

BIOLOGY OF THE SWEET CLOVER WEEVIL AND NOTES ON THE BIOLOGY OF THE CLOVER ROOT CURCULIO^{1, 2}

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Blatchley and Leng (1916) list four species of weevils in the genus *Sitona* which are found in eastern United States, and record two of these as feeding upon clovers: *Sitona hispidula* Fabr. and *Sitona flavescens* Marsham.

A third species of the genus, *Sitona cylindricollis* Fahraeus, the sweet clover weevil, has attracted attention as a major economic pest within the last 20 years. The sweet clover weevil is presumably of European origin and the date of its introduction into North America is far from definite. Munro *et al.* (1949) and Bird (1947) stated that the earliest record for America is 1924. Goble (1937) stated the first record was 1927, although in his opinion, the density of the population in Ontario in 1936 indicated that if the weevil is of European origin, that it must have been in America for at least 20 years.³ The earliest literature record for the appearance of the weevil in the United States was by Hyslop (1934).

Munro *et al.* stated that the weevil is distributed in North America from Maryland to Nebraska and northward into the provinces of Canada east of the Rocky Mountains. Allard (1864) recorded it from France, Hungary, Austria, and Italy. Jackson (1920) reported it from England, but very erratic and localized. Alimdahanov (1941) and Yakhontov (1935) reported it from the irrigated region of central Asia.

Descriptions of the adult weevil have been provided by Schoenherr (1840) and by Allard (1864). Allard considered *S. nebulosis* Ziegler, *S. micellus* Ziegler, and *S. ulicis* Ulrich as synonyms of *S. cylindricollis* Fahr., but cited no source of the above descriptions and no type locality. Jackson (1920) considered *S. meliloti* Walton as a synonym, although Allard retained it as a separate species.

Biological studies were conducted at The Ohio State University for two summers and one winter, covering the period 1950-51. Field studies were supplemented by laboratory experimentation. Biological studies had previously been conducted in Manitoba by Bird, but no study had been made under climatic conditions approaching those of Ohio.

Laboratory examination of field collections of both adults and larvae revealed that two species of the genus *Sitona* were found in sweet clover plantings. The second species was identified as *S. hispidula* Fabr., the clover root curculio. Larvae of this species represent as much as 50 percent of early spring collections, but averaged less than 10 percent in later collections. Adults are especially abundant in central Ohio in autumn and winter, but apparently migrate to other host plants in the spring. White clover (*T. repens* L.) was observed to be an important host plant in spring and summer. Notes on the biology of the species are therefore included in the present study.

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²Conducted in cooperation with the Department of Agronomy of The Ohio State University and Mr. B. A. App of the U. S. D. A. Legume Seed Research Laboratory, Columbus, Ohio. Helpful suggestions by Dr. R. H. Davidson are appreciated.

³Specimens of weevils collected in Ohio in 1904 and previously determined to be *S. cylindricollis* Fabr. have subsequently been determined to be *S. flavescens* Marsham, by the U. S. National Museum. The author sincerely regrets this error.

METHODS

Laboratory temperatures were determined by both hygrothermograph and laboratory thermometer. Field temperatures were determined by laboratory thermometers, for both atmospheric and soil readings.

Field collections of adults were taken with a small aspirator. Throughout the periods when adults are present and active, they may easily be collected by quickly separating the debris from around a plant and closely observing the soil surface. The adults feign death for a short period and then scurry for the nearest shelter. Regular periodic collections were taken during hibernation by bringing debris and soil into the laboratory and heating thoroughly. The weevils are quickly spotted and collected as they move from the heated material.

Larval collections were obtained by sifting the soil taken from around plants. The very small larvae of the first two instars may be more easily collected by placing a removable bottom of 16 mesh screening over the larger mesh of the soil sifter. Some larvae may be killed, but the reduced volume of soil is easier to handle. The sifted soil was placed on dark paper under adequate illumination, and as it was spread thinly over the surface, the active white larvae were collected. Larger larvae and pupae are quickly spotted in sifted soil and may be easily collected in the field. Larvae and pupae were retained in Peterson's killing solution (1948) for at least 24 hours and transferred into 95 percent ethyl alcohol for storage.

Observation and stock cages for adults were prepared by replacing the domes of two piece mason jar lids with 24 mesh screening. In this manner the cage size could be regulated to the population of adults to be retained. Food and feeding methods are discussed under types of oviposition cages.

Two types of oviposition cages were used in obtaining records from mating pairs of weevils. Pairs were confined to numbered homeopathic vials, each of which was closed with a small square of muslin held securely by a rubber band. Females readily oviposited in this cage, but daily feeding of a trifoliate leaf of clover was necessary, as well as a daily cleaning. It was usually necessary to remove the weevils to temporary quarters for cleaning of the cage. Eggs were removed each day and counted under a binocular microscope.

In 1951 pint mason jars were cut in half, the domes of the two piece lids replaced with disks of 24 mesh screening, and the open end closed with a square of muslin held securely by two rubber bands. Small homeopathic vials were fitted with corks having holes through them made with a No. 1 cork borer. The vials were filled with water, stoppered, and the stems or petioles of clover leaves were pushed through the hole in the cork and into the water. The stems were secured with bits of cellu-cotton, and the feeding unit placed in the cage with a pair of weevils. The cages were placed on a board containing circular holes of identical size to that of the domes of the lids. The board was supported by wooden strips just high enough to clear a Petri dish. As the eggs were deposited they dropped through the screen domes into the dishes and a daily record was made of the number from each dish for each pair. The food supply was changed twice weekly and the cage cleaned once weekly.

Eggs collected from the oviposition cages were placed on moistened filter papers in Petri dishes, and either retained in the laboratory or removed to constant temperature chambers to determine incubation periods.

The sweet clover weevil was successfully reared in the laboratory by potting sweet clover seedlings grown in greenhouse benches, and introducing eggs into the loosened surface of the soil. Immature stages were recovered by the same methods used in the field. Collections were taken at regular intervals. Soil temperatures around potted plants were determined by utilizing thermocouples placed at varying depths within the pot, and at several locations on greenhouse benches.

Pupae collected in the field were brought to the laboratory, placed in moistened

sand in dishes, and observed until adults had emerged. The pupae were less active and survived better if placed in small holes in the sand and stored in darkness.

LIFE HISTORY STUDIES

The weevil has apparently but a single generation per year in North America. Two generations per year are reported in Asia on irrigated lucerne by Alimdzhanov.

The adults enter hibernation quarters as early as September 1, and have not been observed actively feeding after the first killing frost; however, they were observed to move about until late November, and if removed from their hibernation quarters, quickly scurried back into a sheltered niche.

Hibernating adults are found in the upper inch of soil or against the soil surface under debris. The better drained areas of the field are selected, while wet areas and extremely porous materials are avoided.

Spring activity begins as soon as the sweet clover has begun growth, and at ground level temperatures near 60° F. Adults were observed actively feeding as early as March 2, and were congregated around plants having new shoots, or feeding on buds and tender sprouts on the tap root; however, most were feeding above ground.

Intensive mating activity was observed as early as March 10, becomes more pronounced as the temperature rises, and continues throughout the natural life of the adult. Males often quickly grasp bits of soil or debris that are in motion, as well as other males, but quickly release them and continue an aggressive search for females. Pairs were observed in copulae for as long as fifteen minutes, and quite often the uncoupled male is carried by the female while she oviposits or feeds.

Spring migration is accomplished by flight as well as by crawling over the soil surface. Flight was not observed until after the temperature had approached 75° F, and was usually very evident just ahead of a storm. Intensive migration by flight persists for approximately three weeks, usually beginning in late April.

Field collection records show that the overwintering adult population is greatly reduced by June 1, or shortly after, although some adults lived as late as November under laboratory conditions.

The spring preoviposition period is as short as one week. Laboratory oviposition was obtained as early as March 12; field oviposition observed as early as March 23, and it is believed that eggs were deposited even prior to this date. Females were observed to oviposit while feeding or resting, and showed no tendency to place eggs in any niche. Some eggs may lodge on objects above ground, but most fall to the soil surface around plants and are hidden in soil crevices or under debris. Freshly deposited eggs may be observed in the field by carefully examining the soil surface under the plant in late afternoon. The white color of the eggs is in direct contrast to the dark color of the soil.

Dyar's Law (Comstock, 1940) states that a linear measurement in successive instars of larvae is in a geometric progression. Head capsule measurements were taken from more than 1600 larvae from both field and laboratory reared material. Molting larvae were observed whose head capsules were near 0.83, 0.53, and 0.33 mm. The average ratio between any two consecutive measurements of the above series is 0.62. This ratio indicates that another molt (the first) must occur near 0.20 mm. The head capsule of the newly hatched larva measures from 0.14 to 0.16 mm. It is therefore concluded that the larvae pass through four instars and that Dyar's Law will serve to determine the approximate instar of a larva. Similar data were obtained by Bird.

In 1951 larvae were first recovered in the field on May 6. Weekly collections of immature stages were taken from yellow sweet clover plantings through June 30, and measurements recorded. Larvae and pupae were recovered from around plants of white varieties as late as the middle of July. The total period over which larvae may be recovered is influenced by the host plant, the ecological

niche, and the soil. Plants growing in heavy soils and in protected situations tend to support a larval population somewhat later than those in open situations and lighter soils.

Two seasons of field sifting have shown that there is a vertical migration of the larvae within the soil. The younger larvae are usually below three inches and the more mature larvae in the upper three inches of soil. Bird observed this migration in Manitoba and presented his findings in tabular form.

The field records (table 1) indicate that the larval instars require from 30 to 40 days under Ohio conditions. The same period is reported in central Asia by Alimdzhanov. Bird reports that the last two instars require 30 days in Manitoba.

Pupae are found in the upper inch of soil, within a small, lined chamber, just large enough to permit unhampered movement. The larval exuvium may be found near the caudal end of the pupa. The preparation of this chamber was not observed. Marshall and Wilbur (1934) reported that *S. hispidula* requires 4 days to complete the pupation chamber and that liquid is added to the soil from the mouth which aids in preventing soil from crumbling. The duration of the pupal stage varies from 7 to 12 days.

TABLE 1
Seasonal Development (1951) of S. cylindricollis Fahr.

Date	Head Capsule Measurements (mm) and Number of Larvae in Each Range							Pupae	Adults
	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9		
6 May	4	5	52	37	23				
13 May	14	22	30	23	1				
20 May			1	17		13	7		
27 May			6	4	3	17	22		
3 June				1	2	12	19	15	
10 June					1	1	7	35	6
17 June					1		6	36	4
24 June							1	2	1
30 June							0	0	0

The new generation of adults remains within the pupation chamber at least 24 and often 48 hours. It was observed that the emergence from the soil begins about dark and is practically completed by 10 p.m. The new generation emerged the latter half of June in both 1950 and 1951. The adults feed voraciously, migrate to new seedlings, and remain active throughout the summer, seeking hibernation quarters with the arrival of cool weather in September or October. Adults have never been observed in flight during summer and it is believed that summer and autumn migration is accomplished entirely by cursorial means.

In the laboratory both species of weevils were observed to sluggishly crawl at temperatures as low as 5° C, but temperatures approaching 60° F were necessary to induce intensive activity.

Caged adults of the sweet clover weevil taken from hibernation fed readily on sweet clover leaves, did not attempt to mate until February, and failed to oviposit before March under laboratory conditions. They were fed young seedlings, new growth from second year plants, growth from mature seedlings, and subjected to varied periods of exposure to low temperatures. No combinations of food or temperature that were used resulted in oviposition.

Laboratory oviposition records were obtained from 20 pairs in 1950 and 25 pairs in 1951 (table 2). Individual oviposition records show that adults are erratic in oviposition habits. Most females produce heavily for a few days, followed by a period of little or no oviposition. The average daily production ranged from 40 to 70 eggs. Approximately 85 percent of the total oviposition was completed by late April. Records for the two years indicate that the maximum number of completely developed eggs deposited by a female ranges from 1600 to 1800. The highest individual records included 671 infertile and incompletely developed eggs in 1950 and at least 876 of the same type in 1951. Infertile and incompletely developed eggs were more evident as the season progressed and especially prominent just prior to death of the female.

Freshly oviposited eggs are pearly white, or tinged with yellow, devoid of reticulations, very slightly oval in shape, and measure approximately 0.33 by 0.40 mm. Eggs turn a jet black color within 24 hours if held at 60° F or above, but may not darken until 48 hours at lower temperatures. A small percentage of eggs do not develop the dark coloration and may or may not be fertile.

Eggs required an incubation period of 7 days at 80° F, 8 to 10 days at 65° F, 30 days at 54° F, failed to hatch after 50 days at 41° F, but hatched in normal time if removed to higher temperatures. Eggs were observed to hatch if moisture was removed from around them after the first few days, but the eclosion mortality of larvae was very high. Eggs hatched in the usual time in vials of water and the immersed larvae were observed to live for 72 hours or longer.

TABLE 2
Oviposition Records of S. cylindricollis Fahr.

Year	Number pairs	Daily* max.	Monthly* max.	Max in month of	Season* max.	Season ave.
1950	20	106	1135	April	2403	780.4
1951	25	86	1080	April	2506	1041.4

*Individual records.

The newly eclosed larva of the sweet clover weevil is pale white, or tinged with yellow along the path of the digestive tract. Larvae range in length from 0.62 to 1 mm; average 0.20 mm in width; the head is prominent, subtriangular to cordate in shape, and hyaline to light chocolate color, the side margins and posterior emargination are more deeply pigmented; it is near 0.16 mm in width and 0.20 mm in length; the body tapers from the thoracic segments, and each segment bears long pale hairs. The mandible is trilobed, the basal lobe is not especially distinct from the distal lobes.

The mature larva of the sweet clover weevil is white or tinged with yellow along the digestive tract, apodous, slightly curved, averaging 4.7 mm in length, 1.8 mm in thickness, and the long hairs of the body segments were more evident near the caudal end; the head capsule is near 1 mm in length and 0.8 mm in width; the mandible is mitten-shaped, trilobed, the lobes being subequal in length. The mature larvae and head capsule are figured in detail by Peterson (1951).

The characteristic manner of larval locomotion was described in detail by Marshall and Wilbur (1934). The description was based on larvae of the clover root curculio, but adequately applies to larvae of the sweet clover weevil.

The pupae are clear white or tinged with yellow on the dorsal abdominal area; they range from 4.7 to 5.8 mm in length, average 5.3; they range in width from 1.2 to 1.4 mm, average 1.3; each abdominal segment bears a row of hairs, usually

quite conspicuous; the posterior margins of the terminal segment bear two prominent recurved spines, pigmented on their apical halves; each spine bears two prominent, spinules whose apices reach approximately one half the distance to the apex of the spine; the penultimate segment bears two prominent, short, dorso-lateral spines, which are usually deeply pigmented and slightly longer than the tubercle which bears them. Young pupae are a clear white, but become tinged with yellow on the dorsum of the abdomen by the second day. The eyes and apices of the mandibles are distinctly reddish by the fourth or fifth day.

The life history was completed in 45 to 70 days. The incubation period required 7 to 10 days, the larval instars 29 to 45 days, and the pupal period 7 to 12 days. The first larval instar required less than 5 days, the second and third about one week each, and the fourth about 12 days. Behavior patterns observed in the field were also observed under laboratory conditions.

The recorded host plants of the sweet clover weevil in North America include alsike clover (*T. hybridum* L.), black medic (*M. lupulina* L.), alfalfa (*M. sativa* L.), and sweet clover (*Melilotus* spp.). Adults were observed to feed very sparingly on alsike clover, and were observed feeding on alfalfa but once. Adults fed on alsike, alfalfa, and black medic when forced by starvation measures under laboratory conditions, but failed to feed on red or white clovers.

Larvae were not recovered from any host plant other than sweet clover in either field or laboratory. They were not observed to destroy or inhibit nodule formation, even when a dense population was present. However, they have been reported to severely destroy nodules on lucerne in central Asia by Yakhontov.

NOTES ON THE CLOVER ROOT CURCULIO

Caged adults of this species, taken from hibernation quarters, fed readily on both sweet and red clover leaves, showed a distinct tendency to mate, and usually oviposited within 4 hours after being brought into the laboratory. Females produced fertile eggs in autumn, winter and spring. Few eggs were obtained from females after the first 24 hours in the laboratory.

The only overwintering stage observed in Ohio was the adult, but it is suspected that the species may also overwinter as egg or larva.

Field and laboratory observations indicate that this species is active at temperatures slightly below those required by the sweet clover weevil, and that it is also active somewhat later in autumn and earlier in spring.

The peak of emergence for the spring generation of adults was observed to slightly precede the peak for the sweet clover weevil, but larvae may be recovered from white clover much later than larvae of the sweet clover weevil.

The eggs of the clover root curculio are so similar to those of the sweet clover weevil that no constant differences or characteristics were found for separating the two species. The eggs required an incubation period of 11 to 14 days, tending to approach the latter figure, when managed in the same manner as eggs of the sweet clover weevil.

The newly hatched larvae of the clover root curculio closely follow the description by Wildermuth (1910), except as to measurements. When hatched under laboratory conditions the larvae has a distinctly cordate-shaped head capsule, averaging 0.18 mm in width and 0.23 mm in length. Larvae averaged 0.96 mm in length and 0.28 mm in width. The body is distinctly more stout than the body of the sweet clover weevil. The head capsule is flattened at the cheeks and often slightly acuminate. The mandible is distinctly trilobed, with the basal lobe shorter than the distal lobes.

The mature larvae closely resemble those of the sweet clover weevil but are characterized by a distinct purplish cast when freshly exposed, their smaller size, and a more curved body. After killing in Peterson's solution the body has a more yellowish cast and is more curved than larvae of the sweet clover weevil. The

head capsule is usually flattened at the cheeks and often slightly acuminate. The mandible is distinctly trilobed, mitten-shaped, and with the basal lobe usually distinctly separated from and shorter than the distal lobes. Wildermuth has given further details.

The pupa is figured by Wildermuth. They are usually smaller than those of the sweet clover weevil, averaging 4.3 mm in length and 1.2 mm in width. Wildermuth states that the terminal spines bear one small secondary spine near the base. All specimens examined in Ohio bear two very small spinules near the base of each terminal spine, which are much smaller and shorter than those of the sweet clover weevil. The dorsolateral spines of the penultimate segment are not pronounced and seldom longer than the tubercle which bears them.

The two favored host plants were observed to be white and alsike clovers, although in some instances, plantings of sweet clover supported a dense population of this species. The species has been reported from a large number of leguminous hosts and also as severely damaging legume root systems while in the larval stage.

Larvae of the species were found to destroy the nodules on sweet clover plants and were observed feeding in lesions on the tap root.

NATURAL ENEMIES OF BOTH SPECIES

Adults of both species were attacked by one or more species of fungi during the hibernation period. Diseased specimens were sent to the U. S. National Museum for identification. The Division of Mycology and Disease Survey reports that the fungus failed to properly sporulate, but was probably near *Sporotrichum* spp. The effectiveness of the agent in reducing populations was observed to be very erratic and localized.

Bird reports that *Beauveria bassiana* (Bals.) is an important pathogen of the sweet clover weevil in Manitoba, and that *Fusarium scirpi* var. *acuminatum* (Ell. & Ec.) was also isolated from diseased weevils. He also states that Allison has reported a new species of *Hirsutella* attacking the weevil in Wisconsin. Steinhilber (1949) stated that *Mycetosporidium jacksonae* Tate is parasitic on *Sitona* weevils.

No insect parasites were recovered from the adults in Ohio and no predators were observed. Munro and Post (1948) reported the importation of two parasites from France to combat the sweet clover weevil. Information regarding their establishment has been given by Munro *et al.* (1949) and by Berry *et al.* (1950). Telford and Munro (1944) reported the plains toad is an important enemy of the sweet clover weevil. Bird reports that he believes that Franklin Gulls feed on the weevil in Manitoba. Wildermuth reports fourteen species of birds that are known to feed upon the clover root curculio.

Diseased larvae were also observed, but were usually not discovered until after killing. The biological agent or agents involved were not determined. Marshall and Wilbur have reported that nematodes of the genus *Diplogaster* attack larvae of the clover root curculio.

Bigger (1941) reported that a specimen of *Stenus* sp. (Staphylinidae) was observed feeding on the eggs of the clover root curculio.

The two weevils are similar in habits and activities and it appears likely that most natural enemies of one species are also important enemies of the other. Additional detailed information is cited in the references presented in the selected bibliography.

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THE ROLE OF THE OHIO ACADEMY OF SCIENCE

The December 28, 1952, issue of the Academy Conference Directory provides pertinent data on the 38 academies affiliated with the AAAS. This publication reveals that the Ohio Academy of Science is second in size among the academies. In addition, only one of the academies publishes a journal as frequently as our academy publishes the Ohio Journal of Science.

Ohio surpasses the state which has the largest academy not only in population and wealth but in the number of colleges and universities in the state. It would therefore be very easy for the Ohio Academy of Science to take its rightful first place among the academies of the nation. Each member of the academy has many acquaintances who are potential academy members. Many of them would be honored by your personal invitation to join the Ohio Academy of Science.

Many of us, especially the older academy members, are apt to think of the academy as just one of those institutions that we have grown up with. We do not often have a 50th anniversary during which we take stock of our accomplishments and during which the scientists of the nation pay tribute to one of the great academies of the nation. The truth is, however, that the academy is a living, growing, energetic force at work initiating the spirit of scientific inquiry in the minds of young people in Ohio, renewing it and spurring it on in the minds of high school and college science teachers of the state, improving the teaching of science in the schools of the state, and providing the opportunity for research workers to lay the results of their research, both verbally and in print, before the people of the state, the nation, and the world.

The Ohio Academy of Science is a powerful force in the state of Ohio but it can do more, and can do its work better, if its membership continues to grow. During the past three years, the Ohio Academy of Science has increased in membership by about 50 percent. Let's double our membership of 1,250 in this sesquicentennial year of the state of Ohio!

Enroll a new member: