Damage by Greenbug (Homoptera: Aphididae) to Grain Sorghum as Affected by Tillage, Surface Residues, and Canopy[1]

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ABSTRACT Different cropping systems for grain sorghum were studied at two Texas locations and one Nebraska location to determine effects of tillage practice, cropping systems, crop residues, and plant canopy on greenbug, *Schizaphis graminum* (Rondani), abundance and crop damage. In each case, reduced tillage or crop residues on the soil surface (or both) resulted in a decreased number of greenbugs and amount of plant injury. In one study, a greenbug-resistant grain sorghum hybrid conventionally tilled was more severely damaged than a susceptible hybrid planted in a no-tillage situation, indicating the negative effect of reduced tillage on greenbug abundance. Influence of reduced tillage on greenbug density occurred on plants in plots as large as 2.8 ha. In one grain sorghum field, a dense canopy of a weedy grass that obscured furrows substantially reduced greenbug infestation. In other fields, independent of surface residues and canopy, greenbugs seemed to distinguish between amount of cultivation and preferred plants growing in soil with the greatest amount of disturbance. Apparently, greenbugs respond to background conditions of the host plant associated with tillage operations and seem to be repelled by crop residues, canopy, and the reduced tilled soil surface.

KEY WORDS *Schizaphis graminum*, sorghum, no-till, cropping systems, plant resistance, mulches

THE SOIL CONSERVATION Service, USDA, has predicted that as much as 95% of United States cropland will be cultivated by conservation tillage by the year 2010 (Myers 1983). Many beneficial factors result from conservation tillage; among them are conservation of soil, water, and energy (Fenster et al. 1977). This major shift to maintaining crop residues on the soil surface, rather than burying them by conventional tillage, will significantly influence density of insects (Gregory & Musick 1976). Therefore, management of insects under minimum and no-tillage systems must be addressed.

Burton & Krenzer (1985) showed that when tillage was reduced in winter wheat fields, resulting in more crop residues on the soil surface, greenbug, *Schizaphis graminum* (Rondani), numbers were dramatically lower. This reduced aphid density was attributed to the different light reflectivities associated with surface residues and soil surfaces. This response to crop residues significantly reduced greenbug host finding and host selection. A similar repellent effect on other aphids by reflective mulches has been exploited effectively in vegetable culture (Kring 1972) to increase yields by delaying the onset of diseases vectored by settling aphids. Apparently, aphids ready to alight are repelled by the shorter wavelengths (<0.5 μm) emitted from the sun and reflected by the mulches (Moericke 1955). Furthermore, Kennedy et al. (1961) concluded that alighting aphids are eminently attracted to contrasting wavelengths radiating from a combination of bare soil and adjacent plants. Greenbugs on winter wheat (Burton & Krenzer 1985) apparently responded to background stimuli in a manner similar to other aphids as described by Kring (1972), Moericke (1955), and Kennedy et al. (1961). Greenbugs distinguished between mulched and unmulched surfaces, differing amounts of residue, and the tilled and untilled condition of the soil surface around the plants.

Because residue management proved to be a possible population management technique for greenbugs in wheat, the study described here was done to determine if this management practice

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would also function in grain sorghum, another host of greenbugs. The development of this greenbug-management scheme would be particularly important in dryland sorghum where conservation tillage systems are being strongly recommended for soil and water conservation.

Materials and Methods

A damage rating system for sorghum (Teetes et al. 1975a) was used throughout this study, except when counts of greenbugs were made, to determine greenbug injury levels to plants. The rating scale for evaluating greenbug damage to sorghum was (natural senescing leaves were not included): 1, no damage; 2, red spotting; 3, red spotting plus a portion of one leaf killed; 4, one dead leaf; 5, two to three dead leaves; 6, four to five dead leaves; 7, six to seven dead leaves; 8, eight or more dead leaves; and 9, dead plant.

Because samples were evaluated at different experiment locations, the number of samples and type of tillage varied depending on location. However, the number of samples taken in the reduced-tilled treatment plots always equaled the number taken in the conventional-tilled control plots.

Bushland, Tex.

Sorghum plots at Bushland, except for the plots of continuous sorghum (CS), were grown under a wheat/sorghum/fallow (WSF) system, which is a major cropping system used on the Texas High Plains. This system follows a winter wheat/fallow/grain sorghum/fallow cycle and allows for two grain crops every 3 yr, with an 11-mo intervening fallow period after each crop (Unger 1972).

Cropping Systems Study. Plant damage ratings and insect density counts were taken in 1984 and 1985, respectively, on a replicated dryland cropping systems study done on bench terraces. A randomized complete-block design consisting of four treatments and three blocks was used for both years. The four cropping treatments evaluated were conventional tillage (conv-till) and no tillage (no-till) on sorghum grown in WSF and CS cropping sequences. The conv-till plots were established with large sweeps (used to control weeds and prepare seedbeds), which resulted in little or no residue remaining on the soil surface when the sorghum was planted. On the no-till plots, weeds were controlled with herbicides, and all crop residues (1,500–2,500 kg/ha) were left on the soil surface. Plots planted on the leveled bench terraces were 12 rows (76 cm) wide and 145 m long (ca. 0.13 ha). On 26 June 1984, no-till plots were planted with DeKalb 'DK-42Y', a hybrid susceptible to greenbug biotype E, and the conv-till plots were planted with DeKalb 'DK-46', a resistant hybrid. According to Kindler et al. (1984), biotype E was the predominant biotype in the area. In 1984, 10 random plants per treatment replication were rated for damage 58 d after planting. In 1985, all plots were planted with DeKalb 'DK-42Y' on 17 June. Treatment effect was determined 65 d after planting by counting the number of greenbugs per plant on 10 randomly selected plants per treatment replication.

Paired Plots. Two unirrigated graded terraces, ca. 2.8 ha, each cropped in a WSF sequence were used for this test. One terrace received conventional tillage with large sweeps. This, combined with five tillage operations to control weeds during the 11-mo fallow period between wheat harvest and sorghum planting, resulted in no residue remaining on the soil surface. The other terrace received no tillage (weeds were controlled with herbicides), which left the wheat residue entirely on the surface. In 1984, DeKalb 'DK-46' was seeded on 25 June and 14 random samples of 10 plants were rated for each treatment (280 plants) 59 d later. In 1985, both plots were planted with DeKalb 'DK-46' on 18 June and 10 random samples of 25 plants were rated (500 plants) 52 d later.

Tillage-level Plots. Three treatments, conv-till, minimum tillage (min-till), and no-till, were evaluated in an unirrigated WSF system for their effect on greenbug damage. The conv-till plots were chiseled after wheat harvest and cultivated with sweep cultivations four times before planting. The min-till plots had two spring sweep cultivations followed by an application of glyphosate for additional weed control. The no-till plots received glyphosate for weed control before planting. The plots were 27 by 300 m and were planted with Funks 'G-499', a hybrid susceptible to biotype E. Terbutryn was applied as a preplant weed control, and escaped weeds were controlled by cultivation (except for the no-till plot) and 2,4-D. Fifty randomly selected plants were rated for each plot ($n = 150$) 58 d after planting using the damage rating system.

Etter, Tex.

DeKalb 'DK-57' sorghum in irrigated plots was evaluated for greenbug damage on 9 August 1985, 78 d after planting. Two treatments, conv-till and no-till, were replicated once across a 3-ha field in an alternate pattern. Each plot consisted of eight 100-cm rows (each 411 m long) planted on 24 May. Seven samples of 25 plants were evaluated for damage in each of the four eight-row plots, for a total of 700 rated plants.

North Platte, Nebr.

Plots at this location were not irrigated and were initially used for studying weed control by herbicides. A total of 64 plots, consisting of six rows (76 cm wide, 9 m long), was planted with Funks 'G-1460', a hybrid susceptible to biotype E, under a no-till regime following winter wheat on 22 May 1985. One-half of the 64 plots, randomly selected, had the residue removed by hand raking, estab-

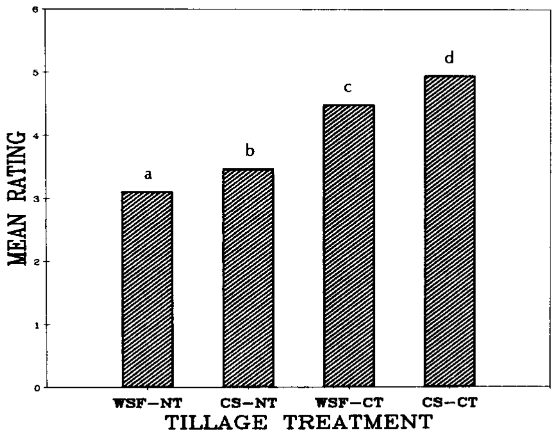

Fig. 1. Plant damage in 1984 for the cropping systems study at Bushland, Tex. Histograms with different letters are significantly different ($P < 0.05$; Duncan's [1955] multiple range test). NT, no tillage; CT, conventional tillage.

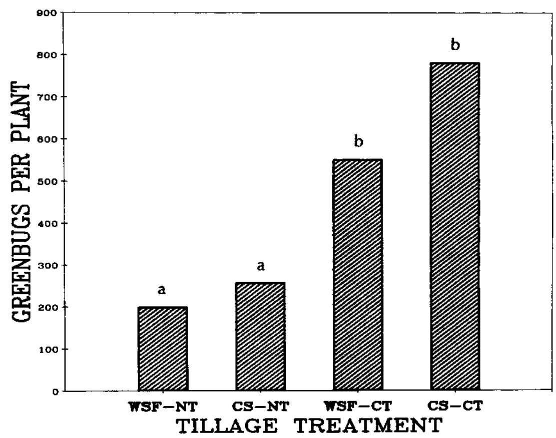

Fig. 2. Greenbug counts in 1985 for the cropping systems study at Bushland, Tex. Histograms with different letters are significantly different ($P < 0.05$; Duncan's [1955] multiple range test). NT, no tillage; CT, conventional tillage.

lishing residue levels of 3,640 and 350 kg/ha, respectively. One-half (16) of each of the different residue-level plots had grass canopies where green foxtail, *Setaria viridis* (L.) Beauv., which was not controlled, created a dense canopy over the furrow. Thus, there were four treatments comprising two residue levels, both with and without grass canopies. Forty of the 64 plots, 10 of each treatment, were randomly selected for study. A completely randomized design consisting of four treatments, 10 replications of each treatment, and 25 samples per treatment replication was used. Accordingly, 250 plants per treatment were rated, for a total sample of 1,000 plants. The sampling technique involved walking 4 m into a plot and then rating 25 plants on one of the center rows. Plant damage ratings were made 71 d after planting.

Data Analysis

A randomized complete-block design was used in 1984 and 1985 for the Bushland, Tex., cropping systems studies. For the test at North Platte, Nebr., and the tillage-level plots at Bushland, Tex., a completely randomized design was employed. Analysis of variance for these tests was done with the SAS system analysis of variance (ANOVA) procedures (SAS Institute 1985, 113–138). Significant differences ($P = 0.05$) among treatment means were determined using Duncan's (1955) multiple range test. For the Bushland, Tex., paired-plot tests, and the study at Etter, Tex., tests of significance ($P = 0.05$) were done using the SAS system TTEST procedures (SAS Institute 1985, 795–800).

Results

Bushland, Tex.

To benefit from summer rains, planting dates for the unirrigated sorghum at Bushland were ca. 2 wk later than those of irrigated sorghum in the area. This practice, because of greenbug migratory peaks, parasites and predators, and other factors, decreases the likelihood of heavy greenbug infestations that cause severe damage. Moreover, at Bushland, greenbug densities differed between the 2 yr. Greenbug infestations occurred during the summer of 1984 and resulted in damage that could be visually rated. Damage ratings were possible in the paired plots in 1985 even though the greenbug density was not as great as in 1984. However, for the cropping systems study in 1985, the damage rating system could not be used because of lower damage levels. Moreover, damage ratings could not be delayed because greenbug abundance declined very rapidly during early August, and by mid-August most greenbugs had disappeared. Similar observations were reported by Teetes et al. (1975b). Consequently, actual counts of greenbugs per plant were used instead of damage ratings.

Cropping Systems Study. In 1984, a greenbug-susceptible grain sorghum hybrid was planted in the no-till plots and a resistant hybrid planted in the conv-till plots. Damage ratings (Fig. 1) for the no-till susceptible sorghum (WSF, $\bar{x} = 3.11$; CS, $\bar{x} = 3.47$) were significantly lower ($P < 0.05$) than the damage ratings of conv-till resistant sorghum (WSF, $\bar{x} = 4.49$; CS, $\bar{x} = 4.95$). Typical leaf damage in no-till plots was red spotting and a portion of one leaf killed, whereas damage in the conv-till plots was typified by two to three dead leaves. Thus, using the number of dead leaves to represent actual damage, 2- to 3-fold more damage occurred in the conv-till (resistant hybrid) plots compared with the no-till (susceptible hybrid) plots. The damage would have been much greater in the conv-till plots if the greenbug-resistant hybrid had not been used. This demonstrates that reduced tillage can be even more effective than plant resistance in decreasing greenbug damage on grain sorghum.

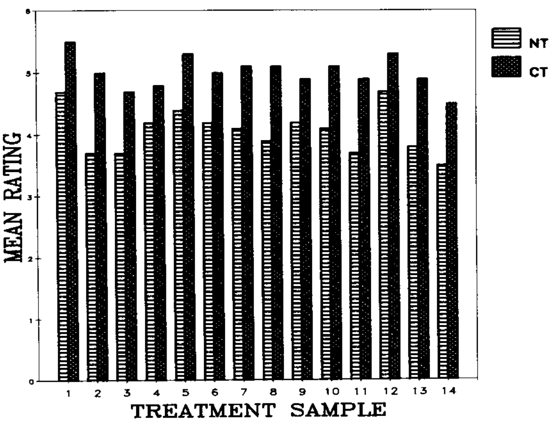

Fig. 3. Plant damage ratings in 1984 for the paired plots at Bushland, Tex. NT, no tillage; CT, conventional tillage.

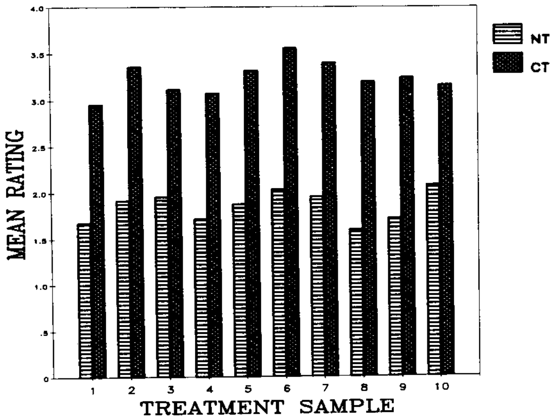

Fig. 4. Plant damage ratings in 1985 for the paired plots at Bushland, Tex. NT, no tillage; CT, conventional tillage.

In 1985, greenbug counts were taken in this study to determine the effect of tillage on greenbug population development. There were no significant differences ($P > 0.05$) in number of greenbugs per plant between the no-till treatments (WSF no-till, $\bar{x} = 257.9$; CS no-till, $\bar{x} = 199.9$), nor between the conv-till treatments (WSF conv-till, $\bar{x} = 781.5$; CS conv-till, $\bar{x} = 551.1$). These results show that the type of crop grown previously (either wheat or sorghum) may not influence the greenbug populations. However, the type of tillage practice does, because the numbers of greenbugs per plant were significantly fewer ($P < 0.05$) in the no-till plots than in the conv-till plots (Fig. 2), with an overall mean difference of 581.6 greenbugs per plant.

Paired Plots. Surface residues in the no-till sorghum provided ca. 50% ground cover during both years. However, the conv-till plots had a small amount of residual surface residue (ca. 10–15% ground cover) in 1984. This probably reduced the greenbug numbers in the conv-till plots and, in turn, reduced the damage rating differences between the tillage practices (Fig. 3). Nevertheless, significantly less ($P < 0.05$) damage occurred in the no-till treatment, demonstrating that an increase in the amount of residue can be effective in reducing greenbug damage.

Plant damage rating differences between sorghums receiving the two tillages were much greater in 1985 than in 1984 when less surface residue occurred in the conv-till plots (ca. 5%) (Fig. 4). However, because the greenbug density levels were lower, the magnitude of damage following both tillage practices was not as large. Damage equivalent to that of 1984 never occurred because of a rapid decline in greenbug numbers that regularly occurs at that time of year (Teetes et al. 1975b, Schweissing et al. 1986). Even so, enough damage occurred to show the effectiveness of no-till in significantly reducing ($P < 0.05$) greenbug damage. These results also demonstrated that the effect of the no-till was not restricted to sorghum in smaller plots.

Tillage-level Plots. The no-till sorghum in this study had a moderate amount of surface residues (ca. 30–40% ground cover), but the min-till and conv-till plots had no surface residue. The no-till and min-till sorghum were significantly ($P < 0.05$) less damaged than the conv-till sorghum (Fig. 5). Likewise, the no-till sorghum had significantly ($P < 0.05$) less damage than the min-till sorghum. The mean damage ratings were as follows: no-till, 2.62 (red spotting of the leaves); min-till, 5.48 (two to three dead leaves); and conv-till, 7.16 (six to seven dead leaves). As would be expected from such ratings, visible damage differences were extreme, ranging from little or no damage in the no-till sorghum, to dead plants in the conv-till sorghum. Min-till sorghum sustained intermediate damage; because there were no surface residues, this indicated that less tillage or soil disturbance reduced greenbug density. There were obvious visible differences in damage at the point where plots adjoined, demonstrating a row-to-row effect.

Etter, Tex.

The mean damage rating for the conv-till sorghum was 5.43 (three to four dead leaves); the mean damage rating for the no-till sorghum was 3.26 (red spotting to one dead leaf), which indicated 2- to 4-fold more damage in the conv-till plots ($P < 0.01$). Slightly higher damage ratings in the no-till sorghum were recorded along the end of the field ($\bar{x} = 3.79$ versus 2.73) where the irrigation was initiated. Less residue remained in that area as a result of being carried along the furrow with the irrigation water, suggesting a quantitative effect of surface residues on greenbug behavior (Fig. 6).

North Platte, Nebr.

Damage ratings were higher for sorghum with no residue (10% ground cover) than for sorghum plus residue (80% ground cover). Differences were

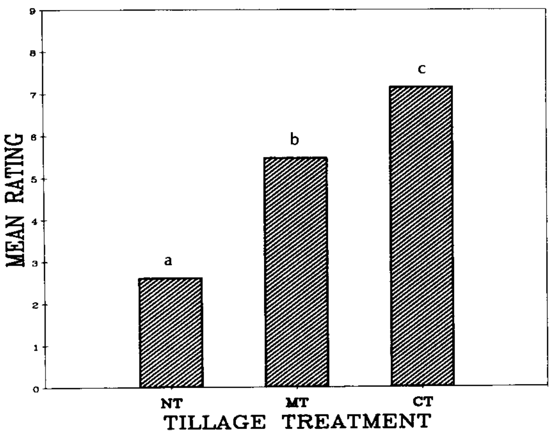

Fig. 5. Mean plant damage ratings for the tillage-level plots at Bushland, Tex. Histograms with the same letters are not significantly different ($P < 0.05$; Duncan's [1955] multiple range test). NT, no tillage; MT, minimum tillage; CT, conventional tillage.

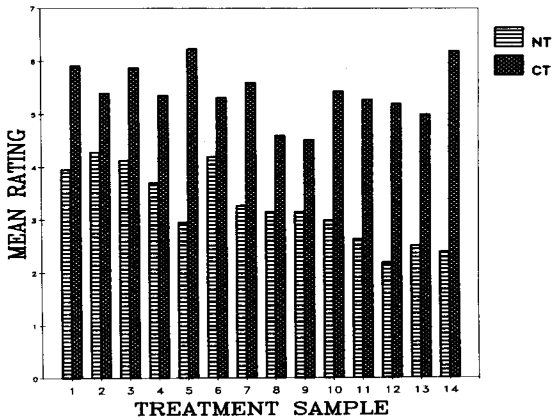

Fig. 6. Mean plant damage ratings for the plots at Etter, Tex. NT, no tillage; CT, conventional tillage.

not great but were significant ($P < 0.05$) (Fig. 7). These results again indicated that the quantity of residue is important in influencing behavior of the greenbug. Based on the results throughout this study, we assume that a conv-till control plot would have shown a much greater damage level had it been available for study, particularly because observations of conv-till fields within ca. 200 m of the study plots had a much greater damage rating (damage rating, ca. 7) than the study plots.

Moreover, these plots showed that canopy has a considerable influence on greenbug behavior (Fig. 7). Where a canopy of weedy green foxtail, (listed by Michels [1986] as a host for greenbugs) covered the furrow, greenbug damage was significantly ($P < 0.01$) less than in plots without the grass. The effect of the grass canopy clearly dominated the influence of the residue: there were no differences ($P > 0.01$) between those plots with and without residue.

Discussion

As a rule, a research environment with the smallest amount of variation is preferred. In our study, we investigated the most variable conditions that we could find to determine the common impact of tillage practices and residues on natural greenbug infestation. Despite the various cropping techniques, irrigation regimes, geographical locations, plot sizes, and varying environmental conditions, our results were consistent: any reduction in tillage, increase in surface residue, or increase in canopy corresponded positively with reduced greenbug damage and density.

The overall, conspicuous differences between the tillages were that the various no-till plots consistently had more surface residues, less soil disturbance, and fewer greenbugs when compared with conv-till plots. At all locations, differences in the distribution of greenbugs on the plants between the no-till and the conv-till plots were pronounced. Typically, greenbugs disseminate to upper leaves as the infestation progresses, producing concatenate leaf damage. In the no-till plots, the infestations had not progressed as far up the plant. Moreover, greenbug densities were not as great, and fewer lower leaves were killed. Thus, the greenbugs remained on lower leaves, leaving a strong impression that the infestation had been in some way delayed.

Because grain sorghum is an annual crop, the fields must be reinfested each year by migratory greenbugs. The influx of these immigrating alates is thought to occur continually throughout the cropping season, although there are seasonal flight peaks (Harvey et al. 1982). We have shown that conditions surrounding the plant can have a significant influence on infestation by the greenbug. Although surface residues seem to be the most influential factor, soil disturbance can also affect greenbug behavior. The width of the standard row

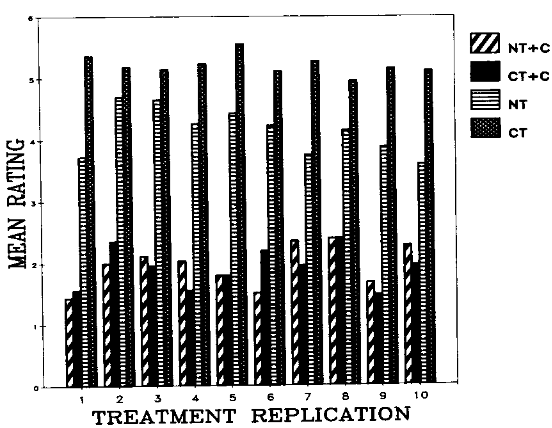

Fig. 7. Mean plant damage ratings for the plots at North Platte, Nebr. NT, no tillage; CT, conventional tillage; C, grass canopy.

spacing (ca. 75–100 cm) in dryland grain sorghum is such that full canopy development does not completely obscure the soil surface. Consequently, the exposed surface conditions, whether mulched or not, can continually influence the influx and establishment of migrating aphids. Bare soil between the crop rows may also be attractive. In fact, Harvey et al. (1982) trapped the greatest number of greenbugs over clean-tilled soil and the smallest over continuous stands of green vegetation. Kring (1972) further stated that many aphids are attracted to and alight on bare soil. Smith (1969) found that more alate cabbage aphids, *Brevicoryne brassicae* (L.), colonize plants in bare soil rather than those in weedy soils and that greater densities develop on plants in bare soil. In this study, the North Platte plots verify those results (Fig. 7). However, bare soil itself can be variable enough to influence alate influx. In the tillage-level study (Fig. 5), greenbugs seemed to differentiate between tilled plots without residue and preferred the plots that had been the most extensively tilled.

A reflective mulch such as aluminum foil is thought to act as a repellent to aphids by reflecting short wavelength light waves (<0.4 μm), thereby masking the attractiveness of the long wavelength light waves reflected by green plants (Moericke 1969, Kring 1972). However, we recognize that all aphids do not respond alike. Variability in response to various hues of reflected light exists between species of aphids (Moericke 1955, Kring 1972). Generally, however, alighting aphids are repelled by short light waves (i.e., ultraviolet) and attracted to the yellow-green wavelengths reflected by plants (Žďárek & Pospíšil 1966). Consequently, the leftover surface residues from the previous crop may function as a reflective agent similar to aluminum foil in reducing the influx of migrating aphids and subsequent population size.

Gausman et al. (1975, 1977), using spectroradiometric measurements of wavelengths ranging from 0.45 to 1.8 μm, were unable to distinguish disked and undisked bare soil in terms of reflectivity. However, greenbugs were apparently able to do this, as shown by the data in both this study (Fig. 5) and a previous study by Burton & Krenzer (1985). In this regard, field measurements of shorter wavelength reflectivity from soil in various conditions and with crop residues seem to be important at this time to identify any bands to which the greenbugs might be responding.

Without exception throughout our studies, when tillage was reduced, so were greenbug densities and crop damage. This does not mean that greenbug infestations were prevented, but they were reduced to the point that some, if not all, pesticide applications might be avoided. Therefore, the reduction in tillage represents a prophylactic treatment for greenbugs that is both practical and compatible with current recommendations of reduced tillage for reducing soil erosion, increasing soil moisture, and reducing fuel consumption.

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