LABORATORY OBSERVATIONS ON CONODERUS VAGUS CANDEZE (COLEOPTERA, ELATERIDAE) [1]

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There is an abundance of information on the biology of many elaterids. The review of literature on this topic which Thomas published in 1940 lists twelve genera, but among them *Conoderus* takes a modest place and is mentioned only in Bryson's notes of 1930 and 1932. At that time, however, *Conoderus* and *Heteroderes* were still considered as separate genera and some additional information on *Conoderus* is available in the papers of Eagerton (1925) and of Cockerham and Deen (1936) which discuss the biology of two *"Heteroderes"* species.

Since 1940, the biology of some species of *Conoderus* has become better known in North America, chiefly through the work of Jewett (1944, 1945, 1948). But he has not discussed *Conoderus vagus* Cand. The notes which follow are a preliminary report on studies conducted at the Potato Investigations Laboratory at Hastings, Florida, during the period of March 1952 - July 1953.

TEST TUBE METHOD OF REARING WIREWORMS

Glass containers for rearing wireworms have been used by other investigators. Rawlins (1937) transferred wireworm prepupae into glass vials and then filled the vials with moist soil. Thus he was able to observe the pupal stage. Among other laboratory facilities employed in wireworm studies, Rawlins mentions also petri dishes being " . . . usually used as breeding cages" and "rearing cages". To the author's best knowledge, there are no previous records of rearing wireworms in test tubes.

Test tubes for housing wireworms (Dobrovsky, 1952) are filled with moist soil to a depth of five or six centimeters. A single newly-hatched larva is then introduced into each tube. An easy way to accomplish this is to place the tiny larva first on a small potato cube, then to lower the cube and larva into the container with the aid of forceps. A normal wireworm larva, tiny as it may be, finds the soil easily. On the next day the

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potato cube may be removed and a moist kernel of corn whose seed base has been cut off to expose the germ is given for food. The germ-side of the seed is pressed slightly into the soil for best results. Moist wheat may be used instead of corn. When potatoes are used as food, they are cut in small cubes. A plug of cotton inserted into the mouth of the test tube serves well for a stopper. Test tubes, thus stocked, are labeled and placed upright on a rack or in any deep container with a soft bottom. Friction-top tin pails are quite satisfactory for this purpose because stocked test tubes kept in them do not dry out rapidly when the lids are pressed in place; when water is needed, it is added to the soil with an eye-dropper.

Almost any size test tube can be used in rearing wireworms, but for making observations on the behavior of laboratory specimens of *C. vagus*, a test tube with a diameter of 10 mm. was best. The larva of this species, when full grown, is 12 - 14 mm. long, and, while it does not appear to suffer from cramped quarters in this size test tube, it is forced to do a considerable amount of tunneling next to the glass. The larva is thus exposed for observations a relatively large part of the time.

When feeding records are to be made, kernels of grain or cubes of Irish potato are inspected by removal from the test tube with a pair of forceps. A potato cube may also be pierced with a large dissecting needle and withdrawn.

The intervals between inspections are determined by factors such as type of diet and nature of information sought. When larvae are fed corn, for instance, one kernel supplies enough food for one to three weeks, depending on the size of the larva, on the temperature, or on the biological disposition of the larva at the moment. On the other hand, when cubes of potato are being fed at summer temperatures, inspection and changing of food are necessary at least every two days, because the potato cube rots or molds easily during warm weather. If behavior is to be observed, the shorter the intervals between inspections, the greater the possibility of seeing the larva perform its various functions.

Counting of instars accurately can be done quite easily by the test tube method of rearing. The contents of the test tube are first emptied on a sheet of white paper, then the larva is found and removed. The soil is now dumped into a 100 cc. beaker or a similar container half full of 70% alcohol. The entire contents quickly sink to the bottom of the container, but the cast skin floats on the surface of the alcohol. After taking the necessary records, new soil is placed in the empty test tube, and the larva is returned to its quarters.

When pupation is completed in a test tube and the adult is not needed for breeding, it can be preserved together with its own pupal and last larval skin by the same flotation method. It is necessary to make sure that the beetle does not escape, as newly-emerged ones are lively. If any difficulty is encountered in this respect, a few drops of ether or chloroform on the cotton plug of the test tube will slow down the beetle quickly. The entire contents of the test tube are then emptied into the flotation alcohol. While everything else drops to the bottom, the beetle, its own pupal skin, and its last larval skin, float to the surface of the alcohol. They are collected and placed together in an individual vial of alcohol properly labeled for future reference. If the adult is needed for breeding purposes, it is removed, and only the larval and the pupal skins are floated.

TEST TUBES FOR MATING

Test tubes 10 mm. in diameter are used also for breeding purposes. The tubes are prepared with soil and cotton plugs as for larvae. Then four or five beetles are transferred into each "mating test tube". Since the sex of the adults can not be determined without time-consuming individual examinations, groups of four or five provide a higher probability that both sexes may be brought together than do single pairs. A larger number of beetles of this species causes overcrowding.

Oviposition can be maintained at a satisfactory rate only if the beetles receive a proteinaceous food. Best results were obtained with a diet of sweetened water and yeast. Either sugar or honey may be used for sweetening. A satisfactory formula is about 10 grams of sugar or honey in 100 ml. of water. Only pure powdered yeast was used in these studies. Jewett (1944) used "a 5 percent solution of brown sugar and water to which a small amount of baker's yeast was added".

The method of feeding the sweet-water-yeast mixture is the following: Four or five drops of the sweetened water are placed on a strip of blotting paper about 4 cm. long and 5 - 6 mm. wide. Then enough powdered yeast to absorb the excess liquid is placed on one side of the blotter with a spatula. This makes a small mass of yeast with the consistency of a thin paste on the surface of the blotter. The blotter is then lowered into the test tube with forceps and allowed to rest on the soil. The paper should be stiff enough to stand straight so that the beetles may climb on it. A new blotter with sweetened water and yeast is needed at least every two or three days. In hot weather, it is often necessary to replace it daily.

Eggs are laid in the upper part of the soil. The following method is used in collecting the eggs. The beetles are first transferred into a new test tube with soil. Then the soil of the first test tube is emptied on a smooth sheet of paper and spread in a thin layer. A "reading glass" is helpful in spotting the eggs. After some practice, one acquires considerable skill in differentiating between eggs and grains of sand or other white particles in the soil. This method permits also the hatching and keeping of many larvae in one test tube, thus it provides opportunities for making observations on cannibalism among them. One group of five adults kept in a test tube and fed sweetened water and yeast lived and oviposited for approximately six months (Dobrovsky, 1953a).

As in the case of adults, the problem of larval nutrition is important. Rawlins (1937) recognized it fully when he stated: "The food requirements of young wireworm larvae needs further investigation, for our present knowledge is contradictory and incomplete." Jewett (1944, 1945, 1948) reared many specimens of three *Conoderus* species on sprouting wheat. He does not mention mortality rates, thus it is not possible to judge about the balance of this diet. It has not been tested in this laboratory yet, nor has a completely satisfactory diet for young larvae been found.

In a preliminary experiment with diets for *Conoderus vagus* larvae, 106 young specimens were placed in individual test tubes. The history of each of these larvae was recorded from day to day for the first five months, and once a week thereafter. All of these larvae received only potato for food after they were isolated in individual test tubes. However, prior to their isolation, some of these larvae were kept in test tubes with other larvae during which time they may have obtained one or more cannibalistic meals. Table 1 gives a summary of the fates of the larvae in this experiment in relation to whether or not they had practiced cannibalism.

The figures in Table 1 demonstrate that young larvae of *C. vagus* are unable to grow and develop without some protein; potatoes alone are totally inadequate for the growth of newly-hatched larvae. Even only a few cannibalistic meals after hatching of the larvae may furnish food for growth to nearly full size and prolong their lives to over three hundred days. The fact that one specimen with a history of cannibalism completed its life cycle on this diet would further strengthen the emphasis on protein early in larval life. On the other hand, full grown or nearly full grown larvae which have had a normal diet in nature when brought into the laboratory, can complete their development on Irish potatoes alone (Dobrovsky, 1953b).

TABLE 1.—SUMMARY OF THE HISTORIES OF 106 SPECIMENS OF *Conoderus vagus* CAND. OBERVED IN THE LABORATORY BY THE TEST TUBE METHOD.

	Completed Life Cycle	Did not Complete Life Cycle Died in					Totals
		1-29 Days	30-99 Days	100-199 Days	200-299 Days	300 or More Days	
Total Number of Specimens	1	65	10	12	16	2	106
Number of Test Tube Specimens Believed to Have Been Cannibals	1	1	5	9	15	2	33
Percent Cannibals	100.0	1.5	50.0	75 0	93.0	100.0	31.1

OBSERVATIONS ON BEHAVIOR

TUNNELING OF LARVAE.—When wireworms are introduced into test tubes, they promptly burrow into the soil. An inspection on the following day usually shows many tunnels next to the glass. They traverse the soil column in every direction, forming a network. These tunnels remain permanently in place as long as the soil in the test tube is undisturbed. The larva uses them as regular travel routes in which it crawls either forward or backward. Locomotion in either direction seems quite natural for the larva in any of the tunnels. When using an outside tunnel, the larva may crawl either on the soil or on the glass. Newly hatched larvae or ones in the early instars seem to tunnel next to the glass with the same ease as older larvae.

FEEDING BEHAVIOR OF LARVAE.—The following observations were made on several occasions when larvae of *C. vagus* were given small cubes of potato placed on the surface of the test tube soil. With mandibles wide open, a larva approaches the potato cube, sinks its mandibles in the flesh of the potato and pulls. The pulling action is executed by anchoring the posterior end of the body on the substratum and backing up with the thoracic legs. It pulls in this manner until it tears off a piece of potato. As the larva chews, the mandibles and maxillae move in a lateral direction while the labium slides forward and backward. After chewing for a while, another piece is broken off.

Since a larva does not have any control over the size of potato piece it may tear off, it chews only on part of a large piece, allowing the remainder to protrude between and above the mandibles. The excess is eventually cut off and discarded.

Other manners of feeding have been observed in test tubes. A larva may move up to the piece of potato, sink its mandibles in the flesh, but instead of pulling, may remain in contact with the potato cube and work its mouth parts in chewing manner. Then it may withdraw and continue chewing. At other times, once the larva has brought its mouth parts in contact with the potato, it remains there for some time during which its mouth parts work continuously. After one or two minutes of such chewing, some potato pulp appears protruding dorsally between the mandibles. As the larva keeps feeding, the pulp grows into a long, white, cord-like mass. On one occasion this process was observed in progress without interruption for slightly over fifteen minutes during which time the resulting pulp cord grew about 8 - 10 mm. long. That larva continued feeding in this manner for about 4½ hours with only brief interruptions.

The last method of feeding described above indicates that larvae of *C. vagus* do not swallow all of the potato tissue which they may chew. There are three possible processes involved in their feeding to explain the discarding of pulp: either only the liquid portions are extracted and swallowed; or in the chewing process, some "predigestion" may occur by which some of the solids are liquefied and then swallowed; or some solids are broken down mechanically into minute fragments and are swallowed together with liquids extracted from the potato, while the coarser solids are rejected in the form of pulp, as observed above.

Apparently, *C. vagus* larvae are able to discriminate to some extent among the physical characteristics of the things which they swallow. In that respect, this species may resemble some other wireworms. According to Woodworth (1938), larvae of *Limonius canus* Lec. have a rather elaborate oral mechanism which can regulate the swallowing of solids of different particle sizes, and may even be "sufficient" to discriminate between desirable and undesirable liquids. The extent to which *Conoderus vagus* resembles *Limonius canus* in this respect is not known.

PUPATION BEHAVIOR IN TEST TUBES.—A few days before the prepupal stage sets in, the larva of *Conoderus vagus* feeds voraciously. Then it suddenly stops feeding and spends about two days making a pupal chamber. Sometimes it takes a small amount of food while the chamber is under construction.

Most of the larvae which have pupated in test tubes in this Laboratory have selected the soil near the bottom of the test tube for the locale of their pupal chambers. Thus, of a group of 22 specimens, 19 pupated in the lower part of the soil column, one in the middle of the soil column, and two in the upper half. In this group of specimens, 18 of the pupae were visible through the glass, most of the time without soil obstructions.

The size of the pupal chamber of *C. vagus* is somewhat variable. It may reach 21 mm. in length, 10 mm. in width, and 7 mm. in depth. These dimensions approach the upper limit. More typical chambers measure about 12 x 7 x 5 mm. The shape of the pupal chamber inside the test tube is also variable. It may be a roughly spherical or pear-shaped pit, or it may resemble a wide tunnel.

From one to three days before turning to pupa, a larva becomes sluggish, then motionless and finally pupates. Pupation in test tubes occurred from 2 to 9 days after completion of the pupal chamber. Pupal periods of 4 to 12 days were recorded. The pupa usually lies on its back but sometime on its side. When disturbed, it makes rapid and violent snapping motions with its abdomen.

BEHAVIOR OF ADULTS IN TEST TUBES.—When the adult emerges, it remains in the pupal chamber for several days. The beetles are vivacious, and in the test tubes used in these studies, they made quick darting runs in the space above the soil. On occasions, beetles were seen darting back to the soil and in a matter of seconds digging themselves to the bottom of the test tube.

When several virgin beetles were to be assembled in one test tube for mating purposes, their vivacious nature made their transfer difficult. A light exposure to ether subdues them long enough to make the transfer and prevents the loss of any specimens.

Mating has not been observed in test tubes thus far. On one occasion a pair was seen in mating position but the beetles separated as soon as the test tube was disturbed. It has been demonstrated that parthenogenesis does not occur in the elaterid *Limonius canus* Lec. (Woodworth, 1942). If we assume that the same is true for *Conoderus vagus,* then we must conclude that mating takes place in test tubes judging from the numbers of viable eggs and young larvae obtained by this method.

SUMMARY

A method using test tubes for rearing wireworms in the laboratory is described. Full grown and nearly full grown larvae of *Conoderus vagus* Cand. collected in potato fields completed their development in test tubes when fed only Irish potatoes. Newly hatched larvae, fed Irish potatoes exclusively, lived usually not more than 30 days. Similar larvae which had obtained a few cannibalistic meals survived much longer, but failed to complete their development if after their limited number of cannibalistic meals they were fed only Irish potatoes. In one case a specimen, allowed to practice cannibalism for several days and then placed on a potato diet, completed its development in 10 weeks. The germ of seeds such as corn and wheat apparently furnishes food for growth. However, mortalities have been high under this diet, and it has given eratic results.

Some observations on the behavior of larvae, pupae, and adults kept in test tubes are given. Tunneling and feeding of larvae, preparations for pupation, and the behavior of adults are mentioned.

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