THE SMARTWEED BORER IN KANSAS

by

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INTRODUCTION

A study of the smartweed borer, Pyrausta ainsliei (Hein.) was begun in the fall of 1929 in connection with the Kansas Experiment Station Project Number 9 on "Insects Injurious to Corn". P. ainsliei is of considerable interest as it is the nearest American relative of the European corn borer Pyrausta nubilalis (Hubn.). It is scarcely distinguishable from the European corn borer in appearance and is quite similar in life history and habits. There is some possibility that parasites, now attaching P. ainsliei may change their habits sufficiently to enable them to utilize the European corn borer as a host.

The purpose of this study is first to accumulate information which might have a bearing on the seriousness of the European corn borer as a pest in Kansas, and second to determine whether or not P. ainsliei is likely to develop into a pest on cultivated crops, particularly corn.

REVIEW OF LITERATURE

A review of the literature shows that there has been a considerable amount of work already done on P. ainsliei. However, the greater part has been incidental to investigations on P. nubilalis. No work has been done on this insect in Kansas; Ames, Iowa, being the point **farthest** west. where the biology of the insect has been studied.

Until 1919 the species P. ainsliei had not been distinguished from Pyrausta penitalis (Grote), and until that date the observations and records of P. penitalis in some cases were certainly applicable to P. ainsliei.

P. penitalis was first described by A. R. Grote as Botis penitalis in 1876. He states that it is common and feeds on the receptacle of the western waterlily Nelubium luteum. In 1890 it was redescribed by John B. Smith as Botis nelumbialus. Smith named Nelubium nucifera as its food plant. In 1880 Coquillett published some notes on a species he believed to be B. penitalis but which has since been shown to be different.

Scouts looking for the European corn borer found larvae of P. ainsliei in corn stalks in 1919, at Milford, Massachusetts. They reported them as the corn borer and some specimens were sent to Dr. F. H. Chittenden of the Bureau of Entomology at Washington. Dr. Chittenden turned them over to a specialist, Mr. Carl Heinrich, who reported them as belonging to the genus Pyrausta. He was unwilling to make a statement as to the species, although he said that he did not believe they were P. nubilalis. Some of the larvae were reared and the adults were provisionally identified as *P. penitalis* (Grote). More detailed studies by Mr. Heinrich led him to believe that two species had been confused under the name *Pyrausta penitalis*. He named the new species *ainsliei* in recognition of Mr. George G. Ainslie of the Bureau of Entomology, then at Knoxville, Tennessee, who had made a life history study of the species.

METHODS AND MATERIALS

The present investigation on the smartweed borer was carried on in the following places at or near the Kansas State Agricultural College, in the laboratory, at the field insectary, the alfalfa experimental plot, and in the field.

That done in the laboratory was the morphological drawings, the instar studies and the general work of organization. For carrying on the instar studies twenty-eight larvae were kept in a series of vials, measured daily and fed on leaves of smartweed. Emergence data were from four cages of infested smartweed stems at the field insectary, Figure 1, Plate II. Daily inspections were made of these cages and the insects emerging in them recorded and removed. There were also some tests carried out at the field house to determine the ability of the larvae to survive on different host plants. Larvae were placed in vials with leaves of different species of plants including smartweed as a check.

The duration of the pupal stage and other data incidental to it were from a series of 25 lamp chimney cages, each containing an individual larva at the beginning of the experiment, Plate II, Figure 2. Daily observations were made of these borers until they were eliminated by emergence as adults, emergence of parasites, or the death of the caged insect, Chart I.

Parasites were secured from dissection of smartweed in the spring, from the emergence cages and the individual cages. Attempts were made to bring about oviposition which in the case of one species, *Microbracon caulicola* Gahan, were in a measure successful. An experiment was also carried out to determine the length of life of the same parasite under three different sets of conditions. All of the species of parasites fed readily on dilute honey and were kept alive for some time on this food.

The literature gives a long list of plants as hosts of *P. ainsliei*. To test some of these plants and a few others, two experiments were carried out at the alfalfa experimental plot. In the first of these a cage was placed over a number of different plants and moths introduced. The plants in the cage were examined daily for egg masses. Occasional observations were made to note injury by the larvae. This cage was six feet long, three feet wide and four feet high. It is shown in Plate III, Figure 1. The second experiment was to fasten on the leaves of certain plants, by means of paper clips, leaves of smartweed each bearing an egg mass. The plants were then examined at intervals for signs of infestation until all possibility of the survival of the larvae was past.

Some patches of smartweeds were not infested and it seemed possible that they might be resistant. To test this representatives were transplanted to the alfalfa plot. The results are not yet evident, the check plants from infested areas were not infested by this generation. This plot is shown in Plate III, Figure 2.

The work in the field consisted in the location of infested smartweed, the collection of infested material for the emergence cages and the dissection of the smartweed stems to determine the percentage of pupation and to supply borers for experimental work.

DESCRIPTION OF THE INSECT

The Egg

According to Ainslie and Cartwright (1921) the eggs are flat, thin and scale-like. They are laid in masses of four to sixteen, with each egg overlapping its predecessor, shingle fashion. The individual egg is broadly elliptic, sometimes almost circular in outline, about 1.213 mm. long and 0.886 mm. broad. The chorion is evenly reticulated with a close network of very fine but sharply elevated lines. It is a pale watery green color and is very nearly transparent when first laid.

The eggs collected at Manhattan did not have the distinct greenish coloration. Those laid on white waxed paper had a translucent white appearance when first laid. Measurements of eggs from the vicinity of Manhattan under natural conditions were practically the same as those of Ainslie and Cartwright, though the eggs laid by moths in confinement were somewhat smaller. Ten eggs laid in masses averaged 0.998 mm. long and 0.870 mm. broad. Five others laid singly the same day averaged 0.900 mm. long and 0.825 mm. broad.

The Larva

Ellis (1925) describes a larva as being cylindrical and about 18.5 mm. long. It is slate grey and plumbeous on the dorsum, a dirty white on the venter with the head usually a deep chestnut brown, sometimes black. When first hatched the head capsule is always a pale brown. The color deepens and the head capsule hardens within a short time.

Observations in Kansas generally agree with this description; however, it was noticed that in some cases there was considerable variation in size and color. Many of the mature larvae were smaller than Ellis' measurements. Some of those which were extraordinarily small were found to be parasitized by a Braconid, Macrocentrus n. sp. There is also a wide color difference ranging from dark plumbeous or olive grey to a light yellowish grey, sometimes even pinkish. On the darker specimens the spots on the dorsum are heavily shaded, on the lighter ones they are usually smaller and lightly shaded.

A larva of this insect is so much like one of P. nubilalis that it is often impossible to distinguish it without the use of a microscope. The general appearance of a larva is shown in Plate I, Figure 1. Figure 2 on the same plate shows the arrangement of Heinrich's setal group on the head of P. ainsliei. These are designated as A, the cranial puncture and B and C, the setae which with it forms the triangle A, B. C. In Figure 3 the corresponding group on P. nubilalis is indicated by A', B' and C' which in the case of this species is practically in a straight line, seta B' being sometimes slightly mesad to the other two points but never laterad as is always the case with P. ainsliei. The members of the genus Pyrausta have a single row of hooks on the prolegs. These hooks are of different sizes and the circle formed by them is open or broken on the laterad. This characteristic is illustrated in Plate I, Figure 4. The portion D is the part of the circle without hooks.

The Prepupa

Upon beginning the prepupal stage, the larva becomes inactive and spins a number of partial partitions across its burrow in front of itself. When the burrow is opened these partitions appear as a series of three or four sheets of silk stretched about half way across the burrow at an angle to the burrow and to each other. This gives the burrow the appearance of being divided into a series of triangular cells. At the rear end of the larva there is a thicker silk webbing without definite plan, which separates the larva from the frass with which the entrance is plugged. When the insect is well within the prepupal stage the body appears to shrink away from the larval skin posteriorly and becomes pointed and shorter. The head has the appearance of being drawn back into the thorax, the head and pronotum do not seem to have room in their normal position and are deflexed downward over the anterior end of the body. The legs appear to be useless in the later stages. The prepupa however has the ability to bend the body to some extent but appears to have difficulty in so doing.

The Pupa

Heinrich (1919) described the pupa as very similar to that of *P. nubilalis* though as a rule smaller and a trifle more slender. It is easily distinguishable by the front, which is developed into a knob-like projection, Plate I, Figure 5, E. The average length is 12-14 mm.

The Adult

The following is from Heinrich's original description (1919) of the adult *P. ainsliei:*

"Underside of palpi near base snow white; palpi otherwise yellow. Head and thorax yellow. Forewings pale yellowish with very slight dusting of darker cream yellow without the distinctly ferruginous powdering of *P. penitalis*; transverse antemedial and transverse postmedial lines as in *P. penitalis*, darker shading beyond transverse postmedial line faint; obicular marking as in *P. penitalis*; the dusky blotch beyond the cell reduced to a mere shading, scarcely distinguishable; terminal margin and cilia pale yellow; no sex scaling at base of inner margin of forewing of male. Hindwing as in *P. penitalis* except more distinctly marked than the pale forms of the latter species and lacking the ferruginous-ochreous margins of the small dark *P. penitalis*. Male genitalia as figured (Pl. 7, C); apex of tegumen rounded;

anellus with two long, slender, dorsally projecting arms (anellus lobes); harpe with two or three stout spines arising from inner margin of sacculus at fusion with base of clasper; face of clasper triangular. Female genitalia as figured (Pl. 8, E, F), with genital opening strongly chitinized anteriorly. Alar expanse, 20 to 27 mm."

DISTRIBUTION

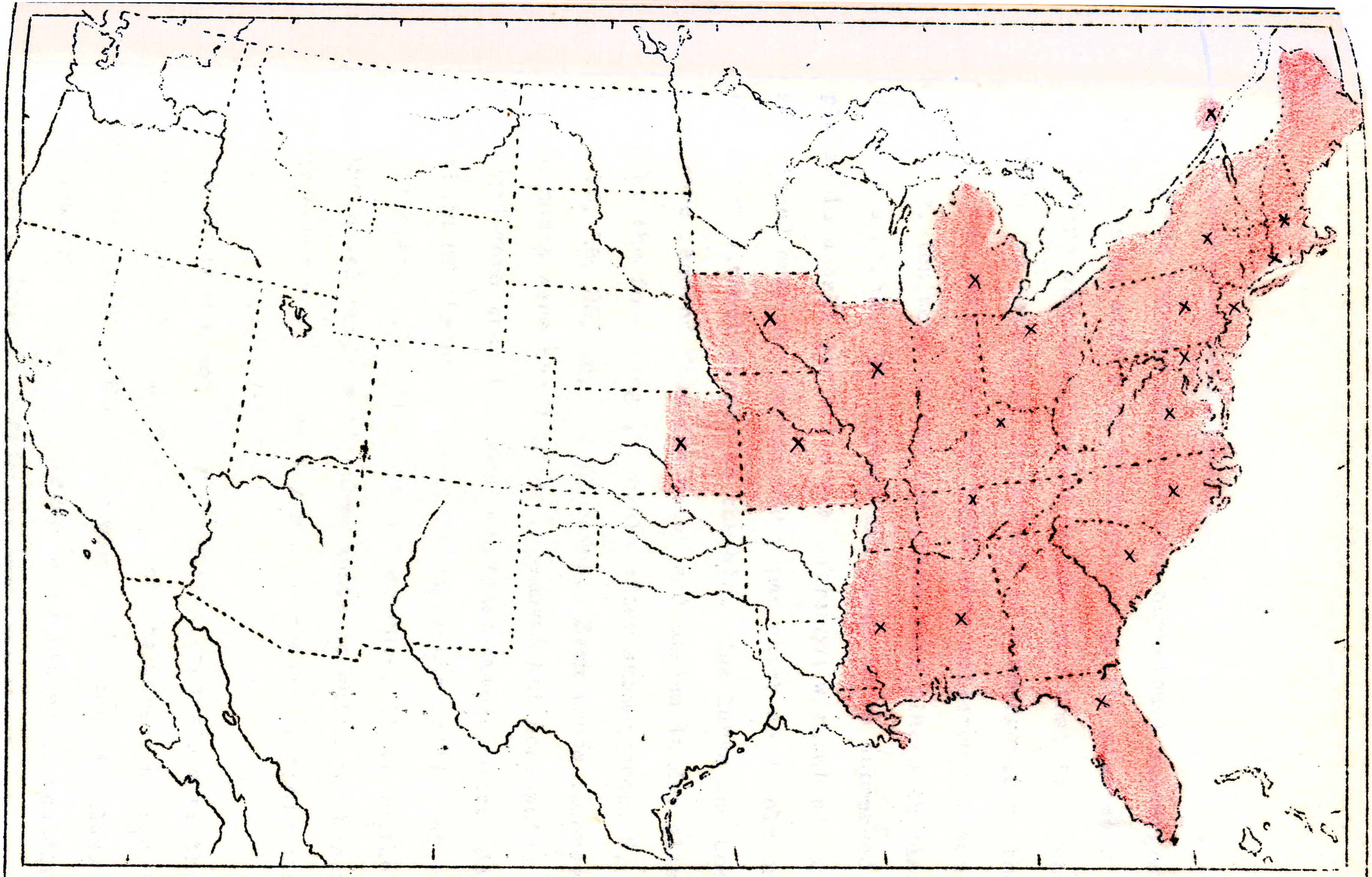
P. ainsliei is widely distributed over the eastern part of the United States. It extends north as far as Quebec and south along the Atlantic Coast to Mississippi and Louisiana. Its western limit has been reported as Kansas. It seems probable that it occurs practically everywhere in the United States east of the Rocky Mountains, where its favorite food plants grow.

Ellis (1925) lists the following as states in which P. ainsliei has been reported to occur in abundance. The new England States, New Jersey, New York, Pennsylvania, Maryland, Virginia, the Carolinas, Tennessee, Florida, Mississippi, Louisiana, Iowa, Michigan and Kansas.

Ressler, 1921, stated that P. ainsliei occurred throughout the Eastern and Middle Western States and that it had been found in Connecticut, Massachussets, New York, New Jersey, Tennessee, Illinois, Missouri, Kansas and Iowa.

Ainslie and Cartwright (1921) report that *Polygonum pennsylvanicum* L., the principal food plant of *P. ainsliei*, occurs throughout the eastern one-half of the United States and that the distribution of *P. ainsliei* probably coincides with it.

The insect was noted in abundance by Dr. E. G. Kelly of the Kansas State Agricultural College in 1926 in the vicinity of Manhattan, Kansas. The distribution in Kansas is still largely unknown. Dickinson County is as far west as the insect has been taken but as it was fairly abundant there it is probably distributed farther west. Surveys have been made in Dickinson, Geary, Riley and Pottawatomie Counties. Perennial smartweeds were examined at the Medora Sand Dunes but as infestations have not been found in any of the perennial smartweeds negative results in this place may not be significant. In Dickinson County and in places near Manhattan in Riley County it was noticed that smartweeds in certain localities were not infested although of varieties of smartweed usually found infested. To discover whether these were resistant varieties some of these plants were transplanted to Manhattan and grown in an experimental plot. The plants were evidently too greatly retarded to be infested as the check plants from infested areas have not yet become infested.



Distribution of Pyrausta ainsliei in Red

X Indicates Points where it has been Reported as Occurring in Abundance

It was thought possible that occasional submergence might have an effect on distribution as the smartweed patches are commonly located on low land that is often flooded. To determine the effect of submergence on the larvae, ten larvae and ten pupae were selected for submergence, ten more larvae and pupae were placed in glass jars as a check. The larvae and pupae to be submerged were placed in a bell jar which was submerged without air in it and placed over the larvae and pupae which were held under the water without access to the air. One larva and one pupa were removed from the water and placed in dry glass vials at the following intervals after submergence: 2, 3, 4, 5, 10, 15, 25, 35, and 60 hours. Even those immersed for 60 hours were not dead when removed but none which were submerged more than 10 hours continued development. As the protection of the stems would increase the ability of the borer to resist the effect of submergence, it is unlikely that the usual periods of submergence to which the borers are subjected would cause any marked change in their distribution.

The check was not under identical conditions as the test larvae and pupae. The test insects were confined in vials while those in the check were all placed in glass jelly jars, the pupae and larvae being placed in two different jars. Another difficulty was that the larvae used did not behave normally. They were from those taken from smartweed during the winter and kept in a metal can on folded paper. Only a small number of this group of larvae ever pupated. In the check there were nine of the pupae emerged and two of the larvae reached the adult stage. One larva and one pupa were killed during the experiment.

HOST PLANTS

Food Plants

Ainslie and Cartwright (1921) listed Polygonum pennsylvanicum L. as the principal food plant of P. ainsliei and were of the opinion that the insect is of about the same distribution. South of the Ohio river it is limited to P. pennsylvanicum as a food plant. In addition to P. pennsylvanicum it is known to occur in Polygonum lapathifolium L., Polygonum hydropiperoides (Michx), Polygonum persicaris L. and has been reared on leaves of Rumex crispus (curled dock) and Fagopyrum fagopyrum (buckwheat).

Ellis (1925) lists the following as food plants of P. ainsliei, the larvae having been found in all stages on them in eastern Massachusetts: Polygonum pennsylvanicum L., Polygonum lapathifolium L., Xanthium sp. (cocklebur), Ambrosia artemisiaefolia L. (ragweed), Eupatorium sp. (Joe-pye weed), Apocynum androsaemifolium L. (spreading dog bane), *Typha latifolia* L. (cat-tail), *Chenopodium album* L. (Lambs-quarter). However, he says that larvae seldom develop in plants other than *P. pennsylvanicum* and *P. lapathifolium*. Drake and Decker (1927) note that *P. ainsliei* never feeds on corn plants.

Tests carried out in Kansas were not extensive enough to be very significant. For one test a number of plants were grown in a 3'x 6' x 4' screen cage (Plate II, Figure 1). One male and five female moths were introduced and daily examinations of the plants were made to determine whether or not the moths would lay eggs on plants other than smartweed. The plants in the experiment and the number of egg masses deposited on them were as follows:

Fagopyrum fagopyrum (Silver hull buckwheat)	0
Ambrosia trifida (Giant ragweed)	0
Helianthus annuus (Sunflower)	0
Helianthus sp.	0
Ambrosia artemisiafolia (Ragweed)	0
Chenopodium album (Lambs-quarter)	0
Persecaria scandens (Wild false buckwheat)	0
Polygonum avicular (Dooryard knotweed)	0
Amaranthus retroflexus (Pigweed)	1
Amaranthus hybridus	0
Rumex sp.	0

Xanthium sp. (Cocklebur)	0
Zea mays (corn)	0
Abutilon theophrasti (velvet leaf)	0
Polygonum pennsylvanicum	8

The mass on Amaranthus did not develop and only three of the eight laid on smartweed are known to have hatched. There was no damage to any of the plants other than smartweed.

Some moths were confined with a buckwheat plant on June 6. An egg mass was laid on the underside of one of the leaves June 8. A spider was found feeding on the eggs on June 14. None of the eggs hatched.

Experiments trying to force larvae of *P. ainsliei* to feed on a series of plants were carried out at the field insectary. In these the larvae were confined in vials with leaves of the following plants:

Polygonum pennsylvanicum and *Polygonum lapathifolium* as a check.

Helianthus annuus

Chenopodium album

Rumex sp.

Ambrosia artemisiafolia

Polygonum avicular

Amaranthus retroflexus

Amaranthus hybridus

Xanthium sp.

Fagopyrum fagopyrum

The only two on which feeding occurred other than P. pennsylvanicum and P. lapathifolium were Fagopyrum fagopyrum (buckwheat) and Rumex sp. (dock) and the borers on these died before completing their development.

As there was some difficulty in getting the moths to oviposit, some of the eggs collected on smartweed were used to infest other plants. This was done by fastening with a paper clip the smartweed leaf bearing the egg mass to the plant selected. In one of these experiments a waterlily, Castalia sp., growing in the greenhouse was treated in this manner and examined daily. The eggs hatched and young larvae were observed feeding on the smartweed leaf for only one day. After that there was no indication of infestation although the daily examinations were continued for six days after hatching.

Similar tests were made at the alfalfa plot with the following plants:

Fagopyrum fagopyrum (Silver hull buckwheat)

Ambrosia trifida (Giant rag weed)

Helianthus annuus (Sunflower)

Helianthus sp. (Sunflower)

Chenopodium album (Lambs-quarter)

Rumex crispus (curled dock)

Rumex sp.

Zea mays (corn)

Abutilon Theophrasti (velvet leaf)

Polygonum pennsylvanicum (smartweed)

None of these plants became permanently infested and none showed any injury from the borers although young freshly hatched larvae were noted crawling on the leaves of the corn plant. The check in this group did not become infested.

Of four plants of *P. pennsylvanicum* growing among the alfalfa a short distance from this group and treated in the same manner only one half became infested.

On September 19, 1929, two third instar borers were confined in a glass jelly jar with a young corn plant. On September 28, both were dead and there were no signs of feeding on the corn.

The only plants found infested with this insect under natural conditions were *Polygonum pennsylvanicum, P. lapathifolium* and *P. persecaria.* Other species of Polygonum are present but have not been studied thoroughly so that there is a possibility that they may also be utilized as host plants.

Tests with other plants carried out at the field house would indicate the possibility of rearing specimens on some of the docks and on buckwheat. There is no evidence that the insect might utilize corn as a food plant. While buckwheat was used when nothing else was obtainable, it was not touched when P. pennsylvanicum was present.

Shelter Plants

Ainslie and Cartwright (1921) believe that the list of shelter plants will eventually include practically all of the pithy stemmed weeds and plants whose bark is not too dense to permit the entrance of the larvae. Some of the larvae overwinter in smartweed, but for some reason many of them leave these plants and seek protection in any plant that will give them dry quarters for the winter.

It is not likely that this habit of migrating to other plants in the fall has any economic significance. The burrows are not very extensive and are made at a time of year when the crops that might be affected by the insect are practically mature. The possible injury would probably be in increasing the breaking over of corn stalks. There was very little migration into corn stalks in the fall of 1929. Only one out of one hundred stalks in a favorable situation for infestation by migrating larvae was found to have become infested. Possibly this is due to the comparatively light infestation of borers at Manhattan.

INJURY TO HOST

The injury to the smartweed resulting from the activity of P. ainsliei is scarcely mentioned in the literature.

Ellis (1925) thought that infested stems showed a red color earlier than those not infested and suggested that infested stems tend to reach a condition of maturity earlier than is normally the case.

In regard to the injury to the smartweeds in Kansas by P. ainsliei, it was noticed that the young larvae, when they fed near the tip of a branch in a group, killed the branch from the point of infestation to the tip. This sort of injury is shown in Plate IV, Figure 1. However, the more mature larvae which feed alone in their burrows do comparatively little damage. Stems infested by the larger larvae usually grow quite vigorously and when they show perceptible injury it seems to be usually caused by secondary invaders to a greater extent than by the borer itself.

The injury from a very heavy infestation may sometimes result in the death of the plant. This however is unusual under the conditions observed in Kansas.

LIFE HISTORY AND HABITS

Generations

Ainslie and Cartwright (1921) in Tennessee and Ressler in Iowa (1921) report two generations. Poos in northern Ohio found one and one-half generations in a season. Ellis in Massachusetts reports only one generation and mentions unpublished data from Bartley and Hofer in New York where they report "apparently one generation", and also unpublished data from Allen, working in Mississippi, which states that there are three generations there. In Kansas, from observations made in the fall of 1929 and in the early part of the season in 1930, it seems evident that there is at least a partial second generation, as one would expect from the information given above. In the early part of September when the first observations were made on the insect at Manhattan, there were present in the stems of the smartweed empty pupal cases, full grown larvae and very young larvae in the first or second instar. These small larvae were quite numerous at this time, but the mortality seemed to be very high as relatively few succeeded in living to go into winter quarters. Only a few of the more advanced appear to have been mature enough to survive the cold weather in the fall. Many of the full grown larvae of the summer generation did not pupate. This group seems to have made up the bulk of the overwintering larvae. There has also been one adult emerged in the laboratory before July 18, which came from an egg mass collected June 3 in the field. This would leave time enough for a second generation from these early emerging moths.

Overwintering

As mentioned under shelter plants, the smartweed borer has the habit of migrating to other plants in the fall. Ellis (1925) says that the number in corn and other shelter plants increased until October 5.

Ressler (1921) observed that the larvae of the second generation fed actively until cool weather when they plugged their entry holes with excrement in preparation for hibernation.

Drake and Decker (1927) report that the second generation larvae complete their development by fall, then hibernate in their food or shelter plants. Poos (1927) noted that migration occurred in the overwintering generation during both fall and spring.

According to Ainslie and Cartwright (1921) the larvae of the overwintering generation reach their full growth about the last of August. Many of them then migrate elsewhere for shelter, some entering cornstalks and other shelter plants. Early in October the larvae close the entrance with a drum-tight sheet of silk camouflaged by bits of chewed bark. The larvae are not torpid during the winter, but there is no evidence of feeding after leaving the food plants in the fall. The larvae do not swallow the material in making their burrows into their shelter plants in the fall, but discharge it in sawdust-like particles from the mouth.

Observations in Kansas by the writer show that the larvae are active when disturbed at any time during the winter except when the temperature is too low for movement.

Spring Pupation

Ainslie and Cartwright (1921) in Tennessee found adults of the smartweed borer emerging from May 26 to October 30. There were two distinct periods of emergence, June 20 to July 5, and August 18 to August 30. The moths which emerged in June oviposited at once.

Ellis (1925) in his investigations in eastern Massachusetts noted that the first pupa was found in the first week in June and that the pupation period was continued until July 10 when the last pupa was found. In confinement he found the pupal stage to be 15.3 days. He also noted that the larvae cut a hole to the exterior before pupating and cover the entrance with silk.

Drake and Decker (1927) observed that overwintering larvae pupate about the middle of May in their winter quarters, which may be in various shelter plants, cornstalks, gartick, ragweed, etc., as well as in smartweed which is the insects' preferred food plant. Ressler (1921) says that at Ames, Iowa, the larvae become active for a short time in the spring and pupate in late May and early June. The pupal period requires 10 to 14 days during the latter part of May and the first one-half of June.

Ainslie and Cartwright (1921) say that Crittenden mentions the pupal stage of two moths reared from corn stalks from Kansas, as being 11 days for one and 17 days for the other.

The beginning of pupation was not observed in Kansas and only five counts of the percentage of pupation were made during the pupation period. To arrive at the probable dates of pupation it was therefore necessary to calculate the dates from the dates of emergence in the emergence cages by subtracting the length of the pupal stage of five reared individuals. This placed the beginning of pupation about April 26, and the end about May 19, a period of 23 days.

The following table shows the actual percentage of pupation in comparison with the percentage of pupation as calculated by the above method. It will be noticed that the correlation is quite close except on May 9 and May 25, and on these days the number of specimens examined was quite small.

Number of specimens examined	Date	Per cent pupation by actual count	Per cent pupation calculated from emergence
63	May 3	27.0	39.7
45	May 5	53.4	51.5
16	May 9	93.8	81.0
47	May 11	74.5	88.3
12	May 25	75.0	100

The Adult Habits

According to Ainslie and Cartwright (1921) the moths frequent low, moist situations where Polygonum grows normally. During the day they rest under the leaves and when disturbed make low flights about their haunts. The authors state that in Missouri emergence began on May 29 and continued until June 6. Other specimens from the same place were labelled October 9. In a series of larvae reared from eggs which hatched August 16 a number of moths emerged October 13 to October 15. This was thought to be abnormal as none were found under natural conditions at that time. They also mention a report from Hart at Urbana, Illinois, which states that the moths came to lights from May 19 to August 6.

TABLE I. REARING CHART

Larvae: No.	May 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1 :	L	L	L	L	O	O	O	R	L	q	q	q	q	q	?	L	L	L	L	L	L	L	L	L	?	D				
2 :	L	L	L	L	L	L	L	P	P	P	P	P	P	P	P	P	P	P	P	P	P	p	P	P	p	p	p	P	P	P
3 :	L	L	L	L	L	q	L	p	P	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
4 :	L	L	L	L	L	L	L	L	L	p	p	p	p	p	p	p	p	p	p	p	?	D								
5 :	L	q	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
6 :	L	L	L	L	L	O	O	R	L	L	L	L	L	L	L	L	L	L	L	L	p	p	p	p	p	p	p	p	p	p
7 :	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	D				
8 :	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	p	p	p	p	p	p	p	p	D		
9 :	L	L	L	L	L	L	L	L	L	?	?	D																		
10 :	L	L	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E
11 :	L	L	L	p	p	?	p	p	P	p	p	p	p	p	p	p	p	p	D											
12 :	L	L	?	L	L	L	L	L	L	L	L	L	q	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
13 :	L	L	L	L	L	L	L	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
14 :	L	L	L	L	L	L	L	L	L	L	L	?	L	L	L	L	L	L	L	L	L	L	L	L	L	L	P	P	P	P
15 :	L	L	L	L	L	L	L	q	?	P	P	?	?	?	?	?	?	?	D											
16 :	L	L	L	L	L	L	L	L	D	L	D																			
17 :	L	L	L	L	L	L	L	L	L	L	L	L	q	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
18 :	L	L	L	L	L	L	p	P	P	P	P	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
19 :	L	q	P	P	P	P	P	P	P	P	P	P	P	P	P	p	P	P	P	P	P	P	P	P	P	P	P	P	P	P
20 :	L	L	L	L	L	L	P	P	P	P	P	P	P	P	P	P	P	P	P	?	?	?	?	D						
21 :	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
22 :	L	L	L	L	L	L	L	R	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	?	D	?	p	p
23 :	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	q	L	L
24 :	L	L	L	L	O	O	O	R	L	L	L	L	L	L	L	L	L	L	L	P	P	P	P	P	P	P	P	P	P	P
25 :	L	L	L	L	L	L	L	p	p	p	p	p	P	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p

Larvae: No.	June 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	July 1
1 :	p	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	D					
2 :	p	p	p	p	E																										
3 :	P	E																													
4 :	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	D						
5 :																															
6 :																															
7 :																															
8 :																															
9 :																															
10 :																															
11 :																															
12 :	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
13 :	p	p	p	p	p	p	E																								
14 :	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E												
15 :																															
16 :																															
17 :	P	P	P	P	P	P	P	P	P	P	P	E																			
18 :	p	p	p	p	E																										
19 :	P	E																													
20 :																															
21 :	P	P	P	P	P	P	P	P	P	P	?	?	D																		
22 :	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	E										
23 :	P	P	?	P	P	P	P	P	P	P	P	P	P	P	P	?	P	P	P	P	P	P	P	P	P	D					
24 :	P	P	P	P	P	P	P	P	P	P	P	P	P	E																	
25 :	p	p	p	p	E																										

L - Larva
q - Prepupa
P - Pupa
p - Parasite
? - Uncertain
E - Emerged
D - Dead
R - Replaced
O - Lost

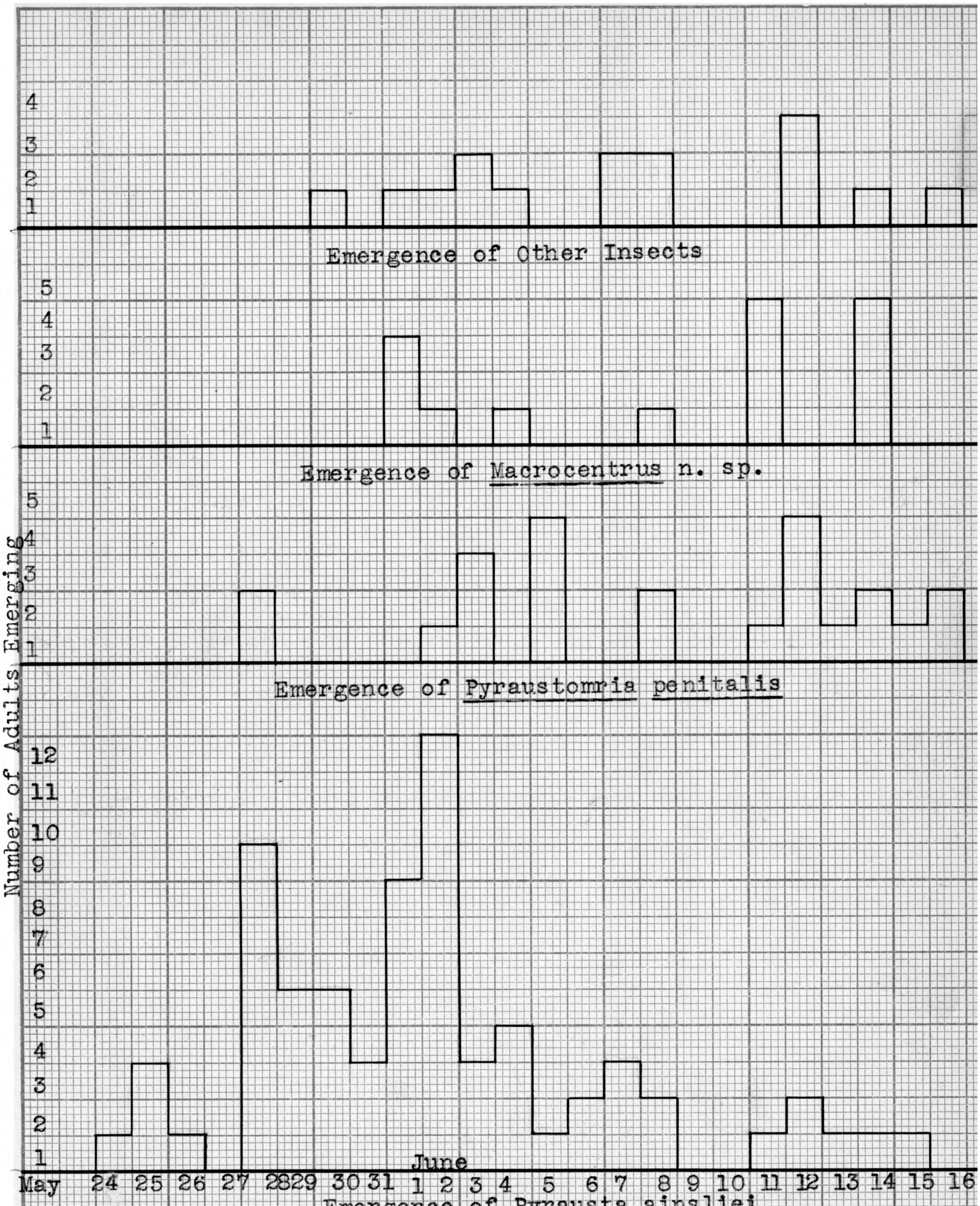


Chart II. The Adults from the Emergence Cages

Drake and Decker (1927) report that the first brood of moths emerges about the end of May and the second brood about August 1.

Ressler (1921) found that the pupal stage of the over-wintering generation extended through the latter part of May and the first half of June, and that the moths after a short flight deposited their eggs on the underside of smartweed leaves in masses containing from 11 to 50. The moths of the summer generation which emerged August 10 were observed in flight until September 4, and deposited their eggs during the latter part of August and the first half of September.

The location of 53 egg masses on the leaves of 21 plants is given below

Location	Below Center	Near Center	Above Center	Total	Percentage
Along midrib	15	17	9	41	77.4
Just off midrib	3	4	0	7	13.2
On disc	3	0	1	4	7.5
Near margin	1	0	0	1	1.9
Total	22	21	10	53	100
Percentage	41.5	39.6	18.9	100	

Some of the types of the localities preferred by this species are shown on Plates V to VII. The localities found most heavily infested were those where shade was available.

Emergence in the cages at Manhattan began May 24 and ended June 15, the peak of emergence being about June 1. The curve of emergence is shown in Chart II.

Some difficulties developed in the handling of the adults as they were short lived and seldom deposited eggs. Many of the eggs that were secured failed to hatch. Ellis (1925) states that the number of eggs in each egg mass varies from 2 to 35. Ressler (1921) reports that in Iowa the egg masses consisted of from eleven to fifty eggs.

Oviposition habits of P. ainsliei were observed by the examination of smartweed plants in this locality with the following results:

Plants examined	210
Plants infested	33
Average number of egg masses on the infested plants	1.727
Average number of eggs on the total number of plants	3.03
Average number of eggs on each of the 33 infested plants	19
Maximum number of egg masses on one plant	5
Maximum number of eggs in an egg mass	21
Minimum number of eggs in an egg mass	6
Average number of eggs in an egg mass	11 1/6

Development of the Egg

In their description of the egg Ainslie and Cartwright (1921) describe it as pale watery green in color and nearly transparent when first laid. A short time afterward the egg becomes somewhat opaque and the embryo begins to take shape as a darker and more transparent object in the center. There is then no marked change in the general appearance of the egg until just before hatching, when the eyes and mandibles darken. The color spreads from these parts over the entire head. The head is then brown and plainly visible through the chorion. The body of the larva at this time lies around the periphery and is almost visible. The period of incubation is six days in June and July, and five days in late August.

The period of incubation in Kansas varied from 5 to 14 days. An egg mass laid in the large open mesh wire screen cage on June 18 hatched June 23. Another mass laid May 29 on waxed paper in confinement and kept at the field insectary under the north work bench in a gallon bucket partly filled with moist earth loosely covered with a tin lid and enclosed in a metal pill box hatched June 12, a period of 14 days.

The eggs are translucent and almost colorless when first laid. Soon a white opaque ring appears around the outside of the egg leaving a more transparent spot in the center. In the case of eggs hatching in five days the head capsules are plainly visible in the central portion of the egg one day before hatching. It is possible to watch the movements of the larvae through the chorion. They are easily disturbed and react to a touch on the chorion by opening and closing their mandibles sometimes two or three times in succession. The heads of the larvae within the eggs face away from the direction of the laying moth, toward the upper overlapping side of the egg. Those on the sides sometimes face out away from the mass. It is practically impossible to make out the outline of the larval body. By opening an egg with a needle the larva was found to be coiled.

Larval Habits and Development

Ainslie and Cartwright write that the young larvae enter the smartweed stem at once near the tip of a branch, choosing the base of the leaf petiole for their point of attack. They are gregarious during the first and second instars, all from a single egg mass usually entering at the same place. This may be several inches from the site of the egg mass.

Ellis (1925) reports that in eastern Massachusetts the young larvae usually feed on the under surface of the leaves for a time. Immediately after escaping from the eggs the heads of the larvae are light brown in color. The head capsules become dark colored and harden during the period in which they are feeding on the leaves. The larvae feed gregariously for a short time but within a day separate and enter the nearby stems. As soon as the tips become wilted they migrate to some other part of the plant, often migrating several times.

Poos (1927), working in northern Ohio, writes that young larvae feed gregariously during the first and second instars and that as many as 18 second instar larvae have been found in a single internode of smartweed stem. When older larvae enter a smartweed plant it is always on the lower sides of leaning stems and at the nodes. Ressler (1921) observed that the newly hatched larvae feed on the midribs of the leaves almost immediately, but noted also that they soon migrate to the stem.

Observations at Manhattan on the hatching and behavior of the larvae agree in general with those of Ainslie and Cartwright. The eggs are usually laid on a leaf attached near the top of the plant; 83 per cent of those found in nature were distributed between two and five inches from the tip of the plant. The eggs hatch in from 5 to 14 days depending on the weather. The larvae seem to enter the stem immediately without preliminary feeding on the leaves. It was noticed that the young larvae often enter the stem at the point just above the node where the ocrea was torn by the growing stem.

Concerning the food habits of larvae past the second instar, Ainslie and Cartwright (1921) state that the tips of the infested stems soon wilt indicating infestation, and that as soon as the food supply here is exhausted, the larvae move out and scatter, each reentering at another point by making its own burrow. The larvae usually enter a stem at the node just below the ocrea, cut into the cavity inside the stem and eat out the more succulent tissue leaving only the tough outer bark. They attack the larger stems first and migrate whenever the food supply begins to fail. At this time they will often be found in branches so small they can hardly crowd into them. The borers keep the burrows clean, all excrement being disposed of through the entrance which is left open.

Ellis (1925) agrees with Ainslie and Cartwright about this part of the life history, and observes in addition that the larvae rarely mine through the nodes of the stem but restrict their feeding to the internodes.

Poos (1927) notes that the larvae of the summer generation do not migrate to pupate in other hosts. He also gives the measurements of the head capsules in the different instars and the length of time in each of the larval instars. He used five specimens of P. ainsliei for the measurements in the first four instars and a different set of six full grown specimens for the fifth. The data on the length of time in the instars was taken over a period of two years, 1924 and 1925. The following gives his results in tabular form:

Instar	Number of days in instar	Measurement of head capsule
1	4.1	.51 mm.
2	4.1	.73 mm.
3	4.1	1.02 mm.
4	6.5	1.51 mm.
5	9.0	2.32 mm.

Observations and measurements of larvae at Manhattan show the instars slightly shorter here than those recorded by Poos (1927) and also the measurements of the head capsules were somewhat less. The following table shows the data in tabular form. The study was not carried on long enough to include the fifth instar.

Instar	Number of specimens measured		Number of days in instar	Measurement of head capsule	Measurement of body length	
					Beginning of instar	End of instar
		Aver.	2.4	.33 mm.	1.65 mm.	2.46 mm
1	5	Min.	2	.33	1.65	2.10
		Max.	3	.33	1.65	2.85
		Aver.	3.4	.48	2.88	4.22
2	5	Min.	2	.45	2.25	3.60
		Max.	6	.525	3.75	4.80
		Aver.	3.5	.720	4.53	6.81
3	4	Min.	3	.660	3.70	6.00
		Max.	4	.750	6.00	7.20
		Aver	6.5	.976	7.0	8.5
4	2	Min.	6	.900	6.0	8.0
		Max.	7	1.05	7.0	9.0

Summer Pupation

According to Ainslie and Cartwright (1921) the larvae reach their full growth early in August and pupate immediately in their burrows in the smartweed stems. The moths emerge later in August. Ellis (1925) gives the duration of the pupal stage as averaging 15.3 days. Poos (1927) working in northern Ohio found that the pupation decreases about the middle of August and that at that time about 50 per cent of the summer generation has pupated. He also found that the larvae of this generation did not migrate to pupate but pupated in their burrows in the smartweed stems. Drake and Decker (1927) report that mature larvae of this generation pupate about the middle of July and the second brood moths appear about August 1. Ressler (1921) found that the length of the pupal stage varied from 9 to 14 days and averaged 12 days. He observed the pupae of this generation about the end of July and the period of pupation continued until August 23, when the last one was found.

The work in Kansas has not been carried on long enough to include the pupation of this generation.

Fall Generation

Ainslie and Cartwright (1921) state that the overwintering generation attacks the smartweed plant in the same way as the summer generation. The larvae feed until fully grown about the last of August, then many of them seek shelter in other plants.

Ressler (1921) says that the eggs of summer brood moths were deposited in the latter part of August and the first half of September. The first of the overwintering larvae hatched about September 8, and the young larvae were in evidence until the end of the month.

Ellis (1925) reports that on September 12 the first larvae were found in corn and the number increased in corn and other shelter plants until October 5.

In Kansas the overwintering larvae seemed to be in part those which had failed to pupate and emerge with the summer brood and those larvae of the fall generation which were sufficiently mature to survive the cold weather.

BIOLOGICAL FACTORS

Parasites

The species of P. ainsliei is heavily parasitized. Ressler (1921) writes that fully 50 per cent of the larvae taken in Iowa were parasitized by a Braconid of the genus Aleirodes. There were four to eight of these parasites in each of the parasitized larvae.

Ainslie and Cartwright (1922) state that Panzeria penitalis is not a parasite of Pyrausta penitalis but is instead a parasite of Pyrausta ainsliei.

Townsend in 1893 reported the rearing of two parasites from Botis penitatis, Exorista hirsuta O.S. and Phorocera comstocki Will.

Ellis (1925) gives the following list from Dettmar W. Jones of the Arlington laboratory: Microbracon n. sp., Panzeria penitalis Coq., Itoplectis conquisitor Say., Bassus agilis Cress, Glypta rufiscutellaris Cress, Ephialtes aequalis Prov., Exorista nigripalpis Town., Rogas rileyi Cress, Microgaster epagoges Gahan.

The following parasites have been reared in Kansas from P. ainsliei:

Pyraustomyia penitalis (Coq.)
Microbracon caulicola (Gahan)
Macrocentrus n. sp.
Trichogramma minuta (Riley)

Others which emerged from smartweed but are not known for certain to be parasites of P. ainsliei are:

Bassus agilis (Cress)
Calliephialtes notandus (Cress)
Chelonus sp.
Microgaster zonaria (Say)
Apanteles sp.

Ainslie and Cartwright (1921) believe that the variation in abundance of P. ainsliei is due to its parasites. The most important one (Panzeria) Pyraustomyia penitalis Coq. killed over 40 per cent of the larvae taken for rearing in the field at Knoxville. They noted also that Crittenden found over 50 per cent of the larvae taken in raspberry stems were killed by the same parasite. Ainslie states that the parasitized larvae grow normally until the final instar when the host becomes sickly and surrounds itself with a loose webbing. The parasite maggot then emerges and pupates beside or partly within the remains of the host. In overwintering larvae the parasite remains in the body of the host until spring, emerging about the middle of May and pupating in the normal manner. The pupal period varies from 13-16 days. Flies reared by Ainslie and Cartwright emerged during two periods, May 30 to June 10, and from August 18 to September 12. This coincides closely with the normal dates for the emergence of the moths and it is thought that the fly attacks the host in its early instars.

In addition to the Tachinid they found what appeared to be three species of Hymenopterous parasites. One was determined as Microbracon sp., the others had not been determined at that time.

They also state that Coquillett recorded three other tachinids, two of them quoted from Townsend, as being reared from Penitalis; *Exorista vulgaris* Fall, *Hypostena variabilis* Coq. and *Phorocera comstocki* Will., but the information is not sufficient to tell whether they are parasites of *P. ainsliei* or of *P. penitalis.*

Pyraustomyia penitalis (Coq.) has been reared from the larvae of *P. ainsliei* at Manhattan and seems to be the most important one in this section.

H. W. Allen (1922) described the oviposition habit of the species. He observed that females approach an infested node and quickly fasten a minute maggot enclosed in a very thin sheath of chorion upon the cane near the entrance hole of the borer. The maggot emerged at once from the sheath and began searching for the entrance of the tunnel of the borer. Some found and entered the tunnel within a few seconds, others failed to find it after 20 minutes of searching. The activity of the maggots after entering the burrow was not observed. They reached and entered the body of the larva however as shown by the presence of the maggots in the blood of the larvae shortly afterward. The fly takes no interest in the exposed larvae.

Oviposition was not observed in Kansas although the flies did seem interested in a leaf on which the larvae of the smartweed borer had been feeding. Microscopic examination of the leaf was not made. The flies paid no attention to exposed larvae introduced into their cage.

Four adults emerged from 25 individually caged larvae of P. ainsliei. Three of these appeared as puparia on May 9, two emerged on June 5, and the third on June 7. The fourth evidently was abnormal as it was somewhat smaller in size, and appeared as a puparia May 30, emerging June 21. The pupation period for the first three were as follows: 28 days in the case of the first two; 30 days for the third and 23 days in the fourth case. This data is from Chart I. The period of emergence in the emergence cages was from May 28 to June 16, the peak being about one week later than that of its host. From material from which 68 P. ainsliei emerged, 23 of these Tachinids appeared. This data is shown on Chart II.

Microbracon caulicola (Gahan), the first parasite to appear in the spring at Manhattan is a small reddish yellow Braconid. It passed the winter in a silken cocoon outside the dead host body in the smartweed stems. Most of the emergence occurred before April 23 in vials though a few delayed until June 28. Up to 12 of these Braconids have emerged from one host larva, the average number emerging being 3.88 per larva. One generation of this parasite was reared in the laboratory. A female was placed in a vial with some of the second and third instar borers June 12.

Larvae of the parasite appeared June 26, spun silken cocoons in the vial and emerged as adults July 5. The female was still alive when the larvae appeared, 14 days after she had been introduced into the vial. Nine days later three male adults appeared which completed the emergence. This would seem to indicate that the female had not been fertilized. Attempts at mating were noted several times in the cages but whether or not mating actually occurred is not known.

Of 67 larvae of P. ainsliei cut from smartweed May 2 and May 3, ten had been killed by these Braconids, which is 14.93 per cent of the larvae. These parasites were taken in the field by sweeping smartweeds on May 2. At this time eggs of P. ainsliei were found on the smartweed. Some of the eggs collected June 2 hatched June 3. A test to determine the effect of different kinds of treatment on the length of life of the adult M. caulicola was as follows: six females all of which emerged from the same larva were divided into three pairs and each pair placed in a vial. The first pair was given no food and only sufficient water to keep the vial moist. The second pair was placed in a vial with a full grown larva of P. ainsliei and given water the same as the first. The third pair was given dilute honey in addition to the water. They lived as follows:

Vial Number 1, lived 9 and 11 days respectively

Vial Number 2, lived 8 and 9 days respectively

Vial Number 3, lived 26 and 27 days respectively

There was one other parasite reared from the 25 individual cages, Macrocentrus n. sp., a rather large Braconid, reddish yellow in color and quite slender. It appeared as a pupa May 8 and emerged June 5. In the emergence cages 14 emerged from the material from which 68 P. ainsliei emerged. The emergence period was from June 1 to June 14 about one week later than the peak of emergence of its host. The size of the host larvae is much smaller in the case of three larvae on which a record was kept, than in the case of normal larvae or of larvae parasitized by any of the other parasites. No difference in size was noted in the case of larvae parasitized by any of the other parasites.

Four specimens of Trichogramma minuta (Riley) were reared from an egg mass of Pyrausta ainsliei collected at Ashland Bottoms on June 4. Adults emerged from the eggs June 10 and parasitized eggs of the forage looper, Caenurgia erechtea, and of the garden web-worm, Loxostege simialis (Guen). Adults appeared from these June 21. The first four adults emerged 6 days from the collection date. The second generation emerged 10 days after the introduction of the eggs and 11 days after the emergence of the first generation.

Brassus agilis (Cress) was reported as a parasite of *P. ainsliei* in Dettmar W. Jones' list. It has also been found parasitizing the larvae of another Lepidoptera of the family Gelechiidae, *Aristotelia absconditella,* which is a borer in smartweed in Kansas. It has not yet been found parasitizing the larvae of *P. ainsliei,* in the work carried out at Manhattan.

Drake and Decker (1927) state that an introduced parasite *Habrobracon brevicornis* Wesm. was reared in large numbers on smartweed borers at Ames during the summer of 1926.

Poos (1927) writes that there are native parasites attacking both *P. penitalis* and *P. ainsliei*, but that they seldom attack *P. nubilalis.*

Predators

Ainslie and Cartwright (1921) noted that larvae of *Callida decora* Fab. were predaceous on the larvae of the smartweed borer. *Chauliognathus pennsylvanicus* DeGeer was also found in the burrows and was thought to account for some of the larvae of *P. ainsliei.*

Chittenden (1918) says that blackbirds eat the larvae before they go into shelter. In Kansas there is often evidence of what would appear to be depredations by birds.

The stems of infested plants are often split as though by a sharp beak in search of the larvae.

In the emergence cages spiders killed some of the adults. Their webs were built across the corners of the cages and whenever they appeared were destroyed. A spider also destroyed the egg mass on buckwheat. It escaped before it could be captured.

Fungous Disease

There seems to be no mention of fungous disease in the literature in connection with this insect. In Kansas there are, in many plants, dead larvae covered with a fungous growth. It is not yet known whether this fungus attacks the living larvae or whether it only grows saprophytically on the dead larvae.

Larvae kept in glass vials sometimes seemed to be attacked by a fungus but this may have been caused by injury or by improper food. These larvae were subjected to a considerable amount of handling and the smartweed leaves that were fed to them were kept on the stem in the laboratory in a beaker of water and may not have been in good condition at times.

SUMMARY

P. ainsliei is morphologically like the pest of corn, *P. nubilalis*. The only reliable method known of distinguishing the two species in the larval stage is by means of Heinrich's setal group on the head.

P. ainsliei is distributed over about the eastern half of the United States, in practically any section where smartweeds of its preferred species occur.

It is practically limited to smartweeds as food plants but may migrate to various pithy-stemmed plants for shelter in the fall and spring. It has been taken in three species of smartweed in Kansas. When provided with no other food borers fed on leaves of buckwheat and dock.

There are three generations in the southern part of the United States, two in the middle section and one or one and one-half in the northern part.

It is heavily parasitized. Forty and fifty per cent has been reported from Tennessee and Illinois, respectively. In Kansas the percentage of parasitism as based on dissection of smartweed and on the 25 rearing cages is 54.93 per cent. The most important parasite, *Pyraustomyia penitalis* emerged from 16 per cent of the 25 larvae in the rearing cages.

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EXPLANATION OF PLATES

PLATE I.

Fig. 1. Lateral view of the larva of Pyrausta ainsliei.

Fig. 2. Cephalic view of the head of the larva of P. ainsliei.

A, Cranial puncture with which setae B and C form a triangle.

Fig. 3. Cephalic view of the head of the larva of Pyrausta nubilalis.

A', B', and C', the corresponding points which in this species are practically in a straight line.

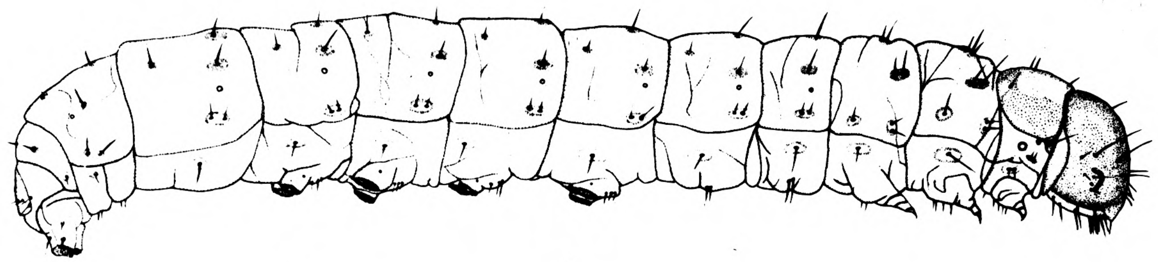
Fig. 4. Ventro-lateral view of the right anterior proleg.

D, the lateral break in the circle of hooks on the proleg.

Fig. 5. The lateral view of the pupa of P. ainsliei.

E, the tubercle on the front which distinguishes this species from the other species of Pyrausta in the United States.

PLATE I.



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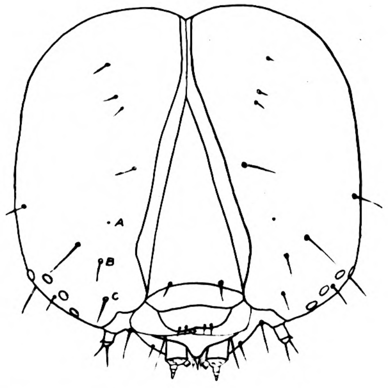

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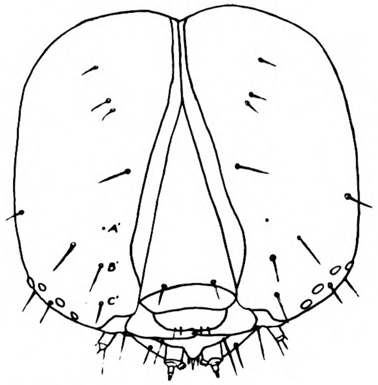

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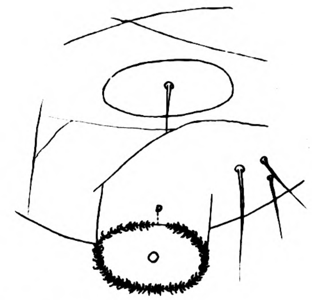

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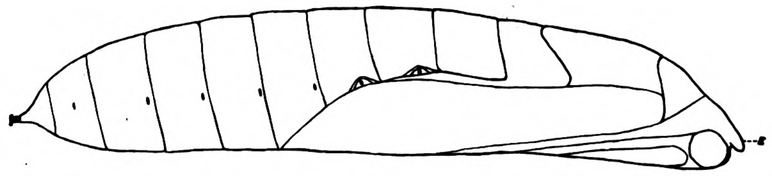

5.

PLATE II.

Fig. 1. Emergence cages at the field insectary.

Fig. 2. The lamp chimney rearing cages at the field insectary.

PLATE II.

Figure 1

Figure 2.

PLATE III.

Fig. 1. The host preference cage at the alfalfa plot.

Fig. 2. Variety preference plot at the alfalfa plot.

PLATE III.

Figure 1.

Figure 2.

PLATE IV.

Fig. 1. Injury by small borers to the tip of the smartweed plant.

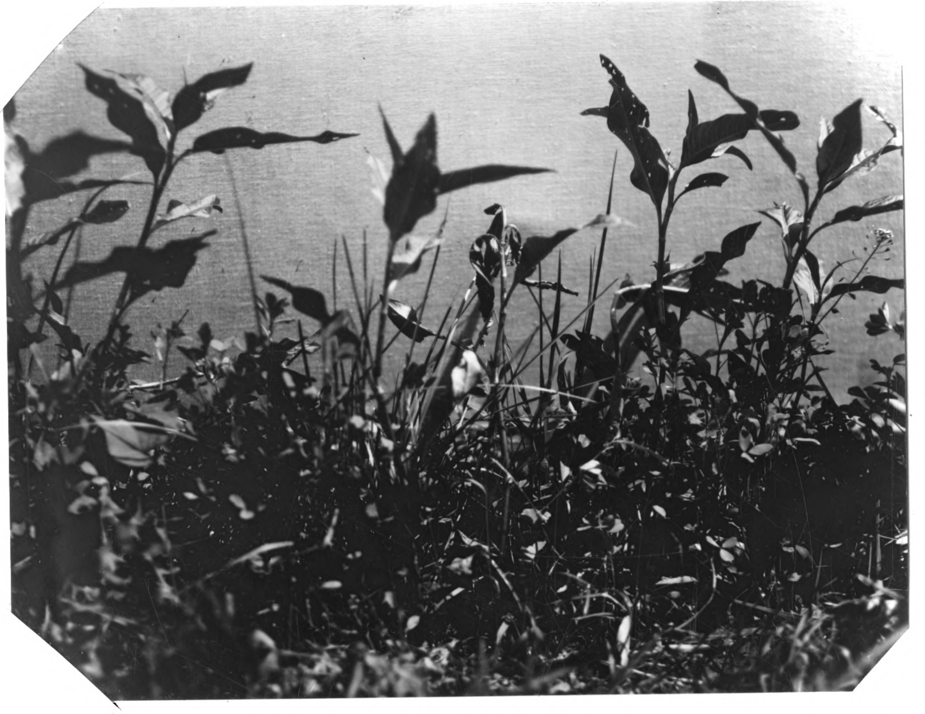

Figure 1.

PLATE V

Figure 1.

Figure 2.

PLATE V.

Figs. 1 and 2. Views showing a situation infested with smartweed at the Agronomy Farm.

PLATE VI.

Fig. 1. Infested smartweed at Ashland Bottoms.

Figure 1.

PLATE VII.

Fig. 1. Infested smartweed in the flood plain of the Kaw River south of the Kaw Dunes.

Figure 1.