Difference in the abundance of scale insect parasitoids among four cardinal directions

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Assessment of the impact of biological control requires a reliable method of estimating the densities and spatial distribution patterns of natural enemies and their prey or hosts. There is no consistent pattern in the distribution and abundance of insect pests among tree canopy quadrants. The proportions of 3 thrips species captured on yellow, white, and blue sticky cards were not significantly different among the 4 cardinal directions (Hoddle et al. 2002). The densities of California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae), and citrus mealybug, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae), were not significantly different among the cardinal directions (Meyerdirk et al. 1981; Orphanides et al. 1984), whereas those of mango mealybug, *Rastrococcus invadens* Williams (Hemiptera: Pseudococcidae), on the southern quadrant (Boavida et al. 1992) and of black scale, *Saissetia oleae* (Olivier) (Hemiptera: Coccidae), on the northern quadrant were higher than on other quadrants (Podoler et al. 1979). To the best of our knowledge, there is no published information on the distribution pattern of scale insect parasitoids within a tree canopy.

We conducted this experiment to assess differences in the abundance of scale insect parasitoids among the 4 cardinal directions. Groups of in-ground, mature willow oak trees, *Quercus phellos* L. (Fagaceae), were sampled in Florence, South Carolina (SC; 6 trees at 1 site), and Virginia Beach, Virginia (VA; 2 sites, 1 tree per site). The trees were 7 to 9 m tall, 10 to 30 cm in trunk diameter at 1.4 m from the ground (at breast height, or DBH), 5 to 6 m in canopy width, and were growing in narrow islands (covered with turfgrass and surrounded by pavement) in parking lots. All trees were infested by mixed populations of oak lecanium, *Parthenolecanium quercifex* (Fitch), and European fruit lecanium, *Parthenolecanium corni* (Bouché) (Hemiptera: Coccidae). These species are commonly found on shade trees in the urban landscapes of the eastern United States. The oak trees were not treated with insecticides during the study.

Yellow sticky cards (7.5 × 12.5 cm) were deployed, 1 at each of the 4 cardinal directions, 1.5 to 1.8 m from the ground, and close to the edge of the canopy. All cards were collected and replaced weekly at each site from Apr to Sep 2011 in VA, and Mar to Aug 2012 in SC. Each yellow sticky card was divided into fifteen 6.25 cm^2 squares per side. Five squares were selected for determining parasitoid morphospecies and density on 1 side of the card. The 5 squares and the side of the card examined were chosen randomly (Urbaniak & Plous 2014). The parasitoid densities obtained from the 5 selected squares were extrapolated to estimate the total abundance on 1 side of each card. Parasitoid species composition in each state was determined. Differences in parasitoid abundance among cardinal directions and sampling times were assessed by repeated measures analysis of variance (ANOVA) (PROC GLM; SAS Institute 2011) in each state for 1) all parasitoid species combined, and 2) the 3 most abundant parasitoid species (at least 10% of the total parasitoid population).

Scale densities were determined for each cardinal direction of each oak tree in SC. One 10- to 15-cm-long twig was collected from each cardinal direction on the same day the sticky cards were collected. The scale insects on each twig were counted in the laboratory, and the densities were calculated as the total numbers of scale insects (adults and nymphs) per cm. Differences in scale insect densities among cardinal directions and sampling dates were assessed by repeated measures ANOVA (PROC GLM; SAS Institute 2011). Spearman correlation was conducted to assess correlation between parasitoid abundance and scale insect density in each cardinal direction (PROC CORR; SAS Institute 2011).

Twenty-one parasitoid species were collected, of which 19 species were found in SC and 16 species in VA (Table 1). Seven encyrtid (*Blastothrix* sp. 1 and 2, *Encyrtus* sp. 1, 2 and 3, *Metaphycus* sp. 2, and *Plagiomerus* sp.), 4 aphelinid (*Ablerus* sp., *Coccophagus lycimnia* (Walker), *Coccophagus* sp. 1, *Coccophagoides* sp.), 2 pteromalid (*Eunotus* sp., *Pachyneuron* sp.), and 1 eulophid (*Aprostocetus* sp.) species occurred in both states. Four encyrtid (*Leptomastix* sp., *Metaphycus* sp. 1, and *Microterys* sp. 1 and 2) and 1 aphelinid (*Marietta* sp.) species were found exclusively in SC, whereas 1 aphelinid (*Coccophagus* sp. 2) and 1 encyrtid (*Ceraptocerus* sp.) species were found only in VA. *Coccophagus lycimnia* and *Eunotus* sp. were the most abundant species in both states, followed by *Blastothrix* sp. 1 in SC and *Metaphycus* sp. 2 in VA (Table 1).

Analyses of variance for all parasitoid species did not detect differences in parasitoid abundances among the 4 cardinal directions in SC ($F = 0.59$; df = 3, 24; $P = 0.6304$) or VA ($F = 2.85$; df = 3, 4; $P = 0.1689$). However, abundances varied through time (week) in SC ($F = 81.26$; df = 26, 624; $P < 0.0001$) and VA ($F = 14.47$; df = 22, 88; $P < 0.0001$). An interaction between abundance and time was detected (SC: $F = 1.46$; df = 78, 624; $P < 0.0089$; VA: $F = 1.46$; df = 66, 88; $P < 0.0486$).

The abundances of dominant species found were similar among the 4 cardinal directions: *C. lycimnia* (SC: $F = 1.15$; df = 3, 24; $P = 0.3474$; VA: $F = 1.46$; df = 3, 4; $P = 0.3524$) (Fig. 1), *Eunotus* sp. (SC: $F = 0.22$; df = 3, 24; $P = 0.8810$; VA: $F = 3.88$; df = 3, 4; $P = 0.1117$), *Blastothrix* sp. 1 (SC: $F = 2.06$; df = 3, 24; $P = 0.1327$), and *Metaphycus* sp. 2 (VA: $F = 0.17$; df = 3, 4; $P = 0.9144$). Abundances varied from week to week in all cases: *C. lycimnia* (SC: $F = 83.20$; df = 26, 622; $P < 0.0001$; VA: $F = 13.66$; df = 22, 81; $P < 0.0001$), *Eunotus* sp. (SC: $F = 98.44$; df = 26, 622; $P <$

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Table 1. Parasitoid morphospecies trapped on sticky cards deployed on willow oaks infested with *Parthenolecanium* spp. in South Carolina and Virginia.

Family	Morphospecies	South Carolina (N = 11,467) % Population	Virginia (N = 1,623) % Population
Aphelinidae	*Ablerus* sp.	0.9 ± 0.1	0.1 ± 0.1
	Coccophagus lycimnia	32.3 ± 2.8	45.0 ± 0.3
	Coccophagus sp. 1	2.1 ± 0.3	3.1 ± 0.9
	Coccophagus sp. 2	N/P[a]	0.1 ± 0.1
	Coccophagoides sp.	0.4 ± 0.1	1.0 ± 0.8
	Marietta sp.	0.3 ± 0.1	N/P[a]
Encyrtidae	*Blastothrix* sp. 1	14.2 ± 1.6	2.7 ± 1.1
	Blastothrix sp. 2	0.3 ± 0.1	2.0 ± 0.1
	Cerapterocerus sp.	N/P[a]	0.2 ± 0.2
	Encyrtus sp. 1	0.2 ± 0.1	4.1 ± 0.5
	Encyrtus sp. 2	2.8 ± 0.2	<0.1
	Encyrtus sp. 3	0.3 ± 0.1	1.1 ± 0.6
	Leptomastix sp.	<0.1	N/P[a]
	Metaphycus sp. 1	1.7 ± 0.3	N/P[a]
	Metaphycus sp. 2	2.5 ± 0.1	12.5 ± 2.9
	Microterys sp. 1	<0.1	N/P[a]
	Microterys sp. 2	0.1 ± 0.1	N/P[a]
	Plagiomerus sp.	4.9 ± 0.4	1.0 ± 1.0
Eulophidae	*Aprostocetus* sp.	4.7 ± 0.4	4.0 ± 1.2
Pteromalidae	*Eunotus* sp.	20.7 ± 4.4	22.7 ± 7.7
	Pachyneuron sp.	8.8 ± 0.6	3.3 ± 1.2

[a] N/P = not present

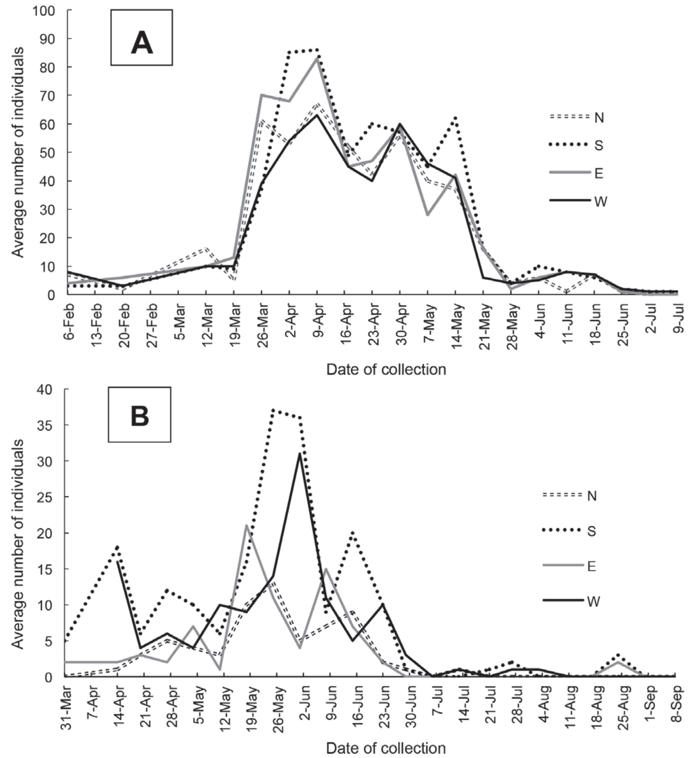

Fig. 1. Abundance of *Coccophagus lycimnia* captured with yellow sticky cards at the cardinal directions on willow oaks in **(A)** South Carolina and **(B)** Virginia. E = East, N = north, S = south, W = west.

0.0010; VA: F = 22.16; df = 22, 87; P < 0.0001), *Blastothrix* sp. 1 (SC: F = 142.85; df = 26, 622; P < 0.0001), and *Metaphycus* sp. 2 (VA: F = 9.99; df = 22, 87; P < 0.0001). Interactions between cardinal directions and time were not significant in most cases: *C. lycimnia* (SC: F = 1.05; df = 28, 622; P = 0.3597; VA: F = 1.28; df = 66, 87; P = 0.1412), *Eunotus* sp. (SC: F = 0.74; df = 28, 622; P = 0.9484), *Blastothrix* sp. 1 (SC: F = 0.67; df = 28, 622; P = 0.9869), and *Metaphycus* sp. 2 (VA: F = 0.66; df = 66, 87; P = 0.9597). *Eunotus* sp. densities in VA exhibited a higher abundance in the eastern quadrant from mid- to late Apr, and a higher abundance in the southern quadrant from mid-May to early Jun (F = 5.14, df = 66, 87, P < 0.0001).

In SC, scale insect densities did not differ among cardinal directions (F = 0.84; df = 3, 644; P = 0.4744). Scale insect densities were greatest in the earlier part of the year (F = 10.77; df = 3, 598; P < 0.0001). As adults completed reproduction and died, the densities of scale insects declined over time. Parasitoid densities were significantly, but weakly, correlated to scale insect densities in all cardinal directions (east: P = 0.0013, ρ = 0.2524; north: P < 0.0001, ρ = 0.3576; south: P = 0.0034, ρ = 0.2290; west: P = 0.0015, ρ = 0.2495). The result suggests that the parasitoid abundance was weakly dependent upon the scale insect densities at each cardinal direction.

Yellow sticky traps are frequently used to monitor insect diversity and seasonal activity, particularly of small insects (Hoelmer et al. 1998; Hoddle et al. 2002). Yellow sticky traps are known to attract many species of parasitoids, including aphelinids, encyrtids, and pteromalids (Neuenschwander 1982; Moreno et al. 1984; Schultz 1984, 1985, 1990; Samways 1986; McClain et al. 1990; Hoelmer et al. 1998). Schultz (1984, 1985, 1990) reported on abundances of natural enemies of *P. quercifex* (especially hymenopteran parasitoids) with yellow sticky cards. However, Schultz (1984, 1985, 1990) did not assess distributions of the parasitoids among tree quadrants. In our study, there were no differences in the abundances of parasitoids and scale insects among the cardinal directions, but the parasitoid abundance was weakly correlated to scale insect density in each cardinal direction. The small sample size of this study (i.e., 8 trees in SC and 2 trees in VA) may not be sufficient to detect statistical differences in parasitoid and scale insect densities among the cardinal directions. Future studies with larger sample size and number of sites would be needed to confirm the observations of this study. Despite this shortcoming, the results of this study suggest that a single sticky card per tree could be used for assessing parasitoid abundance, independently of the quadrant where the trap is deployed. The use of only 1 sticky card per tree can reduce the time, labor, and material costs of sampling.

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Summary

We conducted a study to assess the potential differences in the abundances of hymenopteran parasitoids among cardinal directions. Experiments were conducted on scale insect–infested willow oak trees in the urban landscapes of South Carolina and Virginia. The parasitoids captured on yellow sticky cards deployed at the cardinal directions of the trees were identified and counted. We found that there were no

significant differences in scale insect and parasitoid abundances among cardinal directions, and parasitoid abundances were weakly correlated with scale insect densities. The results suggest that 1 yellow sticky card could be deployed per tree, regardless of tree quadrant, to sufficiently sample for parasitoid abundance.

Key Words: Coccidae; Hymenoptera; tree quadrant; sampling; oak lecanium; European fruit lecanium

Sumario

Se realizó un estudio para evaluar posibles diferencias en la abundancia de parasitoides himenópteros entre los diferentes puntos cardinales. Los experimentos se desarrollaron en árboles de robles sauces infestados con cochinillas en localidades urbanas de Carolina del Sur y Virginia. Los parasitoides capturados en las tarjetas pegajosas amarillas colocadas en los puntos cardinales de los árboles fueron identificados y contados. No hallamos diferencias significativas en las abundancias de parasitoides entre puntos cardinales. Los resultados sugieren que el uso de una sola tarjeta pegajosa amarilla por árbol, independientemente del cuadrante en donde se coloque, sería suficiente para muestrear la abundancia de parasitoides himenópteros.

Palabras Clave: Coccidae; himenóptera; cuadrante arbóreo; muestreo; lecanium del roble; lecanium europeo del fruto

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