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Department of Entomology

The Gray Garden Slug

With Notes on Allied Forms

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CORVALLIS, OREGON

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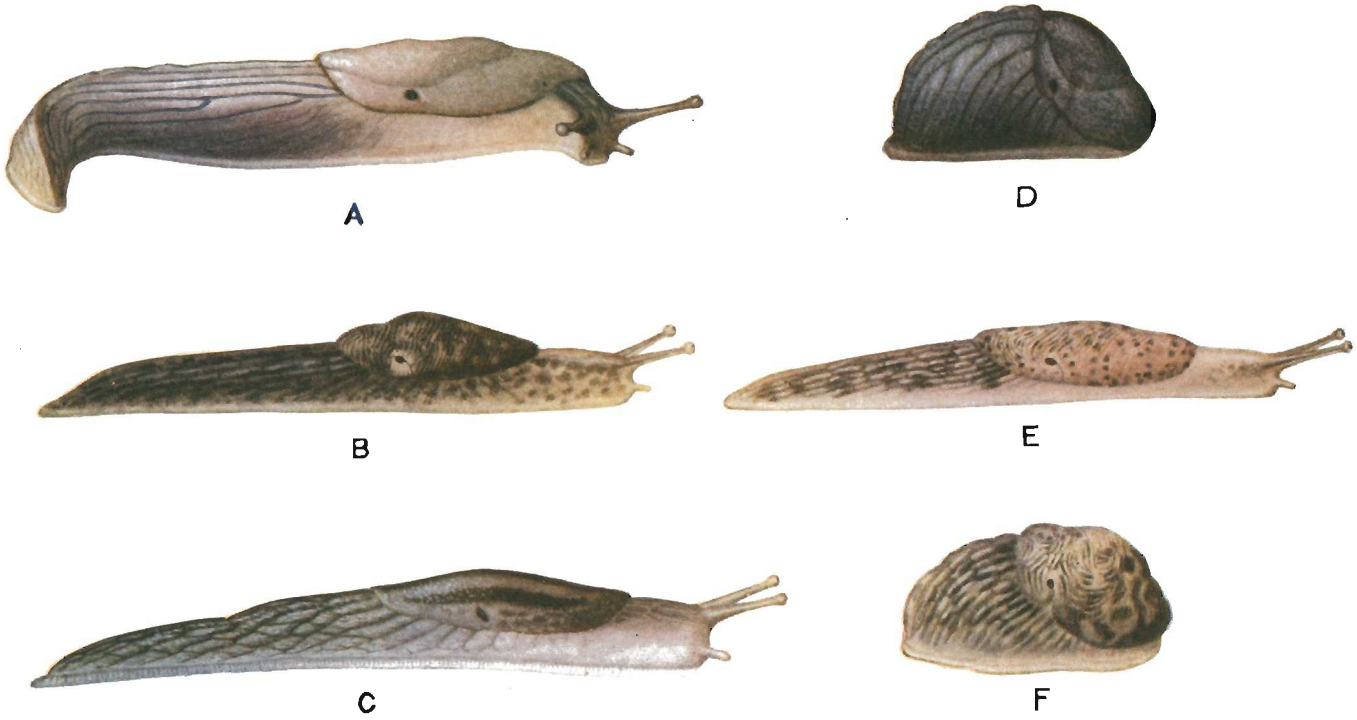

PLATE I.

Common slugs showing color variations. A. The greenhouse slug (*Milax gagates*) extended. B., E. The gray garden slug (*Agriolimax agrestis*) extended. C. The reticulated slug (*Prophysaon andersoni*) extended. D. The greenhouse slug, contracted. F. The gray garden slug, contracted.

The Gray Garden Slug

SUMMARY

The garden slugs are a serious pest of truck crops, ornamentals, small fruits, field crops, and greenhouse plants.

They are especially injurious in early spring and in the autumn during wet weather.

Young plants are most seriously injured although plants in all stages of development are attacked.

The three species of slugs of economic concern in Oregon in order of frequency of occurrence are: the gray garden slug (*Agriolimax agrestis*); the greenhouse slug (*Milax gagates*); and the reticulated slug (*Prophysaon andersoni*).

Slugs are likely to be of increasing seriousness as a crop pest due to their great reproductive capacity, their ability to adapt themselves to constantly changing conditions, their tenacious hold on life, and their tendency to associate themselves with man under conditions of intensive agriculture.

Development from the egg to the adult probably takes from ninety days to nearly a year depending upon food and climatic conditions.

Slugs are noctural in their habits but are often active in the day time during cloudy, wet weather. During the day they normally conceal themselves under waste materials and in vegetation or burrow in the soil.

Dry, hot weather drives them into temporary seclusion and checks their depredations.

Under Western Oregon conditions repellents and irritants in common use are ineffective against slugs.

Many of the poisons in common use as insecticides are of questionable value in controlling slugs.

Bordeaux mixture, either liquid or dry, is an excellent repellent.

Calcium arsenate prepared as a bait is readily devoured and is highly toxic to slugs.

A combination of a repellent and a poison bait constitutes the most effective control procedure.

In our tests Bordeaux mixture 4-4-50 sprayed on the plants combined with the use of a poison bait of calcium arsenate, 1 part to 16 parts chopped lettuce scattered in small heaps over the affected area gave a high degree of efficiency in plant protection and slug control.

INTRODUCTION

To one engaged in the production of vegetables and truck crops on the Pacific Slope, it early becomes apparent that among the serious pests to be considered are the slugs. These slimy, repulsive, slow-moving creatures are voracious feeders, attacking indiscriminately practically all cultivated crops. Although some few insect pests may be capable, under favorable circumstances, of doing greater damage to a particular crop, the slugs, however, feed on such a variety of crops and inflict such wholesale havoc, from the time of their attack on small plants just pushing through the ground until they complete their disgusting work by feeding on and tunneling through mature plants and fruits, that their total injury probably outranks that of any one garden insect pest.

Climatic conditions in the Willamette Valley seem particularly favorable for the growth and reproduction of the slugs. Our mild, moist winters with few sudden marked variations of temperature and our generally moist springs afford them ideal conditions for development. Our dry summers are unfavorable, but do little more than drive them into temporary seclusion. Their wonderful powers of adaptation to change and their tenacious hold on life will be taken up in detail later.

WHAT SLUGS ARE

Slugs are not insects. They belong to the phylum *Mollusca* of the animal kingdom along with the snails, clams, and oysters. They have soft, fleshy, unsegmented bodies covered by ciliated epithelium interspersed with cells which secrete mucus. Slugs belong to the class *Gastropoda* having a broad ventral sole or foot used in locomotion. They belong to the sub-class *Anisopleura* and to the order *Enthyneura* characterized by a torsion of the visceral sac which has transposed the respiratory and excretory organs from a posterior to an anterio-lateral position, resulting in these and other internal organs becoming atrophied and functionless on the left side. They belong to the family *Limacidae* having an elongate, sub-cylindrical body, an anterior mantle, and with the respiratory aperture on the right side behind the middle of the margin of the mantle. They are terrestial in habit and air breathing. Many of the shell-bearing snails are closely allied to the slugs and occasionally feed on crops.

Slugs have a well developed head, bearing two pairs of elongate, hollow retractile tentacles. The upper pair of tentacles bear at their extremities the eyes, in slightly rounded knobs or eye peduncles. The lower pair of tentacles are usually shorter and probably bear the sense organs of touch and smell. The mouth is half concealed on the ventral surface of the head. It is rounding, the upper margin consisting of a sharp, cutting mandible bearing irregular rows of small, saw-like teeth. The food is secured by a snipping or clipping action and carried into the mouth where it is caught by the radula, a ribbon-like organ also armed with rows of minute tooth-like projections. The radula works by undulating movements, carrying the food as by an endless belt back to the gullet.

On the dorsal surface, anterior of center, is the raised and more or less rounded mantle or shield, free at its anterior margin and covering

the pulmonary chamber, heart, kidneys, etc. Within this mantle is a small, flattened, calcareous shell, probably the rudimentary remains of a definite shell covering and constituting a link indicative of close relationship to the shell-bearing snails. Just at the lower right margin of the mantle and slightly posterior to the center is the respiratory aperture or breathing pore. In the gray garden slug this aperture has a raised unpigmented margin and is associated with a small cleft in the mantle. This marginal ring is cut anteriorly by the anal cleft. Located just back of the upper right tentacle is the reproductive orifice.

Morphologically the slugs represent a peculiar condition. The bilateral symmetry characteristic of allied forms is lacking, though more readily apparent after a study of the internal anatomy. The organs of respiration, circulation, excretion, and reproduction are fully developed on the right side only. The corresponding organs on the left side are atrophied or functionless and have no opening to the exterior. Slugs are monoecious or hermaphroditic, though probably in no case capable of self fertilization. So far as known they are oviparous.

The slugs have a remarkable ability to elongate and contract the body. When fully extended in travel the body is elongate, narrow, nearly cylindrical, and terminates in a narrow point. The head protrudes on its slender neck, far beyond the mantle; the upper pair of tentacles are elongate and slender, with the small knobbed eye peduncles prominent; the mouth is changed from a short oval to an elongate ellipse with narrow sides and rounded ends. When contracted the body is shortened to less than one-fourth its former length, is thick, stout, and in most species strongly keeled along the back, with the tip of the body bluntly cut off behind and broadly rounding. The tentacles are retracted and the head is concealed beneath the mantle, the anterior margin of which curves down in front and connects with the anterior margin of the sole.

Slugs have a soft, sensitive, moist skin, provided with numerous minute glands from which they expell mucus slime. This material is produced in abundance when they are disturbed and is exuded on objects over which the slugs crawl, remaining as a dried mucus trail behind them.

They are typically nocturnal in habit and by far the majority of their activities are carried forward at night. During the day they normally conceal themselves in dark moist places in basements, under boards, rocks, and trash, and in tunnels and crevices in the soil. During our protracted periods of dark, cloudy, moist weather, however, the slugs remain active throughout the day, and during periods of protracted precipitation become unusually abundant in slightly elevated areas, walks, etc.

SLUG-CONTROL INVESTIGATIONS

Preliminary studies on the life-history and control of the slug were undertaken by the senior author in 1912. The investigation was given the status of a major project in 1914 and pursued diligently for one season. Due to loss of funds and material changes in the personnel of the department, the investigation was of necessity dropped temporarily. Circumstances prevented its further pursuit until 1918, when the junior author was assigned to this investigation particularly to develop certain suggested control measures which it had been impossible to develop satisfactorily up to the time the project was temporarily dropped.

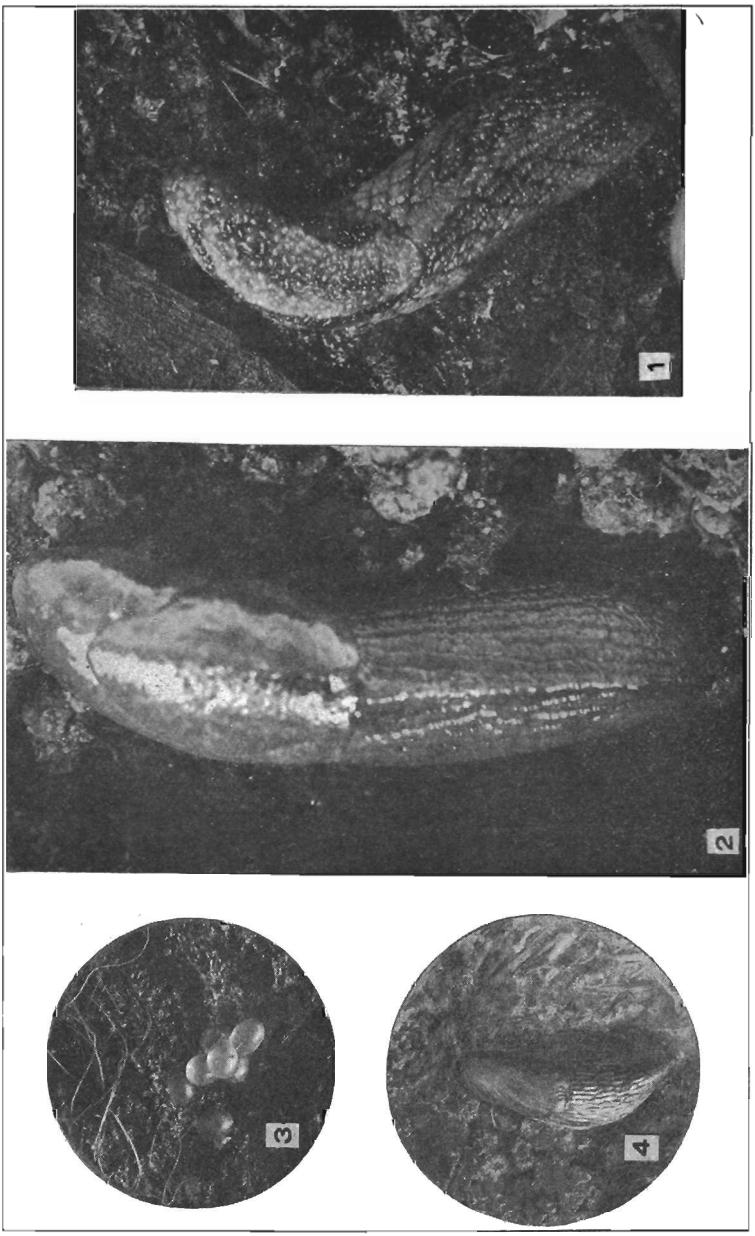

PLATE II.

Fig. 1. The reticulated slug, Prophysaon andersoni, enlarged 1.5x. Fig. 2. The greenhouse slug, Milax gagates, enlarged 2x. Fig. 3. Eggs of the gray garden slug on soil. Fig. 4. The gray garden slug, Agriolimax agrestis, natural size.

THE GRAY GARDEN SLUG

(*Agriolimax agrestis* Linn)

HISTORY AND DISTRIBUTION

The gray garden slug is of European origin. It has been recognized and discussed by many of our economic writers for more than two centuries. It was first known in England in 1674 and is today the most common and generally destructive garden slug there. It is common throughout Wales, Scotland, Ireland, Germany, Netherlands, France, Switzerland, Italy, Austria, and Hungary. It is present and fairly common in Spain and Portugal, the Balkan Peninsula, Scandinavia, Russia, Turkestan, China, Japan, North Africa, Asia Minor, Australia, and the Atlantic isles. In America it is reported from Brazil, Jamaica, and Lower California in the South and from Ontario, Quebec, and British Columbia in the North. It is present in the following states and probably many more: Maine, Massachusetts, New York, New Jersey, Pennsylvania, Michigan, New Mexico, Colorado, Wisconsin, Ohio, California, Washington, and Oregon. In Oregon it is common all along the Pacific Slope, west of the Cascades, and in the Columbia Basin.

Early records apparently show that the garden slug was well established in Massachusetts in the vicinity of Boston as early as 1843. It reached as far west as Colorado in 1890 and was first mentioned from California and Oregon in 1891.

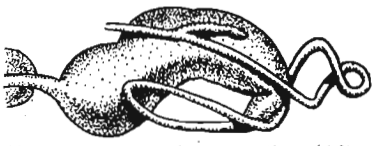

Fig. 11. Alimentary canal of A. agrestis. (After Taylor).

The gray garden slug is the most highly organized species of the family *Limacidae*. It has wonderful powers of adaptation to rapidly changing conditions and to a great variety of situations. From long association with man in regions where gardens and small fields are the rule, it has formed the habit of frequenting cultivated land. It thrives in small gardens, is a common inhabitant of cellars and basements, occurs in numbers about damp foundations and stone walls, and is a general nuisance about dwellings and outbuildings. It has the habit of concealing itself in and near articles of frequent use such as sacks, boxes, etc.; it is frequently found buried in straw and humus. This habit has undoubtedly resulted in its frequent dispersal and enabled it to become, as it now is, practically universal in its range.

From a consideration of the general habits of the species, it is reasonable to suppose that it has been introduced at various points on the western coast at many different times and from many different sources. Our records show that this animal has been a pest in Oregon for eighteen years or more. There is every indication, however, that it has

become more generally distributed, more thoroughly established, and has been doing more wholesale destruction to growing crops in recent years than formerly. This is in keeping with all observations on the species. It thrives in thickly populated districts, always closely associated with man and his activities. As our towns and cities increase in size and as the trucking business develops, this pest will doubtless become increasingly serious.

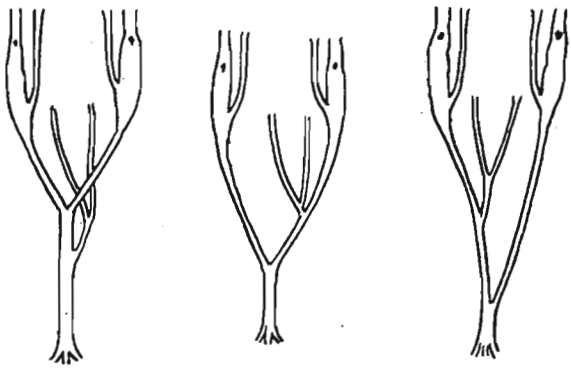

Fig. 12. Cephalic retractors of A. agrestis, showing variations. (After Taylor).

SYNONYMY

Until comparatively recent years external characters were relied upon almost entirely for determining species of slugs. Because of its wide distribution and because of its existence under such a variety of conditions, this slug varies greatly in color markings, size, and minor external characters. This has resulted in a vast amount of confusion. The old name was *Limax agrestis*. Taylor (1) sums up the synonymy as follows:

AGRIOLIMAX AGRESTIS (L)

Aliae parvae, ut quae gregatim folia sectantur, et hortos infestant cinerei aut fusci coloris gesner, Aquatil. lib. 4, pp. 254 et 256.

Limax cinereus parvus, immaculatus, pratensis Lister, Hist. Anim. Angl., 1678, p. 130, tab. 2, f. 16.

Limax cinereous immaculatus L., Fauna Suec., 1746, p. 366, No. 1279.

1758—Limax Agrestis L., Syst. Nat., ed. x., i., p. 652.
1774—reticulatus Muller, Verm. Hist. ii., p. 8, No. 207.
1819—bilobatus Fer., Hist. Moll., p. 74, pl. 5, f. 11.
1841—tunicata Gould, Invert. Massachusetts, p. 3.
1848—pallidus Schrenk, Land u. Susswasser. Livlands.
1855—(Eulimax) agrestis Moq.-Tand., ii., p. 22, pl. 2, f. 18-22, and pl 3, f. 1, 2.
1861—veranyanus Bourg., Spicil. Malac., p. 30, pl. 13, f. 9.
1862—heydeni Heynemann, Mal. Bl., p. 210.
1870—norvegicus Westl., Fauna Moll. Suec., p. 22.
1874—(Agriolimax) fedtschenkoi Koch & Heynemann, J. D. M. G., p. 153.
1815 Limacella obliqua Brard, Coq. Paris, p. 118, pl. 4, ff. 5, 6, 13, 14, 15.
1868—Agriolimax agrestis Malm, Skand. Limac, p. 69, pl. 3, f. 8.
1882—panormitanus Less. & Poll., Monog. Limac. Ital., p. 52, pl. l, f. 5.

(1) Taylor, John W. 1907. Monograph of Land and Freshwater Mollusca of the British Isles. Vol. 2, p. 104.

DESCRIPTION

The Adult. The gray garden slug is, comparatively speaking, one of our smaller slugs. The mature slug, when extended in locomotion, is about two inches long, two-fifths of an inch in width, and approximately the same in height; the body is nearly cylindrical, tapering to a point behind. Near the posterior extremity there is an inconspicuous dorsal carina or keel. The surface of the body along the sides is marked off into irregular oblong reticulations; the upper surface is marked by concentrical longitudinal lines, reticulations less distinct. The sole is longitudinal, narrow, of a dirty white, tripartite, mid-area locomotary, set off by a furrow from body proper. The mantle is prominent, fleshy, convex, tending to oblong oval, covers slightly more than one-third of body, the

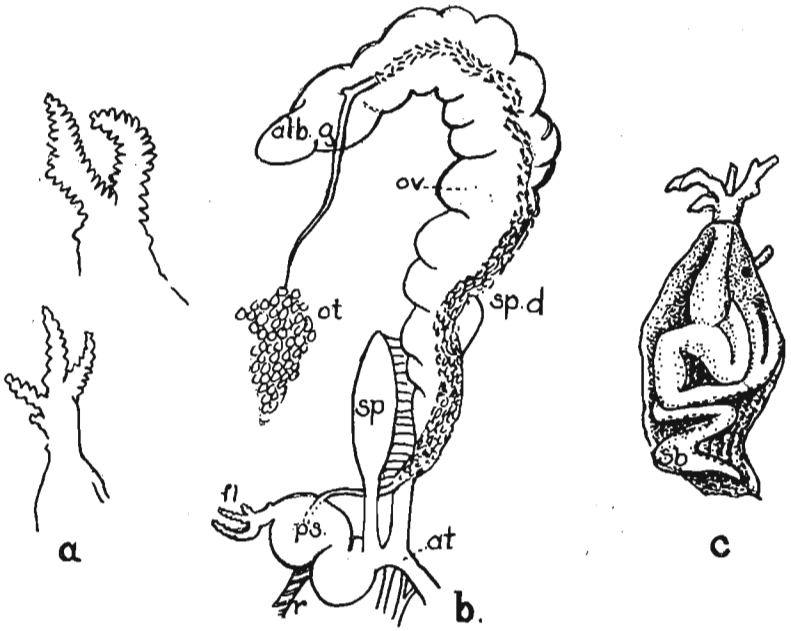

Fig. 13. a. Flagellate penal gland of A. agrestis showing variations. b. Reproductive organs of A. agrestis. alb. g., albumen gland; at., atrium, with protractor muscles; fl, flagellate gland; ot, ovotestis; ov, oviduct; ps, penis sheath; r, penis retractor; sp, spermotheca; sp.d, sperm duct. c. Penis sheath laid open showing point of entry of vas deferens and the internal structure of the organ. sb, sarcobellum or excitatory organ. (After Taylor).

margin free throughout, surface marked by irregular, circular, wavy lines and furrows, tubercles sharper and more defined than on body. The respiratory orifice near posterior lateral margin of mantle is marked by a prominent cleft in mantle and a raised ring or margin, light in color and unpigmented. The slender neck is usually of a light greenish yellow with just a hint of flesh color. The upper tentacles are black at the tip, an indistinct black line extending from tip back through the neck to edge of mantle. The dorsal surface of the neck is marked by two

parallel, longitudinal furrows or lines with a distinct ridge between. (Plate II, Fig. 4.)

The normal color of our Oregon variety of this slug is usually a deep mottled gray, greenish gray, or pale ochreous flecked with brown or dark brown. The colors are subject to considerable range even in the Willamette Valley. In the whole range of this species the marked color variations have occasioned no little confusion. In Oregon the predominant color may vary from a light creamy clay or lavender tint to almost solid blue-black. Almost without exception, however, there is a more or less pronounced tendency to flecking or mottling with specks and spots of brown. (Plate I.) Because of the unreliable nature of color and external markings the best authorities now base species on internal characters. The following very excellent systematic description of the gray garden slug is taken from Taylor (2).

ANIMAL limaciform, with large but flattened tubercles; of a somewhat uniform whitish or pale orchreous ground color, but sometimes dull lavender or other tint, often mottled, speckled, or reticulated with brown or black, and at times totally suffused with black; BODY somewhat compressed and keeled toward the tail; TENTACLES dark colored; SHIELD more than one-third the total length of the animal, rounded in front and behind, concentric striae not deep, with the nucleus on the right side and towards the rear; RESPIRATORY ORIFICE with a broad, usually unpigmented, raised ring which is cut anteriorly by the anal cleft; SOLE pale and longitudinally tripartite, the side areas sometimes darker, especially towards the tail; SOLE-FRINGE separated as usual from the body by a furrow, containing a row of elongate tubercles, upon which the body tubercles rest uncouformably. MUCUS plentiful and viscous, often clear when crawling, but becoming milky white on irritation, due to innumerable particles of carbonate of lime.

Length usually about 35 mm.

SHELL white, oblong-oval in shape, somewhat convex above and correspondingly concave below, usually rather thin; NUCLEUS distinct and placed towards the left side of the posterior margin of the shell; concentric lines of growth perceptible, margin membranaceus.

Length, 4 mm; width, 2¼ mm.

INTERNALLY, the cerebral ganglia are triangular in shape, spotted with brown, especially at the margins, the commissure gray or darkly spotted; the stomato-gastric or buccal ganglia with longish commissure and dark-brown connectives; the parieto-splanchnic ganglia are fused with the pedal ganglia, and both display short commissures; the vestigial osphradium can be traced as a ridge and channel across to the left of the respiratory chamber; the organ of Semper shows well-developed inferior lobes.

THE ALIMENTARY CANAL (Fig. 11) is triodromous, composed of the stomach tract and three intestinal coils; the ingestive TRACT is the shortest, the OESOPHAGUS is also short, and the voluminous CROP of a light-brown color, thin, and scarcely furrowed, having the long and much-indented SALIVARY GLANDS adherent to its sides. The last tract or rectum has, about midway, a short coecum on the right side generally directed backwards, and laid upon the upper surface of the crop. The DIGESTIVE GLAND is of an ochreous color, the right lobe extending quite to the caudal end of the body, and in common with the whole intestinal mass has been subjected to a noticeable spiral twist in such a way as to indicate that an external shell if present would be a dextrally-coiled one.

The CEPHALIC RETRACTOR (Fig. 12) originates in the median-line, behind the lung, from three or more roots, which immediately unite to form a simple slender band, and divides usually but not invariably about halfway. There is considerable variation in the details of the furcation; usually the BUCCAL and TENTACULAR branches separate at nearly the same point, but sometimes the slender buccal branch is an off-shoot of one or other of the tentacular retractors, or may arise from the main-muscle before the tentacular forking. In English forms the buccal retractor is always deeply divided, but not usually down to its origin or root, as Dr. Simroth states is the case in German specimens.

The REPRODUCTIVE ORGANS (Fig. 13) have their orifice about two millimetres behind the right ommatophore; the OVOTESTIS is comparatively enormous, and laid upon the upper surface of the digestive gland, the acini being light-brown, with darker connective tissue; DUCT short and inflated, buff to creamy white, with a

(2) Taylor, John W. Monograph of the Land and Freshwater Mollusca of the British Isles. Vol. II., p. 105.

slender VESICULA SEMINALIS; ALBUMEN GLAND with few lobes, and of a light-brown or slate color; OVISPERMATODUCT broad above, narrow below; OVIDUCT with ample folds, free oviduct short, with a yellowish glandular investment; SPERM DUCT slender above, more compact and broad below; VAS DEFERENS short, and entering penis-heath laterally near the free-end; PENIS-SHEATH a broad, irregular, and medially constricted sac, with narrow outlet, distal-end with a claw-like digitate gland, which varies greatly in size and complexity, each segment or digit having on its concave side a row of papillae. The lower half of the sheath contains a conical and fleshy SARCOBELUM or excitatory organ, which is often pigmented at the tip; the RETRACTOR is a short, broad band, arising from the lung floor, to the right of the mid-dorsal line, anterior to both kidney and pericardium, and is attached, not to the apex, but to the middle of the penis-sheath at the same side as the point to entry of the vas deferens; SPERMATHECA fusiform or claviform, attached closely to the base of the oviduct, stem slender, and opening into the narrow and thick-walled ATRIUM, at the junction of the oviduct and penis-sheath.

The MANDIBLE or jaw is crescentic in shape, with well and bluntly rounded ends; it is a millimetre or more in width, moderately arcuate, of a yellowish-brown color, and smooth in texture but showing several distinct darker lines parallel with the upper and lower margin; median beak or rostrum not prominent, but somewhat acute, its vertical carina not well marked.

The LINGUAL MEMBRANE of a Perthshire specimen is 4 mm. long and 1 1-2 mm. wide; the denticles diminishing in size towards the outer margins; median teeth with a narrow, posteriorly expanded base of attachment, the reflection narrow and distinctly tricuspid, the mesocone slender and projecting beyond the basal plate, the ectocones well developed with distinct cutting points. The asymmetrical laterals each have a moderately slender mesocone; the ectocone is also strongly and acutely developed, but the endocone is more or less obsolete, though becoming stronger towards the margin, the seventeenth tooth being distinctly tricuspidate; the marginals are distinctly aculeate, with an incipient ectocone on some of the teeth.

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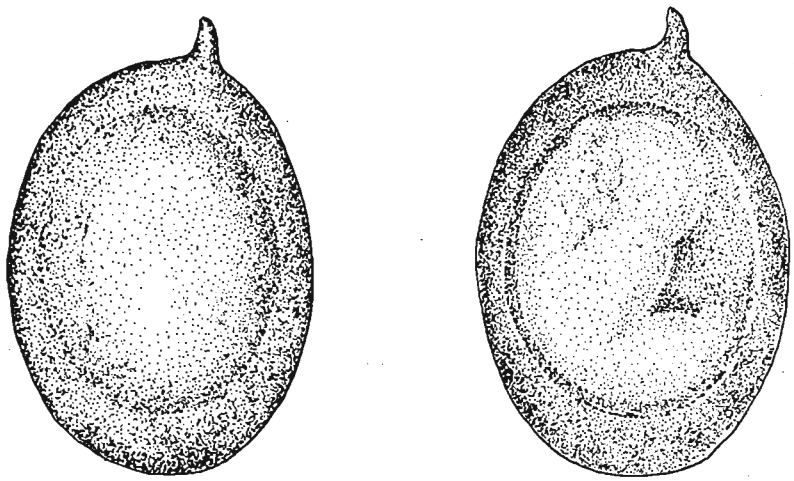

Fig. 15. Eggs of A. agrestis (enlarged), illustrating appearance of newly deposited egg and appearance of developing embryo. (Original).

The Egg. The egg is rounding but more or less elliptical in form, pellucid with a bluish-white, glistening transparency. (Plate II, Fig. 3.) The slight but general milky cloudiness of the first few days later collects into a more or less definite opaque spot which forms the nucleus of the developing embryo (Fig. 15). The eggs vary in size even among those of a single oviposition. The larger forms are about 3 mm. long and

2 mm. wide; the smaller 2 mm. long and 1.7 mm. wide, the smaller eggs tending more to the globular form. On one end of the egg is a small microphyle or nib, (Fig. 15), usually quite pronounced in the turgid egg, but frequently considerably reduced or vestigial.

The eggs occur at all seasons of the year, but are more common in the spring and early summer. They are placed under stones, boards, and rubbish, beneath fallen trees, under accumulations of grass and weeds about fence rows and foundations, and in other moist, shady places. They usually occur in clusters which vary in numbers from 2 or 3 to 40 or even more. Some authorities give the period from copulation until egg deposition at 14 to 20 days. Lowe gives the period as 5 days. In our observations the period varied from 12 to 40 days. It is possible that in some cases previous copulation may have taken place.

Immature Slug. The newly hatched slug is practically colorless, appearing as little more than a bit of protoplasm. After a few hours the eye peduncles show blackened areas and the slug becomes of a pink or grayish pink color, transforming rapidly as feeding and growth take place to the lighter and then darker coloration and reticulation of the mature form.

TENACITY OF LIFE

The gray garden slug is practically destitute of any protective device aside from its somewhat protective coloration and the marked ability to exude an abundance of slime when disturbed. It has no protective covering, is devoid of instruments of offense and defense, is sluggish in its movements and without means of rapid escape from its enemies. This particular species is unique in one respect: the mucus exuded in connection with its ordinary traveling is moderate in amount and practically colorless, while when excited or disturbed the slug exudes an abundance of slime of a milky white color. This, according to Taylor, is due to an abundance of finely divided calcareous deposit in the mucus.

In spite of their seeming precarious existence, slugs continue to increase in numbers even under unfavorable conditions and demonstrate a marked ability to cope against all odds. Some of the factors which help them to maintain themselves are: their marvelous powers of adaptation, their prolific generative capacity, and their ability to reproduce lost parts.

Their powers of adaptation are illustrated in the great diversity of conditions under which they thrive. As a group slugs inhabit moist, shady areas and undoubtedly this species thrives best under such environment. They are found in the depth of the forest and in the great plain areas, along the banks of streams and beside dusty roads, climbing high walls and bushes to feed on foliage and burrowing below ground devouring roots and tubers. Though showing a decided preference for a vegetable diet they are able to grow from egg to maturity on an animal diet, as well as on mushrooms, manure, or decaying vegetation.

Probably the most remarkable examples of their extreme tenacity of life are described by Binney (3). He gives instances where the eggs of this or similar species have been dessicated until only a thin scale remained and so retained for years; yet when again exposed to moisture

(3) Binney, W. G. The Terrestrial Air-breathing Mollusks. Bul. Mus. Com. Anat. and Zool. IV, p. 5.

and favorable conditions they assumed their normal form and function. He cites cases where eggs have been dried eight consecutive times in a furnace until reduced to an almost invisible minuteness and regained their original bulk in a moist situation. Under both treatments the slugs hatched in the usual manner and grew to maturity. Though no such extensive tests with the eggs were made in our studies, several groups were dessicated for a few weeks time, two batches were alternately dried and moistened at weekly intervals until hatched, and one batch of twenty eggs was exposed all summer from a window bench on a flat board covered with a bit of glass and these were brought into the laboratory in the fall. In all these tests the eggs hatched and the slugs were normal in every way. Partially grown and mature slugs can go for an extended period without food, if other conditions are favorable. Three slugs from one-third to one-half grown and six mature slugs were isolated in pots of soil. The soil was largely sand and contained but little humus. For a period of one month during which time the soil was kept moist the slugs were more or less active, did not reduce appreciably in weight or size, nor show any apparent ill effects. When moisture was removed the slugs quickly succumbed.

The gray garden slug is very prolific. Eggs are produced at about every season of the year, though reduced in numbers during August when the season is exceptionally dry and during the more extreme portions of the winter. Easily excited to sexual impulse, they mate often and egg disposition is frequent and abundant.

FOOD HABITS

The food habits of the garden slug are remarkably diversified and afford an excellent illustration of the wonderful adaptation of the animal. They are practically omnivorous feeders; though showing a preference for a vegetable diet, they may often be found devouring small animal life, aphids, earthworms, etc. They feed on decaying vegetation, putrid flesh, mushrooms, manure, etc. They feed below, at the surface, or above the surface of the soil.

The attack is most frequent on plants. It is during the early growth that most serious injury occurs. Young plants just pushing through the ground are consumed entirely; the foliage of plants in cold-frames and of newly transplanted cabbage, lettuce, and tomatoes is devoured or great ragged holes eaten through it. (Plate IV, Fig. 9.) They destroy sprouting corn or tunnel into the base of older corn, killing or devitalizing it. Field peas, young clover, hops, and similar crops adjacent to uncleared areas are often wiped out entirely for a distance of several yards from the border of the field. They eat the leaves, buds, blossoms, and fruit of strawberries; injure the blossoms of many ornamentals; disgust one constantly by their repulsive presence; and everywhere leave behind their disagreeable trail of slime.

The outer leaves of very small plants in contact with the soil are first attacked. On larger and older plants the slugs may be found up among the more tender inner leaves, usually feeding in a more or less concealed position. Very young slugs can feed in more open positions with less danger of detection. As the season advances the slugs frequent

the cool, tender, somewhat moist interior of plants. Head lettuce, cauliflower, cabbage, field beets which have split open, root crops, and plants with broad, heavy, luxuriant foliage are frequently found with from one to several of these repulsive creatures in all stages of development crowded into the interior. Where tunneling into plants at or below the surface of the soil, frequently the puncture so formed affords a ready means of entrance for decays. Radishes, turnips, carrots, clover, and field beets have been observed with slugs from one-half grown to nearly mature feeding on the roots from just below the surface, down to a depth of nine inches. Injuries to potato tubers range from small feeding punctures to examples where little more than a portion of the shell structure remains. Generally speaking, this extreme tunneling habit as with the interior foliage attack is more frequent as the warmer, drier season advances. In late April, May, and June, particularly during periods of unusual precipitation, slugs frequently climb the canes of gooseberries, currants, and similar shrubs to feed. A peculiar phenomenon is observed in connection with this climbing habit; instead of crawling down from this higher position the slug often lowers itself by means of a mucus thread which it exudes.

FOOD PLANTS

In the garden and fields practically all crops are attacked. Among vegetables the *Cruciferae* seem the favorite host, lettuce, cabbage, and cauliflower particularly and radishes and turnips to nearly the same extent. Peas, beans, corn, tomatoes, potatoes, egg plant, and beets are seriously attacked. Among field crops probably peas and beans are more generally injured, though rape, clover, hops, wheat, oats, and many other crops suffer. In small fruits the strawberry and gooseberry are most frequently attacked, though during a protracted wet spell in the spring almost any fruit may serve as a host.

Almost all plants grown under glass including vegetables and ornamentals are often seriously injured.

It has been impossible to record all the native host plants on which this slug has been observed feeding. Mustard, dock, honeysuckle, and stinging nettles are mentioned at random from an almost limitless list. Various species of mushrooms both edible and poisonous are fed upon. Some authors report the death of slugs fed with poisonous mushrooms. While no experiments with confined slugs maintained on such a diet have been made, field observations rather tend to discredit this. Manure, fruit pulp, decaying tomatoes and cabbage, etc., are sometimes articles of food.

Earthworms are often an article of diet. In the warm spring days, following showers, earthworms in numbers frequently crawl out on the cement walks about the campus. The feet of students injure or crush many of them and slugs in abundance are found feeding on their remains. The garden slug feeds on crippled members of its own species and allied forms of slugs; on sowbugs, aphids, and lowly insects and probably on any other animal which is helpless, slow-moving, and frequents the same places as the slugs.

LIFE-HISTORY AND HABITS

Unfortunately, at no time during the extended period devoted to this problem have conditions been ideal for careful life-history studies. In the earlier stages of the project many points concerning habits, etc., had to be determined in order that surroundings as nearly normal as possible might be provided. Much of the work has been carried on under laboratory conditions and the dry air and other factors necessarily have an effect. Other duties and field trips often of several days duration broke in on our observations. Breeding cages dried out, important material in life-history studies died; therefore, notes on this important phase of the work are not as full or complete as might be desired.

No data are at hand regarding the average longevity of the slug. but the average span is probably from eighteen months to two years. The period from egg to maturity will vary with the season and abundance of food but is probably from ninety days to nearly one year. Individuals in the laboratory reached full size in eighty days. The young grow rapidly, doubling in weight and size in a week. They attain sexual maturity, pair, and deposit eggs before reaching full size. One individual had mated and deposited eggs when 66 days old, was full grown in 82 days, and lived approximately 18 months. The tendency to oviposition before the slugs are apparently mature in size is by no means uncommon.

In our breeding work eggs were deposited from 12 to 40 days after mating. One authority gives a record of 6 days. The average egg period is about 3 to 4 weeks. Our egg records vary from 15 to 36 days.

No complete record of the total number of eggs deposited by a normal individual slug of this species is available. Dr. Leuch (4) kept two individuals in confinement for over one year and obtained 776 eggs.

One individual hatched February 23 from eggs collected in the greenhouse was confined in a breeding jar for study. Two eggs were deposited on May 19, 83 days after birth. The slug at this time was about two-thirds grown and had been isolated from birth. The slug escaped sometime after April 12 the following spring, at which time it was apparently in full vigor. The egg record for this individual was 612 eggs as follows:

May ('13)	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.*
9	39	69	2	127	22	16	14	2	99	136	77

Egg records of individuals for short periods are as follows:

Individual	Eggs	Total days
1	49	14
2	220	39
3	136	39
7	83	23
8	119	20
9	66	20

(4) Taylor, J. W. Monograph. Land and Freshwater Molluscs of the British Isles. 1907. Vol. II., p. 107.

* The record for April is given only until the 12th.

A few points of interest were observed in connection with the studies on egg deposition. The slugs almost always bury themselves or become quiescent for from one to three days before commencing egg laying. Then for a period of two to four days they will deposit from one to several groups of eggs varying in number from a single egg to 76 or more. The eggs may be placed in small loose groups on the surface of the soil if some object such as a leaf, board, or stone resting on the ground offers opportunity for concealing the eggs beneath it. Where no such natural protection is available the slugs burrow out a small, shallow pit in the surface soil, with smooth, rounded sides and a small surface opening. For example, frequently in groups examined only two or at the most three egss were visible on the near surface, but by working into the enlarged cell below from 19 to 34 eggs were found clustered together.

One interesting observation in connection with the egg-laying habits was observed in late August, September, and October. Stock turnips which had become pithy and split open were found with great masses of eggs in the fibrous and slightly moist interior.

CONTROL FOR SLUGS

CLIMATIC

While adverse climatic conditions serve to lessen depredations by the garden slug, its remarkable adaptability to adverse conditions make these factors of decidedly minor value.

Dry hot weather drives the slug into temporary seclusion and serves to minimize its injury. Where luxuriant foliage occurs and in the cool moist interior of plants whose edible portion develops into a head, as lettuce, cabbage, etc., the injury continues, simply being transferred to the interior portions. Root crops, potatoes, cabbage, lettuce, cauliflower, canteloupes, and ornamentals continue to suffer attack.

Excessive rains drive the slugs from their seclusion, and frequently slugs will drown in small pools of water. Numbers have been observed dead in wagon tracks filled with water, shallow holes with steep sides, etc.

Excessive cold renders the slug dormant but probably seldom serves to kill.

NATURAL ENEMIES

Poultry including ducks, geese, and chickens feed on slugs. Ducks and geese seem especially fond of them, devouring great numbers where allowed access to infested areas.

Several birds feed on slugs, though to probably none of them is the slug the preferred food. The thrush, robin, and blackbird occasionally have been observed eating these forms.

Predaceous insects might be expected to prey upon slugs, but few observations of such attack have come to our attention. A Lampyrid larva, species undetermined, was occasionally found preying on the slug. Mites are sometimes observed in numbers covering slugs. No actual injury is recorded from these mites, which belong to the *Gammasoidea*

and may be feeding on the slime. Banks (5) reports *Ereynetes concolor* as occurring on snails and slugs. It has the habit of retreating into the respiratory orifice (perhaps to feed).

Fungous diseases occasionally attack the slugs. These were particularly active and virulent in our breeding cages. Field observations indicate that they are of minor importance under natural conditions.

APPLIED CONTROL

In a rather exhaustive review of the literature on slugs, seeking slug-control recommendations based on sufficient experimental data to give them weight, it soon became apparent that such information was extremely meagre. Most recommendations are of doubtful origin and clearly do not apply to conditions in Western Oregon. The general moist conditions and frequent rains in the spring when slugs are particularly active have a decided bearing on the control measures which may be effectively employed.

Sundry practices which appear promising under sheltered conditions or where rains are infrequent, prove of little practical value under average field conditions as we have to deal with them. Materials containing sticky or irritating substances, depended upon as repellents or which are supposed to kill by causing an excessive mucus exudation, would, to prove effective under field conditions, have to be applied several times in the course of twenty-four hours.

Poisons regularly employed in our war on garden insect pests and generally recommended in current articles for the control of slugs either prove so repulsive as to be generally avoided or are eaten by the slugs with little or no deleterious effect. Likewise, we found in our control investigations that results obtained with confined slugs under laboratory conditions must be carefully checked by field tests before drawing conclusions as to their effectiveness as a general control practice.

CLEAN SURROUNDINGS

The protective instinct of slugs, causing them to frequent areas where abundant material is available for concealment, is worthy of note. Fence rows, bramble patches, ditch banks, and uncultivated areas generally adjacent to cultivated fields are utilized by the slugs for winter hibernation and summer protection. Countless examples of serious injury to crops adjacent to such surroundings have been observed in our studies.

Boards, sacks, piles of brush, plant remnants, and debris of all sorts about the premises, adjacent to the foundation and near the garden will be found with their quota of slugs. Crop remnants and refuse left on the field afford food and protection for the slugs during those periods when there is a dearth of succulent plants for attack.

While it has been impossible to run accurate checks on the effect of a general clean up, remarkable results in lessening the numbers of slugs and injury to crops have been obtained. In cases where three years ago, even with the use of poison baits and sprays, it was almost

(5) Banks, Nathan. U. S. Department of Agriculture. Report No. 108. 1915. p. 22.

impossible to grow early vegetables unattacked, last year, following a general and intelligent clean up, considerable search was required to locate a slug and the injury was a negligible factor.

Destroy, burn, or clear fence rows, waste areas and uncultivated tracts adjacent to cultivated fields,

Remove all crop remnants as early in the fall as at all practicable; practice fall plowing where feasible.

Clean up all trash, brush, burlap, boards, and unsightly material about the house, yard, outbuildings, and garden. It is a good practice on general principles and it destroys a slug paradise.

EXPERIMENTS ON SLUG CONTROL

In nearly all references to slug control considerable emphasis is given to the use of irritants with the attendant copious exudation of slime and the gradual weakening and final death of the slugs. Barriers and traps are also frequently mentioned in connection with slug control. Our early studies followed particularly these lines of investigation. In connection with the studies on irritants, tests were also made with the repellents and contact poisons.

For convenience, it seems advisable to separate the tests of 1912, 1913, 1914, and 1916 from those of 1918 and 1919.

TESTS OF 1912 TO 1916

CONTACT POISONS AND IRRITANTS

In the tests with contact materials both the gray garden slug (*A. agrestis*) and the greenhouse slug (*Milax gagates*) were used.

The sulfur-sodium hydroxide mixture was made by mixing 20 grams of sulfur with 1 gram of sodium hydroxide that had been pulverized in a mortar.

The crude carbolic acid-gasoline-sulfur mixture was made by combining crude carbolic acid 1 part with gasoline 3 parts and then adding enough sulfur to make a powder.

Black Leaf and sulfur mixture was made by adding sulfur in sufficient quantities to a limited amount of the old form of Black Leaf to make a powder.

Black Leaf 40 and water was applied at the indicated dilutions by means of an atomizer.

Materials used and results obtained are given in Table I.

Remarks on Table I. The sulfur-sodium hydroxide mixture when applied directly to slugs caused temporary irritation accompanied by heavy exudation of slime but did not prove fatal.

Crude carbolic-gasoline-sulfur mixture when scattered among slugs caused death in a short time. The same is true of Black Leaf-sulfur mixture and tobacco dust respectively.

"Blue Label Slug Destroyer" dusted on slugs proved fatal in 6 hours.

Black Leaf 40 applied directly to slugs as a spray killed in from 40 minutes to 2½ hours depending upon the dilution used.

TABLE I. TESTS OF CONTACT MATERIALS AND IRRITANTS 1912-16

Material	No. of slugs	Date	How applied	Action toward slug	Final effect
Sulfur and sodium hydroxide 20-1	9	10- 6-14	Dusted on slug	Only small one showed great irritation	Recovered within 20 minutes
Crude carbolic-gasoline and sulfur	.....	5- 9-12	Scat'r'd through box containing slugs	Killed in 2½ minutes	.....
Black Leaf and sulfur	.....	5- 9-12	Scat'r'd through box containing slugs	Killed in 4 minutes	.....
Tobacco dust	.....	5- 9-12	Scat'r'd through box containing slugs	Killed in 3 minutes	.....
Blue Label Slug Destroyer	.....	5-29-14	Dusted on slugs	Slugs very restless	Dead in 6 hours
Black Leaf 40 1-800	.....	4-22-16	Sprayed on slugs	"Dopey" at once	Dead in 40 minutes
Black Leaf 40 1-1200	.....	4-22-16	Sprayed on slugs	"Dopey" at once	Dead in 70 minutes
Black Leaf 40 1-1200	.....	4-22-16	Sprayed on slugs	Ill at ease	Dead in 2½ hours

REPELLENTS

The same materials that were tested as contact poisons and irritants were tested as repellents. In addition several other materials and mixtures were experimented with. The results are shown in Table II. The object of these experiments was to determine the repellent value of the materials against slugs and their effect on plants.

All of the materials except Black Leaf 40 and carbolic acid emulsion were applied to the plants as dusts. The two latter materials were applied as liquid sprays.

Remarks on Table II. Crude carbolic-gasoline-sulfur mixture, crude carbolic-gasoline-lime mixture and sulfur-sodium-hydroxide mixture show temporary repellent properties but burn foliage.

Black Leaf 40-sulfur mixture; lime-hellebore; lime-tobacco dust; sulfur-hellebore; and Blue Label Slug Desrtoyer, each proved a temporary repellent for slugs and caused no injury to plants. Rain quickly destroyed or impaired their repellent value.

Black Leaf 40 at strengths of 1-800 and 1-1200 gave good results as a repellent for slugs without causing injury to plants. The period of effectiveness was not determined.

Air-slaked lime; "Insectaline;" lime and hellebore, 10 to 1; Black Leaf 40, 1-2000; and crude carbolic acid emulsion gave little or no control. The carbolic acid emulsion burned foliage severely.

TRAPS AND BARRIERS

In the following experiments certain materials were tested in an effort to find some object on or under which slugs will congregate when they leave the plants to conceal themselves for the day. Later these

TABLE II. EFFECT OF REPELLENTS APPLIED TO PLANTS TO PREVENT SLUG ATTACK 1912-16

Material	Date of treatment	Plants treated	Effect on plant	Action toward slug	Remarks
Crude carbolic acid 1 part, gasoline 2 parts, sulfur to form moist powder	5- 9-12	Cabbage	Slight burn	Repels temporarily	Slugs seemed deterred for 4 days then return. Plants stunted slightly
Black Leaf (old form), sulfur to form powder	5- 9-12	Beans, radishes	None	Temporary repellent	Slugs seemingly repelled for 3 days
Air-slaked lime	6- 6-12	Beans, radishes	None	None	No repellent effect apparent
Air-slaked lime 5 parts hellebore 1 part	6- 6-12	Beans, radishes	None	Fair repellent	Temporary deterrent, kills slugs where dusted lightly
Air-slaked lime 10 parts, hellebore 1 part	6- 6-12	Beans, radishes	None	Slight repellent	Effect as repellent slight and temporary
Air-slaked lime 5 parts, tobacco dust 1 part	6- 6-12	Beans, radishes	None	Very good repellent	Effect as repellent very good for few days
Crude carbolic acid 1 part, gasoline 2 parts, air-slaked lime to form powder	6- 6-12	Beans, radishes	Severe burn	Fair deterrent, kills slug as contact dust	Serious foliage burn renders use dangerous
Crude carbolic acid emulsion 1-60	6- 6-12	Beans, radishes	Severe burn	No repellent	Foliage blistered and discolored
Air-slaked lime 5 parts, tobacco dust 1 part	2-22-13	Lettuce in cold frames	Slight burn to outer leaves	Excellent repellent	Distinct action as repellent apparent for 5 days, rain impaired value
Sulfur 5 parts, hellebore 1 part	2-22-13	Lettuce in cold frames	None	Fair repellent	Fair repellent for 5 days, rain impaired action
Sulfur 10 parts, hellebore 1 part	5-29-13	Cabbage	None	Slight repellent	Effect decidedly temporary
"Blue Label Slug Destroyer"	5-29-13	Cabbage	None	Fair repellent	Effect only temporary, kills by contact
"Insectaline"	10- 6-14	Lettuce	None	Slight repellent	Effect slight and temporary, does not kill by contact
Sulfur 16 parts, powdered sodium hydrate 1 part	10-16-14	Lettuce	Slight burn	Slight repellent	Effect slight and temporary, does not kill by contact
Black Leaf 40 1-800	4-22-16	Lettuce	None	Excellent repellent	Period of effectiveness not determined. Kills by contact
Black Leaf 40 1-1200	4-22-16	Lettuce	None	Fair repellent	Period of effectiveness not determined. Kills by contact
Black Leaf 40 1-2000	4-22-16	Lettuce	None	Slight repellent	Period of effectiveness not determined. Kills by contact

traps were to be examined and the slugs found there destroyed. Sticky substances to prevent slugs from entering uninfested cold-frames were also tested. The materials used and results obtained are shown in Table III.

TABLE III. TRAPS AND BARRIERS IN SLUG CONTROL

Material	Date applied	Method of treatment	Effect and value											
			Feb. 27	March—									Total	
				1	4	5	6	9	10	11	12	13		
Bark	2-23-13	4 pieces 3x4 inches placed in cold frames of lettuce	6	7	6	2	3	3	5	1	5	4	42	More attractive because moist
Burlap	2-23-13	Same as above, same number and same approximate size and shape	0	1	2	0	0	1	0	5	0	0	9	Tended to dry out
Coopers "Tactite" (Tanglefoot)	10-14-15	As 1¼ inch band about seed flats, 2 inches from top	Served as temporary deterrent but not repellent: slugs eventually crossed band.											
"Tactite"	10-14-15	As circle on smooth board around 10 slugs	All showed aversion, in 3 minutes one crossed. in 20 minutes all were out. Slime exuded serves as protection.											
"Tactite"	10-19-15	As 1¼ inch strip 1 inch from top of 1x4 frame about garden	Temporary deterrent, ineffective as repellent.											

Remarks on Table III. Pieces of bark placed at intervals in cold-frames are better traps for slugs than are pieces of burlap because the soil beneath the bark tends to remain moist while beneath the burlap the soil will dry out.

"Tactite" (a commercial compound similar to tanglefoot) in a band 1¼ inches wide was crossed by slugs without permanent ill effects.

STOMACH POISONS

Poison baits have been recommended from time to time for use in slug control. Accordingly experiments were undertaken to test the value and attractiveness of baits.

The tests were made in the College cold-frames and seed beds where slugs were causing great damage to head lettuce. The baits were placed in small heaps at intervals throughout the cold-frames. In some cases the bait was placed under pieces of bark. The baits and surrounding soil were examined daily for slugs and the condition of the slugs noted. Materials used and results obtained are given in Table IV.

Poison bait 1, consisted of bran 16 parts, paris green 1 part, a small amount of salt and sirup made into a crumbly mash.

Bait 2, consisted of: chopped lettuce 1 quart, sugar ½ ounce, acid lead arsenate ¼ ounce.

Bait 3 was the same as No. 2 except paris green was used instead of lead arsenate.

Bait 4 was 1 quart lettuce, ½ ounce paris green, cracklings (ground) one pound.

TABLE IV. STOMACH POISONS

Material	Date applied	Conditions applied	Effect on slugs (Days)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Poison No. 1 bran mash	2-23-13	Small heaps in cold frames of head lettuce									6 dead			2 dead		
No. 2 Chopped lettuce bait and acid lead arsenate	3- 1-15	Small heaps in cold frames of head lettuce		22	sick										Sick and apparently dead slugs later recovered.	
No. 3 Chopped lettuce and paris green	3- 3-15	Small heaps in cold frames of head lettuce	6	sick											Few sick slugs. bait not attractive	
No. 4 Lettuce leaves, paris green, cracklings	3- 4-15	Small heaps in cold frames of head lettuce													Not very attractive.	
No. 5 same as No. 3	3- 5-15	Small heaps in cold frames of head lettuce	Few sick													
			Many sick												Many sick and a few dead slugs and millipeds	
No. 6 same as No. 4	.....	.....													.....	...

Remarks on Table IV. As a whole poison baits did not give satisfactory results. Many slugs that were sick and some that were apparently dead recovered later.

Baits prepared with lettuce without cracklings seemed as attractive as those containing cracklings.

Poison Sprays. Tests of poison sprays on foliage as a protection from slug attack were made in the fall of 1914 and repeated with modifications in the spring of 1915. Lettuce growing in the College cold-frames was used for these experiments. Lead arsenate was the only poison em-

ployed; it was used both as a powder and as a liquid spray. Since the materials varied somewhat a brief summary of each treatment is given:

1914.

No. 1.	Lead arsenate, powdered "Electro,"	1 part
	Sulfur dust	20 parts
No. 2.	Lead arsenate, powdered "Electro,"	1 ounce
	Soap (Napthaline)	1 ounce
	Water	6 quarts

Remarks on Results. Rains occurred immediately after the application and at frequent intervals in the week following. All evidence of the presence of either material on the foliage had disappeared at the end of five days and many evidences of feeding were present. The liquid spray, No. 2, caused considerable burn.

Subsequent tests with reduced amounts of lead and without the addition of soap varied these results but little. What minor differences were apparent in the degree of control obtained were in favor of the powdered application.

1915.

No. 1.	Lead arsenate, powdered "Corona"	15 parts
	Sulfur dust	85 parts
No. 2.	Lead arsenate, powdered "Corona"	1 ounce
	Water	3 gallons

Remarks on Results. Rains were again frequent following the application. The dust was superior to the liquid spray. The liquid spray had a tendency to burn. It did not stick so well nor spread so evenly and was washed off more readily than was the powder. The powder adhered well, spread over the foliage with little waste, and in these experiments and subsequent commercial tests failed to show any tendency to burn.

Neither form proved particularly efficient as a protection from slugs. What protection was afforded was only temporary.

SUMMARY OF CONTROL EXPERIMENTS 1912-16

Irritants and contact sprays are of decidedly minor value in practical field work with slugs. The majority of irritants, while causing a momentary discomfort to slugs, with an attendant exudation of slime, have no permanent ill effect. Repeatedly in our tests where individual slugs were surrounded, covered, or even buried in these irritants, within half an hour after the treatment they showed no apparent ill effects and were induced to feed with evident relish.

Certain deterrent dusts may repel for a time but due to the necessity for frequent renewal because of showers or impaired effectiveness they are not satisfactory under field conditions. The most promising materials tested are:

1. Air-slaked lime 5 parts, hellebore 1 part,
2. Air-slaked lime 5 parts, tobacco dust 1 part.

Poison baits and sprays did not give the degree of control one would expect. In poison sprays the powdered application is superior to the liquid in ease of application, evenness of covering, adhesiveness.

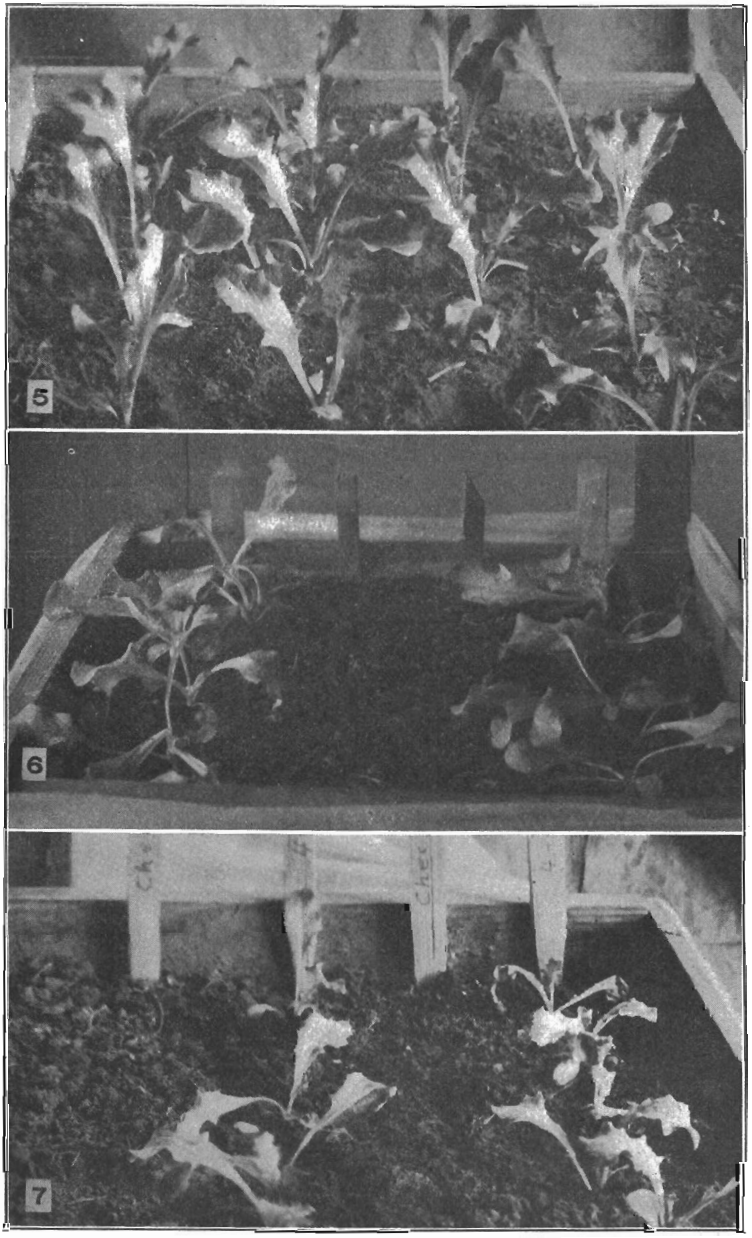

PLATE III.

Fig. 5. Flat of lettuce, untreated, as used in tests. Fig. 6. Test flat of lettuce, row 1 dusted with dry Bordeaux, rows 2 and 3 checks, row 4 dusted with paris green. Fig. 7. Test flat, rows 2 and 4 treated with Bordeaux spray 4-4-50, rows 1 and 3 checks.

TESTS FOR SLUG CONTROL 1918-1919

In 1918 further experiments were undertaken in an attempt to find some method of control that would give satisfactory results during the wet weather of spring and autumn when slugs become especially destructive.

CONTACT POISONS AND IRRITANTS

It having come to our attention that copper sulfate even in very dilute solutions is fatal to water snails, tests were made to determine the effect of this material on garden slugs. Since copper sulfate was known to injure foliage, efforts were made to find some other material of a similar nature that would kill slugs and would not injure foliage. Many copper compounds, various volatile oils, emulsions, tobacco extracts, and other standard contact poisons were tested with the results shown in Table V.

In these tests only freshly collected specimens of the gray garden slug (*A. agrestis*) were used. Individual slugs or groups of slugs were placed on sheets of clean paper or on fresh, clean lettuce leaves and sprayed with the respective solutions. After being treated the slugs were removed with clean forceps to jars containing a layer of fresh moist soil and were fed lettuce leaves. In some cases, as noted, clean lettuce leaves were sprayed and after the spray had dried freshly collected slugs were placed on the leaves.

All spraying was done with a small atomizer which threw a fine misty spray. The atomizer was thoroughly cleaned after each application.

The ten percent copper sulfate solution was made by dissolving 10 grams of commercial bluestone ($CuSO_4.5H_2O$) in 90 c. c. of water. The one percent solution was made by adding 10 c. c. of the ten percent solution to 90 c. c. of water.

The Bordeaux was made by dissolving the proper amounts of bluestone and rock lime respectively in half the total amount of water, the lime being heated in a small portion of the water to hasten slaking. These two solutions were combined and used at once.

For the emulsions, a stock solution of whale-oil soap was made by dissolving 1 ounce of soap in 8 ounces of boiling water. After the soap was dissolved, water was added to make up the amount lost from evaporation. The emulsions were made by combining equal parts, by bulk measure, of the stock soap solution and the respective oils and agitating vigorously. The resulting emulsions were diluted with water, as indicated in the table, just before spraying.

One experiment was the result of accidentally collecting 18 slugs in a paper sack that had been used for weighing copper sulfate crystals. The amount of bluestone adhering to the sack was not enough to be detected readily with the naked eye.

Remarks on Table V. Results of the experiments show copper sulfate to be fatal to slugs when applied externally at strengths of from 1 to 10 percent in water. Slugs so treated died within twenty-four hours.

Bordeaux mixture killed more slowly than did copper sulfate. Some slugs survived the treatment.

TABLE V. CONTACT SPRAY TESTS FOR SLUGS 1918-1919

Material	Date	No. of slugs	How treated	Effect on slugs: 1 minute	3 minutes	5 minutes	15 minutes	1 hour	24 hours	Remarks
Copper sulfate 10% solution	9-19-18	5	Wet with spray	Distressed, slime exuded abundantly	Nearly rigid	Apparently dead	Dead			Dead
Copper sulfate dust	9-21-18	18	In paper sack with few crystals	Distressed, slime exuded abundantly		Apparently dead		Dead		Dead
Copper sulfate 1% solution	9-19-18	5	Wet with spray	Distressed, slime exuded abundantly		Growing rigid	Dying		Dead	Dead
Copper sulfate 1% solution	9-24-18	8	Wet with spray	Distressed, slime exuded abundantly				Dead		Dead
Copper sulfate 10% solution	9-19-18	1	Lettuce leaf sprayed, allowed to dry and slug placed on leaf	Distressed, slime exuded abundantly		Growing rigid	Dead			Dead
Copper sulfate 10% solution	9-19-18	1	Ditto above, paper instead leaf	Distressed, slime exuded abundantly			Inactive		Dead	Dead
Copper sulfate 1% solution	9-19-18	1	Wet with spray	Distressed, slime exuded abundantly	Sloughed off slime	Active	OK			OK
Copper sulfate 1% solution	9-24-18	1	Treated leaf and dried	Decided repellent	Active	OK				OK
Copper sulfate 1% solution	9-24-18	3	Wet with spray	Distressed, abundant slime				Dead		Dead
Oil of lemon 1-100 H^2O	9-21-18	2	Wet with spray	Distressed, abundant slime	Sloughed off slime		Active		Feeding	OK
Whale oil soap 1 lb. to 8 gal. H_2O	9-21-18	1	Wet with spray	Distressed,	Sloughed off			Sick	Sick	8 days dead

				abundant slime	slime					
Clove oil emulsion 1-15	9-21-18	2	Wet with spray	Distressed, abundant slime	Sloughed off slime				Dead	Dead
Cedar oil emulsion 1-25	9-21-18	2	Wet with spray	Crawled rapidly away, little slime					Feeding	OK
Oil of tar emulsion 1-25	9-21-18	3	Wet with spray	Little effect apparent	Active				Feeding	OK
Black Leaf resinate 1-100	.....	3	Wet with spray	Distressed, copious slime			Alive, inactive		2 dead 1 OK	2 small dead adult OK
Bordeaux 4-4-50	9-23-18	6	Wet with spray	Distressed, copious slime					All dead	All dead
Bordeaux 4-4-50	9-24-18	2	Wet with spray	Distressed, copious slime, turned blue					Dead	Dead
Bordeaux 4-4-50	9-25-18	6	Wet with spray on moist soil	Distressed, copious slime	Sloughed off slime				(2 dead 4 OK)	(2 days, 4 alive feeding)

Clove oil emulsion, strong soap solution, and Black Leaf resinate killed more slowly than copper sulfate and failed to kill all the slugs treated.

Copper sulfate in .1 percent solution, oil of lemon in 1 percent solution, cedar oil emulsion, and oil of tar emulsion did not kill slugs.

REPELLENTS

In previous experiments we found that apparently some materials such as sulfur and tobacco were not readily eaten. Copper sulfate, Bordeaux mixture, and paris green seemed also to be distasteful to slugs. Experiments were undertaken to determine the repellent values of these compounds with results as shown in Table VI.

In the first two tests slugs were confined in breeding cages and offered both sprayed and unsprayed food. In all the other tests slugs were confined on greenhouse flats of growing lettuce. In each flat certain rows were sprayed or dusted as indicated in the table and certain rows, designated as "checks," were left untreated.

Spraying was done with a small atomizer that threw a fine misty spray. Dusting was done by shaking the material through a fine cheesecloth bag. While a row was being treated the other rows were covered with clean newspapers.

Only freshly collected specimens of the gray garden slug (*A. agrestis*) were used.

The soil in the flats was kept moist so as to have conditions favorable for the slugs.

Remarks on Table VI. Bordeaux mixture proved to be an excellent repellent in every test. In most cases practically none of the lettuce sprayed with Bordeaux was touched while nearly all of the untreated lettuce was eaten. (Plate III, Fig. 7.) There was no apparent difference in the value of 4-4-50 Bordeaux as compared to 2-2-50.

Glidden's dry Bordeaux showed good repellent properties but was not as effective as the liquid Bordeaux. (Plate III, Fig. 6.)

Paris green gave excellent protection to the plants and was the easiest material to apply of any tested. (Plate III, Fig. 6.)

Sulfur, tobacco, and combinations of the two with lead arsenate seemed to be somewhat repellent to slugs, but not sufficiently so to protect the plants. (Plate IV, Fig. 8.)

Copper sulfate, 1 to 1000, in water showed repellent properties in preliminary tests, but was not tested further since it is known to injure the foliage of many species of plants.

Tests in Cold-frames. Laboratory tests of Bordeaux mixture; tobacco; sulfur; and combinations of tobacco, sulfur, and lead arsenate were supplemented with tests in the College cold-frames. The results are shown in Table VII.

Lettuce particularly and Swiss chard in smaller degree, in the cold-frames showed severe slug injury. Several of the lettuce plants had already been killed by slugs and others were nearly all eaten. The lettuce was about half-grown leaf lettuce.

Sprays were applied with a compressed air knapsack sprayer known as "Brown's Auto Spray." This machine threw a rather coarse mist.

TABLE VI. REPELLENTS 1918-19

Material	No. of slugs	Date	Plant	Effect	Remarks
A. Sprayed with copper sulfate 1-1000*				A. No feeding until 5th day not all eaten in 10 days	One slug disappeared. Some repellent effect
B. Unsprayed		9-23-18	Clover	B. Fed first day and after At end of 10 days all eaten	
A. Bordeaux 4-4-50*				A. Slight feeding until 10th day	
B. Unsprayed		9-25-18	Clover	B. Eaten readily, all gone 10th day All slugs OK	Decided repellent effect.
Bordeaux 4-4-50			9 lettuce plants	8 plants OK, 1 eaten off below ground	Good repellent
Check	25	12- 7-19	10 lettuce plants	All eaten but parts of two plants	
Bordeaux 2-2-50			9 lettuce plants	All OK but one which apparently died of disease and was not eaten	
Check	25	12- 7-19	9 lettuce plants	No trace left	
Dusted with "3 in 1"	25	12- 7-19	6 lettuce plants	Five mutilated plants left	Some repellent effect
Check			7 lettuce plants	No trace left	
Dusted with sulfur	25	12- 7-19	5 lettuce plants	2 plants alive but mutilated	Some repellent effect
Check			8 lettuce plants	No trace left	
Dusted with tobacco		....	5 lettuce plants	3 plants alive but mutilated	Some repellent effect
Dusted with paris green	12	2-12-19	5 lettuce plants	4 OK, 1 cut off near ground	Good repellent
Check			10 lettuce plants	3 alive but mutilated	
Gliddens dry Bordeaux	12		5 lettuce plants	All plants OK	Good repellent
Same	20	2-12-19	10 lettuce plants	One and part of another destroyed	
Check		2-12-19	10 lettuce plants	All but two destroyed	
Sprayed Bordeaux 4-4-50 plus paris green 4-50	35	2-13-19	5 lettuce plants	All OK	
Bordeaux 4-4-50			5 lettuce plants	One cut off	
Check			10 lettuce plants	9 destroyed	
Glidden's dry Bordeaux sprayed 1 gram to 75 c.c.	35	2-13-19	5 lettuce plants	All OK	Eventually one partly eaten before those treated with Bordeaux 4-4-50 were touched
Bordeaux sprayed 4-4-50			5 lettuce plants	All OK	
Check			10 lettuce plants	9 gone 1 left	
Plants protected by border of "dry" Bordeaux on soil.					
Wet down		2-12-19	8 lettuce plants	Slugs crossed border	
Same but not wet down		2-12-19	8 lettuce plants	Slugs crossed border	
Check			4 lettuce plants		

*Slugs confined in breeding cages. Those not marked confined on flats of living plants.

Dusts were applied with a Niagara hand duster that threw a good, even cloud of dust. Both upper and under surfaces of the foliage were dusted.

TABLE VII. REPELLENTS IN COLD-FRAMES

Material	Date	Plant	Effect after 31 days	Remarks
Bordeaux 2-2-50	9-23-18	3 rows lettuce	Practically no slug injury. Spray still in evidence	
Bordeaux 4-4-50 about base of plants	9-23-18	6 rows lettuce	Slight slug injury Spray still in evidence	
Check		6 or 8 rows lettuce	Leaves ragged	
Sulfur 50 Lead arsenate 10 "3 in 1" Tobacco 40 dust	9-28-18	8 rows lettuce	About same as check below	Many leaves with heavy coating of dust were partly eaten
Tobacco 50) Sulfur 50)	9-28-18	6 rows chard 4 rows lettuce	About same as check	Chard was so little eaten in all cases that it gave negative results
Check	.....	4 rows chard 8 rows lettuce	Injury evident but not severe	

Discussion of Table VII. Plants sprayed with Bordeaux mixture, 2-2-50 and 4-4-50 respectively, showed very little indication of slug injury for a month after the time of treatment. Some plants that were nearly dead recovered after treatment.

Bordeaux, 4-4-50, sprayed about the bases of plants greatly reduced the amount of subsequent injury but did not entirely prevent it.

"3 in 1" dust composed of sulfur, tobacco, and lead arsenate did not appreciably reduce subsequent injury. Sulfur and tobacco gave no better results.

Check plants were so badly injured by slug feeding that all the outer leaves, comprising at least a third of the plants, had to be removed before the lettuce was marketed.

BARRIERS

In connection with the tests of repellents, dry Bordeaux was tested as a barrier. A band of a commercial dry Bordeaux about an inch wide was placed on the soil about part of the plants in a greenhouse flat. (Plate IV, Fig. 10.) In one case the material was moistened after being applied.

In every case the slugs crossed the bands of Bordeaux whether dry or wet, without apparent discomfort.

Ten slugs each of the gray garden slug (*A. agrestis*) and the greenhouse slug (*M. gagates*) were placed on a clean board and a circle of pulverized copper sulfate was placed about them.

None of the slugs succeeded in crossing the circle of copper sulfate. In half an hour every slug that attempted to cross the circle was dead.

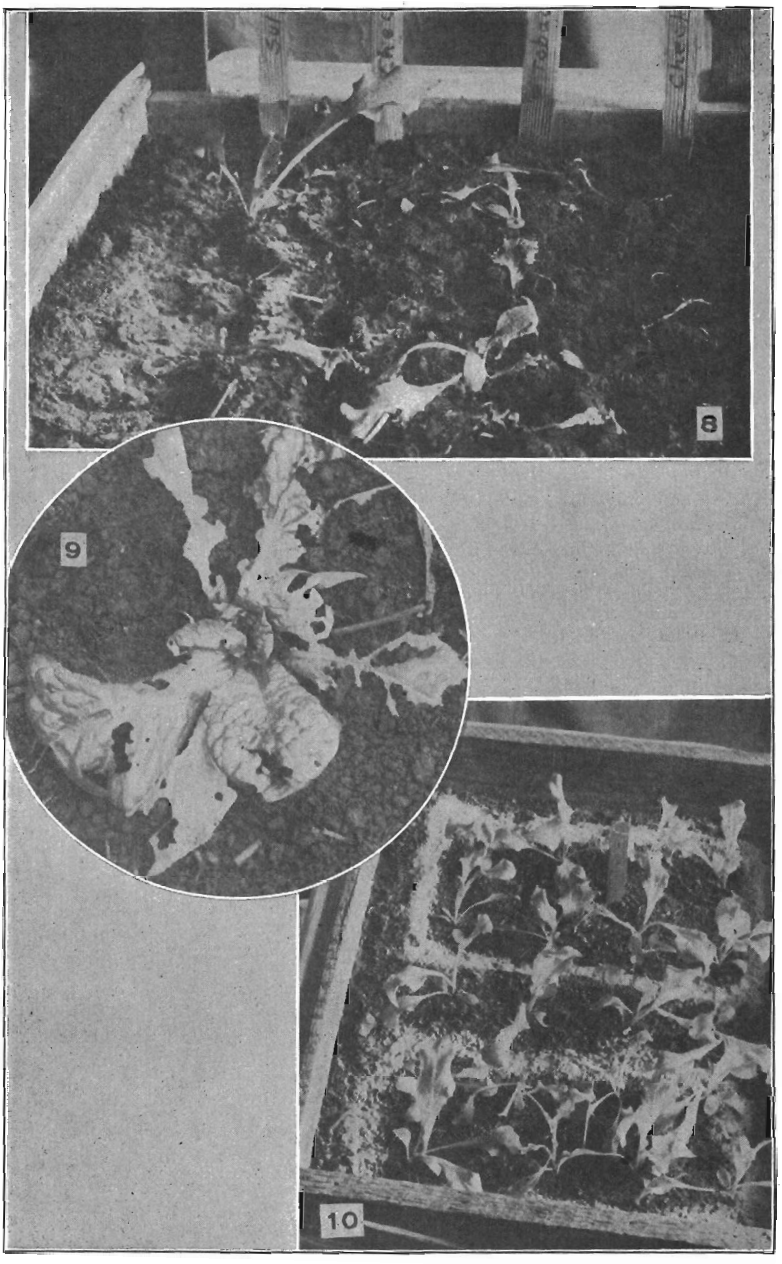

PLATE IV.

Fig. 8. Treated flat, row 1 dusted with sulfur, rows 2 and 4 checks, row 3 dusted with tobacco. Fig. 9. Slug injury to head lettuce. Fig. 10. Treated flat, dry Bordeaux on soil as barriers to slugs.

STOMACH POISONS

Our experiments in former years gave conflicting results as to the killing properties of lead arsenate and other standard poisons when used to control slugs. Tests were made, therefore, in an endeavor to find some material that is readily eaten by slugs and that is fatal to them when eaten. Commercial arsenates of lead and arsenates of calcium, various copper compounds, strychnine sulfate, and many other standard poisons were tested with the results shown in tables VIII and IX.

Freshly collected specimens of the gray garden slug (*A. agrestis*) were used in these tests. When slugs were collected from clover plants, clover was used as food and when they were collected from lettuce, lettuce was used so that the respective slugs would have food to which they were accustomed. Other substances which have been mentioned as suitable materials for baits, such as cracklings and boiled potato, were also tested.

In these tests individual slugs or groups of slugs as indicated were confined in breeding cages on fresh moist earth with poisoned food only. Care was taken not to place the slugs in contact with the poison material. Baits mixed dry were prepared in clean beakers or mortars with a glass stirring rod or a porcelain pestle. Only clean fresh materials were used for baits.

All spraying was done with an atomizer which threw a fine misty spray. Dusts were applied by shaking through a fine cheese-cloth bag.

In all cases checks were placed in the same conditions and were fed the same kind of food, minus the poison. Experiments were run in duplicate.

Remarks on Results. In our tests none of the materials listed in Table VIII gave promise as poisons. Either they were not readily eaten or else they did not kill when eaten.

Calcium arsenate was readily eaten in most cases and killed a high percentage of the slugs that ate it. This material did not blacken lettuce when mixed as a bait.

Lead arsenate was readily eaten but killed very few if any slugs.

Paris green was a decided repellent, was fed upon only under stress and then sparingly, but was usually fatal when eaten.

Strychnine sulfate was readily eaten but in every instance failed to kill.

White arsenic was not very readily eaten and gave only a small percentage of kill.

Sodium arsenate was not readily eaten but killed most of the slugs that did eat it. This material soon blackened lettuce and thus rendered the bait unattractive.

Potassium cyanide destroyed the bait quickly and was not eaten.

Substances used as media for poisons in baits showed the following properties:

Cracklings were but little eaten for several days after being offered. The material soon molded and was not satisfactory.

TABLE VIII. EFFECT OF VARIOUS INTERNAL POISON MATERIALS ON SLUGS

Material	Date	Plants treated	Action toward slugs	Remarks
Copper chloride 1-100 sprayed on plant	10- 5-18	Clover	No feeding. Slug OK	Leaves badly burned
Copper chloride 1-100 in 4-4-50 Bordeaux	10- 5-18	Clover	Some feeding. Slugs OK	No burn
Copper-aceto arsenate 1-100 sprayed	10- 5-18	Clover	Readily eaten. Slug OK	No burn
Same in 4-4-50 Bordeaux	10- 5-18	Clover	Fed some. Slugs OK	No burn
Sodium fluoride 1-100	10- 5-18	Clover	Very little feeding. Slugs dead 8 days	No burn
Copper sulfate 1-100	10- 5-18	Clover	No feeding. Slugs OK	No burn
Copper cyanide 1-100	10- 5-18	Clover	No feeding. Slug dead 8 days	No burn
Copper ferrocyanide 1-100	10- 5-18	Clover	Readily eaten. Slug OK	No burn
Copper benzoate 1-100	10- 5-18	Clover	Readily eaten. Slug OK	No burn
Copper carbonate 1-100	10- 5-18	Clover	No feeding. Slug OK	No burn
Copper chromate 1-100	10- 5-18	Clover	Some feeding. Slug OK	No burn
Lead arsenate 1-100	10- 7-18	Clover	Some feeding. Slug OK	No burn
Borax 1-100	10- 7-18	Clover	No feeding. Slug dead	No burn, leaves coated with slime
Bordeaux 4-4-50	9-23-18	Clover	Some feeding. Slugs OK	
Same	9-25-18	Clover	Slight feeding. One of 6 slugs dead	
Copper sulfate 1-100	9-23-18	Clover	No feeding. One dead	
Same	9-25-18	Clover	Slight feeding. Slugs OK	
Copper sulfate 1-200	9-23-18	Clover	No feeding. All dead	Severe burning of leaves
Same	9-25-18	Clover	Slight feeding. Two of eight dead	
Copper sulfate 1-450	9-23-18	Clover	No feeding. All dead	Slight burning
Same	9-25-18	Clover	Slight feeding. Slugs OK	One disappeared
		Clover		
Copper sulfate 1-100	9-23-18	Clover	Readily eaten. All dead	
Same	9-25-18		Readily eaten. All OK	

TABLE IX. POISON BAITS

Material	No. slugs	Date	How prepared	Palatability	Action toward slugs
a. Calcium Arsenate					
Boiled potato and calcium arsenate	2	1-21-19	Dusted bait with poison	Slight feeding after 24 hours	1 dead 48 hrs. Other alive 96 hrs.
Boiled potato and calcium arsenate	10	1-21-19	Dusted bait with poison	Considerable feeding	2 dead 24 hrs. 3 more dead 72 hrs. 3 OK. 96 hrs. 1 escaped
Boiled potato and calcium arsenate	2	1-21-19	Dusted bait with poison and mashed	Fed slightly	Both OK 48 hrs.
Lettuce and calcium arsenate	2	1-21-19	Dusted bait with poison	Slight feeding	Both dead 48 hrs.
Lettuce and calcium arsenate 1 percent	2	1-21-19	Sprayed bait with poison	Slight feeding by one	Both OK 96 hrs.
Cracklings and calcium arsenate 20 to 1	2	12-16-18	Mixed dry	Slight feeding	1 dead 48 hrs. Other dead 72 hrs.

TABLE IX—CONTINUED

Material	No. slugs	Date	How prepared	Palatability	Action toward slugs
Same but 10 to 1	2	12-16-18	Mixed dry	Slight feeding	1 dead 48 hrs. Other OK 72 hrs.
Same but 5 to 1	2	12-16-18	Mixed dry	Slight feeding	1 dead 48 hrs. Other OK 72 hrs.
Lettuce and calcium arsenate .5 percent	2	12-16-18	Sprayed bait with poison	Some feeding	Both OK 96 hrs.
Same—1 percent	2	12-16-18	Sprayed bait with poison	Considerable feeding	Both dead 48 hrs.
Same—2 percent	2	12-16-18	Sprayed bait with poison	Considerable feeding	1 dead 72 hrs. Other OK 96 hrs.
b. Lead Arsenate					
Boiled potato and lead arsenate	2	1-21-19	Dusted bait with poison and mashed	Both fed	Both OK 96 hrs.
Same	10	1-21-19	Dusted bait with poison and mashed	Fed readily	1 dead 72 hrs. Other OK 96 hrs.
Lettuce	2	1-21-19	Dusted bait with poison	Fed readily	OK 96 hrs.
Cracklings and lead arsenate 20 to 1	2	12-16-18	Mixed dry	Slight feeding	All OK 72 hrs.
Same but 10 to 1	2	12-16-18	Mixed dry	Slight feeding	All OK 72 hrs.
Same but 5 to 1	2	12-16-18	Mixed dry	Slight feeding	All OK 72 hrs.
Clover and lead arsenate 1 percent	1	10- 7-18	Sprayed bait with poison	Some feeding	Slug OK
Lettuce and lead arsenate .5 percent		12-16-18	Sprayed bait with poison	Eaten readily	All OK 72 hrs.
Same but 1 percent	....	12-16-18	Sprayed bait with poison	Eaten readily	All OK 72 hrs.
Same but 2 percent	....	12-16-18	Sprayed bait with poison	Eaten readily	All OK 72 hrs.
Same but 3 percent	....	12-16-18	Sprayed bait with poison	Eaten readily	All OK 72 hrs.
Check, boiled potato	5	1-21-19	.....	Fed readily	OK 96 hrs.
Check, lettuce	4	1-21-19	.....	Fed readily	OK 96 hrs.
c. Paris Green					
Boiled potato and paris green	2	1-21-19	Dusted bait with poison	1 fed slightly	1 dead 72 hrs. Other OK 96 hrs.
Same	10	1-21-19	Dusted bait with poison	No feeding	All OK 96 hrs.
Same	2	1-21-19	Dusted bait with poison and mashed	No feeding	All OK 96 hrs.
Lettuce (chopped) and paris green 20-1	2	1-21-19	Mixed dry	Slight feeding	1 dead 96 hrs. Other OK
Cracklings and paris green 20-1	2	1-21-19	Mixed dry	No feeding	OK 72 hrs.
Same but 10-1	2	1-21-19	Mixed dry	No feeding	OK 72 hrs.
Same but 5-1	2	1-21-19	Mixed dry	No feeding	OK 72 hrs.

TABLE IX—CONTINUED

Material	No. slugs	Date	How prepared	Palatability	Action toward slugs
Lettuce and paris green .5 percent	2	12-16-18	Sprayed bait with poison	Slight feeding	1 dead 24 hrs. Other dead 48 hrs.
Lettuce and paris green 1 percent	2	12-16-18	Sprayed bait with poison	Slight feeding	Both dead 48 hrs.
d. Strychnine Sulfate					
Strychnine sulfate 1/4 gram, Irish moss 1/3 gram, Saccharine 3 pills, Lettuce + 3 oz. H_2O	2	12-16-18	Sprayed bait with poison	Readily eaten	Both OK 96 hrs.
Same but 2 oz. H_2O	2	12-16-18	Sprayed bait with poison	Readily eaten	Both OK 96 hrs.
Same but 1 oz. H_2O	2	12-16-18	Sprayed bait with poison	Readily eaten	1 escaped. Other OK 96 hrs.
e. White Arsenic					
Boiled potato and white arsenic	2	1-21-19	Dusted bait with poison	1 fed slightly	Both OK 96 hrs.
Same	10	1-21-19	Dusted bait with poison	Considerable feeding	1 dead 96 hrs. 9 OK 96 hrs.
Same	2	1-21-19	Dusted bait with poison and mashed	No feeding	Both OK 96 hrs.
Lettuce and white arsenic	2	1-21-19	Dusted bait with poison	Fed some	One dead 24 hrs. 1 OK 96 hrs. A third slug refused to feed
f. Sodium Arsenate					
Lettuce (chopped) and sodium arsenate 20 to 1	2	1-21-19	Mixed dry	Fed some	1 dead 24 hrs. Other OK 96 hrs.	Blackens bait
Same 10 to 1	2	1-21-19	Mixed dry	Slight feeding	1 dead 48 hrs. Other dead 72 hrs.	Blackens bait
g. Potassium Cyanide					
Cracklings and potassium cyanide 40 to 1	2	12-16-18	Mixed dry	No feeding	Both OK 72 hrs.	Blackens lettuce bait
Lettuce and potassium cyanide 40 to 1	2	12-16-18	Mixed dry	No feeding	Both OK 72 hrs.	

Boiled potato was readily eaten by some slugs but not eaten at all by others. It soon soured or molded.

Clover was readily eaten by slugs collected from about clover plants.

Lettuce was very readily eaten by all slugs whether collected about lettuce plants or not. The baits of lettuce on moist soil kept in good condition for several days.

A summary of the results of all the experiments indicates that calcium arsenate, sodium arsenate, and paris green are the only stomach poisons tested that kill a high percentage of the slugs feeding upon them. Of these paris green is not readily eaten and is therefore not satisfactory in baits. Sodium arsenate soon destroys the bait and for that reason may be discarded. By a process of elimination calcium arsenate is the only material tested that kills a high percentage of slugs feeding upon it and at the same time is readily eaten and does not destroy the bait. Lettuce appears to be more satisfactory as bait than cracklings, boiled potatoes, or clover.

COMBINING A REPELLENT SPRAY AND A POISON BAIT

Bordeaux mixture proved in our experiments to be an excellent repellent for slugs and non-injurious to foliage. Calcium arsenate was found to be a poison that kills slugs and is not distasteful to them. We next undertook experiments using a combination of a repellent spray applied to the foliage and an attractive poison bait for the control of slugs. Greenhouse flats of growing lettuce plants were sprayed with Bordeaux mixture 4-4-50; a bait of chopped lettuce leaves, 1 pound, plus calcium arsenate, 1 ounce, was scattered in the flat. Freshly gathered slugs (*A. agrestis*) were introduced into the flat, being uniformly distributed over the soil. Care was taken that slugs were not placed in contact with sprayed foliage or the poison bait. The results of these experiments are shown in Table X.

TABLE X. REPELLENT AND POISON BAIT

Material	No. of slugs	Date		Effect on slugs	Effect on plants
Bordeaux 4-4-50 on plants Poison bait scattered in flat (16 parts lettuce, 1 calcium arsenate)	35	3- 1-19	20 plants	After 24 hours 33 slugs dead, one missing, one OK	Plants uninjured
Check	28	.....	.....	All OK	Considerable injury to plants

Remarks on Table X. Results show that plants sprayed with Bordeaux were not attacked and that over 94 percent of the slugs in the treated plots were dead at the end of 24 hours as a result of feeding on the poison bait.

ALLIED SPECIES OF SLUGS

A number of species of slugs occur in Oregon. Only two allied forms, however, attack cultivated crops in sufficient numbers to be considered at present of economic importance. These are the greenhouse slug, *Milax gagates* Drap. and the reticulated slug, *Prophysaon andersoni* Cooper. Three genera are thus represented and the characters for separating them are quite distinctive. The following brief table offers characters for separating the three species:

A. Sole tripartite. Respiratory orifice in caudal half of mantle.

a. Back acutely keeled the full length, genital orifice half-way between respiratory orifice and right tentacle. Respiratory orifice not cut by anal cleft. Light brown tinged with slaty gray.
(Greenhouse slug) *Milax gagates.*

b. Back not keeled except at caudal end. Genital orifice 2 mm. behind right tentacle. Ring of respiratory orifice cut by anal cleft. Grayish white through gray to black. Spotted or blotched.
(Gray garden slug) *Agriolimax agrestis.*

B. Sole not tripartite. Respiratory orifice in anterior half of mantle. Not keeled.

a. Surface with diamond-shaped reticulation. Tail showing constriction about ⅓ of length from caudal end. Color variable. Mantle usually banded longitudinally with dark color.
(Reticulated slug) *Prophysaon andersoni.*

THE GREENHOUSE SLUG

(*Milax gagates* Drap.)

HISTORY AND DISTRIBUTION

The greenhouse slug is a native of Europe and probably originated in the countries bordering on the Mediterranean Sea. It has spread to nearly all parts of the world and is now found in England, Ireland, Scotland, The Netherlands, France, Spain, Portugal, Italy, Greece, Austria, Hungary, Russia, Australia, Asia Minor, North Africa, Cape Colony, Brazil, Mexico, and the United States. It was first found in England in 1801 and was first reported in this country in 1872 from San Francisco, California, where it was collected in gardens. It is reported from California, Washington, Idaho, and Pennsylvania, and probably occurs in many other states. It is particularly in evidence in the suburbs of cities.

This slug, like the gray garden slug, thrives in densely populated districts. It is especially partial to greenhouses and cold-frames. It hides under boards, rubbish, and garden waste and is largely subterranean in its habits, burrowing from one to four inches in the soil and feeding on roots.

The greenhouse slug is not so widely disseminated in this country as is the gray garden slug, but it is equally destructive where it does occur in numbers. It is likely eventually to become a serious pest in and about cities and trucking districts where plants are raised under glass.

SNYONYMY

The greenhouse slug has been most generally known as *Limax hewstoni* in America. It was first described by Draparnand as *Limax gagates* and was placed in the genus *Milax* by Gray in 1855 when he instituted the new genus. Taylor (6) gives the synonymy as follows:

Limax gagates. Draparnand. Tabl. Moll. p. 100 No. 1 and Hist. Nat. pl. gl. 122, pg. 1,2.
Maurus Qnoy and Gaimard, Voy-Uranie, p. 426.
(Amalia) gagates Moquin-Tandon Hist. Moll. Vol. 2, p. 19.
Hewstoni Cooper Proc. Acad. Nat. Sci. Philad. p. 147, pl. 3 Catal.
Milax gagates Gray. Catal. Pulm. p. 174.
tasmanicus Tate Proc. Roy. Soc. Tasmania p. 16.
Pini, Bull. Soc. Mal. Ital. vol. 2, p 107
Amalia marginata mut. gagates Pini. Bull. Soc. Mal. Ital. vol. 2, p. 107.
babari Collinge, Proc. Malac. Soc.. p. 294.

DESCRIPTION

The Adult. The mature greenhouse slug, when fully extended in locomotion, is about two and three-fourths inches long, two fifths of an inch wide, and four-fifths of an inch high. The body is strongly keeled, even when fully extended; the mantle is granulate-rugose and with a conspicuous groove, subelliptic in outline. (Plate II, Fig. 2.) The color is

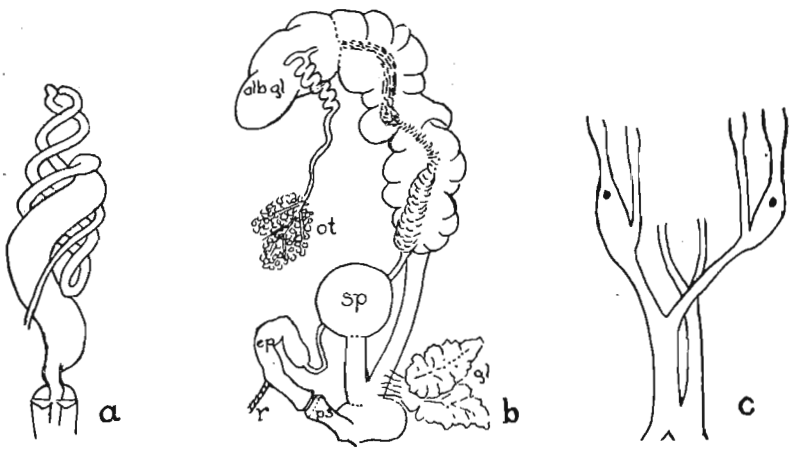

Fig. 14. a. Alimentary tract of M. gagates, showing bucial bulb and nerve ring. b. Sexual organs of M. gagates, the accessory glands turned aside to show the protuberant atrium. alb gl, albumen glands; ot, ovotestis; sp, spermotheca; ps, penis sheath; ep, epiphallus; r, retractor; gl, accessory glands. c. Cephalic retractors of M. gagates. (After Taylor).

solid slaty gray, with brownish reflections. The color is darker above along the back and keel, the body being lighter and the sole whitish. In Europe the color is typically black. Here it varies from very dark slate to light gray, usually with a hint of brown or brownish green ground color. There is an absence of any flecking or blotches of color. The grooves or striae of the body are moderately deep, mostly longitudinal with few cross lines. (Plate IV.)

The following systematic description is taken from Taylor.

(6) Taylor, J. W. Monograph, Land and Freshwater Mollusca of the British Isles. 1907. Vol. 2, p. 139.

Milax gagates (7)

ANIMAL comparatively slender, aud usually 50 mill. or more in length when extended; typically of an almost uniform black above, but in this country more frequently of a drab, lavender, or plumbeous-grey; DORSAL-KEEL very prominent and sharp, especially at the caudal end, where it is abruptly angulated; it extends the whole length of the back, strongly indenting the hind margin of the shield when the animal is at rest, and is usually of the same or a darker colour than the body; the BODY is longitudinally and regularly sulcate, the intervening spaces being only slightly granulate; SHIELD or mantle ample, truncately rounded behind, finely wrinkled and bearing a bluntly lenticular or horseshoe-shaped unpigmeuted sulcus, which circumscribes a somewhat protuberant and slightly darker central area beneath which the vestigial shell is lodged; FOOT-SOLE pale, distinctly tripartite, the mid-area much broader than the side-areas, aud separated by a deep furrow; FRINGE same colour as side of sole, without lineoles, rather thick and rounded at the front, defined from the sides by a deep channel; TENTACLES moderately long and granulose; lower tentacles short. MUCUS thick, glutinous, aud colourless when in health, but wheu irritated or scalded tinged with pale yellow, aud slightly milky from the presence of innumerable minute granules of carbonate of lime.

SHELL more or less elongately oval in shape, glistening white in colour, and somewhat convexly rounded on the upper side; APEX or nucleus subterminal and almost median, encircled with strong and regular concentric lines of growth; under-side flat, or even somewhat convex owing to the presence of an almost flat calcareous plate, the shell thus often presenting a double appearauce when viewed laterally, simulating two shells placed one upon another.

Length, 4¼ mill.; breadth, 3 mill.

INTERNALLY, the NERVOUS MATTER is closely aggregated round the throat, the dark-gray and triangular cerebral ganglia being connected by a short, broad, dark-grey commissure; the buccal ganglia are whitish, a little more than their own diameter apart, and joined to the cerebral ganglia by dark-grey connectives; the SUPRA-PEDAL GLAND is free, and ouly half the length of the body in adults, and eveu less in immature individuals. The LIVER is chestnut-colored, the right lobe forming the posterior end of the viscereal mass, the left is directed forwards to the KIDNEY, which has a long tongue-shaped prolongation beyond the right margin of the organ.

The ALIMENTARY CANAL (Fig. 14a) shows a broad and brown OESOPHAGUS; an ample brown CROP with white SALIVARY GLANDS adherent to its walls; the intestinal coils are triodromous, but owing to the strong spiral twisting to which the whole of the viscera have been subjected they appear much more complex; the second intestinal tract extends beyond the termination of the stomach, and turns in the caudal lobe of the liver, the rectum passing to the anal opening at the right side of the body without loopiug the retractor.

The REPRODUCTIVE SYSTEM (Fig. 14b) opens externally about half-way between the right ommatophore and the respiratory orifice; the OVOTESTIS is oval and whitish, with large acini; the DUCT becomes ample and tortuous as it nears the albumen gland, where there is a well-defined VESICULA SEMINALIS; the ALBUMEN GLAND is pale ochreous, gelatinous and semi-transparent; the SPERM-DUCT is of an opaque milk-white colour and not well developed; the OVIDUCT is semi-transparent, with a tinge of blue; the FREE-OVIDUCT uarrow and cylindrical; the VAS DEFERENS short, entering the epiphallus terminally; the PENIS-SHEATH is small and insignificant, with longitudinal ribbing terminated distally by a large and well-marked bluish white EPIPHALLUS, which is annularly ribbed internally, the ribs being visible externally as opaque-white specks; the basal limits are denoted exteriorly by a distinct sphincter, and interiorly by two annular series of projecting papillae; the penis-sheath enters the bulbous and bulging ATRIUM at the side within the protuberant part of which, opposite the penial openiug, there is a smooth and ploughshare-shaped excitatory organ, or SARCOBELIUM; the PENIAL RETRACTOR, which is quite sleuder, arises from the convex side of the epiphallus, and is fixed to the oviduct; SPERMATHECA large and globose when fully distended, connected laterally to the oviduct by tissue and more firmly at the apex; its short, stout stem opens into the free-oviduct, at whose junction with the atrium are large foliated accessory glands with long ducts, resembling salivary glands in their whiteness and lobular form.

The CEPHALIC RETRACTOR (Fig. 14c) is somewhat variable in its development; it usually arises from the dorsum from a single root, and is often attached to, or beneath, the apex of the shell, travelling a short distance as a single band; occasionally the PHARYNGEAL and TENTACULAR portious may arise independently, each from its own base or root, but these are always closely contiguous; the pharyngeal muscle is invariably deeply cleft, and the retractor of the right tentacle does not separate the male and female organs, as in the typical Limaces.

MANDIBLE or jaw moderately arcuate, thick, and of a deepish horn colour, with very fine striae on the anterior surface; ends bluntly rounded; median beak or rostrum not prominent and very obtuse.

(7) Taylor, J. W. Mon. Land and Fr. Water Mollusca of the British Isles. 1907. Vol. II, p. 140.

The LINGUAL MEMBRANE is of the usual shape, and in a Christchurch specimen displays series of closely-set teeth, projecting forward in the centre and sloping backward towards the margins; the median series of teeth are slightly smaller than the neighboring laterals, and are distinctly tricuspid, with the mesocone strong and well developed; the laterals are also clearly tricuspid, the mesocone gradually increasing in strength and importance; the marginals are chiefly bicuspid, showing a strong mesocone and distinct ectocone, the endocone so well developed on the lateral teeth having become gradually lost, while the extreme marginals are simply aculeate.

The formula of a Christchurch specimen is

$$\frac{16}{2\text{-}1} \div \frac{24}{3} \div 1/3 \div \frac{24}{8} \div \frac{16}{2\text{-}1} \times 98 = 7938$$

The Egg is very similar to that of the gray garden slug. It is slightly oval, measuring about 2 mm. in length by 1 3/5 mm. in width. According to Taylor they are "agglutinated together by a colorless mucosity" but this character is almost if not quite lacking in our Oregon forms.

Eggs are deposited at all times of the year but more particularly in the autumn and spring when the weather is wet and not cold. They are placed in groups in pockets in the soil, under boards and trash or in split roots of carrots and similar plants. The egg clusters may contain from three or four up to thirty-five or forty eggs.

Our records indicate the time from copulation to oviposition to be twelve to twenty-two days. Usually the first deposition of eggs occurs in about twelve to fifteen days and is followed by other deposits at intervals of four or five days. The eggs hatch in from twenty-two to twenty-seven days with an average in our studies of twenty-four and eight-tenths days.

The young slugs when first hatched are almost colorless but otherwise similar to the adults except in size. The newly hatched slugs are 8 to 10 mm. long and 15 mm. wide when traveling. They are 3.5 mm. long and 2 mm. high when at rest. As they grow older their color gradually darkens until they finally assume the color of the adults.

THE RETICULATED SLUG

(*Prophysaon andersoni* Coop.)

HISTORY AND DISTRIBUTION

The reticulated slug is a native species indigenous to the Pacific Coast states. It was first described by Cooper in 1872. It is found in California, Oregon, Washington, and Idaho, and on the Vancouver and San Juan Islands.

This slug is found about city lots, especially about wood piles and under bits of bark and wood. It is not so serious a pest to gardens as the gray garden slug and the greenhouse slug but often attacks young plants and mature vegetables such as squash and pumpkins that lie on the ground. We have rarely if ever found this species in any locality except one in close proximity to moist or decaying wood.

SYNONOMY

The reticulated slug was first described under the name of *Arion andersoni* by Cooper. It has received many names subsequently, most notable of which is *Prophysaon hemphilli* by Bland and Binney in 1873. Cockerell placed the species in the genus *Prophysaon* and Pilsbry and

Vanatta do not "differ radically" from his findings on synonymy. Pilsbry and Vanatta give the synonymy as follows (8):

P. Andersoni (J. G. Cooper). Pl. X. figs. 18-22; Pl. XI. fig. 28, 29, Pl. XIII. figs. 59-62; Pl. XVI. figs. 92, 93.

Arion Andersonii J. G. Cooper, Proc. Acad. Nat. Sci., Phila., 1872, p. 148, pl. 3. f. F. 1-5.

Not "**Prophysaon Andersoni** J. G. Cooper" W. G. Binney. Third Supplement to Terr. Moll., V. p. 208, pl. iii, f. l. pl. vii, f. c. pl. i, f. 3 (dentition), pl. ix, f. 1. J (surface reticulation). Fourth Supplement, p. 179.

Prophysaon Andersoni J. G. Cooper, Proc. Amer. Philos. Soc. 1879. p. 288. Cockerell, Ann. Mag. N. H. (6) VI. p. 278; Nautilus XI. p. 77, 78 (includes P. Hemphilli). Raymond, Nautilus IV. p. 6.

Prophysaon Hemphilli Bland & Binn., Ann. Lyc. N. H. of N. Y. X. p. 295, pl. xiii, exclusive of fig. 5 (external view, shell, jaw, teeth, digestive system and genitalia). W. G. Binney, Terrestr. Moll., v. p. 238, f. 137, 138, 139, pl. v., f. i. (teeth) pl. xii, f. H. (genitalia), "specimens from Mendocino County", excluded. Man. Amer. Land Shells, p. 105, f. 68, 69, 70. Third Supplement to T. M. V. p. 208, pl. vii, f. D. Sinroth, Nova Acta Acad. Caes. Leop. Carol. Germ. Nat. Cur., LVI. 1891. p. 362. pl. 7, f, 5-8 (full account of anatomy), Taylor, The Ottawa Naturalist III, p 90.

Prophysaon pacificum Cockerell, Nautilus III, p. 111. (Feb. 1890) V. p. 31; XI. p. 77 (includes flavum) W. G. Binney, Third Supplement to T. M. V. p. 210, pl. vii, f. B. F. H.

Prophysaon flavum Cockerell, Nautilus III p. III. Ann Mag. N. H. (6) VI. p. 278, 279, as var. of pacifium. W. G. Binney, Third Suppl., p. 210, pl. vii, f. k.

Prophysaon Andersonii var. **pallidum** Ckll. Nautilus V. p. 31.

DESCRIPTION

The Adult. The reticulated slug is the largest of the species commonly found in our gardens. It often attains a length of over three inches, is blunt in front and rather long and tapering posteriorly. There is no keel. (Plate II, Fig. 1.) The foot is whitish and is not divided into three parts as in the other two common species of garden slugs. A distinct transverse crease or constriction occurs in the body about one-third to one-sixth the total length forward from the caudal end. The color is variable but is in general a deep bluish black above, shading to a lighter color and often tinted with green toward the sole. The respiratory orifice is forward of the middle of mantle and the genital orifice is just back of the right tentacle. The mantle has two rather broad dark bands running longitudinally. A yellow slime is given off under irritation. The body bears very characteristic reticulation showing as a diamond-shaped pattern in dark lines and cross lines. (Plate I.)

The following technical description is given by Pilsbry and Vanatta (9):

Length in alcohol 25-35 mm. Upper surface buff-gray or whitish flesh-colored with irregular blackish diamond venation and sometimes suffused with purplish-black, showing a pale dorsal line; the mantle yellowish, with two curved lateral black stripes, with or without scattered marbling; sole pale buff or dirty white; foot-margin pale; below and anterior to mantle whitish. Integument with rather coarse diamond venation, the areolae subdivided into minute polygonal granules.

Shell oval, with moderately consistent calcareous layer.

Genitalia: Epiphallus cylindric, straight or sometimes curved, with an abrupt basal constriction, kink and peduncle secured by a short muscle, as described above. Vas deferens very long, its length measured from end to the abrupt bend at the atrium being about 7 times the length of the epiphallus; thrown into a complicated snarl. Spermatheca globose or oval, on a rather slender duct. Vagina long. Free oviduct short. Ovotestis showing externally a compact mass of rounded follicles. Right eye retractor passing between branches of genitalia.

(8) Pilsbry and Vanatta. Proc. Acad. Nat. Sci. Philadelphia. 1898. Part II. p. 245-247.

(9) Proceedings of the Academy of National Science of Philadelphia. 1898. Part II, p. 246-247.

Measurements of several specimens are as follows: a. (Mus. no. 69,010, Oakland, Cal.), length of swollen epiphallus 9 mm.; length of extended vas deferens, from apex of the epiphallus to base of same 64 mm.; b. (same locality), epiphallus 5, v. d. 36 mm.; c. (Portland, Ore.) epiphallus 5.5, v. d. 37 mm.

Jaw accuate with about 15 well-defined ribs, denticulating the basal margin.

Radula with 44-1-44 teeth; rachidian tricuspid, laterals bicuspid, the ectocones quite small; marginals with moderately long, pointed mesocones and minute ectocones.

Alcoholic P. Andersoni varies in general tone from a smoky lead color to reddish with black marbling or suffusion; mantle light dirty buff, or yellow, variously marked. Very rarely the two curved black stripes on the mantle are wanting, and occasional specimens fail to show the pale dorsal line, which in others is very conspicuous.

The Egg. The eggs are white and slightly translucent. The average dimensions are 2.36 mm. in length, 2.05 mm. in width, and 1.88 mm. in height. There is a small nib on one end.

The eggs are placed in pockets just below the surface of the soil or in groups of 20 to 35 under pieces of wood or bark. In the laboratory some eggs were scattered over the surface of the soil. There is no agglutination tendency apparent.

LIFE HISTORY

Our results in life-history studies of this species are extremely meagre. It was only after many repeated attempts that we were able to secure eggs at all. Although several lots of eggs were kept under as nearly normal conditions as we could obtain, in no case did the eggs hatch. In view of the fact that these slugs, in field conditions, seldom become numerous, it is possible that the eggs are laid in rather small numbers or that a large percentage of the eggs are infertile.

CONCLUSIONS

The garden slugs are a serious pest to crops in Western Oregon. They are voracious and omnivorous feeders, reproduce often and in large numbers, adapt themselves to all conditions that arise, and maintain themselves against all odds. They have comparatively few natural enemies and are surprisingly resistant to poisons either internal or external. Control practices in common use against insects and other animal pests are of little avail against them.

The gray garden slug and the greenhouse slug are the most injurious and we may expect them to become more and more serious as our cities grow in population and truck growing and the culture of plants under glass increase.

In planning a campaign for the control of slugs it is advisable first to clean up all trash, crop remnants, and debris upon the premises. This will usually need to be supplemented with more direct methods to destroy the slugs remaining. Repellents, dusts, and in fact most of the materials commonly used and generally recommended in literature are at best of but temporary value under Western Oregon conditions. A combination of a repellent applied directly to the plants and an attractive poison bait scattered on the soil has given best results.

Bordeaux mixture 4-4-50 sprayed on the foliage of plants is distasteful to slugs and is eaten by them only under stress from lack of other food. The recently developed commercial dry Bordeaux may be dusted over the foliage. Liquid Bordeaux gives perhaps a little better control but the powdered form has the advantage that it sticks better on smooth, waxy foliage like that of cabbage. With dry Bordeaux it is not

necessary to purchase expensive equipment; it may be readily applied by shaking through a coarse sack or cheese-cloth bag. It would probably be economy to use a dust gun when comparatively large areas are to be treated. In conjunction with the Bordeaux application on the foliage as a repellent a poison bait should be used.

Calcium arsenate 1 part by weight to 16 parts of chopped lettuce is readily eaten and is highly toxic to slugs. In case lettuce is not available, cabbage, kale, clover, or other succulent leaves may be used. The bait should be scattered in small heaps at frequent intervals over the infested area.

Spraying or dusting plants with Bordeaux mixture combined with placing of a calcium arsenate and lettuce bait on the soil has been in our tests the most satisfactory means of controlling slugs. The treatment may need to be repeated once or twice at seven- to ten-day intervals until the slug injury has been reduced to a minimum.

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