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BIOLOGY OF THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HÜBN.) AND TWO CLOSELY RELATED SPECIES IN NORTHERN OHIO.

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INTRODUCTION.

The European corn borer, *Pyrausta nubilalis* Hübner, has been referred to as the most important plant pest that has yet been introduced into the United States. It is doubtless one of the greatest potential insect enemies of our corn crop, ranked as the most important crop in the country. Two very closely related American species, the smartweed borer, *Pyrausta ainsliei* Heinrich, and the lotus borer, *Pyrausta penitalis* Grote, although widely distributed over the United States, having been reported from many States east of the Rocky Mountains, have not been found doing commerical damage. Since Heinrich (*8*)† in 1919 published his paper which gives the description of *P. ainsliei* and the distinguishing characteristics of the three very similar species, Ainslie and Cartwright (*1*), Ressler (*9*), Flint and Malloch (*7*), and Ellis (*6*) have contributed much to our knowledge of the biology of *P. ainsliei* and *P. penitalis* from the respective localities in which their observations were made. Previous to the advent of *P. nubilalis* into the United States comparatively little attention had been given to these closely related species which are also often found boring in corn to which the larvæ migrate from other hosts. Earlier

*Resigned March 15, 1926.

†Reference is made by number to "Literature cited," p. 86. For complete bibliography of *Pyrausta nubilalis* to January 1, 1925, see Misc. Cir. 46, U. S. Dept. Agric., by J. S. Wade.

papers by Chittenden (*4*), and others which he refers to, very probably confused *P. ainsliei* with *P. penitalis* when the observations were made upon these insects while infesting the Polygonum group of plants.

The observations on the life history of the three species of *Pyrausta* which are treated in this paper were made at the European Corn Borer Laboratory of the United States Department of Agriculture, Bureau of Entomology, at Sandusky, Ohio, during the four seasons 1922-1925 whereas the observations on the seasonal history were made throughout Northern Ohio, during the same seasons.* No attempt has been made to give a balanced treatment of the three species and the space allotment is not always proportionate to the importance or general interest of the several phases of the biology treated herewith; some phases were less variable and could be summed up more concisely than others, and some were less thoroughly studied.

Distribution and History of Infestation.

Pyrausta nubilalis was first found in Ohio by Mr. P. A. Howell of the U. S. Bureau of Entomology, on Middle Bass Island in Lake Erie, August 21, 1921. The powers of flight of this insect and the nature of the distribution† (namely, a

*Acknowledgment is made to Mr. D. J. Caffrey, Arlington, Massachusetts, in charge of European Corn Borer Investigational work for the U. S. Department of Agriculture, for an annual plan of work on *P. nubilalis* which was used as a guide in order that the more important investigational work on *P. nubilalis* by the U. S. Bureau of Entomology could be coordinated. In order that all of this work on *P. nubilalis* should be comparable, the methods and cages used at Sandusky were largely the same as those used at the Arlington Laboratory for similar work. I am much indebted to Prof. George A. Dean and Mr. W. R. Walton for their encouragement and suggestions. Special acknowledgment is due Dr. Herbert Osborn of Ohio State University, who had general direction of this work as a research problem for the University and whose interest and helpful criticisms were a source of constant inspiration. Determinations of plants were made by Dr. E. N. Transeau and Prof. J. H. Schaffner, Ohio State University, Columbus, Ohio, to whom thanks are due. Thanks are also due Mr. D. W. Jones, Mr. C. F. W. Muesebeck and Mr. R. T. Webber, of the U. S. Bureau of Entomology, for determining all parasites reared from field collections.

It is a pleasure to acknowledge much valuable assistance from Mr. L. H. Patch, who has recorded many observations and tabulated much data for the writer during the three seasons, 1923–1925, also to the following student assistants at the European Corn Borer Laboratory: Mr. H. S. Peters, during 1924 and 1925; Mr. O. L. Cartwright, during 1924; Mr. L. A. Somers and Mr. N. H. Odell, during 1925. It would be unfair to my wife, Edna Ireland Poos, not to express my appreciation here of her interest in the work and the help which she has given with the manuscript.

†Scouting work to determine distribution in Ohio and Michigan is under the direction of Mr. L. H. Worthley and Mr. E. G. Brewer, of the Bureau of Entomology, U. S. Department of Agriculture, in co-operation with the State Departments of Agriculture of Ohio and Michigan. During 1922–1925 material collected for this purpose was sent to the writer for specific determination.

very sparce infestation and one first found only in the townships which border Lake Erie), seem to indicate that the source of the infestation was Ontario and that adult moths came across the Lake with the aid of favorable winds. U. S. Weather Bureau records at Sandusky, Ohio, show that north winds were prevalent during the latter part of June, 1921, a time when the moths were very actively in flight in Ontario. It is doubtful whether this insect was present in Ohio previous to 1921, and this fact affords a singular opportunity for the study of the increase in intensity of infestation, and seems to justify, at this point a more or less detailed report of the results of such study.

During the season of 1922 infestation counts in 55 fields comprising approximately 175 acres in 11 townships bordering Lake Erie showed only a trace of infestation in 16 of these fields. The maximum percentage of infested stalks in these fields was only a very small fraction of 1, although the number of larvæ that could be collected in a given time was many times greater than it had been in the previous season, according to the records of scouting officials of the U. S. Bureau of Entomology in 1921.

During the season of 1923, field counts for the purpose of determining the percentage of infestation were made in 133 fields comprising approximately 443 acres in 21 townships distributed throughout the area of infestation of the two preceding seasons in Ohio and Michigan, and showed an average of 2.5 larvæ per 100 stalks. The maximum percentage of infested stalks was 17 and the average was found to be 1.83.

During the season of 1924 a phenomenal increase in intensity of infestation was recorded. Field counts to determine the percentage of stalks infested in 241 fields comprising approximately 675 acres in 39 townships distributed throughout the area of infestation of the three previous seasons in Ohio and Michigan showed an average of 9.22 larvæ per 100 stalks. The maximum percentage of infested stalks found was 52. The average percentage of infested stalks for the whole area examined was 5.2, or 2.8 times as great as in 1923. In all field counts to determine the percentage of infestation, the data were taken in such manner that weighted averages could be calculated. The average larval population per stalk was computed and the increase in intensity of infestation is here expressed in actual increase in larval population per 100 stalks, both infested and uninfested, because of the distant and significant relation which it bears to the amount of damage caused. This method was derived from the one in use at the European Corn Borer Laboratory, Arlington, Mass., and was adapted for use under Ohio conditions.

Up to Jan. 1, 1926, new records of infestation were reported from 315 townships, totalling 8,529 square miles in area, in 31 counties in Ohio, and from 176 townships, totalling 6,232 square miles in area, in 15 counties in Michigan. In 1925, field counts were made in 272 fields, comprising approximately 1,507 acres, in 38 townships in Ohio and in Monroe County, Michigan. The data taken showed an average of 8.63 larvæ per 100 stalks, or a slight decrease compared with counts made over much the same area in 1924. The maximum percentage of infested stalks in 1925 was 63.8 and the percentage of infested stalks in the whole area examined was found to be 5.9, or only 0.89 greater than in 1924. Thus the increase in area and intensity of infestation was very great each year until 1925 when the same rate of increase was not maintained in Ohio. This was probably due to the hot and dry weather conditions which prevailed during the time when the eggs were being deposited.

It was noted in connection with the study of the infestation of *Pyrausta nubilalis* in Ohio that the increase in area was more or less proportional to the increase in intensity of infestation each season, and that optimum conditions for development seemed to be an abundance of available moisture combined with temperature conditions normal or slightly above normal. Little or no damage to the corn crop by this pest has occurred up to the present time (January, 1926) in Ohio and Michigan; but the situation now is such that considerable damage may be expected in many fields in the infested area of Ohio and Michigan during any year which is favorable for the development of the insect, unless crop refuse containing the larvæ is disposed of very effectively in the areas of heaviest infestation.

Larvæ of *Pyrausta ainsliei* and *P. penitalis* have been sent to the writer from many townships in Ohio and Michigan and it is quite likely that both of these species are commonly distributed wherever *Persicaria pennsylvanica* is found abundantly. No lotus* plantations have been examined by the writer which have not contained some infestation by *P. penitalis*. Lotus has been observed in the following localities in Ohio: Buckeye Lake, Oak Harbor, Toledo, and Sandusky.

**Nelumbo lutea* (Willd.) Pers.

Experimental Methods.

In presenting the data obtained in any biological work a description of the methods used is of the utmost importance. Therefore a brief description of the methods used in obtaining the data which are presented in this paper is given here. Conditions under which some of the observations were made are described in the disscusion of these observations.

Material for life-history studies of *Pyrausta nubilalis*, collected in the fall and spring, was kept in wire-screen cages 6 feet by 3 feet by 3 feet (Pl. VI, Fig. 43) under as nearly normal conditions as possible. Pupation in and emergence of *P. nubilalis* from this material were observed to compare very closely with those of *P. nubilalis* in the field.

In obtaining records of the duration of the pupal period small glass tubes (Pl. III, Fig. 27) about 2½ inches long and having an inside diameter of 4 mm. were used. This cage was developed in 1918 by Mr. S. C. Vinal of the Massachusetts Agricultural Experiment Station. As the time for pupation approached, larvæ were placed individually in these tubes, which were labelled with gummed-paper labels for identification. The tubes had a cotton stopper at each end. To facilitate handling and to supply the proper moisture, four to six of these glass tubes were then placed in each of a number of larger glass vials, 100 mm. long by 29 mm. in diameter, which had a round piece of moist blotting paper tightly fitted into the bottom and which were provided with a wire-screen cover for the top to prevent the larvæ from escaping. These larger vials were then placed in wooden racks (Pl. IV, Fig. 28) which were in turn placed in a tightly covered wooden box to exclude the light. Daily examinations were made and as the larvæ pupated, and later as the adults emerged, the duration of pupation was recorded.

No satisfactory method was devised for obtaining, under laboratory conditions, data on the time of pupation that would be fairly comparable to those obtained under natural conditions in the field. If the larvæ are confined in any kind of a cage, their unnatural environment which prevents them from migrating and seeking a new place in which to pupate, apparently greatly delays pupation if it does not entirely prevent it.

Data on mating, oviposition, and longevity of adult moths were obtained from single pairs confined in lantern-globe cages

(Pl. IV, Fig. 30) in the insectary. Each of these cages consisted of a lantern globe, with a 14-mesh screen-wire or mosquito-netting cover, placed upon a 5-inch flower pot filled with moist sand into which a glass vial 74 mm. in length by 14 mm. in diameter was thrust. The stem of the host plant was placed in this vial, which was filled with water each day in order to keep the host plant in good condition for egg deposition. A suitable gummed label was attached to each lantern globe so that the cage could be identified at all times.

Number and duration of larval instars were obtained in small glass vials 50 mm. in length by 10 mm. in diameter, each of which contained a young larva that had just hatched. These vials were placed with the open end tightly fitting into a plaster of Paris block especially prepared for this purpose. This block (Pl. III, Fig. 25) was 16 inches in length, 5 inches high and 4 inches wide and was placed on a wooden base in order to protect it and facilitate handling it. Each block contained 64 holes which were bored into the sides about ½-inch in depth and into which the open ends of the glass vials fitted tightly in order to prevent the escape of the small larvæ.

The block contained a trough or depression on the upper surface, 13 inches long, 2 inches wide, and three-fourths inch in depth, into which was placed about 4 ounces of water daily in order to supply adequate moisture to the young developing larvæ. At first the young larvæ of *P. nubilalis* were given only fresh tender leaves of corn and those of *P. penitalis* and *P. ainsliei* were given only fresh leaves of smartweed. After the second molt by the larvæ, the pithy portions of these plants were offered. The larvæ were then usually transferred to larger glass vials, 100 mm. in length by 29 mm. in diameter (Pl. IV, Fig. 28) into which a larger amount of food material could be placed. The larvæ were examined daily and fresh food was given when necessary. When the larvæ molted the exuviæ were removed and placed in small vials, 35 mm. in length by 9 mm. in diameter. The head capsules from each individual were kept in separate vials which were numbered to correspond with the larvæ from which they had come. These vials were all kept in a holder (Pl. III, Fig. 26) which was made from a 2-inch block of wood.

For the purpose of obtaining a known number of larvæ in cornstalks under as nearly natural conditions as possible, 50-pound tin lard cans were used. The sections of stalks and the larvæ were placed in the cans so that the larvæ entered the stalks and did not escape. A hole to provide proper ventilation was cut in the lid of the can (Pl. IV, Fig. 29) over which was soldered a 20-mesh screen-wire cover.

For the migration or recovery trap (Pl. IV, Fig. 31, and Pl. VI, Fig 43) used to recover larvæ in the plowing and various other experiments, 1-inch by 6-inch boards, usually 16 feet in length were placed on edge so as to form a square or rectangular inclosure. The edges of the board were buried about 1 inch deep in the ground, the soil being tamped down tightly on both sides to prevent the larvæ from going underneath and escaping. On the side near the top of these boards a strip of double-faced corrugated paper, 1½ inches wide, was tacked for the larvæ to crawl into. On top of the 1-inch by 6-inch boards and the corrugated paper strips boards one-half inch thick and 4 inches wide were nailed with the nails driven only partly down so that the traps could be easily examined. In this way the holes in the corrugated paper were kept nearly dark on top, enough space being left for a ray of light to enter and allow the larvæ a place to spin their hibernating webs but not enough space for the larvæ to escape through the upper opening. Mr. H. G. Crawford, Entomological Branch, Ottawa, Canada, originated the idea of using corrugated paper as a migration trap for larvæ of *P. nubilalis*. If a two-way recovery trap was desired the corrugated paper was placed on both sides of the 1-inch by 6-inch board. The efficiency of this trap was tested during the spring of 1925 by placing a kerosene barrier around a 16-foot by 16-foot recovery trap. Out of 416 larvæ placed on the surface of the ground in this trap during a period of three weeks only 10, or 2.4%, escaped. This trap was therefore 97.6% efficient in this experiment in which every precaution was taken to make it a fair test.

Large larvæ of *P. nubilalis*, *P. penitalis*, and *P. ainsliei* bore through cork stoppers and escape from glass vials in this way; they also escape through cotton stoppers unless these are tightly fitted. It was found necessary to make wire covers for the tops of the vials (Pl. IV, Fig. 28) containing large larvæ of which records were being kept and the loss of which could not be tolerated. The full-grown larvæ easily bore through pasteboard and paper boxes. Larvæ of *P. nubilalis* have been observed boring in soft white pine boards.

Host Plants.

Table 1 is a list of host plants of the three species of *Pyrausta* considered in this paper and is based on the species of plants from within which larvæ of one or another of the three species were collected. The number of host plants of *P. nubilalis* under natural field conditions in Ohio has apparently increased in direct proportion to the increase in the intensity of the infestation. The number of shelter plants will probably continue to increase in direct proportion to the increase in the intensity of the infestation but it is doubtful whether the number of food plants will show the same increase. By food plants are meant those upon which a species develops from the egg to the mature larva; all others are considered shelter plants.

Table I.

Host Plants* of *Pyrausta* spp. found in Ohio under natural field conditions, 1922–1925.

Pyrausta nubilalis:†

1. Corn (*Zea mays* L.) Sweet, dent, pop, ensilage, and flint.
2. Smartweed, Knotweed (*Persicaria pennsylvanica* (L.) Small).
3. Rough Pigweed (*Amaranthus retroflexus* L.).
4. Roman Ragweed (*Ambrosia elatior* L.).
5. Water-hemp (*Acnida tuberculata* Moq.).
6. Cocklebur (*Xanthium pennsylvanicum* L.).
7. Tall Beggar-ticks (*Bidens vulgata* Greene).
8. Barley (*Hordeum vulgare* L.).
9. Panic Grass (*Panicum capillare* L.).
10. Barnyard Grass (*Echinochloa crusgalli* (L.) Beauv.).
11. Wild Lettuce (*Lactuca canadensis* L.).
12. Smartweed (*Persicaria lapathifolia* (L.) S. F. Gray).
13. Giant Ragweed (*Ambrosia trifida* L.).
14. Velvet Leaf (*Abutilon abutilon* (L.) Rusby).
15. Lamb's-quarters (*Chenopodium album* L.).
16. Tumbleweed (*Amaranthus graecizans* L.).

Note.—All of the above, except numbers 1 and 2, were probably only shelter plants.

Pyrausta penitalis:

1. Smartweed (*Persicaria pennsylvanica* (L.) Small).
2. Smartweed (*Persicaria lapathifolia* (L.) S. F. Gray).
3. Smartweed (*Persicaria muhlenbergii* (Wats.) Small).
4. American Lotus (*Nelumbo lutea* (Willd.) Pers.).
5. Corn (*Zea mays L.*) Sweet and dent.
6. Rough Pigweed (*Amaranthus retroflexus* L.).
7. Giant Ragweed (*Ambrosia trifida* L.).
8. Wild Lettuce (*Lactuca canadensis* L.).
9. Curled Dock (*Rumex crispus* L.).

Note.—All of the above except numbers 1 to 4, inclusive, were probably only shelter plants. Eggs only were found on *Rumex crispus* (L.).

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*Nomenclature in this paper is according to "Catalogue of Ohio Vascular Plants," by J. H. Schaffner in Vol. I, Bulletin 2 of Ohio Biological Survey.

†In some instances first records of occurrence were reported by scouting crews and other collectors. The author has personally verified all of the records reported here.

Pyrausta ainsliei:

1. Smartweed (*Persicaria pennsylvanica* (L.) Small).
2. Corn (*Zea mays* L.) Sweet and dent.
3. Rough Pigweed (*Amaranthus retroflexus* L.).
4. Tall Beggar-ticks (*Bidens vulgata* Greene).
5. Lamb's-quarters (*Chenopodium album* L.).
6. Giant Ragweed (*Ambrosia trifida* L.).
7. Cocklebur (*Xanthium* sp.).
8. Roman Ragweed (*Ambrosia elatior* L.).
9. Indian Hemp (*Apocynum cannabinum* L.).

NOTE.—All of the above except *Persicaria* were probably only shelter plants. Eggs only were found on *Apocynum cannabinum* L.

Indications are that *P. nubilalis* has not actually developed to date in plants other than corn with the possible exception of *P. pennsylvanica* (upon which eggs of *P. nubilalis* were found in the field in two instances in 1925), the other hosts mentioned being only shelter plants. Corn is without doubt the preferred host plant of *P. nubilalis.* It has generally been supposed that sweet corn is a preferred host to dent corn or that the latter is more immune to infestation than the former. All data obtained on this point by the writer show that the location of the corn with respect to the source of the infestation, and the stage of the development of the corn either at the time the eggs are being deposited or when the young larvæ are developing, are much more significant factors than the difference in the type of corn. In lantern-globe cages the moths of *P. nubilalis* exhibited little preference, if any, for host plants upon which to deposit their eggs. Several hosts, including corn, dandelion, pigweed, plantain, smartweeds, mustard, beggar-ticks, cocklebur, and burdock, were offered individually for this purpose and no apparent difference in the number of eggs deposited was noted in the case of *P. nubilalis.*

Pyrausta penitalis develops rapidly upon lotus and in the region of Sandusky Bay seems to build up its population on this host. However, the number of individuals that survive the winter in lotus is apparently very small indeed because this plant falls into the water late in the fall in this region, though it may later wash ashore. Very careful search in the remains of this host plant during the spring of 1923, and again during the spring of 1925, revealed no larvæ of this species except in one instance when two larvæ were found within a seed pod which had apparently been washed ashore. Most of the over-wintering larvæ of this species were found in smartweed and in corn in this section. No difficulty was experienced in rearing individuals on smartweed which hatched from eggs that had been deposited on lotus, and vice versa. The mature larvæ, the pupæ, the moths, and the egg clusters were apparently considerably larger, on the average, when they developed on lotus than when they developed on smartweed under natural conditions. In lantern-globe cages, moths of *P. penitalis* seemed to prefer smartweed to other plants which were offered as hosts upon which they might deposit their eggs. Eggs were deposited upon plantain, mustard, catnip, teasel, dandelion, and corn in the cages. None were obtained upon lamb's-quarters. Lotus was not available for a fair comparison in this experiment.

Under natural field conditions *Pyrausta ainsliei* was found to develop only on *Persicaria pennsylvanica.* Eggs of *Pyrausta ainsliei* were collected in one instance in 1925 upon *Apocynum cannabinum*, but in confinement no larvæ could be reared upon this plant. Ellis (6) reports *Apocynum androsaemifolium* L. and eight other species of food plants for *P. ainsliei* in New England, so it is quite evident that the food habits of this species vary greatly in different localities.

Pyrausta ainsliei and *P. penitalis* have often been found to be developing in one plant of *Persicaria pennsylvanica* under natural conditions in the field and sometimes larvæ of *P. nubilalis*, which apparently were migrants, were also found in the same *Persicaria* plant. Larvæ of all three of these species of *Pyrausta* have also been collected in the same cornstalk under natural conditions in the field.

The reaction of newly hatched larvæ of *Pyrausta nubilalis*, *P. penitalis*, and *P. ainsliei* to various plants in confinement was studied. The greater part of this work was done during the season of 1925; all tests, however, carried on previous to this season were repeated with similar results. The host plants which were used in these experiments were placed in glass vials, 100 mm. long and 29 mm. in diameter. Cotton stoppers were used until the larvæ became too large to escape through the wire top covers (Pl. IV, Fig. 28). From 12 to 20 larvæ which had just hatched were placed in each vial upon each host. A minimum of three vials were used for each test; thus a minimum of 36 larvæ were placed upon each host. If feeding occurred the host material was changed as often as necessary in order to keep it in a good palatable condition. *Pyrausta nubilalis* was reared, from egg to mature larva, on 30 of the 63 different plants offered; *P. penitalis* on 17 of the 72 different plants;

and *P. ainsliei* on 8 of the 46 different plants offered to the newly hatched larvæ of this species.

In the case of *P. nubilalis*, rhubarb and Roman ragweed, which are reported as being seriously damaged by this insect in New England, were not accepted as food plants in these experiments.* Potato and beans, which are frequently attacked in New England, were not accepted as hosts in these experiments. Plants which are reported as being occasionaly attacked in New England and which were not accepted were as follows: yarrow or milfoil, velvet leaf, tomato, prickly lettuce, lamb's-quarters, and goldenrod. A few plants were accepted for food in these experiments which have not been reported as hosts in New England under natural field conditions. These were black willow, garden lettuce, garden carrot, and lotus. In confinement, the young larvæ of *P. nubilalis* readily accepted corn, dahlia, buckwheat, beet, lotus, cocklebur, sunflower, chrysanthemum, and 2 species of dock and 5 species of smartweed which were offered as food plants. Burdock, gladiolus, the clovers, pigweed, beggar-ticks, lettuce, cowpeas, Roman ragweed, carrot, beans, black willow, and common mallow were not accepted so readily in these experiments, although at least one individual was reared from egg to mature larva upon each of these hosts. It is evident that plants attacked in confinement might never be attacked under natural conditions. It also seems reasonable to expect that plants not attacked in confinement would not suffer any large amount of damage by these insects in the field.

In the case of *P. penitalis*, dahlia, buckwheat, lotus, and all of the species of dock and smartweed which were offered to the young larvæ as food plants in confinement were accepted readily. Burdock, garden lettuce, black willow, alsike clover, red clover, white clover, and common mallow were not accepted readily but at least one larva was reared to maturity upon each of these food plants. All of the other 55 species of plants which were offered to the young larvæ of *P. penitalis* for food were refused.

In confinement young larvæ of *P. ainsliei* developed with about equal rapidity only upon buckwheat, two species of dock, and five species of smartweed which were offered. All of the

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*With reference to comparative food habits it should be stated that a two-generation strain of *P. nubilalis* occurs in New England and reference is made only to food habits under field conditions in New England.

other 38 species of plants supplied to the young larvæ of *P. ainsliei* as food were refused.

Larvæ of *P. nubilalis* and *P. penitalis* in the third or fourth instar of their development were transferred from corn and smartweed or lotus, respectively, to plants upon which the newly hatched larvæ of these species did not feed in the experiments previously discussed. In all cases, if the plant to which the older larvæ were transferred contained pithy stems of sufficient size for them to enter, the larvæ were able to continue their development to maturity. This was not true of *P. ainsliei*, as larvæ of this species in the fourth instar were transferred from smartweed to separate vials containing cowpeas, tomato, and red clover and did not complete their development to maturity upon any of these hosts. From the observations made in the case of *P. nubilalis* and *P. penitalis*, it seemed to be necessary for the larvæ of these species to have reached the third instar before the transfer could be successfully effected.

The tests previously discussed are not considered final and complete but, together with field observations on host plants, they indicate that *P. nubilalis* and *P. ainsliei* exhibited much less variation in choice of food plants in Ohio than has been reported in some other localities, whereas *P. penitalis* exhibited a wider choice of food plants, both in the field and in confinement, than has hitherto been reported.

Seasonal History.

The three species of *Pyrausta* which are considered in this paper were all observed to overwinter as full-grown larvæ in their respective food or shelter plants. Though there is considerable migrating and boring by the larvæ in the spring before pupation no actual feeding was observed. Small larvæ of *P. penitalis* about which some doubt existed as to whether they were mature were collected from smartweed late in the fall of 1923 to observe if feeding were necessary before pupation during the following spring. No feeding occurred and these individuals pupated normally except that they were smaller than the average.

Only one generation of *P. nubilalis* has been found in Ohio during the seasons 1922-1925 (See Fig. 1). Table 2 gives the comparative records on the phenology of the three species of *Pyrausta* which are considered in this paper. The earliest date that tassels were observed to be broken over by *P. nubilalis*

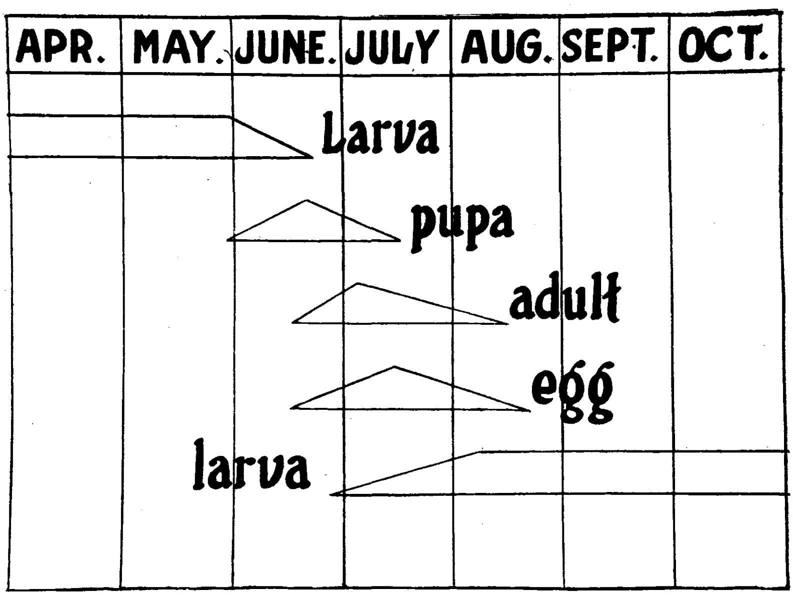

FIGURE 1

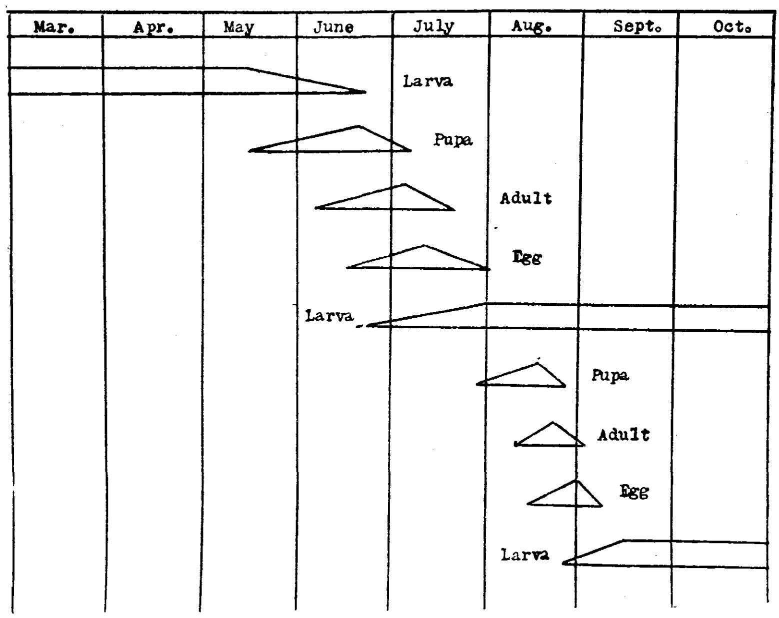

FIGURE 2

was on July 6th; this in 1925, when some larvæ in the fourth instar of their development were observed to be responsible for the work.

P. ainsliei, in the region of Sandusky, Ohio, was found to pass through one complete generation and about 50 per cent

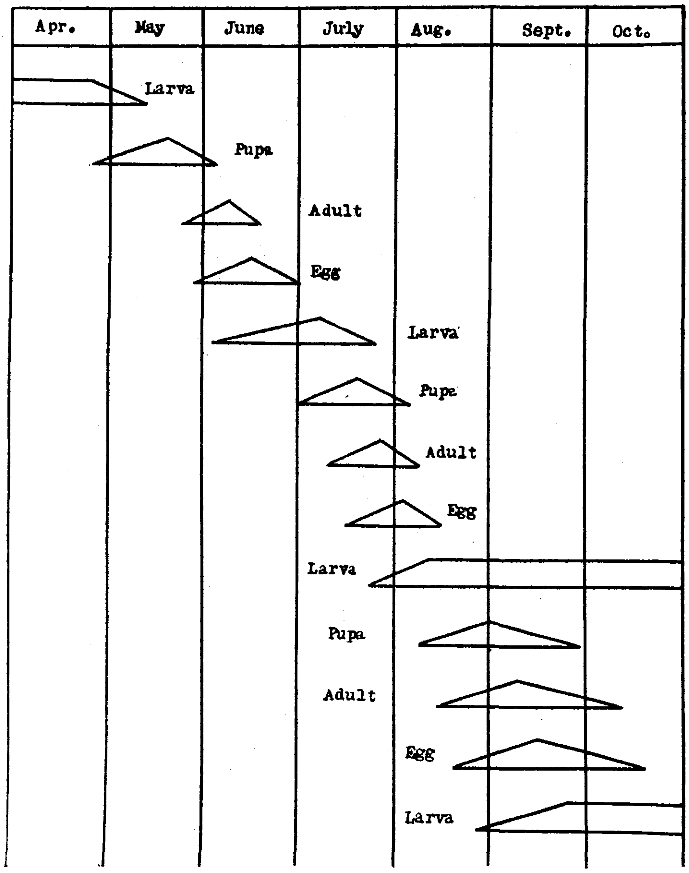

FIGURE 3

of a second generation (See Fig. 2) each season. There was apparently a very marked cessation of pupation by the larvæ of the first generation about the middle of August at which time only about 50 per cent of them had pupated. This also occurred with material which was under observation in the insectary in approximately the same proportion as for individuals in the field.

The observations recorded in this paper on the seasonal history of *P. penitalis* were made almost entirely on lotus which was growing in Sandusky Bay. Three complete generations (See Fig. 3) were observed to develop during the seasons of 1923 and 1925, whereas in 1924 a small percentage of the larvæ of the second generation did not pupate during that season.

TABLE II.

Phenology of *Pyrausta* spp. at Sandusky, Ohio, 1922–1925.

Stage	Generation	Date of first record		Greatest abundance (approximate date)		Last Record	
		In field	In laboratory	In field	In laboratory	In field	In laboratory
Pupa....	*P. nubilalis*.......	May 30	June 2	June 26	July 1	July 14	Aug. 12
Adult...	*P. nubilalis*.......	June 16	June 9	July 6	July 14	Aug. 13	Aug. 25
Egg.....	*P. nubilalis*.......	June 16	June 20	July 15	July 20	Aug. 13	Aug. 23
Larva..	*P. nubilalis*.......	June 26	June 22	Aug. 5	....	....	....
Pupa....	2nd *P. ainsliei*....	May 15	June 4	June 18	June 18	July 4	Aug. 7
Adult...	" " "	June 6	June 6	July 4	....	July 20	July 23
Egg.....	1st *P. ainsliei*....	June 16	June 15	July 11	....	Aug. 1	Aug. 9
Larva..	" " "	June 21	June 21	July 25	....	....	....
Pupa....	" " "	July 30	July 30	Aug. 16	....	Aug. 25	Aug. 31
Adult...	" " "	Aug. 11	Aug. 18	Aug. 25	....	Sept. 3	Sept. 19
Egg.....	2nd *P. ainsliei*....	Aug. 23	Aug. 22	Sept. 1	....	Sept. 3	Sept. 10
Larva..	" " "	Aug. 29	Aug. 31	Sept. 8	....	....	....
Pupa....	3rd *P. penitalis*...	April 24	May 18	May 25	....	June 7	June 22
Adult...	" " " ...	May 23	May 23	June 8	....	June 17	July 10
Egg.....	1st *P. penitalis*...	May 28	May 29	June 16	....	July 1	July 12
Larva..	" " " ...	June 3	June 3	July 8	....	July 26	July 23
Pupa....	1st *P. penitalis*...	July 1	July 14	July 20	....	Aug. 6	Aug. 4
Adult...	" " " ...	July 10	July 19	July 29	....	Aug. 9	Aug. 23
Egg.....	2nd *P. penitalis*...	July 16	July 21	Aug. 4	....	Aug. 15	Aug. 7
Larva..	" " " ...	July 21	July 25	Aug. 8	....	....	....
Pupa....	" " " ...	Aug. 8	July 30	Sept. 1	....	....	Sept. 7
Adult...	" " " ...	Aug. 15	Aug. 18	Sept. 10	....	....	Sept. 22
Egg.....	3rd *P. penitalis*...	Aug. 21	Aug. 19	Sept. 15	....	....	Sept. 2
Larva..	" " " ...	Aug. 26	Aug. 25	Sept. 20	....	....	....

LIFE-HISTORY STUDIES.

THE PUPA

(Pl. II, Figs. 14–17).

By actual measurement, nine male pupae of *Pyrausta nubilalis* ranged from 13 to 17 mm. and averaged 15.1 mm. in length and ten female pupæ ranged from 13 to 18 mm. and averaged 16.2 mm. in length. The average length of the nineteen individuals of both sexes was 15.7 mm. Six male pupæ of *P. ainsliei* ranged from 12 to 13.5 mm. and averaged 12.9 mm. in length and nine female pupæ ranged from 13 to 14 mm. and averaged 13.4 mm. in length. The average length of the fifteen individuals of both sexes was 13.2 mm. The average length of sixteen male pupae of *P. penitalis* was 12.3 mm., ranging from 11 to 15 mm., whereas the average length of fifteen female pupæ was 14.9 mm. and the range was from 14 to 16 mm. The average length of the thirty-one individuals including both sexes was 13.9 mm. In the field the pupæ of *P. ainsliei* may be easily distinguished from those of *P. nubilalis* and *P. penitalis* by the knob-like projection on the front (See Pl. II, Fig 16), as determined by Heinrich (8). The pupæ of *P. penitalis* may be easily distinguished from those of *P. ainsliei* and *P. nubilalis* by the very stout and characteristic cremaster, which is broader than long. (See Pl. II, Fig. 17).

Pupation by *P. nubilalis* under natural field conditions in Ohio has been observed to occur only in corn (Pl. III, Fig. 22) within the tunnels which were made by the larvæ. However, in a few instances observed pupation occurred between the stalk and a closely attached leaf, and in this position the individual was usually surrounded by larval frass. Before pupation a circular exit hole is cut by the larva to the surface of the stalk (Pl. III, Fig. 23, at right, and Fig. 24) and this is covered over by a silken opaque partition which closes the outside entrance to the pupal chamber. Quite often the exit hole was observed not cut entirely to the surface of the cornstalk and a thin layer of the epidermis was left (Pl. III, Fig. 23, at left) so that the future moth could easily break through and escape. The outside entrance was usually only 2 or 3 inches from the pupal chamber. Before pupation the larva spins a thin layer of silk around itself which may be called a thin cocoon to which the small spines borne on the last segment of the pupæ are attached. The pupa of *P. nubilalis* has been observed to change completely to the pupal stage within a period of five minutes. The color of the pupæ is yellowish brown for all the species of *Pryausta* which are considered in this paper.

Pupation of *P. ainsliei* under natural field conditions occurred in the stems of *Persicaria pennsylvanica* when it took place in August. In the spring it was observed to occur in shelter plants as well as in the smartweed. Cocoons were not constructed by this species for the protection of the pupæ. The entrance holes to the larval burrows in smartweed were usually from 1 to 4 inches below the pupa and were not closed as in the case of those of *P. nubilalis* in corn. The entrance holes to the tunnel which leads to the pupal chamber of *P. ainsliei* in cornstalks were never observed to be closed. However, the larvæ usually entered the stalk in a position where a closely attached leaf obscured the entrance. The tunnel in smartweed is lightly plugged above and below the pupa with particles of pith which are held together with a network of silk fibers. The pupa lies with head downward in the burrows in smartweed. This was also found to be the prevailing tendency of 138 individuals of this species which pupated in glass tubes and were observed for this purpose, 102 out of 138 pupating with the head downward. Under similar conditions in glass tubes, 162 individuals out of a total of 197 *P. nubilalis* pupated with the head upward. Under the same conditions 29 individuals of *P. penitalis* pupated with the head upward, and 33 pupated with the head downward. An interesting fact in this connection is that 21 out of 24 individuals collected from smartweed in early spring pupated with the head downward, whereas 30 out of 38 individuals collected from lotus later in the season pupated with the head upward, though all were subjected to the same type of cages and methods of handling.

Pupation of *P. penitalis* under natural conditions in the field was usually observed to occur in *Persicaria pennsylvanica* and lotus. The overwintering larvæ were observed to pupate only in the stems of *Persicaria* (Pl. II, Fig. 20) and in shelter plants to which they had migrated. Pupæ of the first generation have been observed in the stems of smartweed and in the petioles of the leaves of lotus near where the leaf is attached to the petiole, and occasionally a pupa of this generation has been found in the rolled-up margins of the leaves of lotus. Seed pods of lotus were not available for pupation by this generation. Pupæ of the second generation have been observed in the seed pods of lotus, in the margins of leaves occasionally, and in the petioles of the leaves. As many as three pupæ have been found in one petiole which contained exit holes and larval tunnels extending down the petiole as far as 10 inches below the leaf. In instances of this kind, the lotus leaves had grown far enough above the water to keep the entrance holes into the petiole above the surface. Pupæ of *P. penitalis* found in smartweed were usually in the stems of the plant, their location being very similar to that of the pupæ of *P. ainsliei* in the same plant as described above, though in some instances the larvæ made exit holes similar to those described for *P. nubilalis* in corn. There was very little cocoon formation (Pl. II, Fig. 20) as in the case of *P. ainsliei*. In the petioles of the leaves and in the seed pods of lotus, the pupæ were well protected by heavy or thick, tough, paper-like cocoons (Pl. 11, Figs. 19 and 21) which contrast greatly with the unprotected pupæ of the same species in smartweed and the other shelter plants which the larvæ often select for hibernation and pupation.

A point that may still further emphasize the powers of adaptation of this insect was noted in lotus which had developed without having the leaves float on the surface of the water. In the petioles of such leaves, the exit hole for the future adult even when in the end, was not closed as in the case of individuals which pupated in the petioles of floating leaves. Welch (10) has given an excellent description of the pupal chamber and how it is constructed in the petiole of floating leaves. Later Ainslie and Cartwright (1) recorded additional observations upon this part of the development of the insect in Tennessee. The accurate manner of closing the entrance to the cavity in the petiole in which the pupal chamber is constructed is indeed a clever piece of insect mechanics.

The pupal period of 129 male pupæ of *P. nubilalis* averaged 13.43 days and the pupal period of 137 female pupæ averaged 13.01 days, while the total of 266 individuals of both sexes of *P. nubilalis* had an average pupal period of 13.21 days with a minimum pupal period of 9 days and a maximum of 20 days. The pupal period of 77 male pupæ of *P. ainsliei* averaged 14.0 days and the pupal period of 79 female pupæ averaged 13.59 days while the total of 156 individuals of both sexes of *P. ainsliei* had pupal periods of from 7 to 17 days with an average of 13.8 days. The pupal period of 27 male *P. penitalis* averaged 13.8 days and the pupal period of 68 female pupæ averaged 11.5 days while the total of 95 individuals of both sexes were in the pupal stage from 6 to 31 days and the average was 12.2 days.

The Adult.

The adult male and female moths of *Pyrausta nubilalis*, *P. ainsliei*, and *P. penitalis* are shown on Plate I, Figures 1, 2, 4, 5, 7, and 8 and are very intimately related. Distinctive characters for each species are well given by Heinrich (8, p. 178). Superficial adult characters which permit identification of fresh specimens with a fair degree of certainty in the field are as follows: Male moths of *P. nubilalis* have dark, smoky, fuscous wings in combination with the distinct yellow colors of the lighter areas; moths of *P. ainsliei* are usually smaller and do not have the sex scaling of the forewing which is a prominent character in the other two species; moths of *P. penitalis* have a distinctly reddish tinge, the female darker than the male, and beyond the cell in the forewing there is a large conspicuous irregular spot of reddish or grayish scales; this irregular spot is not prominent in the female moth of *P. nubilalis*.

Emergence of the moths of the three species of *Pyrausta* has been observed to take place at all times during the day and night in confinement. The moths of all three species were nost active in cages during the early evening or during periods of high atmospheric humidity. They remained quite inactive in cages during periods of comparatively low temperature. In the field only an occasional moth of these species has been observed except in the case of *P. penitalis* in lotus plantations.

The habits of flight of these species were observed to be more or less similar. The males were most often seen and their flights were quite rapid and irregular and were usually only for short distances. They remained close to the ground, where cover was soon sought. Both sexes are accustomed to hiding on the lower surface of the leaves of available plants, and are not very easily disturbed in the daytime under ordinary conditions in the field. Though the moths have not been observed to fly any great distances in the daytime, and their period of greatest activity is at night, it is doubtless true that winds at night are an important factor in the natural distribution of *P. nubilalis*. The prevailing southwest winds in Michigan during the time that the moths are in flight may account for the rapid distribution of *P. nubilalis* over Eastern Michigan. In the season of 1924, at the time the moths were most abundant in the field, two occasions were noted at Sandusky, Ohio, when periods of high atomspheric humidity during the early evening preceded high winds from the north at 10 p.m. and midnight, respectively. This may have been a more or less local condition and of no significance in explaining the unparalleled distance of spread of this insect in Ohio during 1924. Similar weather conditions were not observed to occur at such an opportune time during the other three seasons of observation.

Time of Emergence and Proportion of Sexes.

In Table III is given the results of data obtained on the progress of emergence and the proportion of sexes of moths of *P. nubilalis* during the seasons of 1924 and 1925. The male moths began to emerge first and it may be noted from the data presented in Table III that during both of the seasons of 1924 and 1925 approximately three-fourths of the individuals which were under observation had emerged before the proportion of males to females became equal. Although the majority of the male moths emerged somewhat earlier than the majority of the female moths,it was observed in these experiments that enough males continued to emerge so that there existed no shortage of males for mating purposes.

TABLE III.

Progress of emergence and proportion of sexes of *Pyrausta nubilalis* at Sandusky, Ohio, 1924–1925.

Generation of 1923					Generation of 1924				
Total Number of Indiv. observed to date	Date	Males	Females	Ratio of males to females	Total Number of Indiv. observed to date	Date	Males	Females	Ratio of males to females
		Percent	*Percent*				*Percent*	*Percent*	
3	7- 1-24	66.6	33.3	2:1	1	6- 9-25	100	0	1:0
230	7-10-24	65.7	34.3	1.92:1	12	6-14-25	91.7	8.3	11:1
308	7-11-24	59.8	40.2	1.49:1	100	6-21-25	85	15	5.7:1
517	7-14-24	54.2	45.8	1.18:1	161	6-23-25	74.6	25.4	2.9:1
613	7-16-24	50.6	49.4	1.02:1	391	6-27-25	65.8	34.2	1.92:1
648	7-17-24	49.7	50.3	.988:1	679	6-30-25	53.6	46.4	1.16:1
683	7-18-24	49.0	51.0	.961:1	1,288	7- 6-25	50.5	49.5	1.02:1
774	7-23-24	48.4	51.6	.938:1	1,366	7- 7-25	49.9	50.1	.996:1
803	7-26-24	47.0	53.0	.887:1	1,474	7-11-25	48.8	51.2	.953:1
828	8-12-24	46.1	53.9	.855:1	1,537	7-15-25	48.5	51.5	.942:1
					1,606	7-30-25	48.2	51.8	.931:1
					1,620	8-14-25	48.3	51.7	.934:1

Longevity.

Observations on longevity of adult moths of the species of *Pyrausta* under observation during the seasons of 1921-1925, inclusive, were obtained in lantern-globe cages. It was observed that 233 male moths of *P. nubilalis* lived from 2 to 42 days and an average of 20.4 days and 125 female moths of *P. nubilalis* lived from 4 to 40 days and an average of 18.9 days. The total of 358 individuals including both sexes of moths lived an average of 19.9 days.

In the case of *P. ainsliei*, 49 male moths lived from 4 to 26 days and averaged 15.7 days and 41 female moths lived from 6 to 24 days and averaged 14.1 days. The total of 90 individuals of both sexes of moths lived an average of 15.0 days.

Seventy-five male moths of *P. penitalis* lived from 5 to 32 days and an average of 14.5 days and 81 female moths lived from 6 to 23 days and averaged 12.5 days. The total of 156 moths of both sexes under observation for this purpose had an average longevity of 13.5 days.

In these experiments no special food was provided. An abundance of moisture and a suitable host plant were provided in the cages (Pl. IV, Fig. 30). All longevity records included in the foregoing data were taken on mated moths or those which had opportunity to mate. Usually two male moths and one female moth were placed in each cage. In some cases when male moths were not available in sufficient numbers, one individual male was used in two or more cages in order to obtain as many fertile females as possible for oviposition records. This apparently did not adversely effect the length of the life of the individual so used. During July, 1925, 25 unmated male moths of *P. nubilalis* lived from 3 to 25 days and averaged 15.2 days.

Five unmated female moths of *P. penitalis* under observation in September, 1925, lived from 5 to 11 days or an average of 8.2 days while 6 mated female moths under observation at the same time lived from 12 to 17 days and averaged 14 days.

The average longevity of male moths of *P. nubilalis* was 1.5 days greater than that of the female moths; the average longevity of male moths of *P. ainsliei* was 1.6 days greater than that of the female moths; the average longevity of the male moths of *P. penitalis* was two days greater than that of the female moths. Both sexes of moths of *P. penitalis* average 1.5 days and 6.4 days less longevity than both sexes of moths of *P. ainsliei* and *P. nubilalis* respectively.

This result would naturally be expected in view of the fact that *P. nubilalis* has only one generation, that *P. ainsliei* has one generation and a partial second, whereas *P. penitalis* usually has three complete generations annually in the locality where the foregoing longevity records were made.

Copulation.

Copulation by moths of *P. nubilalis* was observed to take place at any time during the day or night. Before copulation the male was observed to approach the female from the rear and with the long axis of his body at right angles to the abdomen of the female he vibrated his wings and antennae very rapidly for a period of from a few minutes to an hour continously. With genital organs extended, the male moth then threw the tip of the abdomen toward and at right angles to the genital organs of the female moth. When coition was successful the vibration of the wings and antennae was stopped. One male was observed to make 16 unsuccessful thrusts of his abdomen in attempting coition. In copula, the head of the male moth was sometimes at the right side of the female moth and sometimes at the left side; the wings of the female moth were above those of the male or vice versa on the side where the wings came into contact. The tips of the abdomen were directly opposite each other but the heads and thoraces were at right angles, or less than right angles, to each other. The average duration of the copulation period for seven pairs of moths observed in cages was two hours. The moths are polygamous but one mating is apparently sufficient to insure the fertility of the total complement of eggs. Five male moths of *P. nubilalis* lived from 16 to 41 days or an average of 28.4 days and fertilized from one to four females each or an average of 2.4 females. One hundred and eleven virgin female moths were used in this experiment and kept for fertility records; 70 of them deposited eggs. All of the eggs of 12 of these females were fertile.

Males were observed apparently attempting to mate with females which were engaged in depositing eggs. The males were also observed to attempt mating with a female or male which was already in copula but the observations made showed only one instance where any apparent disturbance was affected.

Oviposition Periods.

The preoviposition period of 119 female moths of *P. nubilalis* ranged from 1 to 14 days with an average of 4.4 days, whereas the oviposition period ranged from 1 to 28 days with an average of 12.8 days and the postoviposition period ranged from 0 to 20 days with an average of 2.5 days. There was an average of 1.9 days, a maximum of 13, and a minimum of 0, in the oviposition periods of these 119 female moths of *P. nubilalis* in which no eggs were laid.

Thirty-nine female moths of *P. ainsliei* had a preoviposition period of from 1 to 9 days with an average of 2.97 days; an oviposition period of from 3 to 16 days, with an average of 9.02 days; a postoviposition period of from 0 to 13 days, with an average of 2. 82 days. There was an average of 2.2 days, a maximum of 8 and a minimum of 0, in the oviposition periods of these 39 female moths of *P. ainsliei* in which no eggs were laid.

Eighty female moths of *P. penitalis* had a preoviposition period of from 1 to 5 days with an average of 1.87 days; an oviposition period of from 3 to 21 days, with an average of 9.4 days; a postoviposition period of from 0 to 12 days, with an average of 1.9 days. There was an average of 1.13 days, a maximum of 15 and minimum of 0, in the oviposition periods of these 80 female moths of *P. penitalis* in which no eggs were laid.

It was observed from a small number of female moths which deposited only infertile eggs that the preoviposition period was, on the average, much longer than for moths depositing fertile eggs. The oviposition periods of the same infertile moths were, on the average, much shorter than those of the moths depositing fertile eggs, whereas the postoviposition periods of the same infertile females would average much longer than those of the moths which deposited fertile eggs.

Oviposition Records.

In Table IV, is given in summary form the oviposition records of *P. nubilalis, P. ainsliei,* and *P. penitalis* which were obtained during the three seasons of 1923-1925 inclusive. Under natural conditions eggs of *P. nubilalis* could not be readily found in Ohio until 1924 when a total of 731 clusters containing from 2 to 69 eggs each and averaging 15.5 were observed in the field. Only 6 of 89 clusters observed in the field on July 15, 1924, were found on the upper side of the leaf. In 1925 a total of 1,210 clusters containing from 1 to 64 eggs each were observed

TABLE IV.

Oviposition records of *Pyrausta* spp. at Sandusky, Ohio, 1923–1925.

Generation of—	Number of individuals under observation	Total Number of eggs			Total Number of Clusters			Average Number of eggs per cluster			Average Number of eggs per day over oviposition period			Greatest Number of eggs in one day		
		Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
P. nubilalis, 1922	25	694	0	321	109	2	24	30.8	3.5	14.0	107	8	49.7	271	17	113.8
P. nubilalis, 1923	50	1,075	0	585	88	1	37.14	39.8	2	16.75	67.1	1	40.8	190	2	114.6
P. nubilalis, 1924	53	1,100	0	635	61	1	35.75	39.7	5.2	19.62	103.3	2.36	51.54	281	9	138.4
Totals and averages	*128*	956.3	0	554.5	86	1.3	33.9	36.8	3.6	17.5	92.5	3.79	46.4	247	9.3	124.0
P. ainsliei, 1922	10	396	12	223.4	37	4	24.2	13.6	3	9.23	49	1.3	26.9	127	6	77.1
P. ainsliei, 1923	14	322	0	196.5	42	6	26.4	17.6	4.4	7.99	45.4	8	26	143	43	68.6
P. ainsliei, 1924 (1st)	7	364	24	191.4	33	2	17.7	16.8	4.6	10.8	115	23	22.6	115	23	66.2
P. ainsliei, 1924	2	195	0	97.5	21		10.5	9	1	9	39		39	87		87
P. ainsliei, 1925 (1st)	8	479	18	254	48	6	25	13	3	10.1	36.8	1.6	23.8	140	10	74.5
Totals and Averages	*41*	351	10.8	212.6	36.2	4.5	23.2	14	3.2	9.36	57	8.5	24.7	122.4	20.5	70.2
P. penitalis, 1922 (3rd)	2	416	347	381.5	66	28	47	14.8	5.3	8.1	69.4	69.3	69.4	168	127	147.5
P. penitalis, 1923 (1st)	9	1,921	1,025	1,436	124	34	70.9	40.3	15.5	22.5	225.8	102.6	156.1	867	302	623
P. penitalis, 1923 (3rd)	16	1,050	47	603.6	75	24	45.5	20.7	1.7	13.2	134.6	29.5	67.1	360	24	196.9
P. penitalis, 1924 (1st)	12	1,703	660	1,313	105	20	71.3	65.1	12	18.4	226	90.5	131	603	324	474.8
P. penitalis, 1924 (2nd)	15	1,486	84	729.5	70	8	41.07	25.6	3.3	17.76	194	29	100.6	690	58	366
P. penitalis, 1924 (3rd)	20	906	407	701.4	77	25	47.65	25	10	15.7	122	40	72.73	271	90	200
P. penitalis, 1925 (2nd)	6	1,544	676	1,230	86	42	59.5	31	13	21	186	75	132	517	214	330
Totals and Averages	*80*	1,289.4	463.7	890.9	86.1	25.9	52.5	31.8	8.7	17.1	165.4	62.3	95.9	496.6	162.7	327.9

under natural field conditions. The total number of eggs thus observed was 17,216 eggs and the average number of eggs per cluster was 14.22. Twenty-eight, or 2.3 per cent, of the clusters containing 470, or 2.7 per cent, of the total number of eggs were deposited upon the upper surface of the leaves. The remainder of the eggs were, for the most part, deposited upon the lower surface of the leaves, mostly near the middle or base, and comparatively few near the distal third or tip. A few eggs were observed on the stalk, and husk of ears of sweet corn. Fifty clusters of eggs deposited upon sweet corn that was under observation throughout the period of egg deposition in the field in 1925 showed 8 on the husk of the ear and 30 of the remaining 42 on the fifth to eighth leaves inclusive. Fifty-six clusters similarly observed on field corn showed 46 of these clusters on the fifth to tenth leaves inclusive.

In 1925 an attempt was made to determine which sides of the plants, if any, were preferred by the female moths of *P. nubilalis* for depositing their eggs. On July 9th and 10th, 956 clusters were observed for this purpose in a single field of corn. The results did not indicate much preference for any particular side of the plant upon which to deposit the eggs, though 407, or 42 per cent, of the clusters were recorded as being in the northeast quadrant whereas 392, or 41 per cent, of the clusters were in the southwest quadrant.

In 1925 under natural field conditions 9 egg clusters of *P. ainsliei*, observed on the lower side of the leaves of *Persicaria* and *Apocynum*, contained from 5 to 34 eggs each and the average was 16.5.

Under natural field conditions 221 egg clusters of *P. penitalis* collected on lotus during the seasons of 1924 and 1925 contained from 1 to 108 eggs each and a total of 6,002 eggs, or an average of 27.1 eggs per cluster. The clusters of eggs of *P. penitalis* observed on other hosts in the field apparently were not much more than half as large, on the average, as those found on lotus.

In cages an accurate record was kept of the number of eggs deposited by the female moths of the three species upon the glass. In the case of one female moth of *P. nubilalis* 89.3 per cent of the total number of eggs were deposited upon glass. In 1924 and 1925, of the 95 female moths under observation in cages only 10 failed to deposit eggs on the glass. Of the 62,920 eggs observed in cages during these two seasons, 23.4 per cent were deposited upon the glass.

During the seasons of 1924 and 1925, of the 28 female moths of *P. ainsliei* under observation which deposited eggs, only five failed to deposit on the glass. One female moth of *P. ainsliei* deposited 98 per cent her total complement of eggs upon the glass. Of the 6,486 eggs observed in cages during these two seasons, 24.4 per cent, were deposited upon the glass. During the seasons of 1924 and 1925, of the 68 female moths of *P. penitalis* under observation which deposited eggs, only 11 failed to deposit eggs on the glass. Of the 57,040 eggs observed in cages during these two seasons, 21.2 per cent were deposited upon the glass. One female moth of *P. penitalis* deposited 98 per cent of the total number of her eggs upon glass. Thus the female moths of these three species paralelled one another closely in this habit.

Female moths of the three species which deposited no fertile eggs in the oviposition experiments during 1923-1925 numbered 23 out of 249 individuals under observation. These infertile moths deposited a much smaller number of eggs when compared with the general average of each species. The eggs of the infertile female moths were, for the most part, deposited singly or in small clusters of from 1 to 5 or 6 eggs, except in the case of one individual from which none of the 277 eggs observed for that purpose were fertile and which deposited a total of 845 eggs.

In comparing adult fecundity of the three species of *Pyrausta* under consideration the data in Table IV show that the female moths of *P. penitalis* deposited on the average more than four times as many eggs as did those of *P. ainsliei* and over 60 per cent more than did *P. nubilalis*. The data obtained indicate that the female moths of *P. penitalis* of the first and second generations deposit considerably more eggs than those of the third generation which are the first adults to emerge each season, the generations being considered as beginning with the egg.

In lantern-globe cages the female moths of *Pyrausta nubilalis* were observed to assume a position with the head uppermost on the leaf or glass just before depositing eggs. The end of the abdomen was bent downward and the tip of the ovipositor was apparently rubbed over the surface upon which the eggs were to be placed. The female vibrated the ovipositor until the eggs appeared, when they were apparently pushed against the surface and flattened somewhat. The female usually did not change her position while depositing a single cluster of eggs; however, in several instances the female was observed to back downward while depositing a large cluster of eggs, especially if it was three or four times greater in length than in width. The eggs were ordinarily placed in depressions on the surface of the leaf, such as exist along the sides of the midrib, and were placed with the long axis parallel with the veins of the leaf. The hairs of the leaf often extended through the clusters. As many as seventeen eggs were observed to have been deposited within the period of one minute. One female was observed to deposit 130 eggs in one hour. Usually a period of about five minutes was required for depositing the ordinary cluster which contained from 12 to 20 eggs.

THE EGG.

Five eggs of *P. nubilalis* on corn averaged 1.24 mm. in length and 1.12 mm. in width; seven eggs of *P. ainsliei* on smartweed averaged 1.33 mm. in length and 1.23 mm. in width; nine eggs of *P. penitalis* on smartweed averaged 1.05 mm. in length and 0.87 mm. in width.

The eggs of the three species (Pl. II, Figs. 10-13) are difficult to distinguish from one another when deposited upon smartweed. The eggs of *P. ainsliei* are usually flatter and slightly larger than the eggs of either *P. nubilalis* or *P. penitalis*. The clusters contain a smaller average number of eggs than in the case of the other two species (See Table IV). By the time one-half of the incubation period is passed the head capsule of the larva of *P. ainsliei* shows through the transparent corium of the egg and is light brown or pale tan in color whereas in *P. nubilalis* and *P. penitalis* it is always jet black. The eggs of *P. ainsliei* are deposited in small irregularly shaped masses or in rows and are placed shingle-fashion, each egg overlapping about one-fourth of the adjoining previously deposited egg, and lying at an angle of approximately 15 degrees with the leaf surface.

The eggs of *P. nubilalis* are deposited in irregularly shaped masses and overlap in a shingle-like manner, each egg covering about one-third of the adjoining previously deposited egg and lying at an angle of approximately 30 degrees with the leaf surface. The eggs are white when first deposited and often quite iridescent. Later a cresent-shaped clear space is formed in the center of the egg on its upper surface.

The eggs of *P. penitalis* are deposited in irregularly shaped circular masses and overlap in a shingle-like manner, each covering about three-fourths of the adjoining previously deposited egg and lying at an angle of from 30 to 75 degrees with the leaf surface. The eggs are apparently at first white and on lotus they soon become amber colored. This apparently does not happen when on smartweed or dock. On smartweed, the color of the eggs is very similar to that described for *P. nubilalis*. On lotus, the egg masses are usually more circular and the angle the eggs form with the surface of the leaf upon which they are deposited is about twice as great as when they are placed on smartweed. Under field conditions, the eggs were observed only upon the upper surface of the leaves of lotus and only on the lower surface of leaves of smartweed and dock.

Incubation Period and Viability of Eggs.

Of the 46,353 eggs of *P. nubilalis* observed only 2 per cent failed to hatch. The incubation period for 799 lots of eggs of *P. nubilalis* observed ranged from 4 to 9 days and averaged 5.47 days.

It was also noted that of the 4,350 eggs of *P. ainsliei* observed during the same three seasons, 9 per cent, failed to hatch and the incubation period of 122 lots of eggs observed varied from 5 to 10 days and averaged 7.02 days.

In the case of *P. penitalis* during the same seasons, 1.8 per cent, of the 37,635 eggs observed for this purpose failed to hatch and the incubation period of 301 lots of eggs ranged from 3.3 to 8 days and averaged 5.2 days.

Thus the incubation period of eggs of *P. ainsliei* was about 37 hours longer than for eggs of *P. nubilalis* and about 42 hours longer than for *P. penitalis*. This difference was observed when the eggs were deposited on the same night and kept under the same conditions in the insectary. The eggs of *P. ainsliei* were about 8 per cent less viable than those of *P. nubilalis* and *P. penitalis* under cage conditions. Only 82 or 0.7 per cent of a total of 11,320 eggs of *P. nubilalis* collected in the field in 1924 were observed to be infertile.

The incubation period was determined in confinement by removing the eggs from the lantern-globe cages each morning. A small section of leaf surface about 1 inch square having eggs upon it was cut in order to remove the eggs from the host plant. These sections of leaves having the eggs upon them were then placed in a 1-ounce salve box containing moist blotting paper upon which the cage number and date had been written for future identification. The eggs were then observed daily and moisture was supplied as needed. Near the end of the incubation period the eggs were usually observed twice daily in order to determine more accurately the duration of this period.

The Larva.

(Pl. I, Figs. 3, 6, 9).

Ten larvæ of *P. nubilalis*, apparently full grown ranged from 20 to 28 mm. in length and the average length was 24 mm. The average greatest width of these larvæ was 3.3 mm. Ten larvæ of *P. ainsliei*, apparently full grown ranged from 18 to 24 mm. and averaged 21.5 mm. in length and the average greatest width was 3.0 mm. Five full grown larvæ of *P. penitalis* which had developed in smartweed ranged from 16 to 20 mm. and averaged 18.6 mm. in length and the average greatest width of these individuals was 3.1 mm. Larvæ of *P. penitalis* which develop on lotus are apparently much larger. One very large individual from lotus measured 33 mm. in length by 5 mm. in width.

The larval characters for distinguishing these species from one another have been well given by Heinrich (8). After examining many hundreds of specimens during the seasons 1922-1925 inclusive, the author is of the same opinion as Ellis (6), that Heinrich's use of the anterior epicranial setal group and puncture to separate *nubilalis* from *ainsliei* is the only character that can be used reliably to separate the two species in all larval stages.

The head capsules of the various instars of *P. nubilalis* and *P. ainsliei* were measured with the following average widths given in millimeters:

Number averaged	*1st*	*2nd*	*3rd*	*4th*	*5th*	*6th*
5 *P. nubilalis*	0.41	0.63	1.00	1.62	2.00	
5 *P. nubilalis*	..41	0.58	0.89	1.38	1.86	2.69
5 *P. ainsliei*	0.51	0.73	1.02	1.51	2.32*	

It was noted in these measurements that the head capsule of the *P. ainsliei* in the first instar was slightly larger than that of *P. nubilalis* in the same stage of development ,though the same proportion is not maintained throughout the other instars. The head capsules of individuals of *P. nubilalis* which molted only five times before pupation were on the average somewhat smaller than those of individuals which molted six times.

Larval Metamorphosis.

A summary of the results of the study of larval metamorphosis during 1924 and 1925 is given in Tables V and VI. The mean temperatures for the various periods during which these larvæ were developing

*Six full-grown individuals were measured. They were not the same individuals from which the head capsules of the other instars were measured, as was the case in all measurements of *P. nubilalis*.

were calculated by the aid of a planimeter and the comparative duration of larval instars shows that the temperature was not the controlling factor in causing the difference in the number of molts. Since all the material that was used in this study was kept in the instrument shelter with the thermograph, the temperature records should be acceptable. In comparing the duration of larval instars of *P. nubilalis* for 1924 and 1925 (See Table VI) it will be noted that the duration of the first three instars compared very favorably during the two seasons but that individuals which molted five times had a fourth instar averaging from 2.12 to 4.26 days shorter in duration than for individuals which molted only four times during their larval stage. Although there are only a comparatively small number of individuals for comparison of the duration of the first four larval instars of *P. ainsliei* and *P. penitalis* with those of *P. nubilalis* the length of each period is quite similar, though of somewhat shorter duration in *P. ainsliei* and *P. penitalis.* Only second-generation individuals of *P. penitalis* were observed each season because they only were available at the time when the other work could be done.

Habits of the Larvæ.

Observations made on the habits of the larvæ of *P. ainsliei* closely parallel those recorded by Ainslie and Cartwright (1) in Tennessee. Young larvæ were always found to feed gregariously during the first and second instars of their development. As many as 18 larvæ in the second instar have been found feeding in one internode in smartweed. When the older larvæ enter the smartweed to feed, the entrance hole (Pl. VI, Fig. 42) was always observed to be on the lower side of the leaning stems at the nodes. As many as ten consecutive nodes of one stem of smartweed have been found thus infested. The larvæ of the first generation were not observed to migrate to other hosts to pupate during the same season. No larvæ of *P. ainsliei* unless full grown were observed in any host other than *persicaria.* Migration to other plants from *Persicaria pennsylvanica* was observed both in the fall and again in the spring.

Observation on the larval habits of *P. penitalis* involve both aquatic and terrestrial studies. The feeding habits of the larvæ on smartweed were observed to differ little from those of *P. ainsliei* on the same plant (Pl. VI, Fig. 39) although the larvæ of *P. penitalis* do not enter the plant early in their development and often have the habit of webbing the leaves together and feeding gregariously under the web. Although both *P. ainsliei* and *P. penitalis* have been observed to injure smartweed considerably, the damage on the whole was slight compared with that often done by *P. penitalis* to the lotus in Sandusky Bay (Pl. V, Fig. 34), where the leaves were found in all conditions, sometimes floating, and sometimes extending 20 to 30 inches above the surface of the water. Often these latter leaves were cupped with the margins higher than the centers. Often the larvæ fed along the margins of the leaves and caused them to roll up and form ideal protection. As many as 38 larvæ were found feeding in this manner on one leaf. A large number of the larvæ, upon reaching the third instar, enter the petioles from the top of the floating leaves; however, many of the larvæ continue to feed and

TABLE V.

Duration of larval metamorphosis of *Pyrausta* spp., at Sandusky, Ohio, 1924–1925.

Generation of—	Number of individuals observed	Date Eggs hatched	First instar (Days)			Second instar (Days)			Third instar (Days)			Fourth instar (Days)			Total Days to Fourth Molt			Fifth Instar (Days)				Total Days to Fifth Molt			Mean Temp to date of last molt. DegreesF.
			Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Number of individuals	Max.	Min.	Aver.	Max.	Min.	Aver.	
P. nubilalis, 1924	100	7–12–24 to 8– 4–24	10	3	4.3	9	2	4.5	17	3	4.8	17	2	7.9	32	14	21.6	24	18	5	8.83	37	24	29.12	See Table No. 6
P. nubilalis, 1925	113	6–27–25 to 7– 6–25	11	3	5.2	7	2	3.8	10	3	4.7	16	4	8.5	32	15	22.4	41	14	6	9.37	34	24	28.8	See Table No. 6
Totals and Averages...	*213*		10.5	3	4.8	8	2	4.1	13.5	3	4.7	16.5	3	8.2	32	14.5	22.1	*65*	16	5.5	9.1	35.5	24	28.9	
P. ainsliei, 1924	7	7–17–24	5	5	5	4	2	3	4	3	3.8	9	6	7	20	18	18.8	1	10		10	28		28	70.74
P. ainsliei, 1925	9	7– 9–25	4	3	3.4	7	3	5.1	6	3	4.4	9	4	6.1	22	17	19.1	5	10	6	8	29	22	26.2	70.40
Totals and Averages	*16*		4.5	4	4.1	5.5	2.5	4.1	5	3	4.1	9	5	6.5	21	17.5	19	*6*	10	6	9	28.5	22	26.5	
P. penitalis, 1924 (2nd)	23	8– 6–24	4	3	3.0	6	4	4.6	7	4	5.7	8	4	5.6	22	17	19.1	3	6	1	3.6	23	19	21.3	69.30
P. penitalis, 1925 (2nd)	11	7–21–25	4	3	3.9	4	2	3.0	8	5	6.0	7	4	5.7	22	17	18.8								68.20
Totals and Averages	*34*		4	3	3.3	5	3	4.1	7.5	4.5	5.8	7.5	4	5.7	22	17	19.0								

develop until mature before entering the petiole for pupation. Feeding under webs was observed in all instars (Pl. VI, Fig. 40) though most of this type of feeding was observed to be done gregariously by larvae in the first and second instars. Illustrations (Pl. V, Fig. 34-37) show the characteristic damage to the leaves and pods of lotus by *P. penitalis.* Welch (10) has given an excellent detailed account of the feeding habits of *P. penitalis* on lotus in Sandusky Bay as well as the action of the larvæ in swimming. Doubtless there is some migration from leaf to leaf by swimming, though there is perhaps more through the agency of floating. Some tests were made with larvæ of *P. penitalis, P. ainsliei,* and *P. nubilalis* as to their ability to swim. All three species apparently have similar integuments which resist the water and enable them to utilize the surface film in remaining afloat. None of the larvæ of these species showed any ability to swim after they had broken through the

TABLE VI.

Comparative duration of larval metamorphosis of *Pyrausta nubilalis* at Sandusky, Ohio, 1924–1925.

Generation	No. Observed	Total No. of molts	Average number of days in—					Mean temp. during larval development to 4th molt. Degrees F.	Average number of days in—		Mean temp. during larval development to 5th molt. Degrees F.
			1st Instar	2nd Instar	3rd Instar	4th Instars	Total of four Instar		5th Instar	Total of five Instars	
1924	76	4	4.31	4.45	4.83	8.45	22.04	71.10			
1924	24	5	4.32	4.94	4.71	6.33	20.30		8.82	29.12	70.50
1925	72	4	5.32	3.79	4.92	10.14	24.17	71.96			
1925	41	5	5.17	3.90	4.51	5.88	19.46		9.37	28.83	71.13

surface film; even though they went through the same jerky movements which permitted them to make some progress on the surface of the water, they slowly sank to the bottom.

Upon hatching the young larvæ of *P. nubilalis* (Pl. II, Fig. 18) are very active and usually feed first upon the epidermis of the leaves when it is tender before entering the buds of the tassel or the stalk of the corn plant. Special observations showed that the percentage of mortality of the larvæ of *P. nubilalis* was very much higher during the first and second instars of their development when not uncommonly 75 per cent of the young larvæ failed to continue their development. The stalk of the tassel is a favorite feeding place in which the central pith is destroyed and the tassel is caused to fall over, usually remaining partly attached to the plant. (Pl. VI, Fig. 38).

If the larvæ do not gain entrance to the plant through the bud or crown, they enter at a node lower down where the leaf sheath surrounds the stem. Their presence is easily recognized here as well as higher up in the stalk (Pl. VI, Fig. 41) by the sawdust-like castings which collect on the axils of the leaf or remain very conspicuously on the side of the stalk. Tunnelling in the lower parts of the stalk is frequent.

The tunnelling is not confined entirely within an internode and is also not parallel to the vascular bundles, but the tunnels may run in almost any fashion and weaken the stalk in a most pronounced manner. A preference for the pedicels is often shown by the larvæ, which frequently enter the ears in this way (Pl. V, Fig. 33), boring through all parts of the cob and grain. Not infrequently the injury to the ear (Pl. V, Fig. 32), without the presence of the larvæ which were responsible for it, is difficult if not impossible to distinguish from that of the corn ear worm. During August and September of 1923, 224, or 8.7 per cent, of 2,568 larvæ collected were found in the ears. In 1924, 110, or 5.7 per cent, of 1,937 larvæ collected during August and September were found in the ears.

The full-grown larvæ, especially of *P. nubilalis*, after finishing most of their feeding, seem to possess a restless disposition and usually migrate considerably. Quite frequently the larvæ leave a stalk one or more times only to re-enter it at some other point. Often several stalks are entered by a single larva.

Winter Mortalitty.

Winter-killing of the larvæ of *P. nubilalis* is not a factor of any great importance in keeping this insect in check. In April, 1924, 1,112 larvæ were observed for this purpose and 69, or 6.2 per cent, were found dead, their death being attributed to winter-killing. During the spring of 1925, a total of 1,660 larvæ were observed and 154, or 9.3 per cent, were found dead.

No definite counts on a large scale were made to determine the percentage of winter mortality of larvæ of *P. penitalis* and *P. ainsliei* in the field. From general observations, however, these two species do not suffer any greater mortality on account of winter-killing than does *P. nubilalis*. During the spring of 1925, of 154 individuals of *P. penitalis* which were observed under natural field conditions only 4, or 2.59 per cent, were found dead, their death being attributed to winter-killing.

Hibernation.

The larvæ of *P. nubilalis* are able to hibernate under unfavorable conditions and, although delayed, a comparatively large percentage are able to transform into adults.

The tendency toward pupation in the soil was greater than was anticipated but it is very doubtful if successful emergence follows such pupation under normal field conditions. Unless crop refuse for pupation were at hand, cultivation and the weathering of the soil would almost certainly preclude successful pupation and adult emergence. Pupation in the soil was tested in a preliminary way in the spring of 1925 by placing a large number of active larvæ among clods in two cages 3 feet by 5 feet which contained the usual recovery traps of corrugated paper and were tightly covered by fine copper-screen wire. The results showed that four individuals emerged from the clods as adults, or 6.8 per cent of the larvæ otherwise unaccounted for.

In the spring of 1925, a suprisingly large number of larvæ of *P. nubilalis* per acre were found in cornstalks and weeds on the surface of the land. The plant remains on an area of 48 square rods distributed throughout seven fields which had from 3 to 31 per cent of their stalks infested by *P. nubilalis* in 1924 contained 110 larvæ, or an average of 366 per acre. These fields were examined between April 24 and May 29 and contained from 106 to 768 larvæ per acre each, according to these data.

Observations on Control Factors.

Trap Crops.

The possibility of using early sweet corn as a trap crop to aid in the control of *P. nubilalis* was a matter of special investigation in 1924. Accurate dates of planting were obtained upon fields of sweet corn and dent corn which were located near together in 19 instances in 11 townships in northern Ohio and Monroe County Michigan. Field counts to determine the value of trap crops were made in these fields, and under the existing status of the infestation by *P. nubilalis* the results obtained were negative. In 1925, 14 similar comparative examinations were made in seven townships in the same area as during the previous year, and the results obtained were similar in that they indicated that early sweet corn did not function as a trap crop under the conditions of the existing sparse infestation.

The comparative infestation by *P. nubilalis* of sweet corn and dent corn was observed each season during 1922 to 1925 and during 1922 sweet corn seemed to be slightly more infested than dent corn. The results obtained during 1923 to 1925 are tabulated in Table VII which shows that during 1923 the larval population was much greater in the fields of dent corn than in those of sweet corn examined. This was because the maximum infestation for the season was found in some large fields of dent corn, late in the season when it was too late to make counts in proportionate areas of lighter infestation. By giving weighted averages of these acreages which included these fields, the figures given above were obtained. The difference in larval population is apparently due to the comparative ability of the larvæ to establish themselves on sweet corn and dent corn rather than to preference of the sweet corn by the moths as was shown by other observations which lack of space prevents recording here.

Observations on the comparative infestation by *P. nubilalis* in relation to the time of planting both sweet and dent corn were started by the writer in 1923 and continued during 1924 and 1925. Accurate dates of planting were obtained in all instances. A total of 137 fields of sweet corn and 138 fields of dent corn were examined for this purpose during the three seasons. A summary of these examinations each season indicated that all corn planted after June 1 showed much less infestation than earlier plantings under the existing status of the sparse infestation. Caffrey (3, p. 105) has published the detailed summary of examinations made in 1924.

TABLE VII.

Comparative infestation of sweet corn and dent corn by *P. nubilalis.*

Year	Number of Fields		Percent of Stalks Infested		Average Number of Larvæ per Infested Stalk		Number of larvæ per 100 Stalks. (inf. and uninf.)	
	Sweet	Dent	Sweet	Dent	Sweet	Dent	Sweet	Dent
1923	73	59	0.3	2.4	1.6	1.4	0.5	3.4
1924	102	139	6.3	4.9	2.5	1.4	16.0	7.2
1925	86	137	8.4	6.4	1.9	1.2	16.7	7.9

Experimental Plantings.

During 1922 and 1923 a very sparse infestation by *P. nubilalis* was obtained in the experimental plantings at Sandusky, Ohio. During 1924 and 1925 plantings were continued in cooperation with the Department of Agronomy, Ohio Agricultural Experiment Station, and the varieties were selected in accordance with the recommendations from that Department after considering the needs from the standpoint of the corn borer problem. Plantings of all plots and harvesting of the dent corn in order to obtain accurate data on yields were personally directed by Mr. L. E. Thatcher and Mr. C. E. Dike. Table VIII gives the summary of the infestation in these plantings. It is recognized that the sparse infestation obtained makes these data of doubtful value in predicting what would occur under conditions of a heavy infestation by *P. nubilalis.* The results obtained indicate that the early planted and more rapidly developing varieties are most subject to infestation if equidistant from the source of the infestation. No tendency of any importance toward immunity has been observed for any variety yet planted for this purpose, and the maximum infest-

TABLE VIII.

Percentage of stalks infested by *P. nubilalis* in experimental plantings at Sandusky, Ohio, 1924–1925.

Variety*	Dates of Planting												Average† for Variety	
	5-1	4-27	5-9	5-7	5-19	5-18	5-28	5-28	6-10	6-8	6-20	6-18		
	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925
Golden Bantam...	4.36	3.04	2.23	4.96	0.70	4.99	0.93	10.00	0	0.77	0	0	1.95	3.99
Stowell's Evergreen......	1.95	3.22	0.40	1.11	0	1.40	0.30	2.69	0	0.23	0	0	0.52	1.17
Country Gentleman......	0		0.48		0		0		0.30		0		0.42	
Red Evergreen....		4.35		2.80		2.30		5.51		0.12		0		2.5
Leaming..........			1.92	1.62	1.92	1.31	4.11	2.53	0.19	0.47	0	0	1.64	1.18
Burr-Leaming.....			4.66	1.34	5.71	0.94	3.07	1.60	0.40	1.02	0	0	2.53	1.00
Clarage...........			3.55	2.56	1.42	3.23	2.09	3.63	2.25	0.32	0.59	0	1.94	1.93
Golden Glow.....				4.79		3.27		4.11		1.12		0		2.64
Low Ear..........				5.45		5.17		6.34		0.65		0.45		3.62
Van Wye's........				2.24		4.29		3.95		0.11		0		2.13
Stone's Calico.....			4.94		5.13		5.57		2.94		0.19		3.90	
Silver King.......			6.19		9.20		4.54		1.33		0		4.06	
Reid's Yellow Dent...........			1.45		4.42		1.77		1.64		0.20		1.94	
Low % Grain Ave. (Clarage)..			3.63		3.27		1.98		1.24		0		1.95	
Northwestern Dent...........			4.81		0		3.16		2.56		0		2.11	
Ivory King.......			1.17		2.27		0		0.52		0		0.73	
Averages†........	2.41	3.91	3.53	3.06	3.63	3.04	2.86	4.68	1.27	0.54	0.12	0.05	2.17	2.31

*All varieties were planted in triplicate plots each one-fortieth acre in area on each date in 1925. During 1924 all varieties except Burr-Leaming, Ivory King, and Northwestern Dent were planted in duplicate on each date.
†Only weighted averages are given.

ation has been found in corn which was planted at about the date for obtaining the optimum yeild, or in earlier plantings. Reference to yield is made to dent corn only. Special observations in the experimental plantings during 1925 indicated that corn planted May 28 developed more rapidly than that planted earlier and thus was taller and in a more thrifty condition during the time most of the moths were in flight.

Cultural Methods.

The effectiveness of disking corn stubble fields as a control measure for *P. nubilalis*, was tested on a small area of stubble during 1924, and again during 1925 and in each instance was found to be an unsatisfactory practice.

Previous to 1923 material of *P. nubilalis* was not abundant enough for plowing experiments in Ohio. Preliminary experiments were started in the fall of that year with artificially infested material. These experiments, together with hand burials of artificially infested stalks containing 750 larvæ, indicated that most of the larvæ which were plowed under or buried before November 1 migrated to the surface during the fall and that the remainder came to the surface during the following spring, as did practically all of those which were plowed under or buried in November. From 8 to 72 per cent of the larvæ were recovered in the traps; the remainder either escaped the traps, were destroyed by birds, moles, mice, ants, beetles, and other predators or died and disintergated in the soil where no trace was left of them. All plowing referred to in this paper was done to a depth of approximately 6 inches with a 14-inch walking plow which was pulled by two horses.

In the spring of 1924 a similar series of plowings were made. These experiments were closed on June 10 and showed that less than 8 per cent of the larvæ remained in the stalks under the surface, whereas 33 per cent were recovered in the traps. In the spring of 1924, 1,250 larvæ were buried in artificially infested cornstalks in two different types of soil at 10 day intervals from April 12 to May 31. These results obtained were extremely variable and only indicated the need for further work under more natural conditions.

During the fall of 1924, an area 16 feet by 16 feet, containing approximately 100 larvæ (the exact number was recorded in each instance) in 12-inch corn stubble was plowed under weekly from September 16 to December 5. These larvæ were allowed to enter the standing stubble via nail holes and were well established before the plowings were made. No larvæ were recovered in the fall from the last two plowings in this series whereas as high as 51 per cent were recovered in some of the traps around the areas which were plowed under earlier. In the spring of 1925, however, the reverse was true and from 4 to 12 percent of the total number of the larvae plowed under in this series in the fall before November 1 were recovered whereas as high as 51 per cent were recovered from the areas which were plowed under after November 7. Of a total of 1,110 larvæ plowed under in the fall, 279, or 25 per cent, were recovered in the fall and 241, or 22 per cent, were recovered from these same areas during the following spring. These experiments were closed on June 9 and 10, 1925, when all stubble was dug up and examined thoroughly. A total of 18 living larvæ, 2 living pupa, and two dead larvæ were found. Most of this material was found in stubble on or near the surface which was there because of settling of the soil or its washing by rains.

From March 24 to May 18, 1925, similar experiments were continued at weekly intervals when 12 more areas containing 1,155 larvæ (after subtracting 9.2 per cent which was the percentage of winter mortality determined) were plowed under. From 19 to 55 per cent of the larvæ were recovered in the traps around the various areas and the total recovery in traps was 38 per cent. When these experiments were closed, on June 10-12, a total of 45 living and 6 dead individuals were accounted for in the stubble which was carefully examined. In addition to the foregoing 1,500 naturally infested, especially selected stalks containing one larva each were plowed under, 500 each on April 13, 27, and May 11, respectively. From 21 to 38 per cent of the larvæ were recovered in the traps and a total of 22.8 per cent. These experiments were closed June 12 and 12 living and 5 dead individuals were found in the stalks. From September 19 to May 18 a total of 3,765 larvæ were plowed under and 1,403 or 37.3 per cent, were recovered in traps. From the data obtained in these experiments it would seem that plowing could not be recommended as a satisfactory control measure for this insect. Crawford (5) has found in Ontario under conditions of serious infestation by *P. nubilalis* that clean plowing is an effective control. Opportunity to test this measure under similar conditions in Ohio has not yet presented itself and it is to be hoped that if such conditions should arise, clean plowing will result in as effective a control in Ohio as it has been found to be in Ontario.

In connection with plowing experiments tests were made in order to compare naturally infested material with that which was artificially infested, and it was found that approximately the same percentage of larvæ were ultimately recovered in the traps although most of the larvæ in the artificially infested material if buried within 24 hours after entering the stalks had a tendency to come to the surface somewhat earlier than those in naturally infested stalks. In connection with the plowing experiments some larvæ of *P. penitalis* were plowed under in smartweed and they exhibited the same habits as did *P. nubilalis* in coming to the surface both in the fall and in the spring.

Enemies.

In Ohio, *P. nubilalis* is rarely attacked by native parasites. A few specimens of each species as listed in Table IX have been reared from field collections. A few specimens of *Microbracon gelechiæ* Ashm. were reared from material collected in Erie and Lucas Counties, both in 1924 and 1925. *Trichogramma minutum* Riley was reared from eggs of *P. nubilalis* collected in Erie and Lucas Counties in 1925. In 1923, 6 out of 49 larvæ collected upon one occasion were parasitized by a tachinid. Unfortunately this material was destroyed before a specific determination was obtained.

Table IX gives a list of ten species of parasites which were reared from field collections of *P. penitalis* during the seasons of 1922-1925. No additional species were added to this list during 1925 although a large number of parasites were collected. This was likewise true of collections of *P. ainsliei*, from which four species of primary parasites, as listed in Table IX were reared from field collections. In addition to these a number of specimens of *Dibrachys boucheanus* Riley and of a species of *Pteromalidæ* were reared as secondary parasites from dipterous pupæ (probably *Panzeria penitalis Coq.*) which had developed upon larvæ of *P. ainsliei*. *Rogas rileyi* Cress. and *Exorista pyste* Walk. were reared from field collections of *P. penitalis* or *P. ainsliei* in 1922. The exact host of these parasites could not be determined since the head capsules of the larvæ upon which these parasites had developed were accidentally lost in the wind when this material was collected.

Parasites undoubtedly are an important factor in controlling the abundance of *P. ainsliei* and *P. penitalis* in northern Ohio. *Microbracon caulicola* Gahan and *Panzeria penitalis* Coq. were by far the most numerous of the parasites reared from field collections. *Apanteles harti* Vier. was found to be of some importance as a parasite of *P. penitalis* on lotus. This parasite was never reared from *P. penitalis* on other host plants. No egg parasites of *P. ainsliei* and *P. penitalis* were reared. All of the primary parasites of *P. ainsliei* and *P. penitalis* referred to above were strictly larval parasites with the exception of *Labrorychus prismaticus* Nort., which emerged from pupæ of *P. penitalis*.

Some collections of *P. ainsliei* and *P. penitalis* from smartweed late in the fall, or in the spring before these species pupated, yielded as high as 85 per cent of parasitized larvæ and not uncommonly as many as 50 per cent of the larvæ were thus attacked.

TABLE IX.

List of parasites reared from field collections of *Pyrausta* spp. in northern Ohio, 1922–1925.

Pyrausta nubilalis:
1. *Microbracon gelechiæ* (Ashm.).
2. *Lixophaga variabilis* Coq.
3. *Trichogramma minutum* Riley.

Pyrausta penitalis:
1. *Microbracon caulicola* Gahan.
2. *Meteorus loxostegei* Vier.
3. *Microgaster epagoges* Gahan.
4. *Apanteles harti* Vier.
5. *Bassus agilis* Cress.
6. *Labrorychus prismaticus* (Nort.).
7. *Microgaster* sp.
8. *Meteorus* sp.
9. *Panzeria penitalis* Coq.
10. *Lixophaga variabilis* Coq.

Pyrausta ainsliei:
1. *Microbracon caulicola* Gahan.
2. *Microbracon epagoges* Gahan.
3. *Bassus agilis* Cress.
4. *Panzeria penitalis* Coq.
5. *Dibrachys boucheanus* Ratz. (Secondary on dipterous pupa).
6. *Pteromalid.* (Secondary on dipterous pupa).
7. *Rogas rileyi* Cress.? (See page 82).
8. *Exortista pyste* Walk.? (See page 82).

No predators of *P. ainsliei* and *P. penitalis* were actually observed though some species were strongly suspected of attacking eggs and larvæ of these two insects. The petioles of floating leaves of lotus at the point where the larvæ or pupæ of *P. penitalis* had been located were often observed to be torn open as described by Ainslie and Cartwright (1, p. 12-13). The depredator which was responsible for this work which occurred at irregular intervals was not observed while actively engaged in destroying *P. penitalis*, a large number of which were destroyed at certain times.

In a few instances larvæ of Coccinellidæ and Chrysopidæ were observed to feed upon larvæ of *P. nubilalis*. All attempts to rear these predators to adult were unsuccessful. The adults of some of the coccinellids were also strongly suspected of feeding upon eggs of *P. nubilalis* under natural field conditions in a few instances, although this was also not actually observed to occur. In the spring of 1924, in connection with plowing experiments, some larvæ of Elateridæ, determined by Mr. J. A. Hyslop as species of *Limonius* and *Melanotus*, were observed in a few instances to be attacking and killing larvæ of *P. nubilalis* in cornstalks under the surface of the ground. At the request of Mr. Hyslop an attempt to rear these wireworms to adult was made in order to secure more specific determination. No adults have emerged to date (January, 1926). In 1-ounce tin salve-box cages, when the larvæ of these wireworms were given a choice of a freshly sprouted grain of corn and a living larva of *P. nubilalis*, about 35 per cent seemed to attack and kill the larva of *P. nubilalis* in preference to feeding on the corn. It is not the intention to imply that wireworms will ever become a factor in the control of *P. nubilalis*.

The studies which are reported in this paper indicate that the affinities of *P. nubilalis*, *P. penitalis*, and *P. ainsliei* are close. Apparently these species are by far more closely related to one another than to any others of the same genus. *P. nubilalis* was first described in 1796, and what is generally accepted as one and the same species, though it has widely different habits, has been reported from many countries in the eastern half of the northern hemisphere varying in latitude from 13 to 58 degrees. *P. penitalis* was first described in 1876 and *P. ainsliei*, though it is now known to have been confused in the earlier records with *P. penitalis*, was first described in 1919. Both of these species, apparently, have been reported only from the eastern part of the United States. The aquatic adaptations of *P. penitalis* indicate that it may be of the most recent origin. The affinities and origins of these species are suggested only in the hope of attracting interest in further study along this line. The possible economic value of the close affinity of these species should not overlooked in considering the enemies of *P. ainsliei* and *P. penitalis* as aids in the control of *P. nubilalis*. Thus far only one parasite of *P. penitalis* has been reared from field collections of *P. nubilalis* in Ohio. It should be stated, however, that little time for this work was available. It is greatly to be hoped that, as *P. nubilalis* becomes more abundant, the parasites of *P. ainsliei* and *P. penitalis* will attack it in greater proportions than at present.

SUMMARY.

1. *Pyrausta nubilalis*, the European corn borer, was first discovered in Ohio and Michigan in 1921 and up to January 1, 1926, infestation had been reported from 315 townships totalling 8,529 square miles in area in 31 counties in Ohio and 176 townships totalling 6,232 square miles in area in 15 counties in Michigan. The importance of our corn crop and the rapid increase in infestation by this insect, both in area and in intensity, in this section and its well-known capacity for causing severe losses in Ontario make this species one of the greatest potential insect enemies yet introduced into the United States.

2. The two nearest related species, *P. ainsliei*, the smartweed borer, and *P. penitalis*, the lotus borer, have not been found to be of economic importance, but because of their similarity in appearance in each of the stages they are often mistaken for one another as well as for *P. nubilalis*.

3. In Ohio and Michigan, *P. nubilalis* preferred corn as a host plant, *P. ainsliei* preferred smartweed, and *P. penitalis* preferred lotus and smartweed. In confinement *P. nubilalis* was reared from egg to mature larva upon 30 of 63 species of host plants offered, *P. penitalis* upon 17 of 72 species of plants offered, and *P. ainsliei* upon 8 of 46 species offered. All three species migrated considerably during their larval stage and were often found in many plants upon which the young larva did not develop. This caused confusion in the idenity of the three species.

4. These species overwintered as full-grown larvæ in their respective food and shelter plants. *P. nubilalis* has been found to pass through only one generation each year at Sandusky, Ohio, whereas *P. ainsliei* passed through one generation and about 50 per cent of a second generation each year, and *P. penitalis* normally passed through three complete generations when feeding upon lotus.

5. Detailed life-history studies indicated no distinct variations of importance in the habits of the three species except that the average number of eggs per female moth in cages was 212 for *P. ainsliei*; 554 for *P. nubilalis*; and 890 for *P. penitalis*. The viability of the eggs under observation for that purpose varied from 90 to 98 per cent. The larvæ normally molted four or five times and the number and duration of instars of the three species compared closely.

6. Winter mortality was not an important factor in the control of these species. Mortality of larvæ of *P. nubilalis* was very much greater during the early instars of their development. A large percentage of the young larvæ failed to complete their development.

7. Experimental plantings of several varieties of corn during three seasons indicated, under the existing status of light infestation, no appreciable varietal immunity to *P. nubilalis*; also, that corn planted on the optimum (or earlier) dates of planting contained more infestation by *P. nubilalis* on the average than corn planted after June 1st at Sandusky, Ohio.

8. Preliminary experiments on disking and plowing as aids to the control of *P. nubilalis* indicated that these methods could not be relied upon as a complete control.

9. Native parasites were an important factor in the control of *P. ainsliei* and *P. penitalis* but have seldom been observed to attack *P. nubilalis*. The value of the enemies of *P. ainsliei* and *P. penitalis* as possible aids in the control of *P. nubilalis*, however, should not be underestimated.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. Adult female of *Pyrausta nubilalis.* About 2×.
Fig. 2. Adult male of *Pyrausta nubilalis.* About 2×.
Fig. 3. Full-grown larva of *Pyrausta nubilalis.* About 2×.
Fig. 4. Adult female of *Pyrausta ainsliei.* About 2×.
Fig. 5. Adult male of *Pyrausts ainsliei.*. About 2×.
Fig. 6. Full-grown larva of *Pyrausta ainsliei.* About 2×.
Fig. 7. Adult female of *Pyrausta penitalis.* About 2×.
Fig. 8. Adult male of *Pyrausta penitalis.* About 2×.
Fig. 9. Full-grown larva of *Pyrausta penitalis.* About 2×.

Plate II.

Fig. 10. Average sized egg cluster of *Pyrausta nubilalis,* on corn. About 2×.
Fig. 11. Egg cluster of *Pyrausta nubilalis* about 36 hours before hatching. About 2×.
Fig. 12. Egg cluster of *Pyrausta penitalis,* on lotus. About 2×.
Fig. 13. Two egg clusters of *Pyrausta ainsliei,* on *Persicaria pennsylvanica.* About 2×.
Fig. 14. Two pupæ of *Pyrausta nubilalis.* About 2×.
Fig. 15. Lateral view of pupa of *Pyrausta ainsliei.* About 2×.
Fig. 16. Ventro-lateral view of pupa of *Pyrausta ainsliei.* About 2×.
Fig. 17. Dorsal view of pupa of *Pyrausta penitalis.* About 2×.
Fig. 18. Larvæ of *Pyrausta nubilalis* just hatching out. About 2×.
Fig. 19. Pupa of *Pyrausta penitalis* in lotus petiole with cocoon removed which is shown in Figure 21. About 2×.
Fig. 20. Pupa of *Pyrausta penitalis* in smartweed showing absence of cocoon formation. About 2×.
Fig. 21. Pupa of *Pyrausta penitalis* in lotus showing cocoon formation and cap used at upper end of petiole of floating leaves in order to exclude the water. About 2×.

Plate III.

Fig. 22. Pupæ of *Pyrausta nubilalis* in situ in pupal chamber in cornstalk, about natural size.
Fig. 23. External appearance of exit from pupal chamber of *Pyrausta nubilalis* in cornstalks. The exit at the right has been closed by the larva by spinning a web before pupating; the exit at the left was left closed by a thin section of epidermis. 2×.
Fig. 24. Internal appearance of exit hole shown in Figure 23 on the right. 2×.
Fig. 25. Cage used for obtaining number and duration of larval instars.
Fig. 26. Method of keeping head capsules of the larvæ observed for number of larval instars.
Fig. 27. Glass tubes in which duration of pupation was recorded.

Plate IV.

Fig. 28. Glass vials with wire screen covers in which rearing of larvæ was carried on; also experiments on duration of pupation, and host preferences in confinement.
Fig. 29. Tin can for confining a definite number of larvæ to host material.
Fig. 30. Lantern-globe cage used in experiments on oviposition, etc.
Fig. 31. Plowing experiments, May, 1924.

Plate V.

Fig. 32. Sweet corn infested by *Pyrausta nubilalis.*

Fig. 33. Larva of *Pyrausta nubilalis* which has entered butt end of ear.

Fig. 34. Lotus plantation in Sandusky Bay. Note rolled-up leaf at right and also the general appearance of the damage to the leaves above the surface of the water, by *P. penitalis.*

Fig. 35. Floating leaf of lotus showing typical injury, to upper surface, in early stages, by *P. penitalis.*

Fig. 36. Distorted and dwarfed seed pods of lotus infested by *Pyrausta penitalis.*

Fig. 37. The pods shown in Figure 36 dissected to show pupa of *Pyrausta penitalis* and injury by the larva.

Plate VI.

Fig. 38. Injury to corn by *Pyrausta nubilalis*, showing typical breaking-over of the tassel which remained attached.

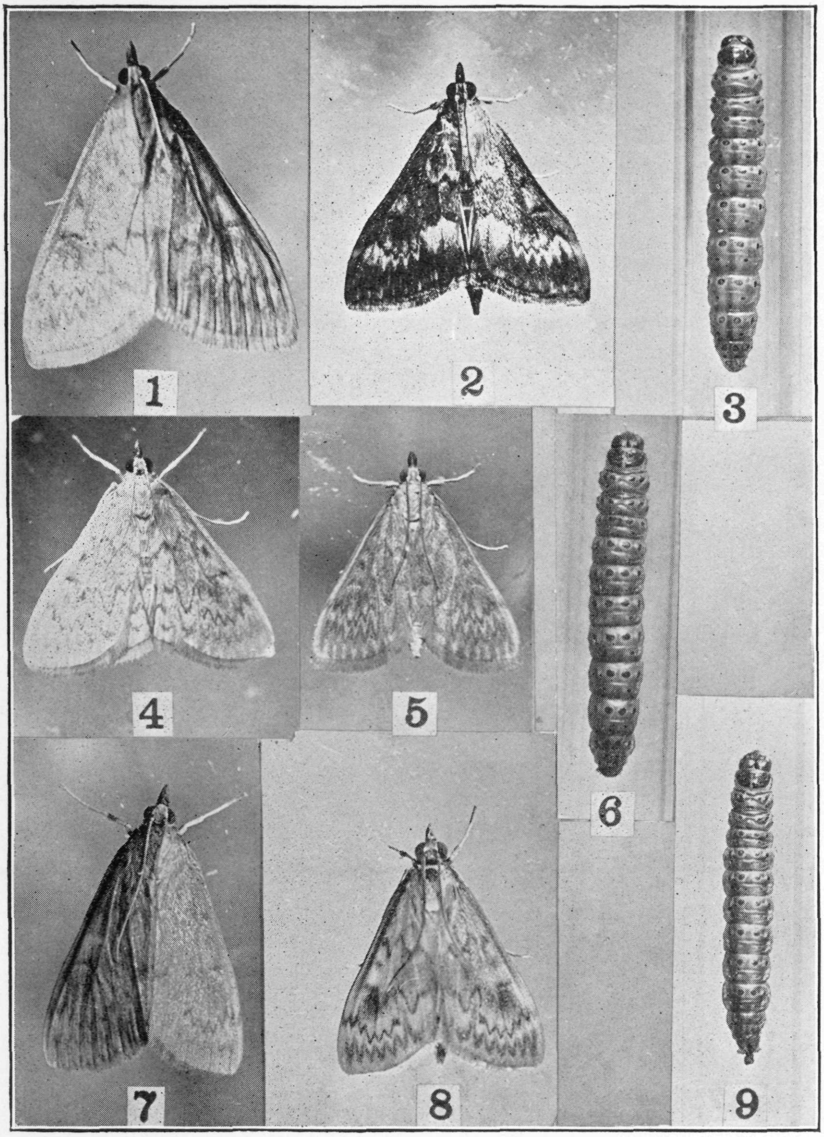
Fig. 39. Stems of smartweed dissected to show feeding tunnels made by larvæ of *Pyrausta ainsliei* and *penitalis.*

Fig. 40. Larvæ of *Pyrausta penitalis* feeding under their web on floating leaf of lotus. The white spots on the leaf at the left indicate places where the green epidermis has been removed by the larvæ.

Fig. 41. Characteristic injury to corn by *Pyrausta nubilalis* under conditions of sparse infestation. Note stalk at right with tassel broken over and frass attached to stalk immediately below.

Fig. 42. Stems of smartweed infested with *Pyrausta ainsliei.* Note entrance holes at every node.

Fig. 43. Cages used for overwintering material. Migration trap was placed around these cages, to prevent escape of larvæ.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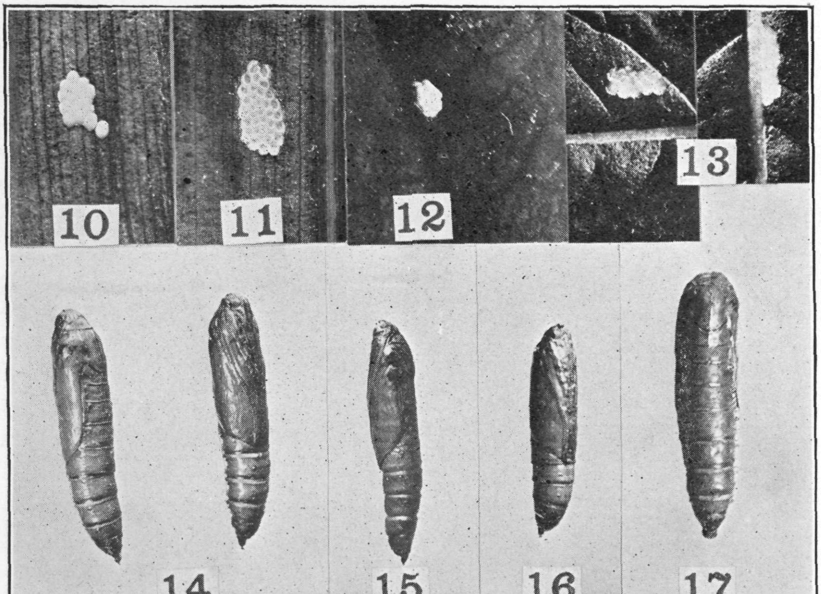
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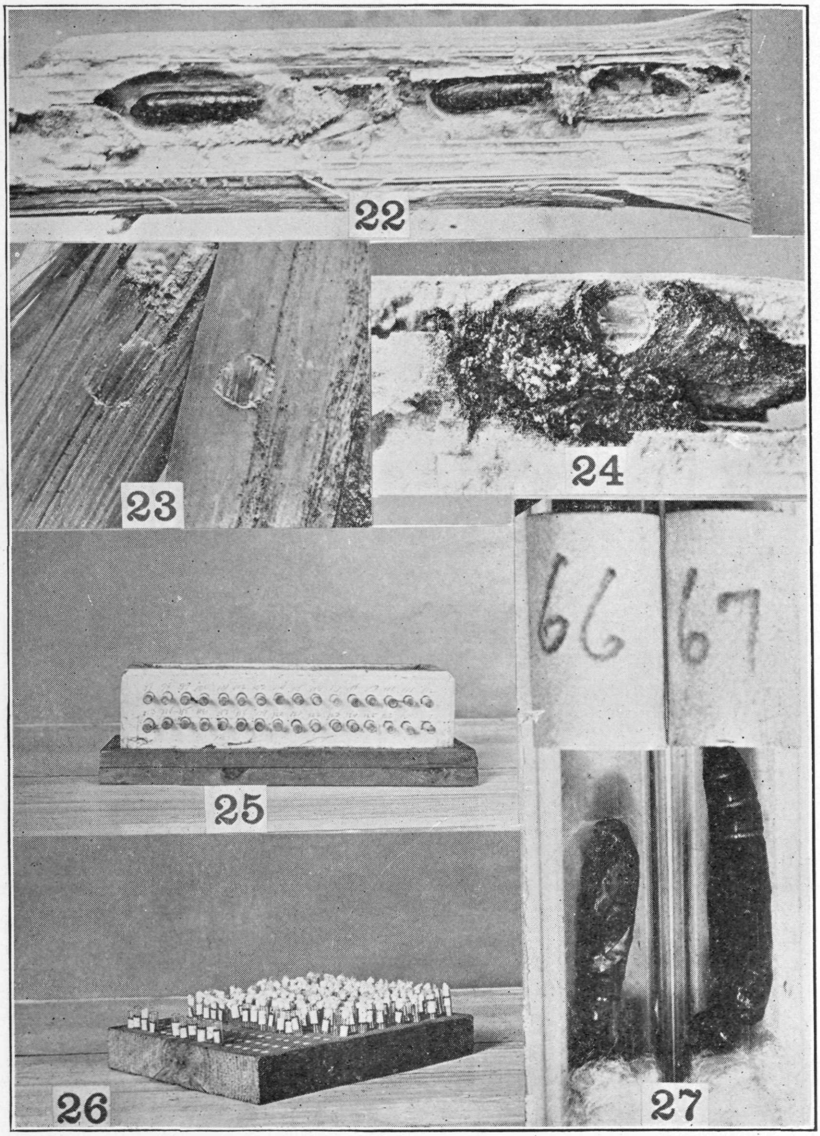
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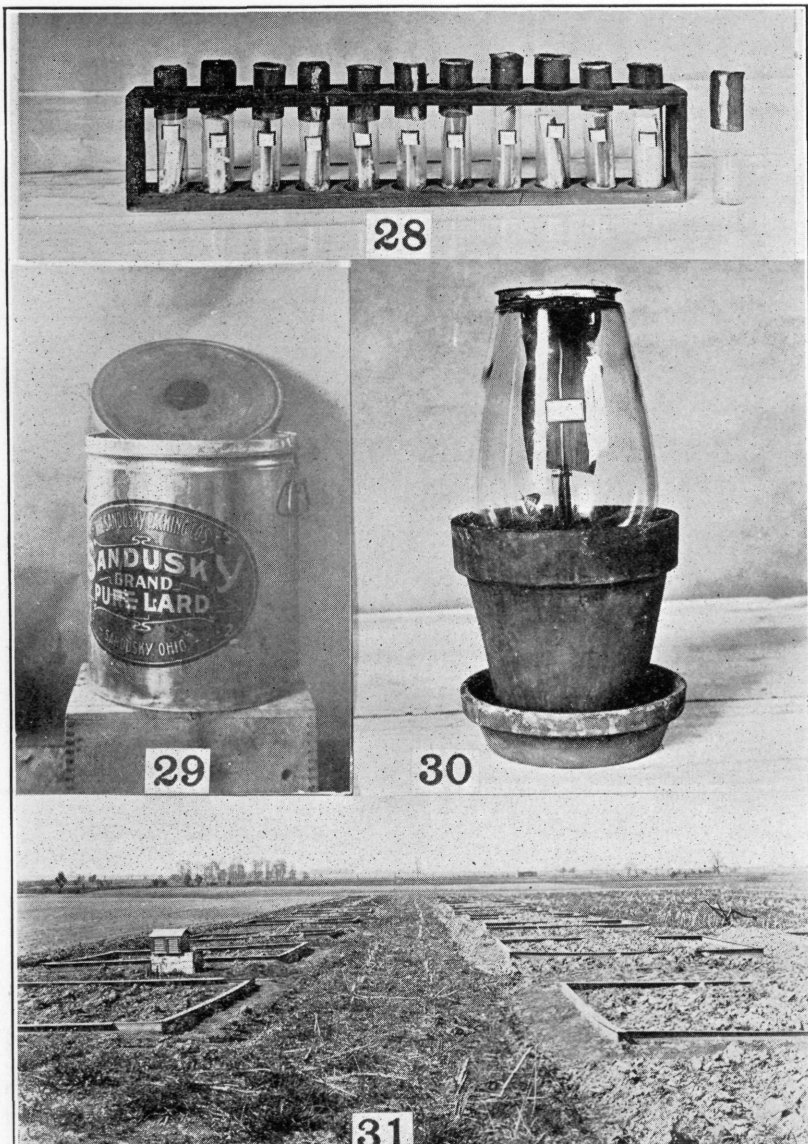
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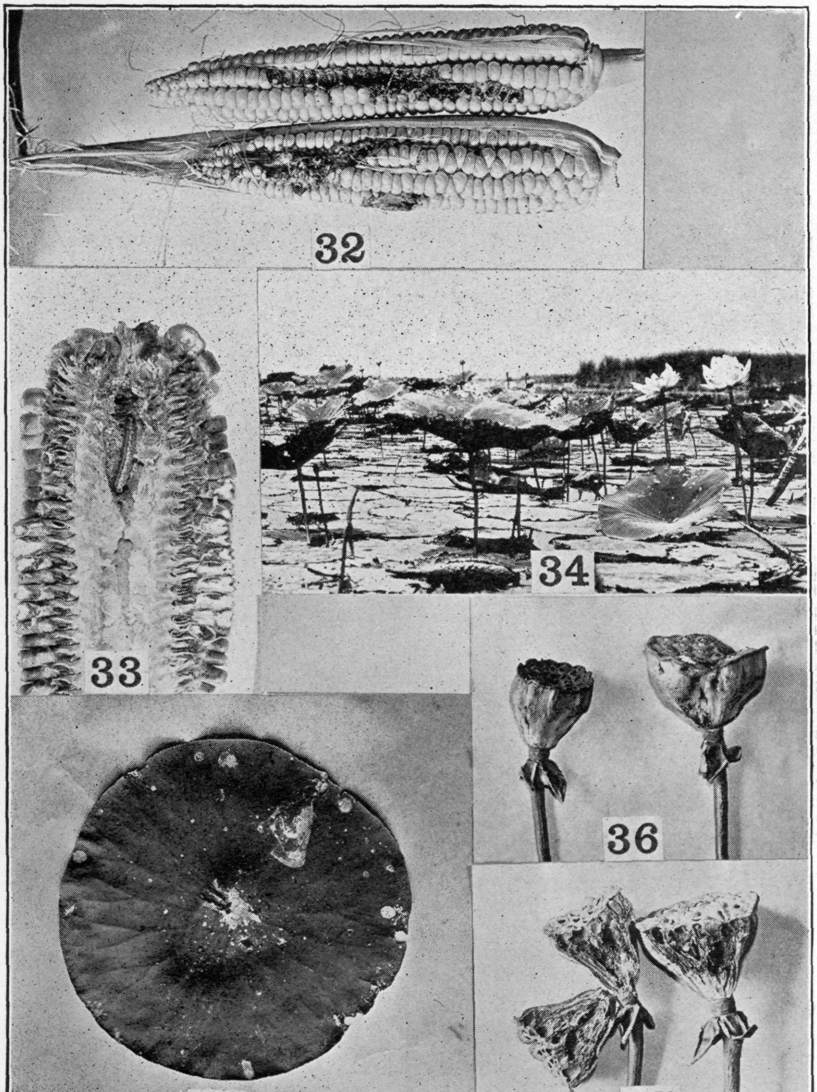
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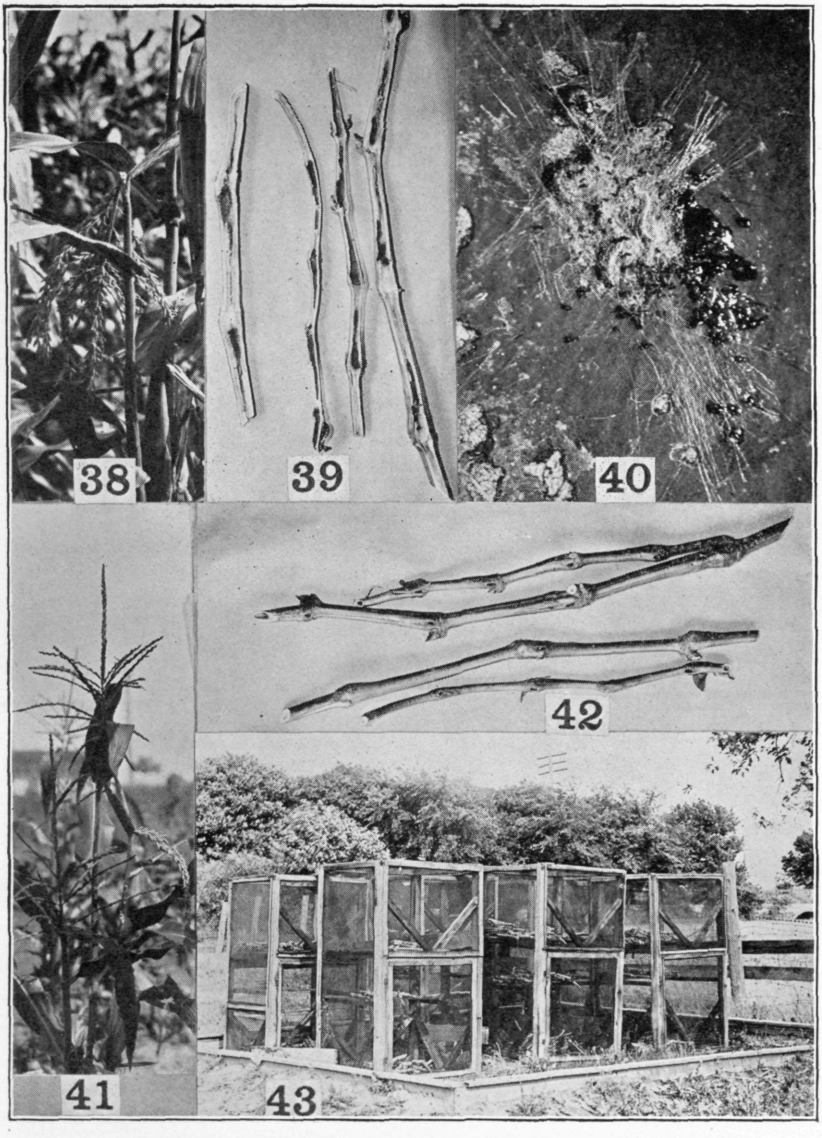
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