BIOLOGY AND CONTROL OF THE BLACK VINE WEEVIL

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INTRODUCTION

The first record of injury to cultivated plants due to the depredations of the larvae and adults of Brachyrhinus sulcatus was made in Germany in 1834 (4, p. 201;) since that time the weevil has been recorded with increasing frequency as causing injury to economic plants not only in continental Europe, England, and Ireland, but also in the United States, Canada, and Australia. Riley (40), in 1871, recorded the first economic damage in North America. A rather extensive list of plants has now been reported as being attacked in the field and in greenhouses.

Life-history studies of B. sulcatus under field conditions have been made in Europe (15, 51), and also in a general way in the United States. Its life history in the greenhouse, however, has received no previous detailed study so far as available publications indicate, except a preliminary report in 1927 (44) and another in 1930 (45) by the present author.

Infestations in the nurseries and greenhouses near Philadelphia, Pa., offered an opportunity for a study of the species which was taken.
up as a project of the Pennsylvania Bureau of Plant Industry at its Willow Grove laboratory in collaboration with the Bureau of Entomology, of the United States Department of Agriculture. From October, 1925, until the spring of 1929 the life history of the species was followed both in the nursery and in the greenhouse, and methods of control in both were investigated. The morphology of the larva and adult has been worked out, but the data covering this phase of the investigation are reserved for a separate publication.

**ECONOMIC IMPORTANCE**

The black vine weevil was recognized as an economic pest of greenhouse plants in Germany as early as 1834 (4). In England Westwood (55) in 1837 described the injury to Sedums and other plants in greenhouses; in 1875 Bolton (3) first recorded injury to grapes; and in 1881 Ormerod (37, p. 361) found that this weevil injured strawberries and raspberries.

Although Harris (25, p. 49) recorded this insect under the name *Curculio apiculatus* as occurring in Massachusetts as early as 1835, Riley (40), in 1871, was the first to mention the species as being injurious in North America. In 1890 Hagen (24) described a rather severe infestation in greenhouse cyclamens, and since that time many notes on the occurrence of injury to various greenhouse and outdoor-grown plants, both in North America and in Europe, have been published.

In many private greenhouses and conservatories in Pennsylvania, in each of which from 200 to 300 plants, principally cyclamen, are grown, the writer has observed from 1 to 70 plants to have been destroyed by the larvae. In commercial greenhouses the losses are greater.

The relation between cultural practices and recurring annual infestations are brought out by the following examples: (1) A florist at Norristown, Pa., experienced his first loss of cyclamens in 1923, and the injury almost doubled each year until the fall of 1927, when about one-third of his crop of 3,000 plants was destroyed; a florist in Scranton, Pa., has lost 200 cyclamens each year since 1924 from an annual crop of 1,000 plants. At both places few food plants of *B. sulcatus* were present outdoors, but each year the soil from the injured cyclamens was dumped on the compost pile located near the greenhouses. Here the larvae developed to adults, the latter returning to the greenhouses to renew the infestations. (2) For about eight years a florist near Philadelphia experienced an annual loss of from 150 to 200 out of about 1,000 cyclamens. Adjoining his greenhouses is an old cemetery in which are growing yews and rhododendrons, and a number of weed host plants. Apparently the adults entered the greenhouse each summer to oviposit after having developed outside. (3) Another florist in the same vicinity has lost from 75 to 300 cyclamen plants annually for the last 15 years. Here selected plants from the main crops are retained for seed production, and young seedlings for the next crop are grown in the same house. In two different years larvae, the offspring of adults from seed plants, have killed a number of the young plants during the summer. This damage has not been counted in the above-mentioned losses of the crop in the fall.
Probably the greatest losses have occurred on the island of Oléron off the west coast of France (15). This infestation increased from an area involving a few grapevines in 1909 to cover 150 acres and involve injury to 300,000 vines in 1914. The adults caused the most concern because of their feeding upon the buds, foliage, and young fruit and their girdling of the shoots. More serious injury, though less evident, was that of the larvae in girdling the roots. Vines so attacked lost vitality and died within a few years. Feytaud (15) also mentioned other less serious infestations on grapes in Germany, Switzerland, Italy, and Belgium. Thiem (51, p. 390) described the destruction in Germany in 1920 of 4,000 young grafted grapevines which was caused by the larvae girdling the roots.

Britton (5, p. 230) recorded considerable losses of yews in Connecticut, and Weiss (54) mentioned damage to yew and rhododendron in a New Jersey nursery. In 1926 the writer observed damage amounting to about $500 to yews at the same nursery. In Pennsylvania the black vine weevil has been well distributed on host plants in nurseries. In only one nursery, however, located near Philadelphia, has serious damage been observed, and there the foliage of yew, rhododendron, azalea, and euonymus was rather badly eaten by the adults. Roots of yews were injured by the feeding of the larvae. Yews and azaleas have also been damaged in certain California nurseries.

Strawberries have been frequently mentioned as being seriously injured by Brachyrhinus sulcatus, but Treherne (52) indicates that, although probably present in almost every strawberry-growing district, it does no serious harm. He believes that at least some of the previous reports have referred to B. ovatus which often seriously injures strawberries. Experiments at Willow Grove, Pa., with various hosts tend to bear out this point. Adults of B. sulcatus, when given a choice, fed almost entirely on primroses (Primula spp.), cyclamens, or dock (Rumex spp.) and very little on strawberry, and when confined on strawberry deposited fewer eggs than others caged on more favored hosts. The larvae, also, avoided the strawberry roots when those of other named plants were available, but when they were forced to feed on strawberry roots, their development was retarded, their mortality increased, and their bodies took on a reddish tinge. There was less accumulation of fat in larvae reared on strawberry than in those reared on primroses, cyclamens, dock, or yew.

Infestations occurring in greenhouses are more regular in their appearance each year and in the amount of damage caused than those under outdoor conditions. In the nurseries under observation infestations decreased in years following seasons of heavy rains during July and August and increased following years when there was less rain during these months. The greatest losses, both in North America and in Europe, have been to crops growing in loose types of soil.

From the foregoing it is evident that B. sulcatus, while rather sporadic in its occurrence, has caused very severe damage in several countries. The injury caused by it, while important to individual nurserymen and florists, probably does not greatly affect the total crop of any of its hosts. It is generally considered that the damage done by this weevil to cyclamens under glass is exceeded only by that of the cyclamen mite (Tarsonemus pallidus Banks).
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DISTRIBUTION

Brachyrhinus sulcatus has been recorded from the following countries: Russia, Norway, Sweden, the Netherlands, Belgium, Germany, Austria, Switzerland, Italy (State of Tyrol and island of Sicily), France (including the island of Oléron, located northwest of Bordeaux on the west coast), England, Scotland, Ireland, Australia, Tasmania, and New Zealand. In the United States the insect has been recorded from the following States: Maine, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, Illinois, Missouri, California, Oregon, and Washington. Infestations have also been recorded from Newfoundland, Cape Breton Island, Nova Scotia, Quebec, Ontario, British Columbia, and Victoria Island.

Britton (5), among others, speaks of B. sulcatus as being of European origin. Frequent interceptions of this insect have been made in shipments of imported plants. Leconte and Horn (31, p. 60) stated that this was a European species which became distributed over the western continent naturally instead of by commerce. Schwarz (43) considered B. sulcatus as belonging to the circumpolar fauna and not as an imported species.

HOST PLANTS

The following list of host plants of Brachyrhinus sulcatus includes 52 previously reported in literature and 25 (indicated by a) found as new hosts in the present studies. The feeding of the adults was confirmed by the writer in these studies on the plants prefixed with b, and on those prefixed with c the larval feeding was confirmed. In general, Standardized Plant Names (1) and Gray’s Manual of Botany (23) were followed in the nomenclature, with revisions by the Bureau of Plant Industry, United States Department of Agriculture.

b, c. Adiantum cuneatum (delta maidenhair).
b, c. Adiantum tenerum (fan maidenhair).
Ampelopsis sp.
b. Amygdalus persica (peach).
b. Asparagus plumosus (fern asparagus).
b. Astilbe rosea (rose astilbe).
Atriplex hortensis (garden orach).
Azalea spp.*

b, c. Azalea amoena (amoena azalea).
a, b, c. Azalea hinodegiri (Hinodegiri azalea).
a, b, c. Azalea indica hybrids (indica azalea).
b, c. Begonia spp. (begonia).
Beta vulgaris (beet).
Beta vulgaris (mangel wurzel).

a, b, c. Callistemma chinensis (China-aster).
Camellia japonica (camellia). (Reported by D. C. Mote in correspondence).
Calla sp. (orchid).
Cheiranthus cheiri (wallflower).
Citrus limonia (lemon).
b, c. Convallaria majalis (lily-of-the-valley).
b, c. Cyclamen indicum, variety (C. gigantium) (cyclamen).
Dracaena sp.
a, b, c. Euonymus americanus (brook euonymus).
a, b, c. Euonymus bungeanus (winterberry euonymus).

* In many previous reports of host plants in literature only the common names were given. In the present studies the attempt has been made to identify them by species. Therefore the number previously reported can not be clearly distinguished from the species here given.
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a, b, c. *Fagelia*, hort. variety (*Calceolaria veitchii*) (Veitch calceolaria).
b, c. *Fragaria* spp. (strawberries).
a, b, c. *Fragaria* sp. (varieties Joe and Chesapeake).
b. *Grossularia* sp. (gooseberry).
b. *Howea belmoreana* (Belmore palm).
b. *Howea forsteriana* (Forster palm).
b. *Humulus lupulus* (hop).
b. *Hydrangea* spp.
a, b, c. *Hydrangea opuloides* (hydrangea).
a, b, c. *Impatiens* suiiani (snapweed).
b, c. *Isoloma bogotense* (isoloma).
b. *Kraunhia floribunda* (*Wisteria floribunda*) (wisteria).
a, b, c. *Leontodon officinale* (*Taxacrum officinale*) (dandelion).
b. *Lewisia* spp.
b. *Nephrolepis crassula bostoniensis* (Boston fern).
a, b, c. *Nephrolepis*, varieties Scott and Verona.
a, b, c. *Oxalis acetosella* (wood sorrel).
a, b, c. *Oxalis enneaphylla rosea* (rosy nine leaf oxalis).
b. *Oxycoccos macrocarpis* (cranberry).
b. *Phaseolus vulgaris* (bean).
b. *Phyllitis scolopendrium* (hartshorn).
a, b, c. *Plantago major* (ripseed plantain).
a, b, c. *Plantago lanceolata* (buckhorn plantain).
a, b, c. *Polystichum acrostichoides* (Christmas fern).
b. *Potentilla canadensis* (common cinquefoil).
b, c. *Primula obconica*, variety (rosy top primrose).
b. *Prunus* sp. (plum).
a, b, c. *Rheum rhamnoides* (rhubarb).
b, c. *Rhododendron catawbiense* (Catawba rhododendron).
b, c. *Rhododendron maximum* (rosebay rhododendron).
b. *Rubus allegheniensis* (blackberry).
b. *Rubus idaeus* (European raspberry).
b. *Rubus strigosus* (red raspberry).
b. *Rubus occidentalis* variety Cumberland (common blackcap).
a, b, c. *Rumex acetosella* (sheep sorrel).
a, b, c. *Rumex crispus* (curly dock).
a, b, c. *Rumex obtusifolius* (bitter dock).
b. *Saxifraga burseriana* and var. (saxifrages).
b, c. *Sedum acre* (gold moss).
b. *Senecio cruentus* hybrids (cineraria).
b. *Sinningia speciosa* (gloxinia).
b, c. *Taxus cuspidata* and varieties (yew).
b. *Thuja occidentalis ericoides* (heath retiniscora).
b. *Thuja orientalis pyramidalis* (arborvitae).
b. *Viburnum dentatum* (arrowwood).
b. *Viburnum prunifolium* (black haw).
b. *Vitis vinifera* varieties (European grape, varieties).
a, b, c. *Zantedeschia aethiopica* (calla).
b. *Zantedeschia eichelliana* (golden calla).

* In many previous reports of host plants in literature only the common names were given. In the present studies the attempt has been made to identify them by species. Therefore the number previously reported can not be clearly distinguished from the species here given.
This extensive host list of *B. sulcalus* suggests the possibility that many additional plants might be favorable hosts.

Fletcher (17, p. 242) among others has suggested that *Brachyrhinus sulcatus* was primarily a grass-feeding species. To test this possibility, larvae were put in pots of quackgrass (*Agropyron repens*), Kentucky bluegrass (*Poa pratensis*), and orchard grass (*Dactylis glomerata*). They fed to a slight extent upon the tips of the underground stems of quackgrass and Kentucky bluegrass, which were softer and more succulent than the root parts, and in a similar way on the tender shoots of orchard grass before these emerged from the soil. Buckhorn plantain (*Plantago lanceolata*) and yarrow (*Achillea millefolium*) were fed upon to some extent about the crown. On red clover (*Trifolium pratense*) the nodules and softer cortex on the roots and crown were eaten to a moderate extent. No feeding was observed on alsike clover (*T. hybridum*), yellow biennial sweetclover (*Melilotus officinalis*), or alfalfa (*Medicago sativa*).

From these tests it is concluded that since no larvae could be reared to maturity on any of these hosts, none of them are of importance as hosts of the black vine weevil. Such plants, however, as dandelion, rippleseed plantain, and sorrel and dock (*Rumex spp.*) generally grow in grasslands and could readily supply food for the weevils found in such situations.

Although palms and geraniums have been recorded as host plants, the tests made by the writer with the Belmore palm, Forster palm, geraniums, and pelargoniums seemed to indicate that they were not favored hosts. When forced by hunger the adults fed slightly on the foliage and, although the larvae fed slightly on the roots, all died within three or four weeks, and none was reared to maturity when they were placed in pots containing these plants.

**SYNONYMY**

Fabricius (11, p. 485), in 1792, described the weevil *Curculio sulcatus* as follows: “Brevirostris femoribus dentatis ater elytris striatus ferrugineo maculatis.” The type locality was given as Saxony. In 1804 Latreille (28, p. 157) erected the genus *Brachyrhinus* and placed *sulcatus* in it. In 1824 Germar (19) erected the genus *Otiorhynchus*, giving characters similar to those used by Latreille and placed many of the same species in it. It appears that Germar was unaware of Latreille’s work. Schoenherr (42, v. 2, pt. 1, p. 620), in his monograph of Curculionidae, listed previous literature but omitted the work of Latreille. Later, in 1843, Schoenherr (42, v. 7, pt. 1, p. 371) placed Latreille’s *Brachyrhinus* in synonymy under *Otiorhynchus* of Germar. Nearly all of the European publications appearing since that time have used the generic term *Otiorhynchus*, and most American authors did likewise until Leng (32, p. 314) corrected the error by placing *Otiorhynchus* as a synonym of *Brachyrhinus*.

In the present paper *Brachyrhinus* is used uniformly for each species mentioned, whether the author cited had used *Otiorhynchus* or *Brachyrhinus* as the generic name.
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HABITS AND DESCRIPTIONS OF STAGES

THE EGG

The egg, which is generally subspherical, ranges in length from 0.65 to 0.80 mm on the long axis and from 0.65 to 0.70 mm on the short axis. When first laid, the egg is a uniformly glistening, pearly white, and its smooth, unsculptured surface reflects light as a mirror. The shell is resilient and rather tough, and the side of the egg may be pressed in without rupturing it. When the egg is forced into a crevice by the ovipositing female it becomes flattened or wedge shaped, but this does not interfere with the hatching.

In from 1 to 3 days, depending upon the temperature, the egg changes during a period of about 12 hours through a grayish yellow to a chestnut brown, the color being uniform throughout, and the egg and shell becoming more rigid. In from 8 to 10 days about one-fourth of the egg becomes still darker, and in this area the head of the larva develops. The mandibles, and then the head sclerites and labrum, take form and color and may be distinguished about 3 days before hatching.

In the process of hatching the mandibles open and close rhythmically and the shell is cut or torn about one-third of the way around the side. The mandibles, followed by the remainder of the head, are forced through the opening, and the body is then drawn out of the shell. After the emergence of the larva the shell collapses somewhat, appears chitinous, and is dark brown.

The darkening of the egg shortly after it is laid is probably due to color changes in the shell rather than in the interior. A few eggs from nearly every observed lot failed to darken, but became grayish and decomposed after from 15 to 20 days. The percentage of eggs failing to develop was much larger at lower temperatures. In the nursery 92 per cent of the eggs observed during July and August hatched. Figure 1 indicates the variations in the length of the incubation period, which ranged from 11 to 22 days, in the greenhouse and nursery during different seasons of the year.

THE LARVA

The width of the head capsule of the various larval instars is indicated in Table 1. The head of the newly hatched larva is chestnut brown, and the rather prominent mandibles are darker brown. The body is pinkish white and sufficiently transparent to show the stomach through the wall. The body is covered with small hairs, as is that of the mature larva.
## Table 1. — Measurements in each instar of width of head capsules of reared larvae of *Brachyrhinus sulcatus*, Willow Grove, Pa., 1928

<table>
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<tr>
<th>Instar</th>
<th>Group A, 9 larvae with 7 instars</th>
<th>Group B, 19 larvae with 6 instars</th>
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<tbody>
<tr>
<td></td>
<td>Mode</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td>Mm</td>
<td>Mm</td>
</tr>
<tr>
<td>First</td>
<td>0.318</td>
<td>0.318</td>
</tr>
<tr>
<td>Second</td>
<td>.403</td>
<td>.446</td>
</tr>
<tr>
<td>Third</td>
<td>.561</td>
<td>.616</td>
</tr>
<tr>
<td>Fourth</td>
<td>(1)</td>
<td>.805</td>
</tr>
<tr>
<td>Fifth</td>
<td>(1)</td>
<td>1.06</td>
</tr>
<tr>
<td>Sixth</td>
<td>1.27</td>
<td>1.27</td>
</tr>
<tr>
<td>Seventh</td>
<td>1.48</td>
<td>1.44</td>
</tr>
</tbody>
</table>

1 The mode is given only when more than half of the larvae in the group have the same width of head capsule.

The young larva crawls about actively. Its body is not curved. It attempts to enter the soil at once, but if the surface is hard or packed it will fail in this, and in such a case death occurs in a few hours. Even firmly pressed sand seems to be penetrated with difficulty, and clay or loam unless covered with mulch or in a loose, well-cultivated condition, seems to be almost impenetrable. The hardness of the soil seems to be a controlling factor in the degree of infestation, the more severe infestations occurring in the lighter types of soil. This bears out the observations of Downes (10) on injury by *Brachyrhinus ovatus* to strawberries in British Columbia. Injury by *B. sulcatus* to yews in Connecticut (as described by W. E. Britton in correspondence with the author) and to grape in France (15) seem related also to the type of soil. In potted plants entrance into the soil is generally made either at the edge of the pot or between the roots at the base of the plant.

Thiem (51) stated that the larvae can subsist on manure or on decaying vegetable matter and probably are transported in this material. Feytaud (15) believed that for the first few weeks the larvae developed on organic matter in the upper soil layers until the grape roots were reached farther down. In the various tests the writer found that few larvae were able to develop to the second instar in potting soil devoid of all living plant roots but containing leaf mold and well-rotted cow manure. In two tests only 3 larvae out of 100 reached the second instar; these then died. When rootlets of food plants were present, however, the larvae attacked these, and as many as 80 per cent of the larvae matured.

In several tests in the laboratory dried stems which had become moistened by contact with the soil, or green foliage and stems of host plants, have served as food for larvae in all instars.

As the larva increases in size in each instar the body becomes curved by the thickening of the thoracic segments, and the head appears small in proportion to the remainder of the body. When ready to molt, the larva stops feeding and forms a cell, preferably in a piece of heavier clay or hard piece of dung, which may be present in the soil. The interior of the cell is smooth-walled, and apparently the larva uses the contents of the alimentary tract to make it so. Evidence of this trait is further indicated by the fact that larvae handled at cell-forming time will eject watery fecal matter, and this has not been observed with larvae at other stages of growth.
After a quiescent period of from one to three days or longer in the cell the head capsule and thoracic segments split along the median dorsal line. The head of the larva is then pushed through the opening, and the old skin is gradually worked off backward by frequent alternating waves of expansion and contraction of the body progressing forward from the posterior end. The old skin is afterward found in a much-wrinkled condition at the bottom of the cell. It was observed that the entire process of molting required 55 minutes in one individual at the fifth molt and about two and one-half hours in another larva at the third molt. At first the head of the freshly molted larva is milky white, only the tips of the mandibles being dark brown. From one to three days are spent in the cell after molting, and the head capsule becomes brownish and quite firm. The larva then breaks out of the cell and returns to the roots of the food plant. The periods of molting, especially the first three, seem to be the most critical stages in the life of the growing larva. Many die in the resting stage before molting; others die while emerging from the old skin.

Until the third molt the larva confines its feeding to the small rootlets (fig. 2), but with the beginning of the fourth instar the larva begins to attack the larger roots. On such plants as cyclamen or primrose the soft fleshy roots are cut off within a short distance of the crown or corm and may or may not be devoured. If a large number of larvae are present, the stumps of the roots are then eaten and the corm or crown gouged or hollowed out. (Figs. 3, 4, and 5.) The feeding during the last two instars is rapid, and the infested plant may exhibit no injury until the sudden wilting due to the cutting of the roots occurs. The young larva feeds on the young rootlets of woody plants such as yew (5) or grape (15), but in later instars it feeds on the cortex of the larger roots. The root may be entirely stripped of its bark for several inches, girdled at one or more points, or only gouged out on one side.
Root cutting and gouging out the corm of certain plants furnish an abundance of material for building up the body preparatory to pupation. Larvae which had not eaten off the plant roots were not reared to the adult stage so successfully as were those (in other pots) which had eaten off the roots. This habit evidently serves also as a protection to the larva in the cell, for examination showed that many cells of the former had been penetrated by the roots and the larvae had died in each instance.

Wilson (56) describes the tunnelling or boring habits of certain specimens of *B. rugifrons* Gyll. into the stems and leaf petioles of Saxifrages. The writer has frequently observed that *B. sulcatus* larvae tunnel out the crown and the bases of the larger petioles of primroses aboveground. Larvae attacking roots of dock usually feed on the cortex outside the woody cylinder, but sometimes they tunnel along the pithy area in the center of the root. In two observed cases, heavily infested cyclamen plants with large corms became honeycombed with larval tunnels. Larvae in less heavily infested pots ate off only part of the roots before finishing their growth. The burrowing habit of *sulcatus* larvae does not seem to be an inherited or racial characteristic with this species as suggested for *rugifrons* by Wilson, but rather it is followed where food is deficient.

Feytaud (15) states that a part of the larvae complete their feeding in vineyards in the fall and that they form cells from 15 to 40 centimeters below the surface and there spend the winter. In the spring these larvae break out of their cells and come nearer the surface, where they form the pupal cells. During the fall of 1927 the author placed about 100 larvae in the prepupal stage in artificial cells (½ by 2 inch glass cylinders) and buried these at depths ranging from 6 to 24 inches. In the following spring, at the normal time for pupation, the cylinders were examined, and the insects had pupated in the overwintering cells without first approaching the surface. From these observations the writer is inclined to believe that Feytaud mistook the larvae in the fifth or sixth instar in their overwintering cells for larvae in prepupal cells. In Pennsylvania the immature larvae were observed to form overwintering cells at varying depths down to 18 inches but usually from 6 to 8 inches below the surface. These had voided the gut contents and appeared quite like the prepupae in all respects except for
size. Mature larvae in prepupal cells were found at no greater depths than 4 or 5 inches. Apparently the larvae rarely if ever leave the prepupal cells to form new ones unless disturbed, as by plowing.

In the nursery, the infested plants do not occur in a definite area but are scattered at random. At Rutherford, N. J., in 1926, about 25 yew plants were severely injured, and with two exceptions each of these plants was located between unaffected plants. Diggings revealed from 18 to 24 larvae about the base of each injured plant and from none to 4 about thrifty ones. The root systems of these heavily infested plants were considerably nearer the surface than were those of the uninjured ones. In Pennsylvania, the weevil was more abundant in well-fed and mulched blocks of yew than in those receiving little care. In the latter case the roots were deeper in the soil which was devoid of surface organic matter.

Figure 4.—Cyclamens and primroses (Primula malacoides). The roots of the center plants have been destroyed by larvae of *Bruchythus salicata*. The outside plants are uninjured. Willow Grove, Pa., 1927.

whereas in the former the roots approached the surface and were more easily reached by the young larvae through the loose surface material.

The mature larva is slightly pinkish white, the food material in the alimentary tract adding other color. If the larva feeds on species of *Rumex* (sorrel or curly dock), the body has a decided yellowish tinge; if on strawberry, it has a reddish tinge. With the formation of the pupal cell the gut contents are completely voided, and the body is then milky white. It seems certain that the material in the intestine is utilized in moistening the soil and in developing the smooth and hardened walls of the cell. The larva lies in a half coiled position supported by its dorsum against one side of the chamber and the tip of the abdomen against the other, about half way between the upper and lower ends of the cell. The prepupal stage has been observed to be as short as three weeks or as long as eight and one-half months, depending upon the soil temperature.

**The Pupal Cell**

The cells (fig. 6) for pupation are formed rather near the surface, usually within 1 or 2 inches, but with extremes of one-half and 6 inches. Unless the soil is rather sandy and crumbly, the cell wall becomes quite firm and is one-sixteenth to one-eighth inch thick. The fine soil particles apparently intermixed with the gut contents of the
larva form a puddled layer which grades off into the surrounding soil with no definite line of demarkation. The cell wall is not entirely impervious to water. The cell is considerably larger in both length and breadth than its occupant at any stage of development. The pupa is usually located toward the upper end of the chamber. Table 2 gives the size of several pupal cells, their depth in the soil, and the size of the emerging adults.

### Table 2.—Summary of measurements of the pupal cells of Brachyrhinus sulcatus, their depth in the soil, and the length of the emerged adult, Willow Grove, Pa., 1927

<table>
<thead>
<tr>
<th>No.</th>
<th>Depth of cell in soil</th>
<th>Inside measurements of cell</th>
<th>Length of emerged adult</th>
<th>No.</th>
<th>Depth of cell in soil</th>
<th>Inside measurements of cell</th>
<th>Length of emerged adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inches</td>
<td>Mm</td>
<td>Mm</td>
<td></td>
<td>Inches</td>
<td>Mm</td>
<td>Mm</td>
</tr>
<tr>
<td>1</td>
<td>1 1/4</td>
<td>6</td>
<td>13</td>
<td>5</td>
<td>2 1/4</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>1 3/8</td>
<td>7</td>
<td>14</td>
<td>6</td>
<td>3/8</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>3/4</td>
<td>7</td>
<td>14.5</td>
<td>7</td>
<td>5/8</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>7</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**THE PREPUPA**

After the formation of the cell at the conclusion of the larval feeding period, the milky-white larva with a glistening chestnut-brown head capsule remains quiescent until pupation. At the beginning of this stage the larva will almost always form a new cell if the original one is broken. As development progresses and the time for pupation approaches, the larva becomes less active and may then be readily placed in an artificial cell for observation.

The body gradually changes to a muddy-yellow color, and the head becomes a weathered brown. Then the thoracic segments enlarge slightly on the dorsal side, and the prothorax and head of the pupa take form there. The larval skin splits along the median line of the thorax and of the head capsule and is worked off posteriorly. The shedding of the larval skin after it splits required 40 minutes in one case and from 60 to 80 minutes in three other observed instances.

**THE PUPA**

At first the pupa is entirely milky white with rather conspicuous dusky spines definitely arranged on the head, femora, and abdomen. The head is bent beneath the body and lies on the breast.

The mandibles are provided with curved hooks which give the mouth parts an overbalanced appearance. The spines seem to be used as hooks in maintaining the position in the upper part of the cell. The pupa can...
move by the bending of the abdomen in any direction. In this manner
the pupa is able to turn its body around in the cell when exposed to
light or when the cell is broken.

In an individual which spends the maximum time in the pupal stage,
the eyes turn brown and then black in the course of the first 8 or 10
days. By this time the striae in the wing pads become evident. About five days before the change to adult the mandibles become a
rusty brown; and during the next two days they become black, and the
rusty color extends to the eyes on the snout. At this time the
antennae, tarsi, and femoral tips also become a rusty brown, which
depens just previous to the shedding of the pupal skin. The legs
darken at the joints, the snout becomes black to the eyes, the
prothorax faintly rusty, the occiput, elytral pads, and abdomen
eramy white. With a shorter pupal period all of these changes are

correspondingly accelerated. In the change to adult the thin-walled
pupal skin splits along the median dorsal line on the prothorax and
occiput and is worked off posteriorly. The whole procedure in one
individual has not been accurately timed, but in several cases it
required less than two hours.

The length of the pupal period of 77 *Brachyrhinus sulcatus* in the
greenhouse at Willow Grove, Pa., from January to March, 1928,
when the soil temperature ranged from 57° to 68° F., during the
observations was as follows:

<table>
<thead>
<tr>
<th>Number of individuals:</th>
<th>Length of stage (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of individuals—Con.</th>
<th>Length of stage (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
</tr>
</tbody>
</table>

Average 17.91
Blatchley and Leng (2, p. 111) describe the adult (fig. 7) of *Brachyrhinus sulcatus* as follows:

Oblong, brownish-black, subopaque. Thorax subcylindrical, not longer than wide, its surface densely covered with rounded tubercles, each bearing a short hair. Elytra oblong-oval, striae coarsely punctured and with remote patches of yellowish hair; intervals feebly convex, each with a row of shining rounded tubercles. Femora strongly club-shaped, deeply sinuate near tip. Length 8.5 mm.

The adults mentioned by these writers are smaller than are most of the present writer’s specimens. A few adults, such as those reared from larvae pupating in the fifth instar, were only 8.5 mm in length, but most living adults measured from 10.5 to 11.5 mm. When recently emerged, the adult is glistening black with irregularly placed tufts of yellowish hairs on the elytra which gives the body a dull appearance. The elytra have no articulation at the base, but the whole is thickened chitin. The two are usually said to be fused along the median line, but in dissection they readily separate after being cut off at the base. The hind wings are reduced to small pads which lie on either side beneath the elytra. The eyes are black, and the head is smoother than the thorax and has a thin covering of short pubescence. The antennae are shining black and slightly pubescent, which gives them a brownish tinge. The legs are black, with the tibiae and tarsi thickly covered with a brown pubescence. The exoskeleton is pliable and easily broken at this time.

The body of the newly transformed adult is milky white, except for the snout and eyes, which are black, the antennae, coxae, femoral tips, tibiae, and tarsi, which are rusty brown; and the prothorax, which is faintly rusty. Within an hour after transformation the elytra expand to cover the abdomen and meet along the median line. On the following day the general body color becomes a dark chestnut brown with the abdomen yellowish brown ventrally. Three days after transformation the body is a glistening black except for the brownish antennae and tarsi. By the fourth or fifth day after transformation the patches of yellowish hair on the elytra become evident, and the adult is apparently ready to emerge.

The adult is seemingly very weak after transformation, but gradually gains strength and, in a few days, responds more quickly when disturbed. In most cases the adult breaks out of the cell and digs its way to near the surface by means of its deciduous mandibular ap-
pendages. The earth is torn into fine particles by means of these appendages, worked past the body, and lodged in the cell cavity as the adult moves into the excavation. With but few exceptions in many observed cases, the adult, during the night in which the cell is broken, continues its digging toward the surface until only a thin crust remains. On the following night, usually in the early evening, the adult completes the act of emergence and goes into hiding without feeding. This differs from the habit of *B. ovatus*, which emerges soon after transformation (32), and then remains in hiding without feeding for several days until the body darkens and hardens.

The period from transformation to emergence of 141 adults of *Brachyrhinus sulcatus* in the greenhouse at Willow Grove, January to April, 1928, when the soil temperature varied from 59° to 70° F. during the observations was as follows:

<table>
<thead>
<tr>
<th>Number of individuals:</th>
<th>Number of days in stage</th>
<th>Number of individuals—Con.</th>
<th>Number of days in stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>28</td>
<td>7</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>51</td>
<td>8</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>19</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>8.06</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After the adults have been hiding beneath elods of earth in the fields the striae often become filled with soil, and the whole elytral surface becomes coated with mud. Adults which seclude themselves among leaves or trash or under bark become dull gray as a result of dust accumulation. Sometimes they acquire a thin incrustation of greenish algae. The original shining black also weathers and fades as the adult ages, and the exoskeleton becomes greatly thickened and very hard.

Feeding by *B. sulcatus* begins on the night after emergence. On thick cyclamen leaves small rounded notches are bitten from the edge, whereas on thin cyclamen and primrose leaves, or on flower petals, the areas eaten are sickle shaped and much larger. (Figs. 8 and 9.)

The adult prefers cyclamen flowers to the leaves, but this preference is less evident with primrose. The pinnae of ferns are notched, bitten off, and either allowed to fall to the ground or eaten entirely. Rhubarb, dock, sorrel, plantain, and other plants are badly notched or eaten out between the veins. Yew needles are bitten off at the tip, notched along one side, or eaten completely. The foliage toward the interior is more severely attacked than that on the terminal growth. (Figs. 10 and 11.)

Many new growths are girdled late in the season by the removal of a narrow ring of bark at the base. These twigs die during the following winter, and often the plant is then mistakenly said to be "winterkilled." As many as 30 per cent of the twigs on some plants

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1 The procedure by which the adult broke the cell and dug toward the soil surface by aid of the mandibular pieces was readily observed through the glass sides of the artificial cells in which the prepupa had been placed for observation of their development. These deciduous mandibular pieces were usually lost between the completion of their approach to the surface and the breaking through of the crust. Some individuals retained one or both appendages for a few days after emergence. One individual emerging naturally and several others removed from their cells before starting to emerge retained these pieces for over two months. Apparently these adults fed without inconvenience. In all observed cases each deciduous appendage was shed in one piece. Several apparently normal adults died after breaking their cells. These individuals were found to have lost these pieces, which less probably accounted for their failure to reach the surface.
have been found girdled in this manner. Leaf petioles and flower stems of such plants as cyclamen, primrose, or strawberry are notched, often so deeply that the stem breaks at the point of injury. (Fig. 10.) Feytaud (15) described the girdling of the new growths year after year on grape, and the throwing out of new branches below the point of injury. An injured plant develops a witch's-broom effect. The buds and foliage are also devoured, and the young grapes are cut from the stems.

The female feeds most extensively during the preoviposition period, less during the egg-laying period, and still less during the period between the close of oviposition and the beginning of hibernation.

It is generally reported that the adult hides during the day beneath pieces of earth, stones, sticks, dried grass, or leaves in the vineyard or strawberry field (15, 51, 54). The writer has observed the adults behaving in this manner in the nursery when the yew and rhododendron plants were small, but where larger plants were infested the beetles were found on the trunks beneath the loose bark or among accumulations of needles lodged in the forks of the branches (44). This was especially noticeable in 1926 at Chestnut Hill, Pa., where in one day 127 beetles were collected from beneath the loose bark and from lodged needles on seven yew trees while none were found among the trash on the ground. This season was very rainy, and observations made at night, together with the ineffectiveness of baits spread to attract the insects to the ground, indicated that the beetles did not move from tree to tree or come down to the ground to any extent. The adult avoids moisture and will not hide in wet trash on the ground. If the small wad of fibrous orchid peat supplied to caged individuals as a hiding place became wetted during watering the beetles avoided their haunt and spent the day in the top of the cage. The arboreal habit of the adults in the nursery may be due, in part, to the moist condition of the trash on the ground.
The adults were abundant in 1926, but the rainy period was accompanied by a high mortality of the weevil before oviposition began. On July 26, 1926, in a block of small yew 284 dead adults and only 56 live ones were collected about the plants. This point may be one factor in the reduction of the infestation in 1927 following a period of abundant rainfall preceding and during the oviposition period, for the insects were scarce in 1927. As there was little rainy weather during July and August of that year they were more numerous in 1928, when again there was little rainfall in the same period. The larvae were rather numerous in the fall of 1928, and adults were correspondingly abundant in 1929.

To compare the oviposition rate in dry and rainy weather, two lots of adults were collected from the field and each lot divided into two equal parts and caged on primroses. For 10 consecutive evenings, cage 1 of each group was sprinkled so that the foliage remained moist during the night while the other cages were kept dry. The 17 individuals in the two wetted cages laid a total of 120 eggs during the 10 nights while the same number of adults in the dry cages laid a total of 715 eggs. The amount of feeding was also reduced in the wetted cages.

Chips, sphagnum, straw, or excelsior laid about on the ground have been recommended by Thiem (51), Weiss (54), and others for catching the adults which hide in the material. Such traps have proved to be of little value in the greenhouses when tested by several florists. As cyclamens, the usual host plant in Pennsylvania, are sprinkled several times daily during the summer to keep down the temperature and the rate of evaporation the trap materials become wetted and are unattractive to the adult in search of a hiding place. The usual hiding place in the greenhouse is on the side of the pot just below the projecting edge of its thickened rim, or among the leaf petioles on a many-leaved plant. The adult's preference for the better protection supplied by the more numerous stems, where more of the eggs are likely to be laid, may explain the usually greater damage by the larvae to the best plants in a lot.

Figure 9.—Normal cyclamen bloom (left) and a bloom showing feeding by Brachyrhinus saltatus. Willow Grove, Pa., 1927
Downes (10, p. 8) described the migratory habit of the wingless weevils of *Brachyrhinus ovatus* at the period just before egg laying begins and again at the close of this period as the adults are in search of hibernating quarters. Downes, working with *ovatus* and Feytaud (15) and Thiém (51) with *sulcatus* observed the gradual spreading of the weevils from a common center or from adjacent fields. The present writer has not had the opportunity to observe the migration of *sulcatus* in the nursery, but the weevils seem to drift into the greenhouses throughout the egg-laying season, as indicated by nightly collections made by florists.

About the close of the oviposition period the weevils apparently leave the greenhouse to hibernate out of doors, this being indicated by a cessation of feeding. During four years' study no feeding on foliage or flowers has been observed in commercial greenhouses between the middle of September and the emergence of the next generation of adults in midwinter.

When adults are being handled a drop of dark-green liquid, probably regurgitated food, often appears on the mouth parts. The fecal matter is dry for the most part and falls to the ground, but sometimes it is soft, adheres to the foliage, and there serves as a medium for fungous growth.

**OVIPOSITION**

Puls (38), who observed adult *B. sulcatus* on grapes in greenhouses in Belgium, described the act of oviposition. He stated that the female, resting on a vine branch, simply dropped the eggs singly; and as no glutinous material covered the outside, they came to rest on the ground. Feytaud (15) agreed with Puls and also noted eggs in soil interstices.

In the nursery the writer has found the eggs on the ground, in trash or among soil particles, lodged beneath loose bark, or between needles of yew plants as high as 3 feet from the ground. In the greenhouse they were found on the soil surface and on the leaves and stems of such hairy plants as primrose; also in hollows or clefts in stems and corms, or inserted about 1 mm into soil crevices. In the latter situation the eggs are often so flattened or wedge shaped that it seems that they were forced into these places.

The writer has observed the act of oviposition by caged females at night. Without any preliminary actions, the anal segment is lowered and the ovipositor is extended about 1½ mm. The egg is then forced down the egg tube and dropped. Adults have been seen...
dropping eggs while resting on the side of the cage, on the foliage, and on the ground. The ovipositor was never seen inserted in a soil crevice or other cleft, but it seems that this is probably what takes place when eggs are found in such situations.

LONGEVITY OF ADULTS UNDER VARIOUS ABNORMAL CONDITIONS

Forty adults collected in the nursery July 29, 1926, were confined in salve boxes without food or water. Twenty-one lived for 10 days; 11 for 11 days; and 8 for 12 days. The weevils appeared normal the day preceding death. Weevils collected on September 24, 1926, lived 8 days in salve boxes without food or water. In March, 1928, a number of adults (Table 3) were confined as soon as they emerged, (1) in watch glasses without food or water, (2) in cages on bare soil but watered daily, and (3) in cages on soil with dried cyclamen leaves as food and watered daily. In lot 3, the adults fed freely on the dried cyclamen leaves. This would indicate that the adults may subsist on areas devoid of green crops until they can migrate to adjacent areas where food plants are being grown. The adults in this test laid no eggs, and examination at death showed the reproductive organs to be undeveloped and the viscera emaciated. From Table 3 it will be seen that the weevils in lot 2 lived the longest on an average.
Table 3.—Longevity of adults of Brachyrhinus sulcatus confined under abnormal conditions in greenhouse at Willow Grove, Pa., 1928

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Condition under which kept</th>
<th>Adults present</th>
<th>Number of adults dying at age of—</th>
<th>Average age of death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 days</td>
<td>11 days</td>
</tr>
<tr>
<td>1</td>
<td>Without food or moisture</td>
<td>18</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>On moist soil</td>
<td>22</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Dried leaves and water supplied</td>
<td>22</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

PARTHENOGENESIS

The first record of parthenogenetic reproduction in the genus Brachyrhinus was made by Ssilantjew (46), in 1905, in his studies with the species turca Boheman. He dissected over 1,000 adults during the season without finding a male and also gathered over 100,000 adults in the field without observing a single pair in copula. He also found that all of 30 adults, isolated before emergence, laid fertile eggs from which larvae developed and matured normally. He contrasted the lack of copulation of turca in the field with the frequent pairing observed between the two sexes of B. asphaltinus Herm., an associated species on the grape. B. ligustici Fab. (53), B. cribricollis Gyll. (22), B. oculus L. (9, p. 86), and B. rugifrons Gyll. (56) were proved, by methods of isolation similar to Ssilantjew's, to reproduce parthenogenetically. The writers reporting on these species found no males in their studies.

Feytaud (14), during three years’ study of B. sulcatus, examined thousands of individuals externally and dissected over 3,000 without finding a male. He collected 100 adults soon after they had emerged, half of which, when dissected, showed no spermatozoa in the seminal receptacles. The other half of the collection was reared through the summer and produced fertile eggs, and later dissection showed that all were females. Feytaud failed to isolate individual pupae or recently transformed adults before emergence, as had been done with the other species, but stated that if any copulation had taken place in the 4 to 5 day interval between emergence and collection of these adults, spermatozoa would have been evident in the receptacles of the first lot.

During the writer's studies on B. sulcatus six generations of isolated adults have been found to reproduce parthenogenetically. In all cases the individuals were isolated in the prepupal stage, and the adults were kept in individual, double-walled, screen cages until found to produce fertile eggs. In two generations larvae were isolated at the time of hatching and kept from others throughout their immature and adult life. Between 1,100 and 1,200 individuals taken in the field or in the greenhouse, or reared from either situation, have been dissected and found to be females. This work reinforces the observations of Feytaud and agrees with the studies made by other workers on the reproduction of five other species of Brachyrhinus. A seventh species, B. asphaltinus (46), has been shown to reproduce sexually and to possess males. Various workers state that their particular species is "irregularly parthenogenetic" (14, 22) and that males may occur sporadically in certain generations. Stierlin (47, p. 226) described the elytra of the male sulcatus as narrower than those of
the female, with the underside of the insect absolutely impressed, and the anal segment subfoveolate. Reitter (39) suggested that *linearis* Stierlin is the male of *sulcatus* and is distinguished from the female by the longitudinal strigae on the second to fourth sternites and by the feeble impression on the anal sternite. Since *linearis* has been found only in Italy, where it is abundant, and Reitter admits having seen his “male *sulcatus*” from no other place whereas the female is widespread, L. L. Buchanan, of the Bureau of Entomology, considers this sufficient grounds to doubt the suggestion of Reitter. In the writer’s life-history studies smaller and more slender adults have been reared from larvae which entered the prepupal stage an instar earlier than normal as a result of a lack of food or of unfavorable food. These adults answered Stierlin’s description of the male of *sulcatus*, but the dissection or rearing of these proved them to be females.

**SEASONAL-HISTORY STUDIES**

Since *Brachyrhinus sulcatus* is a pest on both greenhouse and outdoor-grown plants, it was to be expected that its seasonal life history would be quite different in the two situations. A 3-year study of the life history under each condition was made, and the relationship between the greenhouse and outside infestations was established.

Adults were confined, either singly or in groups of three to nine individuals, in cylindrical screen cages 9 inches high and 4 inches in diameter placed over host plants growing in 4-inch pots. The eggs, as laid, were placed on soil in short tubes with plaster of Paris bottoms. These tubes were corked at hatching time. The larvae on emerging were transferred to the desired food plants, usually from 10 to 15 to a plant in a 4-inch pot. Isolated larvae were reared in 1-ounce salve boxes containing well-decomposed leaf mold and supplied daily, while young, with fine rootlets and later with larger roots and plant crowns. Table 4 gives data on the length and number of instars of two groups of isolated larvae in the greenhouse.

**Table 4.—Summary of length of instars of isolated larvae of *Brachyrhinus sulcatus* reared in the greenhouse, Willow Grove, Pa., 1928**

<table>
<thead>
<tr>
<th>Instar</th>
<th>Group A, 9 larvae with 7 instars</th>
<th>Group B, 10 larvae with 6 instars</th>
<th>Summary of both groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Days</td>
<td>Maximum Days</td>
<td>Minimum Days</td>
</tr>
<tr>
<td>Second</td>
<td>14.54</td>
<td>13.52</td>
<td>14.0</td>
</tr>
<tr>
<td>Third</td>
<td>15.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Fourth</td>
<td>15.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Fifth</td>
<td>15.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Sixth</td>
<td>15.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Seventh</td>
<td>15.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Total length of individual development</td>
<td>98.6</td>
<td>113</td>
<td>92</td>
</tr>
</tbody>
</table>

The larvae in the soil of potted plants were readily transferred to new hosts. The time of completion of feeding and of the formation of prepupal cells was therefore easily determined. Until the time for pupation approaches, the larva is easily disturbed and forms a new cell if the original one is opened. To observe pupation, transformation to adult, and emergence of adult, artificial cells were made by
pushing a cylindrical stick, of a diameter equal to a normal pupal cell, down one side of a soil-filled glass cylinder one-half inch in diameter and 2 inches in length. The larva in late prepupal stage was then taken from its natural cell in the soil, lowered into the artificial cell, and the hole closed above the larva. The cylinder was then placed in the soil, the top even with the surface. Each numbered larva was then observable through the glass by drawing the cylinder from the soil, the cylinder being replaced after each observation. These larvae developed normally as compared with those which formed their own cells against a glass plate placed in the soil. When the adult was about to emerge, a glass shell vial was inverted over the cylinder, and in this way isolated virgins were obtained.

The life-history studies of the adult outdoors were conducted in an insectary, and studies of the larvae and pupae were made in open beds. The greenhouse bench furnished normal conditions for indoor studies.

**SEASONAL HISTORY OUT OF DOORS**

*Brachyrhinus sulcatus* may pass the winter in the larval, prepupal, or adult stage. During five winters' observation in Pennsylvania, from 1924 to 1929, adults were found to pass the winter only in 1924–25 and 1926–27, and then only in small numbers. Of 700 adults placed in hibernation cages during the years 1926–1928, only one emerged the following spring to oviposit the second season. The majority of the individuals hibernated as prepupae or as nearly grown larvae. Seventy-five per cent of the individuals observed in 1925–26 passed the winter as prepupae; 25 per cent in 1926–27; and 95 per cent in 1927–28. The late, warm fall of 1927 permitted later feeding of larvae, thus a larger number reached maturity before being overtaken by cold weather. The immature larvae generally pass the winter in the fifth or sixth instar, but a few may be in the fourth.

Thiem (51), among others, stated that the winter may be passed as pupae or as unemerged adults within the pupal cells. To test this possibility the writer, on February 1, 1928, placed 60 pupae and 38 unemerged adults in cells out of doors in soil below the frost line. By March 16 all of the adults had died within the cells, and two weeks later all of the pupae were dead. One hundred prepupae put out at the same time survived the winter and emerged as adults the following June. No pupae or unemerged adults have been found by the writer in the nursery during the winter. The above test indicates that winter conditions are less favorable for these stages of the insect than for the prepupae or immature larvae.

The immature larvae became active early in the spring, when the soil temperature was 42° F. (Observed March 1, 1928.) The larger
ones completed growth during April, passed through a short prepupal stage, and pupated with the overwintering prepupae. Pupation began about May 10 in 1927 and 1928 as the soil temperature rose above 55° F. The pupal stage lasted about 22 days, and the adults transformed early in June and emerged from 7 to 8 days later, usually about June 10 to 20, as shown in Figure 12 for 1927.

The smaller overwintering larvae completed their growth later in the spring, even as late as June. Some emerged as late as July 20.

![Figure 13: Development of eight lots of *Brachytryhinus sulcatus* outdoors from time of hatching at known dates during the egg-laying season of 1927. Below is given a curve showing the soil temperatures on the dates indicated by darts. Willow Grove, Pa.]

Usually, however, most of these late-maturing larvae died in the prepupal stage. No larvae were observed by the writer to hibernate a second winter in Pennsylvania, though a slightly shorter season might make this possible. This was shown by the fact that larvae which were reared so that they reached maturity late in August, 1927, did not produce adults until the following spring. (Fig. 13 and Table 5.)
Table 5.—Summary of development of Brachyrhinus sulcatus under outdoor conditions from time of hatching at known dates throughout the egg-laying season of 1927, Willow Grove, Pa.

<table>
<thead>
<tr>
<th>Lot No. 1</th>
<th>Larvae hatched</th>
<th>Cells were formed</th>
<th>Pupation</th>
<th>Emergence</th>
<th>Cells were formed</th>
<th>Pupation</th>
<th>Transformation</th>
<th>Emergence</th>
<th>Adults emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>May 31</td>
<td>Aug. 20-Sept. 1</td>
<td>1927</td>
<td>Oct. 6</td>
<td>1927</td>
<td>Nov. 10</td>
<td>1928</td>
<td>May 10-21</td>
<td>1928</td>
</tr>
<tr>
<td>2</td>
<td>June 24</td>
<td>Sept. 13-Oct. 6</td>
<td>1927</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>June 5-10</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>July 7</td>
<td>Sept. 28-Oct. 6</td>
<td>1927</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>June 9-14</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>July 21</td>
<td>Oct. 5-26</td>
<td>1927</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>June 13-18</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Aug. 1</td>
<td>Oct. 21-Nov. 10</td>
<td>1927</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>June 16-22</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Aug. 19</td>
<td>Nov. 1-21</td>
<td>1927</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>June 6-12</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Aug. 29</td>
<td>Nov. 4-21</td>
<td>1927</td>
<td>0</td>
<td>Apr. 6-10</td>
<td>0</td>
<td>May 10-23</td>
<td>1928</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sept. 12</td>
<td></td>
<td>1927</td>
<td>0</td>
<td>Apr. 16-May 2</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) 200 larvae were put out in each of the 8 lots.

\(^{2}\) 1 larva pupated.

\(^{3}\) 1 adult emerged.

\(^{4}\) 68 per cent of larvae formed cells.

\(^{5}\) 32 per cent of larvae formed cells.
The few overwintering adults emerge from hibernation early in May (May 4, 1925, May 7, 1927), begin to oviposit late in May (May 22, 1927), and continue to do so until September. One adult, depositing 41 eggs in 1926, produced 822 eggs during 1927. One adult, captured May 18, 1927, laid 135 eggs before her death, July 20, 1927. During the period of these studies only three adults were found to hibernate successfully outdoors and to deposit eggs a second season. In Pennsylvania, then, hibernation in the adult stage appears to be quite exceptional.

The main adult emergence extended from June 10 to July 20 during three years' observations, the peak occurring about the middle of June. (Fig. 12.) Several writers (5, 15, 18, 51) stated that adults of *B. sulcatus* emerged in April and May. Emergence is very likely dependent upon the soil temperature, as illustrated by the following example in the spring of 1928. A quantity of larva-infested soil had been dumped outside earlier in the winter between the greenhouse and a thick hedge in a place fully exposed to the sun during the day and protected from the winds at night; thus the soil temperature here during April was considerably higher than that in the open. Adults here began emerging on May 3, at a soil temperature of 60° F., or 8° higher than soil at the same depth in the open, where they did not emerge until a month later.

In the 3-year study the first eggs were laid July 17 to 20 by the June-emerging adults. The preoviposition period was from 28 to 50 days. The average number of eggs laid per day by one adult was 13, with a range of from 0 to 27. The individual fecundity seemed to vary considerably as between individuals in different seasons on the same host plants, and between individuals on different host plants. A study of Tables 6 and 7 will show these points. The average number of eggs laid by adults confined to different host plants is especially interesting. Highest averages of oviposition rates were obtained from adults feeding on fairy primroses, although adults on rippled plantain produced nearly as many per individual. Adults confined to yew, strawberry, and curly dock produced only about half as many eggs, and adults on Boston fern produced very few.

### Table 6.

<table>
<thead>
<tr>
<th>Season of</th>
<th>Individuals under observation</th>
<th>Host upon which adults were confined</th>
<th>Preoviposition period</th>
<th>Eggs laid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum</td>
<td>Minimu</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td></td>
<td>Days</td>
<td>Days</td>
</tr>
<tr>
<td>1926 ......</td>
<td>4</td>
<td>Primula malacoides</td>
<td>9</td>
<td>34</td>
</tr>
<tr>
<td>1927 ......</td>
<td>12</td>
<td>Nephrolepis sp.</td>
<td>49</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>P. malacoides</td>
<td>45</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>P. malacoides</td>
<td>45</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Rumex crispus</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>1928 ......</td>
<td>4</td>
<td>Taxus cuspidata</td>
<td>56</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Pragaria sp.</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Plantago major</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

1 1 adult laid 41 eggs in 1926 and 822 eggs in 1927.
2 1 adult lived 38 days, then died without laying eggs; this is a greater age than the average length of preoviposition period.
3 2 adults died without ovipositing after living 59 days and 38 days, respectively. Considered in the average of oviposition records.
4 2 adults died at age of 24 and 25 days, respectively. Not considered in average or minimum of oviposition records.
5 Adults collected in nursery before egg laying began and confined in 5 cages.
6 1 adult lived 83 days without ovipositing. Considered in average for oviposition.
7 2 adults died at ages of 24 and 25 days, respectively. Not considered in average or minimum of oviposition records.
Table 7.—Summary of oviposition records of Brachyrhinus sulcatus out of doors, according to host plant used, Willow Grove, Pa., 1926–1928

<table>
<thead>
<tr>
<th>Host plant</th>
<th>Adults observed</th>
<th>Adults not ovipositing</th>
<th>Eggs laid</th>
<th>Individual egg records</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td>Primula malacoides</td>
<td>49</td>
<td>2</td>
<td>12,656</td>
<td>488</td>
</tr>
<tr>
<td>Plantago major</td>
<td>3</td>
<td>0</td>
<td>738</td>
<td>278</td>
</tr>
<tr>
<td>Taxus cuspidata</td>
<td>4</td>
<td>0</td>
<td>573</td>
<td>293</td>
</tr>
<tr>
<td>Fragaria sp.</td>
<td>12</td>
<td>3</td>
<td>1,353</td>
<td>293</td>
</tr>
<tr>
<td>Rumex crispus</td>
<td>4</td>
<td>1</td>
<td>437</td>
<td>176</td>
</tr>
<tr>
<td>Nephrolepis sp.</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Summary</td>
<td>74</td>
<td>7</td>
<td>15,965</td>
<td>488</td>
</tr>
</tbody>
</table>

1 The adult depositing 863 eggs in two seasons was not considered in the column of maximum individual oviposition.

The larvae hatching from the first eggs laid in late May by overwintering adults entered the prepupal cells in late August or early September. A few of these pupated and emerged as adults during the same fall, but most of them lay in their cells until the following May. Larvae hatching at later periods throughout the egg-laying season completed maturity later in the fall or, if overtaken by cold weather, in the early spring. (Table 5 and Fig. 13.) The developmental period of the larvae was observed to be as short as 74 days and as long as 7½ months, and the prepupal period lasted a minimum of 21 days and a maximum of 8½ months. This variation is apparently due to the soil temperature. The larvae were observed to feed at soil temperatures of 42° F., but none was observed to pupate at soil temperatures below 55°. This habit permits the later hatching larvae in each season to complete growth late in the fall and early in the spring and then to pupate and emerge as adults with the overwintering prepupae developing from early laid eggs.

In Pennsylvania there is, then, one brood of adults annually under field conditions. The few adults, however, which hibernate successfully and oviposit a second summer cause an overlapping of generations. The observations on the experimental life-history studies were frequently checked with natural infestations in nurseries where collections were made and reared.

Seasonal History in the Greenhouse

Studies of the life-history of Brachyrhinus sulcatus in the greenhouse were planned to determine whether infestations continued from year to year independent of any outside infestations and, if so, whether the usual greenhouse practices influence the infestations and the life history of the insect.

Observations in commercial greenhouses and in the laboratory show that the larvae mature for the most part from late October to early December. In the cooler greenhouses where a high temperature is not kept for forcing a Christmas crop, some larvae may not mature until early in March, but this is exceptional. As the larvae complete their feeding by cutting off the roots, the affected host plants sud-
denly wilt, turn yellow, and die at the time for marketing the crop. If these injured plants are allowed to remain on the bench or are thrown beneath it, in the rush to make room for the next crop, the larvae pupate, and adults emerge from late in January to early in April, the majority in February. If such host plants as cyclamen seedlings or ferns are accessible the adults feed on these and begin laying eggs from 50 to 70 days after emergence. The first eggs are usually laid in April or early in May, and the larvae hatching from them will mature in August. During the early summer months the cyclamen plants are often too small to furnish sufficient food for the larvae in the pot, and both plant and insect die.

In many observed cases, however, the thrifty florist threw the infested soil from his unsalable cyclamens on the compost heap near the greenhouse for later use. The larvae in this soil, having completed their feeding and formed prepupal cells in the greenhouse, lay dormant until spring and then emerged as adults in June—about the same time as those developing entirely outdoors. This point was checked by placing larva-infested soil on a compost heap in November and recording the emergence of adults the following June. (Figs. 12 and 13.) These summer-emerging adults, from the compost heap or from outdoor hosts, migrate into the greenhouse and feed and oviposit from the middle of July to early in September. Larvae hatching from their eggs mature in the fall and early winter. (Table 8.)

The temperature of the soil in the greenhouse affects the development of this insect just as does the temperature outside. During the cloudy months, from the latter part of October through the early part of January (in the vicinity of Philadelphia), the soil temperature ranged from 48° to 51° F. in several greenhouses, then rose from 7° to 10° with the coming of more sunny days. Pupation began with this rise in temperature. The adults which emerged early in the spring in the greenhouse also continued to oviposit throughout the spring and summer.
Table 8.—Summary of data on development of 573 adults of Brachyptera sulcatus in the greenhouse during 1926–27 (A) and 1927–28 (B) at Willow Grove, Pa.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Date eggs were laid</th>
<th>Date eggs hatched</th>
<th>Date larvae matured</th>
<th>Date of pupation</th>
<th>Date of transformation to adult</th>
<th>Date adult emerged</th>
<th>Period for development</th>
</tr>
</thead>
</table>

1 Not including incubation period.
Adult feeding on the foliage stops suddenly in September, and it is evident that they normally seek hibernating quarters outside, where most of them die before spring. But in the laboratory tests the adults which otherwise would have migrated outside were kept in the greenhouse in cages on cyclamens or primroses until they died, and records were made of the number of eggs laid. (Table 9.) Egg laying stopped early in October, and the adults became very sluggish and ate little until December or January, when they became active again, ate voraciously, and then began again to oviposit. Oviposition continued, in most cases, until the early part of the next summer, though a few oviposited until September.

In Table 10 is given a summary of the longevity records of the groups shown in Table 9.

**Table 9.—Oviposition records of Brachyrhinus sulcatus in the greenhouse at Willow Grove, Pa., during the seasons 1926-1928.**

<table>
<thead>
<tr>
<th>Season</th>
<th>Group A</th>
<th>Adults Developed in the Field, then Caged in the Greenhouse</th>
<th>Adults Observed</th>
<th>Date of Emergence</th>
<th>Preoviposition Period</th>
<th>Eggs Laid First Season</th>
<th>Eggs Laid Second Season</th>
<th>Eggs Laid Both Seasons by All Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926-27</td>
<td>3</td>
<td>Number</td>
<td>Number</td>
<td>Days</td>
<td>Days</td>
<td>Days</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,864</td>
<td>1,864</td>
<td>78</td>
<td>53</td>
<td>66.2</td>
<td>3,984</td>
<td>1,083</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,671</td>
<td>1,671</td>
<td>90</td>
<td>68</td>
<td>70.2</td>
<td>3,656</td>
<td>907</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,533</td>
<td>3,533</td>
<td>80</td>
<td>54</td>
<td>66.7</td>
<td>14,758</td>
<td>674</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66.2</td>
<td>66.2</td>
<td>64</td>
<td>64</td>
<td>64.7</td>
<td>796.2</td>
<td>796.2</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>80</td>
<td>80</td>
<td>54</td>
<td>66.1</td>
<td>29,763</td>
<td>1,083</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66.2</td>
<td>66.2</td>
<td>64</td>
<td>64</td>
<td>64.7</td>
<td>796.2</td>
<td>796.2</td>
</tr>
<tr>
<td>Summary</td>
<td>45</td>
<td>80</td>
<td>80</td>
<td>54</td>
<td>66.1</td>
<td>29,763</td>
<td>1,083</td>
<td>143</td>
</tr>
<tr>
<td>1927-28</td>
<td>6</td>
<td>Number</td>
<td>Number</td>
<td>Days</td>
<td>Days</td>
<td>Days</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,864</td>
<td>1,864</td>
<td>39</td>
<td>39</td>
<td>39</td>
<td>5,815</td>
<td>1,081</td>
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<tr>
<td></td>
<td></td>
<td>1,671</td>
<td>1,671</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>3,420</td>
<td>907</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,533</td>
<td>3,533</td>
<td>220</td>
<td>220</td>
<td>220</td>
<td>638</td>
<td>674</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66.2</td>
<td>66.2</td>
<td>374.6</td>
<td>374.6</td>
<td>374.6</td>
<td>252</td>
<td>1,229.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66.2</td>
<td>66.2</td>
<td>374.6</td>
<td>374.6</td>
<td>374.6</td>
<td>252</td>
<td>1,229.2</td>
</tr>
<tr>
<td></td>
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<td>80</td>
<td>80</td>
<td>54</td>
<td>66.1</td>
<td>29,763</td>
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<td>64</td>
<td>64</td>
<td>64.7</td>
<td>796.2</td>
<td>796.2</td>
</tr>
<tr>
<td>Summary</td>
<td>45</td>
<td>80</td>
<td>80</td>
<td>54</td>
<td>66.1</td>
<td>29,763</td>
<td>1,083</td>
<td>143</td>
</tr>
</tbody>
</table>

**Group B.—Adults developed in the field, then caged in the greenhouse.**

<table>
<thead>
<tr>
<th>Season</th>
<th>Individuals Observed</th>
<th>Date of Emergence</th>
<th>Preoviposition Period</th>
<th>Eggs Laid First Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926-27</td>
<td>3</td>
<td>June, 1926</td>
<td>41</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td></td>
<td>37</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Summary</td>
<td>45</td>
<td></td>
<td>41</td>
<td>28</td>
</tr>
</tbody>
</table>

1 Of these adults, 8 died at the end of the first season and 18 of them oviposited the second season.
2 These adults were collected in the nursery, June 25, 1926, and caged together.
3 Of these adults which were collected in the nursery, June 25, 1927, 13 died at the end of the first season and 12 oviposited the second season.
TABLE 9.—Oviposition records of Brachyrhinus sulcalus in the greenhouse at Willow Grove, Pa., during the seasons 1926–1928—Continued

GROUP B.—ADULTS DEVELOPED IN THE FIELD, THEN CAGED IN THE GREENHOUSE—Continued

<table>
<thead>
<tr>
<th>Group</th>
<th>Table 9 continued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>Eggs laid second season</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1926-27</td>
<td>Number</td>
</tr>
<tr>
<td>1926-27</td>
<td>1,984</td>
</tr>
<tr>
<td>1927-28</td>
<td>2,769</td>
</tr>
<tr>
<td>Summary</td>
<td>9,344</td>
</tr>
</tbody>
</table>

TABLE 10.—Records of adult life of Brachyrhinus sulcalus in the greenhouse at Willow Grove, Pa., during the seasons 1926–1928

GROUP A.—ADULTS DEVELOPED ENTIRELY IN THE GREENHOUSE

<table>
<thead>
<tr>
<th>Group</th>
<th>Table 10 continued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>Individuals observed</td>
</tr>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>1926-27</td>
<td>5</td>
</tr>
<tr>
<td>1927-28</td>
<td>9</td>
</tr>
<tr>
<td>Summary</td>
<td>45</td>
</tr>
</tbody>
</table>

GROUP A.—ADULTS DEVELOPED ENTIRELY IN THE GREENHOUSE—Continued

<table>
<thead>
<tr>
<th>Group</th>
<th>Table 10 continued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>Individuals observed</td>
</tr>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>1926-27</td>
<td>1</td>
</tr>
<tr>
<td>1927-28</td>
<td>7</td>
</tr>
<tr>
<td>Summary</td>
<td>13</td>
</tr>
</tbody>
</table>

The adults emerging in the greenhouse early in the spring oviposited over a longer period and laid an average of 661.4 eggs, as compared with the average of 251.7 eggs laid by the adults emerging outside in June. During the second season the latter group deposited an average of 644.3 eggs, while the former averaged only 375.8 eggs per individual. However, the adults developing inside averaged 928.7 eggs, as compared with 666.9 eggs, the average laid by the other group. The greatest number of eggs laid by one individual was 1,681.

The cessation of egg laying and the state of inactivity assumed by the adults confined in the greenhouse at about the same time that the adults outdoors enter hibernation seem to indicate a seasonal cyclic
phenomenon independent of the temperature. The period of inactivity in the greenhouse, though short, is of such length that in the three years’ study eggs were never laid in November, the only month of the year in which oviposition did not occur. In commercial greenhouses, the adults disappear in September, and none are present to deposit eggs until January, when adults emerge from the infested soil. It is thus shown that the adults may oviposit through two full seasons, both in the greenhouse and out of doors. Table 11 shows the life span of 10 individuals followed from the time the egg was laid to the death of the adult.

Table 11.—Summary of life span of 10 isolated individuals of Brachyrhinus sulcatus in the greenhouse, Willow Grove, Pa., 1926-1928

| Individual No. | Egg was laid | Egg hatched | Larva matured | Pupation | Adult emerged | Adult died | Total lifespan |
|----------------|--------------|-------------|---------------|-----------|---------------|------------|----------------|---------------|
| G127           | May 5        | May 21      | Aug. 28       | Jan. 16   | Feb. 18       | July 31    | 817            |
| G227           | July 8       | July 22     | Nov. 5        | Jan. 20   | Feb. 25       | Mar. 13    | 645            |
| G427           | Aug. 1       | Aug. 16     | Dec. 5        | Feb. 21   | Mar. 28       | Sept. 8    | 389            |
| G527           | Aug. 13      | Aug. 13     | Nov. 18       | Jan. 28   | Mar. 4        | Apr. 9     | 588            |
| G627           | July 28      | Aug. 13     | Nov. 18       | Jan. 31   | Mar. 6        | Nov. 16    | 476            |
| G827           | Aug. 1       | Aug. 15     | Nov. 14       | Feb. 4    | Mar. 10       | June 13    | 686            |

Table 12 summarizes the development of B. sulcatus in the greenhouse during the spring and early summer of 1928. The larvae, as hatched, were placed in pots containing fairy primroses. As the plants declined from the effects of feeding, the insects were transferred to new uninfested plants. At the approach of maturity some of the larvae were examined every two days, and those which had completed feeding were transferred to soil in pots without plants, where they formed the pupal cells. Usually, these were not disturbed further until the time of pupation, a month later. Others were not examined at all, but records of adult emergence were kept. In this series one larva completed growth in 72 days, spent 21 days as a prepupa, 15 days as a pupa, and 8 days as an unemerged adult, a total developmental period of 116 days.

Table 12.—Development of Brachyrhinus sulcatus in the greenhouse during 1928, Willow Grove, Pa.

| Lot No. | Eggs hatched | Cells were formed | Average period of larval development | Adults emerged | Average total period of development |
|---------|--------------|------------------|--------------------------------------|----------------|------------------------------------|----------------|
| 1       | Jan. 27      | Apr. 8-16        | Days                                 | Days           |
| 2       | Feb. 9       | Apr. 25-29       | 77                                     | 146            |
| 3       | Feb. 24      | May 9-16         | 79                                     | 143            |
| 4       | Mar. 1       | May 10-23        | 80.7                                  | 131            |
| 5       | Mar. 20      | May 31-Jun. 8    | 77.8                                  | 133            |
| Average |              |                  | 77.8                                  | 134.7          |
| Maximum |              |                  | 82                                     | 155.0          |
| Minimum |              |                  | 72                                     | 116.0          |

1Only 32 insects were examined for the period in this stage.
2For 48 adults.
During 1926 and 1927 attempts to rear the insects in the hot summer months through the prepupal and pupal stages to adults were unsuccessful, the larvae dying in the prepupal stage. The mortality in this stage exceeded 60 per cent in the summer of 1928, but the remainder were successfully reared, probably because they were not disturbed during this stage. Figure 14 shows the soil-temperature range correlated with the period of development of this series. From this figure it can be seen that an increase in the soil temperature little affected the development of the larvae, but shortened markedly the prepupal and pupal stages.

Although larvae were reared, as hatched, throughout the three seasons, the mortality of larvae maturing during the hot summer months was 100 per cent. (Table 13.) Larvae maturing late in August and during the remainder of the fall were successfully reared. It is evident that a cool soil is favorable to the insect in the prepupal stage.

Table 13.—Comparison of mortality of larvae of Brachyrhinus sulcatus in the prepupal stage at various seasons, Willow Grove, Pa., 1926–1928

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Time of prepupal period</th>
<th>Average soil temperature during prepupal period</th>
<th>Larvae in prepupal cells</th>
<th>Adults emerged</th>
<th>Mortality in stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January–March</td>
<td>58° F.</td>
<td>322</td>
<td>226</td>
<td>31.82</td>
</tr>
<tr>
<td>2</td>
<td>do</td>
<td>61</td>
<td>208</td>
<td>186</td>
<td>10.68</td>
</tr>
<tr>
<td>3</td>
<td>Late June–August</td>
<td>82</td>
<td>348</td>
<td>0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1 Placed in artificial cells.  
2 Not disturbed after forming cells.
NATURAL ENEMIES

Feytaud (15) stated that the mole ate both larvae and adults, of the black vine weevil, but as it inhabits damp places, while the weevil prefers sandy areas, it is of little value. The hedgehog, he said, eagerly devours the adult weevils; and its dung, found in the vineyards, was composed almost entirely of carapaces of this weevil. One night in July, 1928, the author observed a skunk searching about the bases of yews in a Philadelphia nursery where the adult weevils averaged from 10 to 12 on each plant. In an adjoining fence row near a skunk den was an accumulation of dung in which 147 carapaces, undoubtedly of *Brachyrhinus sulcatus*, were counted. The nest of a deer mouse (*Peromyscus leucopus*), found in a stone pile, in September, 1927, contained chewed portions of *sulcatus* and of May beetles, but it was not determined whether the insects were dead or living when eaten.

Among the bird enemies of *B. sulcatus*, Theobald (56) listed the titmouse, flycatcher, several warblers, finches, and starlings in Great Britain. Godard (21) listed the stone chatterers (*Troquet*), larks (*Alauda arborea* L.), and tufted lark (*Galerida cristata* L.) as particularly beneficial in the control of adults of *sulcatus* in the vineyards of France. Kalmbach and Gabrielson (26) found *sulcatus* among the weevils in the stomachs of starlings (*Sturnus vulgaris*) in the United States. Feytaud (15) found that poultry, especially turkeys, picked up many of the larvae exposed by plowing in the vineyards.

Various lizards (*Lacerta viridis* Gs.n., *L. stirpium* Bon., and *Anguis fragilis* L.) were said by Feytaud (15) to be of value in the control of *B. sulcatus*. He also said that toads, especially *Bufo vulgaris*, were active about the vineyards. In July, 1928, the writer examined two toads near Philadelphia, Pa., whose stomachs contained seven and one adults of *sulcatus*, respectively.

Among the insects Feytaud (15) found carabid beetles, *Carabus auratus* L., *Feronia* sp., and *Poecilus* sp. attacking *B. sulcatus* larvae. The staphylinid beetle *Ocypus olens* Mull. was another enemy. The digging wasp *Cerceris arenaria* L. (15) stored her nest with adults of *sulcatus* after paralyzing them. *Blacus* sp., a braconid, is said to parasitize the adults (13, p. 24). Thiem (51) stated that a tachinid, *Pandelleia sexpunctata* Pand., parasitized larvae and adults in Germany. In the spring of 1928 carabid larvae in the writer's life-history plots and in the nursery were suspected of feeding on the larvae of *sulcatus*. Two of these larvae confined in pots of soil for 21 days, killed and partly ate 14 and 22 *sulcatus* larvae, respectively, in the third and fourth instars. These carabids were not reared to adults. In the laboratory an ant (*Formica* sp.) was seen to carry away many eggs and first-instar larvae of *sulcatus* to its nest, and once a second-instar larva was carried away. Feytaud (15) stated that *sulcatus* larvae were comparatively free of parasites. The present writer found no insect parasites of any of the stages in his studies.

Deeaux (8) was unsuccessful in inoculating larvae of *Brachyrhinus* spp. with the fungi *Entomophthora plusiata* and *E. saccharina*. W. A. McCubbín, of the Pennsylvania Bureau of Plant Industry, found a species of *Isaria* in diseased larvae taken from Pennsylvania greenhouses. He believed that the fungus probably attacked only dead or
weakened larvae and that it was only slightly, if at all, parasitic. Larvae were also examined by Vera K. Charles, of the United States Bureau of Plant Industry, who found a species of Fusarium which she said might be parasitic. The writer has often observed prepupae and pupae of *B. sulcatus* which were dead in their cells covered either with a felted mass of hyphae or with white bands of hyphae extending out from the body in all directions among the soil particles. (Fig. 15.) Occasionally adults developing a similar fungus die before emergence. A larva which has had to construct a second cell is more subject to fungus attack than others.

The larvae maturing during the period of warmer soil temperatures (70° to 80° F.) die in much greater numbers than do those passing the prepupal stage with soil temperatures between 55° and 65° F. (Table 13.) It was not determined whether the fungi were more virulent at higher temperatures and killed the larvae, or whether the latter were so weakened under the warmer conditions that they fell an easy prey to these weakly parasitic fungi. At any rate this factor may have some bearing in the determination of the southern range of the species. With longer seasons maturity would be reached before the soil cools with the approach of fall, and as a result there would be high mortality in the prepupal stage.

**CONTROL**

Many recommendations for control of the black vine weevil have evidently been made without a test of the methods or without a knowledge of the life history and habits of the insects. Recommendations, both preventive and remedial, based on the present studies, are here given.

**PREVENTIVE MEASURES FOR GREENHOUSE PRACTICE**

An understanding of the life history of the black vine weevil in greenhouses will readily indicate several points in general greenhouse practice which may be modified to reduce or eliminate this pest.

1. A thorough clean-up should be made of all host plants grown through the preceding summer before adults emerge in January or February. When this is not possible such plants should be separated from the younger plants to prevent an infestation in the next crop from the migrating weevils. The discarded plants, together with the soil infested with larvae, should not be allowed to remain on the compost heap or near the greenhouse, since adults would emerge from these

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**FIGURE 15.**—A fungus, *Fusarium* sp., growing on a prepupa of *Brachyrhinus sulcatus*, Willow Grove, Pa., 1928. X 0.5
and return to the greenhouse to renew the infestation. (2) Soil that has once been infested should not be used again unless it has been sterilized by steam, or submerged under water for at least eight days. (3) Outdoor hosts should be either eliminated or treated to destroy the infestation. (4) Caution should be exercised in purchasing stock to bring into the greenhouse only uninfested plants.

**BARRIERS, SCREENS, AND TRAPS**

In the present studies, sticky barriers, as suggested by Felt (12), were placed on greenhouse benches in July and August and found to be crossed in some instances by the adults. The florists usually objected to the inconvenience of such a barrier.

On one estate, cyclamens grown during the summers in a coldframe situated near infested yews and rhododendrons, became infested each year until protected by a well-fitting screened frame constructed under the direction of the writer. This method is considered practicable only for protecting small numbers of plants.

The use of materials such as excelsior, orchid peat, and small pieces of board and broken pots on the benches as traps, frequently advocated, attracted very few adults in infested commercial greenhouses. The adults avoid damp or wet situations, and the frequent watering of plants during the summer wets these trap materials and makes them unattractive.

**REMEDIAL MEASURES**

**DROWNING**

Uninfested potted fairy primroses, cyclamen, and ferns (Nephrolepis scottii) were placed in a vat of water at depths just sufficient to cover the soil surface. Submersion for 24 hours caused no apparent injury, but with 48 hours' submersion the fine rootlets died, and the leaves yellowed on both cyclamens and primroses. The ferns yellowed after 72 hours' submersion.

To test the effect of submersion on the insects, potted plants with larvae of B. sulcatus in the third or fourth instar were submerged for varying periods up to 72 hours without apparent harm to any of the larvae. Thirty per cent of the larvae were dead after 96 hours of submersion, 72 per cent after 6 days, and 100 per cent after 8 days. As the plants are injured by a much shorter submersion than is required to kill the larvae, this method, which had been advocated by Kemner (27), can not be recommended for use in greenhouses.

Crowley (7) recommends winter flooding of cranberry bogs in Washington State for the control of the larvae; Feytaud (15) recommends similar treatment for vineyards. The dormant plants would be much more tolerant of flooding than would the tender, growing, greenhouse plants.

**INSECTICIDES FOR CONTROL OF LARVAE**

Since larvae destroy the subterranean parts of the host plants, whereas the adults attack the aerial portions, different control methods must be employed against the two stages of the insect.

Many authors have suggested methods of control, especially against the partly or nearly grown larvae. This is natural since the insect is usually not observed in the adult stage, and the larvae do not produce
conspicuous injury until the fourth or fifth instar. In the present
studies nearly all of these suggested methods have been tested, and
the results, though usually negative, have been briefly summarized.

The following materials were made up in varying concentrations,
and sufficient quantities to just saturate the soil in the pot were
added to each plant: Nicotine sulphate, free nicotine solution (soap
and tobacco (12)), kerosene emulsion (48), kerosene-nicotine oleate,
icotine oleate, liquid extract of derris, pyridine, beech-wood creosote,
cobalt tar creosote (12), potassium thiocarbonate (35), sodium cyanide
solution (7), carbolic acid emulsion (48, 49), and calcium cyanide
mixed with the topsoil (41). All these killed primroses and cyclamens
without harming the third and fourth instar larvae.

Tobacco stem mulch (54) was found ineffective against larvae or
eggs and was considered impractical of application in the greenhouse.
Flake naphthalene (21, 34) mixed with potting soil in varying quanti-
ties up to 8 ounces per bushel of soil was found ineffective against
newly hatched larvae introduced 30 days after the plants had been
potted in the treated soil. The naphthalene had very likely vaporized
before the introduction of the larvae; therefore this material would
not be effective against larvae over the usual 2½ month oviposition
period of the adults during the summer. Naphthalene, introduced
into holes made about the crowns of infested plants, was also ine-
effective against larvae in the third instar. Finely pulverized para-
chlorobenzene applied about the crowns of plants and covered with
soil, killed all larvae in 4-inch pots when applied at the rate of one-
fourth gram per pot. No injury to cyclamens was observed when it
was applied at rates up to a three-fourths of a gram per pot. This
method of application, although encouraging in results, probably
would not be practicable commercially because of the care and time
required. This material dissolved in 70 per cent ethyl alcohol or in
gasoline was very toxic when applied in smaller dosages. The applica-
tion of carbon disulphide, with a pipette, into holes about the crowns
of plants was found to be unsuccessful, as Swaine (48) and Gibson
and Ross (20) had also found it. Carbon disulphide emulsion, even
when applied at much greater concentrations than were recommended
for the Japanese beetle (29), gave inconsistent results and no control
at concentrations tolerated by the host plants. In the nursery, one
series of tests on level, fairly dry soil at a temperature of 52° F. was
made with carbon-disulphide emulsion, as suggested by Britton and
Zappe (6, p. 163), but the result was only 40.9 per cent control of
third-instar larvae.

**LEAD ARSENATE TREATED SOIL**

The results of the use of lead arsenate against Japanese beetle
larvae (*Popillia japonica* Newm.) in the soil, as recommended by
Leach and Lipp (30) suggested tests which were made with a view
to controlling the larvae of *Brachyrhinus sulcatus* in the greenhouse
and nursery and noting the effect on the host plants.

**FOR POTTING GREENHOUSE PLANTS**

The study of the life habits of *B. sulcatus* under greenhouse condi-
tions showed that infestation normally takes place during the ovipo-
sition period, between early in July and early in September. The
florist usually repots his cyclamen plants in May or June, and again
for the last time in August, when he is preparing his crop for sale the following Christmas. Since for this purpose the florist mixes together definite quantities of composted soil, leaf mold, sand, or sifted ashes it was considered that powdered lead arsenate, in determined proportions could be added to these ingredients at the time of mixing.

In the laboratory tests, lots of uninfested host plants were grown in soil containing known quantities of lead arsenate. As soon as rootlets appeared on the outside of the ball of soil, as observed when the plant is knocked out of the pot, newly hatched larvae were placed between the soil particles among those rootlets with a camel's-hair brush. The plant was then carefully replaced in the pot and labelled. At the end of two or three months, if the larvae survived they were nearly grown and could be easily found, and the results of the tests recorded. (Table 14.)

Table 14.—Data of tests with powdered lead arsenate as a soil insecticide for greenhouse use against the larvae of Brachyrhinus sulcatus at Willow Grove, Pa., 1926–1928

<table>
<thead>
<tr>
<th>Treatment (ounces of lead arsenate per bushel of soil)</th>
<th>Larvae introduced (Number)</th>
<th>Pots in test (Number)</th>
<th>Pots uninfested (Number)</th>
<th>Pots infested (Number)</th>
<th>Larvae recovered (Number)</th>
<th>Per cent</th>
<th>Plants destroyed (Number)</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check, no lead arsenate</td>
<td>2,884</td>
<td>203</td>
<td>15</td>
<td>243</td>
<td>1,318</td>
<td>51.0</td>
<td>227</td>
<td>87.98</td>
</tr>
<tr>
<td>1/4</td>
<td>101</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>26</td>
<td>25.74</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1/2</td>
<td>256</td>
<td>21</td>
<td>7</td>
<td>14</td>
<td>48</td>
<td>17.84</td>
<td>14</td>
<td>65.7</td>
</tr>
<tr>
<td>1/1</td>
<td>1,735</td>
<td>111</td>
<td>95</td>
<td>36</td>
<td>95</td>
<td>5.47</td>
<td>77</td>
<td>24.32</td>
</tr>
<tr>
<td>1</td>
<td>3,566</td>
<td>289</td>
<td>265</td>
<td>4</td>
<td>4</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2/3</td>
<td>3,645</td>
<td>273</td>
<td>273</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1/2</td>
<td>1,137</td>
<td>112</td>
<td>112</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The primroses (*Primula malacoides* and *P. obconica*), ferns (*Nephrolepis var. scottii* and *N. var. verona*), and cyclamen, transplanted to the treated soil grew as vigorously as similar lots growing in untreated soil. The cyclamen plants were tested in soil containing various proportions of lead arsenate, with a maximum of 8 ounces per bushel, and exhibited no apparent difference from the checks. Fairy primroses tested in soil containing 16 ounces of lead arsenate per bushel of soil had a slightly more glistening foliage than the checks, but this did not detract from the appearance of the plants. The most striking difference between the plants was the blooming of the treated ones three weeks before the check plants. The roots of *Cuphea ignea* and of geraniums, however, were killed by this treatment.

In June, 1927, a florist potted two lots of 100 cyclamens each with his regular potting soil in which the writer had also mixed powdered lead arsenate in the proportion of 2 and 4 ounces, respectively, per bushel. Both lots of plants developed through the summer with the checks—the remainder of the crop—and were among the first to bloom in early November. Upon visiting the greenhouse on November 25, the author found that the florist had met the demand of his trade by picking out the plants in full bloom. The writer found that only 3 of the 200 plants with the treated soil remained, but that fully three-fourths of the checks remained unsold.
This florist grew his entire 1928 crop of 2,000 plants successfully in soil containing 2 ounces of lead arsenate per bushel. Only 2 plants were lost through larval injury by *Brachyrhinus sulcatus* whereas theretofore the losses had averaged 150 to 300 plants annually.

The above tests show that the use of soil containing lead arsenate appears to be safe for repotting cyclamens and primroses which are being transferred from 2-inch or 3-inch pots to larger ones. In repotting, the practice of removing the surface layer of the soil about the crown of the plant, before placing it in the larger pot, should be followed. This is a usual procedure with many florists, as the hardened surface layer, often incrusted with algae, can then be replaced with fresh soil. When treated soil is used for control of larvae of *B. sulcatus*, according to the potting methods just described, a layer of poisoned soil is presented to the young larvae as it attempts to penetrate to the roots.

From the detailed laboratory tests conducted over a period of three years and summarized in Table 14 and Figure 16 the conclusion may be drawn that effective control of the larvae of the black vine weevil is not obtained by using the proportion of one-half ounce or less of lead arsenate per bushel. The proportion of 1 or 2 ounces per bushel will insure practically complete protection from the larvae if the poison and soil have been thoroughly mixed. This latter precaution can not be overemphasized since the larvae, to be poisoned, must ingest some of the lead arsenate.

**For Outdoor Infestations**

To determine the quantity of lead arsenate necessary to control *B. sulcatus* larvae in the field, duplicate plots were treated with lead arsenate in proportions of 500, 1,000, and 1,500 pounds, respectively, per acre. The first 4 inches of surface soil was thoroughly mixed with the lead arsenate. All plots were planted with fairy primroses and sheep sorrel. Newly hatched larvae of *B. sulcatus* were placed at the base of each plant between August 1 and 20, 1927, at the rate of 180 per square yard. Examination of the plots on April 3, 1928, revealed the results shown in Table 15.
TABLE 15.—Results of tests with lead-arsenate-treated soil in the field against larvae of Brachyrhinus sulcatus at Willow Grove, Pa., 1927–28

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Lead arsenate per acre</th>
<th>Larvae introduced per 2 square yards Aug. 1-20, 1927</th>
<th>Larvae found Apr. 3, 1928</th>
<th>Plot No.</th>
<th>Lead arsenate per acre</th>
<th>Larvae introduced per 2 square yards Aug. 1-20, 1927</th>
<th>Larvae found Apr. 3, 1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5 pounds</td>
<td>360</td>
<td>56</td>
<td>5</td>
<td>1.5 pounds</td>
<td>360</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>1.0 pounds</td>
<td>360</td>
<td>6</td>
<td>6</td>
<td>1.5 pounds</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.0 pounds</td>
<td>360</td>
<td>0</td>
<td>7</td>
<td>1.5 pounds</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1.5 pounds</td>
<td>360</td>
<td>8</td>
<td>8.7</td>
<td>1.5 pounds</td>
<td>360</td>
<td>4</td>
</tr>
</tbody>
</table>

* Check, no poison.

CONTROL EXPERIMENTS WITH ADULTS

Feytaud (16) and Miles (34) reported on the use of lead arsenate sprays for control of adults of Brachyrhinus sulcatus. In the United States the first satisfactory control of the adults of the strawberry root weevil (B. ovatus) was obtained by applying a bait consisting of 95 pounds of apple pomace dried to about 20 per cent moisture content and coated with 5 pounds of magnesium arsenate, zinc arsenite, or calcium arsenate. Mote and Wilcox (36) stated that a poisoned bran bait was as efficient as the dried-apple bait in the control of B. ovatus and B. rugosostriatus. Their experiments showed that the attractive quality was sweetness, which led to the development of the following formula:

Bran........................................... 5 pounds
Molasses...................................... 1 pint
Calcium arsenate........................... 4 ounces
Water.......................................... 2 quarts

They reported that 93.93 per cent of the weevils were killed with this material as compared with 85.33 per cent with the apple bait.

The writer made several tests early in July before oviposition began with both baits in cages and on a screened bench in a greenhouse against known numbers of B. sulcatus. The mortality averaged 96.3 per cent of 314 adults with the apple bait, and 97.1 per cent of 340 adults with the poisoned bran bait in parallel tests. It was evident that the bran bait, especially, was attractive only while moist. Therefore baits applied in the evening gave better results than those applied in the morning and allowed to dry during the day. Watering of the plants after application or before the adults had been exposed overnight to the material reduced the percentage of kill.

Two dusts, one a mixture of equal parts of calcium arsenate and hydrated lime, and the other pure sodium fluosilicate; and a lead arsenate spray, as used by Mote and Wilcox (36), also gave encouraging results in cage tests against B. sulcatus when used by the writer.

No greenhouse was found in which adults were numerous enough to enable a test to be made on a commercial scale, but a moderately heavy infestation of the yew (T. cuspidata) offered an opportunity to test the materials (baits, dusts, and sprays) under nursery conditions. About one-third of the yew block was used in making the first test (Table 16, series A), and the remainder was used for the second series.

* Mote and Wilcox used the name rugifrons under the supposition that this and the European species were the same.
of tests (B of the same table). The spray was applied to these plants in the afternoon, and the dusts and baits were applied at dusk during fair weather. The nurseryman objected to the foliage stain caused by the lead arsenate spray and to the burning caused by the sodium fluosilicate, so these two materials were not applied in the second tests.

Table 16.—Summary of tests to control Brachyrhinus sulcatus on Taxus, Chestnut Hill, Pa., 1928

<table>
<thead>
<tr>
<th>Series</th>
<th>Material</th>
<th>Date of application</th>
<th>Date examined</th>
<th>Adults dead</th>
<th>Adults living</th>
<th>Adults killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Bran bait</td>
<td>July 18</td>
<td>July 24</td>
<td>53</td>
<td>68</td>
<td>288</td>
</tr>
<tr>
<td></td>
<td>Apple bait</td>
<td>do</td>
<td>do</td>
<td>68</td>
<td>45</td>
<td>69.18</td>
</tr>
<tr>
<td></td>
<td>Calcium arsenate-hydrated lime dust</td>
<td>do</td>
<td>do</td>
<td>288</td>
<td>54</td>
<td>84.21</td>
</tr>
<tr>
<td></td>
<td>Lead arsenate spray, 3 pounds to 50 gallons.</td>
<td>do</td>
<td>do</td>
<td>57</td>
<td>68</td>
<td>56.13</td>
</tr>
<tr>
<td></td>
<td>Sodium fluosilicate dust</td>
<td>do</td>
<td>do</td>
<td>87</td>
<td>21</td>
<td>80.56</td>
</tr>
<tr>
<td></td>
<td>Check</td>
<td>do</td>
<td>do</td>
<td>24</td>
<td>24</td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>Bran bait</td>
<td>July 26</td>
<td>Aug. 4</td>
<td>148</td>
<td>34</td>
<td>81.32</td>
</tr>
<tr>
<td></td>
<td>Apple bait</td>
<td>do</td>
<td>do</td>
<td>64</td>
<td>53</td>
<td>64.70</td>
</tr>
<tr>
<td></td>
<td>Calcium arsenate-hydrated lime dust</td>
<td>do</td>
<td>do</td>
<td>157</td>
<td>10</td>
<td>94.01</td>
</tr>
<tr>
<td></td>
<td>Check</td>
<td>do</td>
<td>do</td>
<td>2</td>
<td>153</td>
<td>1.29</td>
</tr>
</tbody>
</table>

These tests, made on yew plants from 3 to 4 feet in height with their very fine needles, presented conditions less favorable for good results than did the strawberry plants used by Mote and Wilcox in tests against other species of Brachyrhinus. The results were very encouraging, however, and indicated that the calcium arsenate-hydrated lime dust or the poisoned bran bait decidedly reduced the numbers of adult \( B. \) sulcatus in the nursery. The greater efficiency of the bran than of the apple bait was doubtless due to the former adhering to the foliage and lodging among the branches in much greater quantities than did the latter. Those weevils hiding in the trash among the branches or under loose bark did not come in contact with the apple bait which dropped to the ground; hence smaller numbers were poisoned. The bran bait may also be used inside and outside the greenhouse during the early part of July to kill the adults just before oviposition begins. If the material is applied only inside, adults from outside will later enter the greenhouse and oviposit. Because of the possible injury arising from the use of dusts or sprays, florists and nurserymen will doubtless prefer the bran bait for the control of adults of \( B. \) sulcatus.

SUMMARY

The black vine weevil, \( Brachyrhinus \) sulcatus, has been found frequently in greenhouses and nurseries in southeastern Pennsylvania and has often been recorded as doing damage to crops in North America, Europe, and Australia. A review of the literature of this pest shows 52 recorded host plants, and to this number 25 new ones have been added as a result of the present studies.

The adults devour foliage or flowers by eating from the margins. They also notch petioles and girdle shoots, which die beyond the point of girdling, the new growth producing a witches'-broom effect. The young larvae feed on the rootlets. The more mature ones cut off the larger roots and gouge out the crowns of herbaceous plants, or
girdle the roots of woody plants. Injury caused by larvae, although often less conspicuous, is more severe than that caused by the adults. The eggs are usually dropped by the adult wherever she may be, but sometimes they are apparently placed in the soil or plant crevices. The incubation period averages 15 days, with extremes of 11 and 22 days.

The larva molts five or six times during its development in the soil, and the normal period of development ranges from 72 to 113 days, though cold weather may interrupt development during the winter. The mature larva forms a cell in the soil and enters the prepupal stage which lasts from three weeks to eight and one-half months, depending upon the temperature.

The pupal stage ranges from 15 to 22 days with an average of 18 days.

The adult spends an average of 8 days, with extremes of 4 and 17 days, in the cell before emerging. During this time the body fully hardens and darkens in color. Adults feed at night on foliage or flowers and hide during the day. The preoviposition period ranges from 4 to 10 weeks.

In the greenhouse isolated adults laid an average of 661.4 eggs the first season and 374.8 eggs the second. The maximum number of eggs laid by one adult for two seasons was 1,681. The adult life of one weevil was 671 days; its age from egg to death of adult, 816 days. In the greenhouse weevils oviposit during July and August, and the larvae mature from October to December. These develop into adults from January to March and oviposit during the succeeding summer on the next crop of plants.

Out of doors, \( B. \) sulcatus passes the winter in the nearly full-grown larval, prepupal, or, less frequently, adult stage. In some years the larvae complete development before fall, but in most years a greater part of the larvae hibernate before completing growth. These immature larvae complete feeding early in the spring and pupate with overwintering prepupae in May or June. Adults emerge in June or July, oviposit during July and August, and go into hibernation in September, most of them dying, however, before spring. The few adults hibernating successfully emerge in May and oviposit through the second summer. The eggs laid early hatch to larvae which mature in the fall and spend the winter as prepupae. Out of doors adults laid up to 488 eggs during the first season with an average of 216.1. One adult deposited 863 eggs in two seasons. The number of eggs laid varied with the species of host plant fed upon.

There is, then, one annual generation, but there is also a partial overlapping of adults of the main generation with the few hibernating adults from the preceding one.

Reproduction in six generations was entirely by parthenogenesis; no males were found during the course of these studies.

No true parasites were found in these studies, but larvae were killed by the larvae of a carabid beetle, by an ant, \( Fornica \) sp., and by two fungi, \( Isaria \) sp. and \( Fusarium \) sp. Skunks, mice, and toads were found to eat the adults.

As a result of life-history studies and control experiments, the following recommendations for control are given:

1. Preventive measures. Remove all infested plants from the greenhouse before the emergence of the adults. Dispose of the soil
from all greenhouse plants which have been destroyed by the weevil larvae in such a way that the latter can not mature to adults and reinfect the succeeding crops. Sterilization by steam or prolonged submersion in water should be resorted to if the soil is to be used again. Otherwise the soil should be dumped at some distance from the greenhouse. Eliminate, as far as practicable, all outdoor hosts about the greenhouse. Erect barriers or screen the plants during July and August to prevent the entrance of adults.

(2) Remedial measures. To control the larvae thoroughly mix lead arsenate in the potting soil at the rate of 1 or 2 ounces per bushel. The larvae are then poisoned as they burrow into the soil in search of roots. To control the adults, apply calcium arsenate-hydrated lime dust, poisoned bran bait, or poisoned apple bait to the host plants early in July before egg laying begins. If staining of foliage is objectionable the poisoned baits are to be preferred.

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