EFFECTS OF VARIOUS FACTORS ON THE LOCAL DISTRIBUTION AND DENSITY OF COCCINELLID ADULTS ON CORN (COLEOPTERA: COCCINELLIDAE)

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Abstract

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The adult densities of *Hippodamia tredecimpunctata tibialis* (Say), *Coccinella novemnotata* Hbst., and *Coccinella transversoguttata richardsoni* Brown, on corn fluctuated in July and August and reached their maxima at pollination, whereas the density of *Coleomegilla maculata lengi* Timberlake fluctuated much less. *C. maculata, H. tredecimpunctata,* and *C. transversoguttata* were more numerous on plants with a liver diet applied to their foliage than on untreated plants. *H. tredecimpunctata, C. novemnotata,* and *C. transversoguttata* were less numerous on plants that had their tassels removed and produced no pollen than on intact plants. *C. maculata, H. tredecimpunctata,* and *C. transversoguttata* were more numerous on plants exposed to the maximum amount of sunshine than on plants that were shaded for part of each day. *H. tredecimpunctata* was more numerous on plants situated at low elevation than at high elevation, whereas *C. transversoguttata* was more numerous at high than at low elevation. *C. maculata* and *H. tredecimpunctata* were more numerous on plants near the middle of a corn field than on plants at the perimeter of a field adjacent to buckwheat, whereas *C. novemnotata* and *C. transversoguttata* were most numerous on plants near the perimeter. Two-species associations of *C. maculata* and *H. tredecimpunctata, C. novemnotata* and *H. tredecimpunctata, C. novemnotata* and *C. transversoguttata,* and *C. novemnotata* and *H. tredecimpunctata* occurred on individual plants. Plant density and time of planting affected coccinellid density. Adult density was greatest at a plant density of 3.2 plants per square metre and adults were more numerous on early than on late planted corn.

Introduction

Spatial limitations caused by environmental factors are characteristic of coccinellids and these factors largely determine prey specificity (Iperti 1965). For example coccinellid species are vertically stratified in response to reactions to light, humidity, and gravity, and in response to food preference (Ewert and Chiang 1966). Also adult coccinellids can be aggregated with synthetic foods (Smith 1966). This paper reports the effects of food, insolation, plant elevation, habitat boundaries, plant density, and time of planting on the distribution of coccinellid adults on corn. The goal is to manipulate the distribution of coccinellid predators to make them more effective for the control of pest damage.

Methods

In 1963, adult coccinellids were identified to species and counted at regular intervals on 542 plants of corn variety Dekalb in a field of 16 plots arranged as a latin square (Fig. 1). Each plot had an area of 9.0 sq. m and a density of four plants per square metre. A border of trees located along the western margin of the field caused its eastern half to be exposed to sunlight for relatively longer intervals of time than the partly shaded western half. The northern half of the field was higher than the southern half. Buckwheat was planted around the field and this resulted in the four inner plots having borders of corn, whereas the outer plots had borders of buckwheat. To prevent the production of pollen, the tassels were removed from all plants in four plots between 29 July and 5 August. Corn pollen was collected with a sampling device described by Durham (1946). One of these

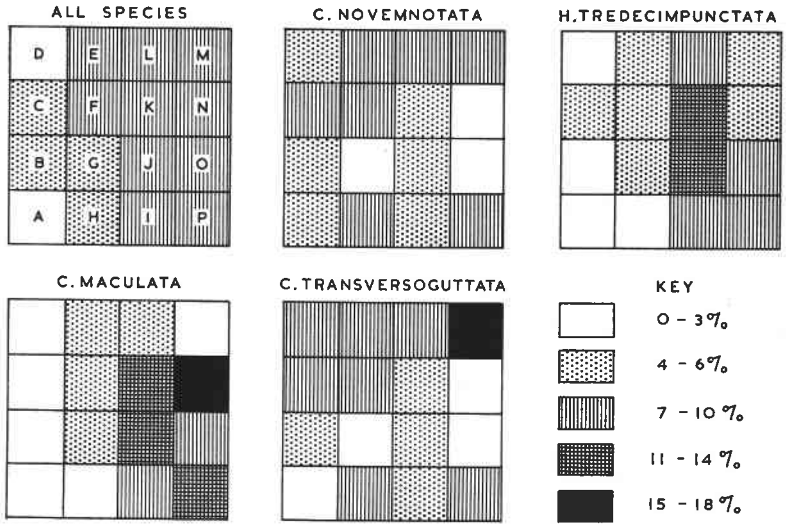

FIG. 1. Percentage distribution of adults of *C. maculata, C. transversoguttata, C. novemnotata,* and *H. tredecimpunctata* in July and August on 16 plots of Dekalb corn given various treatments: no tassels: D, G, I, and N; liver diet: B, E, K, and P; control: A, F, L, and O; yeast diet: C, H, J, and M.

was situated in a plot with, and one in a plot without tassels. Dry, powdered diets of pork liver and of yeast (Smith 1965*a*) were each dusted on the foliage of four plots on 24 and 31 July and on 8, 14, and 21 August. About 20 mg of diet was distributed over the whorl and three upper leaves of each plant. Censuses of coccinellid adults were made on 24, 25, 26, 29, 30, and 31 July and on 1, 2, 6, 8, 14, 15, 20, 21, and 22 August. The occurrences of tassels and silks, and the corn leaf aphid *Rhopalosiphum maidis* (Fitch), were recorded.

The frequency of occurrence of 0, 1, 2, 3, etc. adults on all plants was recorded and the mean number of adults per plant was calculated for all species combined and individually for *Coleomegilla maculata lengi* Timberlake, *Hippodamia tredecimpunctata tibialis* (Say), *Coccinella novemnotata* Hbst., and *Coccinella transversoguttata richardsoni* Brown for the weeks of 28 July and 4, 11, and 18 August. Values of chi-square with correction for continuity (Fisher and Yates 1948) were calculated to test for independence between the proportions of plants with one or more adults in various treatment groups and controls: liver diet vs. controls, yeast diet vs. controls, plants without tassels vs. controls, eastern vs. western, and northern vs. southern halves of the field, and plants on inner vs. those on outer plots. This was done for the four abundant species using pooled data of the censuses. Diets were compared with controls by pooling data for the days before and the days after application. Plants with and without tassels were compared before and after 6 August when the pollen drop began. When chi-square exceeded 3.84 with d.f. $= 1$ and $P < .05$, differences were attributed to treatment. Mean square contingency, i.e. chi-square/n, was used to measure association between pairs of the abundant species. Chi-square$-1/n$ was used as an unbiased estimator of the mean square contingency.

As individual corn plants vary in capacity to provide shelter and food for coccinellid adults and in their effects on light and temperature conditions, it is probable that changes in plant density influence adult density. This was investigated in 1965. Pride 432 corn was planted in 16 plots arranged as a latin square. The area of each plot was 7.5 sq. m. Four plots contained 12 plants each and four contained 24, 48, and 86 plants representing plant densities of 1.6, 3.2, 6.4, and 11.4 plants per square metre respectively. Coccinellid adults were identified to species and counted on all plots on 16 and 30 August and 2 and 10 September. Maximum and minimum air temperatures were recorded daily at the centre of plots with plant densities of 1.6 and 11.4 from 16 August to 10 September.

To determine the effects of differences in stage of development of corn plants on the number of coccinellid adults that are attracted to corn, four plots of variety Seneca Chief were planted on each of 3, 10, 17, and 24 June 1965 and arranged as a latin square. The area of each plot was 7.5 sq. m and each contained 24 plants. Adults were identified to species and counted in all plots on 17, 27, and 30 August.

Results and Discussion

The arrangement of coccinellid species in descending order of frequency of occurrence based on all censuses in 1963 was: *H. tredecimpunctata,* 32%; *C. transversoguttata,* 24%; *C. novemnotata,* 20%; *C. maculata,* 17%; *Coccinella trifasciata perplexa* Muls., 5%; and *Hippodamia parenthesis* (Say), 2%. All species except *C. maculata* were at highest density when corn pollen was dropping, i.e. 6–23 August, and after the occurrence of maximum numbers of *R. maidis* on 30 July (Fig. 2). Adult density was at maximum on 11 August when about half the plants contained one or more adults (Fig. 3). The greatest number of adults found on a plant was nine. The densities of all species except *C. maculata* increased during the last week of July and first 2 weeks of August and were highest when pollen was present. In contrast *C. maculata's* density remained relatively constant. The greatest number of copulating pairs of adults was observed on 11 August for all species except *C. maculata* and for *C. maculata* on 4 August.

Though adult numbers did not differ significantly on treated and control plants on the day before application of liver diet, within 1 day after treatment there were significantly more plants with one or more adults of *C. maculata* ($n = 2056$, chi-square $= 20.22$, $P < .001$), *H. tredecimpunctata* (chi-square $= 9.32$, $P < .01$), and *C. transversoguttata* (chi-square $= 21.33$, $P < .001$) in plots where liver diet was applied than in controls.

Application of the yeast diet did not affect coccinellid adult distribution. Adult numbers did not differ significantly on plants with and without tassels before 6 August but after this date there were significantly more plants with one or more adults of *H. tredecimpunctata* ($n = 1355$, chi-square $= 8.62$, $P < .01$), *C. novemnotata* (chi-square $= 22.15$, $P < .001$), and *C. transversoguttata* (chi-square $=$ 5.28, $P < .05$) in control plots than in those with the tassels removed. There were significantly more plants with one or more adults of *C. maculata* ($n = 8115$, chi-square $= 158.79$, $P < .001$), and *C. transversoguttata* (chi-square $= 8.94$, $P < .01$) in the eastern half than in the western half of the field. There were significantly more plants with one or more adults of *H. tredecimpunctata* ($n = 8115$, chi-square $= 8.62$, $P < .01$) in the southern half than in the northern half of the field, and significantly more plants with one or more adults of *C. transversoguttata* (chi-square $= 5.97$, $P < .02$) in the northern than in the southern half of the field. There were significantly more plants with one or more adults of *C. maculata* ($n = 8115$, chi-square $= 20.27$, $P < .001$) and *H. tredecimpunctata* (chi-square $= 54.59$, $P < .001$) in inner than in outer plots, whereas there were

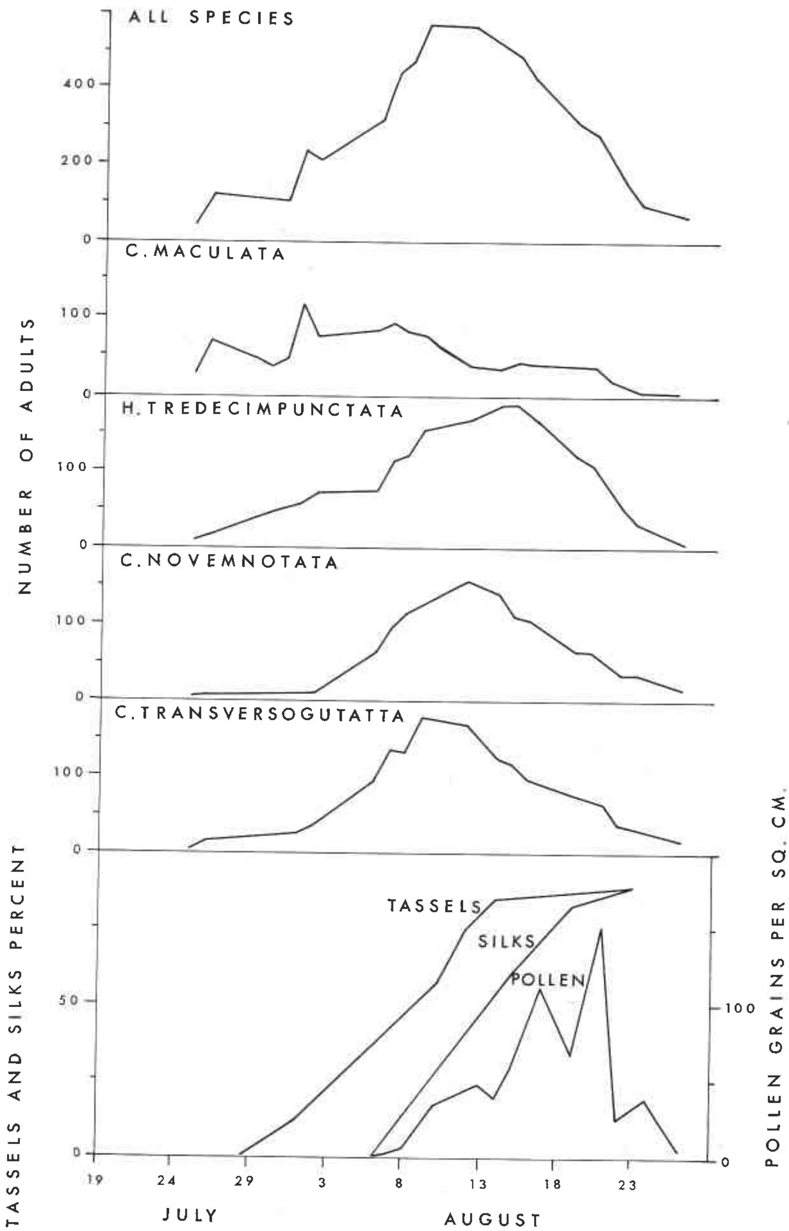

FIG. 2. Changes in numbers of coccinellid adults, occurrence of tassels and silks, and density of corn pollen on Dekalb corn.

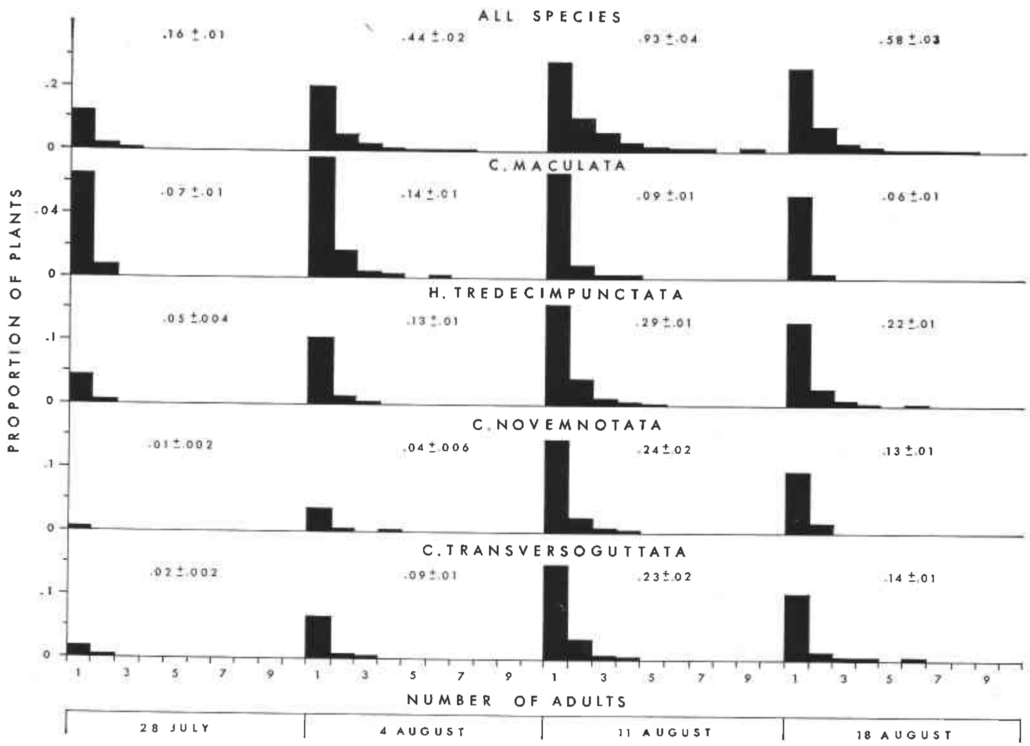

FIG. 3. Changes in the proportions of corn plants with one or more coccinellids at weekly intervals, and mean and standard error of number of adults per plant.

significantly more plants with one or more adults of *C. transversoguttata* (chi-square = 8.39, $P < .01$) and *C. novemnotata* (chi-square = 13.27, $P < .001$) in outer than in inner plots. The local distribution of the four most abundant species on corn is summarized in Fig. 1.

Association on individual plants was significant for *C. maculata* and *H. tredecimpunctata* (chi-square = 15.65, $P < .001$, mean square contingency = .03), *C. novemnotata* and *C. transversoguttata* (chi-square = 19.39, $P < .001$, m.s.c. = .03), and *C. novemnotata* and *H. tredecimpunctata* (chi-square = 9.85, $P < .01$, m.s.c. = .02).

Coccinellid adult density was greatest in plots with 3.2 plants per square metre. The mean numbers of adults in the various plots were: plant density 1.6–.06 adults; plant density 3.2–.17 adults; plant density 6.4–.07 adults; and plant density 11.4–.05 adults per plant. *C. maculata* and *H. tredecimpunctata* were most abundant in plots with 3.2 plants per metre, whereas *C. novemnotata* and *C. transversoguttata* were most abundant in plots with 1.6 plants per metre. Air temperature was regularly higher in corn plots with 1.6 than in those with 11.4 plants per metre. The mean and range of the differences were 2.1(0.5–8.6) °C.

Coccinellid adults were more abundant on early than on late planted corn. The relative numbers of adults recorded on 3, 10, 17, and 24 June were 1:.7:.6:0.5 respectively.

This work shows that the local distribution of coccinellid adults on corn is affected by natural and synthetic foods, insolation, plant elevation, habitat boundaries, plant density, and time of planting. Within limits it is feasible to manipulate all of these factors in control except natural foods and insolation. The findings support the work of Iperti (1965) and of Ewert and Chiang (1966) that the food specificity of coccinellid predators is affected by non-food factors and that distribution and density are regulated by a number of interacting factors. Though corn pollen is a preferred food of *C. maculata* in the laboratory (Smith 1965*b*), its availability in the field does not determine local distribution. Unlike other species, *C. maculata* can maintain a steady adult density during a period of increase in quantity of corn pollen. The liver diet was more effective in attracting coccinellid adults because it adhered to the foliage and was not washed off by rain as readily as the yeast diet. The responses of *C. maculata, H. tredecimpunctata,* and *C. transversoguttata* to sunlight indicate that for some species abiotic factors are more important than food in their effects on local distribution. It is not surprising that no inter- or intra-species competition was detected as coccinellid adult density on corn is generally low and quite variable. This indicates that adult populations will tend to increase and fluctuations in their numbers will be reduced by manipulation of the factors described here.

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