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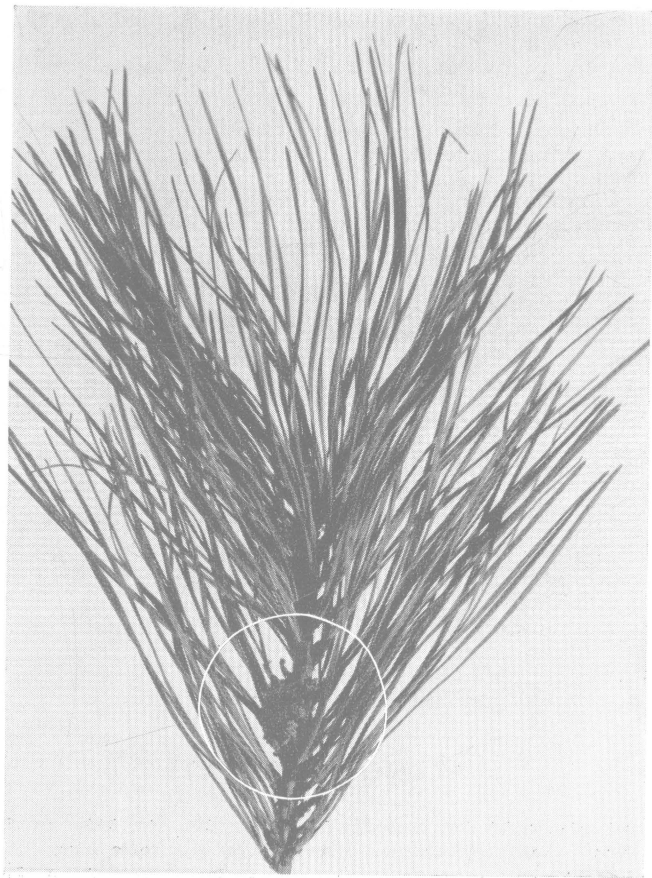

OHIO AGRICULTURAL EXPERIMENT STATION - - WOOSTER, OHIO

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THE PITCH TWIG MOTH,[1] AND ITS OCCURRENCE IN OHIO

WILLIAM E. MILLER[2] and RALPH B. NEISWANDER[3]

INTRODUCTION

The pitch twig moth, *Petrova comstockiana* (Fernald), develops on pine in twigs of the latest year's growth. Vigorously growing twigs usually survive attack, while poorly growing twigs readily succumb. Normally the insect does not kill host trees, but at high population levels its effect on twigs can be of economic importance.

Petrova comstockiana is well known in name. It has received mention in every modern reference work on American forest insects. Its biology has been known in a general way for years, but details of its development have remained uninvestigated. The present paper presents studies made on the insect in Ohio during three growth seasons, from 1951 through 1953. Occasional observations were made in Maryland (vicinity of Washington, D. C.) during 1954-55 while the senior author was in the Armed Forces. Previously existing information on the species has also been incorporated into the text.

The moth was originally described and named by Fernald (1879). The most recent systematic treatment of the species is that of Heinrich (1923). The common name "pitch twig moth" has been approved by the Committee on Common Names (Muesebeck, 1950). Nomenclature of pines in this paper follows that of Rehder (1952).[4]

GEOGRAPHIC DISTRIBUTION

The pitch twig moth is with little doubt indigenous only to the nearctic region. It was described from New York, and there is no mention of it in European literature. Also, comparison of specimens of

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[1]Lepidoptera, Olethreutidae. Initial determination and frequent verifications were made by J. F. Gates Clarke of the U. S. National Museum.

[2]Research Assistant—now at Lower Peninsula Forest Research Center, Michigan State University, East Lansing, Michigan.

[3]Professor of Entomology.

[4]Pines were identified by the writers with an occasional verification by E. L. Little, Jr., of the U. S. Forest Service Herbarium.

Petrova comstockiana with palearctic pine moths by means of colored illustrations (Spuler, 1910), genitalia drawings (Pierce and Metcalfe, 1922), and European specimens in the U. S. National Museum showed that the species is distinct.

In mapping the known range of the insect (Fig. 1), four sources of information were used: label data from museum specimens; personal records (rearing and identifying the adult or noting work of the larva); published records; and unpublished information in the files of the Economic Insect Survey Section, U. S. Dept. of Agriculture, Washington, D. C. In marking on the map localities for which records were available from more than one of these sources, the writers used only one of the available source symbols.

The museums consulted were: the U. S. National Museum, to which the senior author personally had access; the Academy of Natural Sciences of Philadelphia, the Canadian National Collection, the Cornell University Collection, and the American Museum of Natural History (by correspondence).

References not cited elsewhere in this paper that contained distribution records are Kellicott (1891), Smith (1910), and Ins. Pest Surv. Bull. 20:350 and 21:54. A wider distribution than is indicated on the map has been reported for Connecticut (Friend, 1934), Rhode Island (Loveland, 1911), West Virginia (Hopkins, 1899), possibly Pennsylvania (Illick and Aughanbaugh, 1930), and Long Island (Ins. Pest Surv. Bull. 18:211-12).

Published records of the pitch twig moth from Minnesota, Wisconsin, and eastern Canada probably pertained to *Petrova albicapitana* (Busck) (Ins. Pest Surv. Bull. 19:577, Coop. Econ. Ins. Rept. 3:597, and Canadian Ins. Pest Rev. 6:28, 7:19, 8:64, and 11:85). There are no *P. comstockiana* specimens in the collection of the University of Minnesota, and A. C. Hodson (personal communication) stated on the basis of considerable field experience with species of *Petrova* in Minnesota that the Minnesota record probably was in error. There are no *P. comstockiana* specimens from Canada in the Canadian National Collection, the Nova Scotia Museum of Science, or the R. P. Gorham collection; J. McDunnough stated that he had never seen representatives of the species from the Dominion; and Lionel Daviault was of the opinion that in Quebec *P. albicapitana* had been mistakenly called *P. comstockiana* (personal communications).

Further study in the South in the region outside the range of pitch pine might make it necessary to recognize geographic subspecies of *P. comstockiana*. Mississippi specimens in the U. S. National Museum do not have distinctive male genitalia, but their darker hind wings distinguish them from other specimens of *P. comstockiana*. Also, the

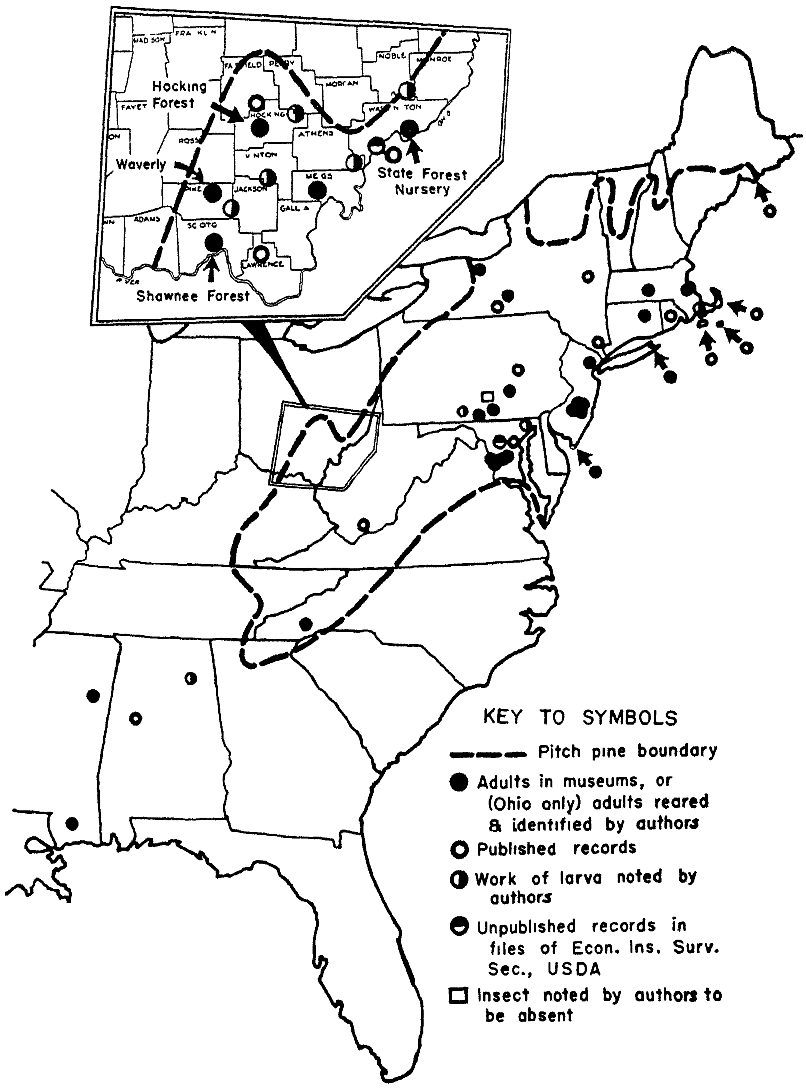

Fig. 1.—Range of pitch pine and distribution of records for the pitch twig moth.

Alabama field observation made by one of the writers (see map) involved scrub pine, *Pinus virginiana* Miller, a pine which in other areas is apparently exempt from pitch twig moth attack.

The unique area in southern Pennsylvania where evidence of previous or current pitch twig moth infestation could not be found (see map) was Pine Grove Furnace State Park. This observation consisted of careful examinations of scores of pitch pine trees along a five-mile length of road.

HOSTS AND OTHER SPECIES OF *PETROVA*

In Ohio, three species of pine are more or less commonly infested by the pitch twig moth: pitch, *Pinus rigida* Miller; Scotch, *P. sylvestris* Linnaeus; and red, *P. resinosa* Aiton. No difference in the ability of the moth to thrive on pitch pine and Scotch pine was detected. Red pine, however, was never found supporting more than a very light population, and then only when growing near infested pitch pine.

Shortleaf pine, *P. echinata* Miller, and Austrian pine, *P. nigra* Arnold, were found serving as hosts in two isolated instances. In the first, a single larva was on a shortleaf pine tree the branches of which interlocked with those of an infested pitch pine tree. In the second, a larva was in one tree of an Austrian pine stand which was adjacent to an infested pitch pine stand.

The ranges of native hosts (as given by Little, 1949 or Harlow and Harrar, 1941) were each compared with the distribution of records for the insect. The range of pitch pine proved to be most nearly coincident with the range of the moth. Pitch pine also is the most often reported host (E. P. Darlington, unpublished records for New Jersey in Acad. Nat. Sci. Phila.; Comstock, 1880; Friend, 1934; Heinrich, 1923; Hopkins, 1899; Illick and Aughanbaugh, 1930; Jones and Kimball, 1943; Procter, 1946; Polivka and Houser, 1936[5]; and others in Ins. Pest Surv. Bull. 19:334 and 405). Scotch and red pines are recorded as hosts in the papers by Friend, Heinrich, and Polivka and Houser; also in Ins. Pest Surv. Bull. 11:307. Friend mentions Austrian pine as a host. Loblolly pine, *Pinus taeda* Linnaeus, is recorded by Heinrich and Polivka and Houser. Six additional host pines are given by Polivka and Houser but it is questionable whether all actually pertain to *Petrova comstockiana* since several species of *Petrova* probably were confused by these authors (discussion further on).

[5]A paper based on the same investigations was also published by Polivka and Alderman (1937).

In an attempt to corroborate host records involving loblolly pine, trees of this species encountered occasionally in natural and planted stands in Maryland were carefully inspected. In several cases infested pitch pine trees were present near loblolly pine trees and in one case the branches of a loblolly interlocked with those of an infested pitch pine tree. Nevertheless, no sign of present or past infestation in loblolly pine could be found.

A similar situation occurred in an estimated 30-year old ornamental mixed planting of Scotch pine and white pine, *Pinus strobus* Linnaeus, in Maryland. All of the dozen or more Scotch pine trees present were currently infested and bore signs of past infestation. The white pine, however, was entirely free from attack even though some specimens touched infested Scotch pine trees. Polivka and Houser (1936) also observed absence of infestation in white pine.

In Ohio, one northern pine (white) and three southern pines (pitch, scrub, and shortleaf) are indigenous within the range of the pitch twig moth. Both in pure and in mixed pine stands pitch pine was found to be the only one of these four pines normally affected in Ohio. This striking specificity was also exhibited by the insect for the same host in Maryland in natural stands containing pitch with either or both scrub and loblolly pines.

Besides *Petrova comstockiana,* two other species of *Petrova* were found occurring throughout southern Ohio: *P. virginiana* (Busck) and *Petrova* sp. (undescribed). These two species build nodules very similar to the nodules of *P. comstockiana.* Where two or more of the three are sympatric, confusion about the specific identity of *Petrova* populations could arise in the field. However, the species of hosts affected can serve as a guide in the differentiation of such populations: *Petrova* sp. occurs exclusively on shortleaf pine and *P. virginiana* exclusively on scrub pine, and these two pines are rarely or never attacked by *P. comstockiana.* Stands were seen in which all three of the nodule making moths occurred together, with each insect affecting only trees of its particular host species.

As mentioned earlier, the validity of some host records given by Polivka and Houser (1936) for Ohio seems questionable. The only *Petrova* listed in their paper is *P. comstockiana,* and they note the incidence of this insect in ten different pines, including scrub and shortleaf. The sharp host specificity and the similarity in larval habit exhibited by the three species of *Petrova* now known to occur in Ohio strongly suggest that Polivka and Houser were dealing not only with *P. comstockiana* but with *P. virginiana* and *Petrova* sp. as well.

SEASONAL HISTORY

The primary sources of pitch twig moth seasonal history knowledge have been the early papers by Comstock (1880) and Felt (1903, 1906), both of whom observed the insect in New York. It was Comstock's opinion that two generations were produced per year, but Felt established that the insect is univoltine. No more than one generation is now known to develop annually anywhere. However, a multivoltine life cycle might occur in the South where the insect has not yet been studied.

In this investigation, three main study sites were used in obtaining seasonal history data: the Shawnee State Forest and two small ornamental plantings, one at Waverly and the other near the State Forest Nursery at Marietta. The ornamental plantings consisted respectively of three and nine Scotch pine trees about 16 feet tall. The locations of study areas are indicated on the map (Fig. 1).

Field observations were made every two weeks during the growing season at one or more of the above localities. To these biweekly observations were added seasonal history observations made in the insectary at Wooster in alternate weeks on a stockpile of infested twigs. Material in the stockpile was never kept longer than ten days and it was discarded after one observation. Thus a more or less weekly account of development was obtained.

Egg Stage. The eggs are circular, slightly convex, and yellow when freshly laid. In glass jars in the insectary they were usually deposited singly. All eggs laid in the insectary proved to be infertile. Eggs were not found in the wild. The minimum time that elapsed from initial emergence of moths in the insectary to initial observation of neonate larvae in the field was 26 days. The incubation period is estimated to have required three weeks.

Larval Stage. Dates of initial activity of neonate larvae were approximately June 21, 1952, and June 15, 1953. These dates are interpolations since the interval between field observations was two weeks.

The earliest feeding focus of the larva is at needle bases. A tiny silken tent is constructed about the base before the larva bores through the sheath to the needles. The larva carries to the silken tent resin droplets that exude naturally from the wound at the feeding point, and the tent becomes saturated with resin (Fig. 2). Frass is also incorporated into the tent. Feeding at needle bases continues for a period estimated at one to two weeks, after which the insect bores into the stem and begins feeding on cortical tissue. Except for the area covered by the nodule, the bark of the twig is left intact. The cortical feeding area shows up clearly when infested twigs are sectioned in the spring (Fig. 3). When a month or more of age, the larva works down to the central part of the twig and from then on feeds primarily on the pith (Fig. 3). There appeared to be little if any tendency for larvae to migrate from the site of initial establishment.

Fig. 2.—Resin saturated tent of a young larva feeding at needle bases. The resin hardened and turned white after the twig was placed under refrigeration to await photographing.

Resin exudes profusely from feeding sites in cortex and pith as well as needle bases. An activity important to the survival of the larva is the prompt removal of these exudates. Enough resin to drown the insect can accumulate in a short time. During the warm seasons, resin and frass are continually being carried to the tent and in this way the characteristic nodule (Fig. 4) is gradually formed. By the time the pith feeding stage of larval development is reached the nodule has attained the general appearance of maturity. The only change in it thereafter is increase in

Fig. 3.—Infested pitch pine twigs sectioned longitudinally at larval maturity. The pith tunnels run much of the length of the sections, and the cortical feeding injury shows up as darkened areas beneath the bark at the upper end of the sections.

size. Comstock (1880) and Felt (1903, 1906) have already noted that nodules usually occur on the upper surfaces of twigs (Fig. 4), an orientation which is probably a response to gravity.

Enlargement of the nodule is accomplished by a process of first excavating, then rebuilding. With its mandibles the caterpillar removes a portion of the old nodule wall bit by bit, thus making an opening to the outside. It then constructs an extension or bulge of the old wall with new deposits of silk, frass, and resin. The basal portions of needles may be removed if they are in the way of expansion.

The basic color of the nodule varies with the species of pine. Nodules on pitch pine are dark red-orange, while those on Scotch pine are a lighter orange. When larvae are inactive for any length of time, as during the cool seasons, the nodules lose their color due to weathering.

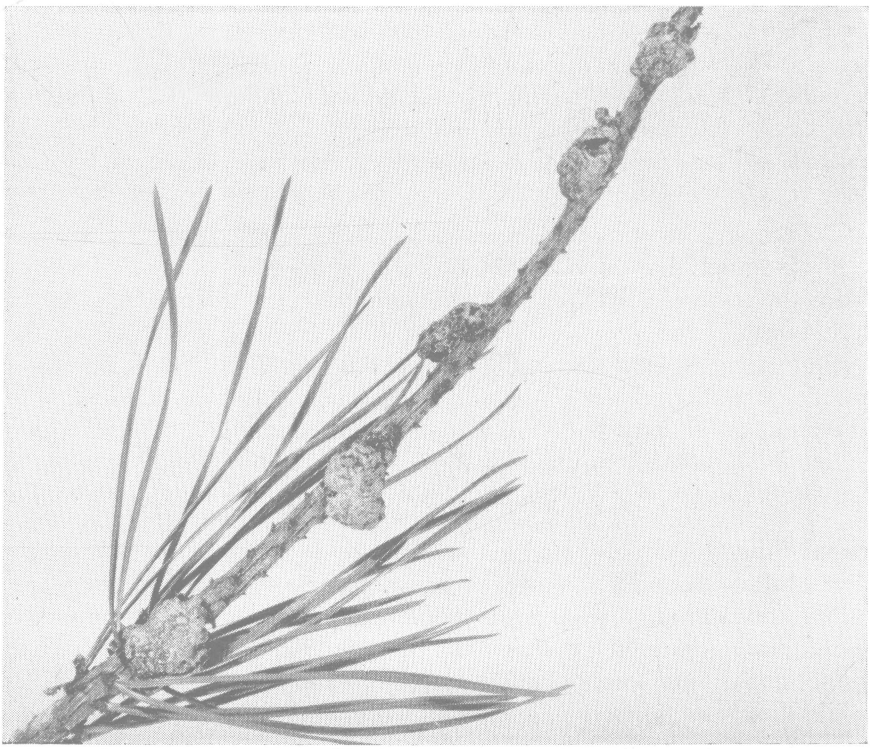

Fig. 4.—A twig of Scotch pine killed by the feeding of larvae.

Nineteen randomly chosen nodules on pitch pine were measured after the makers had pupated. Their lengths varied from ½ to 1¼ inches and averaged ⅞ inch. Their widths varied from ½ to ⅞ inch and averaged ⅝ inch. The heights of the nodules approximated their widths.

The nodule occupies a characteristic position in relation to the pith tunnel. In 99 percent of the infested twigs examined the nodules were nearer the upper or tip end of the tunnel than the lower or base end, indicating that larvae feed more toward the base. In pitch pine, the mean distance from the center of the nodule to the tip end of the tunnel was ½ inch (varying from 0 to 1⅛ inches), and from the center of the nodule to the lower end of the tunnel, 1 3/16 inches (varying from ⅝ to 2⅛ inches). Corresponding measurements in Scotch pine were ⅜ inch (varying from 0 to 1 inch) and 1 inch (varying from ½ to 2⅞ inches). Measurements were made only on twigs in which larvae had completed development.

There appears to be at least one molt while the larvae feed on needle bases. The number and timing of subsequent molts are not known with certainty. A frequency distribution of the head capsule measurements of 200 larvae collected throughout the feeding period produced an irregular pattern. It was thought to consist of five groups, a condition which suggests at least five instars.

The pitch twig moth winters as a partly grown larva. Comstock (1880) stated that larvae were situated during the winter with their heads toward the lower end of the pith tunnel. In the spring, larval activity gets underway early: on April 3, 1952 and 1953, dates of the earliest spring observations in Ohio, practically all the currently inhabited nodules seen already exhibited new extensions. An observation made in Maryland on March 5, 1955, revealed that some larvae had already added new sections to their nodules. Felt (1903, 1906) stated that activity began in New York about April 15.

Pupal Stage. As the larva nears maturity it prepares an exit which later enables the moth to escape from the burrow. A tunnel, the pupal passageway, curving upward from the center of the twig through the nodule is constructed of frass and resin. The upper end of the pith tunnel in the twig is sealed off by this operation. A fine matting of silk is laid down on the walls of the pupal passageway and lower pith tunnel. This process makes the walls smoother, shuts out resin, and presumably provides a more suitable surface for pupal locomotion. At the top of the passageway, the larva prepares the escape hatch by removing all but a thin, translucent layer of the nodule wall. Transformation to the pupal stage then follows. The pupa is usually situated in the nodule near the exit. It can move itself through the burrow by manipulating its abdomen which is equipped with bands of posteriorly directed spines. Traction is probably increased by the spines engaging the silk matting on the walls. Shortly before adult emergence, the pupa forces its way through the escape hatch until it protrudes about half its length. In this position of the pupa the moth emerges. Pupation began in Ohio the latter part of April (Table 1). The duration of the pupal periods is estimated to be between four and five weeks.

Emergence and Adult Stage. In 1951, emergence was already underway on May 24 in the field. Initial insectary emergence was recorded in 1952 and 1953 on May 19 and May 20, respectively. These dates were estimated to be two days later than initial emergence in nature. A lag in insectary emergence revealed itself when comparisons were made of cumulative emergence percentages between field and insectary during the

TABLE 1.—Pupation and Emergence Based on Samplings in Nature

Date	No. Individuals Observed*	Percentage Pupation	Percentage Emergence
	1951 (Forest)		
April 21	25	0	—
28	34	25†	—
May 5	7	100	—
16	7	——	0
24	19	——	32
	1952 (Forest)		
April 14	13	0	—
23	20	15‡	—
May 6	10	100	0
19	12	——	17
	1953 (Ornamental Planting)		
April 26	33	7	—
May 15	11	91	—
19	11	100	0

*No larvae encountered in the forest after May 1 are included because all such larvae observed had been parasitized by *Agathis pini,* a parasite which prevents host pupation (Miller, 1955).

†, ‡ Probably less than true values for pupation. All living larvae found were included in the computations but the number of larvae prevented by *A. pini* from pupating is not known.

course of emergence. The town of Wooster, where insectary work was done, is from 75 to 150 miles north of the study localities, and material had been in the insectary an average of 13 days before initial insectary emergence. Polivka and Houser (1936) state that in 1935 emergence took place from May 25 to the middle of June. In the present study, duration of the insectary emergence period in material from individual localities ranged from 16 to 21 days. There was a lag in female emergence estimated to be between two and four days. The sex ratio of adults was approximately 1:1.

A seasonal history sampling made in Maryland on May 22, 1955, indicated that the majority of pitch twig moth individuals had already emerged. Between 1935 and 1949 in the New Jersey pine barrens, the moth flight period ranged from May 3 to June 4 as determined by E. P. Darlington from light catches and emergence (Acad. Nat. Sci. Phila., unpublished). In New York, Comstock (1880) noted that moths were issuing by May 25, and later Felt (1903, 1906) mentioned June 12 as the earliest date he had seen empty pupal cases. Jones and Kimball (1943) listed June 19 to July 22 as the flight period on Nantucket and Marthas Vineyard Islands, Massachusetts, and Procter (1946) gave June 20 to July 7 as the flight period in Maine.

Numerous attempts were made to induce the moths to mate in the insectary. Jars of about 30 cubic inches and wood frames of about 2 cubic feet covered with muslin or plastic screen were used to hold single or multiple pairs with and without pine twigs, but mating never occurred. Infertile eggs were deposited by five unmated females in jars. The preoviposition period of these females varied from two to six days and averaged four days. The total number of eggs deposited varied from 15 to 84 and averaged 36. The duration of egg deposition per female ranged from one to seven days and averaged four days. Without food or water, length of life of these moths varied from six to ten days and averaged nine days.

INJURY

During its development, the pitch twig moth larva feeds successively on needle bases, cortical tissue, and pith of recent growth twigs. Examination of more than 200 nodules in all stages of formation on pitch and Scotch pines showed that bases of up to four needle clusters, but on the average between two and three, were devoured before the larva turned to cortical tissue. Injury to needles did not cease when the larva moved to other parts of the twig. An average of from two to three with a maximum of five more needle clusters were injured in varying degrees by each larva as a result of cortical feeding and nodule expansion. The average total number of clusters affected per larva was thus about five. In late summer, infested twigs were spotted at some distance from a moving automobile by means of brown, dislodged needles.

The partial or complete girdling of the infested twig that takes place during the cortical feeding stage (Fig. 3) is the most important injury inflicted by the pitch twig moth. Complete girdling kills twigs. Whether or not an infested twig is girdled completely seems to depend primarily on the vigor with which it is growing. Rapidly growing twigs on vigorous young trees were frequently found to survive attack by three larvae per twig. Twigs not growing rapidly sometimes survived attack by one larva, but almost never survived attack by more than one larva. Twigs growing so poorly that they were no greater than 1/8 inch in diameter were never found infested.

Fig. 5.—Pitch pine twigs one growing season after attack. Most of the injuries have not yet been entirely overgrown.

The greatest volume of feeding takes place in the pith. In 46 pitch pine twigs in which larvae had pupated the length of the pith tunnel varied from 7/8 to 3 3/4 inches and averaged 1 3/4 inches. In 48 Scotch pine twigs it varied from 5/8 to 3 1/8 inches and averaged 1 3/8 inches. Pith feeding injury combined with cortical feeding injury (Fig. 3) weakens twigs so that they are more apt to break under stress. If a caterpillar is situated near the tip of a twig, its pith tunnel sometimes will extend into one or more of the terminal buds. Of 543 infested pitch pine twigs in which caterpillars had survived at least to the girdling stage, 7 percent showed this type injury to buds. The same kind of injury was present in 16 percent of 117 Scotch pine twigs from the ornamental plantings.

Twigs that survive pitch twig moth attack usually recover eventually and resume normal growth. It may take up to four years for twigs to overgrow the consumed cortical area, but three years usually is sufficient. Figures 5, 6, and 7 illustrate injuries in various stages of recovery.

Fig. 6.—Pitch pine twigs two growing seasons after attack. Some of the injuries have been entirely overgrown.

INCIDENCE AND ABUNDANCE

The pitch twig moth was found in Ohio in all natural pitch pine stands inspected, as well as in all pitch pine plantations inspected within the natural range of pitch pine. Infested nursery stock could conceivably be the source of infestations in small isolated plantings. Pitch twig moth infestation in at least one nursery in southern Ohio (Belpre, O.) is on record (files of Econ. Ins. Surv. Sec., U. S. D. A.). Nursery infestations have also been reported in Connecticut (Friend, 1934 and other reports of the Conn. State Entomologist) and West Virginia (Coop. Econ. Ins. Rept. 4:226).

No relation was found between tree size and degree of infestation except that, in the forest, nodules were never found at heights less than 4 feet on trees of any size. However, nodules were present at less than 4 feet above the ground in the ornamental plantings. Infestations in nurseries conceivably might involve trees under 4 feet tall.

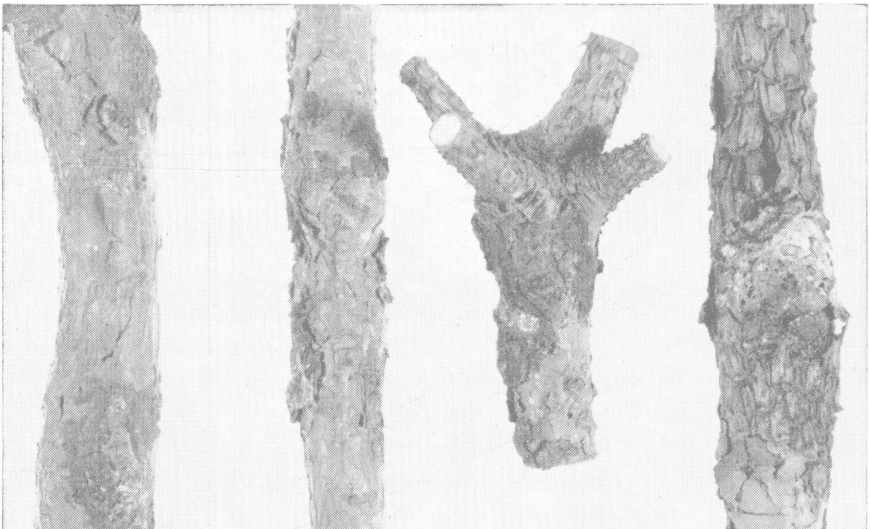

Fig. 7.—Scotch pine twigs, the one at extreme left four growing seasons, the remaining ones three growing seasons after attack. Recovery is largely complete.

Observations on the abundance of the insect in the forest were made on two classes of trees: sapling and saw log. Population data are expressed as number of nodules showing spring larval activity. During April, 1953, in the Shawnee Forest, a sample of 56 trees between 5 and 10 feet tall, representing 7 different sites, were individually inspected for nodules. The sites consisted of abandoned clearings on which pitch pine trees predominantly of sapling age were growing from natural seeding, sometimes widely scattered, but in nearly pure stands. The percentage of sample trees infested proved to be 25, with 79 percent exhibiting one infested twig and the remaining 21 percent exhibiting from two to four infested twigs. The proportion of infested twigs per tree never exceeded an estimated 4 percent. Similar infestation figures were given previously from southern Ohio by Polivka and Houser (1936), but neither sampling method nor stands were described.

During the spring in 1952 and 1953, the writers followed logging crews in the Shawnee Forest and obtained information on pitch twig moth abundance in old trees. The lowest population per tree was found in a group of four pitch pine trees 6 to 15 inches d. b. h.[6] comprising a pine remnant at a site occupied by deciduous species. The number of nodules per tree averaged four, ranging from none to six. A greater abundance of nodules per tree was found at sites where pitch or Scotch pines either were in pure stands or were dominant in pine-deciduous associations. Pitch pine trees at such sites measured as much as 18 inches d. b. h., but Scotch pine trees did not exceed 8 inches d. b. h. The largest twig moth populations per tree in the forest were supported by old trees growing in the open. The density of the insect in such trees was similar to that at most other situations in the forest, the larger populations per tree being a result of larger crowns. Two pitch pine trees in the open, each about 18 inches d. b. h. and still growing vigorously, were supporting approximately 60 nodules each. Nodules were distributed randomly on both trees from the lowermost branches 5 feet from the ground up to the topmost branches.

Diameter of twigs appeared to influence twig moth infestation. As mentioned in the preceding section, nodules were never found on twigs less than 1/8 inch in diameter. Twigs of this size were prevalent on older, less vigorous trees and on the lower whorls of saplings.

The mean number of nodules (in which larvae survived at least to the cortical feeding stage) per twig on 562 infested twigs of pitch pine was 1.2, with 19 percent of the twigs exhibiting more than one nodule. One percent contained a maximum of four nodules per twig.

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[6]Diameter at breast height—4 feet above the ground.

The pitch twig moth population level in the ornamental plantings was considerably higher than in the forest, an estimated 20 percent of current growth twigs being infested. The nodules were randomly distributed over the trees in these plantings also. The mean number of nodules per infested twig on 117 twigs was 1.7, with 40 percent of the twigs exhibiting more than one nodule. Four percent contained a maximum of six nodules per twig.

MORTALITY

Mortality in *Petrova comstockiana* brought about by parasites and by undetermined causes other than parasitization was measured. Mortality from undetermined causes was computed from the numbers of living and dead individuals counted at intervals from early signs of larval activity through the emergence of moths, or about 11 months of the year. Individuals killed by maturing parasites were easily excluded because parasites always left evidences of their development. The data in Table 2 show that this mortality did not proceed at an even rate and that it was highest during the early part of larval development. Of particular interest is the indication that there was no mortality during winter.

TABLE 2.—Mortality Caused by Factors Other Than Parasitization

Season	Stage of Insect	Years Data Obtained	No. Individuals Observed	Percentage Mortality
Summer (July—Sept)	Early Larval	1950-53	250	26
Fall & Winter (Oct.—March)	Middle Larval	1951-53	106	0*
Spring (April—May)	Late Larval and Pupal	Do.	526	16
Do.	Adult†	Do.	108	2

*Determined by comparing counts from early spring with those from preceding summer.
†Moths emerged but failed to escape from nodules.

The parasites causing mortality were *Agathis pini* (Muesebeck), *Hyssopus thymus* Girault, and *Calliephialtes comstockii* (Cresson), all affecting the caterpillar. *Perilampus fulvicornis* Ashmead was a frequent secondary parasite through *Agathis pini* (Miller, 1955). The highest percentage of parasitization occurred in spring, the parasite adults emerging concurrently with moths (Table 3).

In summer, when the pitch twig moth was in the early part of its development, only *Hyssopus thymus* brought about mortality. An examination of 158 nodules of the 1952 and 1953 broods in the Shawnee Forest showed that *H. thymus* had destroyed 7 percent of the young larvae by late summer.

TABLE 3.—Spring Parasitization as Determined from Insectary Emergence

Type of Stands	Years Data Obtained	Total No. Hosts and Parasites*	Percentage Host	Percentage Minor Parasites†	Percentage *Agathis pini*
Forest	1951-53	167	37	4	59
Ornamental	1952-53	52	89	11	0

* † *Hyssopsus thymus* develops in aggregations of several individuals to a host (Miller, 1955). Parasitization by this species is therefore expressed as number of hosts affected (determined during postemergence dissections of the twigs) rather than by number of parasite adults issuing.

To better relate mortality factors to the high and low population levels observed, survival rates were computed separately for the forest and ornamental planting populations. These rates were obtained by multiplying together the mathematical complements of all the mortality figures given in the tables and text. The results indicate that in the ornamental stands five larvae had to begin feeding for every two moths (theoretically one male and one female) that emerged (survival rate of .45); whereas under forest conditions, twice this number of larvae had to begin feeding to produce a pair of adults (survival rate of .23). The lower survival rate in the forest is due almost entirely to the *Agathis pini* parasitization mortality factor. This factor was absent in the ornamental plantings (Table 3). Thus *A. pini* appears to have been responsible for the difference in population levels. Although both ornamental plantings consisted solely of the introduced Scotch pine, the possibility that different species of host plants were involved had to be dismissed. No appreciable difference in mortality from undetermined causes was detected between forest and ornamental plantings, and groups of Scotch pine trees in Ohio and in Maryland growing under forest conditions were no more affected than pitch pine trees in the same stands. Also noteworthy are these two facts: the proportion of the small moth populations removed from the ornamental plantings for laboratory study corresponded approximately to the degree of parasitization by *A. pini* in the forest; and in the one ornamental planting followed up, a drop in population level was noted the generation following this removal.

The conclusion that *A. pini* is a major factor in the differential population levels in question suggests that this parasite plays an important role in keeping the moth at the low or endemic levels noted in forests. *A. pini* is also recorded from the pitch twig moth in New York and Maine (Muesebeck, 1940), and the senior author has found its cocoons in Maryland where the parasite is apparently as abundant as in Ohio.

The annual reproductive potential of the pitch twig moth expressed for a pair of the adults was computed at 84 with the method outlined by Graham (1952, Chap. 4). With the assumption that the population level from generation to generation remained more or less constant, it was further computed by a subtraction method (Morris and Miller, 1954) that a reduction of at least 89 percent in population potential took place during the month after moths issued till young larvae of the next generation established themselves.

CONTROL

The present observations on *Petrova comstockiana* corroborate Graham's (1939) characterization of members of *Petrova* as insects that tend to attain balanced populations at high density. Insect populations of this type usually require frequent or constant application of control measures, for if neglected, they can be expected to build up again shortly to damaging proportions. Balanced populations at high density are ideally suited to the host density requirements of biotic control agents. Graham (1939) has already suggested that forest insects in this population category offer excellent opportunities for the application of biotic control. With the pitch twig moth, the efficacy of biotic control is indicated by the observations discussed in the preceding section. In severe pitch twig moth infestations where *Agathis pini* is absent, introduction of this parasite would appear to hold promise as a practical control measure.

A simple direct control measure for small plantings is removing and destroying infested twigs. Larval habits are such that satisfactory chemical control results would be expected only from a residual toxicant applied prior to hatching.

SUMMARY

1. The pitch twig moth was investigated in the field and insectary in Ohio from 1951 through 1953, and casual observations were made on it in Maryland during 1954 and 1955. Previously known information has been reviewed.

2. The species is indigenous only to North America, and its known range extends from Mississippi northward to Ohio and Maine. It is not known to occur in Canada. Possibly it is a polytypic species.

3. The pitch twig moth is an oligophagous feeder within the genus *Pinus*. The pine most commonly infested is pitch pine. Populations of the pitch twig moth and of two other species of *Petrova* with similar larval habits can be differentiated in the field through the identity of the host trees.

4. In the northern part of its range, the pitch twig moth is univoltine. The period of adult flight is primarily May and June. In Ohio, larvae of the new generation begin feeding in mid-June. The winter is spent as a partly grown larva, and feeding is resumed during March. Pupation begins the latter part of April. The insect has never been studied in the southern part of its range where its voltinism may be different.

5. As the larva develops it feeds on three parts of the host plant in succession: needle bases, cortex, and pith of twigs. Throughout feeding, debris and resin are removed from the feeding area and formed into a hollow nodule which is characteristic of the genus *Petrova*.

6. The most important injury caused by the insect is the girdling of the twigs that takes place during cortical feeding. Whether or not a given twig is killed depends primarily on its vitality. Twigs that do not succumb usually recover in three years.

7. The distribution of the larvae on individual trees is usually random. This randomness is limited by absence of larvae on twigs less than 1/8 inch in diameter and, in the forest, by absence of larvae at heights less than 4 feet.

8. The parasite *Agathis pini* (Muesebeck) appears to be a key factor in the persistence of the low or endemic pitch twig moth population level in the forest. The pitch twig moth is characterized by a tendency to develop balanced populations at high density. Populations of this type are particularly amendable to biotic control.

9. The insect can be directly controlled by removing and destroying infested twigs. The best insecticide treatment would probably be a residual toxicant applied prior to hatching.

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