Influence of Commercially Available Wildflower Mixes on Beneficial Arthropod Abundance and Predation in Turfgrass

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ABSTRACT Conservation and augmentation of indigenous natural enemies are promising strategies for biologically based pest management in outdoor urban environments. This research sought to determine whether the addition of wildflower plantings would enhance the occurrence, abundance and impact of beneficial arthropods in the landscape, and to determine the potential compatibility of pest-resistant turfgrass and natural control of Japanese beetle, *Popillia japonica* Newman, and fall armyworm, *Spodoptera frugiperda* (J.E. Smith). A bermudagrass cultivar (susceptible to fall armyworm), a zoysiagrass cultivar (resistant to fall armyworm), and two different commercially available wildflower mixes all harbored a diverse array of beneficial arthropods in both large and small plot evaluations. A wildflower mix containing 15 species of flowers provided significant, season-long increases in foliar-dwelling spiders and bigeyed bugs during 1-yr of a 2-yr study in large (1,512 m^2) plots. Ground-dwelling spiders were more abundant in bermudagrass turfgrass than in wildflowers both years, whereas ants were not significantly affected by cover type. Each wildflower mix evaluated in a separate 2-yr small plot study increased the abundance of some, but not all beneficial arthropod taxa sampled. This increased abundance was only occasionally also observed in adjacent turfgrass areas. However, fall armyworm eggs and larvae, and Japanese beetle eggs were consistently and heavily preyed upon in small plots regardless of turfgrass species in the plot or surrounding border of flowers or mulch. Most beneficial taxa, even *Geocoris uliginosus*, which was more common in turfgrass, were represented in flowers, suggesting that these floral plantings may be useful in providing refugia for beneficials when insecticide applications are required to suppress turfgrass pests.

KEY WORDS turfgrass, ornamentals, wildflowers, predators, parasitoids, conservation biological control

BENEFICIAL ARTHROPODS ARE well represented in managed turfgrass habitats (e.g., Cockfield and Potter 1983, 1985; Braman and Pendley 1993; Heng-Moss et al. 1998; Braman et al. 2000b). Predators, including ground beetles (Carabidae), rove beetles (Staphylinidae), spiders (Araneae), bigeyed bugs (*Geocoris* spp.), and ants (Formicidae), are particularly well documented. Hymenopterous parasitoids have also been surveyed, demonstrating the occurrence of the families Mymaridae, Trichogrammatidae, Encyrtidae, and Scelionidae in buffalograss (Heng-Moss et al. 1998). Undoubtedly, indigenous parasitoids and predators assist in limiting or preventing outbreaks of potential pests in turfgrass (Potter 1993).

Short-term, but significant, reductions of certain taxa have been documented in response to organophosphate or carbamate insecticide applications such as those made during regular lawn care or landscape management programs have effected (Cockfield and Potter 1984, Braman and Pendley 1993, Terry et al. 1993) but relatively little impact occurred when a chloronicotinyl or an ecdysteroid agonist were applied (Kunkel et al. 1999). Insecticide-induced suppression of predator populations reduces predation on such common turfgrass pests as Japanese beetle, *Popillia japonica* Newman, fall armyworm, *Spodoptera frugiperda* (J.E. Smith), and sod webworms (Pyralidae) (Cockfield and Potter 1984, Terry et al. 1993). Our hypothesis is that a diverse, adjacent, nonturf refugia would support beneficial arthropods and speed the recolonization process when natural controls in turf are disrupted, thereby reducing the length of disruption by application of turf insecticides.

Structurally complex landscapes offer greater diversity that may attract and retain parasitoids and especially generalist predators that can enable better regulation of ornamental plant pests (Shrewsbury and Raupp 2000, Tooker and Hanks 2000). Marking studies demonstrated that lady beetles (Coccinellidae), lacewings (Chrysopidae, Hemerobiidae), syrphid flies (Syrphidae), and parasitic wasps (*Hypoaster* sp., *Trichogramma* sp., and *Macrocentrus* sp.) fed on nectar or

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pollen provided by borders of flowering plants around farms, with many insects subsequently moving at least 76 m into adjacent field crops (Freeman-Long et al. 1998). The relative attractiveness of individual landscape flowering plants and potential insectary plants to beneficial insects has been explored (e.g., Al-Doghairi and Cranshaw 1999, Colley and Luna 2000) and results suggest that the addition of flowering plants in landscape settings may enhance natural pest control. The objective of this study was to evaluate the potential for commercially available wildflower mixes, including those advertised as offering pest control benefits, to increase abundance of beneficial insects in the landscape and enhance pest suppression in adjacent turfgrasses.

Methods and Materials

Effects of Cover Type on Beneficial Arthropod Occurrence: Large Plot Study. During 1992, a 2.0-ha field in Pike County, GA, was divided into areas that were 55 by 27.5 m with 3 m separating each area. Each area was then divided in half so that plots (27.5 by 27.5 m) could be planted with one of three combinations of plant material: common Bermuda grass, *Cynodon dactylon* (L.) Person, adjacent to a 'Smith Mix' customized wildflower mix recommended by University of Georgia Horticulture Extension specialists for optimum southeastern urban color (Corley 1992), or bermudagrass adjacent to bermudagrass or wildflowers-adjacent to wildflowers. Plots were arranged in a randomized complete block design with six replications. Wildflowers bloomed continuously from spring to fall. Species contained in the mix were *Achillea millefolium* L., *Centaurea cyanus* L., *Cassia fasiculata* Michaux, *Consalida ambigua* (L.) P.W. Ball & Heywood, *Coreopsis lanceolata* L., *Coreopsis tinctoria* Nuttall, *Eschscholzia californica* Chamisso, *Gaillardia aristata* Pursh, *Gaillardia pulchella* Fougeroux de Bondaroy, *Monarda citriodora* Cervantes ex Lagaska y Seguera., *Nemophila menziesii* Hook & Walker-Arnott, *Oenothera speciosa* Nuttall, *Papaver rhoeas* L., *Rudbeckia hirta* L., and *Salvia farinacea* Bentham.

Arthropod occurrence and abundance were compared among bermudagrass plots adjacent to bermudagrass, bermudagrass adjacent to wildflowers, and wildflowers alone. Bermudagrass was planted in June 1992 and supplied with overhead irrigation until well established. Wildflowers were seeded in November 1992 and mulched with wheat straw. Borders between plots were maintained vegetation free with spot applications of 41% glyphosate applied at 4.7 liter/ha. No additional herbicides, insecticides, or fungicides were applied. Plots were fertilized with ammonium nitrate at 37 kg/ha in August 1992 and 1993. Wildflower plots were reseeded in November 1993. Turfgrass was mowed weekly at 5 cm.

Carabidae, Formicidae, and ground dwelling Araneae were sampled using 120 ml (6 cm diameter by 7 cm high) pitfall traps (Morrill 1975). Six pitfall traps per plot spaced at 3-m intervals in the center of each plot were maintained as described in Braman and Pendley (1993). The contents were collected weekly and the six traps per plot were combined for each of the six plots per treatment type. Sweep net samples using a standard beating net (40 per plot) were collected along the diagonal weekly in each plot during 1993 and 1994. Samples were returned to the laboratory where foliar dwelling spiders and bigeyed bugs (Lygaeidae) were extracted and counted. Pitfall sampling was conducted during 1993 from 22 March through 16 December. Samples during 1994 were collected from 13 January through 15 December. Sweep samples were collected from 16 June through 9 December 1993 and from 4 May through 19 October 1994.

Effects of Flower Mix and Turf Type on Beneficial Arthropod Occurrence in Small Plots. Experimental plots were established during 1997 at the Georgia Station Research and Education Garden in Spalding County, GA, in an area of tall fescue (*Festuca arundinacea* Schreber). Each plot contained 122 m^2 turf area surrounded on three sides by a 3-m border of either 'Border Patrol' pest control wildflower mix (Clyde Robbins Seed, Castro Valley, CA), or a Smith Mix wildflower mix for optimum southeastern color as described previously, or bare cultivated soil with wheat straw mulch. Border Patrol wildflower mix contained the flowers *Achillea millefolium* L., *Ammi majus* L., *Angelica atropurpurea* L., *Fagopyrum esculentum* Moench, *Helichrysum bracteatum* (Ventenant) Andrews, *Iberis* sp., *Nasturtium* sp., *Nemophila menziesii* Hook & Arnott, *Oenothera biennis* L., *Rudbeckia hirta* L. Turfgrass interiors were equally divided between 'Tifway' bermudagrass (*Cynodon dactylon x C. transvaalensis*) and 'Emerald ' zoysiagrass (*Zoysia japonica x Zoysia tenuifolia*), which had previously demonstrated potential for resistance or tolerance to fall armyworm, twolined spittlebug [*Prosapia bicincta* (Say)] and tawny mole cricket (*Scapteriscus vicinus* Scudder) (Braman et al. 1994, 2000a, 2000b). Three replications of the three treatment blocks (turf surrounded by mulch alone, turf surrounded by Border Patrol flower mix, or turf surrounded by 'Smith' flower mix) were established with a minimum of 30.5 m between plots to minimize potential movement of arthropods between plots.

Arthropod taxa were sampled in the turfgrass and in the surrounding border using pitfall traps (Morrill 1975) and a Vortis vacuum sampler (Burkard Manufacturing County, Herferdshire, England) during 1998 and 1999. Nine, 120-ml pitfall traps per plot were emptied weekly from the beginning of June to the end of August. Ten vacuum samples of 10-s duration each were collected along a diagonal on the same dates that pitfall traps were emptied. Specimens were identified using appropriate keys and reference collections maintained in the museum at the Griffin campus and the Athens campus of the University of Georgia. Voucher specimens are retained in the collection at the Griffin campus.

Effects of Surrounding Flower Mix or Mulch on Predation on Fall Armyworm Eggs and Larvae and on japanese Beetle Eggs in Turf in Small Plots. During July and August of 1998 and 1999, turf in the interior of each plot was artificially infested with fall armyworm eggs and larvae, and with Japanese beetle eggs during 1999. Nine "exposure periods" during the 2 yr were monitored to evaluate the potential differences in predation in turfgrass among plots surrounded with different cover types.

Fall Armyworm Eggs. On 7 July 1998 and 20 July 1999, fall armyworm eggs deposited on paper towels were counted and transferred to the turf plots. Paper around the egg masses was trimmed so that only a small triangle of paper remained around each egg mass. Each egg mass on paper was retained next to the thatch surface with an insect pin. Eggs on the paper towel triangles were allowed to remain in the turf for 23 h. Following the exposure period, paper towel triangles anchored with insect pins were relocated and returned to the laboratory to count the eggs. On 28 July 1998, fall armyworm eggs were exposed in each field plot as described, except that the exposure period was only 2 h from 1300 1500 hours. Weather conditions were sunny and warm (29.4°C) following a morning rain.

Fall Armyworm Larvae. Fifty neonate larvae were released into the center of each turf plot on 5 August 1998. Vacuum samples were taken 24 h later. Fifteen second-instar fall armyworms were introduced within a 15-cm-diameter polyvinyl chloride (PVC) cage inserted 5 cm into the soil in each turf plot on 3 August 1998. Surviving larvae were collected on 7 August by thoroughly vacuuming the area enclosed using the Vortis vacuum sampler. During 1999, 1,900 neonate larvae were released into the center of each turf plot on 30 June. Samples were collected from each plot 24 h later by vacuuming the turf was in ever-widening circles to a diameter of 3 m. Larvae (820 per plot) were also released on 20 July for a 24-h exposure period.

Japanese Beetle Eggs. Japanese beetle eggs were obtained by collecting adult females in pheromone traps, placing them in transparent plastic rearing containers (14 cm high by 38 cm l by 24 cm wide) with topsoil and crape myrtle (*Lagerstroemia* spp.) leaves and allowing the beetles to oviposit. Eggs were placed in 5.5-cm-diameter plastic petri dishes lined with moistened filter paper. Dishes containing eggs were then placed without lids beneath the turfgrass surface in the field plots by opening a wedge 5 cm deep using an adz (a cutting tool with a thin arched blade set at right angles to the handle). Dishes containing eggs were carefully inserted into the opening and the sod resettled over the opening. The location of each dish was marked with a flag so they could be relocated 24 h later. Dishes were collected, covered, marked, and returned to the laboratory to determine their contents. Japanese beetle eggs were placed in the field on 30 June (three eggs per dish, two dishes per plot) and 20 July (seven eggs per dish, two dishes per plot).

Statistical Analysis. *The Effects of Cover Type on Beneficial Arthropod Occurrence, Large Plot Study.* Arthropod abundance data from pitfall traps and sweep samples in wildflowers, turf adjacent to wildflowers and turf adjacent to turf were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure in SAS (SAS Institute 1985). Mean separation among treatments was accomplished using Tukey's studentized range test when ANOVA for a variable was significant.

Effects of Flower Mix and Turf Type on Beneficial Arthropod Occurrence in Small Plots. Arthropod abundance among the borders containing either one of the two flower mixes (Border Patrol and Smith Mix) or bare soil with wheat straw mulch and the interior plot with two turf types (bermudagrass and zoysiagrass) were subjected to ANOVA using the GLM procedure in SAS (SAS Institute 1985) as before. Orthogonal contrasts were used to examine influence of cover type on arthropods within the borders and on adjacent turfgrass areas. Contrasts examined were Border Patrol versus Smith Mix, bermudagrass versus zoysiagrass, grasses surrounded by Border Patrol versus grasses surrounded by Smith Mix, flowers and grass versus mulch, grasses surrounded by flowers versus grasses surrounded by mulch, and flowers versus grasses.

Effects of Surrounding Flower Mix or Mulch on Predation on Fall Armyworm Eggs and Larvae and Japanese Beetle Eggs in Turf in Small Plots. Percent survival data of fall armyworm and Japanese beetle eggs or relative larval recovery with vacuum samples based on initial release numbers were transformed using an arcsine square root of the proportion before being subjected to ANOVA.

Results and Discussion

Effects of Cover Type on Beneficial Arthropod Occurrence: Large Plot Study. Carabid species assemblages collected in this portion of the study were similar to those collected in centipedegrass in a previous study (Braman and Pendley 1993). *Abacdicus permundus* Say, *Agonum punctiforme* Say, *Amara* sp., *Calathus opaculus* LeConte, *Calosoma sayi* Dejean, *Cratacanthus dubuis* Beauvois, *Harpalus pennsylvanicus* DeGeer, and *Scarites subterraneus* F. represented 98% of the total carabids captured in pitfall traps in the current study. Previously, in centipedegrass, *A. punctiforme, H. pennsylvanicus, S. subterraneus, Notophilus novemstriatus* LeConte, *Anisodactylus furvus* LeConte, *Amara aena* DeGeer, and *A. permundus* represented 93 and 87% of carabids collected at two locations in centipedegrass in a 3-yr study. Morrill (1992) determined that five carabid species represented 94% of the total pitfall trap catch in Georgia grasslands during 1975 and 1976. *Abacidus sculptus* (LeConte), *H. pennsylvanicus, Evarthrus unicolor* (Say), *S. subterraneus quadriceps* Chadoir, and *S. subterraneus subterraneus* F. were the most abundant species in that study. Ants were most active during the summer months but were captured year round. Species identified included *Solenopsis invicta* (Buren), *Prenolepis imparis* (Say), *Iridomyrmex humilis* (Mayr), *Formica schaufussi* Mayr, and *Ponera pennsylvanica* Buckley. Spider families captured in pitfalls included Erigonidae, Thomisidae, Hahniidae, Lycosidae, Gnaphosidae, Salticidae, Tetragnathidae, Agelenidae, Clu-

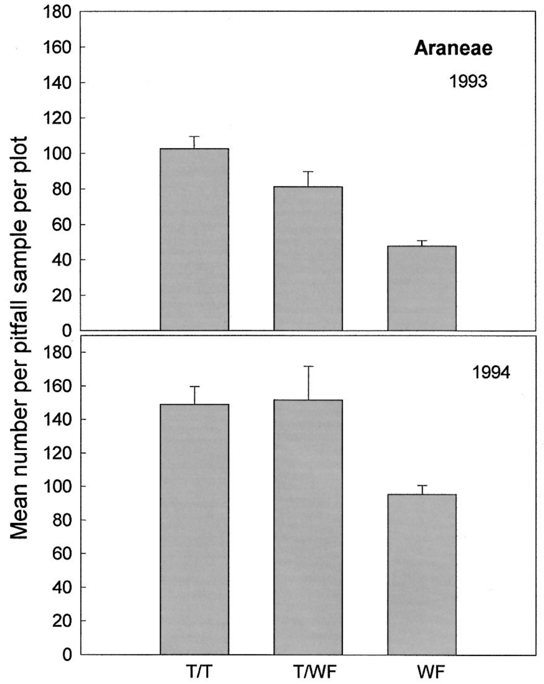

Fig. 1. Season-long abundance of ground-dwelling spiders captured in pitfall traps in Bermuda grass turf adjacent to turf (T/T), turf adjacent to wildflowers (T/WF), or wildflowers alone (WF) in large plots, $n = 6$ blocks.

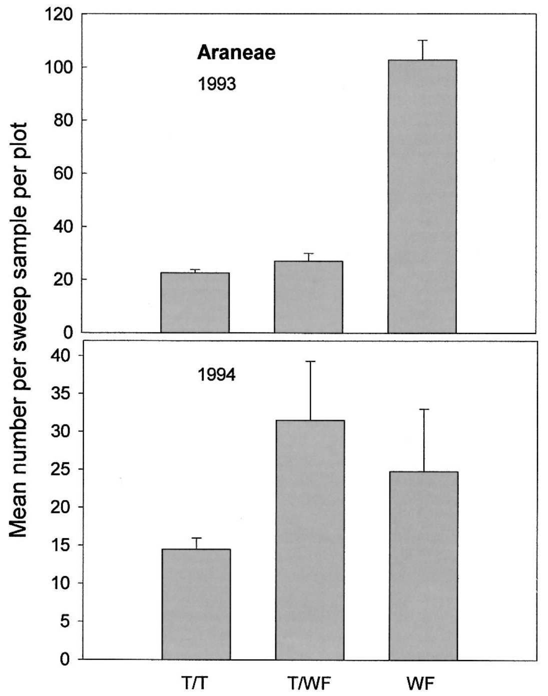

Fig. 2. Season-long abundance of foliar spiders captured in sweep samples in Bermuda grass turf adjacent to turf (T/T), turf adjacent to wildflowers (T/WF), or wildflowers alone (WF) in large plots, $n = 6$ blocks.

bionidae, Ctenizidae, and Linyphiidae. Spiders were abundant throughout the year; immatures were most common during late June and early July and again in September.

As measured by pitfall traps, ground-dwelling spiders were most abundant in turfgrass adjacent to turfgrass and turfgrass adjacent to wildflowers compared with wildflower stands alone during both years (Fig. 1). During 1993, spiders were more than twice as common in turfgrass alone than in wildflowers alone ($F = 25.7$; df = 5, 2; $P < 0.0001$), whereas turf adjacent to wildflower stands supported an intermediate number of spiders. During 1994, spider numbers were statistically similar in both turf treatments, but spiders were significantly more numerous in turf than in wildflowers alone ($F = 7.5$; df = 5, 2; $P < 0.01$). Foliar spiders, however, were more common in the wildflowers during 1993 (Fig. 2) ($F = 87.6$; df = 5, 2; $P < 0.0001$). Similar numbers of spiders were captured in sweep net samples in all three cover types during 1994 ($F = 2.4$; df = 5, 2; $P > 0.05$).

Ground beetle abundance (Fig. 3), exhibited a trend toward increased abundance in wildflower plots and turf surrounded by wildflowers both years, but was not significantly different among these three cover types ($F = 2.2$; df = 5, 2; $P > 0.05$ in 1993; $F = 0.4$; df = 5, 2; $P > 0.05$ in 1994). Ants (Fig. 4) were present in similar numbers in all three cover types each year ($F = 0.3$; df = 5, 2; $P > 0.05$ in 1993; $F = 0.8$; df = 5, 2; $P > 0.05$ in 1994). Both ground beetles and ants demonstrated considerable plot to plot variability in abundance among the six blocks.

Bigeyed bugs (Fig. 5) collected in sweep samples during 1993 were primarily *Geocoris punctipes.* This species was most numerous in wildflowers during 1993 ($F = 11.1$; df = 5, 2; $P < 0.003$). Fewer bigeyed bugs were collected during 1994, and a larger proportion were *Geocoris uliginosus* (Say). Similar numbers were collected among cover type in sweep samples during 1994 ($F = 0.6$; df = 5, 2; $P > 0.05$). The wildflower mix used in this portion of the study provided significant, season-long increases in foliar-dwelling spiders and bigeyed bugs during 1993, but not 1994. Ground-dwelling spiders were more abundant in turfgrass than in wildflowers both years, while ants appeared not to be significantly affected by cover type.

Effects of Flower Mix and Turf Type on Beneficial Arthropod Occurrence in Small Plots. Taxa captured in vacuum samples that were significantly influenced by substrate (flower type, turf type, mulch, surrounding border type) included Berytidae, *Geocoris* spp., Formicidae, parasitic Hymenoptera and Staphylinidae (Tables 1 and 2). Damsel bugs (Nabidae) and spiders in vacuum samples were statistically similar in all plots during both years. Berytids were more abundant in Border Patrol flowers than in Smith Mix during 1998, but equally abundant in both mixes during 1999. They were more likely to be captured in bermudagrass than in zoysiagrass both years, but were also more likely to be captured in flowers than in grasses both years

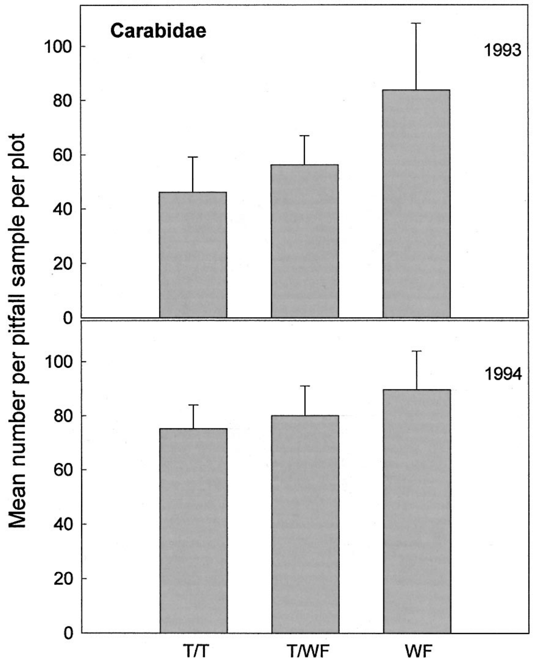

Fig. 3. Season-long abundance of carabids captured in pitfall traps in bermudagrass turf adjacent to turf (T/T), turf adjacent to wildflowers (T/WF), or wildflowers alone (WF) in large plots, $n = 6$ blocks.

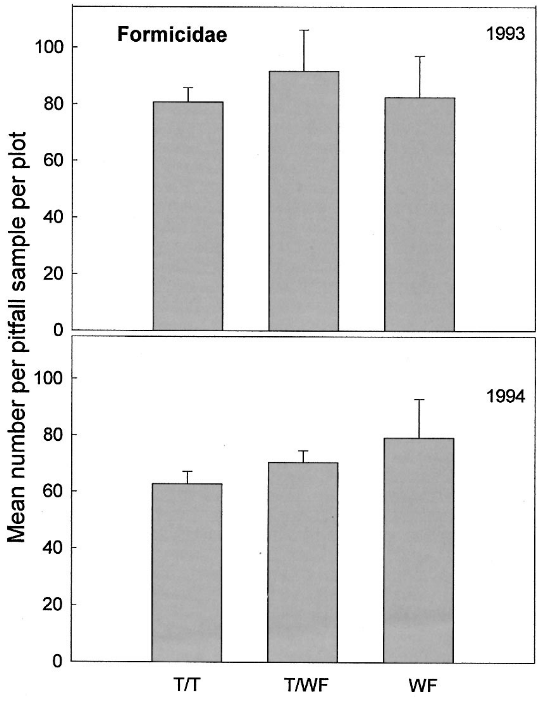

Fig. 4. Season-long abundance of ants captured in pitfall traps in bermudagrass turf adjacent to turf (T/T), turf adjacent to wildflowers (T/WF), or wildflowers alone (WF) in large plots, $n = 6$ blocks.

(Table 2). The bigeyed bugs in these samples were 98% *Geocoris uliginosus.* Bigeyed bugs were equally common in Border Patrol and Smith Mix flowers. These predators were more commonly captured in Bermuda grass than zoysiagrass both years, where they were equally or more abundant than in adjacent flowers. Further, *G. uliginosus* was less numerous in turfgrass bordered by flowers than turf plots surrounded by straw mulch (Tables 1 and 2).

Formicidae and parasitic Hymenoptera were more common in flowers than in grasses during both years of the study, and Staphylinidae were more common in flowers during 1998 only. Formicidae were more abundant in the Border Patrol mix during 1998, and parasitic Hymenoptera and Staphylinidae were better represented in the Smith Mix. However, staphylinids were more common in turf bordered by straw mulch than turf surrounded by flowers during 1998.

Carabids captured in pitfall traps were most common in the Border Patrol flower mix during 1998 and equally abundant in all cover types during 1999 (Tables 3 and 4). Tiger beetles, primarily *Megacephala carolina carolina* L. with some *M. virginica* L., were most abundant in the bare soil with wheat straw mulch compared with flowers and grasses during both 1998 and 1999. Although there were no differences in other Formicidae among substrate types in the pitfall traps, the red imported fire ant, *Solenopsis invicta* (Buren), tended to be more common in flowers than in grasses and most common in the Smith Mix and in turfgrasses surrounded with Smith Mix. Earwigs were equally common during 1998 in all plots, but were most abundant during 1999 in Bermuda grass or zoysiagrass bordered by Border Patrol.

Effects of Surrounding Flower Mix or Mulch on Predation on Fall Armyworm Eggs and Larvae and Japanese Beetle Eggs in Small Turf Plots. Survival of fall armyworm eggs exposed for 23 h in turf during 1998 and 1999 averaged <2% of the >9,000 eggs per exposure period for both years. Eggs were similarly preyed upon in all plots ($P > 0.05$). When fall armyworm eggs were exposed in the field for 2 h during 1998, survival averaged 59% in zoysiagrass surrounded by mulch; 48% in zoysiagrass surrounded by Border Patrol; 36% in bermudagrass surrounded by Border Patrol; 33% in bermudagrass surrounded by mulch; 32% in Bermuda grass surrounded by Smith Mix and 10% in zoysiagrass surrounded by Smith Mix. These differences, however, were not significant ($F = 0.32$; df = 2, 5; $P > 0.05$). Fall armyworm larvae also were heavily preyed upon both years regardless of turf or border type. During 1998, recovery of neonate larvae from vacuum samples was 1.4% in bermudagrass surrounded by Smith Mix, 1.3% in bermudagrass surrounded by mulch, 0.8% in zoysiagrass surrounded by Smith Mix, 0.5% in zoysiagrass surrounded by mulch, 0.4% in bermudagrass surrounded by Border Patrol and 0.3% in zoysiagrass surrounded by Border Patrol ($F = 1.03$; df = 2, 5; $P > 0.05$). Second instars which had been confined in tubes in the plots (left open to allow entry of predators) also survived similarly

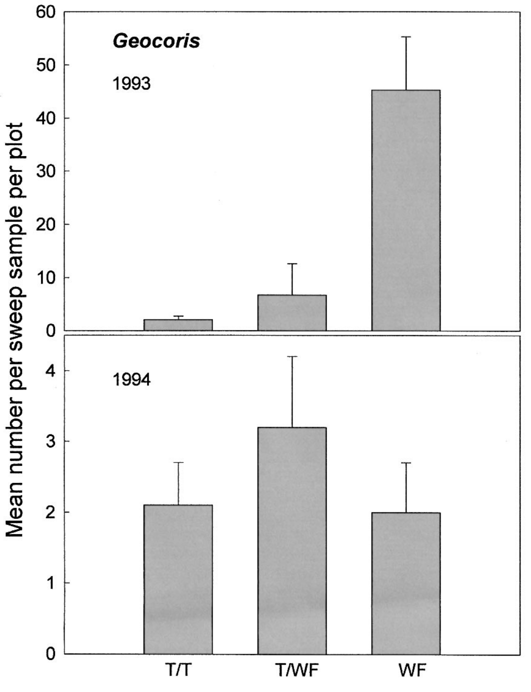

Fig. 5. Season-long abundance of bigeyed bugs captured in sweep samples in bermudagrass turf adjacent to turf (T/T), turf adjacent to wildflowers (T/WF), or wildflowers alone (WF) in large plots, $n = 6$ blocks.

among plots and averaged 20% in turf surrounded by Border Patrol, 18% in turf surrounded by mulch and 13% in turf surrounded by Smith Mix ($F = 0.18$; df = 2, 2; $P > 0.05$). During 1999, average recovery of the 1900 neonate larvae released was 1.1% in bermudagrass surrounded by mulch, 2.4% in zoysiagrass surrounded by mulch, 2.6% in bermudagrass surrounded by Smith Mix, 2.0% in zoysiagrass surrounded by Smith Mix, 0.7% in bermudagrass surrounded by Border Patrol and 1.3% in zoysiagrass surrounded by Border Patrol after 24 h ($F = 0.72$; df = 2, 5; $P > 0.05$). Too few (<0.04%) neonate larvae released on 20 July were recovered in vacuum samples on 21 July to permit statistical analysis. Using our method (without a predator exclusion control) it was not possible to determine what proportion of the larvae that were not recovered was due to predation and what proportion was an artifact of the sampling technique. Average Japanese beetle egg survival on one and 28 July 1999 respectively was 72.1 and 28.5% in bermudagrass surrounded by mulch, 44.5 and 33.3% in zoysiagrass surrounded by mulch, 22.2 and 42.8% in bermudagrass surrounded by Smith Mix, 55.7 and 26.1% in zoysiagrass surrounded by Smith Mix, 55.7 and 30.8% in bermudagrass surrounded by Border Patrol and 66.6 and 23.8% in zoysiagrass surrounded by Border Patrol after 24 h ($F = 0.23$; df = 2, 6; $F = 0.72$; df = 2, 5; $P > 0.05$).

Turfgrass and wildflower mixes all harbored a diverse array of beneficial arthropods in both large plot and small plot studies. Each wildflower mix increased the abundance of some, but not all beneficial arthropod species sampled. This increased abundance was only occasionally observed in adjacent turfgrass areas. Ground-inhabiting spiders were more numerous in turf, foliar spiders were more abundant in flowers, ground beetles were only rarely significantly more abundant in wildflowers than turf. Fall armyworm eggs and larvae and Japanese beetle eggs were heavily

Table 1. Mean number of beneficials per vacuum sample per date in flower mixes (Smith Mix or Border Patrol) or wheat straw mulch or in bermudagrass or zoysiagrass bordered by either Smith Mix (SM) Border Patrol (BP) or mulch

Contrast	Berytidae	Nabidae	Geocoris	Formicidae	Araneae	Parasitic Hymenoptera	Staphylinidae
				1998			
Smith Mix	0.26	0.22	0.92	9.89	3.17	7.67	2.17
Border Patrol	1.04	0.11	0.93	13.59	3.17	4.67	0.33
Mulch	0.07	0.07	0.11	2.48	1	0.5	0
Bermudagrass w/SM	0.67	0.11	0.93	4.44	5.33	0.83	0
Bermudagrass w/BP	0.52	0.11	0.59	5.44	2.33	0.67	0
Bermudagrass w/Mulch	0.33	0.07	0.93	3.22	5.33	1.17	0.33
Zoysiagrass w/SM	0.11	0	0.18	4.04	5.17	0.83	0.17
Zoysiagrass w/BP	0.22	0.04	0.3	3.81	18.17	2	0
Zoysiagrass w/Mulch	0.11	0	0.18	2.48	7.83	0.17	0.5
$F(2.8)$	2.25	1.56	5.2	6.74	0.89	9.03	3.9
P	0.02	0.14	0.0001	0.0001	0.53	0.0001	0.002
				1999			
Smith Mix	0.22	0.12	1.38	10.36	4.26	0.86	0.69
Border Patrol	0.14	0.48	1.07	14.24	8.31	0.86	0.57
Mulch	0.02	0.48	1.12	5.86	2.24	0.21	0.26
Bermudagrass w/SM	0.07	0.02	3.59	7.07	2.76	0.48	0.5
Bermudagrass w/BP	0.07	0.07	2.45	7.53	3.9	0.8	0.8
Bermudagrass w/Mulch	0.22	0.07	4.02	7.51	2.66	0.56	0.7
Zoysiagrass w/SM	0	0.02	1.12	4.35	3.3	0.15	0.79
Zoysiagrass w/BP	0.07	0	1.45	8.98	3.83	0.43	0.79
Zoysiagrass w/Mulch	0.05	0.05	1.83	5.5	3.95	0.38	0.71
$F(2.8)$	1.87	0.86	5.57	2.62	1.13	1.63	1.32
P	0.06	0.55	0.0001	0.009	0.34	0.11	0.23

Table 2. Comparison of beneficial arthropod densities in vacuum samples as influenced by turfgrass species or surrounding border of either Border Patrol (BP) or Smith Mix (SM) wildflowers or bare soil with wheat straw mulch

Contrast	Berytidae	Nabidae	Geocoris	Formicidae	Araneae	Parasitic Hymenoptera	Staphylinidae
				1998			
BP vs SM	**	NS	NS	*	NS	**	***
Bermudagrass vs Zoysiagrass	**	*	***	NS	NS	NS	NS
Grass w/BP vs Grass w/SM	NS	NS	NS	NS	NS	NS	**
Flowers and Grass vs Mulch	**	NS	**	***	NS	***	NS
Grass w/Flowers vs Grass w/Mulch	NS	NS	NS	NS	NS	NS	NS
Flowers vs Grasses	*	**	***	***	NS	***	***
				1999			
BP vs SM	NS	NS	NS	NS	*	NS	NS
Bermudagrass vs Zoysiagrass	*	NS	***	NS	NS	*	NS
Grass w/BP vs Grass w/SM	NS	NS	NS	**	NS	NS	NS
Flowers and Grass vs Mulch	NS	NS	NS	*	NS	NS	NS
Grass w/Flowers vs Grass w/Mulch	NS	NS	*	*	NS	NS	NS
Flowers vs Grasses	**	NS	**	***	**	**	NS

NS, non significant. *, $P < 0.10$; **, $P < 0.05$; ***, $P < 0.001$.

preyed upon in small plots regardless of turfgrass species or surrounding border of flowers or mulch.

López and Potter (2000) have demonstrated that indigenous ants may be an important buffer against pest outbreaks on lawns and golf courses. Ants were among the most abundant predators in each of the experiments described here, and were frequently observed preying on fall armyworm eggs and larvae, as were *Geocoris uliginosus* and the staphylinids *Coproporus laevis* LeConte and an unidentified Aleocharine species.

Most predators were equally well represented in bermudagrass and zoysiagrass, suggesting that the more pest resistant zoysiagrass may be compatible with biological control by natural enemies. The greater number of bigeyed bugs observed in bermudagrass may reflect larger numbers of alternative prey such as leafhoppers associated with this grass (data not presented). While parasitism of turfgrass pests was not evaluated here, the increase in parasitic Hymenoptera present in the flower mixes used in these studies suggests their potential in attracting beneficial parasitoid

Table 3. Mean number of beneficials arthropods per pitfall sample per date in flower mixes (Smith Mix or Border Patrol) or wheat straw mulch or in bermudagrass or zoysiagrass bordered by either Smith Mix, Border Patrol or mulch

Contrast	Carabidae	Staphylinidae	Cicindellidae	Formicidae	Solenopsis	Araneae	Dermaptera
				1998			
Smith Mix	9.67	5.01	0.31	17.81	8.24	10.28	0.36
Border Patrol	15.02	4.19	0.26	27.04	6.52	10.8	0.19
Mulch	6.07	3.09	0.59	38.26	4.36	12.14	0.21
Bermudagrass w/SM	9.45	4.35	0.14	22.07	6.95	12.37	0.52
Bermudagrass w/BP	7.71	3.64	0.12	24.42	5.86	12.24	0.52
Bermudagrass w/Mulch	6.07	4.43	0.14	21.24	5.97	20.21	0.64
Zoysiagrass w/SM	8	5.01	0.07	17.62	9.07	11.33	0.51
Zoysiagrass w/BP	7.24	5.52	0.09	27.01	5.98	11.47	0.54
Zoysiagrass w/Mulch	5.24	4.38	0.12	17.67	9.07	15.04	0.45
$F(2.8)$	2.47	1.04	3.16	1.08	1.87	0.96	1.15
P	0.01	0.4	0.002	0.38	0.06	0.47	0.33
				1999			
Smith Mix	3.79	2.96	0.32	20.59	19.07	13.4	0.45
Border Patrol	4.15	4.44	0.27	30.98	7.49	22.11	0.71
Mulch	3.34	2.41	1.36	104.07	6.02	10.11	0.18
Bermudagrass w/SM	4.89	4.29	0.09	23.59	7.84	25.16	1.27
Bermudagrass w/BP	4.09	4.91	0.08	28.16	5.38	21.84	1.56
Bermudagrass w/Mulch	4.09	3.87	0.07	30.6	6.87	21.8	0.91
Zoysiagrass w/SM	5.02	4.62	0.02	20.78	8.71	25.02	1.11
Zoysiagrass w/BP	5.04	4.38	0.09	25.09	5.64	23.11	1.61
Zoysiagrass w/Mulch	4.78	4.11	0.22	16.87	6.82	17.96	0.93
$F(2.8)$	0.79	1.29	6.58	2.12	2.45	2.63	3.09
P	0.61	0.25	0.0001	0.03	0.01	0.008	0.002

Table 4. Comparison of beneficial arthropod densities in pitfall samples as influenced by turfgrass species or surrounding border of either Border Patrol (BP) or Smith Mix (SM) wildflowers or bare soil with wheat straw mulch

Contrast	Carabidae	Staphylinidae	Cicindellidae	Formicidae	Solenopsis Invicta	Araneae	Dermaptera
			1998				
BP vs SM	**	NS	NS	NS	NS	NS	NS
Bermudagrass vs Zoysiagrass	NS	NS	NS	NS	NS	NS	NS
Grass w/BP vs Grass w/SM	NS	NS	NS	NS	**	NS	NS
Flowers and Grass vs Mulch	***	NS	*	NS	**	**	NS
Grass w/Flowers vs Grass w/Mulch	NS	NS	NS	NS	NS	**	NS
Flowers vs Grasses	***	NS	NS	NS	NS	NS	**
			1999				
BP vs SM	NS	NS	NS	NS	**	*	NS
Bermudagrass vs Zoysiagrass	NS	NS	NS	NS	NS	NS	NS
Grass w/BP vs Grass w/SM	NS	NS	NS	NS	**	NS	NS
Flowers and Grass vs Mulch	NS	NS	***	*	NS	**	**
Grass w/Flowers vs Grass w/Mulch	NS	NS	NS	NS	NS	NS	**
Flowers vs Grasses	NS	NS	NS	NS	**	*	***

NS, Non significant. *, $P < 0.10$; **, $P < 0.05$; ***, $P < 0.001$.

species as well as generalist predators of potential importance in landscape pest management.

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