Abstract

JACKSON, LISA DAWN. Beneficial and pest insect populations in conventional and organic cotton, and organic cotton with habitat. (Under the direction of David B. Orr, H. M. Linker, and Kenneth A. Sorensen)

A field study was conducted in 2004 and 2005 to compare pest and beneficial insect populations in conventional and organic cotton (*Gossypium hirsutum* L.), and organic cotton with managed habitat. A "conventional" (best management practices) control was compared with two organic treatments - one with and one without habitat borders. The habitat treatment consisted of an organic cotton plot bordered and bisected by a 3 m wide mixed planting of soybean (*Glycine max*), German foxtail millet (*Setaria italica*), and buckwheat (*Fagopyrum esculentum* Moench).

Pest and beneficial insect populations were monitored by methods appropriate to the developmental stage of the cotton and pest species populations. Thrips were sampled beginning at cotyledonary stage and were sampled on four dates each in 2004 and 2005. Weekly sweep net samples were taken to monitor pest and beneficial insect populations on eight dates in 2004 and ten dates in 2005. Pest insects recorded included adults and immatures of green stink bug *Acrosternum hilare* (Say), Southern green stink bug *Nezara viridula* (Linnaeus), brown stink bug *Euschistus servus* (Say), tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois) and bollworm *Helicoverpa zea*. Predatory species recorded were adult Dolichopodidae, larvae of Corydalidae and Hemerobiidae, spiders, adults and immatures of *Orius spp*., *Geocoris spp*., predatory Coccinellidae, and Nabidae. Observation of the fate of naturally oviposited *H. zea* eggs was used as a measure of egg parasitism and predation. The level of parasitism of brown stink bug (*Euschistus servus*) eggs was evaluated by gluing *E. servus* egg masses to cotton leaves in the field and

recording levels of parasitism. Cotton terminals, squares, and bolls were monitored for *H. zea* eggs, larvae, and damage. Internal damage to cotton bolls by hemipteran pests was recorded. Organic or conventional insecticides were applied if necessary for control of key cotton pests.

Orius spp. means were significantly higher in the organic treatment than the conventional control. Lady beetles and *L. lineolaris* means, averaged over both years, were significantly higher in both organic treatments than the conventional control. There was no treatment effect in predator plot means in the pitfall study or in levels of *H. zea* egg predation and parasitism in the *H. zea* egg fate study. There was no treatment effect in the level of *E. servus* egg parasitism. *H. zea* larvae and *H. zea*-damaged bolls were higher in both organic treatments than conventional cotton. Damage to bolls by hemipteran pests was higher in both organic treatments than the conventional control.

Organic cotton had higher densities of two predators: lady beetles and *Orius spp.* However, organic cotton had more damage from pests. Presence of habitat did not increase the number of beneficial insects, decrease the number of pests, or reduce damage in adjacent cotton.

BENEFICIAL AND PEST INSECT POPULATIONS IN CONVENTIONAL AND ORGANIC COTTON, AND ORGANIC COTTON WITH HABITAT

by

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DEDICATION

To my husband, Kenton Yang, whose love and wisdom have guided me through my doubts, worries, and moments of crisis. Thank you.

To my parents, Denise and Don Jackson, who have supported me through my many wanderings and adventures. May I finally grow up.

BIOGRAPHY

Lisa Dawn Jackson was born September 5, 1975 in Montgomery, Alabama to Don and Denise Jackson. She relocated to Odessa, Texas in 1982 and Denton, Texas in 1990. She attended the University of Washington and The Evergreen State College for her undergraduate studies and graduated from The Evergreen State College with a Bachelor's of Arts Degree in 1997. In 2003, she relocated to Raleigh, North Carolina to begin work on a Master's of Science degree in Entomology at North Carolina State University.

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Introduction

Interest in organic cotton is increasing due to higher prices, the public's distrust of genetically modified crops, and the potential reduction in farm worker health problems, air pollution, and water contamination caused by pesticides (Myers and Stolton 1999; Sustainable Cotton Project 2005; Organic Trade Association 2005; Pesticide Action Network 2005). Although organic cotton acreage in the U.S. has increased from 900 acres in 1990 to 9,875 acres in 2003 (Marquardt 2002; Economic Research Service 2003), the demand for organic cotton has fluctuated since the early 1990's (Marquardt 2002). Currently, the global demand for organic cotton is increasing as large international clothing manufacturers develop organic cotton clothing lines and combine organic cotton into blends with conventional cotton (Organic Consumers Association 2005). The Swiss government has also set a goal of a 3% increase in organic cotton imports by 2007 (Organic Exchange 2005).

In addition to organic cotton, there is interest in cotton grown by "biologically intensive IPM" and other "sustainable" practices, which utilize trap crops, intensive pest monitoring, beneficial insect habitat, and biological controls for reducing input costs and improving the profit margin for farmers. The Sustainable Cotton Project in California has developed the Biological Agriculture Systems in Cotton (BASIC) program which promotes "biologically intensive IPM" to encourage conventional farmers to convert portions of their acreage to organic and reduced pesticide practices (Sustainable Cotton Project 2005). The intent is to decrease pesticide applications and provide farmers with the information needed to transition from conventional to organic production as demand increases (Sustainable Cotton Project 2005). The program started with six farmers in 1996 and enrolled 45 in 2004 (Sustainable Cotton Project 2005). Clearly, there is an interest by farmers and consumers to

develop practices in cotton that are less harmful to the environment and provide farmers with a higher profit margin.

The Southeast accounts for 25 percent of total upland U. S. cotton production (Cotton Council International 2005), yet produces no organic cotton. In the U.S., organic cotton is currently grown in Arizona, California, Missouri, New Mexico, and Texas (Economic Research Service 2003). Of the 730,000 acres of conventional cotton grown in North Carolina in 2004 (North Carolina Department of Agriculture & Consumer Services 2005), 91% of the cotton seed used was genetically modified (National Agricultural Statistics Service 2005). With rising technology fees for genetically modified cotton, which growers do not always recover with improved yields, conventional growers may be interested in converting portions of their acreage to organic production. The high annual rainfall, humidity, summer temperatures, and late frost of the Southeastern region pose greater challenges with respect to insect pest management, growth regulation, and defoliation of organic cotton than the Western growing region. If better organic management practices were available to Southeastern growers, more of them might decide to take advantage of this profitable niche market.

Surveys of organic cotton growers reported that insect and weed management, defoliation, and soil fertility are key areas in need of research (Marquardt 2002). Under organic management practices, with less effective insecticides available, control of insect pests rests with cultural and biological methods. One approach suggested for management of cotton pest insects is the provision of non-crop habitat to increase numbers of beneficial insects (Parajulee and Slosser 1999).

Habitat can benefit natural enemies by providing shelter, over-wintering, nesting and mating sites, and a different microclimate than the crop (Landis et al. 2000). Habitat can provide natural enemies with alternate hosts that may aid in an earlier establishment of natural enemies in the crop system and increase their effectiveness at controlling the crop pest of interest (Doutt and Nakata 1973). In addition, habitat may provide alternate prey that can increase the population of natural enemies within the crop (Wyss 1996).

Flowering plants within non-crop habitat may provide floral resources in the form of nectar and pollen, which can increase the effectiveness of natural enemies. When prey is scarce many entomophagous insects rely on nectar and pollen for energy and egg production, nutrients, and moisture (Hagen 1986). Adult hoverflies need nectar and pollen for energy, sexual maturation, and egg development (Hickman and Wratten 1996). In addition, it is possible for some natural enemies to complete development in the absence of prey by feeding on floral resources. *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) has been shown to complete development and produce eggs on a diet of pollen and water (Kiman and Yeargan 1985). Some species of coccinellid larvae have been shown to develop after feeding on pollen (Smith 1960). Salas-Aquilar and Ehler (1977) reported 62.5 % survival of *O. tristicolor* (White) (Hemiptera: Anthocoridae) to adult stage when fed pollen only. Kiman and Yeargan (1985) reported 91.2 % survival of *O. insidiosus* to adult stage when fed pollen only.

Fecundity and longevity can increase when natural enemies are provided with floral resources. Fecundity of *O. tristicolor* increased when pollen was added to a diet of green beans and thrips (Salas-Aquilar and Ehler 1977), and longevity of pollen-fed *O. insidiosus* was consistent with individuals fed *Heliothis virescens* (Fabricius) (Lepidoptera: Noctuidae)

eggs (Kiman and Yeargan 1985). Pollen-feeding by parasitic wasps has been shown to increase longevity and fecundity (Leius 1961; Leius 1963, Jervis et al. 1993). Access to flowering plants has been shown to increase longevity (Baggen and Gurr 1998; Foster and Ruesink 1984; Jervis et al.1993) and parasitism by parasitic wasps (Foster and Ruesink 1984; English-Loeb et al. 2003). Naranjo and Stimac (1985) reported increased survival and reproduction of *Geocoris punctipes* (Hemiptera: Lygaeidae) when the insects were provided with supplemental plant food.

The presence of non-crop habitat has been shown to increase the abundance of natural enemies in the adjacent crop (Hickman and Wratten 1996; Wyss 1996; Patt et al. 1997). Some studies have reported higher densities of natural enemies in crop rows within short distances from the habitat but not at further distances into the crop (English-Loeb et al. 2003; Jones and Gillett 2005; Corbett et al. 1991; Platt et al. 1999). Increases in rates of parasitism (Foster and Ruesink 1984; Baggen and Gurr 1998; Eglish-Loeb et al. 2003) and predation (Corbett et al. 1991; Patt et al. 1997) have been recorded in crops with non-crop habitat present.

Practical results, in terms of impacts on crop damage and yield within field experiments are varied. Risch et al. (1983) reviewed 150 studies which utilized row cropping, mixed intercropping, or weedy culture systems to increase diversity within agricultural fields. Risch et al. (1983) found that for herbivorous insects, 53% of studies reported a decrease, 18% an increase, 20% a varied response, and 8% no change. Of the 150 studies, only 19 reported yield results (Risch et al. 1983). Of these 19, four reported an increase in yield, nine reported a decrease, and six reported a variable response (Risch et al. 1983). Yield effects, caused by insect populations, can be difficult to ascertain due to the

possibility of confounding factors such as plant competition in intercropped studies and other plant-plant interactions.

Several studies have reported a decrease in pest numbers (Bank 2000) or effective control of pests by natural enemies (Bostanian et al. 2004; Patt et al. 1997) in crops with habitat present. Decreases in crop damage have also been reported (Doutt and Nakata 1973; Bostanian et al. 2004) in crops with habitat. Neutral effects of habitat are also common, wherein studies reported no reduction in pest numbers (Bugg et al 1991; English-Loeb et al. 2003), pest populations that were not kept below economic threshold (Corbett et al. 1991), no increase in predation (Bugg et al. 1991; Brahman et al. 2002) or parasitism (Nicholls et al. 2000), or no difference in yield (Platt et al. 1999).

The presence of habitat could also have negative effects on the crop system including increased crop damage near habitat (Frank 1997**;** Baggen and Gurr 1998), higher rates of oviposition by pests due to feeding on habitat plants (Baggen and Gurr 1998), or increased pest populations (Andow and Risch 1985; Collins and Johnson 1985; Sheehan 1986; Baggen and Gurr 1998). In addition, habitat can introduce new pests (Aalbersberg et al 1989), increase the population of hyperparasitoids (Stephens 1998; Carroll and Hoyt 1986), or be so attractive to natural enemies that it acts as a sink, retaining predators and parasitoids within the habitat (Perrin 1975).

Though habitat manipulation has had positive, neutral, and negative outcomes, there have been examples of success in cotton. Strip-cropping with non-crop habitat has been shown to increase the number of predator insects when planted near cotton (Robinson et al., 1972; Parajulee and Slosser, 1999). Parajulee and Slosser (1999) found lower densities of bollworm and budworm, *H. virescens* in cotton adjacent to individual strips of canola, hairy

vetch, grain sorghum, forage sorghum, wheat, and a canola and grain sorghum mix, than cotton acreage in the surrounding farm. They reported higher cotton lint yields in one year of the study in cotton adjacent to habitat without the application of insecticides, compared with control plots that received three applications for heliothine control (Parajulee and Slosser, 1999). Due to increased yields in the presence of habitat, Parajulee and Slosser (1999) recommend the use of strip-cropping as a means of pest control in production of cotton without insecticides.

Key cotton predators have been shown to feed on plant parts and additional insect hosts in non-crop habitat. These natural enemies may be better suited to utilizing non-crop habitat, and increases in their abundance, longevity, fecundity, and effectiveness could ensue. For example, plant-feeding can temporarily sustain *Geocoris punctipes* adults (Tillman and Mullinix, 2003) and can support nymphal development to the second stadium (Naranjo and Stimac, 1985). Tillman et al. (2004) reported higher populations of *Geocoris punctipes* in cotton fields previously planted to crimson clover. Burleigh et al. (1973) reported higher populations of lady beetles in cotton adjacent to sorghum due to the presence of aphids and greenbugs in sorghum. Furthermore, access to pollen and prey within the habitat may aid in the development and longevity of predators such as coccinellid larvae, *Orius spp.,* and *Geocoris spp*. (Salas-Aquilar and Ehler 1977; Kiman and Yeargan 1985; Smith 1960; Tillman and Mullinix 2003), which could aid in building predator populations before pest hosts are present within cotton.

Organic agriculture is generally thought to have higher levels of beneficial insects due to the use of less harsh insecticides, use of beneficial insect habitat and crop rotation, greater crop diversity, augmentation of natural enemies, and increased attention to conservation of

beneficial insects (Van Elzakker and Caldas 1999; Berry et al.1996; Lampkin 1990). Berry et al. (1996) reported numbers of parasitic Hymenoptera to be 69% higher in organic carrot fields than conventional. In a meta-analysis of 66 publications reviewing biodiversity and abundance of arthropods on organic and conventional crop systems, Bengtsson et al. (2005) found predatory insects to have a positive response to organic farming. A trend of a higher abundance of spiders and increased species richness of carabids were found on organic farms (Bengtsson et al. 2005). In this review, no difference in pest abundance was found comparing organic and conventional systems (Bengtsson et al. 2005). Even if organic agriculture does tend to have higher levels of beneficial insects, this does not always lead to lower pest populations, less pest damage to crops, or higher yields compared to conventional systems (Platt 1999; Letourneau and Goldstein 2001).

The purpose of this study was to evaluate the efficacy of habitat management as a tool to reduce pest populations and crop damage in organic cotton and to provide North Carolina organic farmers with data regarding the use of habitat to manage insect pests in an organic crop. The specific objectives of this study were to compare pest and beneficial insect populations and crop damage in conventional and organic cotton and evaluate the use of beneficial insect habitat as a tool for organic cotton production.

Materials and Methods

Experimental Design. The experiment was conducted at the Center for Environmental Farming Systems (CEFS), near Goldsboro, NC. It was established using a completely randomized design with selective placement of treatments. A "conventional" (best management practices) cotton control was compared with two organic cotton treatments – one with and one without habitat borders. Organic plots with habitat were always placed

the farthest distance from conventional plots to reduce any potential drift of insecticides onto habitat (Figs. 1-5). The experiment was replicated in three locations in 2004 and four locations in 2005. The distance between replications in 2004 averaged 1.03 km. In 2005, the four replications were split into two fields, 0.5 km apart, with two replications in each field. Replications 3 and 4 were 0–3 m apart in one field, and replications 1 and 2 were 15 m apart in another field.

In 2004, cotton in organic plots with habitat averaged 0.059 ha, with an additional 0.045 ha of habitat. Both conventional and organic plots without habitat averaged 0.07 ha. In 2005, cotton in organic plots with habitat averaged 0.052 ha with 0.038 ha of habitat. The other plots averaged 0.076 ha. Cotton plots with habitat were surrounded by habitat borders and bisected with a strip of habitat 3.6 m wide in 2004 and 2.4 m wide in 2005. The habitat to organic cotton ratio, within the organic with habitat plots, averaged 0.79 in 2004 and 0.74 in 2005.

Within each replication, plots were separated by 3.4 m of sorghum sudangrass (*Sorghum bicolor* X *Sorghum sudanense*) var. Haychow (Seedway, P.O.Box 250, Hall, NY 14463) in 2004 and var. Sweeter-N-Honey II (Jeffreys Seed Company, P.O. Box 887, Goldsboro, NC 27530) in 2005. In 2005, an additional 3 m of bare ground buffer was maintained on either side of the sorghum sudangrass. In 2004, the habitat mix consisted of glyphosate-resistant soybean (*Glycine max*) (Dupont, Pioneer Hi Bred International, Inc., A Dupont Company, Johnston, IA 50131), German foxtail millet (*Setaria italica*) (Jeffreys Seed Company, P.O. Box 887, Goldsboro, NC 27530), and buckwheat (*Fagopyrum esculentum* Moench) (Jeffreys Seed Company, P.O. Box 887, Goldsboro, NC 27530). In 2005, the mix consisted of group III and group IV non-glyphosate resistant soybeans, var.

MD96-5722 (Eddie Mercer Agri Services, Inc., 6900 Linganore Rd., Frederick, MD 21701) and var. Resnik (Ohio Foundation Seeds, Inc., P.O. Box 6, Croton, OH 43013-0006) to ensure a longer blooming period of soybean flowers.

In 2005, habitat was planted at a rate of soybeans 39 kg/ha, buckwheat 29 kg/ha, and foxtail millet 11.2 kg/ha. In 2005, the front and backs of the organic with habitat plots were planted with two adjacent habitat strips to compensate for plants lost by equipment entering and leaving the plots. The soybeans were planted at a rate of 19.5 kg/ha per each variety, in addition to the previously cited rates of German foxtail millet and buckwheat.

In 2004, the habitat was planted after the cotton on 17 May, 2004. In 2005, the habitat was planted on 2 May, 2005, before the cotton was planted. Both years, the habitat was planted with a Sukup no-till grain drill equipped with small and large seed hoppers for seed planting (Sukup Manufacturing Company, Box 677, Sheffield, Iowa). The soybean and buckwheat seeds were combined at rates listed above into a cement mixer for thorough mixing and then placed in the large hopper of the Sukup. The soybean and buckwheat mix was planted through the large hopper at the 1.3 cm setting, and the millet was planted through the small hopper at the 1.6 cm setting. Because of poor soybean germination in 2004, a 1.8 m strip of soybeans was replanted adjacent to the habitat strips on 21 June with glyphosate resistant soybeans variety SN 79628, 3600 (Monsanto Company 800 N. Lindbergh Blvd., Seed Box, St Louis, MO 63167) at a rate of 84 kg/ha.

Crop Management

Planting. All plots were chisel plowed and field conditioned prior to planting. All cotton was planted with a John Deere four row vacuum planter (Deere & Company World Headquarters, One John Deere Place, Moline, Illinois 61265) at a row spacing of 96.5 cm. In

2004, both organic cotton var. Stoneville 474 (Steve McKaskle Farms, 25 Washington, P.O. Box 10, Braggadocio, Missouri 63826-0010) and conventional cotton var. STON 4646 BG2RR (Royster Clark Inc., 141 Luby Smith Rd., Princeton, NC 27569) were planted on 13 May, 2004. In 2005, organic and conventional cotton, of the same variety and from the same source as in 2004, were planted on 18 May, 2005. Seed spacing was set at 8.7 cm for conventional and 8 cm for organic cotton seed. On 11 June, 2004, portions of one replication had to be re-planted using a Planet, Jr. planter (Cole Planter Company, P.O. Box 2, 410 Hodges Ave., Albany, GA 31702) due to poor germination. These portions of the plot were not used for data collection.

Insecticide Application. All insecticides were applied at GPA and PSI according to manufacturer's instructions. Aldicarb was applied into the seed furrow with the conventional cotton seed at the time of planting at a rate of 5.9 kg ai/ha in 2004 and 1.4 kg ai /ha in 2005 for thrips control. Spinosad was applied at a rate of 0.20 kg ai /ha on 24 May, 2004 and at 0.011 kg ai/ha on 27 May, 2004 and on 7 and 10 June, 2005 for thrips control in the organic and organic with habitat plots. Acephate was applied at a rate of 0.21 kg ai/ha on 24 May, 2004 and 0.14 kg ai/ha on 14 June, 2005 for thrips control in the conventional plots. Spinosad was applied on 26 and 27 July, 2004 and 8 and 16 August, 2005 at a rate of 0.011 kg ai/ha for bollworm *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) larvae control in organic and organic with habitat plots. Dicrotophos was applied to conventional plots on 26 July, 2004 at a rate of 0.42 kg ai/ha and 8 August, 2005 at a rate of 0.56 kg ai/ha for control of green stink bug *Acrosternum hilare* (Say) (Hemiptera: Pentatomodae), Southern green stink bug *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae), and brown stink bug *Euschistus servus* (Say) (Hemiptera: Pentatomidae). Insecticides were applied with either a

Johnny Sheppard eight row sprayer (Sheppard Manufacturing, P.O. Box 122, Pink Hill, NC, 28572) used for conventional plots or an identical eight row sprayer used exclusively for organic crop production.

Weed control. All herbicides were applied at GPA and PSI according to manufacturer's instructions. Glypshosate was applied at a rate of 1.15 kg ai/ha to conventional cotton on 14 June and 8 August, 2005 with a hooded sprayer (Reddick Equipment Company Incorporated, P.O.Box 71, W. Main St., Williamston, NC, 27892). Glypshosate, prometryn, and monosodium acid methanearsonate were applied at rates of 1.15 kg ai/ha, 0.56 kg ai/ha and 1.05 kg ai/ha respectively on 21 June, 2004 with a hooded sprayer. Weed control in all organic plots was performed by cultivation with a Glencoe four row Danish tine cultivator (AGCO Corporation, 4205 River Green Parkway, Duluth, GA, USA 30096) as needed until cotton was too tall to cultivate. Hand-weeding was used as needed in organic plots to remove weeds missed by cultivation and between cotton plants.

Growth regulation. All growth regulators were applied at GPA and PSI according to manufacturer's instructions. The growth regulator mepiquat chloride was applied to the conventional cotton at 0.037 kg ai/ha on 30 June, 2004 and 0.047 kg ai/ha on 20 July, 2004 and at 0.037 kg ai/ha on 22 July, 2005 and 0.047 kg ai/ha on 8 August, 2005. All applications were made using a Johnny Sheppard eight row sprayer. In all organic plots, cotton plants were cut just below the terminal with electric hedge clippers on 12 July, 2004 and with gas-powered hedge clippers on 27 July and 17 August, 2005.

Fertilizer. All fertilizers were applied at GPA and PSI according to manufacturer's instructions. On 23 June, 2004 and 5 July, 2005, 40% nitrogen (Royster Clark Inc., 141 Luby Smith Rd., Princeton, NC 27569) was applied to the conventional plots at 17 kg /ha

(actual N) and 6.7 kg/ha (actual N) respectively using a six-row Johnny Sheppard layby sprayer (Sheppard Manufacturing, P.O. Box 122, Pink Hill, NC, 28572) converted to a four row sprayer. Soybean meal, with 7.68% nitrogen, (J. Milo Pierce Farm Center, Inc., 3626 Nahunta Rd., Pikeville, NC 27863) was applied to all organic plots at 1120 kg/ha on 23 June, 2004 and 27 June, 2005 using a 3.7 m wide Gandy (Gandy Company, 528 Gandrud Road, Owatonna, MN 55060-p0-0528). Plots were then cultivated with a Glencoe four row Danish tine cultivator (AGCO Corporation, 4205 River Green Parkway, Duluth, GA, USA 30096) to incorporate the meal.

Defoliants. All defoliants were applied at GPA and PSI according to manufacturer's instructions. A tank mix of tribufos, ethephon, and thidiazuron, at rates of 0.84 kg ai/ha, 1.67 kg ai/ha, and 0.22 kg ai/ha was applied to conventional plots on 24 September, 2004 and 16 September, 2005, and to organic plots on 17 October, 2005. A non-ionic surfactant was incorporated into the tank mix for all defoliant applications at a rate of 0.22 liter ai/ 100 liter of tank mix. Conventional defoliant was applied to organic plots because the citric acid-based organic defoliant, AllDown (SummerSet Products, Inc. 3584 Kennebec Dr.,Eagan, MN 55122), applied at 2.43 liter ai/ha on 5 October, 2005 was not successful at defoliation. No defoliant was used on organic plots in 2004, because all plots were hand-harvested.

Harvest/ Yield. In 2004, 15.2 meter sections of two rows per plot were hand-picked and weighed immediately after harvesting. Two replications were harvested on 24 September, 2004 and one replication was harvested on 1 October, 2004, due to differences in maturity. On 31 October, 2005 cotton was harvested with a John Deere 9930 cotton picker. In each plot, 15.2 m sections of the middle two rows were harvested. Harvested areas were

from the middle of each plot. Samples were bagged in 1.7 m x 0.86 m plastic mesh bags with two mesh squares per cm. Samples were weighed immediately after harvesting.

Cotton Ginning. In 2004 and 2005, a 300-400 g sub-sample of each harvest sample was weighed and ginned using a cotton gin (Continental Eagle Corporation, 201 Gin Shop Hill Road, Prattville, Alabama 36067-1000). Trash weight was subtracted from total weight to give the net weight of lint per sample. The net weight was divided by the total weight to give percent lint per sample. A 25 g sub-sample of lint was sent to Cotton Inc. (Cotton Inc., 6399 Weston Pkwy., Cary NC 27513, United States) for quality testing.

Sampling

Thrips sampling. Beginning at the cotyledonary stage, thrips were sampled on four dates in 2004 (24 and 26 May, 1 and 8 June) and 2005 (1, 6, 9, and 17 June). Four sampling points were randomly selected in each plot. At each sampling point, five randomly selected cotton plants, within a 3 m radius, were cut at soil level with hand pruners, and immediately immersed into quart canning jars (Alistra Consumer Products Company, Muncie, IN 47305-2398) containing 30 ml of 50% ethyl alcohol. Jars were shaken for ca 30 seconds, then cotton plant parts were removed, and jars were transported to the lab to be stored until processing. Immature and adult thrips were counted using a Leica WildMZ8 dissecting microscope (Leica Microsystems, Inc., 2345 Waukegan Rd., Bannockburn, IL 60015), and thrips were transferred to 20 ml scintillation vials (Fisher Scientific, Pittsburgh, PA 15219) and stored in 70% ethyl alcohol.

To identify thrips to species, one subsample of 10 adult thrips was taken from one sampling point per plot, dried briefly on a paper towel, then mounted with CMC-10 mounting medium (Masters Company, Inc., 890 Lively Blvd., Wood Dale, IL 60191) on a

slide. Thrips were identified to species using Palmer et al. (1989) under an Olympus CH2 compound microscope (Olympus America Inc., 2 Corporate Center Drive P.O. Box 9058 Melville, NY 11747-9058). Tobacco thrips *Frankliniella fusca* (Hinds) (Thysanoptera: Thripidae), were the predominant species, with small proportions of onion thrips *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae)**,** soybean thrips *Sericothrips variabilis* (Beach) (Thysanoptera: Thripidae)**,** Western flower thrips *F. occidentalis* (Pergande) (Thysanoptera: Thripidae), and cereal thrips *Haplothrips aculeatus* (Thysanoptera: Phlaeothripidae) in samples. Reference collections were verified by David Stephan of North Carolina State University. Voucher specimens reside in the collection at North Carolina State University.

Pest and beneficial insect sweep sampling. Pest and beneficial insect populations in plots were monitored weekly by sweep sampling with a 37.5 cm diameter sweep net (Bioquip Products, 17803 LaSalle Ave., Gardena, CA 90248-3602) on 8 dates in 2004, beginning on 30 June, 2005 and 10 dates in 2005, beginning on 27 June, 2005. A random numbers table was used to identify four rows per plot to be used for sweep sampling. Ten sweeps were collected in each row from a different starting point each week. Pests of cotton and common predators of cotton pests were recorded. Pest insects recorded included adults and immatures of green stink bug *Acrosternum hilare* (Say), Southern green stink bug *Nezara viridula* (Linnaeus), brown stink bug *Euschistus servus* (Say), tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae), and bollworm *Helicoverpa zea*. Predatory species recorded were adult Dolichopodidae, larvae of Corydalidae and Hemerobiidae, spiders, adults and immatures of *Orius insidiosus*, *Geocoris punctipes*, *Geocoris uliginosus* (Say) (Hemiptera: Lygaeidae), predatory Coccinellidae, and Nabidae. Sweep net contents were emptied into the plot after insect numbers were recorded. In 2005,

habitat strips were sweep sampled each week, for the same species as 2004, in three randomly selected locations per plot. Reference collections were verified by David Stephan of North Carolina State University. Voucher specimens reside in the collection at North Carolina State University.

***H. zea* egg fate.** The fate of naturally laid *H. zea* eggs was monitored to estimate *H. zea* egg parasitism and predation levels in plots. During the peak of the *H. zea* moth flight, naturally laid eggs, < 24 h old (Suh et al. 2000), were located throughout plots between 7:30 AM until 11 AM on 26 July, 2004 and 10 and 11 August, 2005. The upper and lower surfaces of the terminal and lateral terminal leaves were examined. Eggs on squares, bolls, and stems were not used. In instances in which there was more than one egg per leaf, excess eggs were removed manually. Leaves with eggs were identified with 69 x 42 mm white, paper tags (Avery Dennison, Office Products, Brea, Ca 92821) tied to them. On each tag, a map of the egg location was drawn to facilitate re-location of eggs. Four to ten eggs per plot were marked.

Four days after eggs were mapped, egg-bearing leaves were brought back to the laboratory and eggs were inspected using a Leica WildMZ8 dissecting microscope to determine their fates. Fates were recorded as hatched, preyed upon, parasitized, or unknown. Eggs that were black in color were recorded as parasitized. Eggs with only a thin, clear membrane remaining were recorded as hatched. Eggs that were shriveled and brown or yellow, or shriveled with a brown puncture mark were recorded as preyed upon. Remains of eggs that were brown or yellow in color and appeared chewed were recorded as preyed upon. Eggs that were unable to be located were recorded as unknown.

***H. zea* egg, larval numbers, and boll damage.** Cotton terminals, squares, and bolls were monitored to determine if and when insecticide applications for *H. zea* were necessary. Plants were monitored on three dates in 2004 (26 and 29 July, and 2 August) and five dates in 2005 (4, 10, 12, 18, and 30 August). Ten randomly selected plants were sampled from each of two rows, chosen at random on each sampling date. One terminal, one square, one small boll <3.0 cm, and one large boll > 3.0 cm were checked for *H. zea* eggs, larvae, or damage on each plant (Bacheler 2002). The upper and lower surfaces of the terminal leaf were observed. In organic plots, lateral terminals were sampled because terminals had been mechanically removed. Bloom tags (dried flower petals adhering to boll surface) on bolls were removed and the underside was observed for pest presence. Economic thresholds using number of eggs and larvae per terminals or fruiting forms were utilized for management decisions according to the situation (Bacheler 2002).

***Euschistus servus* egg fate.** Eggs from lab-reared brown stink bugs *E. servus* were used to estimate stink bug egg parasitism levels in plots. Field-collected adults were reared in 23 x 23 x 20 cm plastic containers with cheese cloth lids. Fresh beans were provided every three days. Depending on availability, certified organic green, fava, or wax beans, or English or snap peas were purchased weekly. Beans were washed with dish washing liquid to remove any pesticide residues and then thoroughly rinsed with water. Moistened cotton balls were provided for water. Bugs were reared at 25°C, 85% RH and 14 h photophase through one generation (Wilde 1968). Egg masses from F_1 adults were removed from cheesecloth, placed in a 1% bleach solution for 1 minute, rinsed in water, and then transferred to filter paper in a 100x 15 mm petri dish (Fisher Scientific, Pittsburgh, PA 15219). Petri dishes were held at 15.6°C, 80% RH and 14 h photophase for a maximum of

six days. Egg masses were transported to the field and glued to the underside of cotton leaves with Elmer's Glue-all glue (Elmer's Products, Inc., Columbus, OH 43215-3799) approximately 1.3 cm away from cotton leaf midrib. Masses were retrieved 48 hours later, then held at 25°C, 80% RH and 14 h photophase for two weeks. Eggs that turned black were recorded as parasitized. Eggs that hatched or did not turn black were considered non-parasitized. Parasitoid adults that emerged were placed in 70% ethyl alcohol for identification. Voucher specimens reside in the collection at North Carolina State University.

Hemipteran boll damage. Internal boll damage, caused by stink bug and plant bug *Lygus lineolaris* populations, was monitored by collecting bolls from four rows on 21 June, 2004 and two rows on 27 June, 3 and 12 August, 2004; and 2,11,19, 23, and 30 August, 2005. In each row, ten plants were chosen at random and one boll per plant was cut with garden hand pruners. A plastic cutout was used as a guide to collect bolls 3.0-3.3 cm in diameter (Bacheler 2002). Bolls larger than 3.3 cm were considered safe from stink bug damage and were not collected (Bacheler 2002). Bolls from each row were bagged in 3.78 L plastic freezer bags (American Fare Quality Products, Troy, MI 48084), placed in a cooler with ice packs, and transported back to the lab to be assessed by visual inspection. Bolls were sliced into four quarters, the carpel wall was peeled back, and the fiber under the casing was inspected for yellow to brown discoloration (Bacheler 2002). The inside of the carpel wall was also inspected for warty callous growths. A boll with either fiber staining or an internal warty growth was recorded as having internal damage (Bacheler 2002; Barbour et al. 1990; Bundy et al. 2000).

Pitfall traps. Pitfall traps were used to estimate predatory ground beetle and ground-dwelling spider populations. Traps were set on three dates each year, 1 and 21 July, and 11

August 2004 and 8 and 25 July, and 1 September 2005. Six traps were set at randomly selected sites in each per plot. Trap holes were dug using a ca 14 cm deep x 8 cm diameter soil probe within cotton rows. Traps consisted of two stacked 473 ml plastic cups (Food Lion, Salisbury, NC 28144) with drainage holes near the lip of the inner cup and the bottom of the outer cup. Approximately 150 ml of 50% antifreeze (Alsip Packaging, INC. Alsip, IL 60658) and water mixture was poured into each inner cup. Foamboard pieces (Fome-Cor Foamboard, Carolina Pad, Charlotte, NC 28241) were used as roofs to exclude rain water. The 14 cm^2 square and 5 mm thick roofs were placed over the cups, supported by four 8.5 cm long nails (LG Sourcing, Inc. PO Box 1535, North Wilkesboro, NC 28659).

Cup contents were retrieved 24 hours later and poured into quart glass canning jars (Alistra Consumer Products Company, Muncie, IN 47305-2398)**.** All six traps per plot were poured into the same jar and transported to the laboratory. The contents were poured into a small mesh kitchen strainer (16 mesh squares/1 cm), rinsed with ethyl alcohol, then stored in 70% alcohol in 160 ml HDPE plastic wide mouth bottles (Fisher Scientific, Pittsburgh, PA 15219). To identify insects from the traps, contents of plastic bottles were emptied onto a plastic sorting tray. The bottle was rinsed with 70% ethyl alcohol to remove all contents. Numbers of spiders, ground beetles, and tiger beetles were recorded. Reference collections were verified by David Stephan and Bob Blinn of North Carolina State University.

Data Analysis

All statistical analysis was performed using SAS Institute software using a significance level of 0.05 (SAS Institute 2002).

Thrips sampling. Means for thrips adults and immatures were square-root transformed. Transformed means of adults and immatures and non-transformed means of

adults and immatures for both years were subjected to ANOVA using the General Linear Model Procedure (PROC GLM). Adult means were further analyzed by year using PROC GLM. Means of transformed adults per year were separated using the Least Significant Differences Test (LSD).

Transformed means for immatures were further analyzed by year and by date using PROC GLM. Transformed immatures by week were separated using LSD.

Pest and beneficial insect sweep sampling. Sweep data was separated by arthropod genus for analysis, except for spiders and stink bugs. Adults and immatures were combined into one category per arthropod for Nabidae, predatory Coccinellidae, *L. lineolaris*, *Orius spp*., and *Geocoris spp*. Dolichopodidae adults, and *H. zea* larvae and adults were not analyzed due to many dates with zeroes for observations. Larvae of Corydalidae and Hemerobiidae were combined into one category. Adults and immatures of *A. hilare, N. viridula*, and *E. servus* were combined into one category. Spiders were not separated to family.

Plot means, averaged over years 2004 and 2005, were subjected to ANOVA using PROC GLM. Means were tested for treatment effect, treatment by week interaction, year by treatment interaction, and year by treatment by week interaction. Means of arthropods with a significant treatment effect were separated using LSD.

Arthropods with a significant treatment by week interaction, were further analyzed by time period using PROC GLM. Weeks were not analyzed separately since populations in individual weeks in year 2004 did not correspond to the same individual weeks in year 2005. Instead, sampling weeks were broken into before and after insecticide application time periods and analyzed. The time periods were based on weeks after planting, and were

defined as weeks 7-11, before insecticide application, and weeks 12-14, after insecticide application. In 2005, there was one extra week, week 15. This week was not included to keep the two years comparable. Means of organisms with a significant treatment effect were separated using LSD.

Pest and beneficial insect sweep sampling with habitat strips. In 2005, the same arthropods were sampled with a sweep net in habitat strips as were in cotton plots**.** Although a direct statistical comparison can not be made between the strips and the cotton plots, the means will be discussed as a measure of changes in the populations of organisms between the strips and surrounding cotton. Arthropods sampled with a sweep net in habitat strips in 2005, were categorized the same as sampled arthropods in cotton in 2004 and 2005. Plot means were analyzed using PROC GLM. Means of arthropods with a significant treatment effect were separated using LSD.

***H. zea* egg fate.** For each sampling date, the percentage of recovered *H. zea* eggs parasitized, preyed upon, and hatched, was calculated per plot. *H. zea* egg fates were analyzed separately, over years 2004 and 2005, using the Generalized Linear Model Procedure PROC GENMOD.

***H. zea* egg, larval numbers, and boll damage.** Due to the low number of *H. zea* eggs per plant structure, eggs from the four plant structures were combined. Counts of eggs per plot from 10 terminals, squares, small bolls, and large bolls were combined into one category referred to as total eggs. Similarly, *H. zea* larvae means from 10 terminals, squares, small bolls, and large bolls were combined into the category total larvae; and means of *H. zea*-damaged small and large bolls were referred to as total damage. Total damage and total larvae were transformed prior to analysis. Plot means of total damage, total larvae, and total

eggs, averaged over 2004 and 2005, were subjected to ANOVA using PROC GLM. Means were tested for treatment effects and treatment by year interaction.

***E. servus* egg fate.** The proportion of parasitized egg masses was calculated by dividing the number of egg masses with one or more parasitized eggs per plot, by the total number of masses per plot. The resulting proportions were subjected to an analysis of variance using PROC GLM.

In addition, the percentage of parasitized eggs per plot was calculated by dividing the number of parasitized eggs by the number of viable eggs for each of the three sampling dates. The percent of parasitized eggs per plot was subjected to an analysis of variance using PROC GLM.

Hemipteran boll damage. Bolls with internal damage caused by stink bugs and plant bugs were totaled per plot and divided by the total number of bolls sampled per plot to determine the proportion of bolls with internal damage. Plot means of proportion of bolls with internal damage were analyzed using PROC GLM.

Pitfall traps. Plot means of spiders, carabid beetles, and tiger beetles were square root transformed. Transformed plot means were analyzed using PROC GLM.

Yield. Plot means of yield weight were multiplied by the percent lint obtained from the ginning sub-sample to determine lint weight per plot. The resulting lint weights per plot were analyzed using PROC GLM. Means with a significant treatment effect were separated using LSD.

Results

Thrips sampling. Means for adult and immature thrips were significantly higher in both organic treatments than conventional in both years (Table 1). Transformed plot means for adult thrips had a significant treatment effect ($F = 97.80$; df = 2; $P < 0.0001$) and year by treatment interaction ($F = 9.08$; df = 2; $P = 0.0056$) when averaged over years 2004 and 2005. There was no significant treatment by date interaction for 2004 ($F = 2.91$; df = 6; $P = 0.0548$) or 2005 ($F = 1.84$; df = 6; $P = 0.148$). Transformed plot means for immature thrips averaged over 2004 and 2005 had a significant treatment effect ($F = 173.8$; df = 2; $P < 0.0001$), year by treatment interaction ($F = 28.92$; df = 2; $P < 0.0001$), and treatment by date interaction ($F = 5.58$; df = 12; $P < 0.0001$).

Pest and beneficial insect sweep sampling. A significant treatment effect, when data was averaged over both 2004 and 2005, was seen for transformed plot means of *Orius spp.* numbers ($F = 12.76$; df = 2; $P = 0.0018$), transformed plot means of *L. lineolaris* numbers ($F = 25.57$; df = 2; $P = 0.0001$) and transformed plot means of lady beetle numbers ($F = 28.81$; df = 2; $P < 0.0001$). Plot means of *Orius spp.* numbers were significantly higher in organic compared to organic with habitat and conventional, and means in conventional were significantly higher than organic with habitat (Table 2). Plot means of *L. lineolaris* numbers were significantly higher in both organic treatments than the conventional control. Plot means of lady beetle numbers were significantly higher in organic compared to organic with habitat and conventional, and in organic with habitat compared to conventional.

In addition to having a treatment effect, transformed plot means of *L. lineolaris* numbers ($F = 2.23$; df = 14; $P = 0.0147$) and lady beetle numbers ($F = 3.82$; df = 14; $P < 0.0001$) had a significant treatment by week interaction. In weeks prior to insecticide

application, transformed plot means of *L. lineolaris* numbers ($F = 1.88$; df = 2; $P = 0.2025$) did not have a significant treatment effect during this time period. Plot means of lady beetle numbers ($F = 9.43$; df = 2; $P = 0.0050$) had a significant treatment effect and were significantly higher in the organic treatment than the organic with habitat and conventional control (Table 3).

In weeks after insecticide application, transformed plot means of *L. lineolaris* ($F = 12.76$; df = 2; $P = 0.0018$), and lady beetle numbers ($F = 59.06$; df = 2; $P < 0.0001$) had a significant treatment effect. Transformed plot means of both *L. lineolaris* and lady beetle numbers were significantly higher in both organic treatments than the conventional control (Table 3).

Arthropods that did not have a significant treatment effect over years, but did have a treatment by week interaction included transformed plot means of *Geocoris spp.* numbers ($F = 1.90$; df = 14; $P = 0.0413$) and square-root transformed plot means of spider numbers ($F = 2.85$; df = 14; $P = 0.0020$).

In weeks prior to insecticide application, transformed plot means of *Geocoris spp.* numbers ($F = 0.03$; df = 2; $P = 0.9700$) did not have a significant treatment effect. Transformed plot means of spider numbers had a significant treatment effect ($F = 4.71$; df = 2; $P = 0.0363$) and were significantly higher in the conventional and organic with habitat treatment than the organic treatment (Table 3).

In weeks after insecticide application, transformed plot means of *Geocoris spp.* numbers ($F = 7.51$; df = 2; $P = 0.0102$) and transformed plot means of spider numbers ($F = 9.61$; df = 2; $P = 0.0047$) had a significant treatment effect. Transformed plot means of

Geocoris spp. and spider numbers were significantly higher in both organic treatments than the conventional control (Table 3).

Pest and beneficial insect sweep sampling with habitat strips. Numbers of *Geocoris spp*. were numerically higher in habitat strips than in all cotton plots in 2005 (Table 4). Means in the habitat strips were 2 to 3-fold higher than in the adjacent organic cotton throughout the growing season (Fig. 7). Transformed plot means for *Geocoris spp.* numbers had a significant treatment effect ($F = 5.11$; df = 2; $P = 0.050$) and were significantly higher in organic than conventional cotton, but not the organic with habitat treatment.

Numbers of *Orius spp.* were numerically higher in habitat strips than in all cotton plots in 2005 (Table 4). Means in the habitat strips, on average, were almost 3-fold higher than in the organic with habitat plots. Plot means in the strips were higher than the organic with habitat plots for three out of nine dates (Fig. 8). Plot means were higher in the strips early in the season; however, means decreased in the strips and surrounding cotton during weeks 11-15. Transformed plot means for *Orius spp.* numbers had a significant treatment effect ($F = 13.62$; df = 2; $P = 0.0059$) and were significantly higher in the organic and conventional treatments than the organic with habitat treatment.

Numbers of spiders were numerically higher in habitat strips than in all cotton plots in 2005 (Table 4). Plot means for spiders were higher in strips for five out of nine dates (Fig. 9). Plot means for spiders did not have a significant treatment effect ($F = 2.77$; df = 2; $P = 0.1406$).

***H. zea* egg fate.** There was no significant difference in mean percent parasitism ($F = 0.94$; df = 2, 24; $P = 0.4057$), predation ($F = 0.85$; df = 2, 24; $P = 0.4399$), or hatching ($F = 2.93$; df = 2, 24; $P = 0.0729$) of *H. zea* eggs among treatments (Table 5). Date by treatment

interaction was significant for predation ($F = 4.44$; df = 4, 24; $P = 0.0079$), but not for parasitism ($F = 1.98$; df = 4, 24; $P = 0.1300$) or hatching ($F = 0.50$; df = 4, 24; $P = 0.7338$).

***H. zea* egg, larval numbers, and boll damage.** There was a significant difference among treatments for plot means per sample of 10 terminals, squares, small and large bolls of *H. zea* eggs ($F = 4.76$; df = 2; $P = 0.0352$), transformed *H. zea* larvae ($F = 24.49$; df = 2; $P = 0.0001$), and transformed *H. zea*-damaged bolls ($F = 15.60$; df = 2; $P = 0.0008$), averaged over 2004 and 2005. There was no significant treatment by year interaction for *H. zea* eggs ($F = 3.24$; df = 2; $P = 0.0824$), transformed *H. zea* larvae ($F = 1.25$; df = 2; $P = 0.3280$), or *H. zea*-damage plot means, ($F = 4.10$; df = 2; $P = 0.0501$) averaged over 2004 and 2005. Plot means per sample of *H. zea* eggs were significantly higher in the conventional control than the organic with habitat treatment (Table 6). Plot means per sample of *H. zea* larvae and *H. zea*-damaged bolls were higher in both organic treatments than the conventional.

***E. servus* egg parasitism.** The proportion of masses with at least one parasitized egg, averaged over three sampling dates in 2005, did not have a significant treatment effect ($F = 0.17$; df = 2; $P = 0.848$) or treatment by date interaction ($F = 0.60$; df = 4; $P = 0.671$). Plot means of percent parasitism of recovered eggs, averaged over the three sampling dates, did not have a significant treatment effect ($F = 0.08$; df = 2; $P = 0.922$) (Table 7) or treatment by date interaction ($F = 0.51$; df = 4; $P = 0.730$).

Hemipteran boll damage. The mean percent of bolls with internal damage per plot had a significant difference among treatments ($F = 31.08$; df = 2; $P < 0.0001$) and a significant treatment by date interaction ($F = 3.03$; df = 14; $P < 0.0037$). Plot means were significantly higher in both organic treatments than the conventional control.

Pitfall traps. Plot means per six pitfall traps had no significant treatment effect for either transformed spiders ($F = 0.31$; df = 2; $P = 0.7378$), ground beetles ($F = 1.95$; df = 2; $P = 0.1920$), or tiger beetles ($F = 1.18$; df = 2; $P = 0.3463$) (Table 8). Likewise, there were no significant year by treatment interactions for either spiders ($F = 0.43$; df = 2; $P = 0.6644$), ground beetles ($F = 0.50$; df = 2; $P = 0.6189$), or tiger beetles ($F = 2.10$; df = 2; $P = 0.1732$).

Yield. Plot means of cotton lint weight in kg, averaged over 2004 and 2005, had a significant treatment effect ($F = 20.59$; df = 2; $P = 0.0003$) and year by treatment interaction ($F = 9.05$; df = 2; $P = 0.0057$). Plot means for lint weight were lower in both organic treatments than conventional for both years. In 2004, there was no significant difference in lint weight among the three treatments. In 2005, means from organic ($P = 0.0005$) and organic with habitat ($P < 0.0001$) treatments were both significantly lower than conventional (Table 9). There was no significant difference in mean lint weight between the organic treatments in 2005. Mean lint weights for the organic treatment and conventional were higher on average in 2005 than 2004. The mean lint weight for the organic with habitat treatment was slightly lower in 2005 than 2004.

Discussion

For this study, selection of plant species for the habitat mix was based on several conditions. The plants used are common cover crops with inexpensive, readily available seed that may already be grown by farmers to improve soil fertility. The plants needed to be able to compete with weeds, provide resources to beneficial insects; and establish easily, quickly and without irrigation. The plants chosen for the study were buckwheat (*Fagopyrum esculentum* Moench), German foxtail millet (*Setaria italica*) and soybeans (*Glycine max*).

Buckwheat blooms on average 4-6 weeks after planting and was chosen to provide early season blooming (Creamer and Baldwin, 1999). Buckwheat has been reported as harboring high densities of predatory wasps, syrphid flies, and *Orius spp.* (Bugg and Dutcher 1989; Bugg and Ellis 1990; Nicholls et al. 2000). Journet et al. (1981) reported *Orius tristicolor*, *Nabis spp*., 13 Carabidae species, and six Coccinellidae species in buckwheat. Platt (1999) reported buckwheat as easy to establish and able to out-compete weeds. In addition, buckwheat reaches flowering stage quickly and provides a large supply of flowers (English-Loeb et al. 2003).

Soybean establishes quickly, is competitive with weeds, and is somewhat drought-tolerant (Creamer and Baldwin 1999). Soybean seed is readily available, and many varieties in several maturity groups exist. Leguminous cover crops have been shown to have higher densities of *Geocoris punctipes* and *Orius insidiosus* (Say) than other cover crops (Tillman et al. 2004). Bundy and McPherson (2000) found stink bugs more attracted to soybeans than cotton and suggested the use of an integrated planting of early and late maturing soybeans as a trap crop for stink bugs during times of vulnerability in cotton.

Although not represented well in the literature for providing resources to beneficial insects, German foxtail millet was chosen as the third component in the mix due to its ease of planting, competitiveness with weeds, and low water requirement (Creamer and Baldwin, 1999). It was thought that the millet would provide additional height and ecological complexity to the habitat mix.

In this study, in general, there was a lack of significant difference among sampled arthropods between treatments. Arthropods that did differ significantly among treatments included thrips, *Orius spp.,* lady beetles, *L. lineolaris*, *Geocoris spp*., and spiders. Levels of

parasitism and predation of *H. zea* and *E. servus* eggs did not differ between treatments. Organic plots had more damage from thrips and hemipteran pests than conventional plots.

Thrips. Conventional cotton, planted with an application of aldicarb at planting and a foliar application of acephate, was much better protected from damaging levels of thrips than organic cotton. Applications of the insecticide spinosad to organic plots did not keep thrips populations below economic thresholds and subsequently were more stunted than conventional plots.

The presence of habitat strips did not significantly lower populations of thrips in organic cotton adjacent to habitat strips. The original purpose of the habitat in this study, in regards to thrips control, was that habitat could act as an attractant to thrips. It was thought that habitat could act as a trap crop for thrips. Trap crops serve to attract pests away from the target crop and either prevent the pest from invading the target crop or concentrate the pest for ease of management (Hokkanen 1991). However, manipulation of thrips dispersal may be difficult due to the common occurrence of thrips being blown into fields by wind, even before cotton is planted (Layton and Reed 2002; Lewis 1997). Subsequent dispersal of thrips, once within the cotton crop, may be the most effective use of habitat.

In 2004, since habitat was planted after the cotton, plants in the habitat strips were very small and were not flowering during thrips sampling dates. In 2005, the habitat was planted two weeks before the cotton, and buckwheat was established and flowering during some of the thrips sampling dates. In both years, with the presence of buckwheat flowers and without, no difference in thrips populations was observed between the two organic treatments. The main thrips species observed, *F. fusca*, has a wide range of host species

(Groves et al., 2002; Chellemi et al., 1994). It may be necessary to use plant species that are more attractive to *F. fusca* and other thrips species if the habitat is to serve as a trap crop.

In this study, attraction of thrips predators was an important goal, as well as attempting to manipulate thrips dispersal. *Orius spp.* have been reported in higher numbers in polycultures and in crops with weedy areas present (Letourneau and Altieri 1983; Smith 1967). Funderburk (2002) recommends provision of habitat plants that are attractive to both predators and thrips. He suggests that thrips will be drawn away from the crop and condensed in habitat, and predators will aggregate in flowers, utilize pollen, and provide better control of thrips by more concentrated searching behavior (Funderburk 2002). In addition, predators such as *Orius spp.* could utilize plant resources (Smith 1960; Salas-Aquilar and Ehler 1977; Kiman and Yeargan 1985) if the habitat was established before the crop to develop larger populations. Nicholls et al. (2000) reported lower densities of the thrips species *Frankliniella occidentalis* and higher densities of general predators in vineyards that had full season flowering of sunflower and buckwheat habitat. Nicholls et al. (2000) utilized mowing of the habitat as a means of moving predators into the crop.

Further research is needed to determine which habitat plants will be most attractive to thrips and if habitat can incur protection for cotton seedlings. In addition, habitat should also be attractive to thrips predators to provide control in the trapped area. To be effective, habitat should be established earlier in the season to allow for a buildup of predator populations that can then move into cotton by mowing or other means of manipulation of habitat strips.

Pest and beneficial insect sweep sampling. Means of *Orius spp.*, *L. lineolaris* and lady beetles were the only arthropods with a significant treatment effect when plot means

were averaged over years. Means of *Orius spp.* were significantly higher in the organic treatment than the conventional control. Means of lady beetles and *L. lineolaris* were significantly higher in both organic treatments than conventional.

Plot means of the predators *Geocoris spp.*, lady beetles, and spiders were significantly higher in both organic treatments than conventional after insecticides were applied. It appears organically approved insecticides did not have as negative of an impact on predator populations as conventional insecticides did. However, organically approved insecticides also did not provide as much control of Hemipteran pests, such as *L. lineolaris*, as conventional insecticides did. *L. lineolaris* were significantly higher in both organic treatments than the conventional control after insecticides were applied. It is most likely due to the lack of affect on Hemipteran insects by the organically approved insecticides that protected both Hemipteran pest and predators, such as *Orius* and *Geocoris*. However, even with higher densities of predators in the organic plots, higher crop damage was observed.

Habitat strips did not increase numbers of predators in the surrounding cotton in the organic with habitat treatment. Conversely, *Orius spp.* and lady beetles had significantly higher densities in the organic treatment than the organic with habitat over years 2004 and 2005. Plot means of *Orius spp.* in the organic with habitat treatment had significantly lower plot means than both the conventional and organic treatments. When sweep means were compared for 2005 only, and included habitat strips, both organic treatments had higher means of lady beetles than the strips. For *Orius spp.*, strips had on average, almost three-fold the number of *Orius spp.* than the cotton in the organic with habitat treatment. On the third sampling date, *Orius spp.* means in strips were more than double that of any of the cotton

treatments. If at this point, *Orius spp.* populations could be moved from the strips into cotton, better pest control might be observed.

Averaged over weeks in 2005, plot means of *Geocoris spp*. and spiders were higher in habitat strips compared to all three cotton treatments. Due to the high numbers of immatures found in the habitat strips, *Geocoris spp*. appear to have had either higher levels of reproduction or higher levels of survival of immatures in the strips. Naranjo and Stimac (1985) reported phytophagy alone as sufficient in nymphal development to the second stadium of *Geocoris spp*. The habitat could provide moisture and nutrients to nymphs during the first instars, when consuming prey is less important (Stoner 1970). However, the higher populations of *Geocoris spp*. in the strips did not correlate to a higher population in the surrounding cotton, as means of the organic treatment were significantly higher than the organic with habitat in 2005. Averaged over both years, there was no difference between the organic treatments.

Plot means of spiders were higher in strips than both organic plots on average; however, in 2005 there was no significant difference between the organic treatments. In addition, over years 2004 and 2005, there was no significant difference between organic treatments.

Habitat strips had higher means for *Geocoris spp.* over the entire season, and for several weeks out of the season for spiders and *Orius spp.* However, higher populations of these predators in the strips did not correlate to a higher population in the surrounding cotton. Strips could be utilized early in the season, by providing alternate hosts, and after insecticide applications, when host populations may be reduced in the cotton. Plant feeding could maintain *Geocoris spp.* populations in the temporary absence of prey (Tillman and Mullinix

2003), and possibly other predator species as well. At a strategic time, when pest populations are increasing within the crop, the predators could then be forced into cotton by mowing of the strips or other destructive means.

***H. zea* egg fate.** Predation and parasitism levels of *H. zea* eggs did not differ significantly between organic and conventional treatments. Since all sampling dates occurred after insecticide applications (on the same day as application in 2004, and 2 and 3 days afterward in 2005), parasitoids and predators may have been negatively impacted. Future studies should monitor egg fates for several dates before application and for several dates afterward to determine if predator and parasitoid populations recover more quickly in one treatment than another and if resulting egg fates differ.

The larger, more vegetative organic cotton plants may have slowed parasitoid and predator searching behavior. Sheehan (1986) suggests having more leaf surface area to search reduces the effectiveness of predators and parasitoids. Coll and Bottrell (1996) reported variation in the height of maize as the main factor affecting rates of parasitism by *Pediobius foveolatus*. This is consistent with Risch et al. (1982) who found reduced foraging rates of the predator *Coleomegilla maculata* (DeGeer) when the density of plants was increased. Shields and Watson (1980) reported a random, and often redundant searching strategy by adult female *Orius tristicolor*, with time periods of several hours spent searching one leaf and petiole. With this type of searching behavior, large amounts of plant material could considerably slow searching time. In addition, the plant canopy in the organic plots was more closed in comparison to the conventional. This could have created differences in microclimate, as well as predator and parasitoid searching behavior (Barbosa and Benrey, 1998).

Levels of *H. zea* egg predation and parasitism did not differ among organic treatments. Sweep sampling showed higher numbers of predators within the habitat strips but not within the surrounding cotton. It is difficult to determine if parasitoids were similarly impacted by the habitat strips, since no sampling of parasitoids in the strips occurred.

***H. zea* egg, larval numbers, and boll damage.** Though plot means of total eggs were significantly higher in conventional plots than the organic treatment, this was not a meaningful indicator of future larval populations in the conventional plots since the cotton was genetically engineered to contain the *Bacillus thuringiensis* toxins. Plot means of total larvae and total damaged bolls were higher in both organic treatments than conventional, as expected due to the efficacy of *B. thuringiensis* at controlling *H. zea* larval populations. However, the organic plots were not strictly managed for yield, and insecticide applications were not always applied at times for maximum efficacy, due to the presence of delicate egg fate studies in the plots. In 2004, the second application of spinosad was applied three days after the first and in 2005 the second application was applied eight days after the first application. This most likely allowed for an increase in *H. zea* larval populations in 2005, which could have been reduced if spinosad had been applied sooner.

In addition, the mechanical cutting of terminals and lack of an organically approved growth regulator caused organic plants to have more vegetative growth and reduced boll formation. This caused increased pressure by *H. zea* larvae on the lower number of bolls in organic plots. Another effect of the lack of growth regulation in organic plots was that the fruiting structures were more spread out on the plants as opposed to the conventional plants, where structures were condensed in the top 30 cm of the plant. This could have caused predators and parasitoids to have a longer distance to search between fruiting structures, the

most likely locations of *H. zea* eggs and larvae. Grevstad and Klepetka (1992) reported similar findings for predatory Coccinellidae, observing different rates of aphid consumption on crucifer cultivars that had varying leaf structure, and architecture of stems and petioles. Furthermore, the excess nitrogen may have caused the organic plants to be more attractive to pests. High soil fertility has been shown to cause vegetative, succulent cotton, which is attractive to *H. zea* for a longer time period (Bradley 1993).

Plot means of total eggs, total larvae, and total damaged bolls did not differ significantly in organic treatments. The presence of habitat did not lower the populations of *H. zea* larval populations. Even though predator numbers were higher in the habitat strips, predation levels in the surrounding cotton were not higher. This is consistent with similar studies by Platt (1999), who reported higher numbers of predators in crop rows near habitat strips but did not find improved yield or reduction in pest populations. If the higher populations of *H. zea* egg and larval predators in the habitat strips could be moved into the surrounding cotton, *H. zea* egg and larval populations could be reduced.

***E. servus* egg fate.** There were no significant differences in *E. servus* egg parasitism levels between organic and conventional plots. This could be due to reduced effectiveness in parasitoid searching due to more numerous leaf surfaces and differences in plant architecture in organic plots as mentioned above.

The presence of habitat did not increase levels of *E. servus* egg parasitism in organic with habitat plots compared to organic plots. Populations of stink bugs in the habitat strips were higher on several dates than in the surrounding organic cotton. The presence of stink bugs in the habitat strips may have drawn parasitoids out of the surrounding cotton.

Hemipteran boll damage. The reduced boll production in the organic plots increased the proportion of bolls that were damaged by stink bugs and plant bugs. The conventional cotton was able to compensate for damaged bolls by the greater number of bolls produced on the plants. In addition, stink bug and plant bug populations were not reduced in the organic plots as they were in the conventional, and continued to cause damage throughout the season, due to the lack of an organically approved, effective insecticide.

Habitat strips did not reduce internal damage caused by stink bugs in the surrounding cotton. Means of stink bugs were higher in the strips, and slightly higher in the organic with habitat than organic plots, but not significantly. As mentioned above, populations of stink bugs in the strips may have caused the habitat to attract stink bug parasitoids and predators away from the surrounding cotton.

Pitfall traps. Plot means of ground beetles, tiger beetles, and spiders sampled by pitfall traps did not differ among treatments. Berry et al. (1996) reported similar results, with spiders collected by a suction sampler having almost identical numbers in organic and conventional fields. In this study, the land used for the organic plots was not certified organic, and could be considered similar to the conventional plots in terms of soil composition. The existing populations of Carabidae and spiders in the surrounding agro-ecosystem have been shown to determine the population within the crop (Clark et al. 1993). In this study, the fields used had been cultivated prior to planting, field borders were kept mowed, and pesticides had been applied in the year prior. In addition, tillage, which has been shown to disrupt Carabidae populations (Clark et al. 1993), occurred in the beginning of the season in the experimental plots. Tillage and past management practices may have had

greater effects on the Carabidae and spider populations than conventional or organic management practices in one season.

The presence of habitat did not increase the number of sampled arthropods in the surrounding cotton. This is consistent with a similar study in conventional cotton evaluating the effects of field borders (Outward et al. 2000). The habitat strips themselves were not sampled directly and it is possible that ground-dwelling beetle and spider populations were higher in the strips. However, even if populations were higher in the strips, an increase in population in the surrounding cotton was not observed. Future work should sample the habitat strips and surrounding crop rows at increasing distance from the habitat to determine if strips are attractive and if beetles and spiders move out into the crop. Spiders have been reported as having increased populations in cotton a short distance from a sorghum habitat (Burleigh et al. 1973).

The majority of studies on the effects of habitat manipulation on Carabidae and spider populations have focused on establishing perennial habitat strips to promote overwintering refuges within crop fields (Collins et al. 2002; Collins et al. 2003; Lys et al. 1993; Thomas et al. 1991;). It is possible that an annual habitat refuge does not increase Carabidae and spider populations during one growing season. Collins et al. (2003) suggest that colonization of strips may be slowed due to the slow dispersal mechanisms, mainly walking, of Carabidae, and that colonization of the strips may take several years. Thomas et al. (1991) reported an increase in overall number and species diversity of both Carabidae and spiders in habitat strips over three years. To reap full advantage of habitat strips on spider and Carabidae populations, a multi-year approach may be necessary.

Yield. Lint weights were similar among all three treatments in 2004. In 2005, both organic treatments had significantly lower lint weights than conventional. This was most likely due to a combination of factors. Due to a lack of an effective organically approved growth regulator, organic cotton plants tended to have excessive vegetative growth and reduced boll formation. This was especially pronounced in one replication in 2004 and two replications in 2005 that had received high nitrogen applications in previous seasons. Excessive nitrogen is known to cause vegetative growth and reduce boll maturation (Klonsky et al. 1996). Cotton in conventional plots in these replications also had more pronounced vegetative growth than other replications but was able to be controlled by growth regulator applications. In 2004, with only 1 out of 3 organic replications having excessive nitrogen, the effect in yield was not as pronounced as in 2005 when 2 out of 4 replications had increased vegetative growth.

The presence of habitat strips did not significantly increase lint weight in adjacent cotton compared with organic cotton in either year. As mentioned above, levels of pest predation and parasitism, and boll damage did not differ among organic treatments. Likewise, the effects of excessive nitrogen were similar in both organic treatments. These similarities most likely led to similar losses in lint weight in both organic treatments.

Conclusion. The lack of efficacious organically approved insecticides and growth regulators are the main factors limiting yields and insect pest management in organic cotton in North Carolina. Improved organically approved insecticides and a strict timeline of applications could lessen the damage of insects. In California, a combination of nutrient manipulation, water management, and mechanical topping are used to regulate growth of cotton plants (Klonsky et al. 1996; Myers and Stolton 1999). In North Carolina, water

management is not an option due to a larger amount of annual precipitation, especially during the summer and fall months during the hurricane season. Attention to soil fertility and use of cultural practices to limit vegetative growth of organic cotton are needed to increase boll production and lessen insect pressure on bolls. Limiting nitrogen levels may also lessen the attractiveness of organic cotton to insect pests (Bradley 1993) and facilitate predator and parasitoid searching behavior.

The presence of habitat strips did not result in lower pest populations or lower insect damage in organic cotton. Some predators had higher means from sweep sampling in the habitat strips compared to the cotton treatments and control. However, a correlation did not exist between higher populations in the strips and higher populations in the surrounding cotton for any of these predators. A possible reason why the predators did not move into the surrounding cotton was that there was a constant supply of flowering plants and insect hosts in the habitat.

Manipulation of the habitat strips by mowing or other destructive means could force predators into neighboring cotton fields. Platt (1999) and Nicholls et al. (2000) reported increased densities of predators and parasitoids in adjacent rows of a neighboring crop when nearby buckwheat was mowed. Bugg et al. (1991) reported increased numbers of *Geocoris punctipes* in adjoining cantaloupe plants after habitat plants began to die. Platt (1999) suggested the use of habitat for early season colonization by natural enemies, and then disturbance to the habitat to facilitate movement into the crop. The goal may not be to have a constant supply of flowering plants in the habitat, but rather to have an early flowering refuge that provides resources to predators before key cotton pest populations peak (Corbett and

Plant 1993). This refuge could later be destroyed or allowed to senesce to facilitate movement of beneficial insects into the crop.

This study sought to compare pest and beneficial insect populations, beneficial insect activity, and crop damage in conventional and organic cotton and organic cotton with habitat. Overall, densities of the majority of pest and beneficial insects observed did not differ between organic and conventional cotton. Organic cotton did have higher densities of two predators: lady beetles and *Orius spp.* However, organic cotton had more damage from pests due to a lack of population control of pest insects. Predation and parasitism levels did not differ between the two management systems. Cultural methods and more efficacious insecticides are needed to control thrips and Hemipteran pests and thereby improve organic cotton production.

Habitat strips in organic cotton did not increase the number of beneficial insects or decrease the number of pests or damage in adjacent cotton. Densities of *Orius spp.* and lady beetles were actually higher in the organic treatment than the organic with habitat. As the habitat strips were planted and managed in this study, they did not provide any benefit to the surrounding cotton. Higher densities of *Geocoris spp.*, *Orius spp.*, and spiders were observed in the habitat strips than all three cotton systems; however, without manipulation of the habitat strips to force the predators into the cotton, an economic benefit could not be derived from their presence.

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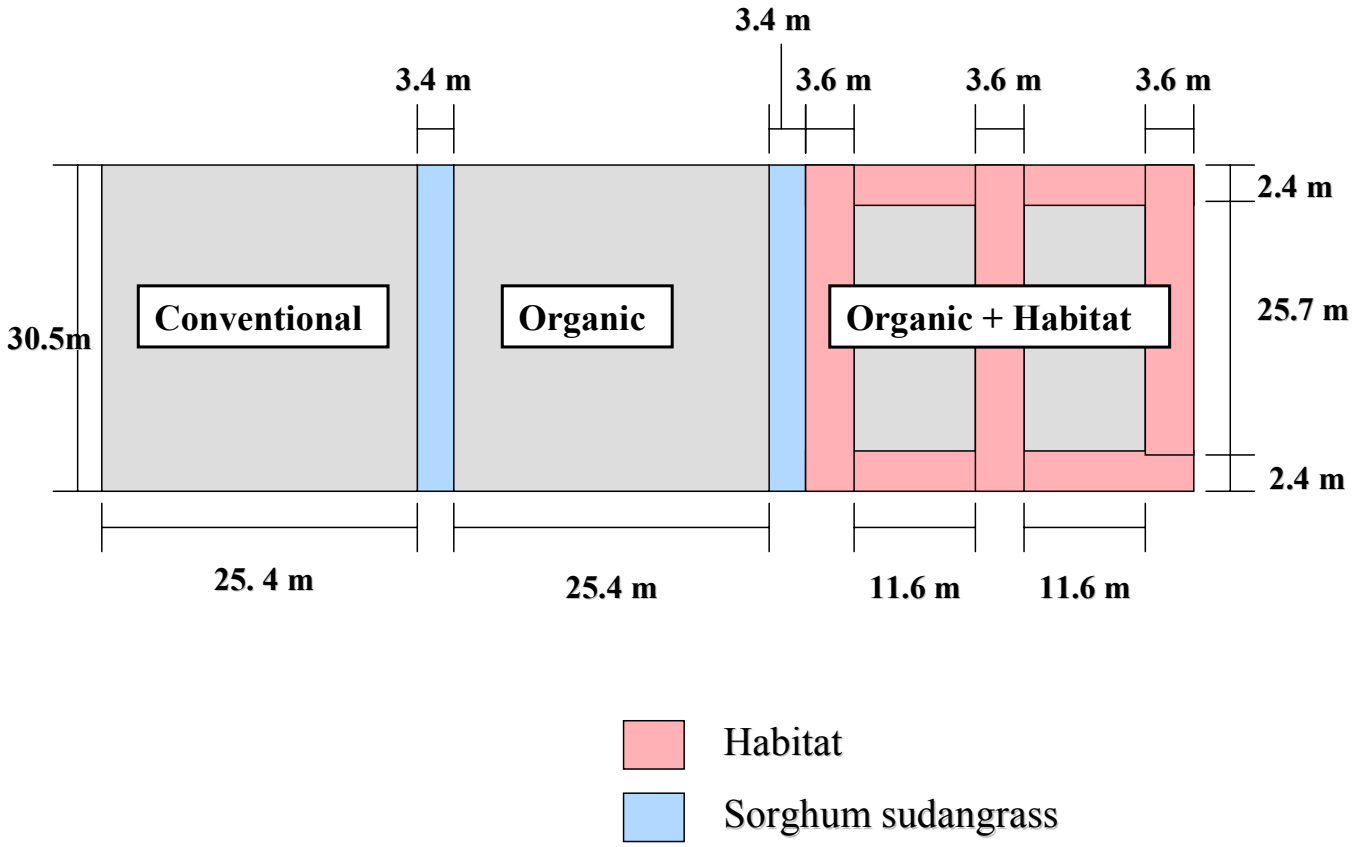
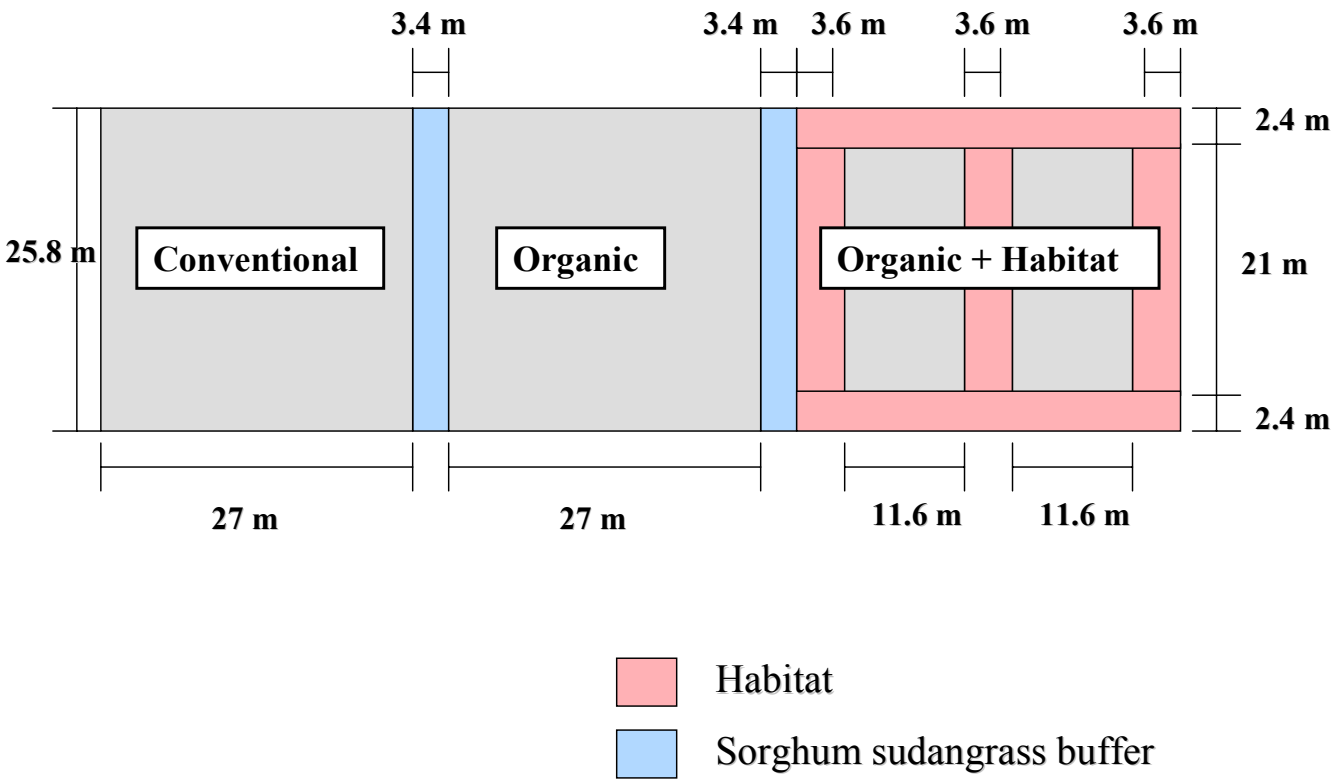
Figure 1. Plot design for Replication 1 in 2004.



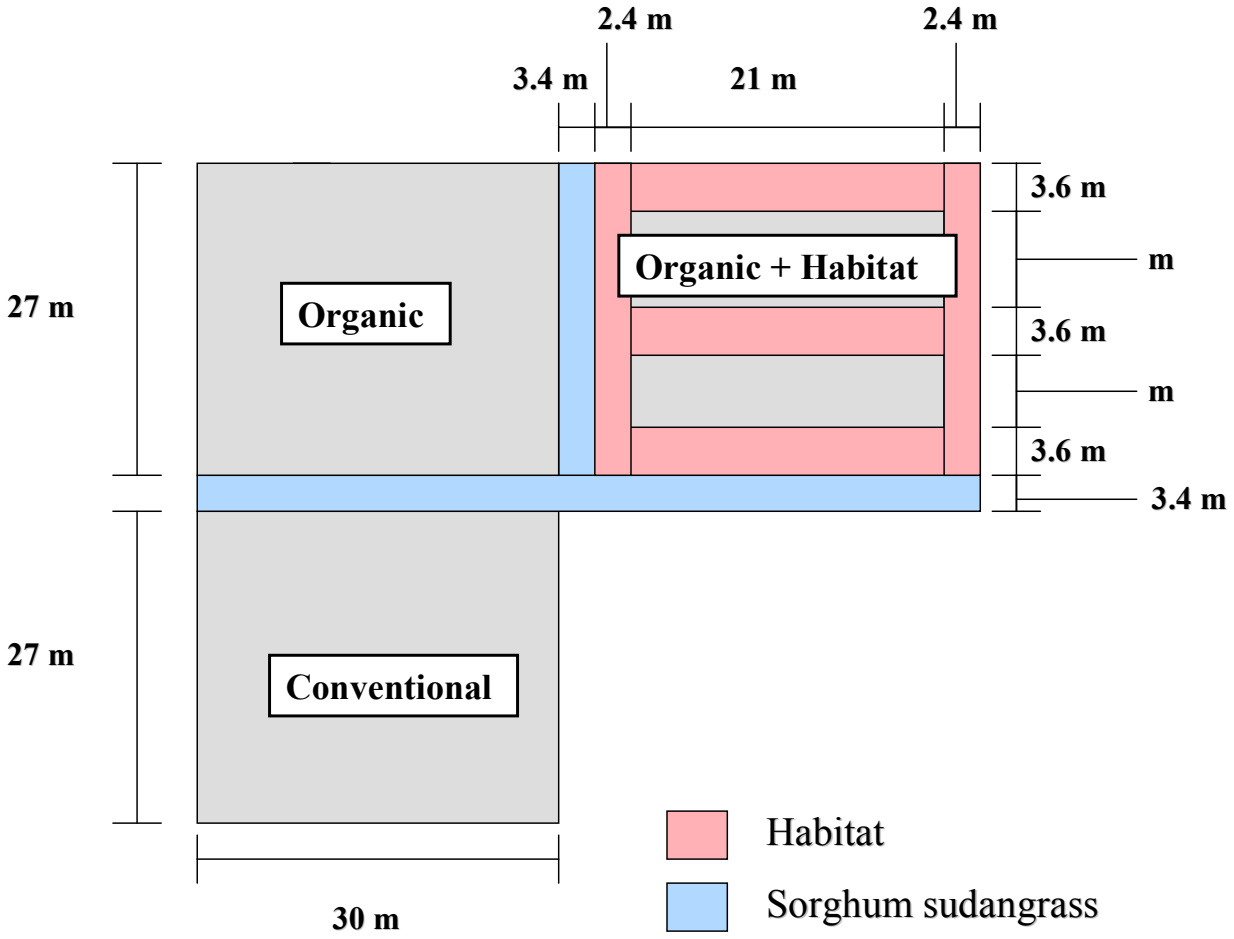
Drawing is not to scale.

Figure 2. Plot design for Replication 2 in 2004.



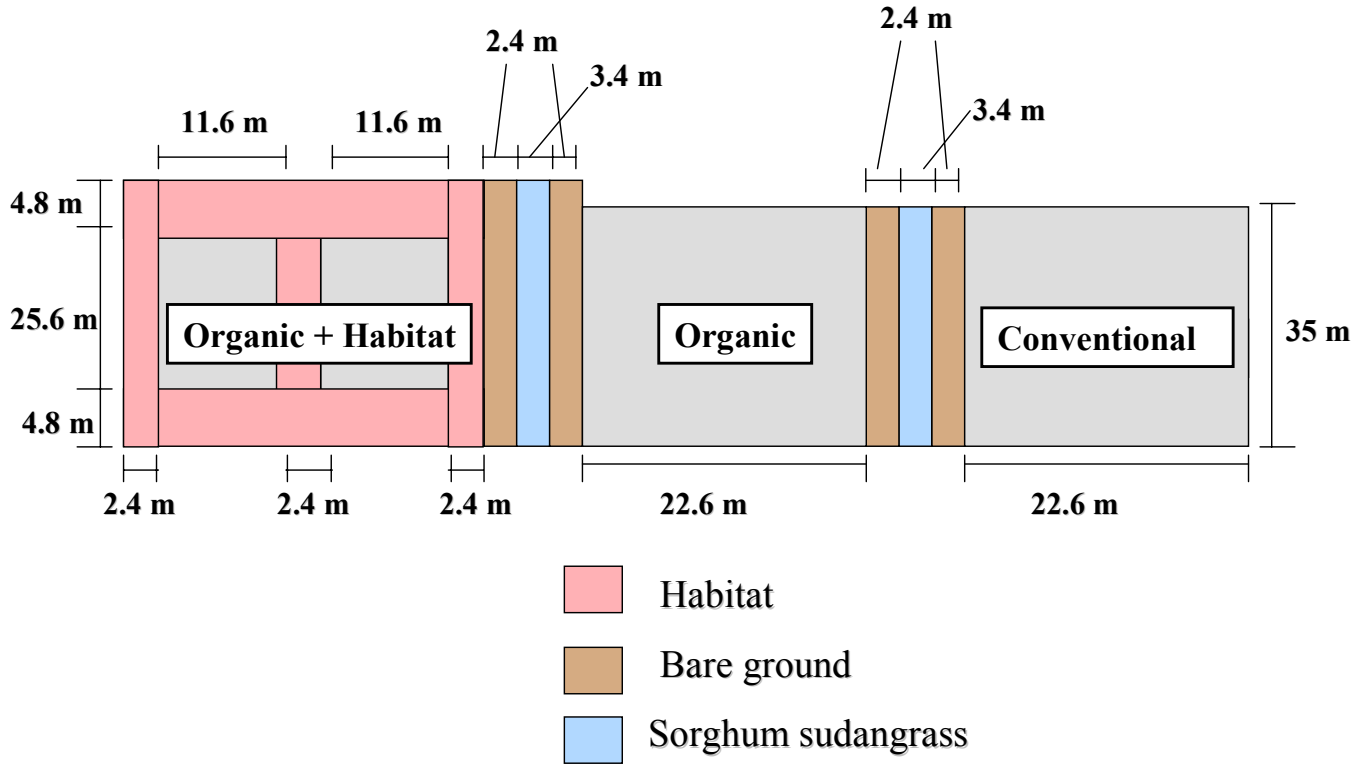
Drawing is not to scale.

Figure 3. Plot design for Replication 3 in 2004.



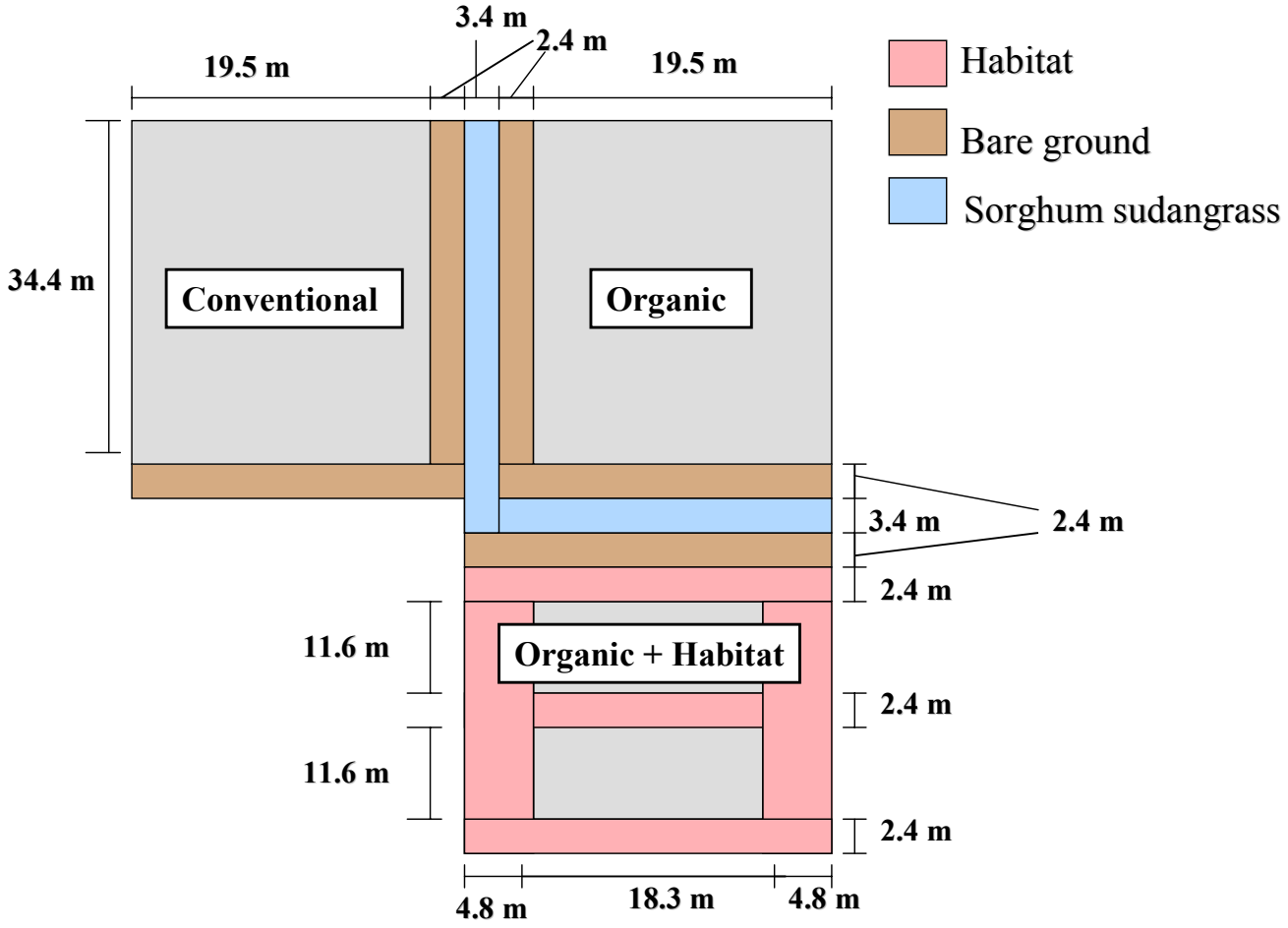
Drawing is not to scale.

Figure 4. Plot design for Replication 1 in 2005.



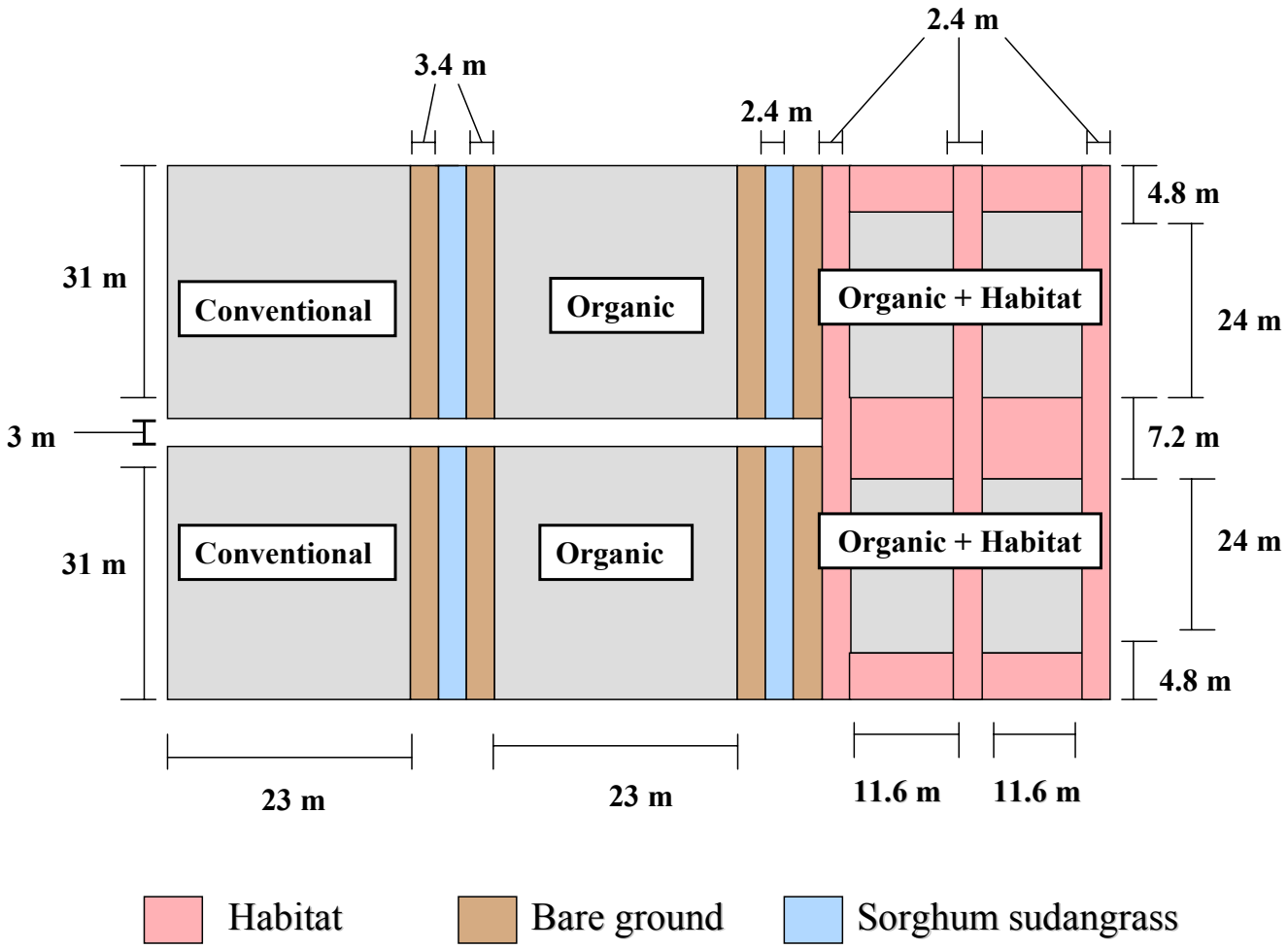
Drawing is not to scale.

Figure 5. Plot design for Replication 2 in 2005.



Drawing is not to scale.

Figure 6. Plot design for Replication 3 and 4 in 2005.



Drawing is not to scale.

Table 1. Mean (± SD) number of thrips per five plants in seedling organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

	2004		2005	
Treatment	**Immatures**	**Adults**	**Immatures**	**Adults**
Organic	18.20 ± 22.75 $_{A}$	14.46 ± 10.14 $_{A}$	7.13 ± 8.21 $_{A}$	10.17 ± 7.99 $_{A}$
Organic w/Habitat	17.13 ± 22.91 $_{A}$	12.50 ± 8.26 $_{A}$	6.47 ± 7.74 $_{A}$	7.30 ± 5.43 $_{A}$
Conventional	2.65 ± 4.75 $_{B}$	2.69 ± 2.74 $_{B}$	2.36 ± 3.82 $_{B}$	3.50 ± 3.52 $_{B}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.

Table 2. Mean (± SD) number of sweep-sampled arthropods with statistically significant population differences in organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

Treatment	Arthropod	Means ± SD [a]
Organic	*Orius spp.*	1.06 ± 1.25 $_{A}$
Organic w/Habitat		0.58 ± 0.64 $_{C}$
Conventional		0.88 ± 0.99 $_{B}$
Organic	*L. lineolaris*	0.53 ± 0.50 $_{A}$
Organic w/Habitat		0.54 ± 0.52 $_{A}$
Conventional		0.27 ± 0.42 $_{B}$
Organic	Lady beetles	1.79 ± 1.49 $_{A}$
Organic w/Habitat		1.52 ± 0.96 $_{B}$
Conventional		0.91 ± 0.77 $_{C}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
[a] Means are for sweep sampled arthropods, per 10 sweeps per row.

Table 3. Mean (± SD) number of sweep-sampled arthropods with statistically significant population differences in organic and conventional cotton in 2004 and 2005. Goldsboro, NC. Sampled weeks are separated into two time periods: before insecticide application and after insecticide application.

Treatment	Arthropod	Before insecticide application [a]	After insecticide application [a]
Organic	*L. lineolaris*	0.52 ± 0.49 $_{A}$	0.54 ± 0.53 $_{A}$
Organic w/Habitat		0.57 ± 0.51 $_{A}$	0.50 ± 0.54 $_{A}$
Conventional		0.39 ± 0.49 $_{A}$	0.07 ± 0.12 $_{B}$
Organic	Lady beetles	2.00 ± 1.73 $_{A}$	1.43 ± 0.91 $_{A}$
Organic w/Habitat		1.56 ± 1.05 $_{B}$	1.46 ± 0.81 $_{A}$
Conventional		1.31 ± 0.68 $_{B}$	0.24 ± 0.28 $_{B}$
Organic	*Geocoris spp.*	0.66 ± 0.54 $_{A}$	0.61 ± 0.57 $_{A}$
Organic w/Habitat		0.65 ± 0.53 $_{A}$	0.49 ± 0.41 $_{A}$
Conventional		0.64 ± 0.55 $_{A}$	0.10 ± 0.17 $_{B}$
Organic	Spiders	1.02 ± 0.72 $_{B}$	1.00 ± 0.80 $_{A}$
Organic w/Habitat		1.22 ± 0.55 $_{A}$	0.92 ± 0.70 $_{A}$
Conventional		1.39 ± 0.90 $_{A}$	0.46 ± 0.45 $_{B}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
[a] Means are for sweep sampled arthropods, per 10 sweeps per row.

Figure 7. Plot means of combined sweep-sampled *Geocoris spp.* adults and immatures per 10 sweeps in organic and conventional cotton in 2005. Goldsboro, NC.

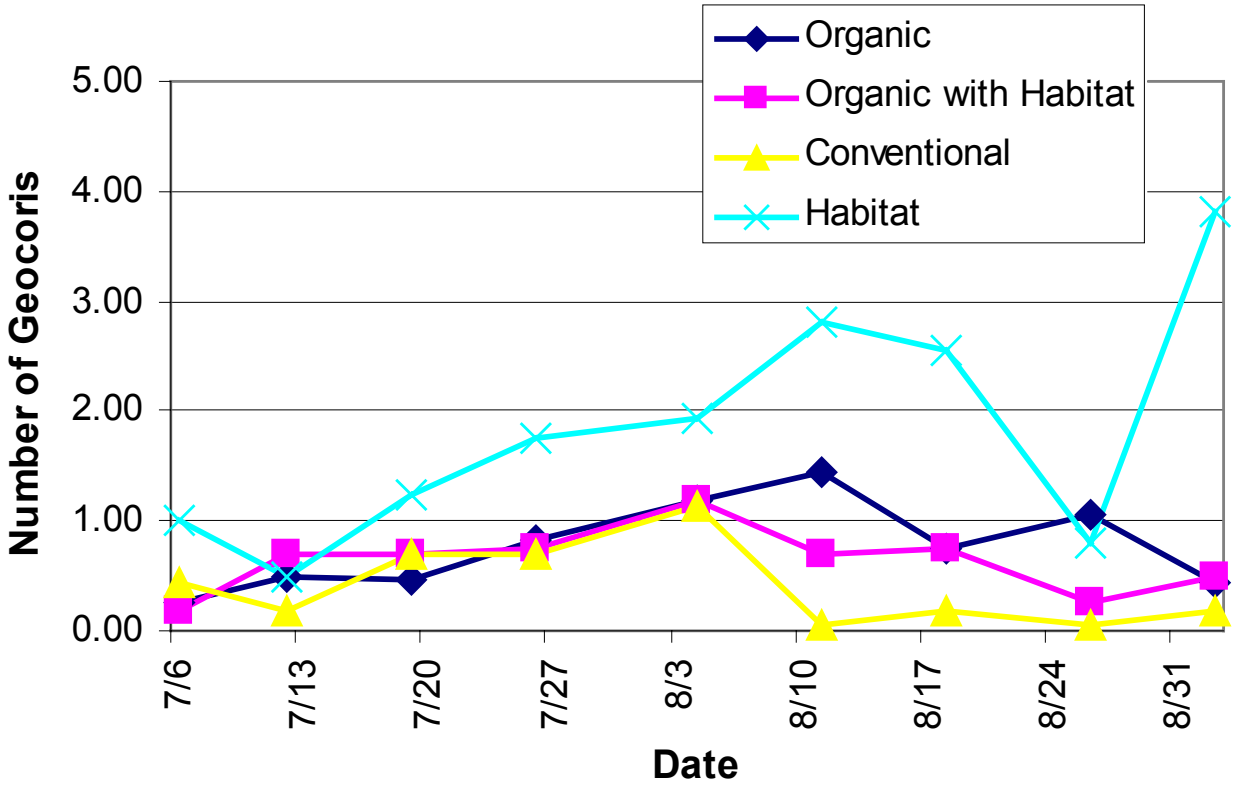


Figure 8. Plot means of combined sweep-sampled *Orius spp.* adults and immatures per 10 sweeps in organic and conventional cotton in 2005. Goldsboro, NC.

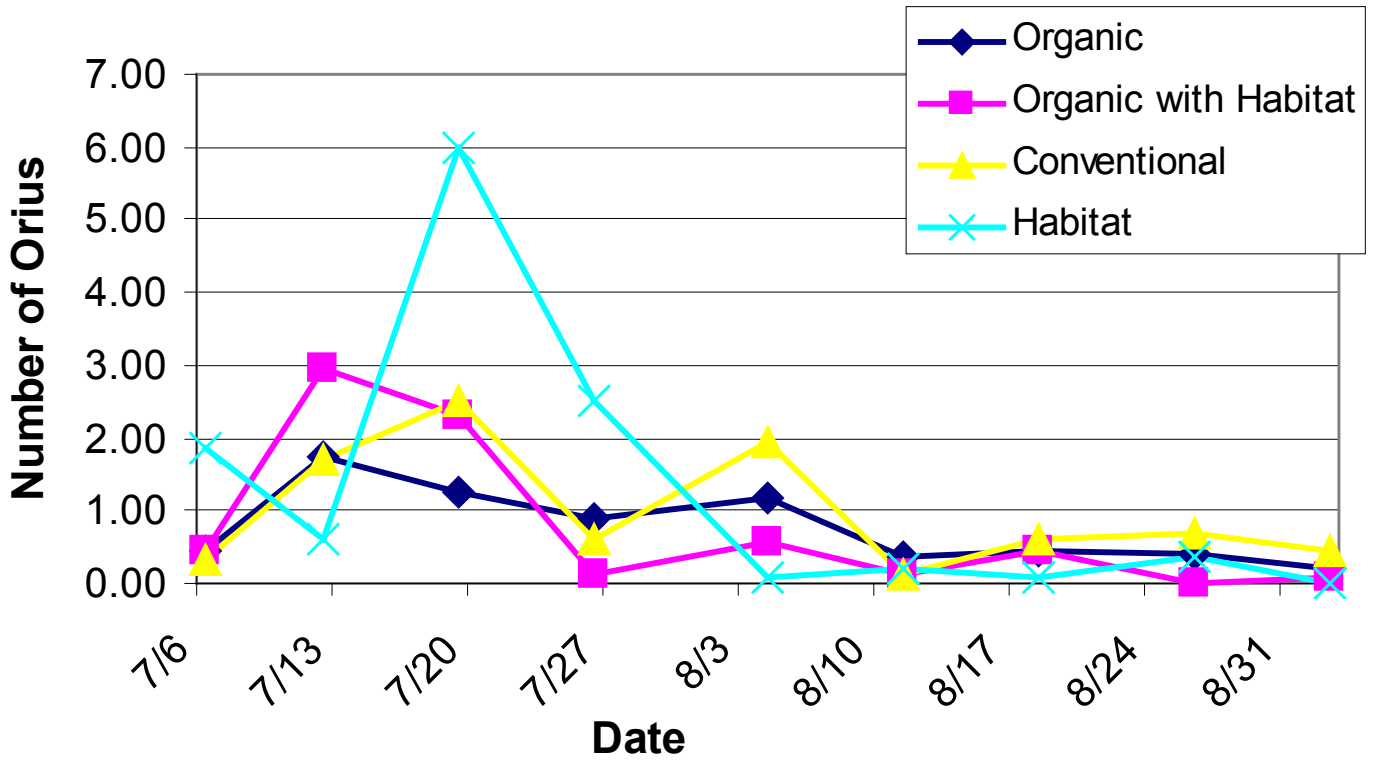


Figure 9. Plot means of spiders per 10 sweeps in organic and conventional cotton in 2005. Goldsboro, NC.

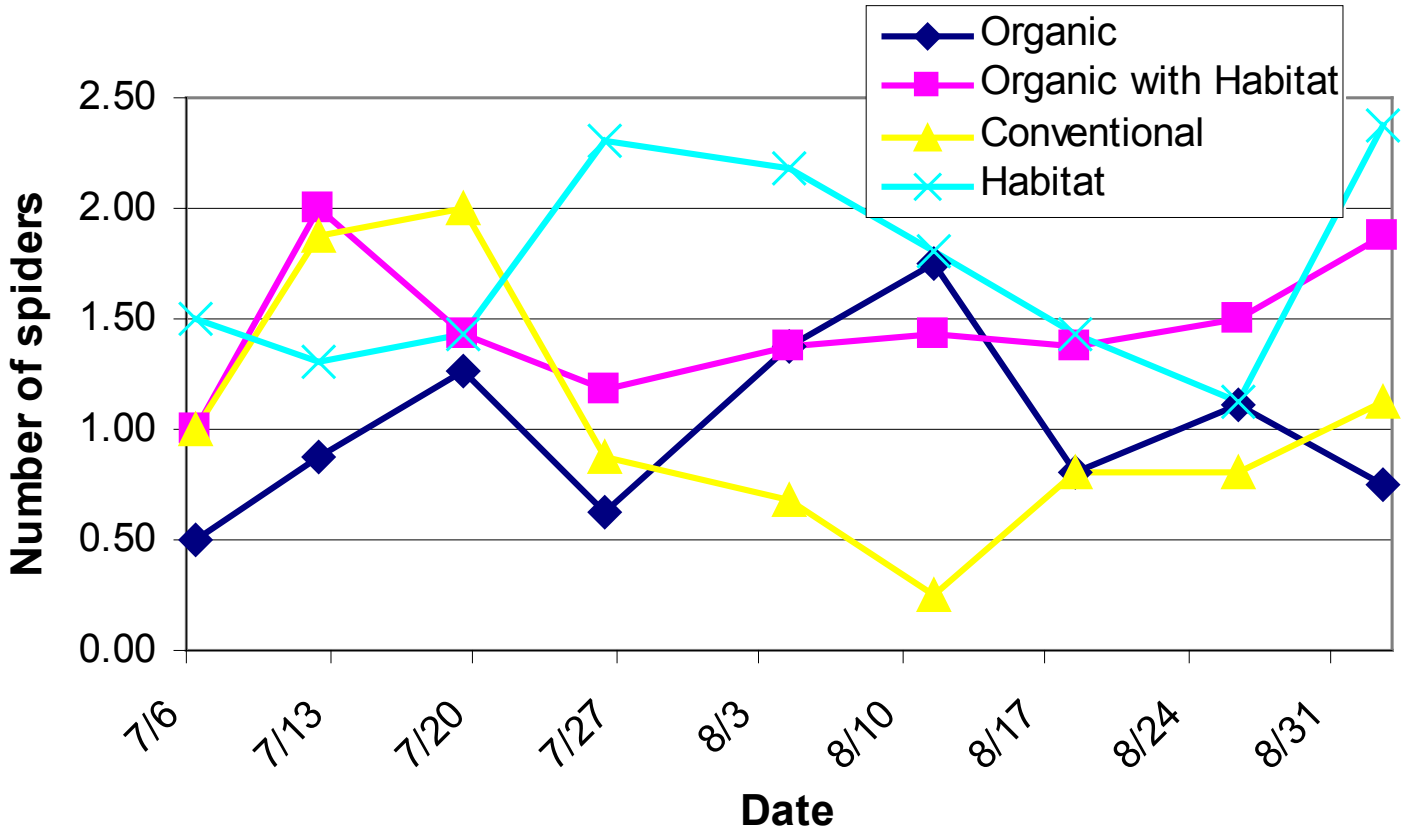


Table 4. Mean (± SD) number of sweep-sampled arthropods in organic and conventional cotton and habitat strips throughout the growing season in 2005. Goldsboro, NC.

Treatment	Arthropod	Means ± SD [a]
Organic	*Geocoris spp.*	0.73 ± 0.52 $_{A}$
Organic w/Habitat		0.61 ± 0.53 $_{AB}$
Conventional		0.40 ± 0.52 $_{B}$
Habitat strips		2.05 ± 1.57
Organic	*Orius spp.*	1.06 ± 1.47 $_{A}$
Organic w/Habitat		0.52 ± 0.72 $_{B}$
Conventional		0.99 ± 1.10 $_{A}$
Habitat strips		1.51 ± 2.41
Organic	Spiders	1.09 ± 0.73 $_{A}$
Organic w/Habitat		1.39 ± 0.58 $_{A}$
Conventional		1.05 ± 0.75 $_{A}$
Habitat strips		1.92 ± 0.74
Organic	Stink bugs	0.31 ± 0.51 $_{A}$
Organic w/Habitat		0.50 ± 0.71 $_{A}$
Conventional		0.16 ± 0.23 $_{A}$
Habitat strips		1.78 ± 3.22

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
Means for habitat strips were not analyzed in LSD tests.

[a] Means are for sweep sampled arthropods, per 10 sweeps per row.

Table 5. Mean (± SD) percent fate of naturally-oviposited *H. zea* eggs in organic and conventional cotton. Data were pooled from one sampling date in 2004 and two sampling dates in 2005. Goldsboro, NC.

Treatment	Parasitized	Preyed upon	Hatched
Organic	7.40 ± 10.9 $_{A}$	34.8 ± 21.9 $_{A}$	57.7 ± 26.2 $_{A}$
Organic w/Habitat	27.1 ± 32.5 $_{A}$	36.9 ± 23.6 $_{A}$	36.0 ± 20.7 $_{A}$
Conventional	11.6 ± 15.6 $_{A}$	29.6 ± 21.7 $_{A}$	58.7 ± 28.7 $_{A}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
Fate percentages are out of known fates. Un-recovered eggs were not included in this analysis.

Table 6. Mean (± SD) number of *H. zea* eggs, larvae, and *H. zea*-damaged bolls per sample of 10 terminals, squares, small and large bolls in organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

Treatment	*H. zea* eggs	*H. zea* larvae	Damaged bolls
Organic	0.88 ± 1.24 $_{AB}$	0.60 ± 0.65 $_{A}$	0.75 ± 0.83 $_{A}$
Organic w/Habitat	0.84 ± 1.10 $_{B}$	0.58 ± 0.64 $_{A}$	0.50 ± 0.64 $_{A}$
Conventional	1.10 ± 1.26 $_{A}$	0.04 ± 0.14 $_{B}$	0.00 ± 0.00 $_{B}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.

Table 7. Mean ± SD percent parasitism of *E. servus* egg masses and eggs in conventional and organic cotton in 2005. Goldsboro, NC.

Treatment	Percent egg masses parasitized	Percent eggs parasitized
Organic	29.7 ± 22.5 $_{A}$	22.0 ± 17.2 $_{A}$
Organic w/Habitat	25.1 ± 22.0 $_{A}$	19.3 ± 17.8 $_{A}$
Conventional	29.2 ± 27.0 $_{A}$	22.7 ± 23.6 $_{A}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.

Table 8. Mean (± SD) numbers of spiders, ground beetles, and tiger beetles per six pitfall traps in organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

Treatment	Arthropod	Means
Organic	Spiders	6.76 ± 9.88 A
Organic w/Habitat		6.48 ± 8.82 A
Conventional		4.95 ± 6.76 A
Organic	Ground beetles	1.19 ± 1.37 A
Organic w/Habitat		1.33 ± 1.39 A
Conventional		0.43 ± 0.60 A
Organic	Tiger beetles	6.48 ± 17.98 A
Organic w/Habitat		3.29 ± 7.06 A
Conventional		4.71 ± 11.73 A

Means of the same arthropod, in the same column, followed by the same letter are not significantly different based on LSD values, ≤ 0.05.

Table 9. Mean (± SD) weight of lint in kg of cotton from organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

Treatment	2004[a]	2005[a]
Organic	0.94 ± 0.24 $_{A}$	1.28 ± 0.74 $_{A}$
Organic w/Habitat	1.09 ± 0.33 $_{A}$	0.98 ± 0.44 $_{A}$
Conventional	1.30 ± 0.26 $_{A}$	2.36 ± 0.22 $_{B}$

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
[a] Kg of cotton from 15.2 m of row per plot.

APPENDIX

Appendix 1.1. Number of hectares of cotton and habitat per plot, per replication, in years 2004 and 2005. Goldsboro, NC.

2004		
Replication 1	**Hectares of Cotton**	**Hectares of Habitat**
Organic	0.080	
Conventional	0.080	
Organic w/ Habitat	0.071	0.048
Replication 2		
Organic	0.057	
Conventional	0.057	
Organic w/ Habitat	0.056	0.044
Replication 3		
Organic	0.082	
Conventional	0.082	
Organic w/ Habitat	0.049	0.044
2005		
Replication 1		
Organic	0.079	
Conventional	0.079	
Organic w/ Habitat	0.060	0.039
Replication 2		
Organic	0.067	
Conventional	0.067	
Organic w/ Habitat	0.040	0.034
Replication 3		
Organic	0.079	
Conventional	0.079	
Organic w/ Habitat	0.057	0.041
Replication 4		
Organic	0.079	
Conventional	0.079	
Organic w/ Habitat	0.057	0.041

Appendix 1.2. Mean (± SD) number of sweep-sampled arthropods in organic and conventional cotton in 2004 and 2005. Goldsboro, NC.

Treatment	Arthropod	Means ± SD [a]
Organic	*Geocoris spp.*	0.64 ± 0.55 A
Organic w/Habitat		0.59 ± 0.49 A
Conventional		0.43 ± 0.52 A
Organic	Lacewing larvae	0.12 ± 0.18 A
Organic w/Habitat		0.09 ± 0.15 A
Conventional		0.10 ± 0.19 A
Organic	Lady beetles	1.79 ± 1.49 A
Organic w/Habitat		1.52 ± 0.96 B
Conventional		0.91 ± 0.77 C
Organic	*L. lineolaris*	0.53 ± 0.50 A
Organic w/Habitat		0.54 ± 0.52 A
Conventional		0.27 ± 0.42 B
Organic	*Orius spp.*	1.06 ± 1.25 A
Organic w/Habitat		0.58 ± 0.64 C
Conventional		0.88 ± 0.99 B
Organic	Stink bugs	0.24 ± 0.44 A
Organic w/Habitat		0.33 ± 0.54 A
Conventional		0.15 ± 0.20 A
Organic	Spiders	1.01 ± 0.74 A
Organic w/Habitat		1.11 ± 0.62 A
Conventional		1.04 ± 0.88 A

Means in the same column followed by the same letter are not significantly different based on LSD values, ≤ 0.05.
[a] Means are for sweep sampled arthropods, per 10 sweeps per row.

Appendix 1.3. SAS input code for thrips sampling years 2004 and 2005

```
PROC IMPORT OUT= WORK.a
            DATAFILE= "F:\SAS form 2004_05\SAS form thrips 2004_05.xls"
            DBMS=EXCEL REPLACE;
     SHEET="Sheet1$";
     GETNAMES=YES;
RUN;


data b; set a;
if rep=. then delete;
sqimmature = sqrt(immature);
sqadult = sqrt(adult);
drop  F1 F11 F12;
proc print;
run;

proc glm; class year rep trt date;
model adult immature sqimmature sqadult = year rep(year)
trt|year rep*trt(year) date(year) date*trt(year) date*rep*trt(year);

test h=trt trt*year E=rep*trt(year) ;
test h=date(year) date*trt(year) E=date*rep*trt(year);
means  trt year*trt date*trt(year);
run;

proc sort data=b; by year date;
Title 'By year';
proc glm; class rep trt date; by year;
model sqimmature sqadult immature adult = rep trt rep*trt date date*trt
date*rep
date*trt*rep;
test h=trt e=rep*trt ;
test h=date*trt e=date*rep*trt ;
contrast 'conv vs 1,2 ' trt -1 -1 2/e=rep*trt;
means trt rep*trt;
means trt /lsd e=rep*trt;
run;
Title 'Immatures By Year and Date';
proc glm data=b; class rep trt ; by year date;
model sqimmature  immature = rep trt rep*trt ;
test h=trt e=rep*trt ;
contrast 'conv vs 1,2 ' trt -1 -1 2/e=rep*trt;
means trt rep*trt;
means trt /lsd e=rep*trt;
run;
```

Appendix 1.4. SAS input code for sweep sampling years 2004 and 2005.

```
PROC IMPORT OUT= WORK.A
            DATAFILE= "F:\SAS form 2005\SAS form cotton sweep 2005.xls"
            DBMS=EXCEL REPLACE;
     SHEET="Sheet1$";
     GETNAMES=YES;
RUN;

data b; set a; if week=. then delete;
Ge = GeA + GEI; Or=OrA+OrI;Na = NaA+NaI; Lb=LbA+LbI; Sb=SbA+SbI;
Pb=PbA+PbI;
*GS=Gsa + Gsl; *Sg=Sga +Sgl; *BS=BSa+ Bsl;
lace=la_;
drop F1 f32-f48 la_;
proc print data=b; run;

proc sort data=b; by rep trt week;
proc means noprint; by  rep trt week; id year;
output out=m mean=; var Ge Or Na Lb Sb Pb Spi Llf CeA CeI lace;
* Gs Sg BS ;
proc print data=m; run;

data m5; set m; year=2005; run;

data a; input Date $ Julian Week Year Rep Trt Site $GeA GeI OrA OrI NaA
NaI LbA LbI SbA SbI PbA PbI Spi GlA GlI BlA BLlar Llf Af Ca CeA CeI;
Ge = GeA + GEI;
Or=OrA+OrI;
Na = NaA+NaI;
Lb=LbA+LbI; Sb=SbA+SbI; Pb=PbA+PbI;
lace= BLlar + GlI;
cards;

proc print; run;

proc sort data=a; by rep trt week;
proc means noprint data=a; by rep trt week;
output out=m mean=; var Ge Or Na Lb SbPb Spi Llf Af Ca CeA CeI lace;
run;
data m4; set m; year=2004;
proc print data=m4; run;

data mm; set m4 m5;
sqOr =sqrt(Or); sqLb = sqrt(Lb);
sqPb = sqrt(pb); sqGe =sqrt(Ge);
sqSpi=sqrt(spi); drop af Ca Cea Cei;
proc print data=mm ; run;
options ps=53 ;

**********************************************************************
**;
data all; set mm; if trt=4 then delete;
if week=15 then delete;
proc print; run;
*** All Weeks ****************************;
```

```
proc glm data=all; class year rep trt week;
model Ge sqGe Or sqOr Lb      Sb    Pb    sqPb Spi sqspi
 lace  = year rep(year) trt|year
rep*trt(year)  week|trt|year rep*week(year) / ss3;
test h= trt year*trt e=rep*trt(year);
test h=week e=rep*week(year);
means trt week;
means trt /lsd e=rep*trt(year);
run;

proc sort data=all; by week;

title 'Weeks 7 to 11, without habitat';
proc glm data=all; class year rep trt week; where week<12 ;
model Ge sqGe Or sqOr Na Lb Sb Pb sqPb Spi sqspi lace
= year rep(year) trt|year rep*trt(year)  week|trt|year rep*week(year) /
ss3;
test h= trt year*trt e=rep*trt(year);
test h=week e=rep*week(year);
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt(year);
means trt week*year ;
run;

title 'Weeks 7 to 11, without habitat';
proc glm data=all; class year rep trt week; where week<12 ;
model Or sqOr Spi sqspi SqGe Ge Sb SqPb Pb Lb=year rep(year) trt|year
rep*trt(year) week|trt|year rep*week(year)/ ss3;
test h= trt year*trt e=rep*trt(year);
test h=week e=rep*week(year);
test h=week e=rep*week(year);
means trt;
means trt/lsd  e=rep*trt(year);
run;

title 'weeks 12 to 15, without habitat ';
proc glm data=all; class year rep trt week; where 11<week<15 ;
model Ge sqGe Or sqOr   Lb    Sb    sqPb Spi sqspi  = year rep(year)
trt|year rep*trt(year)  week|trt|year rep*week(year) / ss3;
test h= trt year*trt e=rep*trt(year);
test h=week e=rep*week(year);
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt(year);
means trt week*year ;
run;
title 'weeks 12 to 15, LSD for Pb and Ge ';
proc glm data=all; class year rep trt week; where 11<week<15 ;
model Ge sqGe sqOr Or Lb Pb sqPb Sb SqSpi Spi  = year rep(year)
trt|year rep*trt(year)  week|trt|year rep*week(year) / ss3;
test h= trt year*trt e=rep*trt(year);
test h=week e=rep*week(year);
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt(year);
means trt;
means trt/ lsd e=rep*trt(year);
run;
```

Appendix 1.5. SAS Input code for sweep sampling year 2005 only.

```
PROC IMPORT OUT= WORK.A
            DATAFILE= "F:\SAS form 2005\SAS form cotton sweep 2005.xls"
            DBMS=EXCEL REPLACE;
     SHEET="Sheet1$";
     GETNAMES=YES; RUN;

data b; set a;
Ge=GeA+GEI; Or=OrA+OrI; Na=NaA+NaI; Lb=LbA+LbI; Sb=SbA+SbI; Pb=PbA+PbI;
GS=Gsa+Gsl; Sg=Sga+Sgl; BS=BSa+ Bsl; la=la_;
drop f32-f55 la_;
proc print; run;

proc sort data=b; by rep trt week;
proc means noprint; by   rep trt week;
output out=m mean=; var Ge Or Na Lb Sb Pb Spi Llf CeA CeI la Gs Sg BS;
proc print data=m; run;

data m; set m;
sqOr =sqrt(Or); sqLb=sqrt(Lb; sqPb=sqrt(pb; sqGe=sqrt(Ge;
sqGS=sqrt(gs); sqspi = sqrt(spi);
proc print data=m (obs=30); run;
options ps=53 ;
proc glm data=m; class rep trt week;
model Ge sqGe Or sqOr Na Lb Sb Pb Spi CeA CeI la Gs sqGs Sg BS = rep
trt rep*trt week rep*week trt*week/ ss3;
test h=trt e=rep*trt; test h=week e=rep*week;
means trt*week; run;

title 'All Weeks, without habitat';
proc glm data=m; class rep trt week; where trt ne 4;
model Ge sqGe Or sqOr Na Lb Sb Pb Spi CeA CeI la Gs sqGs Sg BS= rep trt
rep*trt week rep*week trt*week/ ss3;
test h=trt e=rep*trt; test h=week e=rep*week;
means trt week;
means trt / lsd e=rep*trt; run;
proc sort data=m; by week;

title 'Weeks 7 to 11, without habitat';
proc glm data=m; class rep trt week; where week<12 and trt ne 4;
model Ge sqGe Or sqOr Na Lb Sb Pb sqpb Spi sqspi la Gs sqGs Sg BS = rep
trt rep*trt week rep*week trt*week /ss3;
test h=rep trt e=rep*trt;
test h=week e=rep*week;
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt;
means trt week ;
run;

title 'weeks 12 to 15, without habitat ';
proc glm data=m; class rep trt week; where 11<week<15 and trt ne 4;
model Ge sqGe Or sqOr Lb Sb Pb sqpb Spi sqspi la Gs sqgs BS  = rep trt
rep*trt week rep*week trt*week/ss3;
test h=rep trt e=rep*trt;
test h=week e=rep*week;
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt;
```

```
means trt|week ;
*means trt /lsd e=rep*trt;
lsmeans week*trt /noprint out=wt2;
run;
proc sort data=m; by week;
title 'weeks 12 to 15, without habitat, BY WEEK ';
proc glm data=m; By Week; class rep trt ; 11<week<15 and trt ne 4;
model Ge sqGe Or sqOr Spi= rep trt /ss3;
contrast '1 and 2 versus 3' trt -1 -1 2 ;
means trt /lsd ;
run;

title 'Weeks 7 to 11, with habitat';
proc glm data=m; class rep trt week; where week<12 ;
model Ge sqGe Or sqOr Na Lb Sb Pb sqpb Spi la Gs sqGs Sg BS= rep trt
rep*trt week rep*week trt*week /ss3;
test h=rep trt e=rep*trt;
test h=week e=rep*week;
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt;
means trt /lsd e=rep*trt;
lsmeans week*trt /noprint out=wt1;
run;
*** Trt*week interactn for sqpb, Lb, Sb, Bs ***;
title 'weeks 7-11, With Habitat, BY WEEK';
proc sort data=m; by week;
proc glm data=m; by week; class rep trt ; where week<12 ;
model Lb Sb Pb sqpb BS = rep trt  /ss3;
contrast '1 and 2 versus 3' trt -1 -1 2;
means trt /lsd ;
run;

title 'weeks 12 to 15, with habitat ';
proc glm data=m; class rep trt week; where week>11 ;
model Ge sqGe Or sqOr Lb Sb Pb sqpb Spi la Gs sqgs BS = rep trt rep*trt
week rep*week trt*week/ss3;
test h=rep trt e=rep*trt;
test h=week e=rep*week;
contrast '1 and 2 versus 3' trt -1 -1 2 /e=rep*trt;
means trt|week;
means trt /lsd e=rep*trt;
lsmeans week*trt /noprint out=wt2;
run;
title 'weeks 12 to 15, with habitat, BY WEEK ';
proc glm data=m; class rep trt week; where week>11 ; by week;
model Or sqOr Sb Spi Gs sqgs BS  = rep trt /ss3;
contrast '1 and 2 versus 3' trt -1 -1 2 ;
means trt /lsd ;
run;

proc sort data=m; by week rep trt;
data t2; set m; where trt =2; drop trt;
data t4; set m; where trt=4;
GeH=Ge; OrH =Or; LbH =LB; SbH =Sb; PbH=Pb; SpiH=Spi;
GsH=Gs; BsH=Bs; drop Ge sqGe Or sqOr Lb Sb Pb sqpb Spi la Gs sqgs BS
trt;
```

Appendix 1.6. SAS Input code for bollworm egg fate years 2004 and 2005.

```
data a; input Date $ Julian Week Year Rep  Trt Site $
eggs para pred hatch unknown;
known = eggs -unknown;
cards;
(Paste in 2004 data)
;
proc sort; by date;
proc print data=a; run;
data b; set a;
pctpara = 100*para/known;
proc glm data=b; by date; class rep trt;
model pctpara = rep trt;
means trt;
run;

proc freq; tables para*trt; by date;
run;
*** All dates **********************************;
proc genmod; class date rep trt;
model para/known = date  trt date*trt /d=bin type3 pscale;
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;
proc genmod; class date rep trt;
model pred/known = date  trt date*trt /d=bin type3 pscale;
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;
proc genmod; class date rep trt;
model hatch/known = date  trt date*trt /d=bin type3 pscale;
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;

*** delete rep *****;
proc genmod data=a; class  rep trt; by date;
model para/known =  trt /d=bin type3 pscale;
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;

proc genmod; class rep trt; by date;
model hatch/known =  trt /d=bin type3 pscale;
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;

proc genmod; class rep trt; by date;
model pred/known =  trt /d=bin type3 pscale;
```

```
contrast 'trt 1 vs 2' trt 1 -1 0;
contrast 'trt 1 vs 3' trt 1 0 -1;
contrast 'trt 2 vs 3' trt  0 1 -1;
run;

data b; input Date $    Julian  Week    Year    Rep     Trt     Site $
eggs
do fate = 'para','pred', 'hatch','unknown';
input count @;
output; end;
cards;
(Paste in 2005 data)
;
data c; set b;
proc print; run;
proc sort; by date;
proc freq; tables date*trt*fate/chisq cmh exact;
weight count;
run;

proc freq; tables trt*fate/;
weight count; run;
```

Appendix 1.7. SAS input code for bollworm monitoring (egg, larvae, damage) years 2004 and 2005.

```
data a; input Date $ Julian Week Year Rep Trt Site $ TE TL TD SE SL SD
SBE SBL SBD LBE LBL LBD;
toteggs = Te+SE+SBE+LBE;
totlarvae = TL+SL+SBL+LBL;
bolldam = SBD+LBD;
cards;
(Paste in 2004 and 2005 data)
;
proc print;
run;
data b; set a;

proc sort data=b; by year date rep trt site;
proc means noprint;
by year date rep trt ;
output out=m mean = ;
var toteggs totlarvae  bolldam TE TL TD SE SL SD SBE SBL SBD LBE LBL
LBD;
data m; set m;
sqtoteggs= sqrt(toteggs);
sqtotlarv =sqrt(totlarvae);
sqbolldam = sqrt(bolldam);
proc print data=m; run;

proc glm data=m; class year rep trt date; where date ne '8_30';
model toteggs sqtoteggs totlarvae sqtotlarv bolldam
sqbolldam = year rep(year) trt trt*year rep*trt(year)
date(year) date*rep(year) date*trt(year) ;
test h=trt trt*year e=rep*trt(year) ;
output out=p p=pte psqte r=rte rsqte;
means trt trt*year ;
means trt /lsd e=rep*trt(year); run;

proc plot data=p; plot rte * pte rsqte*psqte; run;
*** Omit trt 3 for boll damage ;
proc glm data=m; class year rep trt date; where date ne '8_30' and trt
ne 3;
model  bolldam    sqbolldam   = year rep(year) trt trt*year
rep*trt(year)
date(year) date*rep(year) date*trt(year) ;
test h=trt trt*year e=rep*trt(year) ;
output out=p p=pte psqte r=rte rsqte;
means trt trt*year ;
means trt /lsd e=rep*trt(year);
run;
```

Appendix 1.8. SAS Input code for stink bug egg parasitism year 2005.

```
data a; input Date $ Julian Week Year Rep Trt Sample $ viablerec
black;
cards;
(Paste in 2005 data)
;
proc sort data =a; by date rep trt;
proc means data=a noprint; by date rep trt;
output out=m sum = totviable totblack;
var viablerec black;
data p; set m;
pctblack = 100*totblack/totviable;
proc print data= p;
run;

proc glm data=p; class rep trt date;
model pctblack = rep | trt date date*rep date*trt;
means date*TRT;
MEANS TRT;
RUN;

DATA B; SET A;
IF BLACK>0 THEN PARASIT =1;
IF BLACK=0 THEN PARASIT =0;
proc means data=B noprint; by date rep trt;
output out=C MEAN = PROPPARASIT;
var PARASIT;

DATA C; SET C; ARPARA = ARSIN(SQRT(PROPPARASIT));
PROC PRINT DATA=C; RUN;
proc glm data=C; class rep trt date;
model PROPPARASIT ARPARA = rep | trt date date*rep date*trt;
means date*TRT;
MEANS TRT;
RUN;
```

Appendix 1.9. SAS input code for hemipteran boll damage year 2005.

```
PROC IMPORT OUT= WORK.a
            DATAFILE= "E:\SAS form 2004_05\bolldamage0405.xls"
            DBMS=EXCEL REPLACE;
     SHEET="Sheet1$";
     GETNAMES=YES;
RUN;

proc print; run;

data b; set a;
if rep=. then delete;
if category=. then delete;
if category = 0 then damage=0; else damage=1;
if category=1 then extdamage=1; else extdamage=0;
if category=2 then intdamage=1; else intdamage=0;
proc print data=a; run;

proc sort data=b; by year date rep trt site;
proc means noprint;
by year date rep trt site; id week;
output out=m mean = propdamage  propintdam;
var damage intdamage;
proc print data=m; run;

proc glm data=m; class year rep trt date;
model propintdam = year rep(year)
trt trt*year rep*trt(year) date(year) date*rep(year) date*trt(year)
date*trt*rep(year);
test h=trt e=rep*trt(year) ;
test h=date(year) e=rep*date(year);
test h=date*trt(year) e=rep*trt*date(year);
means trt date*trt(year);
means trt /lsd  e=rep*trt(year) lines ; run;

proc sort data=m; by year week trt;
proc means noprint; by year week trt;
output out= m2 mean=;
var propdamage propintdam;
proc print data=m2;
proc gplot; by year;
plot  propintdam*week = trt;
run;

*** By Date ****;
proc sort data=m; by year date;
title 'By Date';
proc glm data=m; class rep trt; by year date;
model propintdam = rep trt rep*trt ;
test h=trt e=rep*trt ;
contrast 'conv vs 1,2 ' trt -1 -1 2/e=rep*trt;
means trt rep*trt;
means trt /lsd e=rep*trt lines;
run;
```

Appendix 1.10. SAS input code for pitfall traps years 2004 and 2005.

```
data a; input
Date $ Julian Week Year Rep Trt Site $ SPIDER CARABID TIGER;
cards;
(Paste in 2004 and 2005 data)
;
proc print; run;

data b; set a;
sqspider=sqrt(spider); sqcarabid = sqrt(carabid);
sqtiger = sqrt(tiger);

proc glm; class year rep trt week ;
model SPIDER CARABID TIGER = year rep(year) trt year*trt trt*rep(year)
week(year) trt*week(year) ;
test h=year e=rep(year);
test h= trt trt*year e=Rep*trt(year);

means trt year*trt;
run;

proc glm data=b; class year rep trt week ;
model sqSPIDER    sqCARABID   sqTIGER = year rep(year) trt year*trt
trt*rep(year)week(year) trt*week(year) ;
test h=year e=rep(year);
test h= trt trt*year e=Rep*trt(year);
means year*trt;
run;
```

Appendix 1.11. SAS input code for lint yield years 2004 and 2005.

```
data a;
input
Date $ Julian Week Year Rep Trt Plot $Lintweight;
cards;
```

Date	Julian	Week	Year	Rep	Trt	Plot #	Lintweight
9_24	267	19	2004	1	1	DA-20	0.97
9_24	267	19	2004	1	1	DA-21	0.91
9_24	267	19	2004	1	2	DB-20	0.82
9_24	267	19	2004	1	2	DB-21	0.79
9_24	267	19	2004	1	3	DC-20	1.37
9_24	267	19	2004	1	3	DC-21	1.29
9_24	267	19	2004	2	1	EA-20	1.08
9_24	267	19	2004	2	1	EA-21	1.30
9_24	267	19	2004	2	2	EB-20	1.53
9_24	267	19	2004	2	2	EB-21	1.38
9_24	267	19	2004	2	3	EC-20	1.36
9_24	267	19	2004	2	3	EC-21	1.28
10_1	274	20	2004	3	1	FA-20	0.72
10_1	274	20	2004	3	1	FA-21	0.65
10_1	274	20	2004	3	2	FB-20	0.80
10_1	274	20	2004	3	2	FB-21	1.21
10_1	274	20	2004	3	3	FC-20	1.64
10_1	274	20	2004	3	3	FC-21	0.84
10_31	304	24	2005	1	2	101	1.49
10_31	304	24	2005	1	1	102	2.16
10_31	304	24	2005	1	3	103	2.53
10_31	304	24	2005	2	3	201	2.37
10_31	304	24	2005	2	1	202	1.62
10_31	304	24	2005	2	2	203	1.19
10_31	304	24	2005	3	3	301	2.04
10_31	304	24	2005	3	1	302	0.66
10_31	304	24	2005	3	2	303	0.53
10_31	304	24	2005	4	3	401	2.48
10_31	304	24	2005	4	1	402	0.66
10_31	304	24	2005	4	2	403	0.72

```
;

proc print;

proc glm; class year rep trt;
model lintweight = year rep(year) trt year*trt trt*rep(year);
test h=  trt trt*year e=Rep*trt(year);
contrast 'conv vs 1,2 ' trt -1 -1 2/e=Rep*trt(year);
means year*trt;
lsmeans year*trt / e=Rep*trt(year) pdiff;
run;
```