**Table 1.—Percentages of rutabagas infected with scab after application of heptachlor or parathion to soils of various acidities, and to soils to which various amounts of limestone were applied at seeding.**

| | PERCENTAGE OF RUTABAGAS INFECTED | | | | | |
|---|---|---|---|---|---|---|
| | No Lime Applied; Soil pH at Harvest | | | | | |
| INSECTICIDE[a] | 5.00 | 5.28 | 5.41 | 5.56 | 5.68 | 6.39 |
| Untreated | 0 | 0 | 0 | 0 | 0 | 12 |
| Heptachlor | 0 | 0 | 7 | 10 | 32 | 20 |
| Parathion | 0 | 0 | 5 | 15 | 30 | 18 |
| | Pounds/Acre Lime at Seeding; Soil pH at Harvest | | | | | |
| | 0 | 500 | 1,000 | 2,000 | 3,000 | 4,000 |
| | 5.00 | 5.50 | 5.61 | 5.78 | 6.23 | 6.68 |
| Untreated | 0 | 0 | 0 | 0 | 8 | 6 |
| Heptachlor | 0 | 0 | 13 | 35 | 65 | 65 |
| Parathion | 0 | 0 | 15 | 30 | 80 | 70 |

[a] Applied at 5 lb./acre with a subsurface applicator to give 5-inch bands 1½ inches below the seed in planting ridges.

METHODS.—The experiment was conducted on an area divided into 6 sections, with 4-foot buffer strips between sections. The sections had been treated in a rotation at 5-year intervals, beginning in 1937, with ground limestone at 0 to 4000 pounds per acre, the last application having been made in 1956. In the present experiment, half of each section was again treated at seeding with lime at the same rates as had been used in the rotation plan. The pH of the soil in each subsection, determined from samples taken at harvest, is given in table 1. The lime was broadcast and raked into the upper 3 inches of soil.

The insecticides, granules of 5% heptachlor and parathion, were applied with a machine that sowed the rutabaga seed and applied the precise amount of insecticide in the ridged row; rates and methods of application are given in table 1. The insecticide treatments and one untreated plot were replicated three times in single-row, 20-foot plots in each subsection. All treatments were randomized.

Laurentian rutabagas were planted on June 15 and final records were taken on October 25. All of the plants in the plots were examined for scab.

RESULTS.—Where no insecticide was applied, there was no scab injury on the rutabagas grown in the more acid soils (below pH 5.78) and only slight infection on those in the less acid soils, whether or not lime was applied at seeding (table 1). At pH values from 5.4 to 6.4 both heptachlor and parathion caused a marked increase in the percentage of infection, and in the subsections where lime was applied together with insecticide injury was moderate to very severe. In the subsections with pH 6.2 to 6.68, some of the insecticide and lime-treated plots had 100% infection, the portions of the rutabagas below ground level being almost completely covered with lesions.

There was no significant difference in yield between plots or subsections, although the soils with pH values from 5.5 to 6.0 produced the best type of rutabagas. At higher pH levels, the plants were excessively rooty.

Work now in progress indicates that the pathogen causing the scab on rutabagas is similar to common potato scab, *Streptomyces scabies*. Isolates from scab lesions on both potatoes and rutabagas are morphologically similar and have been found equally pathogenic on Green Mountain potato tubers.

DISCUSSION.—The insecticides evidently promoted development of the pathogenic organism, either directly or by breaking down a protective mechanism within the plant. Also, although lime did not in itself cause any noticeable effect, there was evidently a synergistic effect on development of scab infections when lime was used in combination with insecticide, although the mechanism of such action is not yet known.

Further work on the scab organism and other phases of the problem is being continued. The results reported herein suggest that lime should not be applied to mineral soils where soil treatments of either chlorinated hydrocarbon or organic phosphate insecticides are used against insects attacking rutabagas.

## Influence of Water and Previous Food on the Longevity of Unfed Larvae of *Coleomegilla maculata lengi*[1]

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Ability to survive at low density of prey increases the effectiveness of entomophagous predators. When food is scarce the quality of the available food may increase survival by prolonging the life of the predator and thereby increase its chance of locating food. This is perhaps most important for predators that have relatively weak powers of perception, such as those studied by Fleschner (1950) that were unable to perceive the prey until a physical contact was made. Banks (1956) showed that newly hatched larvae of the coccinellid, *Adalia bipunctata* (L.), that ate one egg of their own species lived twice as long as unfed larvae, but that water extended the life of unfed larvae by only a few hours. The effects of water, a sugar solution, and previously eaten food on the longevity of unfed larvae of *Coleomegilla maculata lengi* Timb. (Coleoptera: Coccinellidae) are discussed below.

MATERIALS AND METHODS.—*C. maculata* adults were kept in petri dishes and larvae in cells as Smith (1960) described for rearing coccinellids on dry food. The larvae used were the progeny of 10 females, three of which were fed the dead nymphs and adults of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch) (Homoptera: Aphididae). These aphid stages were dried at approximately 20° C. and reduced to a fine powder. The food given to the other adults was mainly composed of desiccated liver (Difco Co.). To reduce variation, larvae from the same egg mass were distributed to receive the following treatments: shortly after eclosion one-third of the first-instar larvae of an egg mass was placed individually in cells and given distilled water but no food; one-third was treated similarly except that no water was provided; and one-third was treated similarly except that a 5% solution of sucrose was provided. This procedure was repeated with larvae from other egg masses until there were at least 15 larvae in each group. The larvae were inspected frequently until death and the time lived by each was recorded. In other tests, half the first-instar larvae were reared on powdered aphids and half were reared on a dry powdered food composed mainly of brewers' yeast (Mead Johnson and Co.). Both groups were given water separately. Immediately after the first moult the second-instar larvae of both groups were divided; half of each was given water but no food, and half was given neither water nor food. Enough larvae were started so that the time lived from the first moult to death was recorded for at least seven individuals in each of the four groups. Larvae were similarly reared to the second and third moults for com-

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**Table 1.—Mean longevity and difference in the means for unfed larvae of *C. maculata* with water and without water and reared on *R. maidis* and on yeast.**[a]

| Treatment | Second Instar | | Third Instar | | Fourth Instar | |
|---|---|---|---|---|---|---|
| | Days Lived | Difference Between Foods | Days Lived | Difference Between Foods | Days Lived | Difference Between Foods |
| Water | 4.2 (3.6) | 0.6 | 4.2 (3.0) | 1.2 | 5.2 (4.7) | 0.5[b] |
| No water | 3.4 (2.7) | 0.7 | 3.1 (2.0) | 1.1 | 4.2 (3.4) | 0.8 |
| Difference between treatments | 0.8 (0.9) | | 1.1 (1.0) | | 1.0 (1.3) | |

[a] Results for yeast given in parenthesis.
[b] Significant at 5% level by F test. All other differences significant at 1% level.

parisons with third- and fourth-instar larvae. The work was done in the laboratory under controlled conditions of about 22° C. and 65% relative humiditiy.

RESULTS AND DISCUSSION.—The first-instar larvae given the sucrose solution lived 15.1±5.5 days, but did not moult. The time lived by unfed first-instar larvae was considerably shorter, but those given water lived longer than those without water. The mean number of days lived on water was 3.7 and without water was 3.2: the difference was significant by the F test ($P<.05$). When reared on *R. maidis*, each of the three larval instars was shorter than when reared on yeast. However, the differences between durations were significant ($P>.05$) only for the second instar. Unfed second-, third-, and fourth-instar larvae of *C. maculata* lived longer ($P<.01$) when given water and when reared on *R. maidis* than when reared on yeast (table 1).

Water increased the length of life of unfed first-instar larvae by about 16%. The need for water to replace that lost by respiration and excretion is reflected by this increase. The magnitude of the increase is probably in part attributable to small differences in the relative humidities of the rearing chambers used. The addition of 5% sucrose to the water further increased the life of the first-instar larvae by more than 300%. The times lived by the other instars with and without water indicate that the older larvae are better able to survive starvation, as Jacobson & Blakeley (1960) found also for *Agrotis orthogonia* Morr. (Lepidoptera: Noctuidae). Water encountered in the field by polyphagous species, such as *C. maculata*, probably contains various substances that may increase survival to a greater degree than the sucrose added to the water used here.

The author has found that *C. maculata* can be reared from first-instar larva to adult on the powdered stages of *R. maidis*, and also on yeast with relatively small mortality the details of which will be published later. It is not surprising, therefore, that no important differences were found between the developmental rates on these two foods. However, water had a greater influence on the length of life of unfed larvae reared on yeast than on those reared on *R. maidis*. The percentage increases in times lived by the various instars reared on *R. maidis* and (in parentheses) yeast were: second instar, 23 (33); third instar, 35 (50); and fourth instar, 24 (38). The larvae reared on aphids may have contained more water than those reared on yeast and therefore were better able to withstand desiccation. This would explain why the increases in the times lived by larvae reared on aphids over those reared on yeast are greater for individuals not given water than for those given water. The percentage increases in time lived by the various instars without food but with water and (in parentheses) without water were: second instar, 17 (26); third instar, 40 (55); and fourth instar, 11 (24).

The literature contains little detailed information on the influence of food quality on the rate of development of coccinellids. A possible reason for this is the difficulty of standardizing animal foods such as aphids and scales. Putman (1957) found that the larvae of the two coccinellids *Hippodamia convergens* Guer. and *Adalia bipunctata* (L.) required nearly twice the time for development when fed mites as when fed aphids. He found a smaller but significant difference for *C. maculata*, but suggested that the difference here was caused by the quantity of food rather than quality as this predator spent more time searching for mites than for aphids. It is known that many species of coccinellids eat foods other than the usual prey, particularly when the latter are scarce. Watson & Thompson (1933) showed that some fed at the nectar glands of plants and on sap, pollen, fungi, and honeydew. Some of these substances are probably nutritionally inadequate for normal growth but can supply sufficient energy to enable the predator to continue searching for foods of better quality. The sucrose solution used in the present studies is an example of a subsistence type food with potential survival value. The control value of many aphid-feeding coccinellids is often limited by their inability to find sufficient food at low prey density to bring them to maturity. The present study shows that water and food quality affect the length of life of larvae of *C. maculata* in the laboratory. In the field these influences may be of importance in determining the population density of a predatory coccinellid.

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