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APHIDS AS BENEFICIAL INSECTS? EFFECTS OF A COTTON APHID-FIRE ANT MUTUALISM ON BIOLOGICAL CONTROL

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Abstract

We investigated the effect of a fire ant-aphid mutualism on the efficacy of red imported fire ants as predators of insect pests in cotton fields. In a series of greenhouse and field experiments we found that honeydew produced by aphids prompted fire ants to forage on cotton plants. This microhabitat shift resulted in more frequent encounters between fire ants and insects feeding on cotton plants. Consequently, fire ants reduced the densities of herbivorous arthropods in the canopy of cotton plants when aphids were present. In a caged greenhouse experiment we found reduced beet armyworm caterpillar survival in the presence of fire ants and aphids compared to fire ants alone. In our field experiment, the interaction between fire ants and aphids helped explain the distribution and abundance of caterpillars. Furthermore, this interaction and its resultant impact was density-dependent (i.e., greater aphid densities resulted in greater fire ant impact). Our results indicate that the fire ant-cotton aphid interaction may have a beneficial effect on cotton production and allow growers to predict the impact of fire ants on pests. This conclusion has far-reaching significance for understanding the efficacy of biological control in fire ant-infested areas.

Introduction

Red imported fire ants, *Solenopsis invicta* (Buren) (Hymenoptera: Formicidae), are extremely aggressive generalist predators that have expanded their range across the southeastern U. S. These insects generally occur at high densities in Southern agricultural fields and consequently fire ants may provide effective control of economically important pests in a variety of cropping systems. These include, but are not limited to, the boll weevil, *Anthonomus grandis* Boheman (Sterling 1978), sugarcane borer, *Diatraea saccharialis* (F.) (Negm and Hensley 1969), velvetbean caterpillar, *Anticarsia gemmatalis* Hübner (Lee et al. 1990), and rednecked peanutworm, *Stegasta bosqueella* (Chambers) (Vogt et al. 2001). Eubanks (2001) reported negative correlations between fire ants foraging in the canopy of cotton plants and many cotton pests. These results suggest that fire ants patrolling cotton foliage is favorable for cotton production because they repel insect pests and do not feed on or otherwise damage plant parts. Fire ants, however, are primarily ground-predators and more frequently forage on the soil surface. Thus, factors that serve to attract fire ants onto the foliage of cotton plants are likely to result in lower densities of insect pests and therefore should be encouraged by farmers.

One such factor that may persuade fire ants to explore the canopy of cotton plants is the presence of a common pest species, the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae). Aphids have evolved a unique physiological mechanism for feeding on plant sap that causes these insects to excrete a concentrated, sugar-rich solution called honeydew. Ants, in turn, collect and consume honeydew directly from the foliage of plants. Often this resource functions as a primary food supply for ants due to its abundance, especially in agricultural fields. When aphids occur at high densities in cotton fields they produce such large quantities of honeydew that cotton leaves glisten. This easily obtainable food source serves as a major attractant for fire ants. As a result, we predicted that when aphids feed on cotton plants, fire ants become more abundant on and actively defend plant parts that are particularly vulnerable to insect damage (e.g., leaves and bolls).

Materials and Methods

Greenhouse cages were constructed of a polyvinyl chloride (pvc) pipe frame (75 cm by 30 cm by 33 cm), covered with fine-mesh mosquito netting and placed in 37 liter plastic containers filled with potting soil. All cages contained one cotton plant (5-6 true leaves). Caged plants assigned to a fire ant treatment were connected to plastic pans (53 cm by 43 cm by 13 cm) containing a laboratory colony of ≈ 500 red imported fire ant workers. Colonies were started from local collections and were allowed to acclimate to greenhouse conditions for 24 h prior to the start of the experiment. Pans were connected to cages through plastic tubing (5 cm diameter) that acted as a foraging tunnel. All pans were lined with liquid teflon to prevent ant escape.

In our first greenhouse experiment we established four different treatments on cotton plants in the above-mentioned caged arenas: no aphids, low, medium, and high aphid densities. Cotton aphids were randomly selected from a greenhouse colony. Fire ants were given access to these caged arenas for 24 hrs, after which we cut all cotton plants at their base, placed them in plastic bags and froze them. One to two days later all frozen samples were examined and fire ants were counted. Ant density was compared between aphid treatments. In a second greenhouse experiment we established three treatments on cotton plants in caged arenas: no aphids, low and high aphid densities. Fire ants were again allowed access to cotton plants for 24 hrs. We then placed 7 third instar beet armyworm caterpillars on the foliage of cotton plants in all three treatments and caterpillar survival was recorded over a 6 hr period.

Field research was conducted from May through September 2002 in cotton fields at the E. V. Smith Research Station in Tallassee, AL. One acre cotton field plots were randomly assigned to high or low fire ant density treatments and established using Amdro (granular bait, Hydramethylnon, 40.15 g AI/ha), a commercially available fire ant bait. Amdro is a granular insecticide that is effective at controlling fire ant densities with little to no impact on non-target arthropods. We applied Amdro to low fire ant density field plots at four times during the field season at a rate of 1 kg/acre. Caterpillars were sampled approximately weekly throughout the growing season using beat cloth sampling (4 samples per plot). We spread a 1-m^2 cloth on the ground between two rows of cotton. Six cotton plants, three from each row, were vigorously shaken over the cloth. All caterpillars dislodged onto the cloth were identified and counted. Aphid sampling consisted of visually searching the upper six leaves of one random cotton plant, counting all visible aphids on the top and bottom of each leaf. Four random plants were visually searched per plot.

Results and Discussion

In a caged greenhouse experiment, fire ants were attracted to aphids present on the foliage of cotton plants (Figure 1; $F = 40.53$, $df = 3$, $p < 0.0001$). In a similar greenhouse experiment, aphids, in the presence of fire ants, had a negative effect on beet armyworm caterpillar survival (Figure 2; $F = 40.87$, $df = 2, 236$, $p < 0.0001$). Furthermore, increasing aphid density enhanced the negative impact of fire ants on caterpillars. In a field experiment, aphid density and fire ant presence interacted to determine the distribution and abundance of caterpillars (Figure 3; aphid X RIFA interaction, $F = 5.36$, $df = 1$, $p < 0.025$). In low fire ant density field plots we found a positive relationship between aphids and caterpillars. In high fire ant density plots we found a negative relationship between aphids and caterpillars.

Results from our experiments juxtaposed with current aphid control strategies present a paradox for cotton producers. On one hand, cotton aphids are regarded as primary pests that can significantly reduce yields when occurring at high densities (e.g., Head 1992). Therefore cotton farmers are advised to use chemical control when aphid densities exceed a certain threshold in their fields. Our data, however, suggest that aphids are beneficial for the management of caterpillars and other damaging pests in fire ant-infested areas. Therefore aphid control may detract from the overall effectiveness of biological control programs. Recognizing that aphids are not simply pests, but have beneficial attributes may be justification for reevaluating aphid management in cotton fields. Secondly, by encouraging higher aphid densities, outbreaks of primary cotton pests (e.g., bollworm) may occur less frequently. This approach requires a more comprehensive awareness of interactions among insects occupying cotton fields than currently exists. The advantages, however, of employing natural control agents, such as red imported fire ants, are numerous.

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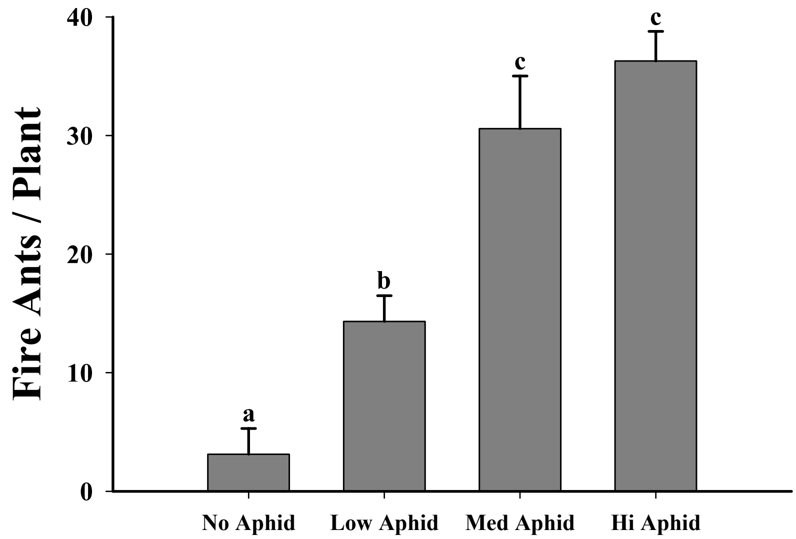

Figure 1. The effect of aphid presence and density on fire ant recruitment to the foliage of cotton plants in a greenhouse experiment. Means with different letters are different at the $P = 0.05$ level (Bonferroni test).

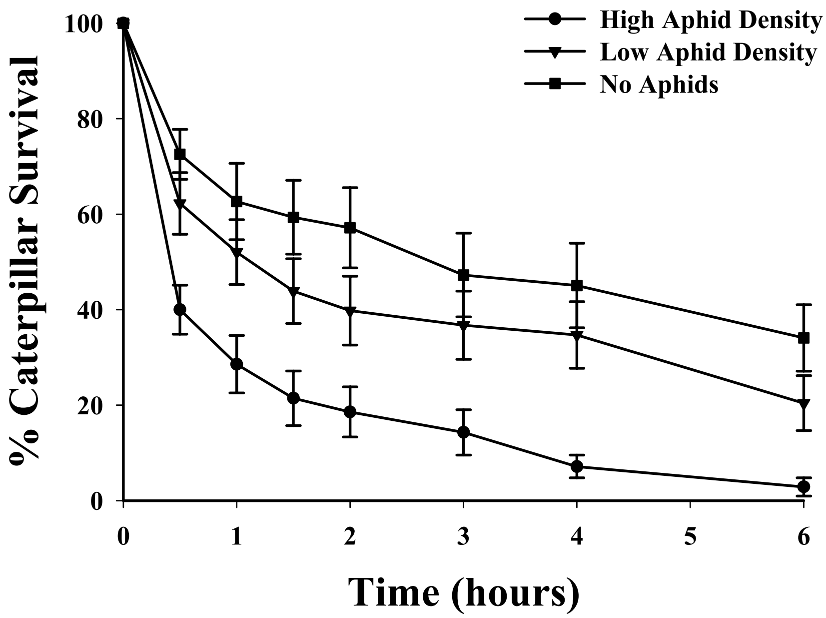

Figure 2. The effect of cotton aphids, in the presence of fire ants, on the survival of beet armyworm caterpillars in a greenhouse experiment.

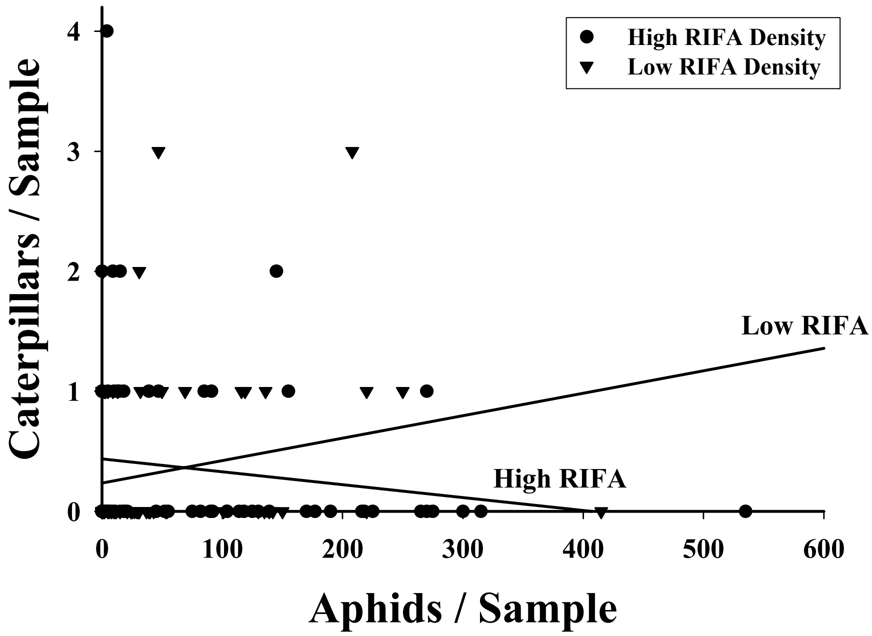

Figure 3. The effect of cotton aphid and fire ant densities on the distribution and abundance of caterpillars in a field experiment.