

Role of Indigenous Coccinellids in Regulating Greenbugs (Homoptera: Aphididae) on Texas Grain Sorghum

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ABSTRACT The effectiveness of the native coccinellid predators of the greenbug, *Schizaphis graminum* (Rondani), was determined in Texas high plains grain sorghum using exclusion techniques. The most abundant greenbug predators encountered were *Hippodamia convergens* (Guerin-Meneville) and *H. sinuata* (Mulsant). Natural enemies showed no significant suppressive capacity during the early portion of the growing season, though both *Hippodamia* species were frequently observed. Selective exclusion of adult *Hippodamia* spp. and larger predators demonstrated the efficacy of these enemies throughout the latter portion of the growing season. Introduction of the two coccinellid species into cages excluding all enemies indicated their capacity to reduce greenbug density in light or moderate greenbug infestations. Regulation of greenbugs in Texas high plains grain sorghum is largely due to the suppressive action of *Hippodamia* spp., not the common greenbug parasites of the region.

THE GREENBUG, *Schizaphis graminum* (Rondani), is a key pest of United States-grown grain sorghum and small grains, and is routinely the object of insecticidal treatments in Texas (Bottrell 1971). A variety of natural enemies contributes toward reducing greenbug (GB) density (Teetes et al. 1975, Teetes 1976, Young and Teetes 1977, Kring and Gilstrap 1983, 1984).

Coccinellids play an important role in aphid regulation and often have the strongest impact of all aphidophagous insects (Hodek 1970). Several coccinellid species are reported as GB predators in the southwestern United States, including *Hippodamia convergens* (Guerin-Meneville), *H. sinuata* (Mulsant), *Scymnus* sp., *Coccinella septempunctata* L., *Menochilus sexmaculatus* (F.), and *Propylea 14-punctata* (L.) (Jackson et al. 1970, 1971, Rogers et al. 1972, Cartwright et al. 1977, U.S. Department of Agriculture 1979, Kring and Gilstrap 1984). However, evidence that shows the effectiveness of coccinellids in regulating the GB or other aphids is limited (Hodek 1970, Kring and Gilstrap 1984). Kirby and Ehler (1977) used an indirect study of predator efficacy to conclude that *H. convergens* was ineffective due to maximum generation mortality of the predator during its egg stage.

Direct evaluation of coccinellid efficacy involves comparison of GB density or damage in plots containing coccinellids with density in plots not containing coccinellids. Direct evaluation of enemy efficacy provides the only proof of pest regulation (Hodek 1970, DeBach and Huffaker 1971). De-

scription of coccinellid effectiveness in regulating GB on grain sorghum can aid in development of improved pest forecasting methods, thereby improving pest management techniques.

This experiment is a direct evaluation of effectiveness of the predominant coccinellid species in regulating GB on Texas grain sorghum.

Materials and Methods

The experiment was conducted in a 1-ha field of grain sorghum during 1982 and 1983 at the Texas Agricultural Experiment Station near Amarillo. Three types of cages were used in the experiment. Cage types were replicated temporally and physically each season. The cage types consisted of tubular cages enclosing a single sorghum leaf (leaf cages); cylindrical cages covering one whole plant (single-plant cages); and large cages covering ca. 30 plants (multiple-plant cages). These cages hereafter will be referred to as "leaf," "SP," and "MP" cages, respectively. All cage types were placed at regular intervals along a diagonal transect across the field.

Cage Designs

Leaf Cages. Leaf cages were constructed of a 0.6-m length of 1.6-mm polycarbonate Lexene cylinders (7.5 cm diam). Cages had four 5-by-15-cm openings on the cylinder sides, each of which was covered with fine Lumite saran cloth (21 cells per cm) for air circulation. The ends of each cage were plugged with 5-cm-thick foam discs. One of these discs was divided, holding the leaf between the halves, thereby securing it in the cage. Wooden supports held the leaf cages close to the plants

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and prevented excessive cage and leaf movement during periods of high wind velocity. Thirty-nine of these cages were constructed for use in the studies.

Single-plant Cages. SP cages were constructed of modified 5-gal white plastic buckets. Four 15-by-15-cm openings were cut in the sides of each 30-cm-diameter bucket and covered with saran mesh. Bucket bottoms were removed and also covered with mesh. The buckets were inverted and placed over a randomly chosen grain sorghum seedling. Thirty of these SP cages were placed in the field each year.

Multiple-plant Cages. MP cages (1.8 by 1.8 by 1.8 m) were placed over two rows of newly planted grain sorghum. The cages were constructed of saran mesh (21 cells per cm) suspended by 2.5-cm-diameter conduit frames. The lower edge of each cage was initially buried 30 cm in the soil, thus completely enclosing the sorghum plants. Eight of these cages were erected diagonally across the study field. Hygrothermographs were placed in two of the cages for dynamic monitoring of environmental conditions.

Experimental Treatments

Two basic treatments were applied to each cage type, and a third was added to leaf cages in 1983. A number of the available cages of each type were modified to allow natural enemies access to the enclosed aphids and plants. Secondly, selected natural enemies were introduced at specified rates into some MP cages. Treatment types were randomly designated after the cages were placed in the field.

Leaf Cages. Thirteen ($\frac{1}{3}$) of the leaf cages were modified to allow all natural enemies access to the caged area, thus serving as control cages. Access was allowed by cutting a large semicircular hole (5.5 cm diam) in the foam plug where the leaf entered the cage. The second third were modified to prevent access by large coccinellid adults. The plug at the point of leaf entry into the tube was modified as above. The large hole in the plug then was covered with a coarse nylon mesh (8 cells per cm) which allowed parasites and small predators to enter the cage, but prevented large predators from having access. These cages were used only in 1983 and served as selective exclusion cages. Preliminary laboratory tests showed that *Hippodamia* spp. adults were unable to pass through the mesh, while the predominant parasite species and several other predators (*Scymnus* sp., syrphids, chrysopids, and anthrocorids) moved freely through the mesh. The final third of the leaf cages remained unmodified and served as exclusion cages.

Single-plant Cages. Fifteen ($\frac{1}{2}$) of the SP cages were modified to allow natural enemies access to the caged plant. The saran mesh was removed from three of the four openings in these control cages.

Table 1. Indigenous dominant coccinellid species composition and effectiveness treatments in Texas high plains grain sorghum during 1982 and 1983

	<i>H. convergens</i>	<i>H. sinuata</i>
% Field ^a		
1982	45	55
1983	32	68
% Introduction ^b		
1982	50	50
1983	30	70

^a Based on field samples of 50 adult beetles semiweekly.

^b Introductions into multiple-plant cage treatments at coccinellid densities of two adult beetles per plant (30 plants per cage).

When placed in the field, the one cage opening covered with mesh was oriented toward the prevailing winds. The remaining half were left unmodified to exclude completely all natural enemies from the cage, and are termed exclusion SP cages.

Multiple-plant Cages. Four ($\frac{1}{2}$) of the MP cages were modified to allow access to natural enemies. The sides of these control cages were raised so that the entire cage perimeter had a 30-cm opening between the lower cage edge and the ground. One of the remaining four cages was used for introductions of the most abundant coccinellid species in the area, *H. convergens* and *H. sinuata*. These introductions were made at peak GB densities in 1982 (ca. 2,200 per plant) to assure establishment of the coccinellids inside the cages. The two species were introduced into MP cages at average densities of two adult coccinellids per plant. They were introduced in the same relative proportions as occurred in the field, based on biweekly samples of adult *Hippodamia* sp. (Table 1). The final three cages were left unmodified, and served as exclusion MP cages.

Sampling Methods

Aphid and natural enemy densities on plants in cages were censused by direct counts of all insects. Counts were recorded with laboratory counters and an electronic data recording device (OmniData Polycorder Model 516-A). All plant material was examined in the leaf and SP cages. Five of the approximately 30 plants in MP cages were randomly chosen and marked after seedling emergence. Insects were censused on these selected plants throughout the season. Counts were made on alternate days in leaf and SP cages, and twice weekly in MP cages. Natural enemy densities in control cages were censused at the same time as aphid densities. Parasite activity was monitored by counting parasitized aphids (mummies). Predators (adult and larval) appearing in leaf and SP cages were counted on each census date. Because of mobility, predator densities in MP cages were recorded as class values (0, 0 predators; 1, 1-5; 2, 6-10;

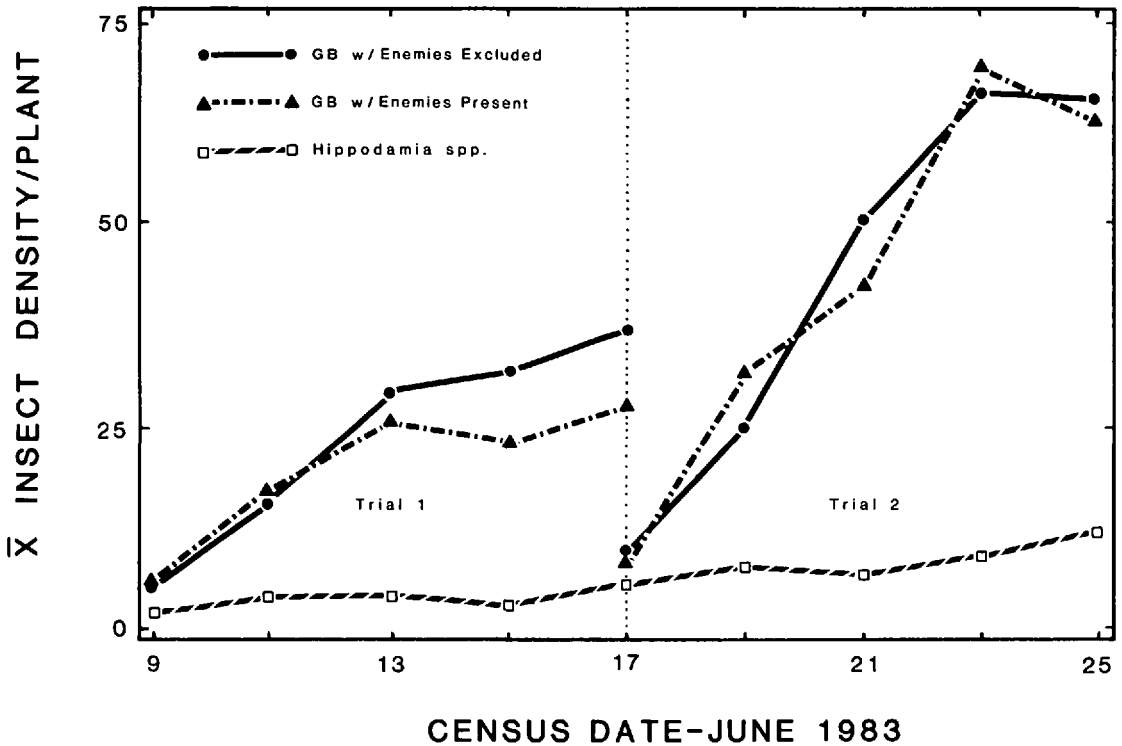


Fig. 1. Greenbug and coccinellid densities in control and exclusion single-plant cages before the eight-leaf stage of sorghum development during 1983.

etc.) for each predator species. Plant damage and developmental stage as categorized by Vanderlip (1972) were recorded also on each census date. Insect densities were compared among cage types by *t* tests.

Experimental trials were initiated in all cage types by infestation of plants in the cages with known numbers of biotype-E GB from laboratory cultures. Plants in control cages were also subject to attack by aphids moving into cages through the openings. Leaf cages were infested with five adult GB when plants attained the eight-leaf stage of development, allowing description of enemy efficacy during the latter portion of the growing season. Following leaf death due to GB feeding, cages were moved to enclose new leaves and then reinfested with GB. This relocation allowed additional replication of the leaf cage experiment through time within each season. Each SP cage was infested with two adult GB shortly after seedling emergence, allowing description of enemy efficacy in the early portion of the season. All plants in MP cages were infested with one adult GB shortly after seedling emergence, and were monitored throughout the season.

Results and Discussion

Meaningful comparison of data from control and exclusion cages requires that access by natural ene-

mies be the only variable that differs between cage pairs. Temperatures and relative humidities were not significantly different in control and exclusion cages ($P > 0.25$). Rain and hail effects were essentially the same for cage pairs due to cage designs. Therefore, only the presence or absence of natural enemies was different between cage pairs.

Several coccinellid species were encountered during the course of the experiment. These were *H. sinuata*, *H. convergens*, *Scymnus* sp., *Coleomegilla maculata lengi* Timberlake, and *Olla v-nigrum* (Mulsant), in descending order of abundance. More than 90% of these predators consisted of the two *Hippodamia* species. The *Hippodamia* spp. were introduced into MP cages at densities based on their relative abundance in the field (Table 1).

Natural enemy efficacy was evaluated before the eight-leaf stage of sorghum development and was accomplished by use of SP cages. GB were not observed in the field during 1982 until nearly 3 weeks after sorghum emergence. However, GB were observed in 1983, 4 days after seedling emergence, and provided a clear definition of coccinellid activity in the early season (Fig. 1). GB densities in control and exclusion cages were not significantly different for either trial ($P < 0.05$). Coccinellids were present in control cages and in the field, though their activity was apparently not sufficient to cause significant reduction of GB den-

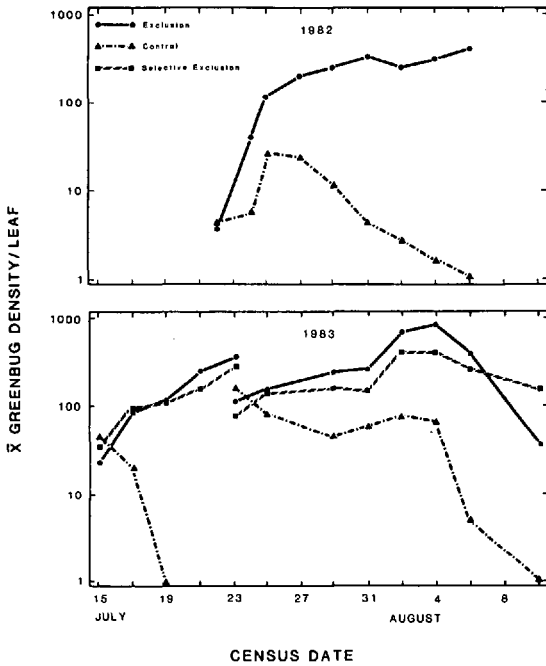


Fig. 2. Greenbug densities in control and exclusion leaf cages during 1982 and 1983, and selective exclusion cages during 1983.

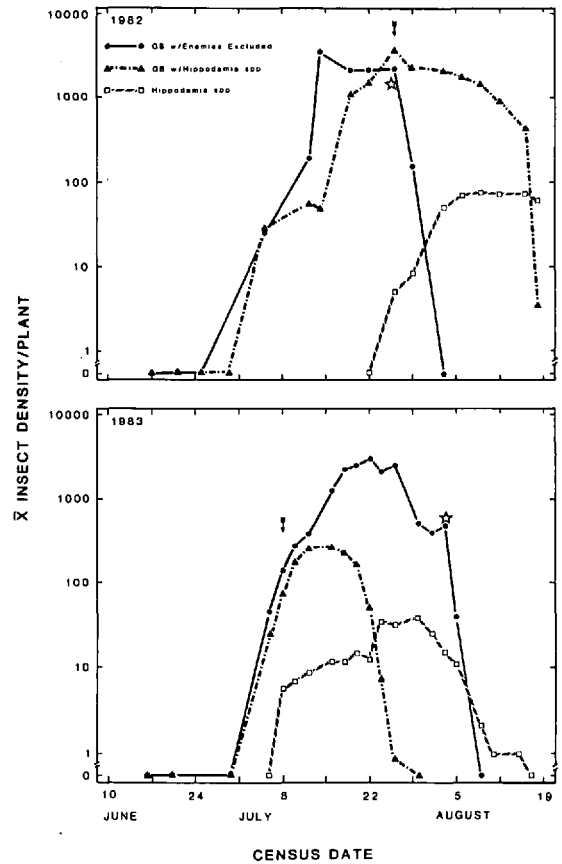


Fig. 3. Greenbug and coccinellid densities in exclusion and coccinellid treatments in multiple-plant cages during 1982 and 1983. Star (☆) denotes date of ca. 90% leaf desiccation due to greenbug feeding damage. Coccinellids introduced into cages at time indicated by the arrow.

sities. Apparent coccinellid inappetence during the spring season has been described for adults emerging from a dormant state in other predator/prey systems (Hodek 1973). *Coccinella septempunctata* and *Adalia flavomaculata* Goetz consume a reduced number of aphids and have increased larval stadia below certain threshold temperatures (Hodek 1973, unpublished data).

GB densities in exclusion leaf cages in 1982 and 1983 increased rapidly within 3 days of infestation at the eight-leaf stage of development, and were significantly different from GB densities in control cages ($P < 0.05$) (Fig. 2). We attribute the suppression of GB densities in control cages to the combined action of the predators and parasites operating in the sorghum agroecosystem. Abundance of adults of the two *Hippodamia* species in 1982 suggests that these insects are the key factors in GB suppression (Fig. 2). Selective exclusion of the large coccinellid adults in 1983 enabled separation of the regulatory impact of these predators from other natural enemies. GB densities in exclusion cages were never significantly different from GB densities in selective exclusion cages (Fig. 2). These data indicate that the level of GB suppression in Texas grain sorghum subsequent to the eight-leaf stage is due to the combined action of *H. convergens* and *H. sinuata*. *Lysiphlebus testaceipes* (Cresson) and *Aphelinus varipes* (Foerster), common GB parasites in Texas (Gilstrap et al. 1984), were encountered in control and selective exclusion cages at peak densities of 55 per leaf, or about

30% parasitism. Parasite densities were not significantly different ($P < 0.05$) in the control and selective exclusion cages. Although mummified GB were numerous, the lack of a significant difference between GB densities in the exclusion and selective exclusion cages indicates the lack of suppressive effect of these parasites before the hard dough stage of sorghum seed development. At this stage of development, about three-fourths of the grain dry weight has accumulated and nutrient uptake is essentially complete (Vanderlip 1972).

Introducing the predominant coccinellid species into MP exclusion cages in 1982 caused very little GB density reduction, but these plants sustained less visually observable injury than plants in cages without enemy activity (Fig. 3). Plants in these coccinellid release cages did not produce panicles due to the high level of damage incurred before coccinellid introduction. Releases of the coccinellids in 1983 were made earlier and at smaller (350 per plant) GB densities (Fig. 3). The action of the predators in exclusion cages had an immediate

suppressive effect on GB densities. Coccinellid densities responded numerically as they did in 1982.

Studies of this type provide accurate evaluation of the effectiveness of natural enemies operating in a given agroecosystem. Although parasites have been implicated as the key regulating factors in several previous studies (Walker et al. 1973, Teetes 1976, Wiseman and Morrison 1981), the level of GB regulation obtained during this experiment was undoubtedly due to the action of the two *Hippodamia* species. The high visibility and large numbers of mummified GB in previous studies apparently contributed to overestimating the regulatory impact of parasites.

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