2-1-2006

Evaluation of Cool- and Warm-Season Grasses for Resistance to Multiple Chinch Bug (Hemiptera: Blissidae) Species

Wyatt G. Anderson  
*University of Nebraska-Lincoln*

Tiffany Heng-Moss  
*University of Nebraska-Lincoln*, thengmoss2@unl.edu

Frederick P. Baxendale  
*University of Nebraska-Lincoln*, fbaxendale1@unl.edu

Follow this and additional works at: [http://digitalcommons.unl.edu/entomologyfacpub](http://digitalcommons.unl.edu/entomologyfacpub)

Part of the [Entomology Commons](http://digitalcommons.unl.edu/entomologyfacpub)

[http://digitalcommons.unl.edu/entomologyfacpub/120](http://digitalcommons.unl.edu/entomologyfacpub/120)

This Article is brought to you for free and open access by the Entomology, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Faculty Publications: Department of Entomology by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
Evaluation of Cool- and Warm-Season Grasses for Resistance to Multiple Chinch Bug (Hemiptera: Blissidae) Species

WYATT G. ANDERSON, TIFFANY M. HENG-MOSS, AND FREDERICK P. BAXENDALE

Department of Entomology, University of Nebraska, Lincoln, NE 68583

ABSTRACT Chinch bugs are common pests of many agronomic and horticulturally important crops and turfgrasses. The extensive overlap of plant hosts and geographic distribution of Blissus leucopterus leucopterus (Say), Blissus leucopterus hirtus Montandon, Blissus insularis Barber, and Blissus occiduus Barber underscores the importance of identifying resistant germplasm. Cool- and warm-season turfgrasses and sorghum, Sorghum bicolor (L.) Moench, were evaluated for resistance to chinch bugs in the Blissus complex, and the presence of multiple resistance was documented. Greenhouse studies established that B. occiduus-resistant (‘Prestige’, formerly NE91-118) and -susceptible (‘378’) buffalograsses, Buchloë dactyloides (Nuttall) Engelmann, were susceptible to all other chinch bug species. KS94 sorghum exhibited resistance to both B. occiduus and B. l. leucopterus, whereas B. insularis-resistant St. Augustinegrass, Stenotaphrum secundatum (Walter) Kuntze (‘Floratam’), was also resistant to B. occiduus. B. l. leucopterus-susceptible sorghum (‘Wheatland’) and B. insularis-susceptible St. Augustinegrasses (‘Raleigh’ and ‘Amerishade’) were highly resistant to B. occiduus. Endophyte-free and -enhanced fine fescues (Festuca spp.) were moderately to highly susceptible to B. l. hirtus but moderately to highly resistant to B. occiduus. The results of this research showed the buffalograsses evaluated, including B. occiduus-resistant Prestige, are moderately to highly susceptible to the three other chinch bug species. In contrast, B. occiduus did not cause considerable damage to any of the turfgrasses or sorghum cultivars evaluated, other than buffalograss, irrespective of whether or not they are resistant to another chinch bug species. This information is increasingly important as various grasses become adapted to regions that may possess chinch bug species other than those with which they are typically associated. These levels of Blissus resistance should be included when selecting resistant germplasm for managing Blissus species pests.

KEY WORDS chinch bug, Blissus, plant resistance, turfgrass, sorghum
Bird and Mitchener 1950, Farstad and Staff 1951, Baxendale et al. 1999, Eickhoff et al. 2004). In addition, recent research by Eickhoff et al. (2004) documented the potential of B. occiduus to use additional turfgrasses, crops, and weeds, including Kentucky bluegrass; perennial ryegrass; tall fescue; Festuca arundinacea Schreber; Bermuda grass; sorghum; yellow foxtail, Setaria glauca (L.); and green foxtail, Setaria viridis (L.), as alternate hosts.

Historically, insecticides have been used as the principle method to control chinch bugs. However, growing concerns over the repeated use of chemicals and the potential negative side effects have led to the development of integrated pest management tactics, including the use of chinch bug-resistant germplasm. Over the past several years, germplasm resistant to each of the four economically important chinch bugs has been identified and integrated into pest management programs.

Chinch Bug Resistance. The use of resistant sorghum crops to manage B. l. leucopterus was investigated by Dahms (1948) who found that the "milos" and "fertitas" are susceptible, and the "kafirs" and "sorgos" exhibit resistance to chinch bug feeding. More recently, Mize and Wilde (1986a, b, c) reported that the sorghum lines 1155, SC 303, SC 261, and BCK60-1155 displayed high levels of antixenosis and tolerance compared with the resistant 'Atlas' and susceptible 'Wheatland' checks. The experimental sorghum selection KS94 has also been shown to be resistant to the common chinch bug (Wilde and Bramel-Cox 1991). Subsequent research by Subramanian (1995) suggested that KS94 exhibited both tolerance and antixenosis.

It has been well-documented that endophyte-infected turfgrasses exhibit resistance to B. l. hirtus (Saha et al. 1987, Mathias et al. 1990, Carrière et al. 1998, Richmond and Shetlar 2000, Yue et al. 2000). Saha et al. (1987) first reported reduced numbers of B. l. hirtus on fine-leaf fescues infected with endophytes. Mathias et al. (1990) reported endophyte-enhanced perennial ryegrass cultivars to be resistant to B. l. hirtus and speculated that both antibiotic and antixenosis were responsible for B. l. hirtus resistance in those cultivars. Unfortunately, many of the perennial ryegrass and fine fescue cultivars known to have resistance to B. l. hirtus are no longer commercially available.

St. Augustine grasses with resistance to B. insularis also have been identified. 'Floratami' and 'Floralawn' were shown to be resistant to B. insularis, and Floratam was extensively planted in the southern United States (Reinert and Dudeck 1974; Crocker et al. 1982, 1989; Busey and Zaanen 1992). Floratam's resistance to B. insularis has been categorized as antibiotic because of high chinch bug mortality and reduced oviposition rates (Reinert and Dudeck 1974, Crocker et al. 1989). However, in parts of southern Florida, biotypes emerged that were able to damage resistant germplasm (Busey and Center 1987). Recent research efforts have identified new sources of St. Augustine grass resistant to B. insularis, including FX-10, which is thought to be resistant to both B. insularis populations (Busey 1990, 1993, 1995).

Heng-Moss et al. (2002) identified the buffalograsses 'Prestige' (formerly NE91-118), 'Tatanka', 'Bonnie Brae', and 'Cody' as moderately to highly resistant to B. occiduus, whereas the buffalograss selections '378' and NE84-45-3 were highly susceptible in greenhouse and field studies. Subsequent research demonstrated that Cody and Tatanka exhibited tolerance to B. occiduus, whereas Prestige displayed both tolerance and antixenosis (Heng-Moss et al. 2003). No antibiotic was detected in any of the buffalograsses examined.

Multiple Chinch Bug Resistance. Buffalograss, a native of the central Great Plains, is currently grown in both high and low management sites throughout the United States. Its aggressive stoloniferous growth habit and dense sod-forming capabilities are well suited for turfgrass use and make it an excellent conservation species. Buffalograss stands are usually established through vegetative propagation, which can result in the unintentional movement of B. occiduus and other arthropods to new regions in the United States. Indeed, the presence of B. occiduus has been documented in vegetatively propagated stands of buffalograss in Kansas, Iowa, Oklahoma, and Arizona.

Because of the extensive geographical overlap of the four economically important chinch bug species (B. occiduus, B. insularis, B. l. leucopterus, and B. l. hirtus) and their host plants, the potential exists for B. occiduus and other chinch bug species to become associated with and damage nontraditional hosts. The presence of host plants with resistance to multiple chinch bug species would be highly desirable in these interfacing turfgrass–crop situations. Unfortunately, limited information is available on turfgrass germplasm with resistance to multiple insect species. Funk et al. (1983) reported that an endophyte-enhanced perennial ryegrass, 'Pennant', was less damaged by sod webworms (Crambus spp.) and billbugs (Sphenophorus spp.) than other grasses in field trials. Otherwise, few reports of multiple insect resistance in turfgrasses exists. Although germplasm resistant to each of the four chinch bug species is known, the existence of plants with multiple chinch bug resistance remains uncertain. The objectives of this research were to evaluate selected cool- and warm-season turfgrasses and sorghum for resistance to chinch bugs in the Blissus complex of B. occiduus, B. l. leucopterus, B. l. hirtus, and B. insularis and to document any incidence of multiple resistance.

Materials and Methods

Acquisition and Maintenance of Chinch Bugs. B. occiduus were collected with a modified ECHO Shred 'N Vac (model #2400, ECHO Incorporated, Lake Zurich, IL) from buffalograss '378' (chinch bug-susceptible) research plots at the John Seaton Anderson Turfgrass and Ornamental Research Facility (JSAS Research Facility), University of Nebraska Agricultural Research and Development Center, near Mead, NE.
Chinch bugs were held under laboratory conditions (26 ± 3°C and a photoperiod of 16:8 [L:D] h) for 24 h to eliminate individuals injured or killed during the collection process, sifted through a 2-mm mesh screen, collected with a battery-powered aspirator, and introduced on to experimental plants.

*B. l. leucopterus* were collected from infested sorghum at the JSA Research Facility by placing infested plants in plastic bags or by using a modified ECHO Shred ‘N Vac to vacuum chinch bugs and plant debris. Collected chinch bugs were processed as described for *B. occiduus*.

*B. l. hirtus* were collected from infested Kentucky bluegrass lawns near Columbus, OH, by collaborators at The Ohio State University and shipped to the Department of Entomology at the University of Nebraska-Lincoln. *B. l. hirtus* were reared and maintained in the greenhouse on ‘5715’ sorghum grown in 15-cm pots containing a potting mixture of sand–soil–peat–perlite in a 2:1:3:3 ratio and maintained under greenhouse conditions (27 ± 3°C and a photoperiod of 16:8 [L:D] h). Plants were watered from the top every other day and fertilized weekly with a soluble 20:4.4:16.6 (N–P–K) fertilizer. Before experiment initiation, chinch bugs were dislodged from plants, sifted through a 2-mm mesh screen, collected with a battery-powered aspirator, and held in small plastic cups for 24 h.

*B. insularis* were collected from infested St. Augustinegrass lawns near Temple, TX, by collaborators at Texas A&M University Blackland Research and Extension Center, shipped to the University of Nebraska-Lincoln, and reared on susceptible ‘Raleigh’ St. Augustinegrass by using the procedures described for *B. l. hirtus*. Similarly, chinch bugs were collected from greenhouse colonies and processed as described for *B. l. hirtus*.

**Acquisition and Maintenance of Plant Material.** The plants used in this research were maintained in a University of Nebraska-Lincoln greenhouse at 27 ± 3°C under 400-W high-intensity discharge lamps (metal halide) with a photoperiod of 16:8 (L:D) h. Plants were watered daily and fertilized weekly with a soluble 20:0:4:4:16.6 (N–P–K) fertilizer. The potting soil contained a mixture of sand–soil–peat–perlite in a 2:1:3:3 ratio.

*B. occiduus*-susceptible 378 and -resistant Prestige buffalograss were obtained from research plots at the JSA Research Facility by extracting sod plugs (10.6 cm in diameter by 6 cm in depth). Plugs were potted in 15-cm pots containing the previously described potting mixture and maintained under greenhouse conditions. These plants served as the vegetative source of buffalograss in the screening studies.

Thirty-five by 50-cm flats of Raleigh (*B. insularis*-susceptible), Floratum (*B. insularis*-resistant), and ‘Amerishade’ (unknown susceptibility to *B. insularis*) St. Augustinegrasses were acquired from Turfgrass America in Granbury, TX. Approximately 5 by 5-cm sections were transplanted into 15-cm pots, maintained under greenhouse conditions, and used in subsequent screening studies.

Fine fescue tillers were shipped from Rutgers University Plant Science Research Center, Freehold, NJ; potted in 15-cm pots in the greenhouse upon arrival; and maintained under previously described greenhouse conditions. Eight experimental fine fescue lines were evaluated for chinch bug resistance, including four lines enhanced with the endophyte *Epichloë festucae* Leuchtmann, Schardl, & Siegel. Two chewings fescues, 1117 DL2 and 3188-1 DL2 (containing the Delaware 2 endophyte), and two strong creeping red fescues, 1171 RC and 1139 RC (containing the Rose City endophyte), as well as their endophyte-free counterparts 1117 E-, 3188-1 E-, 1171 E-, and 1139 E- were evaluated. Endophyte presence was confirmed by Rutgers University Plant Science Research Center before shipping of plant material. Endophyte presence was confirmed after completion of experiments by using 0.5% Rose Bengal staining solution following the protocol of Saha et al. (1988) and also with a Phytoscreen immunoblot kit (catalog no. ENDO7973, Agrinotics, Ltd. Co., Watkinsville, GA).

*B. l. leucopterus*-resistant KS94 and susceptible Wheatland sorghum seed was obtained from Kansas State University, Manhattan, KS. Seeds were held in cold storage until planting.

**Establishment of Experimental Plant Units.** Three weeks before introduction of chinch bugs, three sorghum seeds, individual plants of the two buffalograsses, three St. Augustinegrasses, and eight fine fescues were planted in ‘SC-10 Super Cell’ single cell Cone-tainers (3.8 cm in diameter by 21 cm in height; Stuewe & Sons, Inc., Corvallis, OR). Cone-tainers were maintained under previously described greenhouse conditions. One week before chinch bug introduction, the verdure of all buffalograss, St. Augustinegrass, and fine fescue plants was removed to ensure that all plant material was of similar age. Sorghum seedlings were thinned to one plant per Cone-tainer after germination.

**Introduction of Chinch Bugs.** In total, 10 fourth and fifth stage chinch bugs (sex ratio undetermined) were placed on plants in Cone-tainers fitted with tubular Plexiglas cages (4 cm in diameter by 30 cm in height). Cage tops were sealed with organdy fabric and secured with rubber bands to prevent chinch bug escape. Infestation levels were based on previously reported research (Reinert and Dudeck 1974, Wilde et al. 1987, Crocker et al. 1989, Carrie et al. 1998, Yue et al. 2000, Heng-Moss et al. 2002, Eickhoff et al. 2004), and typical field infestation levels (Heng-Moss et al. 2002).

**Evaluation of Resistance.** Because esthetics is the key criterion for assessing turf quality, visual ratings were used to measure the susceptibility of the plants to chinch bug feeding injury. Plant damage ratings were taken every other day by using a 1–5 scale, where 1 is 10% or less of leaf area with reddish discoloration; 2 is 11 to 30% of leaf area with reddish discoloration; 3 is 31 to 50% of leaf area with reddish discoloration; 4 is 51 to 70% of leaf area with reddish discoloration; and 5 is 71% or more of leaf area

February 2006 ANDERSON ET AL.: RESISTANCE TO MULTIPLE CHINCH BUG SPECIES 205
with severe discoloration, thinned turf, or dead tissue (Heng-Moss et al. 2002).

Plant heights from the soil surface to the tip of the longest extended leaf also were recorded for all sorghums at the end of the experiment. These measurements, in conjunction with chinch bug damage ratings, were used to calculate the functional plant loss index (FPLI) for each plant-insect combination (Morgan et al. 1980, Panda and Heinrichs 1983): 

\[
FPLI = 1 - \left( \frac{\text{height of infested plant}}{\text{height of control plant}} \right) \times \left( 1 - \frac{\text{damage rating}}{5} \right) \times 100.
\]

Low FPLI values indicate plant tolerance, whereas high values signify lack of tolerance.

In all experiments, when 80% of the chinch bug-susceptible plants had damage ratings of 4 or higher, they were individually placed in Berlese funnels (Southwood 1978) to extract and count the number of chinch bugs remaining on each plant. Based on the overall treatment mean of chinch bug damage, levels of resistance were assigned as follows: highly resistant (HR, chinch bug damage rating 1), moderately resistant (MR, chinch bug damage rating >1 but <3), moderately susceptible (MS, chinch bug damage rating ≥3 and <4), and highly susceptible (HS, chinch bug damage rating ≥4) (Heng-Moss et al. 2002).

**Characterization of Chinch Bug-Resistant Turfgrasses.** St. Augustinegrass Resistance to *B. insularis.* The St. Augustinegrass ‘Amerishade’ was screened for resistance to *B. insularis* from 1 September to 15 October 2003. Raleigh and Floratam served as known susceptible and resistant checks, respectively. The experimental design was completely randomized with six replications per treatment. A choice study also was conducted to determine *B. l. hirtus* preference for the endophyte-free and -enhanced strong creeping red fescues 1117 RC, 1117 E-, 1139 RC, 1139 E-, 1171 RC, and 1171 E-) were screened and compared for resistance to *B. l. hirtus* in a completely randomized design with six replications per treatment. The experiment was conducted using second and first generation chinch bugs from 1 September to 13 September 2002 (study 1) and from 4 July to 13 July 2003 (study 2), respectively.

A choice study also was conducted to determine *B. l. hirtus* preference for the endophyte-free and -enhanced strong creeping red fescues 1117 RC, 1117 E-, 1139 RC, and 1139 E-. The experimental design was a randomized complete block design with six replications per treatment. Individual tillers of each grass were placed in vials of water and sealed with paraffin wax (Gulf Wax, Royal Oak Sales, Inc., Roswell, GA) heated to 63 ± 2°C. The wax was allowed to cool and vials were then randomly placed in one of four equally spaced 1.7-cm-diameter holes that were cut in circular arenas. The choice study was conducted in a growth chamber maintained at 28 ± 2°C under 24-h lighting. Fifteen adult chinch bugs were placed in the center of each arena, and the number of chinch bugs on each grass was recorded 1, 2, 4, 8, 18, 24, 48, and 72 h after introduction of chinch bugs.

**Fine Fescue Resistance to *B. occiduus.*** Fine fescues with unknown levels of resistance to *B. l. hirtus* also were screened for resistance to *B. occiduus.* The experimental design was a completely randomized design with six replications per treatment. The four experimental lines screened were 1117 E-, 1117 DL2, 1171 E-, and 1171 RC. Buffalograss 378 and Prestige were used as *B. occiduus*-susceptible and -resistant checks, respectively. The experiment was conducted with second and first generation chinch bugs from 1 September to 13 September 2002 (study 1) and 4 July to 13 July 2003 (study 2), respectively.

**Characterization of Multiple Chinch Bug Resistance.** Selected turfgrasses and sorghums were evaluated for resistance to multiple chinch bug species. These studies were conceived based on the documented potential of chinch bugs to use multiple plant hosts and on the extensive overlap of these plant hosts and the geographic distributions of the four chinch bug species.

*St. Augustinegrass Resistance to *B. occiduus.** Floratam (*B. insularis*-resistant), Raleigh (*B. insularis*-susceptible), and Amerishade (resistance unknown) St. Augustinegrasses were screened for resistance to *B. occiduus* from 1 September to 15 October 2002. Bufalograss 378 and Prestige were used as known *B. occiduus*-susceptible and -resistant checks, respectively. The experimental design was a completely randomized design with six replications per treatment.

**Buffalograss Resistance to *B. l. leucopterus.*** *B. occiduus*-susceptible 378 and -resistant Prestige buffalograsses were evaluated for resistance to *B. l. leucopterus* in a completely randomized design with 10 replications per treatment. *B. occiduus* also was introduced onto Cone-tainers of 378 and Prestige, which served as known susceptible and resistant checks, respectively. The treatment design was a 2 by 2 factorial (two chinch bug species and two buffalograss cultivars). The study was conducted with first and second generation chinch bugs from 9 to 21 July (study 1) and from 31 August to 12 September 2002 (study 2), respectively.

**Sorghum Resistance to *B. l. leucopterus* and *B. occiduus.*** *B. l. leucopterus*-susceptible and -resistant sorghums (Wheatland and KS94, respectively) were evaluated for resistance to first and second generation *B. occiduus* from 9 to 29 July (study 1) and from 31 August to 27 September 2002 (study 2). *B. l. leucopterus* also were introduced onto Cone-tainers of Wheatland and KS94, which served as known susceptible and resistant checks, respectively. The experimental design was a completely randomized design with 10 replications per treatment. The treatment design was a 2 by 2 factorial (two chinch bug species and two sorghums).

**Buffalograss Resistance to *B. insularis* and *B. l. hirtus.*** *B. occiduus*-resistant and -susceptible buffalograsses were evaluated for resistance to *B. l. hirtus* and *B. insularis* from 4 July to 15 July 2003 in a completely randomized design with six replications per treatment. *B. occiduus* also was introduced onto Cone-tainers of 378 and Prestige, which served as known susceptible and resistant checks, respectively. The treatment design was a 3 by 2 factorial (three chinch bug species and two buffalograss cultivars).
Statistical Analysis. Data were analyzed using mixed model analysis (PROC MIXED, SAS Institute 1999) to detect differences in chinch bug damage and number of chinch bugs at harvest. When appropriate, means were separated using Fisher’s least significant difference (LSD) procedure. Interaction effects with means less than or equal to 0.10 were considered significant, and main and simple effects with P values less than or equal to 0.05 were considered significant.

Results and Discussion

Characterization of Chinch Bug-Resistant Turfgrasses. St. Augustinegrass Resistance to B. insularis. Mixed model analyses detected no significant differences in chinch bug damage caused by B. insularis on the three different St. Augustinegrasses (F = 2.59; df = 2, 15; P = 0.11). Amerishade and Raleigh had mean damage ratings of 3.3 ± 0.8 and 2.7 ± 0.8, respectively, whereas Floratam, the known resistant check, had a mean damage rating of 1.3 ± 0.2 (Table 1).

Although the mean damage ratings were not significantly different, significant differences were detected in the number of chinch bugs remaining on the St. Augustinegrasses at the time of harvest, 45 d after experiment initiation (F = 11.80; df = 2, 15; P = 0.0006). At harvest, the mean number of chinch bugs on Raleigh (150.7 ± 35.2) was significantly greater than the number of chinch bugs on Amerishade (48.8 ± 15.4) and Floratam (1.5 ± 0.9). B. insularis had high reproduction on both Raleigh and Amerishade but did not reproduce. Instead, it declined in numbers on Floratam. Previous studies have shown Floratam to be antibiotic to B. insularis (Reinert and Dudeck 1974, Crocker et al. 1989). Busey and Zaenker (1992) suggested this resistance may be because of the presence of antifeedants.

The larger numbers of chinch bugs present after 45 d suggests that the reproductive capability of B. insularis is much greater on Raleigh and Amerishade than on Floratam. These susceptible plants with their elevated chinch bug numbers would have likely shown increasing chinch bug damage had the experiment continued. Although B. insularis biotypes that have the ability to severely damage Floratam have developed in parts of Florida, Floratam was moderately to highly resistant to the chinch bugs (obtained from Texas) used in this study. The results presented here concur with those of Reinert and Dudeck (1974) and Crocker et al. (1989) who observed similar trends in chinch bug damage and numbers on Floratam.

Table 1. St. Augustinegrass resistance to B. insularis and B. occiduus

<table>
<thead>
<tr>
<th>Plant selection</th>
<th>B. insularis</th>
<th>B. occiduus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean damage</td>
<td>Mean no. CB</td>
</tr>
<tr>
<td>Prestige</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>378</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Amerishade</td>
<td>3.3a</td>
<td>48.8b</td>
</tr>
<tr>
<td>Raleigh</td>
<td>2.7a</td>
<td>150.7a</td>
</tr>
<tr>
<td>Floratam</td>
<td>1.3a</td>
<td>1.5b</td>
</tr>
</tbody>
</table>

Means within the same column followed by the same letter are not significantly different (P > 0.05, LSD test).

Statistical Analysis. Data were analyzed using mixed model analysis (PROC MIXED, SAS Institute 1999) to detect differences in chinch bug damage and number of chinch bugs at harvest. When appropriate, means were separated using Fisher’s least significant difference (LSD) procedure. Interaction effects with means less than or equal to 0.10 were considered significant, and main and simple effects with P values less than or equal to 0.05 were considered significant.

Results and Discussion

Characterization of Chinch Bug-Resistant Turfgrasses. St. Augustinegrass Resistance to B. insularis. Mixed model analyses detected no significant differences in chinch bug damage caused by B. insularis on the three different St. Augustinegrasses (F = 2.59; df = 2, 15; P = 0.11). Amerishade and Raleigh had mean damage ratings of 3.3 ± 0.8 and 2.7 ± 0.8, respectively, whereas Floratam, the known resistant check, had a mean damage rating of 1.3 ± 0.2 (Table 1).

Although the mean damage ratings were not significantly different, significant differences were detected in the number of chinch bugs remaining on the St. Augustinegrasses at the time of harvest, 45 d after experiment initiation (F = 11.80; df = 2, 15; P = 0.0006). At harvest, the mean number of chinch bugs on Raleigh (150.7 ± 35.2) was significantly greater than the number of chinch bugs on Amerishade (48.8 ± 15.4) and Floratam (1.5 ± 0.9). B. insularis had high reproduction on both Raleigh and Amerishade but did not reproduce. Instead, it declined in numbers on Floratam. Previous studies have shown Floratam to be antibiotic to B. insularis (Reinert and Dudeck 1974, Crocker et al. 1989). Busey and Zaenker (1992) suggested this resistance may be because of the presence of antifeedants.

The larger numbers of chinch bugs present after 45 d suggests that the reproductive capability of B. insularis is much greater on Raleigh and Amerishade than on Floratam. These susceptible plants with their elevated chinch bug numbers would have likely shown increasing chinch bug damage had the experiment continued. Although B. insularis biotypes that have the ability to severely damage Floratam have developed in parts of Florida, Floratam was moderately to highly resistant to the chinch bugs (obtained from Texas) used in this study. The results presented here concur with those of Reinert and Dudeck (1974) and Crocker et al. (1989) who observed similar trends in chinch bug damage and numbers on Floratam.

Fine Fescue Resistance to B. l. hirtus. Mixed model analyses detected significant differences in chinch bug damage by B. l. hirtus to the fine fescues evaluated in study 1 (F = 3.76; df = 7, 40; P = 0.0032), whereas no significant differences were detected in study 2 (F = 2.02; df = 7, 40; P = 0.08). In study 1, six of eight fine fescues were moderately to highly susceptible to B. l. hirtus, whereas two grasses (3188–1 E- and 1139 RC) were moderately resistant (data not shown). However, all grasses were moderately to highly susceptible in study 2 (data not shown). In addition, no differences in the number of chinch bugs remaining at the end of either study were detected (data not shown). The differences in chinch bug damage between the studies may be because of differences between first and second generation chinch bugs or plant vigor. Furthermore, subsequent endophyte assays documented endophyte presence in all fine fescues and documented high infection rates among 1139 RC, 1171 RC, 3188–1 DL2, and 1117 DL2. In addition, the “endophyte-free” chewings fescues 1117 E- and 3188–1 E- had endophyte infection rates of <5%.

In the choice study conducted with the strong creeping red fescues, mixed model analysis detected significant differences among 1139 E- and 1139 RC, 1171 RC and 1171 E- (F = 4.78; df = 3, 160; P = 0.0032) for numbers of chinch bugs on the plants 1 and 2 h postinfestation. Fewer chinch bugs were observed on 1139 E- than any of the other three grasses. No significant differences were detected at 4, 8, 18, 24, 48, or 72 h. Significant differences in chinch bug numbers also were detected among the eight evaluation times (F = 5.95; df = 7, 160; P < 0.0001). In general, the number of chinch bugs on the plants decreased over time, which may have been a result of decreased plant quality, chinch bug vigor, or a combination. In summary, B. l. hirtus showed no preference toward the endophyte-free grasses (1171 E- and 1139 E-).
In general, grasses enhanced with endophytes exhibit some level of chinch bug resistance (Saha et al. 1987, Mathias et al. 1990, Carrière et al. 1998, Richmond and Shetlar 2000, Yue et al. 2000). Yue et al. (2000) evaluated strong creeping red and chewings fescues for alkaloid concentrations, chinch bug survival, and chinch bug preference and found varying levels in alkaloid concentrations. However, the endophyte-enhanced plants generally decreased chinch bug survival and were avoided by chinch bugs when given a choice between endophyte-free and -enhanced plants. Although no preference toward the endophyte-free plants was exhibited by chinch bugs in our studies, the overall declining vigor of the chinch bugs over time may have resulted in less feeding and thus decreased numbers of chinch bugs observed on the plants.

The lack of difference in the number of chinch bugs surviving on endophyte-free or –enhanced grasses may have resulted because the plants were severely damaged and were no longer suitable hosts. Furthermore, it has been documented that genetic resistance in fine fescues is variable and that the presence of endophytes is not necessarily associated with enhanced insect resistance (Breen 1994). In fact, Breen (1993) has shown endophyte-infected plants can be more susceptible to the southern armyworm, Spodoptera eridania (Stoll), than their endophyte-free counterpart. Various factors such as temperature, drought stress, soil fertility, endophyte concentration within the plant, plant genotype, and host–endophyte interactions can all affect the allelochemical concentration within the plant (Breen 1992, 1994). Unfortunately, most research conducted on endophyte-enhanced resistance to insects has dealt with Neotyphodium endophytes, whereas those plants used in our studies were in the genus Epichloë. Although similarities exist between these two endophyte genera (e.g., alkaloid toxicity and antifeedant activity), there also may be important differences with respect to the environmental conditions that enhance their effects on chinch bug feeding behavior.

**Fine Fescue Resistance to B. occiduus.** In study 1, mixed model analysis detected significant differences in *B. occiduus* damage on the two plant species evaluated ($F = 21.99; df = 5, 30; P < 0.0001$). All fine fescues were moderately to highly resistant to *B. occiduus*, whereas 378 and Prestige buffalograsses were highly susceptible and moderately resistant, respectively (Table 2). Although no significant differences in chinch bug damage were detected in study 2 ($F = 2.31; df = 5, 30; P = 0.07$), 378 buffalograss and 1117 E-fine fescue had the most damage, whereas Prestige buffalograss had the least damage. In general, all fine fescue were moderately to highly resistant to *B. occiduus*, whereas the same grasses were moderately to highly susceptible to *B. l. hirtus*.

The results of this study are similar to those reported by Breen (1993), who found varying levels of resistance in *Neotyphodium*-infected grasses to fall armyworm, *Spodoptera frugiperda* (J.E. Smith), and southern armyworm. The resistance induced by the presence of endophytes may be correlated with the specific insect–plant interactions under investigation. However, it should be stressed that the endophyte-free fine fescues were moderately to highly resistant to *B. occiduus*, indicating that the endophyte may have had little impact and that the plant selections alone may have been unsuitable for this chinch bug. Unfortunately, the scope of this research did not take into consideration the developmental aspects of the chinch bugs, which would have permitted a better assessment of the effects of the endophytes.

**Characterization of Resistance to Multiple Chinch Bug Species.** *St. Augustinegrass Resistance to B. occiduus*. Mixed model analyses detected significant differences in chinch bug damage ratings among the warm-season turfgrasses evaluated ($F = 85.00; df = 4, 25; P < 0.0001$). Raleigh, Amerishade, and Floratam each had a mean damage rating of 1.0 (no damage) (Table 1). By contrast, the buffalograss 378 and Prestige were highly susceptible to *B. occiduus*, having mean damage ratings of 4.5 ± 0.5 and 5.0 ± 0.0, respectively. Although Prestige is known to be resistant to *B. occiduus*, it can be damaged when chinch bug infestation levels exceed the plant’s ability to tolerate feeding (Heng-Moss et al. 2002, 2003). The duration of this experiment (45 d) was over twice as long as previous experiments conducted by Heng-Moss et al. 2002 and likely caused an increased level of damage on the tolerant buffalograss. Also, because of the length of the experiment and severe injury to both buffalograsses, very few chinch bugs (<0.2 ± 0.2) survived on the buffalograss plants, whereas 4.2 ± 0.7 and 2.7 ± 2.3 chinch bugs remained on Raleigh and Amerishade, respectively.

The results obtained from this study are in agreement with those reported by Eickhoff et al. (2004) who observed no damage on Raleigh St. Augustinegrass when exposed to *B. occiduus* for 21 d. Furthermore, the results presented here indicate that Floratam exhibits resistance to both *B. insularis* and *B. occiduus*. Raleigh and Amerishade, however, were highly resistant to *B. occiduus*, but moderately resistant (Raleigh) to moderately susceptible (Amerishade) to *B. insularis*.  

### Table 2. Fine fescue resistance to *B. occiduus*

<table>
<thead>
<tr>
<th>Plant selection</th>
<th>Mean damage$^a$</th>
<th>Resistance rating$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1$^c$</td>
<td>Study 2$^d$</td>
</tr>
<tr>
<td>378</td>
<td>4.2a</td>
<td>2.7a</td>
</tr>
<tr>
<td>Prestige</td>
<td>2.3b</td>
<td>1.3b</td>
</tr>
<tr>
<td>1117 E</td>
<td>1.5c</td>
<td>1.5ab</td>
</tr>
<tr>
<td>1117 DL2</td>
<td>1.2c</td>
<td>2.7a</td>
</tr>
<tr>
<td>1117 E</td>
<td>1.0c</td>
<td>1.5b</td>
</tr>
<tr>
<td>1117 RC</td>
<td>1.0c</td>
<td>1.2b</td>
</tr>
</tbody>
</table>

Means within the same column followed by the same letter are not significantly different ($P > 0.05$, LSD test).

$^a$ Chinch bug damage rating 1–5 scale, with 1 as no damage.

$^b$ HR, highly resistant; MR, moderately resistant; MS, moderately susceptible; and HS, highly susceptible (Heng-Moss et al. 2002).

$^c$ SE = 0.3.

$^d$ SE = 0.4.
Buffalograss Resistance to B. l. leucopterus. Mixed model analyses detected a significant interaction between chinch bug species and buffalograss cultivar with respect to damage in both studies (study 1: $F = 2.87$; df = 1, 36; $P = 0.10$ and study 2: $F = 3.29$; df = 1, 36; $P = 0.08$). In study 1, both chinch bug species caused more damage on the buffalograss 378 than Prestige (Table 3). However, this difference was only significant for B. occiduus ($t = 3.19$, df = 36, $P = 0.003$). Although no significant differences in chinch bug damage were detected in study 2, B. occiduus feeding caused more damage on buffalograss 378 than Prestige, whereas B. l. leucopterus caused slightly more damage on Prestige than 378. In general, both buffalograsses were moderately to highly susceptible to B. l. leucopterus.

Because of the geographic overlap between these two chinch bug species and their host plants, there is potential for B. l. leucopterus to infest and damage both B. occiduus-susceptible and -resistant buffalograsses. This potential is increased because of the host-switching behavior exhibited by B. l. leucopterus as well as its extensive host range. B. l. leucopterus typically move from bunch grasses in the spring to small grains and eventually to crops such as sorghum and corn. However, Lynch et al. (1987) found that when goosegrass, Eleusine indica (L.) Gaertner (the preferred host of B. l. leucopterus in their study), could no longer support the chinch bug population, chinch bugs moved to nearby Bermuda grass stands. Therefore, buffalograss stands located near B. l. leucopterus-infested hosts may be at increased risk of B. l. leucopterus infestation and damage.

Sorghum Resistance to B. occiduus. Significant interactions between chinch bug species and sorghum selections with respect to damage were detected in studies 1 and 2 (study 1: $F = 11.35$; df = 1, 36; $P = 0.002$ and study 2: $F = 27.51$; df = 1, 36; $P < 0.0001$). In both studies, KS94 and Wheatland were moderately to highly resistant to B. occiduus, whereas KS94 was moderately resistant and Wheatland highly susceptible to B. l. leucopterus (Table 4). The presence of resistance to both chinch bug species in KS94 and lack of multiple resistance in Wheatland likely led to the significant interaction.

No significant differences in the FPLI (based on plant height) were detected among the sorghum-chinch bug combinations in study 1 ($F = 1.09$; df = 3, 36; $P = 0.40$). However, significant differences among the sorghum-chinch bug combinations were detected in study 2 ($F = 3.48$; df = 3, 36; $P = 0.03$) (Table 5). KS94 and Wheatland infested with B. occiduus had mean FPLI values of 1.0 and 8.4 ± 4.3, respectively. However, B. l. leucopterus-infested Wheatland had a FPLI value of 34.3 ± 14.4, whereas the FPLI value of KS94 was 16.3 ± 3.2. As mentioned, a low FPLI value indicates plant tolerance. Morgan et al. (1989) reported significant differences in the FPLI values between resistant and susceptible sorghum hybrids in response to greenbug feeding. Our results compare favorably with this study and suggest that this index may be a valuable indicator of sorghum tolerance and should be included as a parameter when accessing tolerance to chinch bugs.

The results presented here confirm the presence of resistance in KS94 to both chinch bug species, whereas Wheatland only exhibited resistance to B. occiduus. The levels of resistance reported for the two sorghums to B. l. leucopterus are in agreement with previous studies (Wilde and Bramel-Cox 1991).

Buffalograss Resistance to B. insularis and B. l. hirtus. A significant interaction between chinch bug species and buffalograss cultivar with respect to damage was detected using mixed model analysis ($F = 6.44$; df = 2, 30; $P = 0.005$). Buffalograss 378 was moderately to highly susceptible to B. occiduus and B. l. hirtus, whereas Prestige was moderately resistant to B. occiduus.

<p>| Table 3. Buffalograss resistance to B. l. leucopterus |</p>
<table>
<thead>
<tr>
<th>Plant selection</th>
<th>Chinch bug species</th>
<th>Mean damagea</th>
<th>Resistance ratingb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1c</td>
<td>Study 2d</td>
<td></td>
</tr>
<tr>
<td>378</td>
<td>B. l. leucopterus</td>
<td>3.1b</td>
<td>3.1ab</td>
</tr>
<tr>
<td>Prestige</td>
<td>B. l. leucopterus</td>
<td>2.7b</td>
<td>4.1a</td>
</tr>
<tr>
<td>378</td>
<td>B. occiduus</td>
<td>4.3a</td>
<td>3.3ab</td>
</tr>
<tr>
<td>Prestige</td>
<td>B. occiduus</td>
<td>2.7b</td>
<td>2.8b</td>
</tr>
</tbody>
</table>

Means within the same column followed by the same letter are not significantly different ($P > 0.05$, LSD test).

a Chinch bug damage rating 1–5 scale, with 1 as no damage.
b HR, highly resistant; MR, moderately resistant; MS, moderately susceptible; and HS, highly susceptible (Heng-Moss et al. 2002).
c SE = 0.4.
d SE = 0.4.

<p>| Table 4. Sorghum resistance to B. occiduus |</p>
<table>
<thead>
<tr>
<th>Plant selection</th>
<th>Chinch bug species</th>
<th>Mean damagea</th>
<th>Resistance ratingb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1c</td>
<td>Study 2d</td>
<td></td>
</tr>
<tr>
<td>Wheatland</td>
<td>B. l. leucopterus</td>
<td>4.2a</td>
<td>4.2a</td>
</tr>
<tr>
<td>KS94</td>
<td>B. l. leucopterus</td>
<td>2.5b</td>
<td>2.1b</td>
</tr>
<tr>
<td>Wheatland</td>
<td>B. occiduus</td>
<td>1.6c</td>
<td>1.3c</td>
</tr>
<tr>
<td>KS94</td>
<td>B. occiduus</td>
<td>1.1c</td>
<td>1.0c</td>
</tr>
</tbody>
</table>

Means within the same column followed by the same letter are not significantly different ($P > 0.05$, LSD test).

a Chinch bug damage rating 1–5 scale, with 1 as no damage.
b HR, highly resistant; MR, moderately resistant; MS, moderately susceptible; and HS, highly susceptible (Heng-Moss et al. 2002).
c SE = 0.2.
d SE = 0.2.

<p>| Table 5. Functional plant loss indices for B. l. leucopterus and B. occiduus on Wheatland and KS94 sorghum |</p>
<table>
<thead>
<tr>
<th>Plant selection</th>
<th>Chinch bug species</th>
<th>FPLI*</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1c</td>
<td>Study 2d</td>
<td></td>
</tr>
<tr>
<td>Wheatland</td>
<td>B. l. leucopterus</td>
<td>6.6a</td>
<td>34.3a</td>
</tr>
<tr>
<td>KS94</td>
<td>B. l. leucopterus</td>
<td>13.2a</td>
<td>16.3ab</td>
</tr>
<tr>
<td>Wheatland</td>
<td>B. occiduus</td>
<td>9.6a</td>
<td>8.4b</td>
</tr>
<tr>
<td>KS94</td>
<td>B. occiduus</td>
<td>4.8a</td>
<td>1.0b</td>
</tr>
</tbody>
</table>

FPLI = 1 − (height of infested plant/height of control plant) × (1 − damage rating/5) × 100.
c SE = 3.7.
d SE = 7.7.
susceptible; and HS, highly susceptible (Heng-Moss et al. 2002).

The reason(s) for the differential responses of the different chinch bug species on resistant and susceptible germplasm may provide explanations for the varying degrees of susceptibility observed.

Acknowledgments

We thank Tom Eickhoff (University of Nebraska) and S. Rochefort (Laval University-Quebec) for technical assistance. We also thank Stacy Bonos (Rutgers University), John Reese (Kansas State University), and Turfgrass America for germplasm as well as David Shetlar (The Ohio State University) and Dennis Hoffman (Texas A&M University) for providing chinch bugs not locally available. We acknowledge Gary Hein and John Foster for reviewing this manuscript. This research was supported in part by the University of Nebraska Agriculture Experimentation Station Project 17-078, the United States Golf Association, and the International Turfgrass Producers. This is paper number 14999 of the journal series of the Agricultural Research Division, University of Nebraska-Lincoln.

References Cited


chinch bug (Hemiptera: Lygaeidae) and to St. Augustine decline virus. J. Econ. Entomol. 70: 515–516.


Received 23 April 2005; accepted 19 October 2005.