MANIPULATING MAINTENANCE PRACTICES TO REDUCE THE SUSCEPTIBILITY OF TWO ST. AUGUSTINEGRASS CULTIVARS TO BLISSUS INSULARIS BARBER (HEMIPTERA: BLISSIDAE)

By

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To my loving family.
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MANIPULATING MAINTENANCE PRACTICES TO REDUCE THE SUSCEPTIBILITY OF TWO ST. AUGUSTINEGRASS CULTIVARS TO BLISSUS INSULARIS BARBER (HEMIPTERA: BLISSIDAE)

By

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Chair: Eileen A. Buss
Major: Entomology and Nematology

The southern chinch bug, Blissus insularis Barber, is a major insect pest of St. Augustinegrass, Stenotaphrum secundatum (Walt.) Kuntze, distributed throughout the southeastern United States. Continuous feeding by this pest can kill an entire lawn, often requiring sod replacement, if infestations are not managed with up to 12 insecticide applications a year in south Florida. The goal of this study was to develop modified cultural practices in St. Augustinegrass that could minimize the risk of B. insularis infestations.

Greater B. insularis survival, faster development rate, and increased fecundity were observed when nymphs were reared on ‘Captiva’ (tolerant) and ‘Floratam’ (susceptible) St. Augustinegrass treated with nitrogen fertilizer used at 400 and 300 kg ha$^{-1}$ yr$^{-1}$ rate compared to unfertilized plants, regardless of fertilizer sources (ammonium sulfate or sulfur coated urea). Highly fertilized plants were preferred by B. insularis in choice tests compared to unfertilized control plants.

Periodic lawn samplings indicated that light intensity, thatch thickness, and mowing height were positively associated with B. insularis densities. Lawns under
regimes of no fertilizer and no pesticide inputs had fewer *B. insularis* than lawns under both a fertilizer and pesticide maintenance program.

Higher densities of *B. insularis* were present in the St. Augustinegrass plots fertilized using 300 kg ha\(^{-1}\) yr\(^{-1}\) rate than in unfertilized plots during field experiments, confirming our laboratory studies. Significantly fewer *B. insularis* occurred in field plots maintained at mowing heights of 7.5 cm than in plots mowed at 10 cm. The decline in thatch layer thickness and subsequent *B. insularis* densities following two verticutting events indicated the significance of thatch management. Application of plant growth regulators to St. Augustinegrass reduced *B. insularis* survival in laboratory bioassays, however no toxicity was observed in a contact bioassay. Significant declines in *B. insularis* densities were observed in plots treated with either Primo Maxx® or Embark® compared to control field plots.

We recommend following recommended nitrogen fertilization practices, maintaining mowing heights based on turfgrass cultivar, and practicing thatch management to reduce insecticide use against *B. insularis*. 
Chinch Bugs

Chinch bugs belong to the family Blissidae within the superfamily Lygaeoidea (Sweet 2000). The members of this family specialize on monocotyledonous plants (Slater 1976). In turfgrass, species in the genus *Blissus* are most notorious for causing damage. Four closely related species or subspecies are most abundant in the United States: the common chinch bug, *Blissus leucopterus leucopterus* (Say), the hairy chinch bug, *Blissus leucopterus hirtus* Montandon, the western chinch bug, *Blissus occidentalis* Barber, and the southern chinch bug, *Blissus insularis* Barber (Reinert et al. 1995, Baxendale et al. 1999).

*Blissus leucopterus leucopterus* and *B. leucopterus hirtus* suck sap from cool season grasses and other monocot hosts throughout the northern United States (Leonard 1966, 1968). *Blissus occidentalis* is an important pest of buffalograss (*Buchloe dactyloides*) (Nutall) Engelmann (Baxendale et al. 1999) and, as the common name suggests, is reported in the western United States including California, Colorado, New Mexico, and Montana (Slater 1964).

*Blissus insularis* was initially considered a color variety of *Blissus leucopterus*, before its distinction from other taxa of the *B. leucopterus* complex on a genetic basis (Leonard 1966). The previously described “Florida lawn chinch bug” was renamed the southern chinch bug, *B. insularis* (Stringfellow 1969, Sweet 2000).
Southern Chinch Bug, *Blissus insularis*

St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze, is the most common turfgrass species injured by *B. insularis* in the southeastern United States (Reinert and Kerr 1973, Potter 1998). Feeding damage to St. Augustinegrass by *B. insularis* in Florida was first documented in 1922 (Newel and Berger 1922). Symptoms resulting from aggregated feeding by *B. insularis* nymphs and adults closely resemble drought stress (Figure 1-1). The damage pattern begins as a small yellowed patch, extends outwards, and eventually large dead areas in lawns become difficult to renovate (Watson 1925). *Blissus insularis* hide between older leaf sheaths and in the thatch, only becoming visible on leaf blades in high population densities. Economic damage and cost of control operations (e.g., insecticide purchases and applications, and/or sod replacement) in Florida was about five million U.S. dollars annually (Strobel 1971, Hamer 1985). Other host plants include bermudagrass [*Cynodon dactylon* (L.) Pers.], bahiagrass (*Paspalum notatum* Flüggé), centipedegrass [*Eremochla ophiuroides* (Munro) Hack], and zoysiagrass (*Zoysia spp.*) (Kerr 1966, Leonard 1966, Reinert et al. 2011), however economic damage has not been reported on any of these species.

**Biology, Morphology, and Behavior**

Development from egg to adult is influenced by temperature. One generation can develop in about 4-5 wk at 28.3° C and up to 10-13 wk at 21.1° C (Kerr 1966, Reinert and Kerr 1973). This pest remains active from at least March to October in northern Florida and completes three to four generations, while seven to 10 generations occur in southern Florida (Reinert and Kerr 1973). Populations are distributed throughout Florida to Alabama, Georgia, Louisiana, Mississippi, North
Carolina, South Carolina, Texas, California, and Mexico (Sweet 2000), wherever St. Augustinegrass is grown.

**Eggs.** Eggs are 0.7 mm in size, oval, initially whitish to cream in color and then bright orange before hatching (Eden and Self 1960). After a short maturation period (E. Buss, personal observation), each female lays 4.5 eggs each day and continues to lay up to 300 eggs within her adult life span (Kerr 1966, Leonard 1966). *Blissus insularis* lay their eggs singly in protected areas such as grass leaf sheaths, the thatch layer, and soft soil (Reinert and Kerr 1973). Warm, dry weather may be most favorable for egg incubation (Beyer 1924).

**Nymphs.** The first instar (0.7 mm long), second instar (1.0 mm long), and third instar (1.8 mm long) are reddish-orange colored with a white band across the dorsal side of the abdomen. The fourth instar (2.5 mm long) is darker and external wing pads become visible, and the fifth instar (3.2 mm long) is black with more prominent wing pads, but both of these latter instars still retain the white band (Figures 1-2 A-F).

**Adults.** *Blissus insularis* adults can be distinguished from other *Blissus* species by the presence of silvery-grey pubescence on the pronotum and a long labium that extends beyond the metasternum (Sweet 2000). Adult (4.7 mm long) survival ranges from 42-100 d in Florida (Kerr 1966). Females can live on average 55 d longer than males (Kerr 1966). There are two polymorphic wing forms of adult *B. insularis*: macropterous (long-winged) and brachypterous (short-winged) (Wilson 1929) (Figures 1-3 A-B). This polymorphism has been primarily associated with
population density, seasonal dispersal flight, migration, heritability, and host plant quality (Leonard 1966, Cherry 2001c).

**Feeding behavior.** Painter (1928) described the feeding injury caused by *B. l. leucopterus* as sap feeding on phloem and xylem in meristematic regions of the grass, leading to wilting, chlorosis, stunting, and ultimately death. It was noted that the thickness of sclerenchyma cells around the vascular bundles may play an important role during the penetration of the *B. insularis* stylets into vascular tissues (Rangasamy et al. 2009). Nymphs tend to feed in groups by hiding inside folds of the leaf sheath at the crown of a phytomere (Kerr 1966). Greater numbers of *B. insularis* (45-90 per m²) tend to occur in sunny and open areas of grass with thick thatch (about 10-15 cm) (Reinert and Kerr 1973) and therefore damage is usually pronounced in such locations in lawns (Wilson 1929). Aggregation behavior of *B. insularis* has been recently studied (Addesso et al. 2012) to better understand their feeding injury to St. Augustinegrass lawns. A stronger aggregation of *B. insularis* occurred when insects were provided with a real St. Augustinegrass leaf blade as opposed to an artificial leaf, which suggested that host derived olfactory and visual cues may affect aggregation behavior. The Y-tube olfactometer assays described in this study also indicated the existence of some volatiles in aggregated chinch bugs that provide the signals for further aggregations.

**St. Augustinegrass Maintenance Practices and Turf Health**

Turf maintenance practices can contribute to *B. insularis* problems by making the St. Augustinegrass habitat more favorable for infestations. This includes plant water stress, use of excess nitrogen fertilizers and thick thatch (Vázquez 2009, Buss 2010). Other problems that are associated with stressed St.
Augustinegrass are weed infestations, diseases and nematodes (Trenholm et al. 2011).

St. Augustinegrass is a warm season, coarse-textured, aggressive, and stoloniferous turfgrass (Sauer 1972). It is commonly used in southern lawns because it can adapt to a wide range of soils, shade, and salt conditions (Turgeon 1999). St. Augustinegrass is vegetatively propagated on sod farms and is usually established in lawns with plugs or sod pieces (Christians and Engelke 1994, Christians 2004). After establishment, healthy St. Augustinegrass lawns in Florida should receive irrigation as-needed basis (Trenholm and Unruh 2008). The UF/IFAS recommended rate for nitrogen fertilizers vary from 100-300 kg ha\(^{-1}\)yr\(^{-1}\) within three geographical regions within Florida (Trenholm and Unruh 2007, Trenholm et al. 2011). Mow height for standard cultivars should be maintained at 9-10 cm and for dwarf cultivars within 5-6 cm. Following proper cultural practices is necessary to keep plants healthy, enabling a lawn to tolerate pests and other stresses (Buss 2010).

Being stoloniferous, St. Augustinegrass is prone to thatch buildup, which is a layer of dead and living stems and roots situated above the soil surface (Beard 1973). Thatch can accumulate from practices like over fertilization, overwatering, use of rapid sod-forming turfgrasses (Shearman et al. 1980), or applying certain fungicides (e.g., mancozeb) (Smitley et al. 1985, Davis and Smitley 1990), insecticides (e.g., carbaryl, chlorpyrifos, chlordane) (Streu 1973, Potter et al.1985), or herbicides (e.g., benomyl, 2,4-D amine) (Turgeon et al. 1975). These compounds can kill beneficial invertebrates like earthworms and millipedes, which also reduces
organic matter decomposition. Davis and Smitley (1990) induced thatch using the fungicide mancozeb and found more *B. leucopterous hirtus* in plots with thicker thatch layers, compared to dethatched plots, thus indicating positive association between thatch thickness and *B. leucopterous hirtus* abundance.

**Need for an Integrated Pest Management Program for *Blissus insularis***

Sustainable turfgrass pest management requires an understanding of why pests infest certain locations, why and how symptoms develop, and how turf maintenance may affect pest biology. Pest outbreaks tend to occur when turfgrass is too stressed to outgrow damage or when adult females are attracted to and lay eggs in locations where their offspring can optimally develop. Insecticide use has been the primary means of preventing *B. insularis* establishment and reducing existing infestations. As a result of improper rotation and repeated applications in many lawns each year, multiple *B. insularis* populations in Florida have developed resistance to different insecticide classes, including the organochlorines and organophosphates (Kerr 1958, 1961, Reinert and Portier 1983) and pyrethroids (Cherry and Nagata 2005, 2007, Vázquez 2009). Thus, a multi-tactic integrated pest management (IPM) program (e.g., planting resistant grasses, conserving natural enemies, improving cultural control) is needed (Held and Potter 2012). Other studies (e.g., Cockfield and Potter 1985, Arnold and Potter 1987) have demonstrated that chemical inputs (e.g., herbicide, insecticide, and fertilizer) exert harmful effects on beneficial insects in a turfgrass system, thus potentially freeing the pests from predation and parasitism.
Breeding Resistant Cultivars Against *Blissus insularis*

Host plant resistance is a foundation of integrated pest management (IPM), and historically has reduced the amount of pesticides used against insect pests in turfgrass (Held and Potter 2012). Installing resistant cultivars or plant species offers a promising approach for managing *B. insularis* as it is sustainable, economical, and environmentally responsible (Busey 1979, Nagata and Cherry 2004, Trenholm et al. 2011). The use of resistant St. Augustinegrass cultivars has been valuable in suppressing populations of *B. insularis* in the southern United States. ‘Floratam’ was released in 1973, with a mode of resistance of antibiosis (Reinert and Dudeck 1974). It minimized *B. insularis* damage and reduced insecticide use for years (Busey 1979, Trenholm et al. 2011, Nagata and Cherry 2004), until populations overcame the resistance (Busey and Center 1987).

A resistant dwarf cultivar of St. Augustinegrass called ‘Captiva’ (previously NUF-76) was released in 2007 (Nagata and Cherry 2003). Captiva has greater *B. insularis* tolerance compared to Floratam (K. Kenworthy, personal communication), but it has plant disease issues. Rangasamy et al. (2006) conducted ovipositional and developmental studies to determine the categories of resistance for the polyploid line FX-10 and a diploid line of Captiva, and found antixenosis with possible antibiosis as a mechanism of resistance.

**Natural Enemies**

Natural enemies do attack *B. insularis*, but limited information exists on how to optimize their presence in an IPM program. A parasitic wasp, *Eumicrosoma benefica* Gahan (Hymenoptera: Scelionidae), attacks *B. insularis* eggs, and field tests in Florida showed an average abundance of 34.5 wasps per 0.1 m² in lawns
with 90 *B. insularis* per 0.1 m² (Reinert 1972). Predators such as *Pagasa pallipes* Stal (Hemiptera: Nabidae), *Xylocoris vicarius* (Reuter) (Hemiptera: Anthocoridae), *Lasiochilus pallidulus* Reuter (Hemiptera: Anthocoridae), *Sinea* spp. (Hemiptera: Reduviidae), *Geocoris bullatus* (Say) (Hemiptera: Geocoridae) and *G. uliginosus* (Say) (Hemiptera: Geocoridae), *Labidura riparia* Pallas (Dermaptera: Labiduridae), *Solenopsis geminata* (F.) (Hymenoptera: Formicidae), and a spider, *Lycosa* sp. (Areneae: Theridiidae), have been observed attacking *B. insularis* in Florida (Reinert 1978). The red imported fire ant, *S. invicta* Buren (Hymenoptera: Formicidae), although abundant in turfgrass, is unable to suppress *B. insularis* populations (Cherry 2001a). *Beauveria bassiana* (Balsamo) Vuillemin was pathogenic on all life stages of *B. insularis*, but its success was limited to conditions of high humidity and large *B. insularis* populations (Reinert 1978), and epizootics have rarely been witnessed in field populations. More recently, a *Hirsutella* species has been discovered, which has caused isolated localized epizootics from 2010 to 2012 in Florida (E. Buss, personal communication).

**Cultural Control**

Cultural control refers to the deliberate modification of the broad set of management techniques or the manipulation of the environment to improve plant production, reduce pest populations, or minimize pest injury to plants (Kogan 1998). Cultural practices such as applying high nitrogen (N) fertilizers, irrigating frequently, having a high mowing height and poor thatch management are believed to compound the management problem with *B. insularis* (Buss 2010).

**Nitrogen Fertilization.** Nitrogen is a limited resource for insects (Casey and Raupp 1999), so by increasing plant nitrogen content through fertilization, sap-
feeding insects often benefit from the increase in nutrients available. An herbivore’s response to a nitrogen application made to a plant may vary. In general, herbivorous insects develop faster; have greater survival and increased fecundity when fed on fertilized plants, as nitrogen content in plants is considered a limited resource (Slansky and Feeny 1977, Price 1991, Fondriest and Price 1996). According to van Emden (1966), increases in fecundity and developmental rates of a sap sucking pest such as the green peach aphid, *Myzus persicae* Sulzer (Hemiptera: Aphididae), were highly correlated to the increased level of soluble nitrogen in leaf tissue. Use of nitrogen fertilizer may influence the fitness of sap sucking, foliage, and root feeding insects on turfgrasses (Lynch et al. 1980, Chang et al. 1985b, Quisenberry 1990, Davidson and Potter 1995, Brandhorst-Hubbard et al. 2001). On the other hand, no influence of nitrogen fertilization on plant resistance of the recently released St. Augustinegrass cultivar Captiva was observed in term of *B. insularis* survival (Cherry et al. 2011).

Earlier field studies reported the positive association of nitrogen fertilization with *B. insularis* damage severity (Horn and Pritchett 1963, Busey and Snyder 1993). Higher nitrogen rates tend to increase *B. insularis* fecundity, and may decrease development time (E. Buss, unpublished data). Any factor which slows insect growth and increases the searching time for more suitable host plants can also increase the insect’s susceptibility to its natural enemies according to the “slow-growth-high-mortality hypothesis” (Feeny 1976, Clancy and Price 1987). The production of volatile organic compounds by plants in response to nitrogen inputs can either positively or negatively influence a predator’s or parasitoid’s host finding
ability (Chen et al. 2010). If moderating fertilization practices can slow \( B. \text{insularis} \) population growth and damage, then it should be an optimal, non-pesticidal way to suppress this pest. Furthermore fertilizer use rates and application times need to conform to existing literature on to maintain turf health and minimize potential nutrient leaching and water quality issues (Trenholm et al. 2012, Trenholm et al. 2013).

**Irrigation.** Water is essential for photosynthesis and other metabolic processes in plants. Fine root hairs absorb water from the soil profile and facilitate nutrient transport to above-ground plant parts. The amount of water required to maintain healthy turf depends on the species, root depth, soil type, and weather conditions (Turgeon 1999). Adequate irrigation or precipitation is necessary to help plants outgrow or mask minor pest infestations (Merchant and Crocker 1998). During drought stress, blades of St. Augustinegrass grass typically fold and wilt, the leaf color changes from green to bluish-gray, and footprints remain visible after walking on the grass (Trenholm and Unruh 2008).

Adults of some insects may be attracted to and lay more eggs in irrigated turfgrass during periods of hot, dry weather (Merchant and Crocker 1998, Potter 2003). Their eggs may need to absorb water to survive, and humidity needs to be high enough to prevent immature desiccation. In addition, the onset of the rainy season in Florida, usually in June, may trigger mole cricket (\( Scapteriscus \) spp.) egg hatch (Hertl et al. 2001, Buss 2009), and flight activity of certain scarab adults (Buss 2006). On the other hand, there are positive effects on pest suppression associated with increased irrigation, such as dislodging above-ground pests from
plants, drowning insects, and spreading beneficial pathogens or nematodes to help suppress pest populations.

*Blissus insularis* damage often occurs in apparently drought-stressed areas along the edges of lawns, on high, dry, sandy, or shell soil (Wilson 1929, Kerr 1966, Potter 1998), or where the grass grows in full sunlight (Short and Black 1997).

This has anecdotally been attributed to *B. insularis* preference for drought-stressed grass or to greater temperatures and thus faster development in those microclimates (E. Buss, personal observations). However, drought-stressed turfgrass may be an early symptom of a *B. insularis* infestation, rather than indicating low soil moisture (Vázquez and Buss 2006). A greenhouse test demonstrated that *B. insularis* density had a greater impact on St. Augustinegrass decline than drought stress did (Vázquez and Buss 2006). Field testing is needed to make science-based recommendations on irrigation manipulation to reduce plant susceptibility to *B. insularis* infestation for turfgrass managers and homeowners.

**Mowing and Thatch Management.** Mowing is another critical turfgrass maintenance practice which involves the periodic cutting of grass blades to a specified height and returning the clippings to the site (Trenholm et al. 2011). Mowing maintains a uniform appearance and stimulates lateral (vegetative) growth, rather than increasing leaf length (Emmons 1995). Recycling turfgrass clippings returns nutrients back into the soil system reducing fertilization requirements (Trenholm et al. 2011). Also being low in lignin content clippings are not a primary reason for thatch accumulation (Ledeboer and Skogley 1967). Low mowing (i.e., scalping) may remove too much leaf material, increase light penetration to the soil
or thatch, reduce humidity in the microclimate, and stress the grass (Beard 1973, Christians 2004). However, mowing at the highest recommended height for your species may moderate temperature extremes near the thatch or soil, and provide pests with greater protection from predators because of the more complex plant architecture (Beard 1973, Joseph and Braman 2009). Homeowners are concerned that insects and pathogens can be transported between sites on commercial mower decks or clippings.

Thick thatch has been previously associated with *B. insularis* infestations and damage to St. Augustinegrass (Reinert and Kerr 1973). Davis and Smitley (1990) demonstrated abundance of *B. l. hirtus* by artificially inducing thicker thatch with a fungicide; more chinch bugs were present in plots with thicker thatch, compared to dethatched plots. Vertical mowing can increase air flow, thus reducing thatch thickness and humidity in a microclimate (Emmons 1995). Thatch reduction should be expected to decrease soil organic matter, which could allow better penetration of some pesticides into the soil to target other pests (Davis and Smitley 1990). It is expected that proper maintenance practices (i.e., moderate fertilizer applications, correct mowing heights, and vertical mowing) can minimize thatch accumulation and chinch bug population growth (Potter 1998). Confirmation of this assumption is needed to determine the effect of different maintenance or cultural practices on *B. insularis* behavior, habitat preferences, and population dynamics.

Although there is a general understanding that nitrogen level and thatch thickness affect piercing-sucking insects, the data are still lacking to support their roles in Florida turf systems. Management recommendations for *B. insularis* have
incorporated this theory, but pest control companies may have a limited ability (i.e., if they don’t offer such services) or incentive to change these cultural practices, so expectations for rapid grass growth, uniformly dense and dark green grass year-round continue. The results from this research will demonstrate the immediate need to practice UF/IFAS recommended turf maintenance or cultural practices as part of an IPM program. This will help maintain St. Augustinegrass in Florida and reduce the need to replace St. Augustinegrass with another turf species (e.g., zoysiagrass or bahiagrass) that have yet other pest complexes that can be difficult to manage. In addition, reduced reliance on insecticides should weaken the selection pressure being exerted on *B. insularis* populations and delay resistance to the remaining insecticide products in the marketplace. Although this research has been conducted in Florida, the results will impact other southern states where *B. insularis* and St. Augustinegrass occur, and provide a model for managing other chinch bug species throughout the southern states.

The goal of this dissertation research was to determine how cultural manipulations of Floratam and Captiva St. Augustinegrass could be made to reduce their susceptibility to *B. insularis*. This goal was achieved with the following objectives:

1. To quantify the effect of fertilizing two St. Augustinegrass cultivars with different rates and sources of nitrogen on *Blissus insularis* population dynamics and host preference in laboratory tests.

2. To understand homeowner’s perceptions of lawn care practices and identify the association between *Blissus insularis* densities and abiotic and biotic factors existing in St. Augustinegrass lawns.

3. To determine the impact of different cultural practices (nitrogen fertility, mowing height and verticutting) on *Blissus insularis* densities under field conditions.
4. To determine the role of application of plant growth regulators in St. Augustinegrass on *Blissus insularis* damage.
Figure 1-1. Damage caused by *Blissus insularis* feeding in a St. Augustinegrass, *Stenotaphrum secundatum*, lawn. (Photo credit: K. Beaulieu)
Figure 1-2. Images showing immature life stages of *Blissus insularis* A) egg, B) first instar, C) second instar, D) third instar, E) fourth instar, and F) fifth instar (Photo credit: L. Buss).
Figure 1-3. *Blissus insularis* adults showing wing polymorphism A) brachypterous and B) macropterous forms; males are on the left and females are on the right of each photo (Photo credit: L. Buss).
CHAPTER 2
EFFECTS OF DIFFERENT NITROGEN RATES AND SOURCES ON THE POPULATION DYNAMICS AND HOST PREFERENCES OF *BLISSUS INSULARIS* ON TWO ST. AUGUSTINEGRASS CULTIVARS

**Introduction**

Nitrogen is a primary macronutrient and is the basis for protein and nucleic acid metabolism involved in the synthesis and transfer of energy (Dudt and Shure 1994). Nitrogen is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis (Glynn et al. 2003, Stiling and Moon 2005). It stimulates rapid plant growth, increases seed and fruit production, and improves the quality of leaf and forage crops. It is the nutrient element needed in largest quantity for maintenance of a healthy turfgrass stand. Nitrogen is foremost among the nutritional factors that influence the level of arthropod damage to plants (Mattson 1980, Scriber 1984, Slansky and Rodriguez 1987).

Nitrogen is often a limited resource for herbivorous insects, so inputs of nitrogen fertilizers are often accompanied by increased insect growth, survival, and fecundity of herbivorous insects (McNeill and Southwood 1978, Casey and Raupp 1999). In addition, nitrogen fertilization may reduce plant resistance to some insect species (Dahms 1947, Barbour et al. 1991) by promoting growth rather than plant defenses (Herms and Mattson 1992). Therefore, an optimal nitrogen application for each plant species is needed to maintain a balance between plant health and its defense against herbivory.

Although fertilizing turfgrass may help it stay green, dense and weed-free, little information exists on how this practice can be manipulated against insect pest populations (Davidson and Potter 1995). Dahms (1947) indicated that higher rates
of nitrogen fertilization benefitted the common chinch bug, *B. leucopterous* leucopterous (Say), feeding on sorghum, *Sorghum bicolor* L. (Moench) seedlings grown on a nutrient solution. Earlier field studies demonstrated that southern chinch bug, *Blissus insularis* Barber, damage occurred faster on St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze, receiving higher nitrogen rates (Horn and Pritchett 1963, Busey and Synder 1993). Plant resistance to *B. insularis* in the St. Augustinegrass cultivar ‘Captiva’ remained apparently unaffected by nitrogen fertilizers as measured by adult survival (Cherry et al. 2011). Additional data to determine the influence of nitrogen fertility on *B. insularis* population dynamics and behavior is needed to optimize turfgrass maintenance practices to minimize turfgrass susceptibility to *B. insularis*. Therefore, the current study was conducted to determine the impact of three to four nitrogen rates and two sources of nitrogen fertilizers on *B. insularis* fitness and host preferences.

**Materials and Methods**

**Insects.** *Blissus insularis* were collected from St. Augustinegrass lawns in Alachua and Marion Counties, FL, using a TroyBilt TB320BV blower vacuum (Troy-Bilt, Cleveland, OH) (Crocker 1993, Nagata and Cherry 1999, Congdon 2004), separated from plant debris, and placed into 7.6 L glass colony jars in the laboratory. Insects were reared using methods modified from Vázquez (2010).

**Turfgrass Cultivars.** Captiva (previously NUF-76) has been commercially produced and marketed as a tolerant dwarf St. Augustinegrass cultivar (Nagata and Cherry 2004). Since host plant resistance can be altered by fertilization practices (Painter 1951), and may increase a cultivar’s susceptibility to pests, we evaluated Captiva’s performance under different nitrogen regimes against *B. insularis* under
laboratory conditions. ‘Floratam’, which was previously resistant to *B. insularis*, was used as a chinch bug susceptible cultivar in all tests.

**Grass Maintenance.** Plastic pots (15 cm diam) were filled with a 50:50 mix of Farfard #4 potting soil (Conrad Farfard Inc., Agawam, MA) and autoclaved sand. Plugs of Floratam and Captiva St. Augustinegrass were obtained (Home Depot, Gainesville, FL, and Agronomy Department Greenhouse, UF, respectively) and transplanted into pots. Pots were maintained in a greenhouse with 14:10 h L:D photoperiod, 60% relative humidity (RH), and about 24°C ambient temperature to prevent plant dormancy during cooler months (Figure 2-1 A). After establishing for 4 wk, plants were treated with different sources and/or rates of nitrogen fertilizer.

**Fertilizers.** Ammonium sulfate (AS), (NH$_4$)$_2$SO$_4$ (21-0-0) (Lesco Professional Turf Fertilizer, Lesco Inc., Cleveland, OH) was the 100% soluble nitrogen fertilizer source, and sulfur coated urea (SCU) (39-0-0) (Lesco Professional Turf Fertilizer, Lesco Inc., Cleveland, OH) was the 35% soluble controlled release/slow release nitrogen fertilizer source. During August to October 2010, the fecundity test was conducted using three rates of either ammonium sulfate or sulfur coated urea (100, 200, and 300 kg ha$^{-1}$ yr$^{-1}$). During January to March 2011, four rates of either ammonium sulfate or sulfur coated urea (100, 200, 300, 400 kg ha$^{-1}$ yr$^{-1}$) were used. All fertilizer treatments were applied to plants in five equal split applications throughout the test duration. Control pots received no nitrogen, but were treated with Granular Iron Plus (0-0-0) (Lesco Micronutrient Supplement, Lesco Inc., Cleveland, OH) at the rate of 49 kg ha$^{-1}$ yr$^{-1}$ in five equal split applications throughout the test duration.
Total Kjeldahl Concentration

To confirm treatment differences among fertilizer rates, grass clippings (about 2 g fresh wt) were collected from pots of each treatment 1 wk after the final fertilizer application, oven-dried in paper bags at 70-80°C for ≥48 h, weighed, ground, and analyzed for total Kjeldahl nitrogen (TKN) by the University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS), Soil and Plant Testing Laboratory in Gainesville, FL. Data were analyzed using PROC GLM (SAS Institute 2008) and means were compared using Tukey’s HSD test.

Survival and Development Test

It was hypothesized that increased rates of soluble fertilizer would increase *B. insularis* survival and fecundity and reduce nymphal development time because of its immediate availability to plants and presumably insects, compared to slow release or unfertilized plants.

Nymphal jars (Figure 2-1 B) containing 10-15 cm diam grass plugs (with soil and roots removed) grown under the different fertility treatments (five replicates, RCBD) were maintained at 14:10 h L:D and 28-32°C in a rearing room. Initially, a small cloth with 30 *B. insularis* eggs (<24 h old) from the laboratory colony was placed onto a St. Augustinegrass plug in each jar. A fresh plug was added to the old plant material in each jar each week to minimize handling damage to and accidental removal of *B. insularis*. The number and life stage of live *B. insularis* were recorded after 5 wk. Percentage survival and development data were square root transformed and analyzed using PROC GLM (SAS Institute 2008). Model assumptions were examined to detect any violations, and means were separated with Tukey’s HSD test.
Fecundity Test

*Blissus insularis* adults from the previous experiment (<7 d old) were separated by the treatments on which they had been reared. Two randomly selected male/female pairs from the same nitrogen rate, source, and cultivar (five replicates per treatment) were placed on two terminal stolons (three nodes long) that were cut from the plants that received the same treatment as that on which the insects had previously developed. Stolons were temporarily soaked in water to remove any incidental pests, and the cut end was placed in a floral water pic (1 cm diam, 7.5 cm length, Marshall Floral Product Inc., Jackson, MI). Each plastic container (15.2 cm diam × 6.4 cm tall) had dental castone (Henry Schein Inc., Indianapolis, IN) (1 cm thick) at the bottom, a 2 cm wide band of fluon (Ag Fluoropolymers, Chadds Ford, PA) along the side, and a vented lid (Figure 2-1 C). Stolons were replaced every 3 d and the numbers of eggs laid were counted weekly for 5 wk. Adults (male/female) were replaced if mortality occurred in any of the treatments every week during the egg count. Data were square root transformed and analyzed using repeated measures in PROC MIXED (SAS Institute 2008).

Choice Tests

The choice tests were designed using intact plants to determine *B. insularis* preferences for Captiva or Floratam under four rates of nitrogen (100, 200, 300, or 400 kg ha⁻¹yr⁻¹) in 2011, applied as either 100% soluble nitrogen (ammonium sulfate) or as a 35% soluble nitrogen source (sulfur coated urea). Control plants for each cultivar were treated as previously described. Six sets of different choice tests were performed (Table 2-1).
Arenas for choice tests were constructed from circular polypropylene food storage containers [measuring 33.0 (top diam) × 17.8 (bottom diam) × 10.6 cm (height) Rubbermaid 3907, Wooster, OH)], according to Rangasamy et al. (2006). Holes (6 mm diam) that were equally spaced around the perimeter of the plastic arena and 3 cm below the open edge were drilled to accommodate the grass stolons from five treatments in test numbers 1, 2, 4, 5, and nine treatments in test numbers 3 and 6. Vertical channels were cut from the top, open edge of the container to the hole drilled in the side. Stolons (three nodes long), still attached to potted plants, were passed through the channels to rest in the holes. The portions of the stolon in contact with the arena were wrapped with parafilm strips (Parafilm “M” Laboratory film, Chicago, IL) to minimize plant damage. After positioning the stolons, the channels were sealed with clear cellophane tape (Scotch Tape, St. Paul, MI) to prevent insect escape (Figure 2-2).

Adult *B. insularis* (2 wk old) were obtained from the laboratory colony and starved for 24 h to precondition the insects (Reisenman et al. 2013). In test numbers 1, 2, 4 and 5, 26 adult *B. insularis* (13 males and 13 females) were released into the center of the arena and the lid was sealed. In test numbers 3 and 6, 50 adult *B. insularis* (25 males and 25 females) were released into the center of the arena. The percentage of *B. insularis* that were ‘on’ stolons of each treatment at 24, 48, and 72 h after release was recorded. The experimental design was completely randomized with five replications. Mixed model analyses (PROC MIXED, SAS Institute 2008) were used to identify differences in *B. insularis* preference among the fertilizer treatments using repeated measures.
Results and Discussion

Total Kjeldahl Concentration

Nitrogen rate and source had no significant effect on the TKN concentration present in Captiva and Floratam during August to October 2010 (Table 2-2). However, the TKN concentration during January to March 2011 (Table 2-3) confirmed that St. Augustinegrass treated with higher nitrogen rates had significantly greater TKN than the unfertilized control in Captiva \((F = 62.19; \text{df} = 8, 18; P < 0.0001)\) and Floratam \((F = 113.22; \text{df} = 8, 18; P < 0.0001)\). These differences in TKN concentrations between August to October and January to March samplings may be due to differential shoot versus root growth and nutrient allocation (Seitz 1974). Greater shoot growth than root growth may have diluted the applied nitrogen within the larger biomass available, thus lowering the TKN concentration.

Survival and Development Test

Overall \(B.\ insularis\) survival in the test was 70%. Some drowning occurred when tiny first instars became stuck in water droplets inside the feeding arena. In August to October 2010, significantly more \(B.\ insularis\) (71%) \((F = 9.05; \text{df} = 6, 28; P < 0.001)\) survived on Captiva plugs treated with 300 kg ha\(^{-1}\) yr\(^{-1}\) nitrogen rate (Figure 2-3), compared to lower \(B.\ insularis\) survival when reared on plugs treated with nitrogen rate of 100 kg ha\(^{-1}\) yr\(^{-1}\) and the unfertilized control (50%), regardless of the nitrogen source used. Higher survival on fertilized Captiva plugs indicated the increased susceptibility of fertilized versus unfertilized Captiva St. Augustinegrass.

Similarly, a higher percentage of \(B.\ insularis\) survival (74%) \((F = 8.54; \text{df} = 6, 28; P < 0.0001)\) occurred when fed on the treatments that received from Floratam
plugs treated with nitrogen at the rate of 200 or 300 kg ha\(^{-1}\) yr\(^{-1}\). No significant difference among the sources of nitrogen fertilizer (i.e., ammonium sulfate and sulfur coated urea) was observed.

In January to March 2011, the effects of different rates of nitrogen fertilizers on *B. insularis* survival were significant at \(P < 0.001\) in both cultivars (Figure 2-4). Significantly more *B. insularis* (70%) survived to 5 wk when reared on grass treated with nitrogen fertilizer at the annual rate of 300 or 400 kg ha\(^{-1}\) yr\(^{-1}\) as compared to the unfertilized control (50%) in Captiva (\(F = 6.56;\) df = 7, 37; \(P < 0.0001\)) and Floratam (\(F = 3.39;\) df = 7, 37; \(P = 0.0067\)). No significant effect of nitrogen fertilizer source was observed.

Our results are consistent with that of Dahms and Fenton (1940), who noted that plant resistance in sorghum cultivars to the common chinch bug, *B. leucopterous* (Say), declined in response to the addition of sodium nitrate fertilizers. Similarly in St. Augustinegrass, the addition of inorganic fertilizers was reported to influence the damage caused by *B. insularis* by increasing the susceptibility of the ‘Floratine’ cultivar (Horn and Pritchett 1963). Greater survival at higher nitrogen rates in both the cultivars in current studies indicated the influence of nitrogen fertility on the breakdown of a plant’s resistance to *B. insularis*. Our findings do not corroborate the earlier study that indicated no effect of nitrogen fertilization on Captiva resistance in terms of adult survival (Cherry et al. 2011). Nitrogen fertilization may reduce plant resistance (Herms and Mattson 1992) because during the growth process stimulated by nitrogen, a plant’s carbon resources get used so
there are less nonstructural carbohydrates available for synthesizing defensive compounds.

In August to October 2010, the percentage of *B. insularis* that reached the adult stage when reared on Captiva St. Augustinegrass was four times greater in treatments fertilized with any nitrogen rate than the unfertilized control ($F = 10.84; \text{df} = 6, 28; P < 0.0001$) (Figure 2-5). Similarly, significantly more (51%) *B. insularis* adults had developed on Floratam fertilized with sulfur coated urea at 300 kg ha$^{-1}$ yr$^{-1}$ rate ($F = 4.00; \text{df} = 6, 28; P = 0.0051$) compared to insects reared on unfertilized grass (33%). Also in January to March 2011, significantly more *B. insularis* became adults within the 5 wk test in all the fertilized treatments, compared to the unfertilized control, when reared on Captiva ($F = 3.89; \text{df} = 8, 37; P = 0.0029$) or Floratam ($F = 7.05; \text{df} = 8, 37; P < 0.0001$) (Figure 2-6). These tests indicate that fertilizing either St. Augustinegrass cultivar, regardless of the nitrogen source, decreases *B. insularis* development time. Nitrogen availability is critical for faster insect development, and insects with less nutritious host plants grow slower (McClure 1980, Karowe and Martin 1989).

**Fecundity Test**

In August to October 2010, females reared as nymphs on turfgrass treated with 200 and 300 kg ha$^{-1}$ yr$^{-1}$ nitrogen rate using either ammonium sulfate ($F = 59.49; \text{df} = 3, 16; P < 0.0001$) or sulfur coated urea ($F = 33.0; \text{df} = 3, 16; P < 0.0001$) on Captiva laid significantly more eggs (Figure 2-7 A-B). *Blissus insularis* fecundity increased two-fold when fed the stolons receiving higher nitrogen rates than compared to unfertilized stolons. A similar trend was observed in Floratam treatments receiving ammonium sulfate ($F = 57.97; \text{df} = 3, 16; P < 0.0001$) and
sulfur coated urea \((F = 25.46; \text{df} = 3, 16; P < 0.0001)\) at the annual rate of 200 and 300 kg ha\(^{-1}\) yr\(^{-1}\) (Figure 2-6 C-D).

In 2011, there was a significant difference in number of eggs laid per female per week for the 5 wk period among the treatments receiving ammonium sulfate and unfertilized control (Figure 2-8 A) in Captiva \((F = 8.04; \text{df} = 4, 20; P = 0.0005)\). The oviposition pattern changed significantly with time \((F = 4.71; \text{df} = 4, 80; P = 0.0018)\), peaking in the third week and then declining.

Significantly more eggs were laid when \textit{B. insularis} were reared on Captiva treated with different rates of sulfur coated urea \((F = 8.81; \text{df} = 4, 20; P = 0.0003)\) than on unfertilized plants (Figure 2-8 B), but no effect of time was observed. Similarly, the number of eggs laid on Floratam stolons was significantly higher in treatments with higher rates of sulfur coated urea \((F = 4.91; \text{df} = 4, 20; P = 0.0063)\), compared to the unfertilized control plants. However, a marginally significant difference was observed among plants fertilized with ammonium sulfate and unfertilized control \((F = 2.81; \text{df} = 4, 20; P = 0.0532)\) (Figure 2-8 C-D). The nutritional adequacy of a plant is known to drive host selection and acceptance for oviposition by herbivores (Bernays and Chapman 1994). Similarly, Chen et al. (2007) demonstrated that armyworm (\textit{Spodoptera exigua} (Hübner)) females preferentially oviposited on cotton plants receiving higher nitrogen levels. Bentz et al. (1995) reported that \textit{Bemisia argentifolii} (Bellows and Perring) preferred to oviposit on poinsettia plants that received increased rates of nitrogen fertilizer.

Several studies have reported that phytophagous insects, when subjected to nutritionally poor diets, had reduced lower growth rates and fecundity (Dixon 1970,

**Choice Tests**

In choice test 1, more *B. insularis* were present on Captiva stolons that received a higher rate of ammonium sulfate ($F = 23.87; df = 4, 20; P < 0.0001$) (Figure 2-9 A) consistently at 24, 48, and 72 h after release. Similarly in test 2, significantly more *B. insularis* were observed feeding on stolons fertilized with sulfur coated urea at 400 kg ha$^{-1}$ yr$^{-1}$ rate ($F = 17.40; df = 4, 20; P < 0.0001$) (Figure 2-9 B). In choice test 3, *B. insularis* did not distinguish among different nitrogen sources but consistently preferred St. Augustinegrass stolons receiving higher nitrogen rates from any sources than unfertilized control at 24 and 48 h after release ($F = 5.53; df = 8, 36; P < 0.0001$) (Figure 2-9 C).

More *B. insularis* were counted on stolons from Floratam plants receiving nitrogen at 400 kg ha$^{-1}$ yr$^{-1}$ rate (three times higher than on the unfertilized control) in choice tests 4 ($F = 3.36; df = 4, 20; P = 0.0294$) and 5 ($F = 32.58; df = 4, 20; P < 0.0001$) (Figure 2-10 A-B). In the same manner, in choice test 6 (Figure 2-10 C), no significant difference occurred among sources but more insects were counted on stolons from plants receiving higher nitrogen rates at 24 h after release ($F = 7.74; df = 8, 36; P < 0.001$), suggesting that nitrogen rate has a significant role in influencing host selection.

Higher preferences by *B. insularis* adults to high rates of fertilizers in choice tests also indicated the existence of some cues (visual, olfactory or gustatory) in the
host selection process. Application of organic fertilizers attracted ovipositing green June beetle (*Cotinis nitida* (L.)) females via strong odor emitted by applied fertilizer (Brandhorst-Hubbard et al. 2001). Increase in the suitability of turfgrasses that received nitrogen fertilizers to different insect pests has been reported (Lynch et al. 1980, Chang et al. 1985b, Quisenberry 1990, Davidson and Potter 1995) which supports our findings of increased susceptibility of *B. insularis* in St. Augustinegrass as a consequence of nitrogen fertilization.

Consequently, there is a need to follow appropriate fertilizer practices in St. Augustinegrass to reduce *B. insularis* damage. The UF/IFAS recommendations for St. Augustinegrass fertilization are a yearly range of nitrogen fertilizer applied at the rate of 100-300 kg ha\(^{-1}\) yr\(^{-1}\) (2-6 lbs per 1,000 ft\(^2\)) depending on the location within the state (Trenholm et al. 2011). Our results suggest that cultural management of *B. insularis* is possible if fertilizer practices in St. Augustinegrass are optimized to maintain a balance between turf health and insect resistance. Future studies can be conducted by incorporating other cultural tactics (e.g., mowing) with nitrogen fertilization in St. Augustinegrass to develop a sound cultural management program for this pest.
Table 2-1. Series of choice tests involving different rates and sources of nitrogen on two St. Augustinegrass, *Stenotaphrum secundatum*, cultivars.

<table>
<thead>
<tr>
<th>Choice test</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>‘Captiva’ grass plugs treated with ammonium sulfate at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
<tr>
<td>2.</td>
<td>‘Captiva’ grass plugs treated with sulfur coated urea at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
<tr>
<td>3.</td>
<td>‘Captiva’ grass plugs treated with ammonium sulfate or sulfur coated urea at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
<tr>
<td>4.</td>
<td>‘Floratam’ grass plugs treated with ammonium sulfate at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
<tr>
<td>5.</td>
<td>‘Floratam’ grass plugs treated with sulfur coated urea at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
<tr>
<td>6.</td>
<td>‘Floratam’ grass plugs treated with ammonium sulfate or sulfur coated urea at the rate of 100, 200, 300, or 400 kg nitrogen ha$^{-1}$ yr$^{-1}$ and unfertilized control</td>
</tr>
</tbody>
</table>
Table 2-2. Percent total Kjeldahl nitrogen concentration (TKN) in ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, treated with different rates and sources of nitrogen fertilizers in August to October 2010. The grass blades were collected a week after the last fertilizer application to measure TKN.

<table>
<thead>
<tr>
<th>Fertilizer rate (kg ha⁻¹ yr⁻¹)</th>
<th>Ammonium</th>
<th>Sulfur coated urea</th>
<th>Ammonium</th>
<th>Sulfur coated urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.1 ± 0.9</td>
<td></td>
<td>1.0 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1.2 ± 0.1</td>
<td>1.2 ± 0.9</td>
<td>1.3 ± 0.7</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>200</td>
<td>1.3 ± 0.1</td>
<td>1.3 ± 0.9</td>
<td>1.4 ± 0.2</td>
<td>1.5 ± 0.2</td>
</tr>
<tr>
<td>300</td>
<td>1.5 ± 0.6</td>
<td>1.9 ± 4.4</td>
<td>1.7 ± 0.1</td>
<td>1.8 ± 1.2</td>
</tr>
</tbody>
</table>
Table 2-3. Percent total Kjeldahl nitrogen concentration (TKN) in ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, treated with different rates and sources of nitrogen fertilizers in January to March 2011. The grass blades were collected one week after the last fertilizer application to measure TKN.

<table>
<thead>
<tr>
<th>Fertilizer rate (kg ha⁻¹ yr⁻¹)</th>
<th>‘Captiva’</th>
<th>‘Floratam’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ammonium sulfate</td>
<td>Sulfur coated urea</td>
</tr>
<tr>
<td>Control</td>
<td>1.8 ± 0.1 e</td>
<td>1.5 ± 0.1 f</td>
</tr>
<tr>
<td>100</td>
<td>1.9 ± 0.1 cde</td>
<td>1.7 ± 0.1 e</td>
</tr>
<tr>
<td>200</td>
<td>2.3 ± 0.1 c</td>
<td>1.9 ± 0 cd</td>
</tr>
<tr>
<td>300</td>
<td>2.8 ± 0.1 b</td>
<td>2.3 ± 0.1 cd</td>
</tr>
<tr>
<td>400</td>
<td>3.9 ± 0.2 a</td>
<td>3.1 ± 0 b</td>
</tr>
</tbody>
</table>

Within cultivar, means followed by the same letter do not differ statistically (ANOVA, *P* < 0.05); three replicates were made.
Figure 2-1. Images showing set-up of the plants in greenhouse and containers used to conduct laboratory tests A) St. Augustinegrass, *Stenotaphrum secundatum*, plants grown in plastic pots in the greenhouse, B) nymphal rearing jar, and C) a fecundity test arena. (Photo credit: N. Kaur).

Figure 2-2. Images showing the set-up of choice test A) the whole plant choice test using St. Augustinegrass, *Stenotaphrum secundatum*, and B) *Blissus insularis* release into an arena. (Photo credit: N. Kaur).
Figure 2-3. Percentage survival of *Blissus insularis* (mean ± SEM) when reared for 5 wk on ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, treated with different rates of ammonium sulfate (AS) or sulfur coated urea (SCU) in August to October 2010. Means within a cultivar followed by the same letter do not differ statistically (ANOVA, $P < 0.05$); five replicates were made.
Figure 2-4. Percentage survival of *Blissus insularis* (mean ± SEM) when reared for 5 wk on ‘Captiva’ and ‘Floratam’ St. Augustine grass, *Stenotaphrum secundatum*, treated with different rates of ammonium sulfate (AS) and sulfur coated urea (SCU) in January to March 2011. Means within a cultivar followed by the same letter do not differ statistically (ANOVA, $P < 0.05$); five replicates were made.
Figure 2-5. Development rate of *Blissus insularis* when reared for 5 wk on ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, treated with different rates of ammonium sulfate (AS) and sulfur coated urea (SCU) in August to October 2010. Means within a cultivar followed by the same letter or without a letter do not differ statistically (ANOVA, *P* < 0.05); five replicates were made.
Figure 2-6. Development rate of *Blissus insularis* when reared for 5 wk on ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, treated with different rates of ammonium sulfate (AS) and sulfur coated urea (SCU) in January to March 2011. Means within a cultivar followed by the same letter or without a letter do not differ statistically (ANOVA, \( P < 0.05 \)); five replicates were made.
Figure 2-7. Mean number of eggs laid by *Blissus insularis* when reared for 5 wk on St. Augustinegrass, *Stenotaphrum secundatum*, including A) ‘Captiva’ fertilized using ammonium sulfate (B) ‘Captiva’ fertilized using sulfur coated urea C) ‘Floratam’ fertilized using ammonium sulfate and D) ‘Floratam’ fertilized using sulfur coated urea at 100-300 kg ha\(^{-1}\) yr\(^{-1}\) rate in August to October 2010.
Figure 2-8. Mean number of eggs laid by *Blissus insularis* when reared for 5 wk on St. Augustinegrass, *Stenotaphrum secundatum*, including A) ‘Captiva’ fertilized using ammonium sulfate B) ‘Captiva’ fertilized using sulfur coated urea C) ‘Floratam’ fertilized using ammonium sulfate and D) ‘Floratam’ fertilized using sulfur coated urea at 100-400 kg ha\(^{-1}\) yr\(^{-1}\) rate in January to March 2011.
Figure 2.9. Choice made by *Blissus insularis* adults 24, 48, and 72 h after release in A) test 1 arena containing 5 treatments; B) test 2 arena containing 5 treatments and C) test 3 arena containing 9 treatments, of ‘Captiva’ St. Augustinegrass, *Stenotaphrum secundatum*, stolons fertilized using ammonium sulfate (AS) or sulfur coated urea (SCU) at 100-400 kg ha\(^{-1}\) yr\(^{-1}\) rate.
Figure 2-10. Choice made by *Blissus insularis* adults 24, 48, and 72 h after release in A) test 4 arena containing 5 treatments; B) test 5 arena containing 5 treatments and C) test 6 arena containing 9 treatments, of ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, stolons fertilized using ammonium sulfate (AS) or sulfur coated urea (SCU) at 100-400 kg ha\(^{-1}\) yr\(^{-1}\) rate.
CHAPTER 3
HOMEOWNER’S PERCEPTION OF LAWN CARE PRACTICES AND ASSOCIATION BETWEEN BLISSUS INSULARIS DENSITIES AND ST. AUGUSTINEGRASS LAWN PARAMETERS

Introduction

The southern chinch bug, *Blissus insularis* Barber (Hemiptera: Blissidae), is a major insect pest of St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze (Crocker 1993). The feeding damage caused by aggregations of *B. insularis* on St. Augustinegrass leads to symptoms of wilting, chlorosis, stunting, and ultimately plant death (Watson 1925, Wilson 1929, Reinert and Kerr 1973). The damage pattern of feeding injury extends outward and eventually larger dead patches in lawns develop that are difficult to repair (Kerr 1966).

More *B. insularis* tend to occur on lawn edges and in the perimeter rather than in the interior of turfgrass areas (Cherry 2001b). Various abiotic and biotic factors play an important role to determine the insect abundance within a habitat (Hunter and Price 1992). Insect distribution can be influenced by competition, natural enemy avoidance, microclimate, resource quality, and food availability (Lawton and McNeill 1979, Munch et al. 2005), which in turn depend upon plant health. Therefore, it is important to follow the recommended turf cultural practices to maintain plant health and suppress *B. insularis* in St. Augustinegrass. In this study, we sought to determine the pattern of fertilizer and irrigation practices in St. Augustinegrass lawns along with the homeowners’ environmental concerns. Results from this study will aid in determining how much homeowners know about their lawn care practices and if they do not follow the best management practices (BMPs).
The objectives of this study were to understand homeowner perceptions of their lawn maintenance practices and determine the association between *B. insularis* densities, lawn health (e.g., turf quality, color, chlorophyll concentration, turf density, and weed abundance), and site (or environmental) conditions (e.g., soil temperature, moisture, light intensity, and thatch thickness) in residential St. Augustinegrass lawns from Florida. We hypothesized that *B. insularis* would be more abundant in areas of thicker thatch, higher nitrogen fertility, and warmer temperatures.

**Materials and Methods**

**Participant Recruitment**

An electronic request for participation in the “Your Florida Yard and You” survey was sent in September 2010 to faculty and staff at the University of Florida, employees of the Florida Department of Agriculture and Consumer Services, the Division of Plant Industry (DPI), and Master Gardeners and other clientele of the Alachua and Marion County Extension offices. The response rate to the survey request was 6% (out of about 2,500 people). A link to the University of Florida Institutional Review Board (UF IRB) approved online survey entitled “Your Florida Yard and You” ([http://pdec.ifas.ufl.edu/evaluation/hoa.pl](http://pdec.ifas.ufl.edu/evaluation/hoa.pl); Appendix B) was sent to the 150 initial respondents, and 100 respondents (66.7%) completed the online survey by December 2010. The survey included 45 questions on the demographics, fertilization, irrigation practices, and environmental concerns that could be held by homeowners. In addition, the 100 respondents gave written permission that allowed us to enter and sample their front lawns. An initial site visit in March-April 2011 eliminated six of those lawns because they lacked a dense stand of St.
Augustinegrass. Participants were asked to avoid any insecticide applications during the study.

**Lawn Sampling, 2011**

Ninety-four lawns were sampled once in May and 90 lawns were resampled in June 2011 (drought stress significantly damaged four lawns). All sampling occurred between 0900 and 1600 h. The sampling areas (Figure 3-1) within each lawn were haphazardly selected by tossing four 30 cm diam PVC rings onto the St. Augustinegrass. A 1 m² grid with nine equal quadrants was placed over each PVC ring. St. Augustinegrass density was determined by counting the number of live shoots and turf height was measured with a ruler (cm) from the soil level to the height of the grass blades within a 15 cm diam PVC ring (Figure 3-2 A). The percentage of weed cover in each grid quadrant was visually estimated.

*Blissus insularis* were collected within each ring (700 cm² area for 30 sec) using a TroyBilt TB320BV blower vacuum (TroyBilt, Cleveland, OH) (Crocker 1993, Nagata and Cherry 1999, Congdon 2004), deposited into a white bucket, and the number of *B. insularis, Geocoris* spp. (big eyed bugs) and ants were counted on site. If >20 *B. insularis* were collected per ring, samples were bagged and insects were counted in the lab.

Ten sprigs (about 5 g fresh weight) were removed from within the 15 cm diam PVC ring (Figure 3-2 B), placed in bags, and transported to the laboratory in a cooler. Samples were oven-dried at 70-80°C for ≥ 48 h, weighed, ground, and analyzed by the University of Florida Institute of Food and Agricultural Sciences soil and plant testing laboratory for total Kjeldahl nitrogen concentration (TKN).
To determine thatch thickness, a 2 cm diam soil probe was inserted just outside the vacuum-sampled area. When the core was removed (Figure 3-2 C), the thatch layer between the soil and living plant tissue was measured with a ruler (cm). The soil pH and temperature of each soil core were measured (5 cm depth) using a Field Scout pH 110 Meter (Spectrum Technologies, Inc., Plainfield, IL) (Figure 3-2 D).

Inside each 15 cm diam PVC-ring, turf color was determined using a FieldScout TCM 500 NDVI Turf Color Meter (Spectrum Technologies, Inc., Plainfield, IL) (Figure 3-2 E). Soil moisture was measured with a TDR 300 Soil Moisture Probe (Spectrum Technologies, Inc., Plainfield, IL) (Figure 3-2 F). Turf chlorophyll index was measured using a FieldScout CM-1000 Normalized Difference Vegetative Index (NDVI) (Spectrum Technologies, Inc., Plainfield, IL) (Figure 3-2 G). Each sampling location was described as being in a sunny or shady area based on the light intensity reading taken by a Soil Master Light Meter (Mosser Lee, Co., Millston, WI) (Figure 3-2 H). The distance to the nearest hardscape was measured with a measuring wheel (Rolotape Corporation, Spokane, WA) (e.g., sidewalk, driveway, wall).

A further subset of 17 lawns was selected based on presence of *B. insularis*, and sampled weekly from 8 July to 26 August 2011 for continued *B. insularis* densities and the same turf parameters. Four haphazardly selected areas per site were vacuumed for insects and turf health was quantified as previously described.

**Lawn Sampling, 2012**

Thirteen lawns were sampled weekly for *B. insularis* densities and turf parameters from June to August 2012, as previously described. Lawns were
categorized by the homeowners’ responses about their lawn management practices: 1) no fertilizer and no pesticide used, 2) no fertilizer but pesticide used, 3) with fertilizer but no pesticide used, or 4) both fertilizer and pesticide used.

**Statistical Analyses**

The online survey data were analyzed using PROC FREQ (SAS Institute 2008). To achieve normality of residuals, *B. insularis* counts from lawn samplings were log transformed, log \((y + 0.1)\). The correlation coefficients (PROC CORR, SAS Institute 2008) were calculated to determine any relationship between the lawn parameters and *B. insularis* densities for data collected in May and June 2011. Linear mixed models were fitted using PROC MIXED (SAS Institute 2008) using restricted maximum likelihood and the Kenward-Rogers method to calculate the degrees of freedom. We pooled the data collected in May 2011 (94 lawns) and June 2011 (90 lawns) for analysis with “month” as a fixed effect factor to control for measurement points and “lawn” as a random effect to account for measurements in the same experimental unit (i.e., lawn). The inclusion of the different explanatory variables (turf color, chlorophyll content, TKN concentration, turf density, weed abundance, soil temperature, moisture, light intensity, thatch thickness, number of big eyed bugs, number of ants, and distance of sampling site from hardscape) was evaluated in the model interactively by using an approximated t-test to select those variables with a \(P\)-value \(\leq 0.05\).

For the data from the 17 lawns in July and August 2011, a linear mixed model was fitted according to the earlier mentioned procedure to identify the significant parameters of lawn health associated with *B. insularis* densities. Data
collected from 13 lawns from June to August 2012 were similarly analyzed. A two-way factorial model was evaluated that included the factors of fertilizer, pesticide and their interaction, together with a covariate representing date and a random effect of lawn to account for measurements on the same experimental units. Comparisons among treatment combinations were done using the least significant differences (LSD) at a 5% level.

Results and Discussion

Homeowner’s Profile

Nearly all respondents (n = 99) owned the property on which they lived, with almost half (n = 43) living in the current home for more than 10 yr. The demographics of the respondents/homeowners are summarized in Table 3-1. Survey respondents were on average 55 yr old, and consisted of males (n = 57) and females (n = 42). According to the U.S. Bureau of Census (2010), the average age of people in Alachua and Marion Counties is 30 and 47 yr, respectively. The most common education level obtained among respondents was a graduate degree (n = 66), followed by Bachelor’s degree (n = 17), some college (n = 10), and then high school diploma or equivalent (n = 5). The median annual household income was $66,000, which is comparable to the median annual household income of families in both counties (U.S. Census Bureau 2010).

Most homeowners (n = 90) reported that they managed their lawns themselves, 20% (n = 18) hired lawn care services, and only a few (n = 6) were maintained by homeowner’s associations. This is consistent with the earlier survey results of Florida residents, where 25% reported using lawn care services and 75% were non-users (Israel and Knox 2001). Since most lawn care decisions were made
by the homeowners, it was vital to inform them about proper lawn care practices that emphasized correct fertilization practices.

**Lawn Fertilization**

Nearly 75% of the St. Augustinegrass lawns (n = 72) had been treated with nitrogen fertilizer, indicating the understanding of homeowners that fertilizers were necessary to maintain turf quality (Table 3-2). Of the 43 homeowners who responded to the question about if they had bought the fertilizer, nearly all homeowners (n = 42) bought the fertilizer themselves. In another question, when asked to rank possible criteria used to select a fertilizer from most important (1) to less important (3), price and recommendations/advertisements from lawn books and news articles were the top two criteria (Figure 3-4). Nitrogen amount and coverage for the bag were the second most important factors followed by brand name and convenience of the store.

Our survey results are consistent with earlier reports (Landry 1996, Morris and Traxler 1996) that homeowners tend to use nitrogen fertilizers to enhance their lawn’s appearance. Carpenter and Meyer (1999) indicated that less than 6% of homeowners were aware of the appropriate fertilization practices and therefore needed an informative program about proper lawn maintenance. In another report, Varlamoff et al. (2001) emphasized the development of educational material to reduce homeowner dependence on chemicals, since 75% of the homeowners (n = 76) were reported to be using nitrogen fertilizers in their landscape maintenance.

When we asked about what information they usually read from the label (Table 3-3), almost two-thirds of the responding homeowners (n = 28 out of 43) read about fertilizing frequency and the best season for application. Nearly three-
fourths of the responding homeowners (n = 36 out of 43) read about the application rate, irrigation interval (n = 33 out of 43), and proper selection and placement of plants in a landscape (n = 34 out of 43).

In two different survey questions, when asked about the month or time of year the fertilizer application was made, half of the homeowners indicated that they fertilized their lawns twice a year, typically in spring (n = 58) and late fall (n = 49). The response was consistent with how many times they had fertilized their lawn (Figure 3-5). The University of Florida BMPs for St. Augustinegrass lawns recommend application of 100-300 kg nitrogen ha⁻¹ yr⁻¹ depending upon geographic region, with no more than 0.2 kg (water-soluble nitrogen source) to 0.45 kg (slow-release nitrogen source) per 0.009 ha in one application to grow healthy turfgrass and reduce potential nonpoint pollution of water resources (Trenholm et al. 2011). Best management practices for nitrogen fertilization and irrigation in turfgrass has been important for maintaining water quality in Florida (Erickson et al. 2010, Trenholm and Sartain 2010). Hochmuth et al. (2012) reviewed the role of fertilizer BMPs and summer fertilizer bans in Florida to reduce the unintended consequences of nutrient losses from turfgrass species.

**Irrigation Practices**

More than half of the homeowners (n = 60), indicated that they had automatic irrigation systems. Of the 60 homeowners, who responded to how the irrigation system was set to operate, more than half indicated that the schedule was adjusted seasonally (n = 37). In another question, the response of homeowners indicated that irrigation schedule was adjusted on need basis according to the plants’ water requirements by more than half of the homeowners (n = 56) (Table 3-
4). However, in an earlier study, landscapes with automatic timers used 47% more irrigation water than those without automatic irrigation systems (Mayer et al. 1999). Nearly half of the homeowners followed the recommended irrigation practices by watering their lawns twice a week during summer (n = 52) and only weekly during winter (n = 47) (Figure 3-6). The BMPs for St. Augustinegrass lawns are to provide between 0.5-0.75 in (1.3-1.9 cm) of water per irrigation event at 2-3 d intervals per week during a warm period of active growth and at a 10-14 d interval during a less active growth period or cool season (Trenholm et al. 2011).

**Environmental Concerns**

More than half of the respondents (Table 3-5) strongly agreed that human beings can progress only by conserving nature (n = 54), making wise use of natural resources (water conservation) (n = 56), maintaining ecological balance (n = 53), and preserving resources to ensure the demands of future human beings (n = 57). Thus homeowners’ responses indicated that they were adapting and seeking environmentally friendly landscape practices to reduce non-target impacts and conserve natural resources. However Blaine et al. (2012) reported that homeowners’ attitudes toward lawn care practices are ambiguous because of the simultaneous concern about environment impacts and drive to use chemicals for lawn care. Many Florida homeowners were considered poorly informed about the environmental impacts resulting from their landscaping practices (Knox et al. 1995, Israel and Knox 2001).

**Lawn Sampling, 2011**

About one-third of lawns sampled had at least one *B. insularis* collected in May (n = 37) and June 2011 (n = 29) (data not shown). The densities of *B. insularis*
were positively correlated with light intensity ($r = 0.30, P = 0.0034$) and soil temperature ($r = 0.27, P = 0.0086$) in May 2011. Thatch thickness ($r = 0.22, P = 0.0390$) and soil temperature ($r = 0.25, P = 0.0155$) were positively correlated with *B. insularis* densities in June 2011 (Table 3–6).

For the combined analysis, light intensity and grass height were the most significant explanatory variables influencing *B. insularis* densities in lawns sampled from May to June 2011. Light intensity was positively associated with mean *B. insularis* densities (coefficient = 0.00138; $F = 13.89; P = 0.0003$), indicating that more *B. insularis* were in sunny areas of St. Augustinegrass lawns (Figure 3-3). Light intensity and the soil temperature were positively associated ($r = 0.46, P < 0.0001$), which may result in microclimates that are conducive to faster *B. insularis* population growth (Kerr 1966, Dudeck and Peacock 1992). Similarly, a positive association between *B. insularis* density and grass height (coefficient = 0.1347; $F = 5.09; P = 0.0255$) was observed.

Taller grass may promote thicker thatch, two parameters being positively associated ($r = 0.50, P < 0.0001$). Presence of more organic matter (Beard 1973, Baxendale 1997), resulting from taller grass height and thicker thatch layer could provide a more favorable microclimate for insect development. Grass species composition and thatch thickness were important predictors of hairy chinch bug, *Blissus leucopterus hirtus* Montandon, presence in home lawns (Davis and Smitley 1990). Taller grass can buffer against extreme temperatures and increase the searching area for natural enemies (Carstens et al. 2007, Joseph and Braman 2009).
Turf color and percentage of weed infestation were the most significant variables associated with *B. insularis* densities in lawns sampled from June to August 2011 (Table 3-7). As *B. insularis* density increased, turf became more yellow and brown, whereas less infested areas remained green (coefficient = -4.7562; $F = 4.62; P = 0.0343$). Cherry (2001b) and Addesso et al. (2012) documented the symptoms caused to St. Augustinegrass by aggregated feeding of various life stages of *B. insularis*.

More weeds occurred in areas of heavy *B. insularis* infestation (coefficient = 0.01905; $F = 4.78; P = 0.0319$) (Table 3-7). Similarly, Rainbolt et al. (2006) indicated that weed numbers were seven times greater in areas infested with *B. insularis*. Weed seeds naturally exist in the soil, so any disruption of the turfgrass cover allows greater light penetration to the soil so weed seeds can germinate and outcompete the existing turfgrass (Richmond 2004).

**Lawn Sampling, 2012**

Turf color, thatch thickness, and soil temperature were the most significant parameters associated with *B. insularis* densities in lawns from sampling conducted from June to August 2012 (Table 3-7). This confirmed our 2011 results that turf thatch thickness (coefficient = 0.4561; $F = 5.69; P = 0.0188$) and soil temperature (coefficient = 0.1680, $F = 13.48; P = 0.0004$) were important factors in the St. Augustinegrass lawns where *B. insularis* infestations occurred. Majeau et al. (2000) found no significance of thatch thickness in their investigation of lawn parameters influencing the distribution of *B. leucopterus hirtus* Montandon in cool-season turfgrass.
In addition, turf quality and color diminish (coefficient = -6.4492; \( F = 5.15; P = 0.0251 \)) as a consequence of \( B. \) insularis feeding (Table 3-7) and the damage resembles symptoms of drought stress. Yet, soil moisture was not associated with \( B. \) insularis presence or damage in our sampling (data not shown).

Unexpectedly, using pesticides on lawns was significantly associated with greater \( B. \) insularis densities in that lawn (\( F = 7.63; \text{df} = 1, 9; P = 0.0220 \)). About five times fewer \( B. \) insularis occurred in lawns managed without pesticide (Table 3-8), compared to lawns managed with pesticides. Knowledge of pesticide application history and data on insecticide resistance in a particular lawn will more clearly explain why \( B. \) insularis were abundant in lawns that applied pesticides.

The reduced abundance of \( B. \) insularis in lawns that did not use any pesticide in year 2012 may be due to the presence of natural enemies, such as Geocoris spp. (big-eyed bugs), considered the most important predator of \( B. \) insularis (Cherry 2001a). Because vacuum sampling is inefficient at collecting fast moving insects, like predators, it is likely that the number of big-eyed bugs has been underestimated, so a correlation between predators and \( B. \) insularis was not possible.

In conclusion, there were several factors that were associated with \( B. \) insularis densities in St. Augustinegrass; some of these were the outcomes rather than the reason for higher densities. For example, yellowed turf in areas of infestation was the consequence of \( B. \) insularis feeding. Similarly, pesticide applications were made by the homeowners who already had \( B. \) insularis present in their lawns or as preventive measures taken by the homeowners who had
neighboring lawns infested with *B. insularis*. Fewer *B. insularis* in lawns on the lower maintenance regimes could be speculated on the presence of natural enemies but future studies are needed on how turf maintenance practices influence biocontrol agents. Grass height and thatch thickness were most closely associated with *B. insularis* densities in St. Augustinegrass indicating the need to manipulate these cultural practices to maintain a healthy lawn that can suppress *B. insularis* infestation.
Table 3-1. Demographic profiles of 100 homeowners (North Florida) that participated in an online survey in fall 2010 and volunteered their St. Augustinegrass, *Stenotaphrum secundatum*, lawns for sampling in summer 2011.

<table>
<thead>
<tr>
<th>Survey question</th>
<th>Response options</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent's age (years)</td>
<td>&lt;30</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30–39</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>40–49</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>50–59</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>60–69</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>≥70</td>
<td>12</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>57</td>
</tr>
<tr>
<td>Education level</td>
<td>High school diploma or GED</td>
<td>5</td>
</tr>
<tr>
<td>completed</td>
<td>Some college</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>4-year degree</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Graduate degree</td>
<td>67</td>
</tr>
<tr>
<td>Household income (US $)</td>
<td>&lt; $30,000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>$30,000–$49,999</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>$50,000–$74,999</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>$75,000–$149,000</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>≥ $150,000</td>
<td>17</td>
</tr>
</tbody>
</table>
Table 3-2. Percentage of homeowners responding in terms of either yes or no to the questions asked related to nitrogen fertilizers used in their lawns. No response is the percentage of respondents who did not answer the question.

<table>
<thead>
<tr>
<th>Question / response</th>
<th>Yes</th>
<th>No</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has anyone fertilized the lawn in the last year?</td>
<td>72</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Did you buy the fertilizer?</td>
<td>42</td>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>Did you select fertilizer based on price?</td>
<td>22</td>
<td>16</td>
<td>62</td>
</tr>
<tr>
<td>Did you select your fertilizer based on the amount of nitrogen formulation?</td>
<td>23</td>
<td>13</td>
<td>64</td>
</tr>
<tr>
<td>Did you select your fertilizer based on the amount of slow release nitrogen?</td>
<td>18</td>
<td>19</td>
<td>63</td>
</tr>
<tr>
<td>Did you select your fertilizer based on the amount of phosphorus?</td>
<td>19</td>
<td>18</td>
<td>63</td>
</tr>
<tr>
<td>Did you select your fertilizer based on the convenience of store location?</td>
<td>29</td>
<td>9</td>
<td>62</td>
</tr>
<tr>
<td>Did you select your fertilizer based on coverage of the bag?</td>
<td>16</td>
<td>21</td>
<td>63</td>
</tr>
<tr>
<td>Did you select your fertilizer based on brand name?</td>
<td>17</td>
<td>22</td>
<td>61</td>
</tr>
<tr>
<td>Question / response</td>
<td>Yes</td>
<td>No</td>
<td>No response</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-------------</td>
</tr>
<tr>
<td>How often to use the fertilizer?</td>
<td>28</td>
<td>15</td>
<td>57</td>
</tr>
<tr>
<td>The month of season it can be used?</td>
<td>28</td>
<td>15</td>
<td>57</td>
</tr>
<tr>
<td>The rate to apply on the lawn?</td>
<td>36</td>
<td>7</td>
<td>57</td>
</tr>
<tr>
<td>When to water?</td>
<td>33</td>
<td>10</td>
<td>57</td>
</tr>
<tr>
<td>Which grasses or plants are best suited for product?</td>
<td>34</td>
<td>9</td>
<td>57</td>
</tr>
<tr>
<td>I do not read any information on the product bag or container.</td>
<td>2</td>
<td>41</td>
<td>57</td>
</tr>
</tbody>
</table>
Table 3-4. Percentage of respondents describing the irrigation practices they followed. No response is the percentage of respondents who did not answer the question.

<table>
<thead>
<tr>
<th>Question asked</th>
<th>Response</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you water your lawn?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic irrigation system</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>Sprinkler hose attachment</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>Hose or watering can</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>What best describes the operating settings of your automatic irrigation system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set and left alone</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>Set seasonally</td>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>Turn on manually</td>
<td>14</td>
<td>40</td>
</tr>
<tr>
<td>Someone else sets it</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Do you adjust your irrigation schedule throughout the year?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjust monthly</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Adjust seasonally</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>Adjust as needed</td>
<td>56</td>
<td>12</td>
</tr>
<tr>
<td>Do not adjust schedule</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 3-5. Percentage of respondents indicating their opinion (strongly agreeing to strongly disagreeing) on ecological questions asked.

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human beings can progress only by conserving nature's resources</td>
<td>53.7</td>
<td>35.8</td>
<td>6.3</td>
<td>3.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Human beings can enjoy nature only if they make wise use of its resources</td>
<td>55.8</td>
<td>32.6</td>
<td>6.3</td>
<td>3.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Human progress can be achieved only by maintaining ecological balance</td>
<td>52.6</td>
<td>34.7</td>
<td>6.3</td>
<td>5.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Preserving nature now means ensuring the future of human beings</td>
<td>56.8</td>
<td>30.5</td>
<td>8.4</td>
<td>3.2</td>
<td>1.1</td>
</tr>
<tr>
<td>We must reduce our consumption levels to ensure well-being of the present and future generations</td>
<td>61.1</td>
<td>31.6</td>
<td>5.3</td>
<td>2.1</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3-6. Parameters of St. Augustinegrass, *Stenotaphrum secundatum*, lawns and their correlation coefficients with *Blissus insularis* densities collected from May to June 2011.

<table>
<thead>
<tr>
<th>Lawn variables</th>
<th>May 2011</th>
<th></th>
<th></th>
<th>June 2011</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SEM</td>
<td>r</td>
<td>P value</td>
<td>Mean ± SEM</td>
<td>r</td>
<td>P value</td>
</tr>
<tr>
<td>No. <em>Blissus insularis</em> (vacuum 30 sec per ring)</td>
<td>5.1 ± 0.5</td>
<td>-</td>
<td>-</td>
<td>5.0 ± 0.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turf color (NDVI)</td>
<td>6.0 ± 0.1</td>
<td>-0.1644</td>
<td>0.1134</td>
<td>6.0 ± 0.1</td>
<td>0.0051</td>
<td>0.9620</td>
</tr>
<tr>
<td>Turf chlorophyll index (NDVI)</td>
<td>0.7 ± 0.1</td>
<td>-0.0135</td>
<td>0.8976</td>
<td>0.7 ± 0.1</td>
<td>0.0375</td>
<td>0.7260</td>
</tr>
<tr>
<td>Soil moisture (NDVI)</td>
<td>12.0 ± 1.3</td>
<td>-0.0357</td>
<td>0.7325</td>
<td>12.7 ± 1.3</td>
<td>-0.0927</td>
<td>0.3850</td>
</tr>
<tr>
<td>Thatch thickness (cm)</td>
<td>2.0 ± 0.2</td>
<td>-0.0840</td>
<td>0.4208</td>
<td>1.1 ± 0.1</td>
<td>0.2180</td>
<td>0.0390</td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.6 ± 0.6</td>
<td>-0.0808</td>
<td>0.4390</td>
<td>5.6 ± 0.6</td>
<td>-0.0894</td>
<td>0.4021</td>
</tr>
<tr>
<td>Light intensity (lux)</td>
<td>10,149 ± 1,057</td>
<td>0.2991</td>
<td>0.0034</td>
<td>9,942 ± 1,048</td>
<td>0.1965</td>
<td>0.0635</td>
</tr>
<tr>
<td>Soil temperature (°C)</td>
<td>27.2 ± 2.8</td>
<td>0.2694</td>
<td>0.0086</td>
<td>28.4 ± 3.0</td>
<td>0.2545</td>
<td>0.0155</td>
</tr>
<tr>
<td>Grass height (cm)</td>
<td>8.5 ± 0.8</td>
<td>-0.0078</td>
<td>0.9407</td>
<td>9.5 ± 1.0</td>
<td>0.1041</td>
<td>0.3288</td>
</tr>
<tr>
<td>Grass density (no. of live shoots within 15 cm PVC ring)</td>
<td>27.3 ± 2.8</td>
<td>0.0342</td>
<td>0.7433</td>
<td>27.1 ± 2.9</td>
<td>0.0889</td>
<td>0.4047</td>
</tr>
<tr>
<td>Distance of tossed ring to closest pavement (m)</td>
<td>3.9 ± 0.4</td>
<td>0.1067</td>
<td>0.3063</td>
<td>4.2 ± 0.4</td>
<td>0.0089</td>
<td>0.9335</td>
</tr>
<tr>
<td>Weed infestation (%)</td>
<td>4.8 ± 0.5</td>
<td>0.0940</td>
<td>0.3677</td>
<td>6.3 ± 0.7</td>
<td>0.1185</td>
<td>0.2660</td>
</tr>
<tr>
<td>No. ant mounds</td>
<td>0.1 ± 0.01</td>
<td>0.0679</td>
<td>0.5157</td>
<td>0.01 ± 0.01</td>
<td>-0.0792</td>
<td>0.4579</td>
</tr>
<tr>
<td>No. <em>Geocoris</em> sp. in bucket</td>
<td>0.6 ± 0.1</td>
<td>0.0966</td>
<td>0.3543</td>
<td>1.1 ± 0.1</td>
<td>-0.0273</td>
<td>0.7999</td>
</tr>
<tr>
<td>No. ants in bucket</td>
<td>4.7 ± 0.4</td>
<td>0.0816</td>
<td>0.4345</td>
<td>3.9 ± 0.4</td>
<td>0.0246</td>
<td>0.8181</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (%)</td>
<td>1.5 ± 0.1</td>
<td>-0.0465</td>
<td>0.6564</td>
<td>1.4 ± 0.1</td>
<td>0.1522</td>
<td>0.1569</td>
</tr>
</tbody>
</table>
Table 3-7. Association of St. Augustinegrass, *Stenotaphrum secundatum*, lawn parameters with *Blissus insularis* densities measured during summer of two years (2011-2012).

<table>
<thead>
<tr>
<th>Lawn variable</th>
<th>Mean ± SEM</th>
<th>Estimate</th>
<th>F</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>July to August 2011</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. <em>Blissus insularis</em></td>
<td>3.3 ± 0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(vacuum 30 sec per ring)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turf color (NDVI)</td>
<td>6.0 ± 0.3</td>
<td>-4.7562</td>
<td>4.62</td>
<td>0.0343</td>
</tr>
<tr>
<td>Weed infestation (%)</td>
<td>5.1 ± 0.3</td>
<td>0.01905</td>
<td>4.78</td>
<td>0.0319</td>
</tr>
<tr>
<td><strong>June to August 2012</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. <em>Blissus insularis</em></td>
<td>3.2 ± 0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(vacuum 30 sec per ring)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turf color (NDVI)</td>
<td>6.0 ± 0.2</td>
<td>-6.4492</td>
<td>5.15</td>
<td>0.0251</td>
</tr>
<tr>
<td>Thatch thickness (cm)</td>
<td>2.9 ± 0.1</td>
<td>0.4561</td>
<td>5.69</td>
<td>0.0188</td>
</tr>
<tr>
<td>Soil temperature (°C)</td>
<td>33.2 ± 1.5</td>
<td>0.1680</td>
<td>13.48</td>
<td>0.0004</td>
</tr>
</tbody>
</table>
Table 3-8. Association of fertilizer and pesticide regimes on *Blissus insularis* densities from June to August 2012.

<table>
<thead>
<tr>
<th>Turf maintenance regime</th>
<th>No. <em>B. insularis</em> (vacuum 30 sec per ring)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>0.902 c</td>
<td>0.3706</td>
</tr>
<tr>
<td>Yes</td>
<td>1.494 c</td>
<td></td>
</tr>
<tr>
<td>Pesticide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>0.541 c</td>
<td>0.0220</td>
</tr>
<tr>
<td>Yes</td>
<td>2.394 b</td>
<td></td>
</tr>
<tr>
<td>Interactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No fertilizer / no pesticide</td>
<td>0.468 bc</td>
<td>0.6604</td>
</tr>
<tr>
<td>No fertilizer / with pesticide</td>
<td>1.669 abc</td>
<td></td>
</tr>
<tr>
<td>With fertilizer / no pesticide</td>
<td>0.622 abc</td>
<td></td>
</tr>
<tr>
<td>With fertilizer / with pesticide</td>
<td>3.417 a</td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letter do not differ significantly. *P* values refer to *F*-tests evaluating difference among levels of the same factor or their interaction.
Figure 3-1. Example of a 1×1 m St. Augustinegrass, *Stenotaphrum secundatum*, sampling grid over a 30 cm diam PVC ring (Photo credit: N. Kaur).
Figure 3-3. Damage caused by *Blissus insularis* in sunny areas of a St. Augustinegrass, *Stenotaphrum secundatum*, lawn. (Photo credit: K. Beaulieu).
Figure 3-4. Percentage of respondents indicating ranking of various factors considered from the most important to third-most important factor, when buying a lawn fertilizer.
Figure 3-5. Percentage of respondents indicating the months of the year when they had their St. Augustinegrass, *Stenotaphrum secundatum*, lawns fertilized in 2009.
Figure 3-6. Percentage of respondents indicating irrigation schedule ranging between less than once a week to nearly every day in their St. Augustinegrass, *Stenotaphrum secundatum*, lawns in summer and winter, 2009.
CHAPTER 4
EFFECT OF FERTILIZATION, THATCH REDUCTION, AND MOWING ON
‘FLORATAM’ AND ‘CAPTIVA’ ST. AUGUSTINEGRASS HEALTH AND BLISSUS
INSULARIS DENSITY

Introduction

With increased scrutiny on fertilizer and other turfgrass maintenance practices in Florida to protect natural water resources (Hochmuth et al. 2012), it is also critical to examine how these practices impact key pests. St. Augustinegrass (Stenotaphrum secundatum Walt. Kuntze) needs periodic fertilization, mowing, irrigation, and possibly aeration or thatch reduction (Turgeon 1999). Highly managed lawns are also often treated preventively with pesticides to minimize the risk of pest damage. However, a trade-off exists between keeping turfgrass healthy (Potter 1998, Held and Potter 2012) versus providing optimal habitat and host plant quality for pest populations.

Thatch is a layer of organic material between living turfgrass plants and the soil (Beard et al. 1978). The organic matter binds and thereby reduces the efficacy of pyrethroid insecticides, and provides an optimal habitat for insects like the hairy chinch bug, B. leucopterus hirtus Montandon (Davis and Smitley 1990). Thatch reduction or verticuting, a mechanical control option, can physically kill insects and decreases the amount of habitat and humidity available to chinch bugs and spittlebugs (Davis and Smitley 1990, Majeau 2000). It also can improve pesticide efficacy by facilitating better penetration to the soil to contact the target pest.

Mowing is another important maintenance practice that affects the aesthetics (e.g., uniformity) and health of turfgrass (Trenholm et al. 2011). However, adjusting mowing heights can be used to remove black cutworm eggs laid on leaf tips (Williamson and Potter 1997a, Williamson and Potter 1997b), directly kill surface-feeding insects
(Potter et al. 1996), or obtain better penetration of pesticides into the thatch or soil (Davis and Smitley 1990). According to Beard (1973) and Joseph and Braman (2009), higher mowing heights predispose turfgrass species to insect susceptibility by providing protection against temperature extremes and predators. Mowing too low can stress turfgrass and increase its vulnerability to additional pest damage (Held and Potter 2012). Thus, it is important to identify the proper height of cut for a turfgrass cultivar or species to minimize plant stress.

Fertilization may be the most important cultural practice that affects turfgrass insect pests. Organic fertilizers (e.g., turkey or chicken litter) can attract green June beetle \((Cotinis nitida)\) adults and result in severe grub damage (Brandhorst-Hubbard 2001). It may reduce host plant resistance and allow insects to feed and survive on the plants that they formerly were not able to feed (Dahms 1947, Painter 1951, Panda and Khush 1995, Altieri and Nicholls 2003). Moderating fertility or fertilization application times can affect adult fall armyworm and grass looper oviposition preferences and subsequent larval performance (Lynch et al. 1980; Chang et al. 1985a, 1985b). Turfgrass that receives the proper source and amount of nitrogen fertilizer for its growing conditions is more likely to have a dense enough canopy to prevent weed encroachment (Trenholm et al. 2011) and may tolerate some feeding injury.

Using higher than recommended rates of nitrogen may cause problems like increased herbivore feeding preference (Dahms 1940, Davidson and Potter 1995), or disease incidence (Elliot and Harmon 2011). Nitrogen fertilization can promote thicker thatch in turfgrass (Beard 1973, Kim and Beard 1985), which may increase humidity and provide favorable temperatures for insect development. This microclimate may be
ideal for southern chinch bug, *B. insularis* (Kerr 1966), by reducing the risk of egg desiccation, predation, and/or insecticide efficacy (Davis and Smitley 1990), and may provide a refuge for *B. insularis* (Reinert and Kerr 1973). It is important to recognize that nitrogen is needed for turfgrass health and growth and that it supplies plants with amino acids and proteins needed for growth and sustenance.

Thus, we sought to 1) determine the impact of nitrogen fertilization on *B. insularis* densities in field plots and subsequent turf health, 2) evaluate the influence of nitrogen fertilization and different mowing heights on *B. insularis* densities, and 3) determine the effect of verticutting and different mowing heights on the densities of *B. insularis* and turf health. We hypothesized that if turfgrass is properly maintained according to best management practices; it will remain healthy and would be able to suppress *B. insularis* densities.

**Materials and Methods**

**Study Site**

‘Floratam’ and ‘Captiva’ St. Augustinegrass field plots were located at the University of Florida Plant Science Unit in Citra, FL. Plots (2×2 m) used in the nitrogen fertility and thatch induction trials were established in 2008, and plots used in the mowing test were established in 2011. Plots were separated by 0.5 m untreated grass buffers.

**Nitrogen Fertility Trial**

The effect of three rates (100, 200, or 300 kg ha⁻¹yr⁻¹) of two nitrogen sources (ammonium sulfate or sulfur coated urea) on *B. insularis* density and damage, as well as several turf health parameters, was evaluated on plots of Captiva and Floratam St. Augustinegrass. Ammonium sulfate, 21-0-0 (Lesco Professional Turf Fertilizer, Lesco...
Inc., Cleveland, OH) was the soluble nitrogen source and sulfur coated urea, 39-0-0 (Lesco Professional Turf Fertilizer, Lesco Inc., Cleveland, OH), was the slow release source. Only an iron fertilizer (0-0-0) (Lesco Micronutrient Supplement, Lesco Inc., Cleveland, OH) was applied to control plots at the rate of 49 kg ha⁻¹ yr⁻¹. Treatments were applied in a randomized complete block design with five replicates in equal split applications on 13 April, 12 June, and 8 August 2011.

To ensure that each plot contained a minimal number of insects, *B. insularis* were vacuum-collected from another site (Gainesville, FL), and a combination of 30 fourth and fifth instars and adults were released into the center of each test plot on 11 May 2011. Populations were allowed to establish for 1 mo. To evaluate treatment effects, the center of each plot (700 cm² area) was vacuum-sampled for 30 sec with a TroyBilt TB320BV blower vacuum (TroyBilt, Cleveland, OH) (Crocker 1993, Nagata and Cherry 1999, Congdon 2004) on 20 June, 20 July, and 19 August 2011 between 1000 to 1400 hr.

Multiple turf quality parameters were measured on each sampling date. Turf color, chlorophyll content, TKN concentration, turf height, turf density, soil pH, soil moisture and thatch thickness were measured as described in Chapter 3. Linear mixed models were fitted using PROC MIXED (SAS Institute 2008) using the restricted maximum likelihood and Kenward-Rogers method to calculate the degrees of freedom. The inclusion of different explanatory variables (turf color, chlorophyll content, TKN concentration, turf density, soil pH, soil moisture, and thatch thickness) was evaluated in the model interactively by using an approximated t-test to select those variables with a
When appropriate, means were separated using Tukey’s HSD test.

**Nitrogen Fertility and Mowing Test**

In summer 2012, we assessed the influence of nitrogen fertility (100 or 200 kg ha\(^{-1}\)yr\(^{-1}\)) in combination with mowing height (5 cm, 10 cm) and either recycling or removing mowed grass clippings on *B. insularis* abundance. The test was arranged as a split plot design, with grass height as the main plot (13.5×4 m\(^2\)). Grass clippings (collected versus not collected) were completely randomized as four subplots (6.7×2 m\(^2\)), and within the subplots were the sub subplots (3.3×2 m\(^2\)) fertilized with ammonium sulfate (21-0-0) at the rate of 100 or 200 kg ha\(^{-1}\)yr\(^{-1}\). Fertilizer was applied to plots on 10 April, 5 June, and 2 August 2012. Plots were mowed weekly using a Honda HRX217VKA (American Honda Power Equipment Division, Alpharetta, GA). Grass clippings were bagged, placed in a cooler, and transported to the lab to count any *B. insularis*.

To ensure a baseline population, 30 *B. insularis* (fourth instars, fifth instars, and adults) were released into each plot on 10 May 2012. Vacuum sampling was done to assess *B. insularis* densities in plots (700 cm\(^2\) area for 30 sec) on 12 and 26 June, 10 and 24 July, and 7 and 21 August 2012, as previously described. Turf quality ratings (0-9 scale; 0 = yellow, thin grass, 9 = dark green, dense turf) were recorded on each sampling date.

Data were analyzed using mixed model analyses (PROC MIXED, SAS Institute 2008) to detect differences in *B. insularis* densities among different treatments. When appropriate, means were separated using Tukey’s HSD test. Effects with *P*-values ≤ 0.05 were considered statistically significant.
Verticutting and Mowing Height Test

The impact of verticutting in combination with different mowing heights on *B. insularis* densities in Floratam and Captiva plots was tested in summer 2013. We hypothesized that fewer *B. insularis* would be present in plots that had mechanically reduced thatch.

The test was arranged as a split plot design. Whole plot (8×2 m²) treatments consisted of three mowing heights (5.0, 7.5, and 10 cm), and sub plot (4×2 m²) treatments were verticutting or no verticutting. Plots were mowed weekly with a mulching type mower Honda HRX217VKA (American Honda Power Equipment Division, Alpharetta, GA). Plots were verticut on 18 April and 3 June 2013 using a Ryan Mataway Dethatcher (Schiller Grounds Care, Inc., Johnson Creek, WI) with blades spaced 2.5 cm apart and the vertical blade set at 5 cm deep. Ammonium sulfate was applied after verticutting at a rate of 100 kg ha⁻¹yr⁻¹ on 18 April, 3 June, and 2 August 2013.

Thirty *B. insularis* (fourth instars, fifth instars, and adult) were released in each plot on 9 May 2013. To evaluate treatment effects, plots (700 cm² area for 30 sec) were vacuum-sampled on 12 June, 12 July, and 12 August 2013, and the number of *B. insularis* collected was counted. Turf health was estimated by measuring thatch thickness and a visual turf quality rating (0-9 scale).

Data were analyzed using mixed model analyses (PROC MIXED, SAS Institute 2008) to detect differences in the densities of *B. insularis* among different treatments. If significant, means were separated using Tukey's HSD test.
Results

Nitrogen Fertility Trial

Significantly more *B. insularis* were collected from Captiva plots treated with 300 kg ha\(^{-1}\) yr\(^{-1}\) rate (ammonium sulfate = 64.7 ± 13.5) compared to the unfertilized plots (27.8 ± 8.0 *B. insularis*) \((F = 2.57; \text{df} = 6, 28; P = 0.04)\) (Figure 4-1). This trend was similar for samples collected in June, July, and August, so pooled mean monthly data (five replicates per treatment on each sampling date) are presented. Similarly, significantly more *B. insularis* were present in Floratam plots \((F = 3.92; \text{df} = 6, 28; P = 0.0057)\) treated with 300 kg ha\(^{-1}\) yr\(^{-1}\) (ammonium sulfate = 69.1 ± 8.2 *B. insularis*) compared to unfertilized plots (30.6 ± 2.0 *B. insularis*) (Figure 4-1). Nitrogen source did not statistically vary. Significantly higher TKN concentration (Table 4-1) was present in Floratam fertilized using sulfur coated urea at 200 and 300 kg ha\(^{-1}\) yr\(^{-1}\) rate \((F = 9.92; \text{df} = 6, 28; P < 0.0044)\). Total Kjeldahl nitrogen concentration was the most significant variable affecting *B. insularis* populations \((F = 4.29; \text{df} = 1, 96; P = 0.0411)\), with turf height also associated with the number of *B. insularis* collected in vacuum samples in Captiva plots (Table 4-2). None of the turf parameters explored could explain *B. insularis* densities in the Floratam plots (Table 4-2).

Nitrogen Fertility and Mowing Test

Significantly more *B. insularis* occurred in Captiva \((F = 62.45; \text{df} = 1, 27; P < 0.0001)\) (10.1 ± 2.6 *B. insularis*) (Figure 4-2 A) and Floratam \((F = 32.70; \text{df} = 1, 27; P = 0.0001)\) (8.5 ± 2.2 *B. insularis*) (Figure 4-2 B) plots cut at 10 cm than in plots cut at 5 cm in Captiva (5.8 ± 1.5 *B. insularis*) and Floratam (5.4 ± 1.5 *B. insularis*). No effect of nitrogen rate was observed in either cultivar (Figure 4-3 A-B). In addition, *B. insularis* densities were statistically similar among plots where clippings were collected versus
not collected (Figure 4-3 C-D), even if the plots were already infested with *B. insularis*. It is important to note that turf was mowed and clippings were collected when the turf was dry, not wet from dew or other precipitation. Thus, there is little risk of transferring *B. insularis* from an infested lawn to an uninfested lawn if the grass is dry or can be dislodged from the mower deck. However, *B. insularis* has been anecdotally observed being transferred on wet clippings that drop from commercial mower decks (E. Buss, personal communication). Treatments used did not significantly affect turf quality ratings (0-9) in either cultivar (Table 4-3).

**Verticutting and Mowing Height Test**

As previously determined, mowing height was significantly associated with *B. insularis* densities in both cultivars. Plots of Captiva cut at 10 cm had significantly more *B. insularis* (26.3 ± 1.9) (*F* = 73.41; df = 2, 20; *P* < 0.0001) (Figure 4-4 A) compared to plots cut at the shorter mowing heights (7.5 cm = 13.4 ± 1.1; 5 cm = 14.0 ± 1.5) as averaged over the three sampling dates. Although there was a significant effect of verticutting (*F* = 9.65; df = 1, 20; *P* = 0.0056) on *B. insularis* densities in Captiva (Figure 4-4 B), mean *B. insularis* collected during each sampling date did not differ significantly among treatments. Similarly the overall effect of mowing height on thatch thickness in Captiva (Figure 4-4 C) was significant (*F* = 11.14; df = 2, 20; *P* = 0.0006) with marginal differences in the mean thatch thickness recorded on each sampling date among different treatments. Thatch thickness reduced significantly in verticut plots than compared to non verticut Captiva plots consistently from the first to the last sampling date (Figure 4-4 D) (*F* = 78.16; df = 1, 20; *P* < 0.0001).

In Floratam plots, mowing height was associated with more *B. insularis* collected (*F* = 15.41; df = 2, 20; *P* < 0.0001) (Figure 4-5 A) (21.8 ± 2.6 at 10 cm, 13.9 ± 1.9 at 7.5
cm, and 12.9 ± 1.2 at 5 cm as averaged over the three sampling dates). The overall association of verticutting in Floratam plots on *B. insularis* densities was significant (verticut plots = 13.6 ± 2.2 *B. insularis*; non verticut plots = 18.8 ± 2.9 *B. insularis*) (*F* = 18.12; df = 1, 20; *P* = 0.0004) (Figure 4-5 B) indicating the importance of thatch management to suppress *B. insularis* densities. Thatch thickness was associated with mowing height (*F* = 7.76; df = 2, 20; *P* = 0.0032), but no significant difference existed in thatch thickness among treatments as recorded on each sampling date (Figure 4-5 C). A significant reduction in thatch in Floratam (Figure 4-5 D) (*F* = 105.65; df = 1, 20; *P* = 0.0004) indicated that suppression of *B. insularis* is possible through verticutting practices. No significant effect of mowing height and verticutting on turf visual quality was observed (Table 4-4).

**Discussion**

Cultural manipulations that alter habitat characteristics of the turfgrass ecosystem are useful tools in the successful management of insect pests. Better understanding of insect-plant interactions under modified maintenance practices provides groundwork for development of cultural control. Nitrogen fertility in turfgrasses can have positive or negative influences on insect damage. Crutchfield et al. (1995) suggested that optimal nitrogen rate is required for turfgrasses to sustain a healthy root system to avoid damage caused by root feeding insects. On the other hand nitrogen fertilizer application to plants benefits many foliage feeding and sap sucking insects by making plants succulent and more nutritive (Davidson and Potter 1995).

The adverse effect of nitrogen fertility on expression of host plant resistance was also noted on centipedegrass, *Eremochola ophiuroides* (Munro) Hackel as 16-fold higher damage of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), occurred on
fertilized plants than non-fertilized plants (Chang et al. 1985b). Similarly increased
susceptibility was indicated by *B. insularis* abundance in field plots receiving nitrogen at
300 kg ha\(^{-1}\) yr\(^{-1}\) rate. These results confirmed the negative influence of increased
nitrogen fertility on resistance characteristics of Captiva, in contrast to the findings of
Cherry et al. (2011). Earlier findings suggested that *B. insularis* damage occurred faster
on heavily fertilized turf with soluble sources i.e. ammonium nitrate used at 800 kg ha\(^{-1}\)
yr\(^{-1}\) rate than on St. Augustinegrass plots that received less fertilizer or a slow release
fertilizer (Horn and Pritchett 1963). Similarly, Busey and Snyder (1993) used very low
fertilizer rate of 100 kg ha\(^{-1}\) yr\(^{-1}\) and found more number of eggs per female per week
and faster development rate with soluble source of fertilizer (ammonium nitrate) than
slow release sources used.

Mowing height is another important practice studied extensively for insect pest
management in turfgrasses (Williamson and Potter 1997a, Williamson and Potter
1997b). In current studies the presence of greater number of *B. insularis* in plots
maintained at a higher mowing height can be speculated on favorable temperatures for
insect development, more organic debris, and protection from natural enemies. These
results are consistent with Carstens et al. (2007) who reported that higher densities of
*Blissus occiduus* Barber were present in buffalograss, *Buchloe dactyloides* (Nutall)
Engelmann maintained at a higher mowing height compared to the lowest mowing
height (2.5 cm). On the other hand, certain root feeding insects were observed to prefer
ovipositing in shorter-cut turf (Potter et al. 1996). We did not find any significant
differences in *B. insularis* densities among plots with different clipping management
method. Recycling of grass clippings is a recommendation (i.e., mowing and leaving
clippings on turfgrass) since it returns nutrients to the growing plants through mineralization of the plant material (Kopp and Guillard 2002). These clippings are low in lignin content and are readily decomposed by soil microbes, and therefore do not significantly contribute to thatch build up (Ledeboer and Skogley 1967).

Earlier studies suggested that over-fertilization and overuse of earthworm-suppressing pesticides promote thatch, which in turn makes the hairy chinch bug, *B. leucopterous hirtus*, habitat more suitable (Davis and Smitley 1990). Our results on association of thatch thickness with *B. insularis* abundance are consistent with Davis and Smitley (1990). More *B. leucopterous hirtus* occurred in plots where thicker thatch was artificially induced by fungicide application. Repeated application of acidifying fertilizers such as ammonium sulfate may decrease soil pH in the long run and thereby the population of beneficial invertebrates that decompose thatch layer thus providing advantage to turf dwelling insects (Potter 2005).

Based on these findings, *B. insularis* densities were associated with plots that received higher nitrogen rates, higher mowing height, and thicker thatch layer. Our results indicated that increased nitrogen fertility at 300 kg ha$^{-1}$ yr$^{-1}$ rate makes plants more vulnerable to insect attack by possibly modifying the plant’s architecture, i.e. grass height, and thatch layer thickness. Thus, using nitrogen fertilizers within the recommended rates would be an important management practice to significantly reduce insect susceptibility in St. Augustinegrass. Steps should be taken to follow proper nitrogen fertilizer practices, optimize mowing height, and reduce the thatch layer in St. Augustinegrass in Florida to suppress insect damage.
Table 4-1. Percent total Kjeldahl nitrogen (TKN) concentration in St. Augustinegrass, *Stenotaphrum secundatum*, plots treated with different rates and sources of nitrogen (data from samples collected in June, July, and August 2011 were pooled).

<table>
<thead>
<tr>
<th>Fertilizer rate (kg ha(^{-1}) yr(^{-1}))</th>
<th>'Captiva'</th>
<th>'Floratam'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Sulfate</td>
<td>1.1 ± 0.7</td>
<td>1.2 ± 0.3 b</td>
</tr>
<tr>
<td>Sulfur coated Urea</td>
<td>1.3 ± 0.5</td>
<td>1.4 ± 0.6 ab</td>
</tr>
<tr>
<td>Ammonium Sulfate</td>
<td>1.2 ± 0.6</td>
<td>1.5 ± 0.5 ab</td>
</tr>
<tr>
<td>Sulfur coated Urea</td>
<td>1.4 ± 0.6</td>
<td>1.7 ± 0.8 a</td>
</tr>
<tr>
<td>Control</td>
<td>1.5 ± 0.5</td>
<td>1.5 ± 0.5 ab</td>
</tr>
</tbody>
</table>

Within cultivar, means followed by the same letter do not differ statistically (ANOVA, \(P < 0.05\); there were three replicates per fertilizer rate and source.
Table 4-2. Influence of turf health parameters on *Blissus insularis* densities in two St. Augustinegrass, *Stenotaphrum secundatum*, cultivars as pooled across all sampling dates in 2011.

<table>
<thead>
<tr>
<th>Turf parameters</th>
<th>'Captiva'</th>
<th>'Floratam'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>$F$</td>
</tr>
<tr>
<td>Thatch thickness (cm)</td>
<td>-7.1283</td>
<td>0.97</td>
</tr>
<tr>
<td>Soil pH (NDVI)</td>
<td>-8.0532</td>
<td>1.41</td>
</tr>
<tr>
<td>Soil moisture (NDVI)</td>
<td>-0.8920</td>
<td>1.61</td>
</tr>
<tr>
<td>Turf color (NDVI)</td>
<td>31.2435</td>
<td>1.16</td>
</tr>
<tr>
<td>Turf chlorophyll (NDVI)</td>
<td>15.4883</td>
<td>0.28</td>
</tr>
<tr>
<td>Turf height (cm)</td>
<td>0.3593</td>
<td>3.34</td>
</tr>
<tr>
<td>Turf density (no. of live shoots)</td>
<td>0.3210</td>
<td>1.08</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen concentration (%)</td>
<td>0.0026</td>
<td>4.29</td>
</tr>
</tbody>
</table>

NDVI= Normalized Difference Vegetation Index
Table 4-3. Influence of mowing and nitrogen fertility practices on turf quality ratings in two St. Augustinegrass, *Stenotaphrum secundatum*, cultivars as pooled across all sampling dates 2012.

<table>
<thead>
<tr>
<th>Mowing height (cm)</th>
<th>Clippings collected (Y) vs. Not collected (N)</th>
<th>N rate (kg ha(^{-1}) yr(^{-1}))</th>
<th>‘Captiva’</th>
<th>‘Floratam’</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>N</td>
<td>100</td>
<td>6.4 ± 0.1</td>
<td>6.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>6.8 ± 0.1</td>
<td>7.1 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>100</td>
<td>6.9 ± 0.1</td>
<td>6.9 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>7.0 ± 0.1</td>
<td>6.8 ± 0.1</td>
</tr>
<tr>
<td>10</td>
<td>N</td>
<td>100</td>
<td>7.2 ± 0.1</td>
<td>7.1 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>6.7 ± 0.1</td>
<td>6.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>100</td>
<td>7.1 ± 0.1</td>
<td>6.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>6.8 ± 0.1</td>
<td>7.1 ± 0.1</td>
</tr>
</tbody>
</table>

Turf quality ratings (0-9 scale; 0 = yellow, thin grass, 9 = dark green, dense turf) were recorded on each sampling date; there were 12 replicates per treatment.
Table 4-4. Influence of mowing and verticutting practices on turf quality ratings in two St. Augustinegrass, *Stenotaphrum secundatum*, cultivars as pooled across all sampling dates in 2013.

<table>
<thead>
<tr>
<th>Mowing height (cm)</th>
<th>Verticut (V) vs. non-verticut (NV)</th>
<th>'Captiva'</th>
<th>'Floratam'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NV</td>
<td>7.1 ± 1.3</td>
<td>7.0 ± 1.8</td>
</tr>
<tr>
<td>5.0</td>
<td>V</td>
<td>6.4 ± 1.6</td>
<td>6.8 ± 2.0</td>
</tr>
<tr>
<td></td>
<td>NV</td>
<td>7.2 ± 1.0</td>
<td>7.2 ± 2.0</td>
</tr>
<tr>
<td>7.5</td>
<td>V</td>
<td>6.2 ± 2.0</td>
<td>6.3 ± 2.0</td>
</tr>
<tr>
<td></td>
<td>NV</td>
<td>7.0 ± 2.0</td>
<td>7.0 ± 2.0</td>
</tr>
<tr>
<td>10</td>
<td>V</td>
<td>7.0 ± 1.5</td>
<td>7.0 ± 2.0</td>
</tr>
</tbody>
</table>

Turf quality ratings (0-9 scale; 0 = yellow, thin grass, 9 = dark green, dense turf) were recorded on each sampling date; there were 12 replicates per treatment.
Figure 4-1. Mean number of *Blissus insularis* (± SEM) vacuum-sampled from St. Augustinegrass, *Stenotaphrum secundatum*, plots on 20 June, 20 July, and 19 August 2011; pooled data are presented since time effect was non-significant in a repeated measure test. ‘Captiva’ and ‘Floratam’ plots were treated with ammonium sulfate (AS) or sulfur coated urea (SCU) at the rate of 100, 200, and 300 kg ha$^{-1}$ yr$^{-1}$. Within cultivar, means followed by the same letter do not differ statistically (ANOVA, $P < 0.05$); there were 15 replicates per treatment.
Figure 4-2. Mean *Blissus insularis* densities (± SEM) on St. Augustinegrass, *Stenotaphrum secundatum*, cultivars including A) ‘Captiva’ maintained at different mowing heights and B) ‘Floratam’ maintained at different mowing heights during six sampling dates at 15 d intervals from June to August, 2012. Means followed by the same letter do not differ statistically (ANOVA, $P < 0.05$); there were four replicates per treatment.
Figure 4-3. Mean *Blissus insularis* densities (± SEM) on St. Augustinegrass, *Stenotaphrum secundatum*, cultivars including A) ‘Captiva’ maintained under different nitrogen regimes; B) ‘Floratam’ maintained under different nitrogen regimes; C) ‘Captiva’ plots if clippings were collected or recycled; and D) ‘Floratam’ plots if clippings were collected or recycled, during six sampling dates at 15 d intervals from June to August, 2012.
Figure 4-4. Mean *Blissus insularis* densities (± SEM) on ‘Captiva’ St. Augustinegrass, *Stenotaphrum secundatum*, maintained A) under different mowing heights, and B) under different verticutting regimes, (v = verticut, nv = non-verticut) on three sampling dates, June to August 2013. Thatch layer thickness (cm) of ‘Captiva’ maintained C) under different mowing heights, and D) at different verticutting regimes on three sampling dates, June to August 2013. Means followed by the same letter do not differ statistically (ANOVA, *P* < 0.05); there were four replicates per treatment.
Figure 4-5. Mean Blissus insularis densities (± SEM) on ‘Floratam’ St. Augustinegrass, Stenotaphrum secundatum, maintained A) under different mowing heights, and B) under different verticutting regimes, (v = verticut, nv = non-verticut) on three sampling dates, June to August 2013. Thatch layer thickness (cm) of ‘Floratam’ maintained C) under different mowing heights, and D) at different verticutting regimes on three sampling dates, June to August 2013. Means followed by the same letter do not differ statistically (ANOVA, P < 0.05); there were four replicates per treatment.
CHAPTER 5
EFFECT OF USE OF PLANT GROWTH REGULATORS ON ST. AUGUSTINEGRASS
HEALTH AND SUBSEQUENT DAMAGE BY BLISSUS INSULARIS

Introduction

Plant growth regulators (PGRs) effectively suppress vegetative growth and therefore reduce mowing frequency in warm season grasses (Beard 1973). Also known as “chemical mowers”, PGRs can alter a plant’s physiological processes (Weaver 1972). These chemicals can be categorized as Type I and Type II PGRs. Application of Type I products inhibit cell division and amino acid synthesis while Type II products suppress production of the gibberellic acid hormone that is responsible for cell elongation (Weinbrecht and Miller 2009).

A standard cultivar of St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze, ‘Floralawn’, responded better in terms of evapotranspiration rates, leaf extension rate and turf visual quality when PGRs were used, even under low soil moisture regimes (Green et al. 1990). Use of mefluidide (Embark®) (Type I) and trinexapac-ethyl (Primo Maxx®) (Type II) was recommended for future testing to evaluate the response of St. Augustinegrass to applied PGRs (Green et al. 1990, McCarty et al. 2004).

Due to their influence on plant’s physical and biochemical/nutritional properties plant growth regulators have also been used for insect pest management in various plant systems (Singer and Smith 1976, Coffelt and Schultz 1988, Campbell 1998, Turgeon 1999). Given the lack of data, we sought to investigate the impact of use of mefluidide and trinexapac-ethyl on turf health and fitness of *Blissus insularis* Barber in St. Augustinegrass in laboratory and field tests. This data will help the turfgrass industry
optimize the use of PGRs with the goal of reducing mowing frequency and potentially reducing pest outbreaks in St. Augustinegrass lawns.

**Materials and Methods**

**Plant Growth Regulators**

According to its label, Trinexapac-ethyl (Primo Maxx®, Syngenta Crop Science, Raleigh, NC) (Type II) is a micro-emulsion concentrate used to manage turfgrass growth on golf courses and commercial sod farms. It regulates turfgrass growth about 3-5 d after application. It may cause temporary yellowing or phytotoxicity, which disappears about 1 wk post-application. A nitrogen fertilizer application is suggested on the label to minimize grass yellowing. Reapplications can be done every 4 wk as needed, to achieve about 50% growth inhibition, however if not retreated, turfgrass can rebound and grow faster than untreated turf for several weeks. Similarly, mefluidide (Embark®, Gordon Corporation, Kansas City, Missouri) (Type I), suppresses seedhead formation, decreases the amount of clippings, and reduces mowing requirements for up to 4 weeks.

**Laboratory Bioassay**

This test was conducted with a working hypothesis that PGRs lack direct toxicity to *B. insularis*. Tests were conducted using a stem-dip bioassay similar to previous assays (Reinert and Portier 1983; Cherry and Nagata 2005, 2007), but with BioServe bioassay trays (BAW128, BioServe, Frenchtown, NJ) (Vázquez 2009) rather than Petri dishes.

Trinexapac-ethyl and mefluidide were diluted with water to eight concentrations (0, 0.1, 1, 10, 100, 1000, 10,000, and 100,000 μg mL⁻¹) (label rate for both the chemicals for St. Augustinegrass is equivalent to 0.1 ppm). ‘Floratam’ St.
Augustinegrass stems (about 1.5 cm long) were freshly harvested from the greenhouse on the test day, separately dipped in each freshly prepared solution for 10 sec, and air-dried on wax paper for 2 h. Control stems were dipped in water and air-dried.

One unsexed *B. insularis* adult (either brachypterous or macropterous) was placed into a bioassay tray cell with one treated St. Augustinegrass stem (Figure 5-1), and sealed in with a perforated clear plastic lid (BACV16, BioServe, Frenchtown, NJ). This test was replicated 15 times for each concentration of trinexapac-ethyl and mefluidide. Thus, a total of 240 *B. insularis* adults were used for the whole test. To minimize desiccation, all trays were held in large Zip lock plastic bags with moistened paper towels, and trays were held in a rearing room at a constant temperature (27 ± 2°C) and photoperiod (14:10 h L:D), as recorded with HOBO indoor data loggers (Onset Computer Corporation, Bourne, MA). Mortality of *B. insularis* was evaluated at 4, 24, 48, and 72 h post-exposure. Insects were scored as dead if they were paralyzed (i.e., on their backs or twitching) or dead at 24 h. Any paralyzed individuals were held up to 72 h, and if any recovered within that time, they were scored as alive. Mortality data were analyzed using PROC PROBIT (SAS Institute 2008) to calculate the LC$_{50}$ values for *B. insularis* to trinexapac-ethyl and mefluidide.

**Laboratory Rearing Test**

Forty-five plugs of Floratam St. Augustinegrass were obtained from a neighborhood in Ocala, FL, and transplanted into plastic pots (15 cm diam) with a 50:50 mix of Farfard #4 potting soil (Conrad Farfard Inc., Agawam, MA) and autoclaved sand. Plugs were allowed to establish in a greenhouse for 4 wk with a 14:10 h L: D photoperiod and an ambient temperature of ≥ 24°C. After establishment, trinexapac-
ethyl (0.45 L a.i. ha⁻¹) or mefluidide (0.17 L a.i. ha⁻¹) were applied weekly to 15 plugs per treatment (three plugs per block). Control plugs remained untreated. Potted plugs were arranged in a randomized complete block design with five replications.

To evaluate the effects of the PGRs on B. insularis survival, 30 first instar B. insularis were reared on grass plugs for 3 wk in 7.6 L glass colony jars (as described in Chapter 2) in the laboratory (with 14:10 h L:D photoperiod, 60% RH, and about 28ºC ambient temperature). One colony jar containing fresh plugs from the respective treatments represented one replicate. Five replicates were made. Grass plugs obtained from the greenhouse were added to containers weekly for 3 wk. Old grass plugs were kept in the container to minimize insect handling mortality. After the third week, the number of live B. insularis per container was recorded. Data were square root transformed, then analyzed using PROC GLM (SAS Institute 2008). If significant, means were separated using Tukey’s HSD test.

**Total Kjeldahl Nitrogen Concentration.** To confirm treatment differences among various PGR applications, grass clippings (about 2 g fresh wt) were collected from five replicates of each treatment 1 wk after each PGR application (for a total of three collections). Clippings were placed in paper bags, oven-dried at 70-80ºC for ≥48 h, weighed, ground, and analyzed for TKN by the University of Florida, Institute of Food and Agricultural Sciences, Soil and Plant Testing Laboratory in Gainesville, FL.

**Field Test**

We hypothesized that applications of plant growth regulators would affect the suitability of St. Augustinegrass to B. insularis by changing the plant’s chemical characteristics (chlorophyll and TKN concentration) and morphological characteristics (color and thatch thickness).
Plots (2×2 m) of Floratam St. Augustinegrass at the G.C. Horn Turfgrass Research Field Plots Area at the University of Florida Plant Science Unit in Citra, FL, were used for this experiment in summer of 2013. Thirty fourth and fifth instar and adult *B. insularis* were released in each plot in May 2013. Treatments were applied in a randomized design to five complete replicates. Trinexapac-ethyl was applied at the rate of 0.45 L a.i. ha⁻¹, and mefluidide was applied at the rate of 0.17 L a.i. ha⁻¹ once per month for 3 mo from June to August 2013 using a CO₂ pressurized backpack sprayer. Control plots remained untreated.

*Blissus insularis* were vacuum-sampled (700 cm² area for 30 sec) in plots every month, beginning 1 wk after the PGR application. Data on turf health parameters (e.g., thatch thickness, turf color, turf chlorophyll content, TKN concentration, soil moisture and damage ratings) were taken, as described in Chapter 3. Data were analyzed using mixed model analyses (PROC MIXED, SAS Institute 2008) to detect differences in the densities of *B. insularis* among the treatments. When appropriate, means were separated using Tukey’s HSD test. Effects with *P* values ≤ 0.05 were considered significant. Thatch thickness, turf color, turf chlorophyll content, TKN concentration, and soil moisture were included in the linear mixed model to identify the most significant factor associated with *B. insularis* densities.

**Results and Discussion**

**Laboratory Bioassay**

No mortality occurred in the control treatments, and mortality was negligible in all other treatments except at the highest concentration of both PGR products. Therefore, corresponding LC₅₀ values were very high (trinexapac-ethyl = 23.1 g/ml, mefluidide = 1.5 g/ml) with wide confidence intervals (χ² = 2.1539; df = 5; *P* = 0.8275). Thus, the two
PGRs tested are considered non-toxic to *B. insularis*, which is consistent with Oetting and Latimer (1995), who demonstrated that plant growth regulators could not directly kill the minute pirate bug, *Orius insidiosus* (Say). The authors in this study suggested the use of plant growth regulators for thrips management due to their compatibility with predators and other biological control agents.

**Laboratory Rearing Test**

Percent survival of *B. insularis* significantly decreased when reared on PGR-treated St. Augustinegrass (mefluidide = 52 ± 1.7, trinexapac-ethyl = 55 ± 3.7) compared to the control (69.3 ± 2.8) (*F* = 18.42; df = 2, 36; *P* = 0.001). The TKN concentration is indicative of host quality and differed significantly among the treatments (*F* = 10.06; df = 2, 8; *P* = 0.006), being highest in the control plants (1.8 ± 0.9) and least in the plants treated with mefluidide (1.2 ± 0.2).

Honeyborne (1969) suggested that PGRs influence phloem feeding insects by decreasing the availability of nutrients in the phloem. Being Type I in nature, mefluidide inhibited amino acid synthesis and reduced the host quality in terms of TKN and thereby insect feeding. Our results also support the findings of Coffelt and Schultz (1988), who showed that mefluidide slowed the development of azalea lace bug, *Stephanitis pyrioides* (Scott) on *Rhododendron* sp., because of the poor host quality as exhibited by the plant’s chlorotic symptoms. Similarly, the use of prohexadione-calcium (Type II PGR/ gibberellic acid inhibitor) on apple and pear trees resulted in significant reduction in the population of sap sucking insects due to its synergistic effect with the insecticides applied (Paulson et al. 2005). It was suggested that reduced vegetative growth exposed the insects for better penetration and coverage of pesticides. In contrast, Rogers et al.
(2001) did not find any significant effect of PGRs tested on the suitability of creeping bentgrass for black cutworms, *Agrotis ipsilon* Hufnagel and sod webworms (Pyralidae).

**Field Test**

Significantly fewer *B. insularis* (*F* = 15.54; df = 2, 8; *P* = 0.0018) were present in field plots on the treatments that received PGR treatments (mefluidide = 7.0 ± 1.7, trinexapac-ethyl = 5.9 ± 1.3) compared to control plots (12.6 ± 1.3) (Figure 5-2).

Among the turf parameters (Table 5-1) measured, turf TKN concentration was the only factor to significantly influence *B. insularis* densities (*F* = 9.09; df =1, 16; *P* = 0.008). These results were consistent with the laboratory test that demonstrated that a PGR application indirectly influences the nitrogen concentration available for insect feeding. PGRs appeared to have no effect on thatch thickness or turf quality ratings among plots, compared to control plots, possibly because of the short duration of the test. We suggest that further testing with PGRs be done to provide recommendations for *B. insularis* management.
Table 5-1. Influence of turf health parameters on *Blissus insularis* densities in ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, as measured from June to August 2013 (data were pooled).

<table>
<thead>
<tr>
<th>Effect</th>
<th>$F$ Value</th>
<th>$Pr &gt; F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thatch thickness (cm)</td>
<td>0.67</td>
<td>0.4254</td>
</tr>
<tr>
<td>Soil moisture (NDVI)</td>
<td>0.34</td>
<td>0.5658</td>
</tr>
<tr>
<td>Turf color (NDVI)</td>
<td>1.59</td>
<td>0.2255</td>
</tr>
<tr>
<td>Turf chlorophyll (NDVI)</td>
<td>3.18</td>
<td>0.0939</td>
</tr>
<tr>
<td>TKN concentration (%)</td>
<td>9.09</td>
<td>0.0082</td>
</tr>
</tbody>
</table>

Data was pooled across three sampling dates since the time effect was non-significant. 15 replicates per treatment (df =1, 16).
Figure 5-1. BioServe bioassay tray used in the contact bioassay that enclosed one *Blissus insularis* and treated ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, sprig per cell. (Photo credit: N. Kaur).
Figure 5-2. Mean *Blissus insularis* densities (± SEM) in St. Augustinegrass, *Stenotaphrum secundatum*, from vacuum sampling in plots treated with mefluidide, trinexapac-ethyl, or the untreated control, 2013. Means followed by the same letter do not differ statistically (ANOVA, $P < 0.05$); there were five replicates per treatment.
The southern chinch bug, *Blissus insularis* Barber, is a challenging pest to manage in St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze in Florida. Nymphs and adults feed in turf areas that are hard to reach with contact insecticides, but turfgrass managers have had to rely on such insecticides for over 60 years. Given a life cycle that is conducive to developing insecticide resistance (e.g., rapid development, overlapping life stages, limited dispersal, near-constant exposure and selection to insecticides) and the lack of effective rotation products, this pest has become resistant to nearly every chemical class that has been used against it. Gaining an understanding of how non-chemical controls might impact *B. insularis* development and survival is critical to developing an integrated pest management (IPM) strategy.

Host plant resistance is another key component of an IPM program. The work done in this dissertation focused on a previously resistant cultivar, ‘Floratam’, and a newer cultivar ‘Captiva’ that may have increased resistance or tolerance to *B. insularis* feeding damage. I speculated that increased fertility of a resistant cultivar, as Floratam was in past decades, would weaken the plant’s defenses and increase its nutritional value to *B. insularis*, which was confirmed in this dissertation research. This work has clearly demonstrated the direct effect of nitrogen, through both laboratory and field tests, on the development, survival, and fecundity of *B. insularis*. Insect fitness measured on fertilized Captiva plants was comparable to Floratam cultivar indicating negative influence of nitrogen fertility on host plant resistance. Nitrogen fertility was observed to increase *B. insularis* densities in highly fertilized field plots and thus more damage occurred due to increased insect fitness, as confirmed by our laboratory
studies. Therefore, to maintain a balance between turf health and insect resistance, the moderate use of nitrogen fertilizers is recommended. Since only one soluble (ammonium sulfate) and one slow-release (sulfur coated urea) source of nitrogen was tested, we cannot say that the source of nitrogen is completely irrelevant. Another interesting aspect of this work was discovering that St. Augustinegrass mowing height, thatch thickness and soil temperature were closely associated with \textit{B. insularis} density within a lawn. These results will help homeowners, lawn care companies and sod growers to follow proper cultural practices to reduce insecticide use and non-target impacts. Homeowner’s negligence toward following best management practices was identified through the online survey questions. In future more questions on homeowner’s pesticide application history will be helpful to understand why \textit{B. insularis} repeatedly infest the same property or neighborhood.

Plant growth regulators are known to influence plant’s architecture (turf height) and therefore can be used as an alternative strategy in making the \textit{B. insularis} habitat unfavorable for their survival. The reduction of \textit{B. insularis} densities followed by the application of mefluidide and trinexapac-ethyl in field plots signified the use of PGRs in St. Augustinegrass for \textit{B. insularis} management.

The results of this study indicated the need to inform homeowners about following appropriate nitrogen fertilization practices, recommended mowing heights based on turfgrass cultivar, and practicing thatch management when necessary to reduce insecticide usage for \textit{B. insularis} suppression in St. Augustinegrass lawns in Florida.
Additional studies are needed to monitor the effect of modified cultural practices (reduced nitrogen fertilization, increasing mowing heights, and thatch reduction) on the effectiveness of beneficial organisms for managing *B. insularis* in St. Augustinegrass. Reduced chemical inputs should conserve natural enemies and naturally suppress *B. insularis* populations. Furthermore, the reduced reliance on chemicals will help delay the development of insecticide resistance in *B. insularis*. 
A Y-tube olfactometer bioassay was conducted to determine if southern chinch bug, *Blissus insularis* Barber, adults prefer St. Augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze, plants under different nitrogen treatments. We hypothesized that host selection behavior of *B. insularis* is olfactory based on the findings of Addesso et al. 2012 and that St. Augustinegrass plants receiving different nitrogen fertility rates would be preferred by *B. insularis* over the unfertilized control.

A horizontal, glass Y-tube olfactometer (internal diam = 1.5 cm, arm length = 5 cm, stem length = 14 cm) (Analytical Research Systems Inc., Gainesville, FL) were set up in a room at 25-30°C on a padded bench. Three nodes from the whole plants treated with different rates of N, contained in Teflon Bags (SKC Inc, Eighty four, PA) were used as an odor source (test stimuli). Compressed carbon-filtered and humidified air (Airgas® South, Tampa, FL) was delivered via Teflon tubing into each arm of the Y-tube. One *B. insularis* (unsexed) was released into the stem of the glass Y-tube and the time was recorded until the insect reached the far end of an olfactometer arm. Insects that failed to choose within 10 min were considered non-responsive. Experiments consisted of eight sets of choices between each nitrogen rate treatment and control for both cultivars (i.e., ‘Floratam’ and ‘Captiva’) (Table A-1). After testing five insects, the entire set-up was turned 180° to minimize positional effects, all parts were cleaned with acetone, and oven-dried at 80-90°C for ≥1 h. Data were analyzed with a Chi square test (SAS Institute 2008).

Even though more *B. insularis* adults walked into the arm of the olfactometer containing smell of the air coming from fertilized turf (Figures A-1 and A-2) on both
cultivars, Chi square values tended to be very low. This lack of significant differences among all comparison between fertilized versus unfertilized grass was due to the small sample size of the insect tested (10 adults) in our experiment. Higher preferences by _B. insularis_ adults to high rates of fertilizers also indicated existence of some chemical cues in host selection process which was in confirmation with Addesso et al. (2012). In the future, more insects should be used in similar testing.
<table>
<thead>
<tr>
<th>Choices</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unfertilized control versus 100 kg ha(^{-1})yr(^{-1}) nitrogen rate using ammonium sulfate</td>
</tr>
<tr>
<td>2</td>
<td>Unfertilized control versus 200 kg ha(^{-1})yr(^{-1}) nitrogen rate using ammonium sulfate</td>
</tr>
<tr>
<td>3</td>
<td>Unfertilized control versus 300 kg ha(^{-1})yr(^{-1}) nitrogen rate using ammonium sulfate</td>
</tr>
<tr>
<td>4</td>
<td>Unfertilized control versus 400 kg ha(^{-1})yr(^{-1}) nitrogen rate using ammonium sulfate</td>
</tr>
<tr>
<td>5</td>
<td>Unfertilized control versus 100 kg ha(^{-1})yr(^{-1}) nitrogen rate using sulfur coated urea</td>
</tr>
<tr>
<td>6</td>
<td>Unfertilized control versus 200 kg ha(^{-1})yr(^{-1}) nitrogen rate using sulfur coated urea</td>
</tr>
<tr>
<td>7</td>
<td>Unfertilized control versus 300 kg ha(^{-1})yr(^{-1}) nitrogen rate using sulfur coated urea</td>
</tr>
<tr>
<td>8</td>
<td>Unfertilized control versus 400 kg ha(^{-1})yr(^{-1}) nitrogen rate using sulfur coated urea</td>
</tr>
</tbody>
</table>
Figure A-1. Percentage of _Blissus insularis_ choosing odor sources in a two arm Y-tube olfactometer where odor sources were ‘Captiva’ and ‘Floratam’ St. Augustinegrass, _Stenotaphrum secundatum_, fertilized at rates of nitrogen using ammonium sulfate (AS) (i.e., 100, 200, 300 or 400 kg ha$^{-1}$ yr$^{-1}$) and an unfertilized control plant.
Figure A-2. Percentage of *Blissus insularis* choosing odor sources in a two arm Y-tube olfactometer where odor sources were ‘Captiva’ and ‘Floratam’ St. Augustinegrass, *Stenotaphrum secundatum*, fertilized at rates of nitrogen using sulfur coated urea (SCU) (i.e., 100, 200, 300 or 400 kg ha$^{-1}$ yr$^{-1}$) and an unfertilized control plant.
DATE: August 10, 2010

TO: Glenn D. Israel, PhD; Paul F. Monaghan
   PO Box 110540
   Campus

FROM: Ira S. Fischler, PhD; Chair
       University of Florida
       Institutional Review Board 02

SUBJECT: Renewal of Protocol #2009-U-0849

TITLE: Your Florida Yard and You Survey

SPONSOR: None

Your request to continue your research protocol involving human participants has been approved. Participants are not placed at more than minimal risk by the research. You are reminded that any changes, including the need to increase the number of participants authorized, must be approved by resubmission of the protocol to the Board.

Re-approval of this protocol extends for one year from the date of the review, the maximum duration permitted by the Office for Human Research Protection. This approval is valid through August 19, 2011. If this project will not be completed by this date, please telephone our office (352-392-0433) at least six weeks in advance so we can advise you how to reapply.

It is important that you keep your Department Chair informed about the status of this research project. In addition, if your project is funded, you should send a request to extend your grant along with a copy of this project renewal notification to DSR, Awards Administration, P.O. Box 115500.

ISF:dl
Thank you for participating in the *Your Florida Yard and You* survey.

This study is conducted by your county Extension office and the Program Development and Evaluation Center at the University of Florida. Our goal is to better understand how Floridians think about their yards and how they care for them. Your responses will help us find out what we can do to help homeowners create a Florida Friendly Landscape. The survey will take about 15 minutes to complete.

You are one of a small number of persons chosen to participate in this study. Since your responses will also represent others who were not selected, we hope that you will complete the survey as soon as possible. Your participation is voluntary. You do not have to answer any question that you do not wish to answer.

We believe that there are no risks to you from participating in this study. There also are no direct benefits or compensation to you for participating. If you have questions about your rights, contact the UFRB office, Box 112250, University of Florida, Gainesville, FL 32611-2250.

We will keep your answers confidential to the extent provided by law. Your name will not be used in any report. We will only use your answers after they have been combined with the other respondents' answers.

If you have any questions, please call 352-392-0502, ext. 246, or send an email to gdisrael@ufl.edu. We hope that you enjoy completing the questionnaire.

Sincerely,

Glenn D. Israel
Professor
Program Development & Evaluation Center
University of Florida

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2009-U-0849
For Use Through 08-19-2011

Link to the questionnaire used: [http://pdec.ifas.ufl.edu/evaluation/hoa.pl](http://pdec.ifas.ufl.edu/evaluation/hoa.pl)
LIST OF REFERENCES


Cherry, R. H. 2001c. Seasonal wing polymorphism in southern chinch bugs (Hemiptera: Lygaeidae). Fla. Entomol. 84: 737-739.


Erickson, J. E., J. L. Cisar, G. H. Snyder, D. M. Park, and K. E. Williams. 2010. Effect of sod type, irrigation, and fertilization on nitrate-N, and orthophosphate-P leaching from newly established St. Augustinegrass sod. Crop Sci. 50: 1030-1036.


http://edis.ifas.ufl.edu/LH036.


BIOGRAPHICAL SKETCH

Ms. Navneet Kaur was born in 1984 in Punjab, India. She went to Punjab Agricultural University for her bachelor’s degree in plant protection in 2002. After completing her bachelor’s degree, she worked on her master’s degree program at Punjab Agricultural University majoring in entomology from 2006 to 2008. After her graduation, she was appointed as a pesticide residue analyst by an insect toxicology laboratory at Punjab Agricultural University in 2009. In early 2010, Navneet moved to the United States to pursue a Ph.D. in entomology at Louisiana State University. She started working on a project focused on the microbial gut flora of termites. She learned various microbial and molecular techniques during her short stay at LSU. She became interested in working on a more applied project in the landscape entomology lab at the University of Florida. Therefore she joined UF in fall 2010 and began her research on the development of cultural control methods for the southern chinch bug. While at UF, Navneet gained hands-on experience in research by working in research field plots and residential St. Augustinegrass lawns. She was a teaching assistant, a member of the UF Linnaean Games team, and was actively involved in Extension outreach programs. She also was awarded a Grinter Fellowship, several travel awards, and the Florida Turfgrass Association’s Col. Frank Ward Memorial Scholarship Award in 2013. She is a member of the Entomological Society of America, the UF Entomology and Nematology Student Organization (ENSO), the Florida Entomological Society, and the Florida Turfgrass Association. After graduation, Navneet seeks to work as a post-doctoral researcher to strengthen her research experience.