Foraging by a Predaceous Beetle, *Coleomegilla maculata* (Coleoptera: Coccinellidae), in a Polyculture: Effects of Plant Density and Diversity[1]

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ABSTRACT

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Experimental studies in a greenhouse demonstrated that the foraging rate per individual of a predaceous beetle, *Coleomegilla maculata*, on egg masses of the European corn borer was significantly reduced by increasing density, but not diversity, of the plants on which it foraged. In higher-density plantings, the beetles apparently spent more time foraging on plants that contained no food, indicating a certain degree of randomness in the foraging behavior of the beetle. These data help explain why observed predation rates on European corn borer egg masses were higher in field plantings of corn monocultures than the more densely planted corn-bean-squash polycultures. Since polycultures are nearly always more dense than their respective monocultures, intercropping may act to decrease the predation rate and abundance of certain insect predators or parasites.

Considerable attention has recently been focused on the potential of intercropping as a cultural method of insect pest control (Root 1973, Perrin 1977, Cromartie 1981, Risch 1981). Based on the theory cited by these authors, one of the advantages of polycultures is that they can support higher numbers of insect predators and parasites than monocultures and therefore can better control the herbivore pests. Yet this need not be the case. Associated plants in a polyculture can interfere with the chemical attractiveness of a plant to a herbivore's enemies, thus decreasing rates of predation and parasitism (Monteith 1960). In addition, polycultures are almost always more spatially complex and have more leaf surface area than monocultures; both features can decrease the foraging effectiveness of natural enemies (Huffaker and Messenger 1976, Need and Burbutis 1979).

Recent research in Ithaca, New York, has demonstrated that predation on European corn borer, *Ostrinia nubilalis*, egg masses by a predaceous beetle, *Coleomegilla maculata* (De Geer), was significantly higher in corn monocultures than corn-bean-squash polycultures (unpublished data). This paper describes experimental studies suggesting that a decreased predation rate per individual beetle may have significantly contributed to the lower predation rates.

Materials and Methods

Three nylon organdy cages (165 by 70 by 120 cm), were placed side by side in a greenhouse, and 18-day-old potted squash and bean plants, three plants per pot, were placed into the cages. Cage 1 had 15 bean pots, cage 2 had 15 bean pots and 15 squash pots interspersed, and cage 3 had 30 bean pots.

Two egg masses of the European corn borer, *O. nubilalis*, were attached to each of 15 bean plants in each cage, one to the upper surface of a leaf and the other to the lower surface of a leaf on the opposite side of the plant. The eggs had been laid on pieces of wax paper which were than pinned to the leaves.

Twenty *C. maculata* were caught in the field during September and released into each cage. After 24 h, the egg masses were removed and examined under a microscope to determine if any of the eggs had been eaten by the beetles. An egg mass was scored "eaten" if any of the eggs were eaten. Although the actual number of eggs eaten varied among egg masses, visual inspection indicated that there was no trend in number of eggs eaten per mass among the three treatments. After 5 replicate days of experiments, the plants in each cage were replaced by fresh plants and five more replicates were completed.

A two-way analysis of variance on the number of egg masses eaten in each cage was used (factor 1 = treatment, 3 levels; factor 2 = days, 10 levels). Factor 2 was included to account for day-to-day variation in temperature, humidity, daylight, and hunger levels of the beetles. Orthogonal contrasts (low density vs. high density [1, −1/2, −1/2] and polyculture vs. monoculture [0, 1, −1] were tested by Scheffé's criterion.

To estimate the leaf surface areas of the bean and squash plants, the leaves of 21-day-old plants (five pots bean, five pots squash) were removed and weighed. Squares (2.5 by 2.5 cm) were cut from the leaves of the bean and squash plants, 10 squares from each plant type. The mean weight of the squares was then used to calculate the leaf surface area for each pot of plants. An unpaired *t* test was used to compare the mean leaf surface area for pots of bean and squash plants.

Results and Discussion

The average numbers of egg masses eaten by *C. maculata* per cage for a 24-h period for the 10 replicates were as follows: cage one with 15 bean pots, 4.7 ± 0.97 egg masses; cage two with 15 bean and 15 squash pots, 2.8 ± 0.53 egg masses; cage three with 30 bean pots, 3.0 ± 0.60 egg masses. Significant differences were found in the means among the three treatments (ANOVA, $F_{CALC} = 3.67$, $P < 0.05$). The mean for cage one was significantly greater than the average of the means of cages two and three ($\text{Scheffé}_{2,18} = 2.665$, $4_{SL} = 2.699$, $P < 0.05$), but no significant difference was found between cages two and three ($\text{Scheffé}_{2,18} = 1.732$, $4_{SL} = 0.260$, $P > 0.25$).

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The mean leaf surface area for squash was 136 cm^2 per pot and for beans 152 cm^2 per pot. No significant difference was found between the means for the two types of plants (t = 1.705, $P > 0.10$). Therefore, cage one had about half the leaf surface area of cages two and three, which had about the same area.

Apparently plant density, but not diversity, had a significant effect on the foraging rate of *C. maculata*. When more plant material was provided, it seems that the beetles spent time foraging on it, even though there was no food on these plants, thus leading to the differences in predation rates. Yet the beetles seem not to have foraged completely randomly. Halving the plant surface area should lead to twice the predator density per plant. At the low predator density, 9.7% (2.9 of 30) of the egg masses were discovered and eaten. Doubling the predator density should result in another 8.7% discovered and eaten (9.7% of the remaining 90.3%). Thus, although we expected 1.90-fold higher predation in the less dense cage, we observed only 1.53-fold. There are two possible explanations: (1) when plant surface area was halved, there was an increase in interference among beetles and thus they may have had less time available for foraging; (2) foraging is not a completely random process, but beetles forage randomly only until they detect food items from a certain distance, and thereafter direct their movements toward the food.

These data can probably explain in part why there were lower rates of beetle predation on the European corn borer egg masses in the field polycultures of corn-bean-squash than the field monocultures of corn. In these field plots, corn density was the same in monocultures and polycultures; thus, total plant density was much higher in the polycultures. Equal numbers of egg mass baits were placed on corn plants in both treatments. Although *C. maculata* shows a preference for foraging on corn, we have frequently observed it on squash and beans as well. Time spent on these plants apparently decreases its foraging effectiveness on egg masses of the European corn borer.

If an insect colonizes a habitat in which the foraging success rate is low, one would expect it to leave, and in fact it has been shown for several insect species that decreased foraging effectiveness results in faster movement out of the nonproductive habitat (Thorsteinson 1960, Hassell and Southwood 1978). This of course results in lower population numbers in the less productive environment. In the same field polycultures of corn, beans, and squash in which we found lower predation rates on European corn borer egg masses, we also found lower numbers of the predator, *C. maculata* (unpublished data). If, as is reported by Obrycki (1978), the principal foods of *C. maculata* in a system such as ours are egg masses, aphids, and corn pollen, time spent foraging on bean and squash would be much less productive than time on corn (squash and bean plants had fewer aphids than corn and no borer egg masses; unpublished data). Based on the results of the laboratory experiment reported here, we suspect that *C. maculata* had more difficulty encountering prey in the more densely planted polycultures and therefore moved through the habitat more quickly, resulting in lower populations in the polycultures than monocultures. In support of this idea, Wetzler and Risch (unpublished data) have recently used diffusion modeling techniques to show that *C. maculata* move faster through corn-bean-squash polycultures than corn monocultures.

The plant populations in optimally yielding polycultures are usually higher than their respective monocultures (Kass 1978). In these cases the popularly accepted notion that intercropping will have a beneficial effect on the insect predators and parasites should be critically examined. The results of the present study show that a predator may forage less effectively in such polycultures because of the higher plant density. This in turn can ultimately lead to lower predator abundance.

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