soil were shaved off by means of pointing trowels so that the frothy coating of each egg mass could be seen before the pod was cut. Each pod was dug out and dissected as it was located and if it had been damaged by some predator, soil from below it was examined to determine the nature of the predator.

Table 3

Data Showing the Number of Grasshopper Egg Pods that Were Damaged in a Wheat Field in Hand County, August, 1938.

Stations—	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Uninjured Egg Pods	4	1	3	5	3	4	1	2	0	0	23
Damaged Egg Pods											
By Blister beetle											
Larva instars											
1st											0
2nd				2							2
3rd				1				1			2
4th				2	1	*1	1		1		*6
5th		1	1	1	1						4
6th	2	4		4		2				2	14
TOTAL	2	5	1	10	2	3	1	1	1	2	*28
By Bee fly larvae		10	3	6	5	*4		2	10	3	*43
By Scelio larvae				1				1			2
By Unknown sources		1	2	1	1	12		1	2	1	21
Hatched pods			1			1					2
Total egg pods	6	17	10	23	11	23	2	7	13	6	118

Percentage of Egg Pods Damaged By:

Blister beetle larvae	23.7
Bee fly larvae	*35.6
Scelio	1.7
Unknown	17.8
Total	78.8

* One bee fly larva and one blister beetle larva in same pod.

Results. In the 100 square feet examined, 118 grasshopper egg pods were found. Of these, 28 had been damaged by larvae of blister beetles, which upon emergence proved to be the spotted blister beetle, *Epicauta maculata,* 42 had been damaged by larvae of bee flies, two were attacked by a species of a tiny wasp, *Scelio Calopteni* Riley,[1] and 21 were destroyed by means unknown. Only 23 egg pods had been undamaged by parasites or predators. Blister beetles, therefore, damaged 23.7 percent, bee flies 35.6 percent, *Scelio,* 1.7 percent, and unknown causes 17.8 percent. In all, 78.8 percent were damaged by parasites or predators.

1. Determined by H. C. Severin.

In the 100 square feet selected, 28 larvae of blister beetles were found, or an average of 0.28 larvae per square foot. If this average obtained throughout the entire field of 80 acres, nearly one million blister beetle larvae were present in the field. All of the results are summarized in the Table 3.

Control Measures

Blister beetles are difficult to control. They appear suddenly and often do a large amount of damage before being detected. They are not readily poisoned with ordinary stomach poisons. More often they are repelled rather than killed through usual arsenical sprays. If a spattering spray of poor coverage is used, the results are often disappointing. However, of late years fluosilicate dusts have been used to advantage. Results are disappointing at times, but it is still one of the most effective controls. Of the fluosilicate salts used, barium fluosilicate is safest to apply.

Barium fluosilicate. This material, used as a dust, has given us the best control, particularly on gardens, sugar beets and potato plantings. Any good type of duster which gives good coverage and penetration can be used. As a common diluting agent for the poison a cheap grade of flour mixed in a proportion of one volume of the insecticide to three or four times its volume of flour is recommended. Good kills have been secured with this material. Barium fluosilicate dust applications are not as good protective cover treatments as sprays would be. While a number of beetles may be destroyed through eating dusted foliage, a greater number are killed through ingestion by other means. As the beetles are hit with the dust, the fluorine proves irritating to leg and antennal joints. This causes the beetle to gnaw at the irritated areas in order to remove the irritating substance. The chemical is, therefore, taken into the mouth and thence into the stomach. For this reason dust applications must be made as often as beetles appear. It has produced no burning on truck crops but has caused a small amount of injury on tree seedlings in nurseries. Brannon (1934) reports burning on dusted dahlia flowers. However, barium fluosilicate is not regularly stocked by retailers. More often a proprietary compound is to be found on the market containing up to 82 percent barium fluosilicate. This material is oftentimes used in place of the straight salt.

In many places barium fluosilicate is not procurable and crops face destruction by the time the material can be ordered and shipped. In that event we recommend the use of the old treatment of arsenicals and Bordeaux mixture.

Bordeaux Mixture and Paris Green. This spray has given some protection from blister beetles on potatoes. Failures which have attended its use are usually caused by poor spraying equipment. This spray, when properly mixed and applied under high pressure to insure good coverage and penetration, has given fair results. However, coarse spattering sprays have been largely worthless.

Bordeaux mixture can be purchased in powder form but a better spray can be made at home. It should be prepared according to the following formula:

Bluestone (copper sulfate)	4 lb.
Hydrated lime	6 lb.
Water	50 gal.

Dissolve the bluestone in a wooden or earthenware vessel, using hot water. Dilute with half the water. Dissolve the lime in the rest of the water. Pour the diluted bluestone and lime solutions together, straining them through a fine cheescloth or brass-wire strainer, and mix thoroughly. The mixture should be made fresh each time it is used, as it does not keep well. To this mixture of 50 gallons add one to one and one-half pounds of Paris Green. Spray thoroughly for good coverage and penetration. If possible, a pressure of 200 pounds should be maintained.

Proprietary Compounds. There are a number of spray compounds on the market that have given fair results when applied thoroughly with sufficient pressure. They rely upon arsenites, chiefly zinc and copper, for their killing action of blister beetles. A typical analysis of one of these compounds is as follows:

Zinc arsenite	36 percent
Paris Green	25 percent
Bordeaux copper	12½ percent
Inert materials	26½ percent
Arsenic as metallic	22 percent
Arsenic water soluble	1 percent

Very often the grower cannot procure barium fluosilicate, and he does not care to make up Bordeaux mixture. He, therefore, buys these proprietary compounds. Some failures and some successes have been reported and observed in fields treated with these proprietary mixtures.

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