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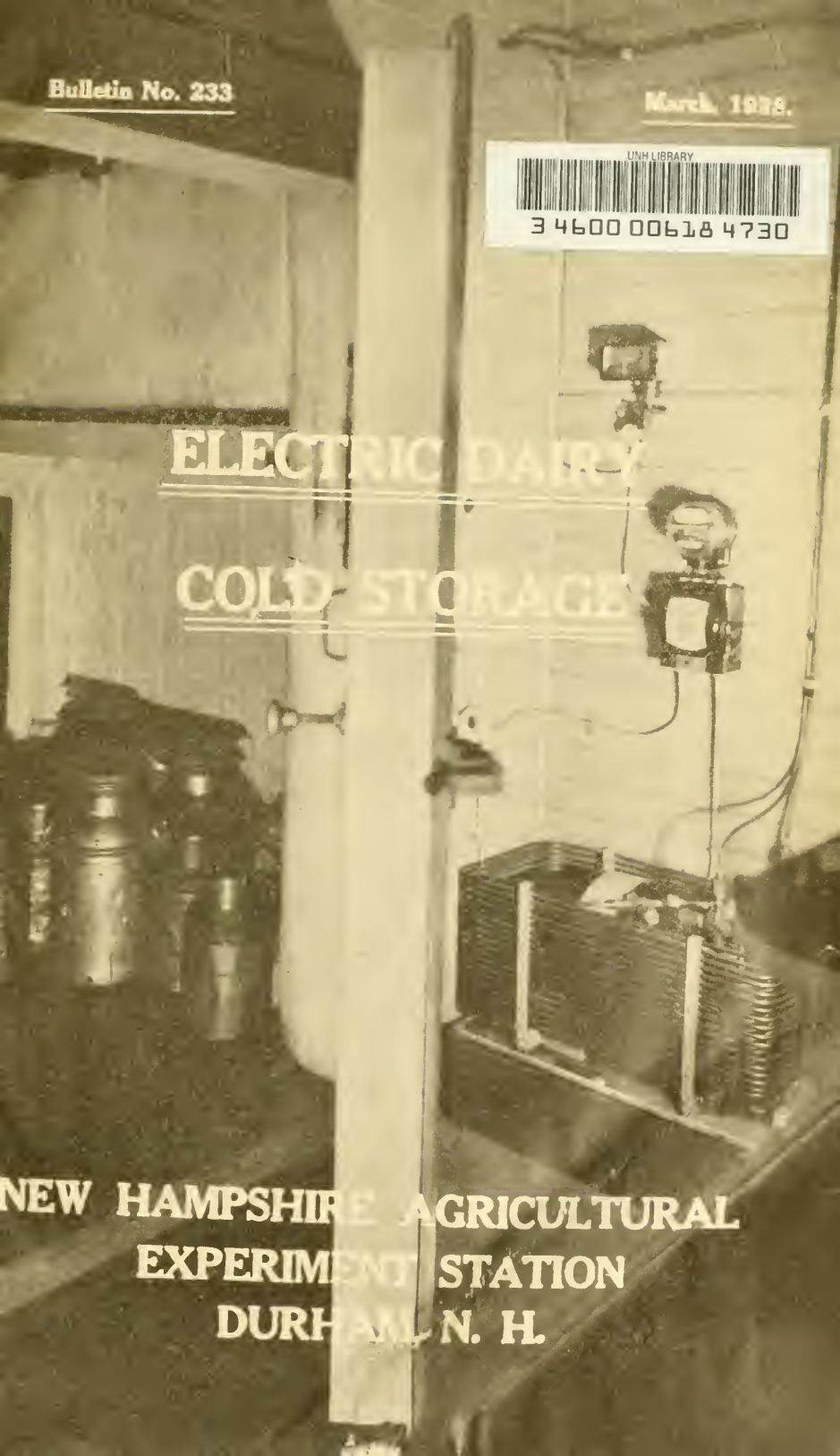
Bulletin No. 233

March, 1928.

ELECTRIC DAIRY COLD STORAGE



NEW HAMPSHIRE AGRICULTURAL
EXPERIMENT STATION
DURHAM, N. H.

SUMMARY TABLE

Showing General Results of Seed Inspection Work
for the year ending June 30, 1929

Kind of Seed	Number of Samples	Purity Compared to Guarantee			No Guarantee	Germination Compared to Guarantee			No Guarantee
		Above	Satisfactory	Below		Above	Satisfactory	Below	
Alfalfa	9	1	8	0	0	1	5	2	1
Alsike	31	2	26	3	0	0	26	5	0
Barley	14	0	14	0	0	2	12	0	0
Bluegrass, Canada	1	0	1	0	0	0	1	0	0
Bluegrass, Kentucky	2	0	1	1	0	0	2	0	0
Buckwheat	3	0	3	0	0	0	3	0	0
Canada Field Peas	2	0	2	0	0	0	2	0	0
Corn	1	0	0	0	1	0	0	1	0
Millet, Golden	2	0	2	0	0	0	1	1	0
Millet, Hungarian	36	5	26	5	0	0	24	12	0
Millet, Japanese	43	6	23	14	0	2	38	3	0
Oats	22	0	22	0	0	0	21	1	0
Orchard Grass	1	1	0	0	0	0	0	1	0
Rape	3	0	3	0	0	0	3	0	0
Red Clover	51	9	32	10	0	5	38	8	0
Red Top	35	6	24	5	0	0	21	14	0
Rye	5	0	5	0	0	0	1	4	0
Soy Beans	1	0	1	0	0	0	0	1	0
Sweet Clover	1	1	0	0	0	0	1	0	0
Timothy	55	2	52	1	0	0	55	0	0
Vetch	1	0	1	0	0	0	1	0	0
Wheat	4	0	4	0	0	0	4	0	0
White Clover	8	0	7	1	0	0	8	0	0
	331	33	257	40	1	10	267	53	1

Bulletin 247 October, 1929

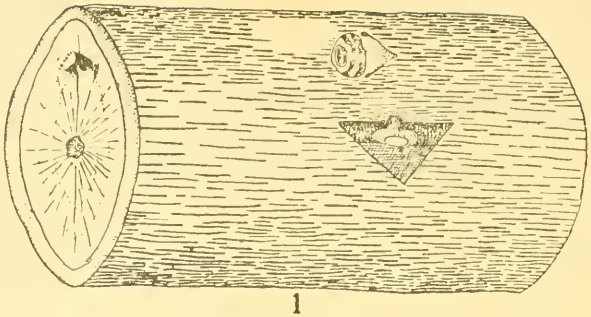
UNIVERSITY OF NEW HAMPSHIRE

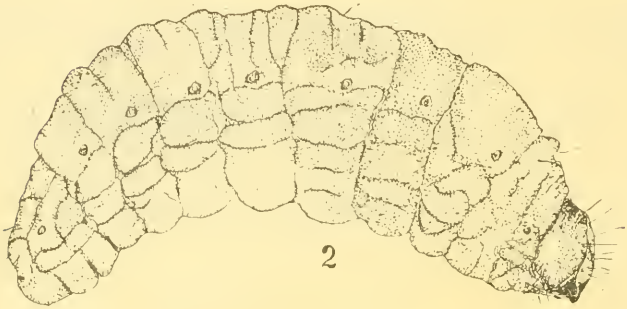
EXPERIMENT STATION

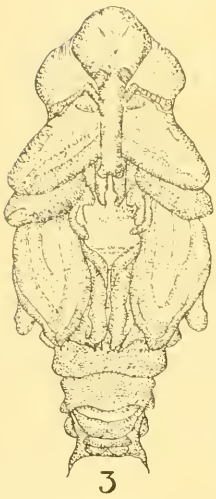
THE WHITE PINE WEEVIL IN NEW HAMPSHIRE

By C. C. PLUMMER *and* A. E. PILLSBURY

UNIVERSITY OF NEW HAMPSHIRE
EXPERIMENT STATION
DURHAM, N. H.







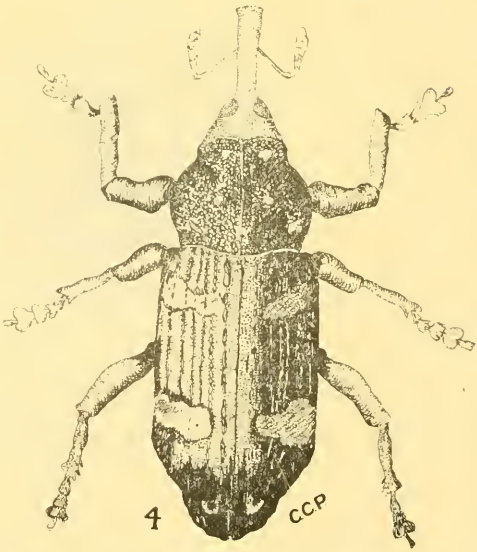


FIG. 1—Egg in Situ, x 4. FIG. 2—Larva, x 10. FIG. 3—Pupa, x 10.5.
FIG. 4—Adult, x 14.

THE WHITE PINE WEEVIL IN NEW HAMPSHIRE*

By C. C. Plummer and A. E. Pillsbury

INTRODUCTION

The white pine weevil, *Pissodes strobi* Peck, is a forest insect of major importance in New Hampshire, where large areas of white pine, *Pinus strobus,* are grown. It is estimated that at least 70 per cent of the white pines in New Hampshire are attacked at some time, or at various times, in their growth. Some trees are attacked as many as 20 times before attaining maturity. After the tree has been injured several times the timber is of lower grade and often can be used only for box boards or other relatively cheap lumber. In this way the value of the lumber may be reduced 30 per cent.

The damage caused by this insect has done much to discourage reforestation with white pine. It has resulted, in many cases, in the substitution of red pine, *Pinus resinosa,* for the better known and better liked species.

In New Hampshire the weevil is universally present wherever white pine is found. Isolated and small, scattered areas of white pine, common in the southern part of the state, are injured as much as extensive plantations.

The work described in this bulletin has been carried on since the fall of 1925.

HISTORICAL

The white pine weevil is an indigenous American insect, described in 1817 as *Rhynchænus strobi,* by Professor W. D. Peck, of Harvard University, in a paper published in the "Massachusetts Agricultural Repository and Journal." Incidentally, this paper is believed to be the first in which an American injurious insect was described. (Britton, 1919.) Thomas Say (1831) first referred to the weevil as *Pissodes strobi.* Since that time the white pine weevil has often been mentioned in entomological literature. Early writers contributed a few facts and many erroneous suppositions regarding the life history. No doubt some of these early workers confused *P. strobi* with closely related species, for several of their observations have never been verified. Dr. A. D. Hopkins (1907) was the first to work out the general life history of the weevil. In recent years contributions on the life history and control, made by Walden (1914, 1915) and Britton (1919) in Connecticut, Peirson (1922) in Massachusetts, and Graham (1926) in New York and Minnesota, have added materially to our knowledge of the weevil.

*The writers are indebted to Professor W. C. O'Kane and Assistant Professor P. R. Lowry for their valuable assistance at all times.

DESCRIPTIONS

Egg

The egg (Fig. 1) is pearly white, slightly oblong, and equally rounded at both ends. It varies in length from 0.735 mm. to 0.825 mm., the average being 0.782 mm. The width varies from 0.405 mm., to 0.480 mm., the average being 0.452 mm.

Larva

The larva (Fig. 2) is a yellowish-white to white cylindrical footless grub. The body is divided by transverse constrictions into three thoracic and nine distinct abdominal segments, the anal lobes forming the tenth. The thoracic segments are not larger than the first abdominal segment. The width of the head is about one-half that of the body and is of a light brown to deep yellow color, the anterior margin and the mandibles being much darker. A shining dorsal plate and a distinct sternal plate are found on the first thoracic segment. There is a distinct spiracle on the first thoracic segment; none on the second and third thoracic segments; and again distinct spiracles on the first to eighth abdominal segments. The spiracles are round. The length of the full grown larva varies from 6.25 mm. to 9.5 mm., the average

Pupa

The pupa (Fig. 3) is exarate or free and is of a creamy white color. The eyes at the base of the snout are light brown. As the pupa matures the snout, head, and legs become brown, this shade gradually extending as the pupa approaches the adult form and color. The abdomen is square at the tip and has a sharp, slightly curved spine on either side. The length of the pupa varies from 5.50 mm. to 6.75 mm., the average being 5.93 mm.

Adult

The adult (Fig. 4) is an oblong-oval weevil. Its color varies from dark brown to light brown but usually is dark reddish brown. Both sexes are marked with irregular small patches of grayish-white and yellow scales. The grayish-white hind-spots form an almost continuous band across the posterior third of the elytra. The thorax is definitely marked with several small round spots of light-colored scales. Small patches and scattered white scales are found on the sides of the thorax and femora, and the ventral aspect of both thorax and abdomen. The beak is shorter than the thorax in the male while it is equal to it in the female. The geniculate antennæ are inserted on the sides of the beak near the middle. The thorax is as broad at the base as it is long, the sides parallel along the basal half, beginning to narrow toward the front. The disc is densely and finely rugose-punctate. The elytra are slightly wider than the thorax, the sides parallel to a point beyond the hind-spot where they start to converge and are compressed to an apex. The stria-

tions are distinctly punctured. The legs are strong, subequal. The tibiæ have an incurved spine at the apex. The tarsi are short and broad. The tarsal claws are simple. The length of the adult varies from 4.0 mm. to 6.9 mm., the average being 5.2 mm.

INJURY

Exudations of small clear drops of pitch from the punctures made in the upper part of the leader are the first evidence of injury. The pitch may later run down the stem or remain in small spots which become white upon hardening. Often injury is not noticed until the larvæ cause the young growth to become discolored and wilted. Later in the season the appearance of dead tips indicates further development of the insects in the leader.

The most important injury, readily observed, is confined to the terminal shoot or leader of the white pine, usually extending only as far as the first whorl of lateral branches.

After the terminal portion has been killed by the feeding of the larvæ the lateral branches next below tend to grow more upright the following year and to compete for the place of leader. The longest lateral branch assumes this role. In some cases two laterals will make approximately the same growth and both will replace the dead leader, resulting in the formation of a forked tree. Rarely three or even more laterals exhibit this phenomenon.

When a lateral branch replaces a leader the trunk of the tree has a bowed appearance between the nodes where the replacement has taken place. The number of times a tree has been attacked can readily be calculated by the appearance of the internodes and by the remains of the killed leader, which can often be found projecting from the side of the trunk, even many years later.

The host tree may be injured repeatedly from the time it is about five years old until it reaches maturity. In general, the most extensive injury takes place when the trees are from eight to eighteen years of age, or from five to fifteen feet high. The weeviling gradually declines as the trees approach maturity. It is surprising to note the number of trees thirty or more feet high showing recent weevil injuries. The height of the older trees makes the injury less noticeable and has led to the general belief that trees over thirty years of age are rarely attacked.

Graham (1926) has shown in the relation of injury to crown class and rate of growth that the weevil seems to choose the most thrifty and rapidly growing trees in a stand, not necessarily the tallest trees.

Experiments were carried on to note the preference, if any, for dominant and recessive leaders. A dominant leader of large tip diameter is a good indication of the relatively vigorous condition of the tree by which it was produced. A screened cage four feet long, two feet wide, and eighteen inches high with three-eighths inch holes spaced five inches apart in the wooden floor was used in the experiments. Twenty-two recessive leaders, one-quarter inch in tip diameter and thirteen inches

long, were alternated in the holes with dominant leaders, one-half inch in tip diameter and thirteen inches long. Fifty weevils were liberated on the floor of the cage.

Two days later, June 27, 1927, thirteen weevils were found on the recessive leaders and twenty on the dominant leaders. June 28 the experiment was repeated with different weevils and fresh leaders. This time the leaders were arranged alternately as before, but in reverse order. After two days twelve weevils were taken from the recessive and twenty-six from the dominant leaders.

The experiments confirm field observations, which show that the weevil prefers the large and dominant to the small and recessive leader.

In numerous instances it has been noticed that certain trees, which from their vigorous growth would appear susceptible to weevil attack, are not injured, while others in the immediate vicinity, which would appear less susceptible, are attacked. To a certain extent infestation may be based on chance.

HOST TREES

The white pine weevil feeds principally on white pine. Although workers have reported this insect as damaging other species of conifers, such infestation is not economically important. Norway spruce is probably the next most susceptible host.

Hopkins (1911) listed as hosts jack pine, *Pinus Banksiana;* pitch pine, *Pinus rigida;* and red spruce, *Picea rubra.* Peirson (1922) observed or verified Japanese pine, *Pinus densiflora;* Scotch pine, *Pinus sylvestris;* and Norway spruce, *Picea abies.* Currie (1905) lists deodar or Himalayan cedar, *Cedrus deodara.* Packard (1890) mentions balsam fir, *Abies balsamea;* and hemlock, *Tsuga canadensis.* In the course of this study in New Hampshire the weevil has occasionally been found on Scotch pine, pitch pine, red pine, and Norway spruce.

No doubt some of the earlier writers confused the white pine weevil with other species in the same genus. Probably Currie (1905) and Packard (1890) erred in this respect. Further, it is possible to find an accidental specimen on some species of conifer other than white pine, although breeding may not take place on the trees noted.

June 21, 1927, several white pine weevils were noted copulating and feeding on the leaders of two Norway spruce trees about eight years old, located in Barrington, N. H. They made a large number of feeding punctures. On either side of the row in which these two trees stood were other rows of mixed and pure white pine, red pine, and Scotch pine, 15 to 20 feet high. These trees were from 15 to 100 feet away. In these rows no weevils were found on any other species than white pine.

At the time of the first observation noted above the weevils on the two Norway spruces were allowed to remain there in order to determine the extent of injury. Two months later the leaders exhibited no evidence of larval tunnels and no signs of injury other than the feeding punctures

made by the adults. Norway spruce is apparently resistant although it is a host.

In order to determine if the white pine weevil can live and breed on pitch pine and red pine, four leaders from each were placed on June 30, 1928, in glass vials eight inches long and one inch in diameter. Two pairs of weevils were liberated in each vial. The vials were inserted in a plaster-of-Paris block to provide moisture.

July 19, thirteen of the sixteen adults on the four red pine leaders were alive. Larvæ were present. Eleven of the weevils placed on pitch pine leaders were alive, and larvae were present in every leader.

Later in the season larvæ in two of the red pine leaders had died while three and four adults respectively emerged from the remaining two leaders about September 6. Five, seven, eight, and seven adults respectively emerged from the four pitch pine leaders about the same date.

REARING METHODS

Rearing was carried on in a screened insectary cage with a canvas roof. The floor is of earth. The cage is surrounded by a number of white pine trees and is partially shaded during the day. The temperature is slightly below that to which the insect is exposed under natural conditions. Certain phases of the life history work were carried on in a small greenhouse where the temperature was slightly higher than in the field.

Life history data, such as the length of the several developmental stages, were obtained from material in the insectary cage and greenhouse. When possible, observations were checked with field conditions.

Rearing in the greenhouse and insectary cage was accomplished by using several plaster-of-Paris blocks. Each block is two feet long, six inches wide and four inches high. Twenty or twenty-one holes, one inch in diameter and one-half inch deep, spaced one inch apart, were drilled in the broad upper surface of the block. A one inch hole was drilled from end to end through the central part of the block. A one inch hole drilled in the broad surface near one end connects with the longitudinal central canal. Corks inserted in the ends of the longitudinal canal retain water poured in the connecting hole on the broad surface.

Eight glass vials, eight inches long and one inch in diameter, each containing three or four pairs of adults and a fresh white pine leader, were inserted in the plaster-of-Paris block every day, the open end of the vial in the block. Twenty-four hours later the leaders were removed and fresh ones substituted. The weevils were replaced when necessary. The leaders removed from the vials were examined for eggs under a binocular microscope. Part of the leaders containing eggs were placed in vials inserted in blocks kept in the greenhouse and part in blocks in the insectary cage.

The material was examined daily. Accurate observations could be made without disturbing the insects. When the larvæ advanced to a point where the food supply was endangered a fresh section of a leader

of the same diameter was spliced on and wound with thread to hold it in position. With few exceptions this technique was entirely satisfactory. Three or four successive splices on one leader often were made. Usually it was not necessary to furnish water more than once a month.

The insectary cage and greenhouse are located in Durham, N. H. Most of the field observations were made in Madbury, seven miles north of Durham. Certain field work was carried on in Durham plantations and a plot outside of Dover, seven miles northeast of Durham.

SEASONAL LIFE HISTORY AND HABITS

In brief, the life history of the weevil is as follows:

The adults leave hibernation about the last of April or the first of May and make their way to the leaders of white pine. Here they feed in the vicinity of the new growth and tender buds before moving down the leader to feed and oviposit. They are found on the leader until the middle of July, at which time they either die or go to other parts of the tree. The eggs, inserted in the cambium, hatch in from 6 to 20 days. The larvae work their way down the leader, feeding on the inner bark and cambium. After they have fed for three or four weeks each one enters the wood and constructs a pupal cell where it remains for a varying length of time before pupating. The larval stage occupies about 36 days. The pupal stage lasts about two weeks and is followed by the eclosion of the adult. The adults remain within the leader for two or more weeks. After emerging the adults are found feeding on the branches of the white pine in increasing numbers from the middle of September until the middle of October. On the advent of cold weather they hibernate in the duff.

Some adults, as discovered in this work, do not die after completing egg-laying but remain alive until a second season when they again lay eggs.

APPEARANCE IN THE SPRING

In the latter part of April or the first of May, depending on weather conditions, the weevils leave hibernation and make their way to leaders.

The following dates were noted in this study:

May 5, 1926, at Durham, an adult was noted cling to the top of a hibernating cage in which several weevils had been confined since November, 1925. Weevils were first noted at Barrington Depot, May 6.

In 1927 weevils were found on leaders April 20.

In 1928 the first observation for the year was made May 6. On that date numerous weevils, feeding and copulating, were found on leaders and buds exposed to the sun.

In 1929 weevils were first observed April 24.

The work of Graham (1926) with tanglefoot bands on the lower internodes of white pine showed that the weevil after leaving hibernation may either fly or crawl up the trunk in order to reach the leader. We have obtained similar results.

Weevils leaving hibernation in the spring appear considerably darker than they were on emerging in the fall. Some of their scales have been lost or discolored.

EARLY ACTIVITIES OF THE ADULT

Aside from the more important damage done by the larvæ, the adults inflict considerable injury to the tree by chewing broad cavities in the new buds of the leader. In a few cases eggs have been found in some of these feeding cavities.

The weevil chews a small circular hole through the bark and cambium and sometimes slightly into the wood parenchyma. The feeding punctures may extend a short distance into the bark or may extend through the bark to include the cambium. The weevils seem especially fond of cambium tissue. The cavity made by the weevil is much wider basally (Fig. 1) because of its activity in securing as much cambium as possible from one feeding puncture. While feeding, the weevil is constantly turning its head in order to use the natural curve of its beak to obtain the cambium tissue. The structure of the head makes it possible for the weevil to feed with little movement of the body. An hour or more may be spent in making one feeding puncture. There is no marked difference between the cavities made by the male and female.

Eggs may be found in cavities that enter the bark for only a short distance. Usually, however, they are placed in the deeper cavities, which provide ample room for one or more eggs. Early in the season the punctures are usually found near the terminal buds, but as the season progresses the eggs are laid further down in the leader. No observation has been made to ascertain if the female oviposits in cavities made by the male.

The adults seem able to live without food for only a short time. Thus, 20 weevils were placed without food in a muslin covered cage on June 29, 1928. Nineteen were dead July 2. The last one died July 3.

MATING

Mating of the weevils takes place in the spring following emergence from the infested leader, and not in the fall. Shortly after their appearance in the spring and up until their disappearance in July, the weevils are constantly found in copula. Few single individuals are present during this period.

Apparently the female does not have to be fertilized more than once in the season in order to continue laying fertile eggs. This was brought out in the course of an experiment to determine the number of eggs laid by a single female. In several instances the male of the original pair died early in the season and the female continued to lay fertile eggs throughout the remainder of the oviposition period. In two instances the males died sometime between May 8, 1928, when they were first introduced, and June 11, when the leaders were removed in order to count the eggs.

When new leaders were inserted from time to time it was found that these females continued to lay fertile eggs until July 17, the end of the oviposition period in the insectary cage.

Graham (1926) cites an example where a female apparently was fertilized before entering hibernation. This is probably a rare occurrence. In the light of recent observations the instance was more likely that of a weevil hibernating a second winter. If insemination should happen to take place in the fall it is a question whether fertile eggs could be laid in the spring.

RESPONSES

The death-feigning habit of the white pine weevil is strongly developed. A shadow or movement close to the weevil will cause it to drop from the leader. This habit appears stronger on bright warm days when the weevils are active. During cool, windy, or rainy weather they remain in a sluggish condition at the top of the leader among the buds.

The weevil is negatively geotropic and positively phototropic. The former response is easily demonstrated by completely covering an 8 inch vial with black paper. When a leader and eight adults were inserted in such a vial and placed in a block, the feeding punctures were concentrated in the top inch of the leader, the remainder containing but few punctures.

When a similar vial was completely covered except for a quarter of an inch around the top, 20 punctures were found in the first inch, 26 in the next 4½ inches, and 8 in the last 2 inches of the leader. When such a vial was completely covered, except for a band 2 mm. wide at the base, a more general distribution of the feeding punctures occurred.

The fact that the weevil is positively phototropic is used to advantage in control by silvicultural methods.

PREOVIPOSITION

The preoviposition period extends from the time the adults emerge in the fall until shortly after their appearance on the leaders in the spring, at which time oviposition begins. Histological studies of the ovaries of the weevil (Plummer, 1929) before and during hibernation have proved that the oocytes are only partially developed. The weevil is unable to oviposit in the fall, previous to hibernation.

OVIPOSITION

The oviposition period extends from the time the females begin laying eggs in the spring until some time in July, when they disappear from the leader. Thus, the oviposition period may last two months or more. July 8, 1926, no adults could be found in the field. In 1927 the oviposition period in the field terminated on July 9; in 1928, July 12. Weevils confined in a glass moist chamber continued to lay eggs until September 9, 1927.

After the cavity is prepared the act of oviposition is quickly accomplished, occupying from a few seconds to a minute or more. Usually one egg is inserted in each egg cavity. However, frequently two, occasionally three, and rarely four or five eggs are found.

To determine the number of eggs laid by a single female a pair of weevils was placed on each of forty-seven white pine leaders in glass vials inserted in plaster-of-Paris blocks. The experiment was begun May 8-11, 1928. Leaders were removed and replaced with fresh ones on the dates indicated in Table I for the purpose of counting the eggs, or larvæ if any had hatched.

Thirteen females or pairs of weevils were dead at the end of the first period. These are not included in Table I. The experiment was continued a week longer than shown in Table I to ensure that all of the females had finished ovipositing. It is impossible to tell exactly when egg laying began and when it ceased.

SUMMARY OF THE DATA IN TABLE 1

Average number of eggs per female for first five weeks	35.7
Average per female per week	7.
Average number of eggs per female for the next two weeks	32.8
Average per female per week	16.4
Average number of eggs per female for next three weeks	59.2
Average per female per week	18.7
Average total number of eggs laid	129.
Maximum number laid by a single female	201.
Minimum number laid by a single female	25.

More eggs are laid near the end of the oviposition period, that is from June 25-26 to July 17, and not early in the season as stated by some writers.

Under field conditions the female may oviposit on several leaders, or two or more pairs may work together on the same leader. In this way it is possible for leaders in the field to contain more eggs than the maximum number found in the insectary cage.

POSTOVIPOSITION AND LONGEVITY

The oviposition period terminates when the weevils gradually disappear from the leaders in July.

After leaving the leader at least a part of the weevils move to other parts of the tree, especially to the vicinity of the new growth on lower lateral branches, which seem particularly attractive to them at this season of the year. Here they are found in a semi-dormant condition. Their condition is not such that the term "estivation" can be used, for they feed to some extent and are slightly active. They do not make their typical feeding punctures but eat small patches of bark and cambium. These feeding evidences are not found previously to the disappearance of the

TABLE I.—*Number of Eggs Laid by a Single Female, 1928*

FEMALE NO.	1	2	3	5	6	7	8	9	12	13	16	17	18	19	21	22	23	24	25	26	27	28	29	30	31	34	36	37	38	40	41	42	44	46
Eggs laid—May 8-11 to June 11-13	26 M	12	44	21	49	35	43	79	61	40	51	55	51	27	31	19	39	38	46	28	34 M	63	67 M	47	15	0	4	51	0	44	28	23	3	33
NO. OF DAYS	35	35	35	35	35	35	35	35	35	35	34	34	34	34	33	33	35	35	35	35	35	35	35	35	34	34	34	34	34	34	34	34	34	34
Eggs laid—June 11-13 to June 25-26	41	32	0	0 D	34	19	19	53	15	23	0 D	42	0 D	0 D	59	80	65	0 D	0 D	31	50	42	51	0 D	25	1	14	43	23	25	9	0 D	35 M	22 M
NO. OF DAYS	15	15	15		15	15	15	15	15	15		15			15	15	12			12	12	12	12		12	12	12	12	12	12	12		12	12
Eggs laid—June 25-26 to July 17	35	63 M	61 M		49	0 D	73	46	10	73		50			54	52	80			14	55	83	78		161 M	24	68	76	59	54 M	0 D		52	51
NO. OF DAYS	21	21	21		21		21	21	21	21		21			21	21	21			21	21	21	21		21	21	22	21	21	21			21	20
TOTAL NO. EGGS	102	107	105	21	132	54	135	178	86	136	51	147	51	27	144	151	184	38	46	73	139	188	196	47	201	25	86	170	82	123	37	23	90	116
TOTAL NO. DAYS	71	71	71	35	71	50	71	71	71	71	34	70	34	34	69	69	68	35	35	68	68	68	68	35	67	67	68	67	67	67	46	34	67	67

M-Male Dead.
D-Female Dead.

weevils from the leaders and are found only on trees infested during the current season. For over a month before any of the weevils of the new generation emerge from the leader these feeding areas are present.

What percentage of the weevils enter this semi-dormant condition was not determined because of the difficulty in collecting them. Usually a single weevil was found on a tree, although sometimes two or three were taken. None was found in copula. In 1928, weevils, few in number, were continually observed on the lower lateral branches until August 12. Searches in the duff under infested and uninfested trees failed to reveal any weevils.

In 1928 adult weevils, surviving the experiment to determine the number of eggs laid, were found alive on November 12. In this case, where the weevils were in cages, several were in copula. They died sometime in the winter. In general, weevils in cages often exhibited longer periods of feeding, egg-laying and some other activities than those in the field.

Other species of American and European weevils in the genus *Pissodes*, according to Hopkins (1907), may live and deposit eggs for two or three years. It had been suggested that the white pine weevil might live for more than one year, although no worker had secured definite information to that effect.

Barnes (1928) in a longevity experiment succeeded in carrying adults through a second winter of hibernation. He states nothing concerning their performance but ends his observations May 28, 1926, saying that two leaden colored weevils were found at the base of the tree.

In 1928, at Durham, screened cages, five feet high and three feet square, were placed over four uninfested white pine trees slightly less than five feet high. The duff under the trees was not disturbed in any way. Ten adults known to have emerged in 1927 and marked with purple show-card ink on the elytra were liberated in each cage August 9, 1928. October 12, several adults were observed feeding at the tips of the lateral branches. Fresh feeding evidences were abundant.

Examination of the trees in the cages April 27, 1929, definitely proved that the weevil may live more than one year. Seven, four, two, and five weevils, respectively, were noted on various parts of the trees in the four cages. The paint markings on the elytra were plainly visible. Numerous feeding punctures were observed on all of the leaders. Some females were dissected, and fully developed eggs were found.

A part of the marked weevils removed from these cages were kept alive and were given access to a white pine leader. These weevils laid eggs in the leader and the eggs hatched.

The cages were removed temporarily for close examination May 18. Six, three, two and six weevils were found on the trees. Thus nearly 50 per cent of these weevils lived for more than one year.

The leaders were finally removed from the cages August 27, 1929, and were examined. At that time the leaders were dead or dying. On examination two dead larvæ were found in one leader, three in another,

and a dead weevil was found in a third leader. The fourth leader contained no stage of the weevil, although many feeding punctures were present.

The writers have been unable to find any gross or histological details to distinguish the weevils living for more than one year.

DISPERSION

Knowledge concerning the dispersion of *Pissodes strobi* is incomplete. At present it is believed that dispersion does not take place in the fall previous to hibernation. Repeated observations before and after hibernation show that the weevils are found on trees or in the duff below trees that were infested during the current season. Graham (1926) made similar observations.

Seldom has the weevil been seen in flight in the course of this study. It was first observed June 12, 1928, on a bright, warm afternoon. A slight breeze was blowing. The observation from field notes is as follows: "First it walked to the tip of a needle, parallel with the ground, near the top of a leader. This tree was about five feet high. The weevil stamped its legs rapidly and then flew to another tree about the same height 15 feet distant. It alighted on the tip of one of the lateral branches about two feet from the ground. As soon as it alighted the weevil walked quickly to the trunk of the tree, paused a short time, walked about six inches down the trunk and then turned and went to the top part of the leader."

Graham (1926) had much the same experience for he says, "Only once in the course of these investigations has it been observed on the wing. This one occasion was in mid-afternoon of a warm day in the early spring of 1916. On that day many weevils were flying. They were strong fliers and when in the air their movements were similar to such bark beetles as Hylurgops. This unusual occurrence suggests the possibility of a short period of flight during the early spring whereby the weevils become widely disseminated, followed by a period when it seldom, if ever, takes wing."

On bringing *P. strobi*, collected from the leaders of young white pine, into the laboratory on May 14th, 1926, the weevils, after turning themselves about several times, unfolded their wings and flew toward the window, one by one.

Barnes (1928), in studies of dispersion, used a five foot staff stuck through a circular disc of cardboard and projecting four inches above the disc. The edges of the cardboard were smeared with tanglefoot to prevent the weevils from walking in the wrong direction. A string was attached to the disc to tell the direction of the wind. He recorded flight paths of the weevil by placing several adults on the cardboard disc. The weevils would crawl to the top of the staff where several splinters of wood were tacked so that they could take wing more easily.

He states, "125 flight paths over young trees showed that the weevil

flew about eight feet above or at about the level with the leaders. Over open spaces they flew nearer the ground at an average of about five feet; the longest about one hundred yards."

He observed that most of the flights were made to adjacent trees although a number of weevils flew 25 feet or more above the tips and descended at a point near the center of the pine tree.

The same method used by Barnes was tried at this station on three different occasions under ideal conditions with little success. Two weevils flew 15 and 30 feet respectively. The weevils did not fly readily and were inclined to remain on top of the staff.

In the season of 1928 weevils were collected at least once a week, and usually twice a week, from several of the plots under observation, in order to secure specimens for experimental purposes. Throughout the season, up to the first of July, it was always possible to collect approximately the same number of weevils from a plot. Collections from a plot did not seem to materially reduce the weevil population. It seemed remarkable if all of these later collections were made up of weevils previously overlooked. On the other hand, few white pines of the more susceptible ages were in the immediate vicinity of these plots. The following experiments suggest that weevils may be overlooked, even when search is repeated and thorough.

Fifty weevils, their elytra marked with red paint, were liberated June 16, 1928, about one foot from the ground on a five foot white pine tree, located in the center of the Madbury plot. On the same day 50 white-marked weevils were liberated on a four foot tree, the only white pine in a large field adjoining the Madbury plot on the east. This tree was at least 150 yards from the nearest pines located in the above plot.

June 18, twenty-three red-marked weevils were found on the tree on which they were liberated and 31 white-marked weevils were taken from their tree. Careful scouting failed to reveal any marked weevils on any of the other trees in the plot.

When these trees were next examined, June 21, six additional white and seven red-marked weevils were taken from their respective trees. June 26 two more white and four red-marked weevils were taken. Another red weevil was collected June 28.

Thus a total of 38 red and 39 white-marked weevils of the original 50 liberated on each tree were recovered in a period of 12 days, all from their respective trees.

EGG STAGE

The period when eggs may be found extends from the time when oviposition begins in the spring to about ten days after the weevils finish ovipositing in July. (Chart 1).

Considerable data were secured on the length of the egg stage by utilization of the plaster-of-Paris blocks already described. Observations on the length of the egg stage, and to a less extent subsequent stages, determined by this method, are open to a certain degree of error insofar as

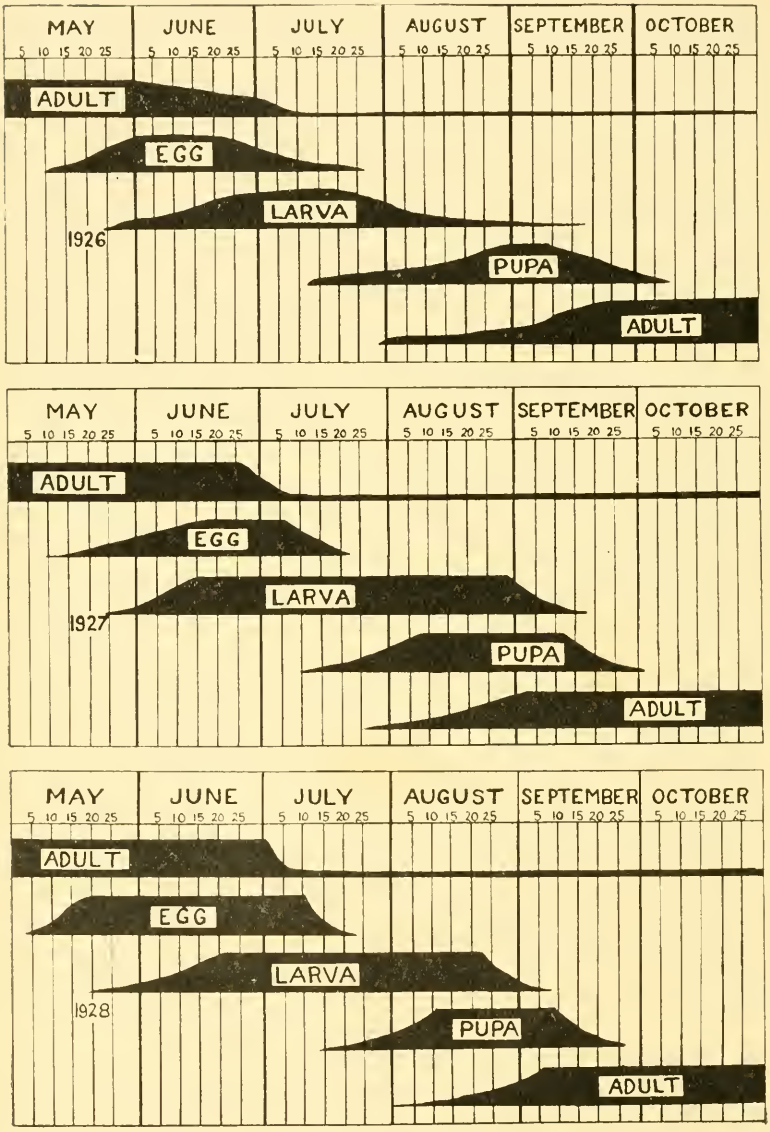


CHART I. Life history of the white pine weevil.

the material under observation was examined only once each day, usually in the morning. For instance, eggs may have been laid an hour after a fresh leader was introduced or an hour before it was removed. Likewise the eggs may have hatched only a few hours after they were examined. After some experience, however, it is possible to determine by the appearance of the egg, or newly-hatched larva, the approximate termination of the incubation period. Since a large number of specimens was used the results probably closely approach the length of the several stages of development.

TABLE II.—*Length of the Egg Stage, 1928*

IN THE INSECTARY CAGE

Date of Oviposition	Number of Days									
	6	7	8	9	10	11	12	13	14	15
June 13									2	
June 14									2	
June 15										1
June 16								1		
June 18								6		
June 21								3		
June 24							2			
June 25					2					
June 26					7	14				
June 27					20					
June 28				15	9					
June 29				21						
June 30			4	9						
July 1			11							
July 2			9							
July 4		10								
July 5		6	8							
July 6		6								
July 7		1								
July 8		6								
July 9		22								
July 10				1						
July 11	3	10								
July 12	5	1								
July 13		10								
Number of Specimens	8	72	32	46	38	14	2	10	4	1

IN THE GREENHOUSE

Date of Oviposition	Number of Days							
	5	6	7	8	9	10	11	12
June 14								3
June 15							3	5
June 16								3
June 26					7			
June 27						5		
June 28						2		
June 29					2	1		
June 30				4	1			
July 1			1	3				
July 2				11				
July 4			5					
July 5			2					
July 6			1					
July 11	3	1						
July 12		1						
Number of Specimens	3	2	9	18	10	8	3	11

When several eggs were laid in a single leader within 24 hours, most of the larvæ hatched on the same day. Occasionally the eggs did not all hatch on the same day and it was necessary to mark the unhatched eggs by inserting in the leader a labelled pin close to the egg in question. In some instances larvæ hatching on different days were destroyed because of difficulty in following their subsequent movements in the leader.

In Table II the gradual shortening of the egg stage as the season progressed is evident. In the insectary cage the maximum number of 15 days was recorded for eggs laid June 15. The maximum in the greenhouse was 12 days for 11 eggs laid from June 14 to 16. Near the end of the oviposition period a minimum number of 6 days was required in the case of 8 eggs laid July 11 and 12. A minimum of five days was necessary in the greenhouse for three eggs laid July 11. Earlier in the season, before the observations were made that are included in Table II, it was found that eggs laid May 19, 1927, required an incubation period of 20 days. The average length of the egg stage in the cage was 9.32 days; in the greenhouse, 8.66 days.

The averages for this and other stages have been determined by including, first, separately, the data for each day in the cage and in the greenhouse rearings. These daily averages were combined to get final figures.

THE LARVAL STAGE

The larva, after eclosion from the egg, remains for several hours in the pitch of the cavity. It then moves downward, feeding only on the cambium and innermost bark while still very young. Later it consumes the entire cortex, except the outer bark. When approaching maturity the larva may also attack the outer wood parenchyma. The thin outer bark remains intact forming a loose, brown jacket around the dead leader.

Usually the larvæ encircle the leader and work downward together under the outer bark. This concentrated manner of attack is of advantage to the larvæ for the tissues are killed quickly and little resin is exuded. If a larva feeds alone it seldom is able to survive the copious flow of resin induced in a vigorous tree by feeding activities.

The larvæ progress rapidly down the leader. The route of descent can easily be traced by the brown discoloration of the bark, which is evident soon after the larvæ have fed on the underlying tissue. When conditions are favorable and larvæ are abundant they may work down as far as the second or third whorl of lateral branches, a distance of three or more feet. Often, however, they do not go below the first whorl of lateral branches, a distance of eight to thirty or more inches.

In general, from our observations, the average number of larvæ in a single leader varies from 30 to 40. However, a considerable percentage of these fail to reach the pupal stage. July 17, 1928, one hundred sixty-one larvæ were noted in a single leader under cage conditions. One hundred forty-four of the larvæ were together in a band one inch wide around the leader near the base. Over 100 have often been found in

TABLE III.—*Length of the Larval Stage, 1928*

IN THE INSECTARY CAGE

Date Hatched	Number of Days														
	26	27	28	29	30	31	32	33	34	35	36	37	39	41	42
June 27								1				1			
June 28										1					1
June 30								1							
July 1								5	1						
July 4				3											
July 6					1	7	5		3						
July 7	4	1			15	4		9	1		3				
July 8					9	2	13			7				1	
July 9			3	5	2	3			2						
July 10			1		2	1		4							
July 11					1		4	1	2		2				
Number of Specimens.....	4	1	4	8	30	17	22	21	9	8	5	1	0	1	1

IN THE GREENHOUSE

June 26										4					
June 27								5							
June 28												2			
July 5			2				2	1							
July 7	2					1							1		
July 8					1		1		2	1	1				
July 9									1	1		2			
July 10			6					2			2				
July 11				3											
July 16														2	
Number of Specimens.....	2	0	8	3	1	1	3	8	3	6	3	4	1	2	0

leaders taken from the field. In field and insectary material, evidences of cannibalism have been observed when the larvæ are crowded and have insufficient food.

Individuals hatching after most of the larvæ have moved down the leader consuming all the available food are in a precarious position. If they are too far from the food supply they perish; if they succeed in reaching food the competition is often too great for them.

Each larva when nearly mature drops out of line, chews a tunnel into the heartwood and forms a pupal cell. The entrance to the pupal cell is blocked by the chips removed during its construction. Under crowded conditions the inner heartwood is not sufficient to accommodate all of the

maturing larvæ. Consequently, shallow pupal cells are constructed in the outer wood parenchyma next to the dead bark. In such a case the outer surface of the larva is covered over with an arched mass of chips removed in making the pupal cell. These peripheral pupal cells cause a bulging of the bark and can be readily detected without its removal.

In New Hampshire larvæ are first found about the last ten days of May. Some are present, though in greatly diminished numbers, the middle of September. (Chart I). There is a marked tendency for the larval stage to be considerably longer in the spring and early summer. This is followed by a period in mid-summer when optimum development takes place. This in turn gives way to another period of lower mean temperatures during which larvæ that failed to complete development during the previous period may linger for several weeks as larvæ or prepupæ before transforming to pupæ. In that part of the larval stage known as the prepupal period, varying from one to three weeks in length, the larva remains in a sluggish condition within the newly constructed pupal cell before transforming to a pupa.

Table III, including studies in the summer of 1928, shows the maximum length of the larval stage for one individual hatching in the cage June 28, to be 42 days; in the greenhouse the maximum was 41 days for two larvae hatching July 16. A minimum length of 26 days was recorded for four larvæ hatching July 7 in the cage. The same minimum was found in the greenhouse. The average length of the larval stage was 36.1 days in the cage and 33.4 days in the greenhouse.

PUPAL STAGE

The pupal stage is passed in the pupal cells previously described. In 1928 the first pupa was found in field material July 13. Six more were taken from leaders examined July 18. Pupæ were present in infested leaders until September 26. The greatest number were found between August 10 and September 10, before and after which dates comparatively few were in this stage of development. Twenty days, the maximum pupal length in the cage (Table IV), were required for two larvæ pupating August 9; in the greenhouse 19 days were required for one larva pupating August 7. In the cage the minimum was 10 days, observed in the case of several larvæ pupating between August 6 and 9. A nine-day minimum was required in the greenhouse for larvæ pupating July 30 and August 26. The average length was 13.9 days in the cage and 12.2 days in the greenhouse.

PERIOD FROM EGG TO ADULT

Table V shows the wide range of time that was necessary for development from egg to adult, in 1928, under cage and greenhouse conditions. The maximum total of 69 days in the cage is shown for an egg laid June 14; in the greenhouse 61 days for an egg laid June 26. The minimum in the cage was 44 days for an egg laid July 2; in the greenhouse, 46 days

for two eggs laid June 15 and for one laid June 27. The average total developmental period was 56 days in the cage and 52.7 days in the greenhouse.

TABLE IV.—*Length of the Pupal Stage, 1928*

Date Pupated	Number of Days											
	9	10	11	12	13	14	15	16	17	18	19	20
IN THE INSECTARY CAGE												
July 30					1							
August 2				5	4	4		1				
August 3			2									
August 5					1							
August 6		1	1	1	1	3	1	16		1		
August 7		2		3	2			3	4	4		
August 8				2						2		
August 9		1	1	3	6	8	7	2	1			2
August 10					1		1	1				
August 12			3		5	2	3	2			1	
August 13						1						
August 14				1		1						
August 16			1		1							
Number of Specimens.....	0	4	8	15	22	19	12	25	5	7	1	2
IN THE GREENHOUSE												
July 30	1	2		3	1							
August 2							2					
August 4			2									
August 5		1										
August 6		2										
August 7		1		1	1	2	2	1			1	
August 9			1			2		1				
August 11			2									
August 12		2				2						
August 13			1		1							
August 15		1	1	1	2							
August 26	1				1							
Number of Specimens.....	2	9	7	5	6	6	4	2	0	0	1	0

TABLE V.—*Period from Egg to Adult, 1928*

IN THE INSECTARY CAGE

Date of Oviposition	Number of Days																			
	46	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	69
June 13														1		1				
June 14																	1			1
June 15																1				
June 18												5	1							
June 21									3											
June 24										1	1									
June 26				1	3	1	4		1	2	1	2	2							
June 27							1			14		1	2							
June 28					1	2				2	8	2		1	2	1	1	1		
June 29				1		2	7	2	4	3										
June 30				1	2	1	3			2	2			1						
July 1									4	6		1								
July 2			1			2														
July 4						1	3	4	1	1										
July 5							3				1	4		1	2	2				
July 6					1	2			3											
July 8									4						1					
July 9								10	9	1				1			1			
July 11						1		7		2	1								1	
July 12									1		1	1		2				1		
July 13									1	3	1		1	1		1	1		2	
Number of Specimens...	0	0	1	3	7	12	21	23	31	37	16	16	6	8	5	6	4	2	3	1

IN THE GREENHOUSE

June 14										1										
June 15	2		1						2		3									
June 16														2						
June 26					2										1					
June 27	1				2									1						
June 29						1														
June 30					1	1	3													
July 1								1	1	1	1									
July 2		1		2	2	1			2		2									
July 4				2		1														
July 5					2															
July 9						2														
July 11									1				1							
July 12		1																		
Number of Specimens...	3	2	1	4	9	6	3	1	6	2	6	0	1	3	1	0	0	0	0	0

NEWLY EMERGED ADULTS

When the weevils emerge from the pupal stage they do not vacate their pupal cells immediately but remain in this location for two or more weeks. As late as the middle of September many weevils have emerged and are within the leader. No exit holes in the leaders nor weevils in the field, were found September 10, 1927, when several plantations were scouted. In general, we can say that the weevils do not leave the leader much before the middle of September. Emergence from the leader is continued well into October. For this reason, when interpreting Chart I, it must be remembered that newly emerged adults may be present in the leader the last of July, but they are not found outside of the leader for several weeks.

After they leave the leader through circular holes in the loose bark the weevils immediately go to all parts of the tree and feed. The tips of the lateral branches, in the region of new growth, seem particularly attractive. The weevils eat small patches of bark and cambium at this time, but cause no appreciable damage to the tree.

As shown in the first part of this paper, the adults of this generation seldom, if ever, mate in the fall. No egg laying takes place at this season. Dispersion is believed to take place in the spring.

The weevils after feeding for a varying length of time hibernate in the duff below the tree from which they have emerged. Many weevils were found on infested trees examined October 12, 1928. Usually the weevils gradually disappear from the tree about the latter part of October and enter hibernation. Hibernation will take place even if the weather is warm. They hibernate in the duff close to or on top of the ground but do not enter the soil. The position of the weevils in the duff varies from just beneath the surface needles to a point next to the underlying ground, a distance of three inches. Graham (1926), with a modification of the Berlese trap, succeeded in securing weevils from hibernating material with little effort. The task of attempting to find weevils without using some special apparatus is difficult, due to their close resemblance to particles of duff.

THE NORTHERN PINE WEEVIL

Pissodes approximatus, Hopkins

In this investigation a weevil, presumably *Pissodes approximatus*, Hopkins, was found attacking the trunk and roots of white pine. The eggs are laid in the trunk about a foot from the ground. The larvae upon hatching work under the bark of the trunk and larger roots, usually killing the tree.

The life history of *P. approximatus* appears to be similar to that of *P. strobi*. In 1926 adults in white pine were first found at Madbury, N. H., August 6. Specimens were taken the latter part of August from the roots of eight year old red pine located in Keene, N. H. On August 30, 1927, fifteen adults, presumed to be *P. approximatus*, were taken from

the trunk and roots of a dead white pine located in the Dover Road plot. Mature larvæ and pupæ, and predacious *Lonchea* larvæ, were found in the same tree. In 1928, one pupa taken from the roots of a dying white pine transformed July 12.

P. approximatus was first described in 1911 by Dr. A. D. Hopkins in his monograph of the genus *Pissodes*. Since that time little has been written concerning it. Felt (1926) reports this species in company with *Hylobius pales, Hbst.*, attacking Scotch pine. Britton (1919) mentions it as attacking red pine and stone pine.

Hopkins (1911) says *P. approximatus* can be distinguished from *P. strobi* by the average larger size and elongate body. The sides of the elytra are more narrowed posteriorly. He figures the stems and forks of the male genitalia. It has been impossible to determine this species by the key given by Hopkins.

A number of experiments were made to determine if the white pine weevil is able to breed on the trunk and roots of white pine. Several *P. strobi* adults were confined to the trunk of a five foot tree by means of a cylindrical glass tube. Later the tree was dug up and placed in a pail in the laboratory. Three larvæ pupated in the trunk on July 12 and emerged July 25, 1927.

Wire cages, each containing four pairs of white pine weevils, were fastened to the trunks of several trees near the base. Much feeding was evidenced by the exudation of pitch. Repeated experiments for two years failed to show breeding in this part of the tree.

The white pine weevil evidently can breed in the trunk of a weakened tree, such as the one brought into the laboratory.

It is possible that adults passing up the trunk after leaving hibernation may lay eggs in the lower part of the tree. If eggs are laid, they may hatch and produce larvæ which might survive in a weakened tree.

It may be significant that the type specimen of *P. approximatus* was reared from a larva in the bark at the base of a white pine tree defoliated by the gipsy moth (*Porthetria dispar L.*) and therefore presumably weakened.

Our data raise the question whether *P. approximatus* may not be identical with *P. strobi*, though further observations would be necessary for a definite statement.

CONTROL

No methods of complete control have been developed, although several satisfactory measures for materially reducing infestation are applicable in ornamental or commercial plantations of white pine. Manifestly, it may be economically impossible to apply some of the methods used for controlling the weevil in ornamental plantings to plantations grown for timber purposes.

Control methods can be divided into two groups, direct and indirect. Included in the first group are chemical measures such as sprays, washes and repellents. Direct mechanical measures include, also, the collection

of adults and the removal of infested leaders. Indirect methods consist of silvicultural practices to reduce the infestation and to assist the tree in recovering from weeviling. This is accomplished by adoption of mixed stands or densely planted stands. Natural or biological control by insect parasites and predators is important.

DIRECT CONTROL METHODS

Chemical Control

Chemical control methods for the white pine weevil have not been fully investigated. It is a question whether the cost of such control would be justified in a commercial plantation.

At present we have no spray material giving full control. Walden (1915) reported that lime-sulphur (1 to 8) was one of the best repellents tried. Lime-sulphur cannot be expected to give complete control but will reduce the infestation if applied early in May. Graham (1916) tried 16 different materials including various common spray chemicals. His results indicated that creosote, which slightly injures the tree, and carbolineum, may be of value. Graham found the above materials more effective than lime-sulphur or arsenate of lead. Experiments by Graham (1916) and MacAloney (1926), confirmed by us, show that trees banded with tanglefoot at the base of the leader show a substantial decrease in weeviling.

In our investigation oil of pine, oil of pine needles, and pinene, were tried as attrahents. Small muslin bags containing three ounces of bran saturated with the above oils were tied to the middle lateral branches of nine trees scattered throughout a plantation. None of these oils attracted any weevils.

Collection of Weevils.

Frequent collection of weevils from the leaders may be applicable to small ornamental plantings. In order that this method may be effective weevils should be removed at least once a week during the season. Felt (1914) and Walden (1915) used a large net, 15 inches in diameter, to make collecting more expeditious. The net was held on one side of the leader and the weevils were knocked into it by a sharp blow with a stick on the opposite side. In New Hampshire collection of weevils has not proved to be a practical means of control.

Removal of Infested Leaders.

The removal of infested leaders just below the farthest point reached by the larvæ is a common method of control. It is important that this method be practiced successively for several years in order to be effective. Weevils living for more than one year may be sufficient to cause infestation the following year after the leaders are pruned. A marked decrease may not be noticed until the third year.

This method of control can be used to advantage in smaller plantations if practiced regularly during the years when the trees are at the age most susceptible to attack. Of course if all white pine trees in the vicinity are thus pruned the measure is more effective. Whether this method is practical in large plantations is a matter for individual decision, according to circumstances. Pruning the infested leaders is not ideal, for like other methods it does not give absolute control. The trees attacked are just as crooked as the ones whose leaders are not removed, but of course fewer leaders are weeviled.

The infested leaders should be removed the latter part of June before the larvæ proceed below the first whorl of lateral branches. Another cutting the last of July will get those previously missed. Care is necessary to prevent the removal of leaders which are injured from other causes and which would have a chance to recover.

When removed the leaders should not be left on the ground for the larvae are able to complete development and emerge, thus offsetting all the benefit that would be derived from pruning.

Often the leaders are burned to destroy the weevils. This procedure at the same time destroys beneficial insect parasites and predators, important in reducing later attack. A method that will kill the weevils and at the same time allow the parasites and predators to escape is to place the collected leaders in a tight box or barrel covered with 12 or 14-mesh wire screen. If 16-mesh wire is used many of the larger insect enemies are unable to escape. The box or barrel must be tight to prevent the escape of the weevils. It should be placed in such a position that water will not collect and drown the beneficial insects. Leaders should remain a year in the screened container, to allow time for parasites emerging late in the season to escape and to make sure all of the weevils are dead. The same container can be utilized from year to year.

Experiments in New Hampshire in cutting off infested leaders show a reduction in the percentage of weeviling after two years, (Table VI).

In 1928 the trees in the Madbury plot were 11—13 years old; in the Dover plot, 14—15 years old. From the figures in Table VI it appears probable that a marked reduction in the Dover plot will be found in 1929. It may be that the weevils that live over a second year are responsible for the high infestation at Madbury in 1927.

TABLE VI.—*Removal of Infested Leaders*

Place	Madbury			Dover	
Year	1926	1927	1928	1927	1928
Total Number Trees	3500	3500	3500	1600	1600
Number Weeviled	203	208	66	130	78
Percent	5.5	5.6	1.8	8.1	4.8

INDIRECT CONTROL METHODS

Silvicultural Control

Silvicultural control may be brought about (1) by planting white pine in mixed stands with hardwoods or other species of conifers; (2) by planting white pine densely.

In planting white pine in mixed stands the principle involved is to shade the trees sufficiently to reduce weevil attack and at the same time not interfere with the growth of the white pine. The fact that the weevil is a sun-loving insect makes some measure of control by this method possible. The hardwoods or conifers used in the mixture should slightly overtop the white pine during the most susceptible period to weevil attack, that is, until the trees are about 20 feet high. If this practice is followed care must be taken not to let the shade trees overtop the white pine to such an extent that growth of the latter is retarded and the trees become dwarfed and weakened from competition. Definite schemes of white pine and hardwood mixtures cannot be suggested since each plantation will present its own problem.

At best this method is not easily planned, since it is difficult to regulate the proper amount of hardwood shade for the pine. In New Hampshire the prevalence of the gipsy moth, *Porthetria dispar, L.*, should also be considered. Caterpillars of the gipsy moth in the third or later instars will migrate to white pine and feed on it.

Dense planting of pine is perhaps the most satisfactory method of control. When white pine is closely planted the trees attacked by the weevil are better able to recover from injury because the competition for light and space stimulates them to grow straighter. The actual percentage of infestation per tree is reduced. In widely spaced stands the trees tend to become bushy, forked, and crooked and are known as "pasture" or "cabbage" pines for this reason. Volunteer seedings of pine, commonly found in New Hampshire, can be made promising plantations by planting additional pines so that the density approximates 1800 trees to the acre. In connection with this method it is advisable to remove the infested leaders in the manner previously described in order further to reduce the infestation.

TABLE VII.—*Effects of Spacing*

Kind of Stand	Spacing	Rate Per Acre	No. in Plot	1926 No. Infested	1926 Per Cent	1927 No. Infested	1927 Per Cent
White Pine	4 x 4	2,722	875	20	2.2	48	5.4
White Pine	6 x 6	1,210	378	29	7.6	31	8.2
White Pine	8 x 8	907	288	27	9.5	32	11.1
Mixed Red Pine and White Pine	8 x 8	907	420	18 White Pine	8.6	33 White Pine	15.1

The figures in Table VII, derived from plots at the Yale Forestry School in Swanzey, N. H., show the correlation between density and infestation. These trees were from 8 to 12 feet high.

These trees had been left open to sunlight for three years. Up to the time of these observations no advantage had been gained by mixing the red pine and white pine. It is true that the percentage of total trees attacked in this stand was much smaller, but as the red pines were practically immune anyway no advantage to the white pine was obtained.

Peirson (1922) and Graham (1926) concluded that planting white pine at the rate of 1200 or more to the acre will reasonably control the weevil. The writers believe that planting 1500 or preferably 1800 trees to the acre will be advantageous.

The trees should be allowed to remain dense until they are from 25 to 30 feet high. Careful thinning as the stand grows will make it possible to produce good trees showing little unmerchantable timber.

Biological Control

The part nature plays in reducing the number of weevils is of vital importance. If the high biotic potential of the weevil were not checked their numbers would far exceed the population actually present. Because of various natural checks the number of weevils present year by year is fairly constant; that is, the factors of control are strong enough to prevent marked outbreaks of this insect.

Since the white pine weevil is an indigenous insect it is improbable that these natural checks can be artificially increased to any marked extent. The rearing and liberating of parasites and predators, as practised against introduced insects, is probably out of the question.

In addition to insect predators birds play some part in control. In this study the white-breasted nuthatch, *Sitta carolinensis,* was the only bird observed feeding on the larvae in a white pine leader. There are, no doubt, more species that attack the weevil, for evidences of their feeding are common.

The insect parasites and predators that have been reported attacking the weevil in its several stages comprise a considerable list of species. The list of species mentioned in this paper includes only the more important ones found in New Hampshire. In addition to these, there are numerous insects and other Arthropods that are found inhabiting the weeviled leaders. Their co-existence with the weevil is of little importance. Taylor (1928) has listed 90 species of Arthropods taken from weeviled leaders, in connection with his study of parasites and predators.

Material collected in the course of this study was submitted to Dr. R. L. Taylor, then at the Bussey Institution, Harvard University, and parasites and predators found were reported by him. Also records were available from material sent to him from Concord by Mr. W. F. Hale, assistant state forester. The list of species found, together with those secured by collection and breeding, follows:

Predators

DIPTERA

Lonchæa corticis Taylor (1929), formerly considered as *L. rufitarsis* Macq.; *L. polita* Say; and *L. laticornis* Meig., is the most important predator and also the most important single factor of control in New Hampshire. *L. corticis* is responsible for about 50 per cent reduction in the number of larvæ. It also attacks pupæ and, to a less extent, adults. Emergence records extend from May 27 to July 2, 1928. The fly, shortly after emerging, lays her elongate eggs in small masses in the bark of an infested leader. After hatching the larvæ remain close together and are found in the larval tunnels made by the weevil. *L. corticis* is capable of devouring a larva in short order. The larvæ hibernate together in the pupal cells and pupate within the leader in the spring. This predator would be much more effective were it not for a Chalcid, *Pleurotropis* sp., a secondary parasite found in large numbers.

COLEOPTERA

Several predaceous clerid beetles are known to attack the weevil. During this study they have been repeatedly observed on white pine. Graham (1926) records *Elasmoserus terminatus*, Say.

Parasites (Parasitoids)

CHALCIDOIDEA

Eurytoma pissodis Gir. is considered an important ectoparasite of the weevil. Graham (1926) reports 50 per cent parasitism by this insect in New York. In New Hampshire the parasitism seems much less, for emergence records show a total of only 9 males emerging from 37 leaders compared with 221 male and 187 female *Lonchæa* from the same material. Twenty-three leaders from Concord contained 11 males and 14 females, compared with 33 male and 10 female *Lonchæa*. The adults emerge during the first half of July. One specimen pupating June 13 emerged July 12. The eggs are deposited in infested leaders. Usually only a single larva is found. After feeding on the larval, pupal, or possibly the adult stage of the weevil, they pass the winter as larvæ in pupal cells.

Four specimens of *Rhopalicus suspensus* Ratz. were taken the middle of June, 1927, from a cage containing infested leaders. One *R. pulchripennis*, Crawford, was collected in W. Swanzey on September 3, 1926. It pupated June 13, 1927, and emerged June 27.

One specimen of *Coclopisthia suborbicularis* Prov. was taken from a cage the latter part of May, 1927.

Pleurotropis n. sp., previously mentioned as a secondary parasite, may emerge from June 1 to the middle of July. Thirty and 43 emerged, respectively, from 37 Durham and 23 Concord leaders infested in 1927.

Eupelmus pini Taylor, a primary parasite, has not been found in New Hampshire.

ICHNEUMONOIDEA

A total of 10 male and 20 female *Microbracon pini* Mues. emerged from May 27 to June 14, 1927. Only one female emerged from Concord material. On the basis of numbers this parasite appears to be important in Durham and not in Concord.

One female *Hemiteles hydrophilus* Ash. emerged May 29, 1928, from Concord material.

One male and one female *Coeloides pissodis* Ash. emerged June 18 and July 2 from Durham leaders.

On September 3, 1926, two specimens of *Calliephialtes comstockii* Cress. were collected at W. Swanzey, N. H. This insect has been reported as a parasite of *Petrova comstockiana* Fernald, the larva of which burrows in the twigs of certain conifers, not including white pine.

Among the braconid parasites mentioned in the literature are *Habrobraconidea bicoloripes* Vier.; *Microbracon nanus* Prov.; *Bracon pissodes* Ashm.; *Spathius brachyrus* Ashm.; and *Doryctes* sp.

CYNIPIDAE

The cynipid, *Eucoila* sp. was fairly abundant in Durham material. Emergence takes place the first half of July. Barnes (1928) says it is a secondary parasite on *Lonchæa*.

SUMMARY

The white pine weevil is the most important pest of white pine in New Hampshire.

It attacks dominant trees of large tip diameter in preference to recessive trees of small tip diameter.

Some other species of conifers are occasionally attacked.

The weevil appears the latter part of April or the first of May and begins ovipositing.

Mating takes place in the spring. The female does not have to copulate throughout the season in order to produce fertile eggs.

The female may lay from 25 to 201 eggs in one season. The average in these observations was 129.

The ovipositing period terminates near the middle of July.

At the end of oviposition the weevils move to other parts of the tree, especially to the tips of the lateral branches in the vicinity of new growth.

Some weevils do not die the first year but hibernate and appear a second season.

The weevils have a marked tendency to remain on a single host tree.

Dispersion is believed to take place in the spring.

The egg stage varies from 5 to 20 days, the average in these experi-

ments being 9.3 days in the insectary cage and 8.6 days in the greenhouse.

Larvæ may be found from the last of May to the middle of September.

The larval stage varies from 26 to 41 days, the average being 36.1 days in the cage and 33.4 days in the greenhouse.

The pupal period extends from the middle of July to the last of September.

The pupal stage varies from 9 to 20 days, the average being 13.9 in the cage and 12.2 in the greenhouse.

Total development required an average of 56 days in the cage and 52.7 days in the greenhouse.

The newly-emerged adults remain in the leader for several weeks.

Newly-emerged adults feed in the region of new growth before hibernating in the duff.

Observations on *Pissodes approximatus* Hopkins are given.

Lime-sulphur (1-8) may be of value in control.

Mixed stands of white pine and other conifers or hardwoods when properly grown will show reduced weeviling.

Dense planting at the rate of 1800 trees to the acre will materially reduce the percentage of infestation.

Lonchæa corticis Taylor, a dipteron predator, is the most important natural control factor in New Hampshire.

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