Effect of shading on trap nest utilization by hole-nesting aculeate Hymenoptera

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For many years, trap nests have been used to study hole-nesting bees and wasps (aculeate Hymenoptera) and to monitor their diversity and abundance (Krombein 1967; Danks 1971; Godfrey and Hilton 1983; Frankie *et al.* 1998). Trap nests are valuable for environmental assessment (Tscharntke *et al.* 1998) and for agriculture through improved pollination by bees (Bosch 1994; Stubbs *et al.* 1997; Hallett 2001) and biological control by wasps (Harris 1994). Frankie *et al.* (1988) indicated that shaded environments might be preferred habitats for some solitary bees that use tree holes for nesting. Shading could offer protection from natural enemies as well as wind, rain, and sunlight, resulting in stabilized humidity and temperature. As far as we are aware, ours is the first experimental study to consider the effect of shading of trap nests.

Our study was made during the summer of 2003, in the Carolinian forest zone, southern Ontario, Canada (42°37′–42°48′N, 80°25′–80°39′W). We selected eight sites in the forest, each separated from the others by at least 4 km. At each site, six nest boxes were attached to trees 1–1.5 m above ground at the corners of a hexagonal array 50 m from the randomly selected centre point. The directionality of each box was randomly selected (north-, south-, east-, and west-facing entrances). Each nest box was constructed from a 2-L milk carton (9.5 cm × 9.5 cm × 16.5 cm) with a polystyrene insert (Fig. 1). Each box contained nine paper tubes of each of four different sizes (3, 5, 7, or 9 mm internal diameter × 15 cm depth) (Custom Paper Tubes Inc, Cleveland, Ohio) to give various bee and wasp species opportunities to make their nests. The tubes were supported by holes in the polystyrene insert. The six nest boxes at each site were divided randomly between the two treatments: three boxes in the shaded treatment and three boxes in the non-shaded treatment. Shading was provided by pieces of burlap that extended 10–15 cm over the edges of the tops and sides of the nest boxes (Fig. 1). We collected and counted tubes plugged by aculeate Hymenoptera five times, at 13- to 16-day intervals, from 25 June to 20 August 2003. After each collection, we replaced plugged tubes with empty ones. The total number of tubes with end plugs from each of the nest boxes at each of the sites was counted.

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FIGURE 1. Nest box, shaded by burlap, with 36 tubes of four different diameters (3, 5, 7, and 9 mm). Some tubes have end plugs.

TABLE 1. Number (mean ± SE) of tubes with end plugs (i.e., containing aculeate Hymenoptera nests) collected at each of the five sampling times from shaded and non-shaded nest boxes.

	Sampling time				
Treatment	1st	2nd	3rd	4th	5th
Shaded	2.3±0.80	8.0±1.59	8.0±2.54	26.0±8.39	25.9±5.68
Non-shaded	1.0±0.38	5.9±1.93	5.3±2.40	15.4±5.53	17.6±6.77

NOTE: Mean numbers of tubes with end plugs differed between shaded and non-shaded treatments ($P = 0.0433$).

A total of 921 plugged tubes, 92 from 3-mm tubes, 308 from 5-mm tubes, 318 from 7-mm tubes, and 203 from 9-mm tubes, were collected. Of the total, 561 were collected from shaded nest boxes. More plugged tubes were collected from shaded than from non-shaded boxes at each of the five sampling times (Table 1). Scatterplots and the Shapiro–Wilk test of normality were made using SAS (version 8.2, SAS Institute Inc, Cary, North Carolina) to confirm the assumptions of residuals to the variance analysis. Non-normally distributed variables from all tubes were $\log(x + 1)$ transformed. Analysis of repeated measurements was then used with the PROC MIXED procedure of SAS for comparison of the mean numbers of plugged tubes between the two treatments.

Our results indicate a significant difference ($F_{1,7} = 6.06$, $P = 0.0433$) between the treatments. No interaction of treatment × sampling times was detected ($F_{4,56} = 0.05$, $P = 0.9943$). Analyses to compare the effects of shading on colonization among tube sizes were not performed because the sample sizes were too small to obtain normalized variance for each of the tube sizes. Many hole-nesting bees and wasps show preferences for different sizes of trap tubes (Fricke 1991), and forthcoming identification of the insects we collected and reared from the study tubes will enable more detailed discussion in a

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future paper. However, this study's results clearly indicate that our simple, easily obtained, and inexpensive shading technique leads to an increase in the number of plugged tubes. Use of this technique, therefore, could enhance environmental monitoring and improve rearing of agriculturally important hole-nesting aculeate Hymenoptera.

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