of doubtful value in this connection, because these materials themselves are mixtures of soaps and other materials, of which the soap alone is toxic.

Factors Influencing the Treatment

The experimental results indicate that temperature is the limiting factor in the use of this treatment. The best results are secured by spraying when the insects are exposed to the sun during the heat of the day. Under these conditions a consistent kill of 90% of the beetles was obtained whereas simultaneous spraying of beetles in the shade never resulted in more than 50% mortality.

In applying the material the best results are secured by using a coarse nozzle and sufficient pressure to thoroughly wet the foliage.

The sodium and potassium soja-bean soaps are now selling at 8 to 9 cents per pound and at the present price of these materials it costs from 80 to 90 cents for 50 gallons of spray.

The experimental work with these materials has been confined entirely to field tests and observations and under the circumstances no explanation can be offered at this time regarding the physiological action of the material upon the insect.

LARVAL FOOD HABITS OF THE JAPANESE BEETLE (*POPILLIA JAPONICA* NEWM.)[1]

By Loren B. Smith, *Riverton, New Jersey*

For several years it was believed that the larvae of the Japanese beetle fed largely on decaying vegetable matter in the soil.[2]

Observations made during the present season indicate that while a certain amount of humus and mineral matter passes through the digestive tract, the larvae feed principally upon the living roots of various plants.

Field Observations

During April and May, 1921, the writer observed the larvae actively feeding on the roots of rye, clover, and several of the pasture grasses. Further observations made in fields of rye disclosed the fact that in nearly all cases the larvae were congregated about the roots of the rye stools. The larvae have also been found feeding on the large tap-roots of clover, some of which were nearly eaten through between

[1]Published by permission of the Secretary of Agriculture of the U. S. Dept. of Agriculture and New Jersey Dept. of Agriculture.

[2]Davis, J. J. Green Japanese beetle. New Jersey State Department of Agriculture. Circular No. 30. p. 14. 1920.

one and two inches below the crown. The larvae do not confine their attacks to grasses and legumes, since records have now been obtained of their feeding on the roots of such plants as iris, peony, gladiolus, arbor vitae, small conifers, as well as other ornamental plants and shrubs, and also on the roots of corn, beans and tomatoes.

The first injuries to grass sod which were noted occurred in a pasture in which the abundance of the larvae was between 150 and 200 to the square yard. Areas were injured to such an extent that the sod could be easily rolled up with the fingers. Many of the plants which did not have the roots entirely eaten off by the grubs were killed by the hot, dry weather which ocurred later in the season. Many weeds and coarse rooted grasses do not show any appreciable effects from the feeding of the larvae, whereas the finer rooted species such as blue grass and red top are killed. For this reason it is probable that the most important injury by the grubs will not usually result in the destruction of the sod, but rather in the killing out of the more desirable species of grasses for pasture or hay purposes, and their being replaced by less desirable species.

Golf courses offer particularly favorable situations for the development of *Popillia japonica* larvae. The Country Club course at Riverton, New Jersey was found to be generally infested with the grubs early in the Autumn of 1921. On the fairways and in the rough the infestation was variable, on an average of a number of diggings less than fifty larvae were found to each square yard. On several of the putting greens the larvae were very numerous, as high as one grub to the square inch being found. The grass was killed in limited areas on someof the greens. That the greens were not more seriously injured was probably due to the fact that they were regularly watered and rolled. Aside from the direct injury to the grass roots, the playing surface was rendered soft and spongy by the burrowing of the insects in the soil. It was noticeable that the most severe injury to the grass occurred on the higher portions of the greens and especially about the margins. These would probably be the places which would receive the least water when the greens were sprinkled. Much of the feeding on the greens was done close to the surface of the ground, the larvae in most cases occurred between ½ inch and ¾ inch deep.

Feeding Habits

The feeding habits of the larvae have been observed many times both in the laboratory and in the field, and have been found to differ somewhat from those of certain of our native species. The larva

forms a cell in the soil slightly larger than its body and feeds on the fine rootlets at the top or bottom of the cell. The grubs usually follow the course of the rootlets until these are consumed before attacking others. It is this habit of feeding which has prevented the injury to grass from being extremely serious, since it is only in areas of heavy infestation that many plants are found which have all of their roots destroyed. It also follows that in areas which suffer from drought the injury has been the most noticeable and severe.

The general movements of the larvae in the soil are vertical, whereas the larvae of *Cyclocephala immaculata* and *Anomala* sp., which are abundant in this region, usually feed and move in a direction parallel with the surface of the ground. During the seasons when the *Popillia japonica* larvae are feeding they occur in the soil at depths varying between ½ inch and 3 inches. For a short time before the grubs descend on the approach of cold weather in the autumn and again during the period immediately preceding pupation, the depth at which the various individuals are found is more uniform.

THIGMOTROPISM

The larvae are positively thigmotropic to living roots and if these are not available, to stones, sticks, or to the bottom or sides of the breeding cage. The larvae have been found abundantly beneath stones in the field and for a distance of two or three feet from these stones no larvae could be found, although at a distance of five or six feet from the stones there would be twenty to twenty-five larvae to the square yard. In a young peach orchard which was cultivated the previous season and allowed to remain fallow over winter, there were numerous chickweed plants growing in the Spring of 1921. In the spaces between these plants the ground was bare. Fifty plots, each three square feet in area, were examined where no vegetation occurred and no larvae were found. On the removal of fifty chickweed plants an average of 7 larvae were found at the roots of each plant

EXAMINATION OF THE CONTENTS OF THE FORE INTESTINE

Dissections were made of a large series of larvae collected in grass sod and the contents of the fore part of the alimentary canal were carefully removed. It was found that the material eaten by the insects was composed of small soil particles, fresh plant tissue, and small pieces of plants which were partially decomposed. In order to determine the approximate amount of plant tissue as compared with the mineral matter eaten by the larvae, four samples of about five grams

each were collected from the fore intestines of the grubs. These were dried, weighed, ignited and weighed again and the loss from ignition considered as representing the approximate proportion of plant tissues, by weight to the total material found in the fore intestines of the insects. The loss by ignition of the soil from which these larvae were collected was about equal to the per cent of ash in the grass roots and for our purpose these factors can be considered to offset each other. These figures indicate that plant tissues constitute about 67.33 per cent. by weight of the total material consumed by the larvae.

ANALYSIS OF MATERIAL EATEN BY LARVAE OF *P. japonica*

Total weight of food collected	21.4134 grams
Dry " " "	15.4769 "
Ash remaining after ignition	5.0556 "
Loss from ignition	10.4213 "

Examination of the material contained in the fore part of the alimentary canal indicates the soil particles and pieces of plant tissue to be relatively uniform in size. The greatest variation occurred in those tissues which were partially decomposed. The following data on the extremes in size of particles found in the fore intestine are in each case based on fifty measurements:

Fresh plant tissue	minimum length	0.45 mm.
	maximum "	1.22 mm.
Fresh plant tissue	minimum width	0.25 mm.
	maximum "	0.36 mm.
Soil particles	minimum length	0.72 mm.
	maximum "	1.125 mm.
Soil particles	minimum width	0.327 mm.
	maximum "	0.875 mm.

In order to determine the relative number of pieces of fresh plant tissue, decaying vegetable matter and particles of soil composing the aggregate in the fore intestines of the larvae, determinations were made of the number and character of the particles obtained from twenty-five grubs. The larvae were collected from grass sod May 20th, killed by dropping in boiling water, and dissected immediately afterward. To separate the fresh plant tissues from those which were dead or partially decayed, it was necessary to stain and compare the cellular structure of the pieces found in the insect with the structures in fresh root tissues taken from the plants where the larvae had been feeding. The following tabulated statement indicates the approximate number and character of the particles of material found in the fore intestines of the larvae:

Total number of pieces of fresh plant tissue	1375	64.3%
" " " " " decayed plant tissue	419	19.0%
" " " " " mineral matter	344	16.0%

From the figures given it will be seen that from twenty-five larvae approximately 84.0% by volume of the material eaten was vegetable matter, and 64.3 per cent. of the total amount of material consumed was from the roots of living plants.

In an experiment started May 2, 1921, 200 three-ounce tin boxes were filled with the following materials and one larva placed in each tin. The object was to note the effect on the larvae, as shown by the mortality, of the presence or absence of living plant roots in the soil. Fifty tins were filled with rich sifted garden soil. Fifty tins were filled with sifted subsoil taken at a depth of four feet, containing 1.45 per cent of organic matter. Fifty tins were filled with subsoil to which was added pieces of partly decayed grass roots from which the soil had been washed. Three weeks after the experiment was started the tins were examined and the number of live and dead larvae were noted. Replicate series were conducted in the autumn using young larvae. The results obtained were similar. The following tabulated data gives the results obtained.

	Number dead in three weeks.	Per cent.
50 larvae placed in garden soil	27	54
50 larvae placed in subsoil	44	88
50 larvae placed in subsoil and decayed roots	22	44
50 larvae placed in garden soil and fresh sod	3	6

The data presented indicate that while the larvae may survive in the soil for a certain length of time without living roots upon which to feed, their presence is extremely important to the development of the grubs. This fact applies particularly to the summer, early autumn and spring, during which periods most of the feeding is done. This has also been borne out in our rearing cages where entire series have died for no apparent reason other than starvation when sod was not added to the soil.

Summary

In the past it was generally believed that the larvae of *Popillia japonica* fed largely on decaying organic matter in the soil. Observations made during the season of 1921 indicate that during the spring and autumn, when most of the feeding is done, live plant tissues constitute between 60 and 70 per cent of the food of the grubs.

Injury has been noted to grass sod in pastures, golf courses, especially on the putting greens. In some places the grass was killed in patches. It is probable that the most serious injury to grass land will occur through the destruction of the finer rooted species, particularly blue grass and red top.

The larvae form cells in the soil and feed on the plant roots either at the bottom or top of the cell. The movements of the larvae in the soil tend to be vertical and most of the feeding is done between ½ inch and 3 inches below the surface.

The larvae are positively thigmotropic to roots, stones, sticks or to the bottom or sides of the breeding cages.

Analysis of the material found in the fore intestines of the larvae indicates that plant tissues constitute about 67.33 per cent by weight of the total material eaten. When this material was examined microscopically it was found to be composed of somewhat uniformly sized pieces of fresh plant tissue, pieces of decayed plants, and particles of soil. The fresh plant tissue, on the basis of the number of pieces, constituted 64.3 per cent of the aggregate.

Experiments conducted in the laboratory indicate that the mortality of the larvae is greatly increased when they are in soil or subsoil without access to living roots, compared with the mortality occurring when they are in a mixture of soil and fresh sod.

EULIA MARIANA FERNALD, A NEW APPLE FEEDER IN PENNSYLVANIA AND SOME RELATED FORMS ON APPLE

By S. W. FROST, *State College, Pennsylvania*

This species has not been found as abundant as the red banded leaf-roller, *Eulia velutinana* Walker which was previously referred to in the Jl. Econ. Ent. Vol. XIII 6, 1920. Although it is not as abundant it has been repeatedly collected, feeding both on the foliage and the fruit of the apple. An insect survey of Pennsylvania made during the summer of 1921 revealed the species in several different counties, indicating that it is well established in this state and that it has apparently become adapted to the apple. Engel[1] (1908) records it from New Brighton, Pa. He notes that it was rare at that time and found it at rest on trees in the forest. Fernald[2] (1882) records it from Maine, Massachusetts and New York as a feeder on Oak. It has also been recorded as a feeder on Blueberry, Vaccinium by Smith[3] (1910). The larvae resemble the red banded leaf-roller in appearance, being entirely yellowish green in color and about three quarters of an inch long when full grown. They are similar in habits, the majority winter as pupae and the adults issue in the spring, laying their eggs in masses on the trunks and larger branches of the trees.

Since the original note on *Eulia velutinana* Walker, as a pest of apple, it has been found that the species passes the winter as pupae and