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SEASONAL LIFE HISTORY AND CONTROL OF THE PEACH TREE BORER, *SANNINOIDEA EXITIOSA* (SAY), IN TENNESSEE[1]

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ABSTRACT

Larvae and/or pupae of the peach tree borer were dug from peach trees and incubated in the laboratory. Adults that emerged or adults collected in the field oviposited in paper bags. The eggs were incubated at 80F ± two degrees. One-year-old trees were artificially infested to determine the emergence period of adults in Tennessee. Adult longevity was also investigated. Pesticides were applied at various intervals to dormant-budded "nursery trees," prior to and after budding practices, over a two-year period. The best protection in both tests was obtained with endrin.

INTRODUCTION

The peach tree borer, *Sanninoidea exitiosa* (Say), is a native insect of eastern North America. Its original hosts were the wild cherry and the wild plum until early settlers introduced the peach (Gossard and King 1918). Now it is a chief pest of the flowering varieties as well as the fruit-bearing varieties of the genus *Prunus*. It is the larval stage of a clear-wing moth of the family Aegeriidae (=Sesiidae) whose members are known universally as borers. Members of the family feed on both herbaceous and woody plants. Some species feed on the inner bark, some on the pith and others on the roots as well as on other plant tissues. Primarily, the larvae of the peach tree borer feed at or somewhat below ground level, eating galleries or burrows in the soft cambium at the crown (junction of roots and stem) or along the larger roots.

The damage caused by this insect to the stone-fruited species throughout Tennessee is of economic importance. Its damage was first noted in commercial orchards, but now nurserymen throughout the state are greatly concerned because this insect can render thousands of nursery trees worthless during one growing season.

The literature on this species is very extensive. According to Snapp and Thomson (1943), nearly five hundred papers on the peach tree borer had been published by the end of 1933. Since that time the literature has probably increased four-fold. The writers, therefore, will mention only those articles that have the greatest significance for their work.

Cory (1911) studied the habits of the moths during mating and noted that caged females mated twice. He also reported on egg laying and on the time of pupation and emergence of the adults in orchards. Becker (1917) also reported on the habits of the moths including time factors of pupation and emergence.

Gossard and King (1918) studied the life history and noted some of the natural enemies of the borer. The first report from Tennessee was by Butler (1930, 1931) who observed emergence dates and determined the average potential oviposition of several females. In east Texas, King and Morris (1956) found that the peach tree borer completed one generation annually. They also noted that some larvae required six instars for development, although others passed through only five instars. They determined that the peak of emergence for the adults occurred in September.

A simple method for rearing peach tree borers on immature apple fruits was described by Smith (1965). Studies on larval development were reported and comparisons were made on the rate of development of the larvae under natural and laboratory conditions.

Fitch (1855) presented a list of measures that were recommended by agricultural workers for the control of the peach tree borer. Blakeslee (1919) was the first to demonstrate that a chemical, paradichlorobenzene (PDB), controlled the peach tree borer effectively when applied in bands around orchard trees. Butler (1930, 1931) evaluated the use of PDB for controlling the borer in Tennessee. Snapp (1938), experimenting with ethylene dichloride emulsion, noted that extreme care must be exercised in the use of this chemical to prevent injury to the tree.

Interest in tree-trunk spraying resulted from reports by Driggers and Smith (1944) that a reduction in peach tree borer population occurred after they used DDT for control of Japanese beetles and oriental fruit moths.

Wallace (1946) reported that DDT, applied as an emulsion in late June at the rate of three pounds per 100 gallons of water, gave effective control in commercial nurseries. It was less effective at lower concentrations. Snapp (1961), working with nursery stock, found that four applications of DDT (eight pounds per 100 gallons of water) gave complete control of the borer. This is about two and a half times more DDT than Wallace (1946) used for effective control. A single application of dieldrin (six pounds per 100 gallons of

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water) gave good control, and three applications of parathion (two pounds per 100 gallons of water) gave fair control.

Materials and Methods

Cocoons and larvae were dug from peach trees in an orchard at Kingston, Tennessee, to obtain borers for laboratory rearing. In the laboratory, cocoons were kept in a rearing cage that consisted of a glass base and a glass globe for a top. The base had a diameter of 100 mm and a depth of 43 mm. The chimney had a depth of 160 mm. The opening at the top was covered with fourteen-mesh nylon screen.

The base of the cage was filled with sand to within 5 mm of the top. To simulate natural orientation, cocoons were placed perpendicularly in the sand. The sand was kept moist to insure a relatively high humidity for the pupae.

Larvae were collected in the field during the fall and winter. They were allowed to feed upon Winesap apples in glass half-gallon or gallon jars. Six to eight holes, depending upon the size of the apple, were made in each apple with a 95 mm cork borer. One larva was put into each hole. The small core made by the cork borer was cut in such a way that ¼ inch remained on the end with the peeling to form a plug. This plug was then used to seal the hole to give the larva a moist habitat.

To minimize the changing of larvae to fresh apples, a diet was formulated on which larvae thrived after the second or third instar (Russell 1968).

To obtain first instar larvae, fertilized females were retained in paper bags and their eggs were transferred into salve boxes lined with moist paper toweling. Approximately 50 eggs were put into each container and incubated at 80F. After eclosion, the first instar larvae were transferred to slices of fresh apples or put into vials containing a prepared diet.

Peach seeds were planted in November, 1964, and the resulting young trees were artificially infested between August 15 and August 30, 1965. These trees were infested with first instar larvae, two larvae being put on the base of each tree with a camel hair brush. The following spring, 1966, all limbs were removed from the peach trees so that a cone-shaped wire cage could be placed around the base of each tree. (Fig. 1).

The cages were constructed from fourteen-mesh copper screen rolled into a cone to provide a three-inch opening at the top and a six-inch opening at the base. Where the screen met on the side the edges were slightly overlapped and stapled to a twelve-inch stake. Cardboard was stapled around the top of the cone to provide a stiff collar. About one square foot of cheese cloth (80-mesh) was taped to the cardboard with vinyl electrical tape.

The period of emergence was determined by weekly emergence counts with Friday of each week considerd the last day of the week. The cages were checked from two to four times per week because a moth that emerged on Saturday and Sunday usually died by the middle of the following week and was devoured by ants.

Fig. 1. A block of peach trees with cages to retain adult moths after emergence.

Beginning in 1965, eight insecticides with relatively long residual properties were evaluated for borer control. It was determined that peach tree borers would attack young seedlings as well as dorman-budded stock. Thus, it was necessary to establish the spray program the year the seedlings were established and continue it the next year after the dormant stock had been budgrafted. Two intervals (four and six weeks) between spraying were used during the egg-laying season of the moths. All chemicals were applied with a two-gallon garden type sprayer at a pressure of about 35 PSI.

All insecticides used are listed in Tables 1 and 2. Three of these chemicals: endosulfan, dieldrin and DDT, are generally recommended for the control of the peach tree borer in Tennessee. All chemicals, except DDT and Mobil MCA-600 were emulsifiable concentrates applied at the rate of one pound of actual insecticide per 100 gallons of water. DDT and Mobil MCA-600, which were 50 per cent wettable powders, were applied at the rate of two pounds of actual insecticide per 100 gallons of water. A spray mist was directed in such a manner that the trunk of each tree was covered to a height of about twelve inches above the soil. Also, the mist struck the ground and provided a small circular area of insecticide at the base of each

Table 1. Summary of data for the control of the peach tree borer in nursery peach trees at McMinnville, Tennessee.

Treatment	Rate of Actual Per 100 Gallons	Average % of Trees Infested	Significance at 5% Level*
Check	—	35.0	a
Mobil MCA-600	2 lb.	31.8	a b
Dimethoate	1 lb.	29.0	a b
Dimethoate**	1 lb.	22.5	a b c
Shell SD-7438	1 lb.	21.8	a b c
Shell SD-7438**	1 lb.	20.0	a b c
Endosulfan	1 lb.	19.0	a b c
Endosulfan**	1 lb.	18.5	a b c
Dieldrin	1 lb.	18.3	a b c
Mobil MCA-600**	2 lb.	18.0	a b c
Lindane**	1 lb.	16.8	b c
Lindane	1 lb.	16.0	b c
DDT**	2 lb.	15.8	b c
DDT	2 lb.	14.8	b c
Dieldrin**	1 lb.	14.3	b c
Endrin**	1 lb.	4.5	c
Endrin	1 lb.	4.3	c

*Any two means followed by the same letter are not significantly different. Duncan's Multiple Range Test.
**Materials applied at 6-week intervals for a total of six applications in two years. All others were applied at monthly intervals for a total of ten applications in two years.

Table 2. Summary of data for the control of the peach tree borer in nursery peach trees at Winchester, Tennessee.

Treatment	Rate of Actual Per 100 Gallons	Average % of Trees Infested	Significance at 5% Level*
Mobil MCA-600**	2 lb.	72.0	a
Check	—	69.3	a b
Lindane	1 lb.	69.0	a b
Shell SD-7438	1 lb.	63.8	a b
Mobil MCA-600	2 lb.	59.8	a b c
DDT	2 lb.	55.3	a b c
Dimethoate	1 lb.	53.0	a b c d
Lindane**	1 lb.	51.5	a b c d
Endosulfan	1 lb.	50.5	a b c d
Dimethoate**	1 lb.	50.5	a b c d
DDT**	2 lb.	48.8	a b c d
Dieldrin	1 lb.	47.5	a b c d
Shell SD-7438**	1 lb.	47.0	a b c d
Endosulfan**	1 lb.	45.0	b c d
Dieldrin**	1 lb.	33.0	c d e
Endrin**	1 lb.	24.8	d e
Endrin	1 lb.	13.8	e

*Any two means followed by the same letter are not significantly different. Duncan's Multiple Range Test.
**Materials applied at 6-week intervals for a total of six applications in two years. All others were applied at monthly intervals for a total of ten applications in two years.

tree. All sprays were directed from opposite sides of each tree to provide complete coverage.

To evaluate the effectiveness of these chemicals for controlling the peach tree borer, the trees were dug carefully, the soil was removed and each plant was examined for evidence of borer infestation.

Since many of the trees may have been infested and damaged during the first growing season, any tree showing signs of damage, whether old or recent, was counted as infested.

Data were analyzed by Duncan's New Multiple Range Test.

Results and Discussion

The Adult. Unlike some members of the clearwing moth family, the sexes of *Sanninoidea exitiosa* are easily distinguishable. The adult male has a lighter and slenderer steel-blue body than the female. There are several narrow yellow bands marking the thorax and around the abdomen which are quite conspicuous on the steel-blue background. The legs have thick black scales and articulations are announced by tufts of yellow scales. Front and rear wings are both entirely transparent, with dark, narrow veins delicately fringed with black hairs on the rear portion and with a wider dark strip on the front. The wing spread of the male moth is about one inch and its length about three-fourths of an inch (Fig. 2). The adult female is similar to the male, but it has opaque forewings and the fourth abdominal segement is covered with bright orange scales (Fig. 2).

The moths are diurnal, and are very swift fliers. Thus, when observed in flight they closely resemble and are often mistaken for small wasps (Metcalf and Flint 1962). When in flight a steady hum is produced by both male and female due to the rapid beating of their wings. Observations indicated that the flight of the female appeared more laborious and nearer the ground than that of the male. This confirms earlier observations of Gossard and King (1918).

Under favorable conditions, the males and females may mate about an hour after emergence from the pupal case. As many as ten males were observed to be attracted to one female within minutes after she protruded her genitalia. In the laboratory, a high intensity light source was necessary to induce copulation. The male approaches the female from behind while on the wing and dips his abdomen to her upturned genitalia. Clasping occurs; he then turns, hovers a few seconds and comes to rest (Fig 3). The length of copulation was observed to be from 47 to 100 minutes, with an average of about 60 minutes.

Adults were not observed to eat, except that in the laboratory, the moths reared from larvae and/or pupae collected in the field would partake very readily of a solution of dextrose (1 gram of dextrose in 9 ml. of distilled water).

Since the female of many insects must feed before she can produce fertile eggs, the following experiment was conducted to determine if this was also true for the female peach tree borer. Pupae were collected in the field and reared in the laboratory. When males and females emerged they were placed in a cage and moved into bright sunlight, and copulation was observed. The eggs when placed in a moist chamber as previously described, hatched within ten days. Thus a nutrient meal was not essential for the production of fertile eggs.

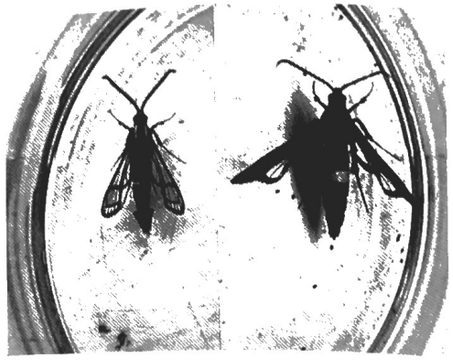

Fig. 2. Female (right) and male (left) peach tree borers. Note opaque forewings and yellow band around abdomen of female, and transparent forewings and the arrow-shaped tuft of hairs at the tip of the abdomen of the male.

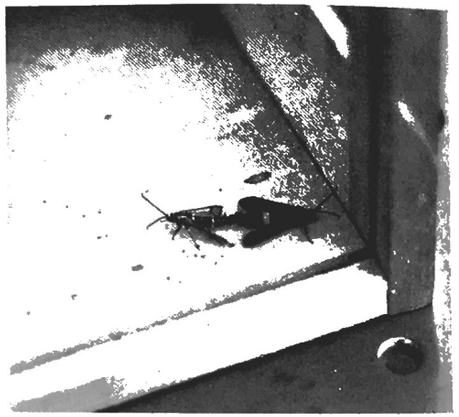

Fig. 3. Copulation position assumed by the peach tree borers after clasping has occurred.

Longevity of Adults. The longevity of the adult peach tree borer, as determined for a relatively few individuals, ranged from a few hours to 21 days, with an average of 6.0 days. This was 0.2 day shorter than Armstrong (1940) reported. Evidently other factors had a greater effect upon the longevity of these adults reared in the laboratory than the solution of dextrose which was supplied as a source of food since one male and three females lived for more than two weeks as compared to the over all average of 6 days. Males lived less than half as long as females.

Two moths, a male and a female, were found to be parasitized by nematodes. Each moth had from 10 to 23 nematodes in its intestine or body cavity. Neither moth distended its wings and both died about 24 hours after emergence. Each of their exuviae contained about 100 unidentified nematodes.

Period of Emergence. In 1966 the infested and caged trees were observed as described under "Methods." Four hundred and nine adults, 200 males and 209 females, were trapped. The data (Fig. 4) indicate two peaks of emergence. During the first peak (June 11-July 9) a total of 186 moths emerged, averaging about 37 moths per week. The second peak occurred in mid-August.

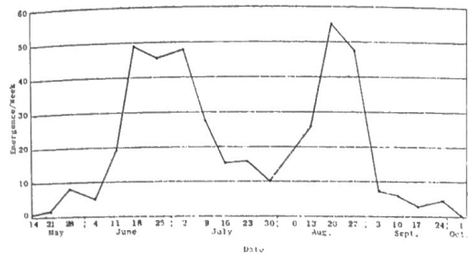

Fig. 4. The duration of emergence of borers in Knox County, Tennessee for 1966.

These data indicate that, in Tennessee, the peach tree borer is a major problem from the latter part of May to the first of October, or later. Therefore, control measures should be employed from about the first part of May to the middle of October. A program so devised would compensate for any change in weather which would allow a few adults to emerge prior to May 24 or later than October 1.

The Egg. The egg of the peach tree borer is reddish-brown to brown in color, ellipsoidal in shape, and measures about 0.57 mm by 0.41 mm. The chorion is somewhat rough and finely reticulated. The upper surface is slightly depressed, the concavity being oval and following the contour of the egg margin. Eggs held at a room temperature of about 80F hatched in eight to ten days with an average of 8.67 days. Smith (1965) found that the incubation period is approximately 8.5 days at 80F for eggs collected from females that were reared in the laboratory. The number of eggs per female varied from 265-704 with an average of 448 which is similar to Butler's (1930) data. Fertility, which was determined for all of the eggs deposited, varied from 97 to 100 per cent. This is in accord with reports from other sources (Becker 1918, Snapp and Thomson 1943, and Smith 1965).

The Larva. The destructive stage of *Sanninoidea exitiosa* is a dirty white larva whose head capsule has a yellowish-brown to a dark reddish pigmentation. The cervical shield, which is pale yellowish-brown, has a brown edge and a groove that cuts the posterior lateral angles to form an arc. The larvae range from 1½ mm in length when newly hatched to about 30 mm when mature. Immediately after eclosion, the young larvae seek suitable points of entrance into the tree. According to Armstrong (1940) and Snapp (1943) the newly hatched larvae are negatively heliotactic and positively geotactic. These tactic responses cause the larvae to concentrate at the base of the tree, usually near the soil surface, where they burrow directly into the bark to the cambium. Their entrance, unlike some members of their family, does not require wounds or breaks in the bark.

The larvae, while overwintering, are exposed to extremely low temperatures without ill effects. Boyce (1962) reported that for hibernation larvae constructed a rough cocoon which may be located on the trunk in gummy exudate or in burrows. Smith (1965) reported that before larvae reach full maturity, they enter diapause. He also stated that diapause could be broken by exposing the larvae to low temperatures (40 F) for a month or more.

Observations in the laboratory and the field indicate that there is no true hibernation of the larvae in Tennessee. When the temperature falls below 40F, the larvae become sluggish and inactive, but when the temperature becomes sufficiently high they again resume their feeding and activity. At freezing temperatures, larvae above the soil line on the sun-exposed side of trees became active, while those on the shaded side remained inactive. A silken mat or what may have been a hibernaculum, was found between the larvae and the outside bark during the winter. This structure could have had some insulating effect against the cold.

The peach tree borer larvae, unlike many Lepidopterous larvae, soon die from desiccation if exposed directly to the atmosphere. They are usually in the tissues of a tree, where there is a relatively high and constant humidity, but occasionally larvae are found alongside the roots. When on the outside of the roots they are usually associated with a large gummy mass or in soil with an exceptionally high moisture content. When removed from trees and placed in containers with pieces of cut bark or apple, their first act was to seal a few pieces of bark around themselves or to burrow into the apple. Either act prevented death from exposure and desiccation.

Larval Food Habits. According to Metcalf and Flint (1962) peach, wild and cultivated cherry, plum, prune, nectarine, apricot, and ornamental shrubs of the genus *Prunus* are fed upon and may be damaged or destroyed by peach tree borers. Young trees are sometimes completely girdled by the borers; and though older trees are less likely to be girdled, they are often so severely injured that their vitality is lowered and their resistance to other insects or diseases reduced to such an extent that some secondary pest will complete their destruction.

The number of larvae that may be found infesting a tree varies from one region to another. In some regions there are only one or two borers per tree whereas in

others eight to ten borers are present. In extreme cases ninety borers have been found infesting the roots and crown of individual peach trees six or seven years old (Quaintance, Porter and Snapp 1932).

Trees previously attacked by borers, unless killed, are usually highly susceptible to repeated attacks. Seldom is a tree with old damage free from borers. Trees of "nursery size" seldom contain more than five or six larvae, but twenty-one larvae were removed from a tree one and one-half inches in diameter in late summer of 1964. In the nurseries, the larvae feed primarily at the crown or just below the soil surface. Occasionally one may be found on the large lateral roots several inches from the trunk of the tree.

The Cocoon and Pupa. The mature larvae construct their cocoons from bark fibers. They "web" these particles into an elongated cocoon approximately one inch in length. The newly constructed cocoon is light brown and becomes darker with age.

Some cocoons are constructed just beneath the bark, an exit having been made by the larvae before the cocoon was formed. Other cocoons are made on the side of the trunk just below the surface of the soil, or concealed under lumps of exuding gum just at the soil surface. It is not uncommon to find cocoons twelve inches or more from the tree trunk. Such cocoons are generally constructed by larvae which fed on the larger lateral roots or far down on the main trunk. Many cocoons were found 12 in. and a few as far as two feet from the tree trunk in an orchard at Kingston, Tennessee. In the nurseries the greatest distance of a cocoon from the tree trunk was five inches; this was observed in a block of two-year-old dormant budded stock at McMinnville, Tennessee.

Normally, the cocoon constructed by a female is larger than that of the male (Gossard and King 1918). However, we observed that it would have been impossible to have been 80% correct in separating the sexes if the only identifying characteristic had been cocoon size. Male and female pupal cases of the peach tree borer can be separated by identifying characteristics stated by Lintner (1882) (Fig. 5).

After the cocoon has been constructed, the larva remains sluggish for a period of four to six days before pupating. Then, pupation begins and the pupal stage lasts approximately three weeks. Both sexes escape from the cocoon by working their way through the anterior end.

The earliest emergence of an adult in the season was observed on the twenty-fifth of April, 1964, in a nursery at McMinnville.

The earliest date on which an adult was trapped in Knox County was May 24, 1966, at The University of Tennessee Agricultural Experiment Station in a plot of peach trees that had been caged to determine date of emergence (Fig. 6).

Chemical Control

In both tests, trees receiving applications of endrin had significantly reduced borer infestations as compared to the control; however, there was no significant borer reduction due to different intervals of application (Tables 1 and 2).

The average infestation at Winchester was from two to four times greater for monthly applications than at McMinnville, while it was two to six times greater for

Fig. 5. Male and female pupal cases. The 7th abdominal segment with two rows of teeth on the male and one on the female.

Fig. 6. Female striking mating position within cage after emergence.

applications every six weeks. The higher borer infestation at Winchester can probably be attributed in part to the large number of weeds and grasses which prevented the chemicals from being properly applied during the second season. Also, the weeds and grasses provided a higher humidity at the base of trees than in the clean block at McMinnville and this may have enabled many of the larvae to gain access to a tree with smaller chances of death due to desiccation.

From these data, endrin appears to be the best insecticide for the control of the peach tree borer. Three applications of endrin per year, as a trunk spray at the approximate dates used in this test, are as effective as five. Weed control may greatly influence the residual effect of this chemical.

Summary

The study of the peach tree borer in Tennessee conducted over a period of three years, included laboratory studies, field collections and observations, caged studies under natural conditions and evaluation for borer control in nursery plots of various insecticides applied as trunk sprays. Nurseries and orchards throughout middle and east Tennessee were used to study this insect in its natural habitat.

Adults were reared from field-collected cocoons and observations of mating and egg laying were conducted in the laboratory. Adults were fed a solution of water and dextrose without increasing their life expectancy. It was established that feeding was not necessary before the females would copulate and oviposit fertile eggs. The longevity of the males was established at about 3.7 days and that of the females at about 7.16 days, with an average of 6.0 days for both sexes.

At Knoxville adults began to emerge about the middle of May and continued until the first week of October. Two peaks occurred, the first peak (June 11-July 9) covered a period of five weeks; the second peak (August 6-August 27) covered a period of four weeks. The number of males and females that emerged indicated that a 1:1 ratio exists between the sexes.

There was no indication that the peach tree borer has more than one brood per year or that more than one year is required for completion of the life cycle.

It was established that under laboratory conditions, a high intensity light source was necessary before copulation would occur. Females which were collected in the field as larva and/or pupae deposited from 265 to 704 eggs, with an average of 448.

The incubation period for the eggs at room temperature (about 80 F) ranged from eight to ten days, with an average of 8.67 days.

Larvae of the peach tree borer were found at various stages of development throughout the year. They feed about one year in the cambium at the base of the trunk or upon the roots and one to several dozen larvae may infest a single tree.

Pupation occurs within the tunnel made by feeding of the larva or underneath masses of gum near the trunk or roots. The length of the pupal stage is from 18 to 25 days.

Eight chemicals were evaluated for borer control in dormant-budded peach trees during two growing seasons. Endrin gave the best control in both tests. There was no significant difference in borer control between monthly and six-week frequencies of application during the egg-laying period of the moths. Thus, three applications of endrin per year, as a trunk spray at approximately the dates used in this test, should give adequate control. However, adequate weed control may greatly improve the results with an insecticide.

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