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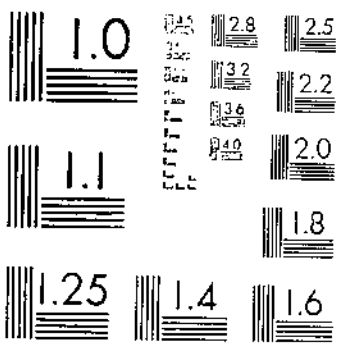
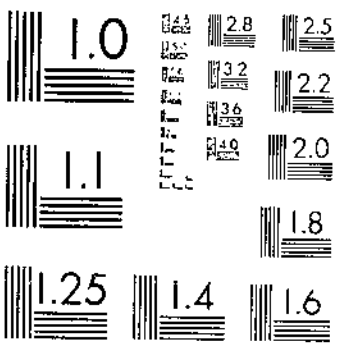


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



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WASHINGTON, D. C.

BIOLOGY AND MORPHOLOGY OF THE SPINDLE WORM, OR ELDER BORER[1]

By J. C. SILVER,[2] formerly *Assistant Entomologist, Division of Cereal and Forage Insects, Bureau of Entomology*[3]

CONTENTS

INTRODUCTION

The spindle worm or elder borer (*Achatodes zeae* Harr.) is primarily a pest of the elder shrub (Sambucus [Tourn.] L.) but has been recorded (*7, p. 318; 4, p. 791*)[4] as injurious to corn plants. The first report of this insect as injuring corn was made by T. W. Harris of Massachusetts in 1841 (*7, p. 318*). He referred to the species "known to our farmers as the spindle worm" and said that "the insect receives its common name from its destroying the spindle [tassel] of the Indian corn" just before it becomes visible above the enveloping tuft of leaves at the top of the plant. The writer has searched for *A. zeae* in various plants growing in close proximity to infested elder clumps but has failed to find it in any plant other than elder.

The investigations reported in this bulletin were conducted from the European corn borer laboratory at Toledo, Ohio, most of the field observations being made in the district immediately surround-

[1] *Achatodes zeae* (Harr.); order Lepidoptera, family Noctuidae.
[2] Mr. Silver was transferred to the Bureau of Plant Quarantine on Apr. 16, 1931.
[3] The writer is greatly indebted to D. J. Caffrey, of the Bureau of Entomology, for his interest, enthusiasm, helpful suggestions, and instructive criticism, and to Carl Heinrich, W. R. Walton, and Philip Luginbill, of the same bureau, for their corrections and suggestions. Acknowledgment of assistance from others is made at various places throughout the bulletin.
[4] Italic numbers in parentheses refer to Literature Cited, p. 18.

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ing that point. The study of this insect was made because of reports that it attacked corn and because the larva is sometimes mistaken for the European corn borer (*Pyrausta nubilalis* Hbn.).

CHARACTER AND EXTENT OF INJURY TO CORN

The following quotation is taken from a description by Harris (*7, p. 318–319*) of the injury caused by this insect to corn:

> This insect receives its common name from its destroying the spindle of Indian corn; but its ravages generally begin while the corn-stalk is young, and before the spindle rises much above the tuft of leaves in which it is embosomed. The mischief is discovered by the withering of the leaves, and, when these are taken hold of, they may often be drawn out with the included spindle. On examining the corn, a small hole may be seen in the side of the leafy stalk, near the ground, penetrating into the soft centre of the stalk, which, when cut open, will be found to be perforated, both upwards and downwards, by a slender worm-like caterpillar, whose excrementitious castings surround the orifice of the hole.

A similar description of the character of injury by *A. zeae* to corn was made by W. O. Ellis (*4, p. 791*).

Spindle-worm attack on young corn causes the plant to wither and fall over, thus rendering its presence more noticeable in corn than in elder. In records of attacks on corn, it is usually mentioned that such corn was grown near elder bushes and that the infestation in the corn plants was apparently occasioned by migration from the elder. However, in the instance cited by Harris the proximity of the injured corn to infested elder is not indicated. Ellis (*4, p. 791*) mentions that elder was growing closely adjacent to the corn found infested by *A. zeae*.

According to Harris (*7, p. 318–319*), corn plants that are attacked usually wither and die. However, as this insect rarely attacks corn, and even then attacks only a few plants, the species is not considered to be of great economic importance to corn.

HISTORICAL

Harris's original article on the spindle worm (*7, p. 318–320*) included a brief description of the insect and its habits. Since this description has caused some discussion it seems desirable to quote it from the article. It is as follows:

> These insects are fatal to the plants attacked, the greater part of which however, are without value to the farmer. Indian corn must be excepted; for it often suffers severely from the depredations of one of these Nonagrians, known to our farmers by the name of spindle-worm. The Rev. L. W. Leonard has favored me with a specimen of this insect, its chrysalis, and its moth, together with some remarks upon its habits; and the latter have also been described to me by an intelligent friend conversant with agriculture. * * * This caterpillar grows to the length of an inch, or more, and to the thickness of a goose-quill. It is smooth, and apparently naked, yellowish, with the head, the top of the first and of the last rings black, and with a band across each of the other rings, consisting of small, smooth, slightly elevated, shining black dots, arranged in a double row. With a magnifying glass a few short hairs can be seen on its body, arising singly from the black dots. This mischievous caterpillar is not confined to Indian corn, it attacks also the stems of the Dahlia, as I am informed, both by Mr. Leonard, and by the Rev. J. L. Russell, both of whom have observed its ravages in the stems of this favorite flower. The chrysalis, which is lodged in the burrow formed by the spindle-worm, is slender, but not quite so long in proportion to its thickness as those of most Nonagrians. It is shining

mahogany-brown, with the anterior edges of four of the rings of the back roughened with little points, and four short spines or hooks, turned upwards, on the hinder extremity of the body. The moth produced from this insect differs from the other Nonagrians somewhat in form, its fore-wings being shorter, and more rounded at the tip. It may be called *Gortyna*[5] *Zeæ*, the corn Gortyna; Zea being the botanical name of Indian corn. The fore-wings are rust-red; they are mottled with gray, almost in bands, uniting the ordinary spots, which are also gray and indistinct; there is an irregular tawny spot near the tip, and on the veins there are a few black dots. The hind-wings are yellowish gray, with a central dusky spot, behind which are two faint, dusky bands. The head and thorax are rust-red, with an elevated tawny tuft on each. The abdomen is pale brown, with a row of tawny tufts on the back. The wings expand nearly one inch and a half.

In order to check the ravages of these insects they must be destroyed while in the caterpillar state. As soon as our corn-fields begin to show, by the withering of the leaves, the usual signs that the enemy is at work in the stalks, the spindle-worms should be sought for and killed; for, if allowed to remain undisturbed until they turn to moths, they will make their escape, and we shall not be able to prevent them from laying their eggs for another brood of these pestilent insects.

Ellis (*4, p. 791*) wrote an article in 1925 comparing *A. zeae* with the European corn borer. Forbes (*5, p. 85*) includes an account of its activities because it had been reported as a pest of corn by Harris. Balduf (*1, p. 218*) has discussed the parasites attacking *A. zeae*, but Breakey (*2, p. 175*) gives a record of parasites and life-history data and mentions in his article that he was unable to find *A. zeae* attacking the red-berried elder (*Sambucus racemosa* L.).

DISTRIBUTION

The spindle worm was found rather abundantly in elder along the roadsides in the vicinity of Toledo, Ohio, and in southern Michigan. Ellis (*4, p. 791*) reports it as occurring rather abundantly in Massachusetts and attacking corn in that State. Dyar (*3, p. 174*) gives its distribution as in the North Atlantic States. Forbes (*5, p. 85*) reports it as being common in Illinois. Balduf (*1, p. 218*) recorded it as being present in Illinois and Ohio and stated that it has been found in Michigan. Breakey (*2, p. 175*) found this insect rather abundant in Wisconsin. The National Museum at Washington has specimens that were collected in the following States: Florida, Louisiana, Tennessee, Alabama, North Carolina, Maryland, Maine, Missouri, Illinois, New York, Pennsylvania, Connecticut, Iowa, and in the District of Columbia. C. E. Smith,[6] of the United States Bureau of Entomology, reports that he made several collections in the vicinity of Baton Rouge, La. Without doubt, *A. zeae* has a greater range of distribution than that already listed, as elder is found in nearly all the States of the Union. Mathews (*8, p. 400*) says that the American elder (*Sambucus canadensis* L.) is common in rich moist lowlands, mostly in thickets, and is distributed from Nova Scotia to Florida, and westward to Manitoba, eastern Kansas, Arizona, and Texas and that it ascends to an altitude of 3,500 feet in the Allegheny Mountains. *S. racemosa* L., a similar shrub, is distributed from Newfoundland to Nova Scotia, west to British Columbia, Michigan, Iowa, Colorado, and south to Georgia.

[5] Gortyna, in ancient geography, was the name of a city in Crete, so called from its founder.

[6] Letter to J. C. Silver, dated March 14, 1930.

The writer has records of *A. zeae* attacking *S. racemosa* in Morgan Township, Ashtabula County, and Vermilion Township, Erie County, Ohio, and in Oxford Township, Oakland County, Mich.

Severe damage by this pest to the golden American elder (*S. canadensis aurea*) and the cutleaf American elder (*S. canadensis acutiloba*) was apparent at Toledo, Ohio, where these two varieties were planted for ornamental purposes on the grounds of the Toledo Zoological Park. R. T. Everly, of the United States Bureau of Entomology, found the spindle worm attacking *S. canadensis aurea* in Conneaut Township, Erie County, Ohio.

FOOD PLANTS

Elder (*S. canadensis*, *S. racemosa*, *S. canadensis aurea*, and *S. canadensis acutiloba*) is its most common host. Corn and dahlia[1] have been recorded as rare hosts.

In an experiment conducted at Bono, Ohio, the writer confined several larvae of *Achatodes zeae* in a small cage containing elder and young corn plants, to determine whether the larvae would migrate from the elder to the corn. In this test the elder was severely damaged, all the young shoots becoming badly withered, but the larvae failed to migrate to the corn planted among the elder plants. In another test the *A. zeae* larvae failed to migrate to corn that was planted out of doors near a large group of infested elder bushes.

CHARACTER AND EXTENT OF INJURY TO ELDER

Characteristic injury by this insect to elder is not so noticeable as is that of many other insects, as the work is confined principally to the pithy portion inside the annual shoots; but the heap or mound of frass at the base of the injured stalk and the castings at the entrance hole (fig. 1) can be detected by the trained observer. With the continued feeding and boring of the larva this frass increases in bulk and accumulates around the base of the infested stalk.

The activity of the larva in the dead, dry branches before pupation results in the accumulation of a thin layer of fine sawdustlike material near the point of attack. Its early feeding on the new foliage in the spring is not superficially noticeable, as this feeding is slight and occurs within the unfolding leaf curls. The larva feeds for a few days within the curl before it bores into the new shoots. Usually it remains within its originally selected shoot until the food supply is exhausted, then it migrates to quarters where more succulent food is afforded. The entrance to the lateral stems, or shoots, is usually made on the upper side and near the base of the shoot.

Regarding the actual damage to elder, the writer has not observed any loss that could be considered of economic importance, with the exception of the damage caused to the ornamental varieties of *Sambucus canadensis* L., listed horticulturally as *S. aurea* and *S. acutiloba*. Although the young ground shoots of elder suffered great damage, only a few of them were injured to the extent of causing their death. However, the seriously injured shoots failed to pro-

[1] There has been doubt as to whether the larvae found in dahlia were *A. zeae* but, as there is no way of disproving this record, Harris's statement should be accepted.

duce new shoots the following spring. Had these ground shoots been under commercial cultivation, the injury caused by this insect could have been considered of economic importance. In 1929 and

FIGURE 1.—Entrance holes of the spindle worm (*Achatodes zeae*) in ground shoots of elder. Note frass at base of holes on portions of stalks

1930 the ground shoots and several of the lateral shoots of the ornamental varieties located at Walbridge Park, Toledo, Ohio, were destroyed and the shrubs badly disfigured.

DESCRIPTION OF ACHATODES ZEAE

THE EGG

The egg (fig. 2) is round, flattened dorso-ventrally, and about 0.61 mm in diameter by 0.28 mm in thickness. They are deposited usually in clusters or masses, but the individual eggs do not overlap. Each egg mass or cluster contains from 2 to 46 or more eggs, averaging 18. Occasionally 1 or 2 eggs were found separated by a short distance from the main egg mass. The egg masses vary in shape as well as size, sometimes exceeding 7.5 mm in length and 2.5 mm in width. When the eggs are deposited they are light yellow but shortly develop a shade of tan. The surface of the egg is rough or pebble-like, the center or polar area having a less roughened and more glossy appearance than its periphery. Shortly before hatching, the egg becomes much darker, owing to the appearance of the black head of the larva within.

FIGURE 2.—Eggs of *Achatodes zeae* on underside of outer bark of elder. The eggs are covered with the material used by the female for gluing them to the bark. ×8. Photo by Philip Luginbill

THE LARVA

Larva (fig. 3) when full grown about 1½ inches long by about one-eighth inch wide. Head, thoracic and anal shields, pinacula, spiracles, and thoracic legs are glossy black; body otherwise yellowish white; the markings very prominent.

No secondary hairs. Legs and prolegs normal. Crochets arranged in mesoseries, uniordinal. Anal shield strongly chitinized, very rugose, bearing three pairs or a row of prominent spines. Prothoracic shield broad, with a defined median line or band. Mesothoracic and metathoracic shields without setae, located near cephalic border and near meson, cephalad to setae 1^a and 1^b. Spiracles elongate oval; prothoracic spiracles larger than spiracles on abdominal segments 1–7; spiracles on abdominal segment 8 about the same size as spiracle on prothorax.

Body setae (fig. 4) moderately long; tubercles very pronounced, broadly chitinized; IV on abdominal segments 1–7 caudad of spiracle, caudo-ventrad on segment 8; prespiracular shield of prothorax nearly twice as large as spiracle and broadly ovate, bearing only two setae (IV–V), situated somewhat cephalo-ventrad of the spiracles: III on prothorax absent; group VI bisetose on prothorax but unisetose on mesothorax and metathorax; IV–V united on abdominal segment 9, not approximate to III; III cephalo-mesad of spiracle on abdominal segments 2–7, mesad on abdominal segment 1, and somewhat cephalo-dorsad on abdominal segment 8; III^a present on abdominal segments 1–8, before the spiracle on abdominal segments 2–7, more cephalo-dorsad of spiracle on abdominal segment 1, and cephalo-ventrad on abdominal segment 8; group VII trisetose on abdominal segments 2–6, unisetose on 7, 8, and 9, bisetose on abdominal segment 1; abdominal segment 9 bearing 6 prominent setae and 1 small one; II equidistant from I and III; II longer on segment 9 than on 1–8; setae on prothoracic shield as follows; I^a and I^b along frontal margin of the shield; I^c on ventral margin with II^c; distance separating I^b and I^c much less than distance separating II^b and II^c; I^c and II^c approximate; ninth abdominal segment bearing setae II, I, and III on a single pinaculum which forms a moderately broad shield extending to and almost touching the pinaculum of seta IV.

Head capsule spherical, slightly trapezoidal or broadly ovate in outline when viewed from above, a trifle wider than long; greatest width back of middle of

head, incision of dorsal hind margin pronounced but not real deep. Frons much longer than wide, not quite reaching to middle of head; adfrontal ridges parallel from lower limit of epistomal area to point of juncture of tentorial arms, thence converging to slightly curved lines to the longitudinal ridge;

FIGURE 3.—Larvae of *Achalodes zeae*: *a*, Entrance hole in a ground shoot of elder; *b*, *c*, *d*, larvae in tunnels. Note size of tunnels

longitudinal ridge slightly longer than frons; adfrontal sutures meeting longitudinal ridge slightly behind the middle of the head.

Ocelli six, normal; IV, V, and VI arranged in the form of a triangle; I, II, III, and IV equidistant from each other, but V and VI farther apart.

Epicranium with the normal number of primary setae and punctures and with three ultraposterior setae and one or two ultraposterior punctures. Anterior setae (A^1, A^2, A^3) in a right-angle triangle; A^2 smallest of the three; anterior puncture A^a ventrad of and slightly posterior to A^2. Posterior seta (P^1) slightly nearer to the longitudinal ridge than P^2, P^2 being posterior to and somewhat laterad of P^1; P^1 nearly on level with beginning of longitudinal ridge; posterior puncture (P^u) out of line with P^1 and P^2, slightly mesad, nearer to P^2 than to P^1; P^a antero-laterad of P^1, lying between P^1 and A^2. Lateral seta (L^1) postero-laterad of A^3, remote; lateral puncture (L^a) postero-dorsad of L^1, rather remote. Ocellar setae (O^1, O^2, O^3) well separated; O^1 approximate and slightly ventrad of ocellus IV, posterior to and slightly ventrad of ocellus I; O^2 remote from and posterior to ocellus VI; puncture O^a posterior and approximate to ocellus VI. Subocellar setae (SO^1, SO^2, SO^3) triangularly placed; SO^2 approximate to and postero-ventrad of ocellus V; puncture SO^a anterior to SO^3; SO^3 longest. Genal seta (G^3) postero-ventrad of O^2; puncture G^a dorsad of G^3.

Labrum normal, with usual number of setae and punctures; median incision moderately concave; setae (M^1, M^2, M^3) triangularly placed; M^2 nearer M^3 than M^2 is to M^1; M^3 posterior to M^2; puncture M^a approximate to and slightly laterad of M^1; M^3 longest of the three; L^u1 and L^u2 closely approximate; L^u3 remote from L^u2.

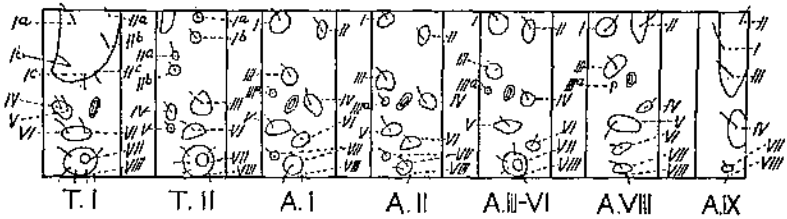

FIGURE 4.—Setal map of body segments of the spindle worm (*Achatodes zeae*)

Epipharyngeal shield not sharply defined, merging in a chitinized area on the central forward part of the labrum. Epipharyngeal setae slightly triangularly grouped behind anterior margin of epipharynx, moderately long, narrow, and equidistant.

Full-grown larva 29–34 mm long.

THE PUPA

After completing its growth the larva enters the pupal stage, or quiescent period. The pupa at first is a creamy white but soon changes to tan and later to a mahogany brown. (Fig. 6.) It measures 17 to 21 mm in length.

Pupa is moderately robust; abdominal segments gradually tapering; smooth except for some rugosity on cephalad margin on dorsum; wings extending to or nearly to the ventro-caudal margin of the fourth abdominal segment; cephalic end bluntly rounded, with two prominent knobs somewhat separated and dorsad of a prominent produced clypeus; epicranial suture present, represented by a curved line; vertex not distinct; labrum well developed, maxillary palpi absent; labial palpi moderately large; prothoracic legs extending three-fourths the length of the wings; prothoracic femora exposed; mesothoracic legs not extending to end of wings; maxillae extending to tips and the antennae nearly to tips of mesothoracic legs; metathoracic legs extending nearly to tips of wings; abdominal spiracles visible and pronounced; anal and genital openings slitlike in both sexes, ninth abdominal segment with four small stout dorsal spines; cremaster short, truncate, much broader in female than in male, and armed with four short heavy spines.

THE ADULT

The fore wings of the adult (fig. 5) are rust red, mottled with gray, with an irregular tawny spot near the tip. The hind wings are yellowish-gray with a faint discal mark. The head and thorax are

rust red, with raised tufts. The abdomen is pale brown, with a row of rust-red tufts on the dorsum. The adult varies in size, average specimens measuring about 1¼ inches across the wings.

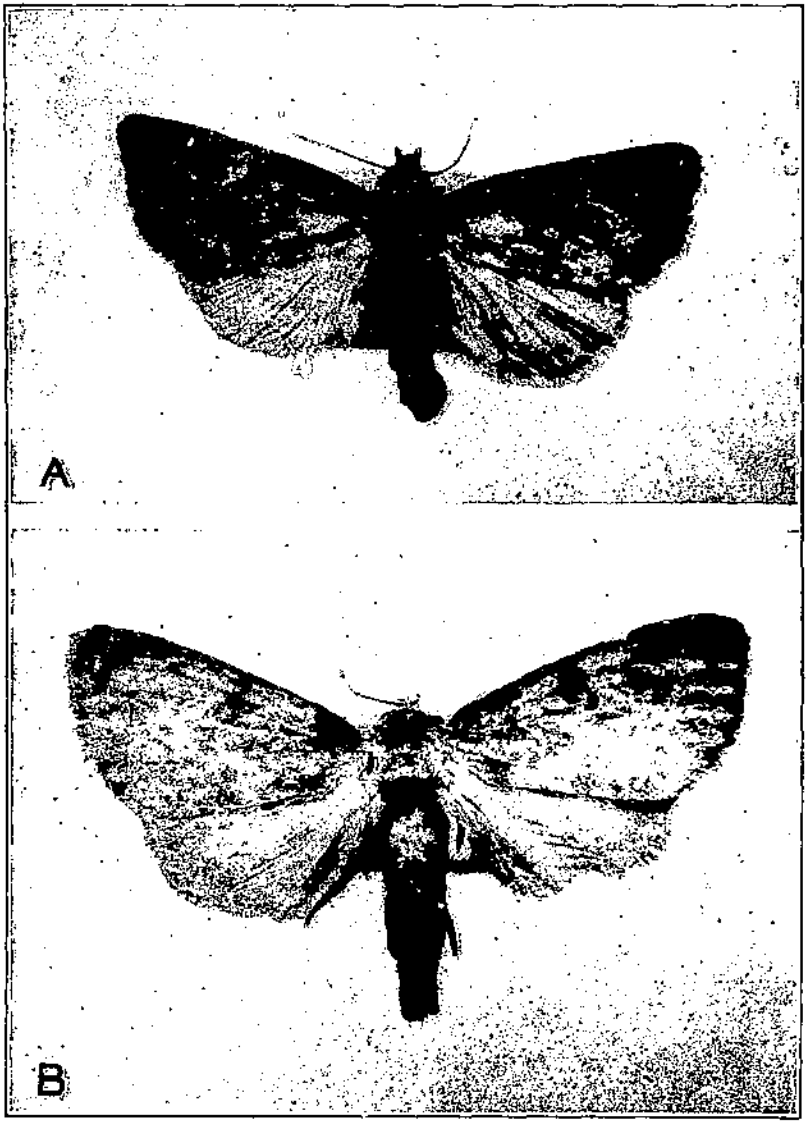

FIGURE 5.—*Achatodes zeae:* A, Male moth; B, female moth. ×3

Hampson (*6, v. 9, p. 31*) describes the moth as follows:

Head and thorax fiery red mixed with pale yellow; palpi and sides of frons dark brown; tegulae with brown patches at sides; patagia with brown upper edges; pectus and legs dark brown, the tarsi ringed with white; abdomen dorsally fiery red, ventrally dark brown. Fore wing with the costal half grey-brown suffused with fiery red at base, in end of cell and at apex, the inner

half grey with some red suffusion at the base, middle, and termen, the veins with dark streaks; subbasal line indistinct, double, from costa to median nervure; antemedial line indistinct, double, waved, with black point on its inner edge at vein 1, nearly erect; claviform small, defined by brown; orbicular small, narrow, oblique, with brown center and grey annulus; reniform grey, its center defined by brown, rather oblique; an indistinct oblique waved red line from lower angle of cell to inner margin; postmedial line brown defined by grey on outer side, slightly bent outwards below costa, oblique to vein 6, then dentate and produced to a double series of black points on the veins, oblique below vein 4, some grey points beyond it on costa; subterminal line yellow, from costa to vein 6 and bent outwards at vein 7, then represented by a series of slight yellow spots on red streaks in the interspaces, somewhat excurved at middle; a terminal series of slight dark spots; cilia brown with series of slight whitish spots. Hind wing white suffused with grey-brown, especially on costal area, the terminal area rather whiter; an indistinct discoidal spot, curved postmedial line, and diffused subterminal line; a brown terminal line; cilia white tinged with brown toward apex; the underside white, the costal area tinged with red and irrorated with brown, a dark discoidal spot and rather diffused curved postmedial line.

Hab. Canada; U. S. A., Northern, Middle, Central, and Southern States. New York, Trenton Falls (*Doubleday*) 5 ♂ type *sandix*, Evans Center (*Grote*), 2♂, 1♀, Florida (*Doubleday*), 1♂, Colorado.

Exp. 28–34 mm.

EXPERIMENTAL METHODS

Experiments with the spindle worm were conducted in the field, and also in a wire cage 3 feet square and 3 feet high. Elder clumps were transplanted in the cage and developed satisfactorily. Two complete generations of the insect, or one each year, were reared under these conditions during the seasons of 1929 and 1930. Several infested thickets of elder, located within 25 yards of this cage, gave a fine comparison and an adequate check on cage conditions. Also, individual larvae were reared in green elder shoots kept in fresh water. Records of oviposition and longevity of adults were made under laboratory conditions.

LIFE HISTORY AND HABITS

THE MOTH

EMERGENCE

The moth (fig. 5) forces its way out of its pupal cell through a slightly protected exit, made for its escape by the larva before pupation. The pupa may be located in the green stalk in which it has fed as a larva, or as a free pupa on the surface of the ground, but more commonly in the dead, dry elder branches or stalks that are standing or lying on the ground under clumps of elder. At the time of emergence the wings are unexpanded, but within a short time they expand and become dry.

The moth is seldom observed, as it flies at dusk and during the night and hides among the weeds and at the base of the elder clumps during the day. Its rusty-gray color, blending well with that of the surrounding vegetation, probably aids in protecting it from its natural enemies.

MATING

Two pairs of moths in a wire-screen cage were mating at 7.30 p. m. on July 18. One pair remained thus 28 minutes and the other pair only 6 minutes. All these moths had emerged during the previous

night. No mating was noted during daylight hours, although several males and females were confined in a cage, and close observations were made to determine possible mating under daylight conditions.

OVIPOSITION

Oviposition was not actually observed. The eggs are placed and held in position with the aid of a sticky substance, between the outer and inner bark (fig. 6, *a*), or between the inner bark and the wood. In some instances the outer bark is loose and the inner bark is tightly attached to the wood, and under such conditions the moth deposits her eggs between the outer and inner barks. The greater part of the bark is tightly glued back to its original position—in fact, so tightly that the imprint of the eggs may be seen through the thin papery outer bark. Since eggs were repeatedly found at 9 p. m. on dead branches known to be free of eggs just prior to that hour, it was concluded that oviposition usually begins at dusk, although the actual deposition of such eggs was not observed.

The maximum number of eggs deposited by any one moth was 505, the minimum was 184, and the average for 10 moths was 309. The daily average oviposition for 10 moths was 76 eggs.

Hatching usually occurs during the morning hours. The peaks of the hatching period for 1929 and 1930 were April 20 and April 19, respectively. The larva emerges from the egg by chewing its way through the chorion. Most of the larvae emerge from the side of the eggs, rather than from the polar areas. The empty eggshell is transparent.

The duration of the egg stage is of great interest, as the insect spends nearly 10 months of the year in this stage. The eggs are deposited in July and hatch the following April.

THE LARVA

FEEDING HABITS

As soon as the larvae emerge, they immediately begin searching for food. They migrate from the egg masses to the new leaves that are just breaking forth from the new lateral shoots, or to the new shoots sprouting directly from the ground. As soon as the larvae reach these, they begin feeding in the leaf curls, where they are protected to a great extent from adverse weather conditions and from their natural enemies. Very little feeding occurs in cold weather, but during the warm portion of the day the larvae move about and feed. After feeding in the leaf curls for a few days they bore into the stems, where they continue to feed. They usually remain in the lateral shoots until the third or fourth stage is reached, when they migrate to the larger and more succulent ground shoots. However, if they first attack a ground shoot, they usually remain therein until their full larval development is completed. The ground shoots that sprout from the soil are large and grow very rapidly.

The larvae (fig. 3) feed up and down the interior of the shoots—usually up from the point of entrance—eventually producing a tunnel or burrow that extends from a point an inch or two above the ground to the apex of the shoot. The tunnel is rather small at first, but as the larva increases in size, it is enlarged until the pithy portion of the stem is entirely consumed. Two and three larvae have been

found in one shoot. The frass is ejected through the entrance hole, and an accumulation of this material appears at the base of the shoot. Small quantities of frass may be found in the tunnel near the base of the shoot, and usually some of the frass adheres to the

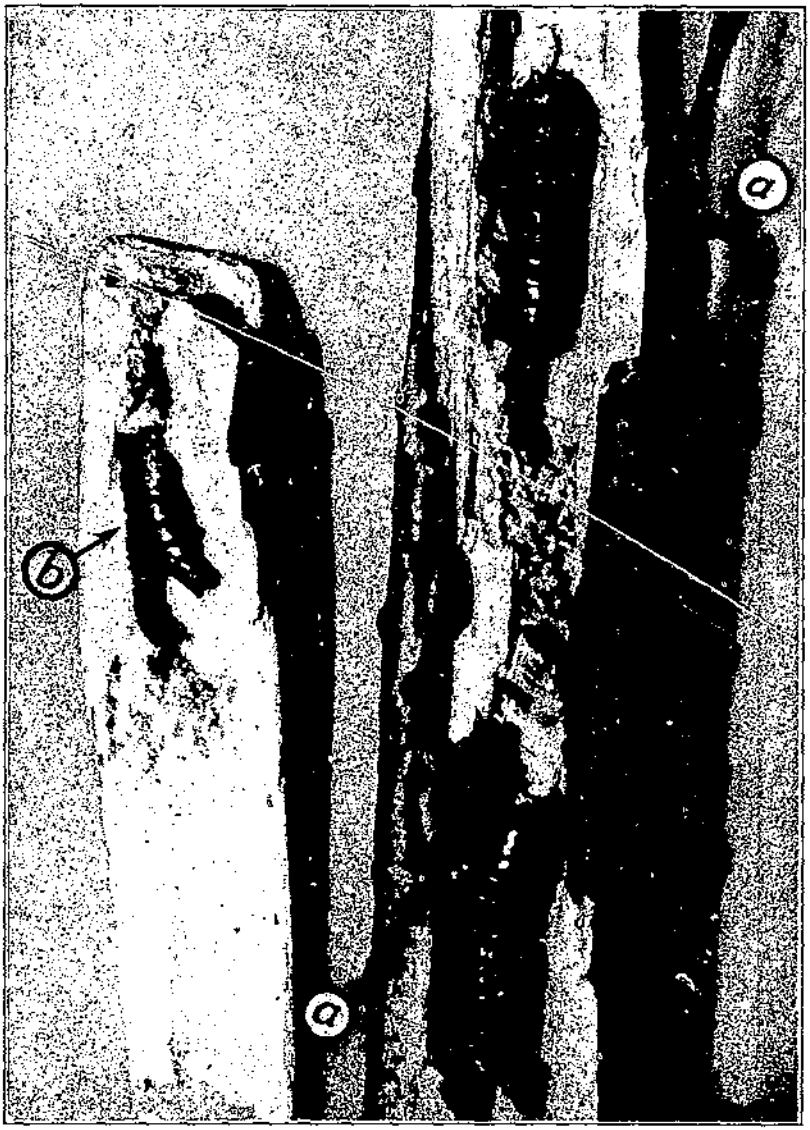

FIGURE 6.—The spindle worm (*Achatodes zeae*): *a*, Eggs laid under loose bark of elder; *b*, pupa in cell. ×3

outside of the entrance hole, particularly during the earlier part of the season.

No cannibalism was observed by the writer. Several third-stage and fourth-stage larvae were confined together overnight in a small

wire container, but no cannibalistic action was observed under these conditions or during the progress of numerous field observations.

MOLTS

The larvae cease feeding just prior to molting and appear inactive, or lethargic, for several hours. The skin ruptures directly back of the head, and as a result of a series of wriggles, contractions, and expansions the molted skin is worked back over the body. The head capsule may be cast before the skin or afterwards but is usually cast during the process of molting. Certain of the larvae were seen scratching their heads back and forth against some object, attempting to free themselves of the old head capsules. Under cage and field conditions a larva occasionally fails in this attempt and dies from starvation.

The newly molted larvae are white. The head and chitinous markings are at first white but turn grayish and finally black. The entire process of ecdysis requires from 10 to 30 seconds. Within a few hours the larvae are again feeding and very active.

Ordinarily five molts occur, but certain individual larvae developed only four.

LARVAL INSTARS

First instar.—Segments mottled with reddish, sutures yellowish white. Cervical and anal shields brownish black. Setae moderately long. Spines on anal shield absent. Seta III^a absent. Length of larva 1.95 mm; width of head 0.29 mm; length of cervical shield 0.319 mm; width of cervical shield 0.087 mm; length of anal shield 0.174 mm; width of anal shield 0.116 mm. Spiracles circular.

Second instar.—Tubercles more prominent, brownish black; body greenish white. Head and cervical and anal shields black. Spines on anal shield showing slightly. Spiracles circular. Length of larva 3.59 mm; width of head 0.522 mm. III^a present.

Third instar.—Body greenish white, tubercles black. III^a more prominent. Spines more prominent. Spiracles slightly ovate. Length of larva 9.48 mm; width of head 1.14 mm.

Fourth instar.—Body white, tubercles black. Spiracles ovate. Length of larva 17.59 mm; width of head 1.68 mm.

Fifth instar.—Body yellowish white, very much like the sixth-stage larva. Length of larva 25.50 mm; width of head 2.28 mm.

Sixth instar.—Body yellowish to dirty white. Tubercles prominent, anal shield dull black, cervical shield and head shiny black, as are the other tubercles. Length of larva 34.75 mm. Width of larva 4.1 mm; width of head 2.55 mm.

DURATION OF LARVAL PERIOD

The duration of the larval period, as in other insects, is pronouncedly influenced by the prevailing meteorological conditions and the food supply. The first molt occurs from 4 to 7 days after the larva hatches from the egg. At this time the larva is from 2 to 4 mm in length. From 3 to 7 days are spent in the second stadium, and during this period the larva attains a length of from 5 to 9 mm. The third stadium occupies from 3 to 8 days, the length of the larva of this instar ranging from 10 to 17 mm. The fourth stadium is from 4 to 8 days in duration, the larva attaining a length of 18 to 24 mm. From 7 to 16 days are spent in the fifth stadium, the larva attaining a length of 25 to 30 mm; while the sixth and final stadium lasts from 14 to 22 days, the larva attaining a length of 30 to 35 mm.

PUPAL CELLS

The full-grown larva constructs a cavity or cell in preparation for pupation. This cell (fig. 6, *b*) is made infrequently in a green stalk but more commonly in old, dry elder branches possessing soft pithy centers. The cell is usually composed of frass and silk, and the orifice for the exit of the moth is filled lightly with the same material. Even though this material functions as a protection against natural enemies, the nature of its construction is such that the emerging moth can escape.

In a collection of 100 pupae, 93 were found in old dead branches and stalks, 5 were found in green shoots that had been severely attacked by the larvae, and 2 were on the ground without any protection

PREPUPA

After the cell is completed, the larva becomes quiet and shrinks in size, gradually becoming inactive and helpless. After a few days in this condition the larval skin is cast, and the pupa is formed.

PUPA

When first exposed the pupa (fig. 6, *b*) is creamy white, very delicate, and easily injured. It gradually hardens and assumes a mahogany-brown coloration, which in turn becomes darker just prior to the emergence of the moth. Except for spasmodic wriggling movements when disturbed, the pupa is inactive. In the 10 specimens under observation the duration of the pupal period ranged from 14 to 26 days, with an average of 18.3 days.

LONGEVITY OF ADULTS

Adults were observed to live from 2 to 11 days under cage conditions, with an average of 5 days for the 10 specimens under observation. Various flowers, and also a sugar-water solution, were placed in the cage for food.

SEASONAL DEVELOPMENT

The spindle worm passes nearly 10 months of the year (from July to April) in the egg stage. (Fig. 7.) The duration of the larval stage is approximately 58 days, and that of the pupal stage approximately 18 days. The adult stage, under cage conditions, lasts approximately five days.

On April 18, 1929, newly hatched larvae were found in the leaf curls. On April 17, 1930, the first eggs hatched. The first sixth-stage larva was found on May 22, 1929, and the first full-grown larva on June 7, 1929. In 1930 the first sixth-stage larva was observed on May 21, and the first full-grown larva on June 4. In 1929 pupae were first observed on June 15, and in 1930 on June 13. In 1929 moths appeared under cage conditions on July 5, and in 1930 on June 22.

C. E. Smith sent the writer a collection of larvae of *A. zeae* which he had collected in elder at Baton Rouge, La., on March 12, 1931, and upon arrival at Toledo, Ohio, on March 15, they were in the second and third stadia. This collection shows that the date of hatching in Louisiana is approximately a month and a half earlier than in northern Ohio.

ARTIFICIAL DISSEMINATION

Dissemination of the spindle worm, at least in important numbers, by the aid of man seems rather questionable, as the elder growth on which the eggs are deposited or in which the pupae are imbedded has no appreciable economic value. At the time of year when the elderberries are harvested, the insect has deserted the green stems on which the berries are borne. The only possible avenue of artificial dissemination would appear to be in the shipping of ornamental varieties of elder from nurseries. However, plants intended for shipment from nurseries are carefully pruned and the old, dead wood ordinarily bearing the eggs is removed before shipment.

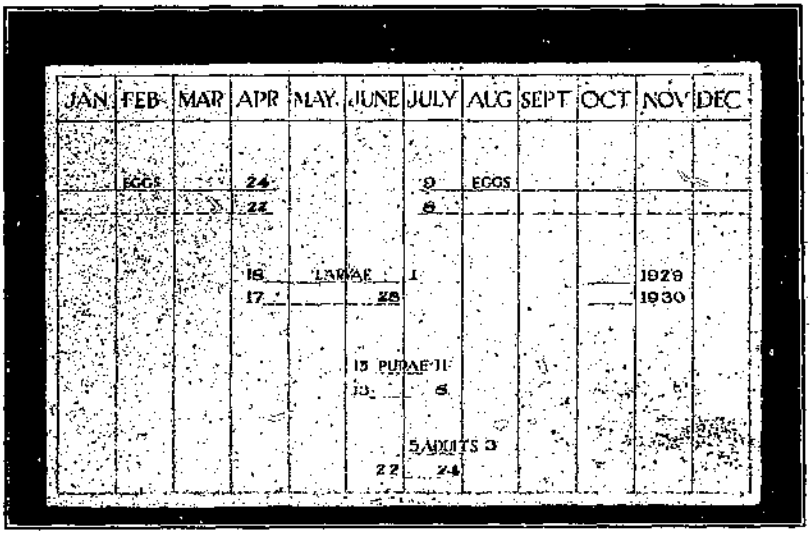

FIGURE 7.—Seasonal history of *Achatodes zeae*

NATURAL DISSEMINATION

As the moths of the spindle worm are active only after dusk, it is difficult to determine the details of their flight habits, and, particularly, their powers of flight.

It has been observed that several isolated patches of elder were infested, even though several miles away from other elder, thus indicating that the moths are able to fly for some distance. The robust structure of the moth also supports this theory.

NATURAL CONTROL

PARASITES

Several species of hymenopterous and dipterous parasites were found attacking *Achatodes zeae*. A small hymenopterous parasite, *Microplitis gortynae* Riley (fig. 8), has been found to be the most numerous of this group. Parasitism by this species attained a maximum of 11 per cent, according to Balduf (*1*), who determined this parasite species for the writer, and who records it as being numerous in other localities. He found the first mass of cocoons of *M. gortynae*

of the season of 1929 on June 20, at Monroe, Mich. On June 20, 1929, D. J. Caffrey found a mass of these cocoons at Mentor, Ohio. The writer observed the first mass of these cocoons at Bono, Ohio, on July 1, 1929. On June 14, 1930, masses of cocoons of this parasite were found at Bono.

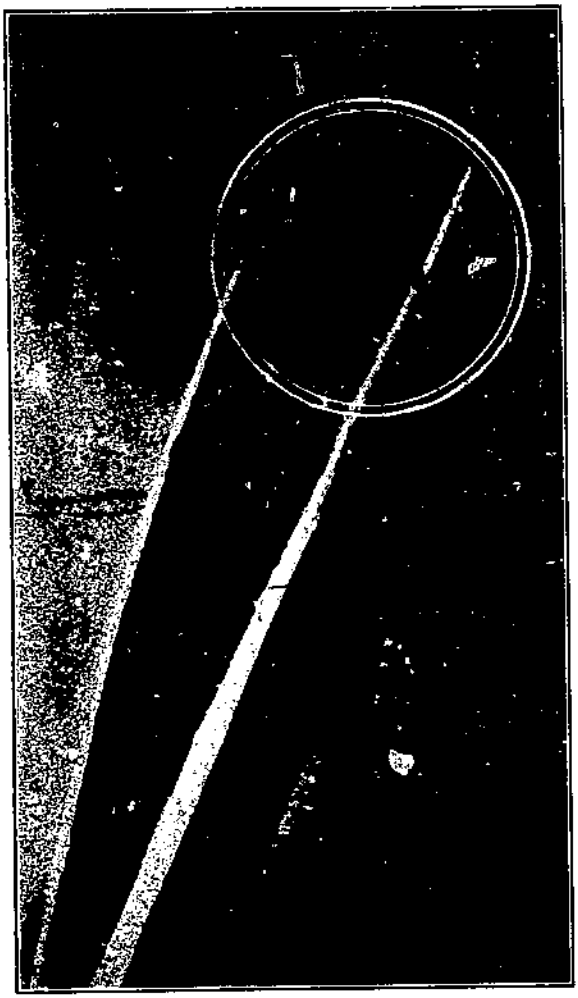

FIGURE 8.—Cocoons of *Microplitis gortynae* in tunnel in elder. Note host remains (*Achatodes zeae*) in front of cocoons. ×3

M. gortynae issues from the full-grown larva of *Achatodes zeae* and remains closely adjacent thereto. The parasite pupates and overwinters within its cocoon, emerging the following spring. The cocoons are fluted and dirty white. The number of individual parasites issuing from each host larva ranges from 10 to 38.

Another hymenopterous parasite, *Microbracon lutus* (Prov.), was recorded by the writer as parasitizing 3 per cent of the spindleworm larvae during 1929 in the Bono, Ohio, district. This species was determined by Balduf, who found it present June 20, 1929, at Monroe, Mich. *M. lutus* was first observed at Bono by the writer on June 1, 1929. This parasite is gregarious and the masses of cocoons are found closely adjacent to the host remains. The cocoons are chocolate brown and are glued closely together. The number of individuals issuing from one host larva ranges from 4 to 12. This parasite overwinters in the cocoon stage, in a similar manner to *Microplitis gortynae*.

Two specimens of the large ichneumonid *Amblyteles sclestus* (Cress.)[8] were reared from a collection of 100 pupae of *Achatodes zeae*. They issued on July 11 and 17, 1929.

[8] Determined by C. F. W. Muesebeck, of the U. S. Bureau of Entomology.

Several specimens of *Miotropis clisiocampae* Ashm. issued from one pupa of *Achatodes zeae*. The specimens were determined by Muesebeck, who stated in a memorandum at the time that "this species occasionally acts as a primary parasite of various lepidopterous larvae, but under certain conditions may also become a secondary parasite." The writer also found this species attacking cocoons of *Microplitis gortynae*.

On July 19, 1929, one specimen of *Phytodietus pulcherrimus* Cress.[8] was found by Caffrey and the writer near the remains of a larva of *A. zeae* in an elder shoot. It was in the pupal stage and failed to issue.

One cocoon of *Epiurus pterophori* (Ashm.)[9] was found on May 28, 1930, at Bono, Ohio. The adult issued on June 12, 1930.

One cocoon of *Sagaritis oxylus* Cress.[9] was found on May 28, 1930, from which the adult issued on the afternoon of the same day.

W. V. Balduf found a tachinid puparium, determined as *Masicera* sp. (probably *myoidea* Desv.)[10] as a coparasite with *M. gortynae* at Monroe, Mich. Both species developed from one larva of *A. zeae*.

FIGURE 9.—Elder shoots, showing punctures made by birds to obtain larvae of *Achatodes zeae*

[8] Determined by C. F. W. Muesebeck, of the U. S. Bureau of Entomology.
[9] Determined by R. A. Cushman, of the U. S. Bureau of Entomology.
[10] Determined by R. T. Webber, of the U. S. Bureau of Entomology.

Another tachinid, *Nemorilla floralis* Fall.,[10] was reared from a larva of *A. zeae* at Baton Rouge, La., by C. E. Smith.

No egg parasites were reared.

BIRDS AND RODENTS

The northern downy woodpecker (*Dryobates pubescens medianus* (Swains.)) was observed attacking young elder shoots in search of spindle-worm larvae. An examination of these green shoots disclosed that the bird had removed the larvae. Several clumps of elder in various localities showed distinct signs of attack by birds. (Fig. 9.)

Several clumps of elder in widely separated localities exhibited signs of attack by rodents that apparently removed the spindle-worm larvae from the green shoots.

ARTIFICIAL CONTROL

As the spindle worm spends such a large proportion of its life in the egg stage, and as the eggs are deposited under the bark of old, dead elder branches and stalks, its control is relatively easy to accomplish. None of the moths overwinter to deposit eggs for a new generation, therefore the species can be controlled by removing from and about the elder clumps all dead wood on which the overwintering eggs have been deposited, raking it into a pile, and burning it during the fall, winter, or early spring to destroy the eggs. Actual field tests have demonstrated the efficiency of this method of control, and it has proved to be so practical that no other methods were tried.

SUMMARY

The spindle worm, or elder borer (*Achatodes zeae* Harr.) sometimes seriously injures elder and very rarely injures corn, but this insect can not be considered of much economic importance.

The larval, or injurious stage of the insect, is short in duration and is usually confined to uneconomic plants.

Natural control by several species of parasites and by birds and rodents usually holds this insect in check.

The eggs are easily destroyed during the fall and winter months by burning the old, dead elder wood to which they are attached.

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