Occurrence of Hymenopteran Parasitoids in Residential Turfgrass in Central Georgia[1]

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Abstract The influence of turfgrass genotype (bermudagrass, *Cynodon dactylon* (L.), centipedegrass *Eremochloa ophiuroides* Munro Hack, St. Augustinegrass *Stenotaphrum secundatum* [Walt.] Kuntze, zoysiagrass, *Zoysia* spp., and tall fescue, *Festuca arundinacea* Schreb) on occurrence of hymenopteran parasitoids was evaluated in residential turf during May, June and July in 2005. Most wasps belonged to Chalcidoidea (55%) and Platygastroidea (29%). Adult wasps representing Mymaridae, Platygastridae, Scelionidae and Braconidae were captured in all turfgrasses. Among all wasps, 26.5% were mymarids and included *Gonatocerus* sp. and *Mymar* sp. Eulophidae, *Aprostocetus* and *Pnigalio* sp. were less abundant in centipedegrass compared with other turfgrasses. Trichogrammatids (18.2% of total wasps) were more abundant in St. Augustinegrass or tall fescue than in zoysiagrass. Platygastrid wasps, *Allotropa* and *Fidiobia* sp., were most often collected from zoysiagrass and St. Augustinegrass. Scelionids represented 23% of the total parasitoids collected. *Baeus* sp., a scelionid, was found in all turf types except in tall fescue, whereas another scelionid, *Trimorus* sp., was found among all turfgrass taxa. Figitids were most common in St. Augustinegrass, whereas a greater number of dryinid wasps were found in tall fescue than in all other turfgrasses. Vacuum sampling proved to be a better collecting technique than sweep netting for minute wasps. Chalcidoidea, particularly mymarids, eulophids and trichogrammatids, were abundant in July. Most aphelinid wasps were captured in June with none collected in July. Ichneumonids and braconids were more common in June than in July. Knowledge of species occurrence, abundance and distribution is important for conservation as well as pest management efforts. Our results demonstrate an abundant and diverse community of parasitic wasps in residential turfgrasses in central Georgia that could be a focus of conservation efforts.

Key Words hymenopteran parasitoids, turfgrass, bermudagrass, centipedegrass, St. Augustinegrass, zoysiagrass, tall fescue

Natural enemy communities may be shaped temporally or spatially by direct natural enemy-prey or indirect host plant-prey interaction (Price 1986). Host plants have been shown to influence parasitism, e.g., parasitism of forest caterpillars (Lill et al. 2002), suggesting the possibility of top down influence on host plant use. In the

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turfgrass environment, studies have revealed a range of herbivore-turfgrass genotype interaction effects (e.g., Braman et al. 1994, 2000a, b, Joseph and Braman 2009a, Reinert and Vinson 2010). Marked effects of individual plant taxa and landscape complexity on natural enemies associated with turfgrass also have been demonstrated (Braman et al. 2002, 2003, 2004, Frank and Shrewsbury 2004, Joseph and Braman 2009b). Evaluation of hymenopteran parasitoids in the turfgrass ecosystem has largely focused on key pests, e.g., Japanese beetle, *Popillia japonica* Newman (Cappaert and Smitley 2002, Rogers and Potter 2002), southern chinch bug, *Blissus insularis* Barbar (Reinert 1972, 1978), rhodesgrass scale, *Antonina graminis* Maskell (Chantos et al. 2009, Dean and Schuster 1958, Dean et al. 1961, Questel and Genung 1957, Riherd 1950, 1951), and mole crickets, *Scapteriscus* spp. (Hudson et al. 1988, Held 2005, Abraham et al. 2010) on golf course and landscape turf. Other studies reported parasitism by braconid wasps on fall armyworm, *Spodoptera frujiperda* (J. E. Smith) (Ashley et al. 1983, Braman et al. 2004) and dryinid wasps parasitizing leaf and planthoppers on forage-type bermudagrass (Buntin 1989).

Broader surveys of parasitic Hymenoptera in turf are less well represented. Families of parasitoids captured on sticky traps in buffalograss (Heng-Moss et al. 1998) included Scelionidae, Encyrtidae, Mymaridae, and Trichogrammatidae. Mymarids and trichogrammatids were the most abundant parasitoid families in that study, representing 76.8% of the total parasitoids collected. In a subsequent study scelionid wasps represented 66.3% of the total parasitoids collected in buffalograss (Carstens et al. 2007).

Knowledge of species occurrence, abundance and distribution is central to conservation as well as pest management efforts. Residential and recreational turfgrass sites are often under intensive management, with regular mowing and fertilization, and often pesticide applications (Braman et al. 1997, Carstens et al. 2007) all of which may impact parasitoid dynamics. Wang et al. (2001), for example, reported that a lower density of scelionids was found in chlorpyrifos-treated bermudagrass than in untreated bermudagrass. A better understanding of resident parasitic hymenopterans and how they are influenced by turfgrass taxa will improve conservation efforts based on knowledge of ecosystem dynamics.

Materials and Methods

Twenty-one urban lawns in Spalding Co., GA, were sampled during May, June and July in 2005. A preliminary questionnaire indicated that none of the lawns were treated with insecticides within a 12-month period prior to sampling. Sites included 2 common bermudagrass (*Cynodon dactylon* (L.)), 9 centipedegrass (*Eremochloa ophiuroides* Munro Hack), 6 St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze), 3 zoysiagrass, (*Zoysia* spp.), and 1 tall fescue, (*Festuca arundinacea* Schreb.) lawns.

Two methods, sweep netting and vacuum suctions, were used to sample parasitic wasps. Samples were collected from a 9.1 × 9.1-m transect from each residential lawn. This area was further subdivided into quadrants (plots) of 4.6 × 4.6 m. Twenty-five sweeps were collected along a diagonal in each quadrant and were stored in plastic bags. The sweep net (Ward's Rochester, NY) had an opening of 0.03 m^2 area, net volume of 0.024 m^3, and handle-length of 0.92 m. Twenty random suctions of 0.4 m^2 lawn area using a 'Vortis' vacuum sampler (Burkhard Manufacturing Co., Ltd, Herefordshire, England) were collected . The air throughput of the vacuum sampler was 10.5 m^3 per min. Both types of samples were temporarily stored overnight at 4°C, then cleaned using 0.84 mm and 3 mm mesh sieves and permanently stored in 70% ethanol for subsequent evaluation. Parasitic wasps were identified to family or genus using a stereomicroscope (10 X magnification). Hymenopterans were identified to genus by taxonomists at the Systematic Entomology Laboratory, Agricultural Research Service, US Department of Agriculture, Beltsville, MD.

Abundance data for parasitic wasps were analyzed for effect of turfgrass taxon, sampling method and date. ANOVAs were conducted using the GLM procedure of SAS (SAS Institute 2003). Number of wasps collected was the response variable. Differences in least square means were determined by pairwise *t*-tests.

Results and Discussion

We examined 4,014 adult parasitic hymenopterans from different turfgrass taxa belonging to superfamilies Chalcidoidea (55% of the total wasps sampled), Platygastroidea (29%), Cynipoidea (0.05%), Ichneumonoidea (0.04%), Ceraphronoidea (0.05%), Chrysidoidea (0.01%) and Proctotrupoidea (0.004%). Eight families of Chalcidoidea, which included Mymaridae (48% of total Chalcidoidea), Trichogrammatidae (33.5%), Eulophidae (11%), Aphelinidae (0.03%), Encyrtidae (0.02%), Pteromalidae (0.02%), Eurytomidae (0.001%) and Eupelmidae (0.001%), were represented in the samples (Table 1). Mymarids, 26.5% of total wasps sampled, were largely comprised of *Gonatocerus* sp. and *Mymar* sp., and were evenly represented among turfgrass types. *Gonatocerus* spp. are egg parasitoids of hemipterans belonging to the suborder Auchenorrhyncha and include primary parasitoids of the glassy-winged sharpshooter, *Homalodisca vitripennis* (Say), in many agro-systems (Irvin and Hoddle 2005). Eulophid wasps, *Aprostocetus* sp. and *Pnigalio* sp., were less abundant in centipedegrass compared with other turfgrasses. *Aprostocetus* is the largest eulophid genus found in North America, parasitizing eggs of spiders, mites and nematodes (LaSalle 1994) whereas *Pnigalio* spp. parasitize mostly leaf miners. The role of mymarids and eulophids and impact on turfgrass pests remains unknown.

Encyrtid wasps are parasitoids of eggs and larvae of many insect and mite species and are widely used as biological control agents in many ecosystems (van Driesche et al. 2008). This family was collected from all grasses except tall fescue. The encyrtid wasps included *Pseudaphycus* sp., a genus containing mealybug parasitoids in non-turf systems. For example, *Pseudaphycus* sp. have been documented parasitizing *Pseudococcus* sp. mealybugs on horticultural crops (Sandanayaka et al. 2009). Reinert (1972) reported the encyrtid egg parasitoids, *Eumicrosoma benefica* Gahan, on southern chinch bug, *B. insularis* Barber, in St. Augustinegrass in Florida. He further documented an average population of 35 *E. benefica* associated with 90 southern chinch bugs per ft^2 (0.09 m^2).

Pteromalid wasps were not collected from tall fescue but were evenly collected from other grasses. Trichogrammatid wasps were more abundant in St. Augustinegrass and tall fescue than in zoysiagrass (Table 1). *Oligosita* sp. (Trichogrammatidae) was most numerous in tall fescue. Although there were many other unknown trichogrammatid wasp genera in our samples, host-insect association essential to specifically identify them to genus was lacking. In a similar study, Carstens et al. (2007) reported an abundance of Aphelinidae, Mymaridae, Trichogrammatidae and Braconidae on sticky traps in buffalograss. In our study, Chalcidoidea were most abundant in July with a corresponding 50.1% of total mymarids, 54.6% of total eulophids and 78.9% of trichogrammatids in July collections (Table 2). However, 96.4% of total

Table 1. Mean (± S. E.) parasitic hymenopterans per 4.6- by 4.6-m collected from various turfgrasses (21 residential lawns) during May-July 2005 in Spalding Co., GA.

Hymenopteran Taxa	*F*	df	*P*	Bermudagrass	Centipedegrass	St.Augustinegrass	Zoysiagrass	Tall Fescue
Chalcidoidea	2.1	4, 467	NS	4.19 ± 1.05a	3.47 ± 0.45a	6.69 ± 1.74a	3.51 ± 0.62a	6.47 ± 2.01a
Mymaridae (includes *Gonatocerus* sp.)	0.6	4, 467	NS	2.13 ± 0.62a	2.52 ± 0.36a	2.06 ± 0.30a	1.73 ± 0.46a	2.35 ± 0.77a
Mymar sp.	0.5	4, 466	NS	0.06 ± 0.05a	0.09 ± 0.03a	0.04 ± 0.12a	0.09 ± 0.04a	0.04 ± 0.04a
Aphelinidae	1.8	4, 467	NS	0.05 ± 0.04a	0.06 ± 0.05a	0.13 ± 0.04a	0.29 ± 0.13a	0.0 ± 0.0a
Eulophidae (includes *Aprostocetus* sp.)	2.8	4, 467	0.0243	0.89 ± 0.30a	0.36 ± 0.08b	0.40 ± 0.08ab	0.90 ± 0.29a	0.39 ± 0.14ab
Pnigalio sp.	4.1	4, 467	0.0030	0.02 ± 0.02b	0.02 ± 0.01b	0.12 ± 0.04ab	0.17 ± 0.06a	0.04 ± 0.04b
Encyrtidae (includes *Pseudaphycus* sp.)	3.6	4, 467	0.0049	0.15 ± 0.05a	0.03 ± 0.01ab	0.15 ± 0.04a	0.13 ± 0.06ab	0.0 ± 0.0b
Pteromalidae	2.6	4, 467	0.0368	0.09 ± 0.04ab	0.05 ± 0.02ab	0.15 ± 0.05a	0.19 ± 0.07a	0.0 ± 0.0b
Trichogrammatidae	3.6	4, 467	0.0062	0.78 ± 0.28ab	0.43 ± 0.09ab	3.75 ± 1.48a	0.27 ± 0.08b	3.74 ± 1.34a
Oligosita sp.	24.1	4, 467	<0.0001	0.36 ± 0.14b	0.09 ± 0.03c	0.01 ± 0.01c	0.06 ± 0.03c	1.43 ± 0.54a
Eurytomidae	0.8	4, 467	NS	0.0 ± 0.0a	0.01 ± 0.01a	0.02 ± 0.01a	0.0 ± 0.0a	0.0 ± 0.0a
Eupelmidae	0.6	4, 465	NS	0.0 ± 0.0a	0.0 ± 0.0 a	0.01 ± 0.01a	0.0 ± 0.0a	0.0 ± 0.0a
Platygastroidea	3.2	4, 470	0.0130	2.25 ± 0.65abc	1.95 ± 0.22bc	2.94 ± 0.49ab	3.57 ± 0.69a	1.17 ± 0.38c
Platygastridae	3.4	4, 470	0.0087	0.23 ± 0.09bc	0.33 ± 0.06abc	0.89 ± 0.24a	0.86 ± 0.24ab	0.13 ± 0.07c
Allotropa sp.	6.1	4, 470	<0.0001	0.21 ± 0.08b	0.12 ± 0.03b	0.19 ± 0.6b	0.67 ± 0.21a	0.09 ± 0.06b
Fidiobia sp.	4.1	4, 470	0.0028	0.0 ± 0.0b	0.05 ± 0.02b	0.55 ± 0.20a	0.01 ± 0.01b	0.0 ± 0.0b
Scelionidae	2.4	4, 467	NS	2.02 ± 0.59a	1.61 ± 0.18a	2.05 ± 0.31a	2.71 ± 0.51a	1.04 ± 0.36a
Baeus sp.	3.0	4, 470	0.0178	1.29 ± 0.50a	0.75 ± 0.12ab	0.75 ± 0.19ab	1.58 ± 0.44a	0.04 ± 0.04b

Table 1. Continued

Hymenopteran Taxa	*F*	df	*P*	Bermudagrass	Centipedegrass	St.Augustinegrass	Zoysiagrass	Tall Fescue
Trimorus sp.	1.7	4, 468	NS	0.5 ± 0.15a	0.57 ± 0.09a	0.93 ± 0.17a	0.82 ± 0.18a	0.78 ± 0.26a
Cynipoidea	15.7	4, 466	<0.0001	0.26 ± 0.09b	0.17 ± 0.04b	1.11 ± 0.17a	0.30 ± 0.09b	0.0 ± 0.0b
Figitidae	14.3	4, 466	<0.0001	0.28 ± 0.11b	0.17 ± 0.04b	1.04 ± 0.17a	0.24 ± 0.07b	0.0 ± 0.0b
Hexacola sp.	13.7	4, 465	<0.0001	0.15 ± 0.11b	0.12 ± 0.03b	0.94 ± 0.16a	0.28 ± 0.08b	0.0 ± 0.0b
Emargo sp.	0.4	4, 465	NS	0.04 ± 0.03a	0.05 ± 0.02a	0.07 ± 0.04a	0.03 ± 0.02a	0.0 ± 0.0a
Cynipidae	1.7	4, 466	NS	0.0 ± 0.0a	0.0 ± 0.0a	0.03 ± 0.02a	0.0 ± 0.0a	0.0 ± 0.0a
Ichneumonoidea	2.9	4, 465	0.0215	0.23 ± 0.08ab	0.24 ± 0.04ab	0.49 ± 0.09a	0.25 ± 0.18ab	0.22 ± 0.11b
Ichneumonidae	2.7	4, 466	0.0295	0.06 ± 0.04ab	0.04 ± 0.02ab	0.17 ± 0.05a	0.07 ± 0.04ab	0.0 ± 0.0b
Braconidae	1.2	4, 466	NS	0.19 ± 0.09a	0.19 ± 0.04a	0.31 ± 0.06a	0.17 ± 0.04a	0.22 ± 0.11a
Ceraphronoidea	1.9	4, 466	NS	0.15 ± 0.09a	0.63 ± 0.15a	0.32 ± 0.06a	0.56 ± 0.12a	0.04 ± 0.04a
Ceraphronidae	1.9	4, 466	NS	0.54 ± 0.14a	0.04 ± 0.04a	0.31 ± 0.06a	0.54 ± 0.14a	0.04 ± 0.04a
Megaspilidae	0.8	4, 466	NS	0.01 ± 0.01a	5.10 ± 4.27a	0.01 ± 0.01a	0.01 ± 0.01a	5.10 ± 4.27a
Proctotrupoidea								
Diapriidae	0.7	4, 466	NS	0.01 ± 0.01a	0.09 ± 0.06a	0.04 ± 0.02a	0.01 ± 0.01a	0.09 ± 0.06a
Chrysidoidea								
Dryinidae (*Gonatopus* sp.)	12.4	4, 466	<0.0001	0.0 ± 0.0b	0.84 ± 0.42a	0.13 ± 0.04b	0.0 ± 0.0b	0.84 ± 0.42a

Means followed by the same letter are not significantly different ($P < 0.05$; Fisher's LSD).

Table 2. Mean (± S. E.) parasitic hymenopterans per 4.6- by 4.6-m collected using two sampling method on three dates from 21 residential lawns during May-July 2005 in Spalding Co., GA.

	Method of Sampling					Sampling Date					
Hymenopteran Taxa	*F*	df	*P*	Sweep Net. (*n* = 246)	Vacuum (*n* = 228)	*F*	df	*P*	May 2005 (*n* = 158)	June 2005 (*n* = 160)	July 2005 (*n* = 157)
Chalcidoidea	44.9	1, 467	<0.0001	1.27 ± 0.16b	8.19 ± 1.09a	10.9	2, 467	<0.0001	2.91 ± 0.35b	2.86 ± 0.39b	8.09 ± 1.56a
Mymaridae (includes *Gonatocerus* sp.)	93.9	1, 467	<0.0001	0.53 ± 0.08b	4.06 ± 0.38a	10.1	2, 467	<0.0001	1.46 ± 0.19b	1.85 ± 0.31b	3.39 ± 0.47a
Mymar sp.	13.4	1, 466	0.0003	0.01 ± 0.08b	0.14 ± 0.03a	2.1	2, 466	NS	0.03 ± 0.01a	0.07 ± 0.02a	0.12 ± 0.05a
Aphelinidae	8.5	1, 467	0.0037	0.03 ± 0.02b	0.21 ± 0.06a	13.9	2, 467	<0.0001	0.34 ± 0.09a	0.01 ± 0.01b	0.0 ± 0.0b
Eulophidae (includes *Aprostocetus* sp.)	11.5	1, 467	0.0008	0.30 ± 0.06b	0.73 ± 0.12a	7.3	2, 467	0.0008	0.45 ± 0.08b	0.23 ± 0.05b	0.84 ± 0.17a
Pnigalio sp.	1.6	1, 467	NS	0.05 ± 0.02a	0.09 ± 0.03a	13.1	2, 467	<0.0001	0.18 ± 0.04a	0.02 ± 0.01b	0.02 ± 0.01b
Encyrtidae (includes *Pseudaphycus* sp.)	0.4	1, 467	NS	0.08 ± 0.02a	0.09 ± 0.02a	0.3	2, 467	NS	0.10 ± 0.03a	0.08 ± 0.02a	0.09 ± 0.03a
Pteromalidae	0.2	1, 467	NS	0.09 ± 0.02a	0.11 ± 0.03a	2.4	2, 467	NS	0.15 ± 0.04a	0.11 ± 0.03a	0.05 ± 0.02a
Trichogrammatidae	11.0	1, 467	0.0010	0.22 ± 0.06b	2.97 ± 0.88a	6.5	2, 467	0.0016	0.39 ± 0.12b	0.57 ± 0.10b	3.71 ± 1.28a
Oligosita sp.	17.3	1, 467	<0.0001	0.03 ± 0.02b	0.29 ± 0.07a	4.5	2, 467	0.0112	0.11 ± 0.04b	0.08 ± 0.03b	0.3 ± 0.09a
Eurytomidae	0.1	1, 467	NS	0.01 ± 0.01a	0.01 ± 0.01a	0.2	2, 467	NS	0.01 ± 0.01a	0.01 ± 0.01a	0.01 ± 0.01a
Eupelmidae	0.9	1, 465	NS	0.0 ± 0.0a	0.0 ± 0.0a	0.9	2, 465	NS	0.0 ± 0.0a	0.01 ± 0.01a	0.0 ± 0.0a
Platygastroidea	83.3	1, 470	<0.0001	0.61 ± 0.11a	4.26 ± 0.38a	0.2	2, 470	NS	2.34 ± 0.35a	2.64 ± 0.35a	2.39 ± 0.38a

Table 2. Continued

Hymenopteran Taxa	Method of Sampling					Sampling Date					
	F	df	*P*	Sweep Net. (*n* = 246)	Vacuum (*n* = 228)	*F*	df	*P*	May 2005 (*n* = 158)	June 2005 (*n* = 160)	July 2005 (*n* = 157)
Platygastridae	23.1	1, 470	<0.0001	0.17 ± 0.04b	0.94 ± 0.16a	0.2	2, 470	NS	0.61 ± 0.14a	0.53 ± 0.09a	0.49 ± 0.18a
Allotropa sp.	20.1	1, 470	<0.0001	0.06 ± 0.03b	0.40 ± 0.07a	1.5	2, 470	NS	0.25 ± 0.07a	0.29 ± 0.08a	0.13 ± 0.05a
Fidiobia sp.	5.8	1, 470	0.0163	0.04 ± 0.02b	0.32 ± 0.12a	1.4	2, 470	NS	0.25 ± 0.11a	0.04 ± 0.02a	0.25 ± 0.14a
Scelionidae	96.3	1, 467	<0.0001	0.61 ± 0.08b	3.31 ± 0.27a	0.6	2, 467	NS	1.73 ± 0.26a	2.11 ± 0.28a	1.89 ± 0.25a
Baeus sp.	45.9	1, 470	<0.0001	0.20 ± 0.05b	1.63 ± 0.21a	0.2	2, 470	NS	0.98 ± 0.22a	0.89 ± 0.16a	0.81 ± 0.19a
Trimorus sp.	51.9	1, 468	<0.0001	0.26 ± 0.05b	1.2 ± 0.13a	3.3	2, 468	0.0391	0.48 ± 0.09b	0.87 ± 0.15a	0.79 ± 0.12ab
Cynipoidea	8.3	1, 466	0.0042	0.31 ± 0.05b	0.61 ± 0.10a	2.9	2, 466	NS	0.28 ± 0.05a	0.54 ± 0.09a	0.55 ± 0.13a
Figitidae	6.3	1, 466	0.0122	0.30 ± 0.05b	0.56 ± 0.09a	3.0	2, 466	NS	0.25 ± 0.05a	0.49 ± 0.09a	0.54 ± 0.13a
Hexacola sp.	6.9	1, 465	0.0091	0.30 ± 0.05b	0.50 ± 0.09a	3.4	2, 465	NS	0.19 ± 0.04a	0.41 ± 0.08a	0.50 ± 0.13a
Emargo sp.	1.4	1, 465	NS	0.03 ± 0.01a	0.07 ± 0.03a	2.6	2, 465	NS	0.02 ± 0.01a	0.09 ± 0.04a	0.03 ± 0.01a
Cynipidae	0.0	1, 466	NS	0.01 ± 0.01a	0.01 ± 0.01a	2.7	2, 466	NS	0.03 ± 0.02a	0.0 ± 0.0a	0.0 ± 0.0a
Ichneumonoidea	0.0	1, 465	NS	0.30 ± 0.05a	0.32 ± 0.04a	8.7	2, 465	0.0002	0.50 ± 0.0a	0.22 ± 0.05b	0.21 ± 0.04b
Ichneumonidae	0.4	1, 466	NS	0.07 ± 0.03a	0.09 ± 0.02a	5.6	2, 466	0.0040	0.16 ± 0.04a	0.06 ± 0.02b	0.03 ± 0.02b
Braconidae	0.0	1, 466	NS	0.23 ± 0.04a	0.22 ± 0.03a	4.7	2, 466	0.0099	0.34 ± 0.06a	0.17 ± 0.04b	0.17 ± 0.04b
Ceraphronoidea	21.2	1, 466	<0.0001	0.15 ± 0.03b	0.79 ± 0.14a	2.7	2, 466	NS	0.32 ± 0.08a	0.38 ± 0.07a	0.69 ± 0.19a
Ceraphronidae	20.7	1, 467	<0.0001	0.15 ± 0.03b	0.78 ± 0.14a	2.8	2, 467	NS	0.31 ± 0.08a	0.37 ± 0.07a	0.69 ± 0.19a

Table 2. Continued

Hymenopteran Taxa	Method of Sampling					Sampling Date					
	F	df	P	Sweep Net. (n = 246)	Vacuum (n = 228)	F	df	P	May 2005 (n = 158)	June 2005 (n = 160)	July 2005 (n = 157)
Megaspilidae	2.1	1, 466	NS	0.0 ± 0.00a	0.01 ± 0.01a	2.0	2, 466	NS	0.01 ± 0.01a	0.0 ± 0.0a	0.0 ± 0.0a
Proctotrupoidea											
Diapriidae	2.8	1, 466	NS	0.03 ± 0.01a	0.06 ± 0.02a	0.1	2, 466	NS	0.04 ± 0.02a	0.05 ± 0.02a	0.04 ± 0.02a
Chrysidoidea											
Dryinidae (*Gonatopus* sp.)	4.2	1, 466	0.0412	0.06 ± 0.02a	0.16 ± 0.05a	4.2	2, 466	0.0159	0.02 ± 0.01b	0.19 ± 0.07a	0.11 ± 0.03ab

Means followed by the same letter are not significantly different ($P < 0.05$; Fisher's LSD).

aphelinids were recorded in May and very few or none were collected in June or July samples.

Platygastridae and Scelionidae were most abundant in zoysiagrass, St. Augustinegrass and bermudagrass compared with centipedegrass or tall fescue (Table 1). Platygastrid wasps (mean ± SE = 0.54 ± 0.08) collected in our turfgrass samples included *Allotropa* sp., which are known to be egg parasitoids of mealybug pests (Pseudococcidae) (Muesebeck 1954), and *Fidiobia* sp. which have not been reported on any turfgrass pest. Other studies have demonstrated the parasitic capability of the endoparasitoid, *Fidiobia dominica* Evans & Peña, on root weevils, *Diaprepes* sp., in citrus (Jacas et al. 2007) and on chrysomelid leaf beetles in other ecosystems. Scelionids comprised 22.8% of wasps among all turfgrasses sampled in the present study. In contrast, Carstens et al. (2007) reported that 66.3% of parasitoids collected in buffalograss were scelionids. A wingless scelionid, *Baeus* sp., was found in all turf types except tall fescue, whereas another wingless scelionid, *Trimorus* sp., was evenly collected from all turfgrasses. Guarisco (2001) reported *Baeus* sp. as a parasitoid on pirate spider, *Mimetus* sp., egg sacs. Carstens et al. (2007) recorded occurrence of a higher number of scelionid wasps during late- July corresponding to a second-generation of western chinch bug, *Blissus occiduus* Barber. In the southeastern United States, southern chinch bug, *B. insularis* is a serious pest of St. Augustinegrass (Reinert 1978, Cherry 2001). More studies are required to further determine the potential of scelionid wasps for suppressing chinch bugs.

Figitids, mainly *Hexacola* sp., were more abundant in St. Augustinegrass than in all other turfgrasses in this study (Table 1). Eskafi and Legner (1974) observed *Hexacola* sp. as a parasite of the dipteran eye gnats, *Hippelates* sp. (Chloropidae). *Emargo* sp., also figitids, were evenly represented in all grass types in our study. Little is known about their role in turfgrass systems.

Both ichneumonids and braconids were captured equally in all turfgrass types except in tall fescue. Braman et al. (2004) noticed significant parasitism of first- or second-instar fall armyworm, *S. frugiperda,* larvae by the braconid, *Aleiodes laphygmae* Viereck in different turfgrasses. Parasitism was greatest in the seashore paspalum grass cultivar, 'Sea Isle 1', compared with bermudagrass or zoysiagrass cultivars. Occurrence of braconids, *Cotesia marginiventris* Cresson and *Meteorus* sp., was also observed on first- or second-instar fall armyworm larvae in their study. In our study, we noted greater representation of both ichneumonids and braconids in June than in July samples. Conversely, Braman et al. (2004) recorded higher events of parasitism by *A. laphygmae* in July than in other summer months. Other parasitic hymenopterans collected were 216 ceraphronid, 21 diapriid, and 4 cynipid wasps among all turfgrasses.

Dryinids develop within the host abdomen creating a protrusion or 'bulged cyst' lined by the molted skin of wasp larvae (Krombein et al. 1979). While we did not observe any dryinid wasps or dryinid-parasitized host from zoysiagrass in our samples, all the adults collected were *Gonatopus* sp. and were more abundant in tall fescue than any other turfgrasses sampled (Table 1). The total of 45 dryinids including both free-living adults and those within parasitized-hosts were collected during the entire season. Parasitized-hosts, cicadellids ($F = 12.54$; df = 4, 472; $P < 0.0001$) and delphacids ($F = 4.16$; df = 4, 473; $P = 0.0025$) were more abundant in tall fescue and St. Augustinegrass, respectively (Table 3). It is noteworthy that a greater proportion of the delphacids were parasitized by dryinid wasps than cicadellids in identical settings (Table 3).

Table 3. Mean (± S. E.) Cicadellidae or Delphacidae parasitized by Dryinidae per 4.6- by 4.6-m during May-July 2005 in Spalding Co., GA.

	Parasitized Cicadellidae		Parasitized Delphacidae	
Grass Genotype	Mean ± SEM	P:H	Mean ± SEM	P:H
Bermudagrass	0.13 ± 0.06a	1:1	0.00 ± 0.00a	-
Centipedegrass	0.01 ± 0.01a	1:1	0.01 ± 0.01a	2:1
St.Augustinegrass	0.00 ± 0.00b	-	0.07 ± 0.03a	1.16:1
Zoysiagrass	0.00 ± 0.00a	-	0.00 ± 0.00a	-
Tall Fescue	0.70 ± 0.44a	1:1	0.00 ± 0.00b	-

Means followed by the same letter are not significantly different ($P < 0.05$; Fisher's LSD). The abbreviation P:H = No. of parasitoids (P) per individual host (H).

Dryinid wasps parasitized leafhoppers (Cicadellidae) and planthoppers (Delphacidae) in forage-type bermudagrass (Buntin 1989). Approximately 10% parasitism occurred in that study, with peak incidence starting from May through July. We observed only 0.07% and 0.08% parasitized cicadellids or delphacids, respectively. More dryinids were captured in July than in June samples.

Vacuum sampling proved to be more efficient than sweep sampling for collecting minute Hymenoptera in our study (Table 2). However, whereas 82.2% of the total minute wasps were collected in vacuum samples, encyrtid, pteromalid, ichneumonid, braconid, diapriid and dryinid wasps were captured in similar numbers by both collecting methods.

Our results demonstrate an abundant and diverse community of parasitic wasps in residential turfgrasses in central Georgia that could be a focus of conservation efforts. More than half of the parasitoid taxa examined varied with turf type in our study, consistent with our other published data on turf taxa impact on natural enemy occurrence and abundance (Braman et al. 2003, 2004, Joseph and Braman 2009a,b). This may reflect microhabitat suitability or primary or alternate host preference for turf species. It is important to conserve parasitoids to enhance natural suppression of turfgrass pests without compromising aesthetic value. Additional research addressing impact of parasitic wasps as mediated by turf genotype may help to more effectively manage parasitoids in specific arthropod communities in the turfgrass ecosystem.

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References Cited

Abraham, C. M., D. W. Held and C. Wheeler. 2010. Seasonal and diurnal activity of *Larra bicolor* (Hymenoptera: Crabronidae) and potential ornamental plants as nectar sources. Online. Appl. Turfgrass Sci. doi:10.1094/ATS-2010-0312-01-RS.

Ashley, T. R., C. S. Barfield, V. H. Waddill and E. R. Mitchell. 1983. Parasitization of fall armyworm of volunteer corn, bermudagrass, and paragrass. Fla. Entomol. 66: 267-271.

Braman, S. K., R. D. Oetting and W. Florkowski. 1997. Assessment of pesticides use by commercial landscape maintenance and lawn care firms in Georgia. J. Entomol. Sci. 32: 403-411.

Braman, S. K., R. R. Duncan and M. C. Engelke. 2000a. Evaluation of turfgrasses for resistance to fall armyworms (Lepidoptera: Noctuiidae). HortScience 35: 1268-1270.

Braman, S. K., R. R. Duncan, W. W. Hanna and W. G. Hudson. 2000b. Evaluation of turfgrasses for resistance to mole crickets (Orthoptera: Gryllotalpidae). HortScience 35: 665-668.

Braman, S. K., A. F. Pendley, R. N. Carrow and M. C. Engelke. 1994. Potential resistance in zoysiagrasses to tawny mole crickets (Orthoptera: Gryllotalpidae). Fla. Entomol. 77: 302-305.

Braman, S. K., A. F. Pendley and W. Corley. 2002. Influence of commercially available wildflower mixes on beneficial arthropod abundance and predation in turfgrass. Environ. Entomol. 31: 564-572.

Braman, S. K., R. R. Duncan, W. W. Hanna and M. C. Engelke. 2003. Arthropod predator occurrence and performance of *Geocoris uliginosus* (Say) on pest-resistant and susceptible turfgrasses. Environ. Entomol. 32: 907-914.

Braman, S. K., R. R. Duncan, W. W. Hanna and M. C. Engelke. 2004. Turfgrass species and cultivar influences on survival and parasitism of fall armyworm. J. Econ. Entomol. 97: 1993-1998.

Buntin, G. D. 1989. Dryinid (Hymenoptera: Dryinidae) parasites of leafhoppers and planthoppers (Homoptera) in forage-type bermudagrass. J. Kans. Entomol. Soc. 53: 441-447.

Cappaert, D. L. and D. R. Smitley. 2002. Parasitoids and pathogens of Japanese beetle (Coleoptera: Scarabaeidae) in southern Michigan. Environ. Entomol. 31: 573-580.

Carstens, J., T. Heng-Moss, F. Baxendale, R. Gaussoin, K. Frank and L. Young. 2007. Influence of buffalograss management practices on western chinch bug and its beneficial arthropods. J. Econ. Entomol. 100: 136-147.

Chantos, J. M., S. B. Vinson and K. R. Helms. 2009. Distribution and abundance of parasites of the rhodesgrass mealybug, *Antonina graminis:* reassessment of a classic example of biological control in the southeastern United States. J. Insect Sci. 9: 48.

Cherry, R. 2001. Spatial distribution of southern chinch bugs (Hemiptera: Lygaeidae) in St. augustinegrass. Fla. Entomol. 84: 151-153.

Dean, H. A. and M. F. Schuster. 1958. Biological control of rhodes-grass scale in Texas. J. Econ. Entomol. 51: 363-366.

Dean, H. A., M. F. Schuster and J. C. Bailey. 1961. The introduction and establishment of *Dusmetia sangwani* on *Antonina graminis* in South Texas. J. Econ. Entomol. 54: 952-954.

van Driesche, R., M. Hoddle and T. Center. 2008. Control of pests and weeds by natural enemies. Blackwell Pub., Boston, MA.

Eskafi, F. M. and E. F. Legner. 1974. Parthenogenetic reproduction in *Hexacola* sp. near *zvebsteri*, a parasite of *Hippelates* eye gnats. Ibid. 67: 767-768.

Frank, S. D. and P. M. Shrewsbury. 2004. Effect of conservation strips on the abundance and distribution of natural enemies and predation of *Agrotis ipsilon* (Lepidoptera: Noctuidae) on golf course fairways. Environ. Entomol. 33: 1662-1672.

Guarisco, H. 2001. Description of the egg sac of *Mimetus epeiroides* (Araneae: Mimetidae) and egg parasitism by *Baeus* sp. (Hymenoptera: Scelionidae). Trans. Kans. Acad. Sci. 104: 237-238.

Held, D. W. 2005. Occurrence of *Larra bicolor* (Hymenoptera: Sphecidae), ectoparasite of mole crickets (*Scapteriscus* spp.), in coastal Mississippi. Fla. Entomol. 88: 327-328.

Heng-Moss, T. M., F. P. Baxendale and T. P. Riordan. 1998. Beneficial arthropods associated with buffalograss. J. Econ. Entomol. 91: 1167-1172.

Hudson, W. G., J. H. Frank and J. L. Castner. 1988. Biological control of *Scapteriscus* spp. mole crickets (Orthoptera: Gryllotalpidae) in Florida. Bull. Entomol. Soc. Am. 34: 192-198.

Irvin, N. A. and M. S. Hoddle. 2005. Determination of *Homalodisca coagulata* (Hemiptera: Cicadellidae) egg ages that are suitable for oviposition by *Gonatocerus ashmeadi, G. triguttatus* and *G. fasciatus* (Hymenoptera: Mymaridae). Biol. Control 32: 391-400.

Jacas, J., J. E. Peña and R. E. Duncan. 2007. Morphology and development of immature stages of *Fidiobia dominica* (Hymenoptera: Platygastridae: Sceliotrachelinae). Ann. Entomol. Soc. Am. 100: 413-417.

Joseph, S. V. and S. K. Braman. 2009a. Influence of plant parameters on occurrence and abundance of arthropods in residential turfgrass. J. Econ. Entomol. 102: 1116-1122.

Joseph, S. V. and S. K. Braman. 2009b. Predatory potential of *Geocoris* spp. and *Orius insidiosus* (Say) on fall armyworm in resistant and susceptible Turf. J. Econ. Entomol. 102: 1151-1156.

Krombein, K. V., P. D. Hurd Jr., D. R. Smith and B. D. Burks. 1979. Catalog of Hymenoptera in America and North of Mexico. Smithsonian Institution Press. Symphyta & Apocrita (Parasitica). 1:1240.

LaSalle, J. 1994. North America genera of Tetrastichinae (Hymenoptera: Eulophidae). J. Nat. Hist. 28: 109-236.

Lill, J. T., R. J. Marquis and R. E. Ricklefs. 2002. Host plants influence parasitism of forest caterpillars. Nature 417: 170-173.

Muesebeck, C. F. W. 1954. Three new mealybug parasites of the genus *Allotropa* (Hymenoptera: Platygrasteridae). Bull. Brooklyn Entomol. Soc. 46: 18-21.

Questel, D. D. and W. G. Genung. 1957. Establishment of the parasite *Anagyrus antoninae* in Florida for control of rhodesgrass scale. Fla. Entomol. 40: 123-125.

Price, P. W. 1986. Ecological aspects of the host plant resistance and biological control: interactions among three trophic levels, Pp. 11-30. *In* D. J. D. J. Boethel and R. D. Eikenbary [eds], Interactions of plant resistance and parasitoids and predators of insects. Wiley, New York.

Reinert, J. A. 1972. New distribution and host record for the parasitoid *Eumicrosoma benefica*. Fla. Entomol. 55: 143-144.

Reinert, J. A. 1978. Natural enemy complex of the southern chinch bug in Florida. Ann. Entomol. Soc. Am. 71: 728-731.

Reinert, J. A. and S. B. Vinson. 2010. Preference among turfgrass genera and cultivars for colonization by rhodesgrass mealybug, *Antonina graminis* (Hemiptera: Pseudococcidae). Southwest. Entomologist 35: 121-128.

Riherd, P. T. 1950. Biological notes on *Anagyrus antoninae* Timberlake (Hymenoptera: Encyrtidae) and its host *Antonina graminis* (Maskell) (Homoptera: Coccidae). Fla. Entomol. 33: 18-22.

Riherd, P. T. 1951. Status of the rhodes grass scales parasites in Texas. J. Econ. Entomol. 44: 622-623.

Rogers, M. E. and D. A. Potter. 2002. Kairomones from scarabaeid grubs and their frass as cues in below-ground host location by the parasitoids *Tiphia vernalis* and *Tiphia pygidialis*. Entomol. Exp. Appl. 102: 307-314.

Sandanayaka, W. R. M., J. G. Charles and D. J. Allan. 2009. Aspects of the reproductive biology of *Pseudaphycus maculipennis* (Hym: Encyrtidae), a parasitoid of obscure mealybug, *Pseudococcus viburni* (Hem: Pseudococcidae). Biol. Control 48: 30-35.

SAS Institute. 2003. User's manual, version 9.1, SAS Institute, Cary, NC.

Wang, Y., R. L. Crocker, L. T. Wilson, G. Smart, X. Wei, W. T. Nailon Jr. and P. P. Cobb. 2001. Effects of nematode and fungal treatments on nontarget turfgrass-inhabiting arthropod and nematode populations. Environ. Entomol. 30: 196-203.