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COMPARISON OF THE NEST MATERIALS OF *POLISTES GALLICUS* (L.), *POLISTES DOMINULUS* (CHRIST) AND *POLISTES NIMPHA* (CHRIST) (HYMENOPTERA: VESPIDAE)

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Abstract - The aim of this study was to determine and compare the nest materials and some physical features and elemental composition of the nests of *Polistes gallicus* (L.), *Polistes dominulus* (Christ) and *Polistes nimpha* (Christ) collected in similar ecological conditions. The nest architectures of the three species were similar. In the *P. gallicus* nest, the average thickness of the fibers was 5.73 µm, the nitrogen concentration was 26.14%, and percentages of the fibers and saliva were 77% and 23%, respectively. In the *P. dominulus* nest, the average thickness of the fibers was 8.7 µm, and the nitrogen concentration was 27.42%; the percentages of fiber and saliva were 78% and 22%, respectively. In the *P. nimpha* nest, the average thickness of the fibers was 9.04 µm, the nitrogen concentration was 25.82%, and the percentages of the fiber and saliva were 42% and 58%, respectively. There were differences in the amount of saliva and nitrogen concentrations.

Key words: *Polistes gallicus*, *Polistes dominulus, Polistes nimpha,* nest material, SEM, Vespidae, Turkey

INTRODUCTION

The genus *Polistes* is known as a eusocial paper wasp (Reeve,1991). They use paper pulps that are obtained from a mixture of oral secretions and plant fibers to construct their nests (Evans and West Eberhard, 1970). The oral secretion is used to physically protect their nest from the effects of rain and weathering (Kudô et al., 2001). They build up their nests by using various organic and inorganic materials (Spradbery, 1973; Edwards, 1980). The nests of *Polistes* consist of a single petiolate and a comb. The comb is not covered with an envelope. The nest is made of chewed plant fibers from weathered wood and other sources (Jeanne, 1975). Nests occur in or on vegetation, and on manmade structures such as the roofs and eaves of buildings. There are interspecific variations in preferred nesting sites (Evans and West Eberhard, 1970).

The physical properties of nest paper were studied in *Dolichovespula sylvestris, Dolichovespula norwegica* and *Vespula vulgaris* (Cole et al., 2001). The nests of *Polistes fuscatus* and *Polistes dominulus* were tested for water absorbency, toughness and protein concentration (Curtis et al., 2005). The chemical composition of oral secretion and the amino acid composition of protein were examined in *Polistes annularis* (Espelie and Himmelsbach, 1990), *Polistes metricus* (Singer et al., 1992), *Polistes riparius* (Kudô et al., 2000), *Polistes chinensis* (Kudô et al., 1998, Kudô 2000) and *Polybia paulista* (Kudô et al., 2001).

A genus (*Polistes*) and 9 species belonging to Polistinae are known in Turkey (Yildirim and Kojima, 1999); however, the kind of nest material and their chemical and physical properties have not been studied in detail. In this study, the nest materials of *Polistes gallicus* (L.), *Polistes dominulus* (Christ) and *Polistes nimpha* (Christ) collected from similar

habitats were studied to identify whether there were differences in the nest material chosen, the features of nest material and nest construction of the three *Polistes* species in similar ecological conditions. The aim of this study was the determination of similarity and diversity of their nests in terms of some physical and chemical features. The kind of nest materials, their chemical components, and some physical properties were determined and compared.

MATERIALS AND METHODS

Nest collection and material examined

All nest materials were collected from various districts in Nigde, located in southern Anatolia at an altitude of 1200 m. In this province, a terrestrial climate and steppe vegetation prevail. The nests of *Polistes gallicus* were collected in Campus on 01.09.2008, in Bor on 03.09.2008, and in Bahceli on 05.09.2008 (n=5). The nests of *Polistes dominulus* were collected in Zengen on 15.08.2008, and in Bor on 21.08.2008 (n=5). The nests of *Polistes nimpha* were collected in Bor on 21.08.2008, and in Campus on 01.09.2008, 12.09.2008 (n=5). Larvae, pupas and eggs were removed from the nest. The nests were stored in the Entomology Laboratory at Biology Department of Nigde University, Turkey.

Observation of surface and analysis

Small fragments of the nest's outer wall were cut from the combs and observed with a Stereomicroscope (OLYMPUS SZX16) and Scanning Electron Microscope (LEO 440). The thickness of plant fibers were measured and elemental composition analysis was made with SEM (LEO 440). The edge length and diameter of the combs' cells were measured with a Stereomicroscope.

Data analysis

Measurements are given as mean±standard error. Differences in both the edge length and diameter of the combs' cells were analyzed by one-way ANOVA and post-hoc analyses (Tukey's Test). The statistical program SPSS 11.1 was used for all analyses.

Percentage of plant material and oral secretion

The dried nest fragment was weighed. A fragment of the wall was immersed in 0.5 N KOH solution and kept at 70°C for 4-5 h. After the oral secretion was melted and the fibers were unbound, the fibrous components were filtrated and separated from the secretion. The fibrous material was washed with water and dried in an electric oven. It was weighed with filter paper. Then the percentage proportion of plant material and oral secretion were estimated as in the following formula:

$$\text{Fiber (cellulose) (\%)} = (k_1 / k_2) \times 100$$

where k_1= dried weight of sample before process; k_2 = dried weight of sample after process) (Yamane et al., 1999).

RESULTS

The colors of the nests of three species were beige and grey, with dark grey linings. The smallest and largest sizes (width and length) of *P. gallicus, P. nimpha* and *P. dominulus* nests were 3.4x5.6 cm, 3.3x4.5 cm, 3.5x11.6 cm and 7.1x8.5 cm, 7.9x9.1 cm, 8.5x8.7 cm, respectively. The weights of the nests of *P. gallicus, P. nimpha* and *P. dominulus* were 1.5813 ± 0.36 g, 3.1519 ± 1.95 g and 3.7246 ± 0.39 g, respectively. The measurements of the edge length and diameter of the combs' cells of *P. gallicus, P. nimpha* and *P. dominulus* were 2.1 ± 0.08 mm, 3.2 ± 0.04 mm, 4 ± 0.06 mm and 2.5±0.09 mm, 4.3±0.03 mm, 5.3±0.06 mm, respectively (n=50 for each species).

There were overall significant differences in the edge length of the three species ($F_{(2,147)}$=79.88, P<0.0001). Post-hoc analyses showed that these differences arise from significant differences between *P. gallicus* and *P. nimpha* (Tukey, $HSD_{[50.00]}$ =0.98, P<0.0001) and significant differences between *P. gallicus* and *P. dominulus* (Tukey, $HSD_{[50.00]}$ =1.16, P<0.0001), but there were no significant differences between *P. nimpha* and *P. dominulus*. There were also

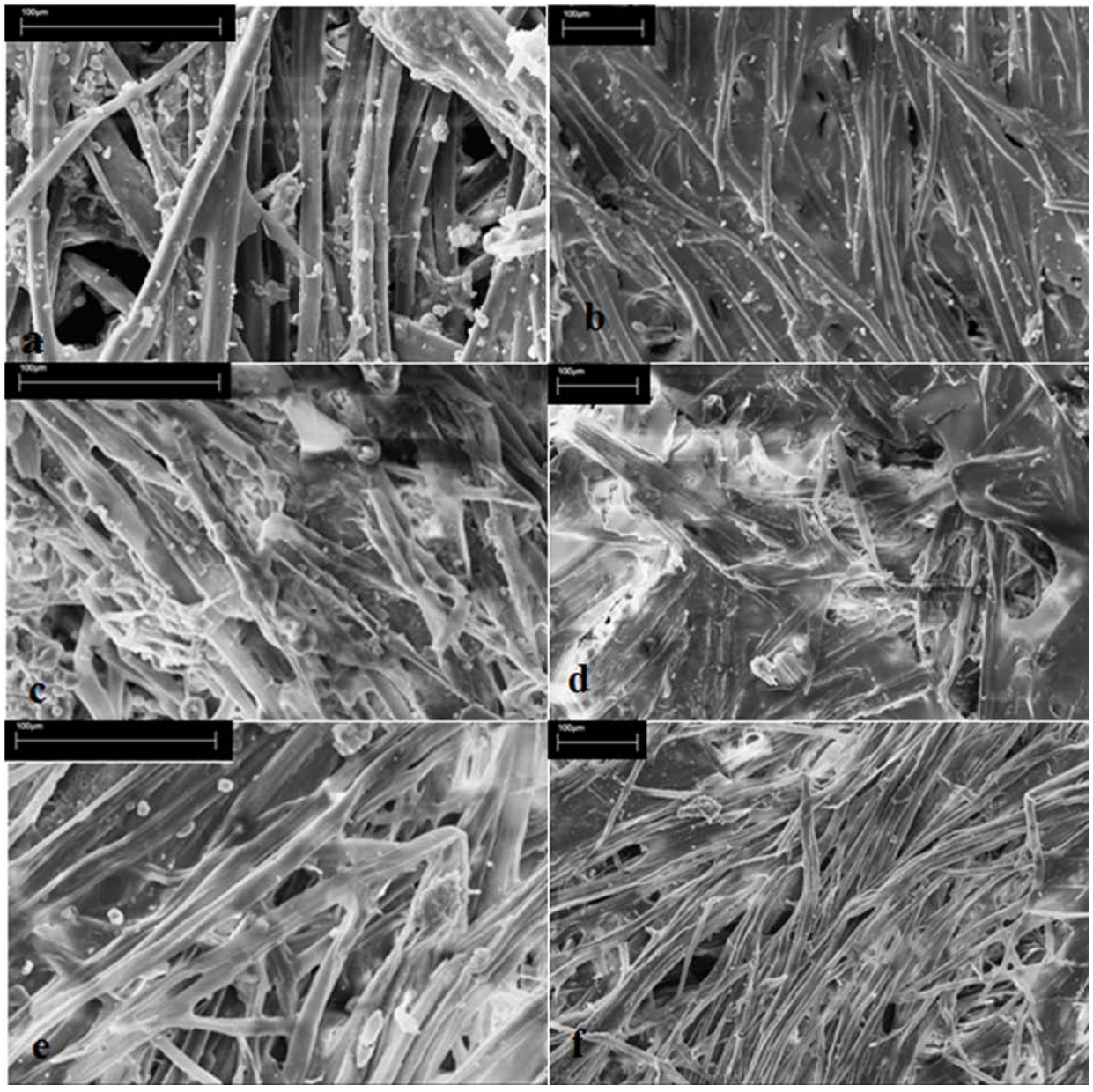

Fig. 1 (a-f). Surface of the nest's wall observed by SEM: a-b, *Polistes dominulus;* c-d, *Polistes nimpha;* e-f, *Polistes gallicus* (each scale is 100μm).

significant differences in the diameter of the three species' nests ($F_{(2,147)}$=433.34, P<0.0001). Post-hoc analyses showed that these differences resulted from differences between each group measurements (e.g. between *P. gallicus* and *P. nimpha* (Tukey, $HSD_{[50.00]}$ =1.96, P<0.0001), between *P. gallicus* and *P. dominulus* (Tukey, $HSD_{[50.00]}$ =2.88, P<0.0001), between *P. nimpha* and *P. dominulus* (Tukey, $HSD_{[50.00]}$ =0.92, P<0.0001)).

The fundamental structures of the nest surfaces observed by SEM were similar. The fibers were bound together with the oral secretion. The fibers were fine and long. The plant fiber thicknesses of the nests of *P.*

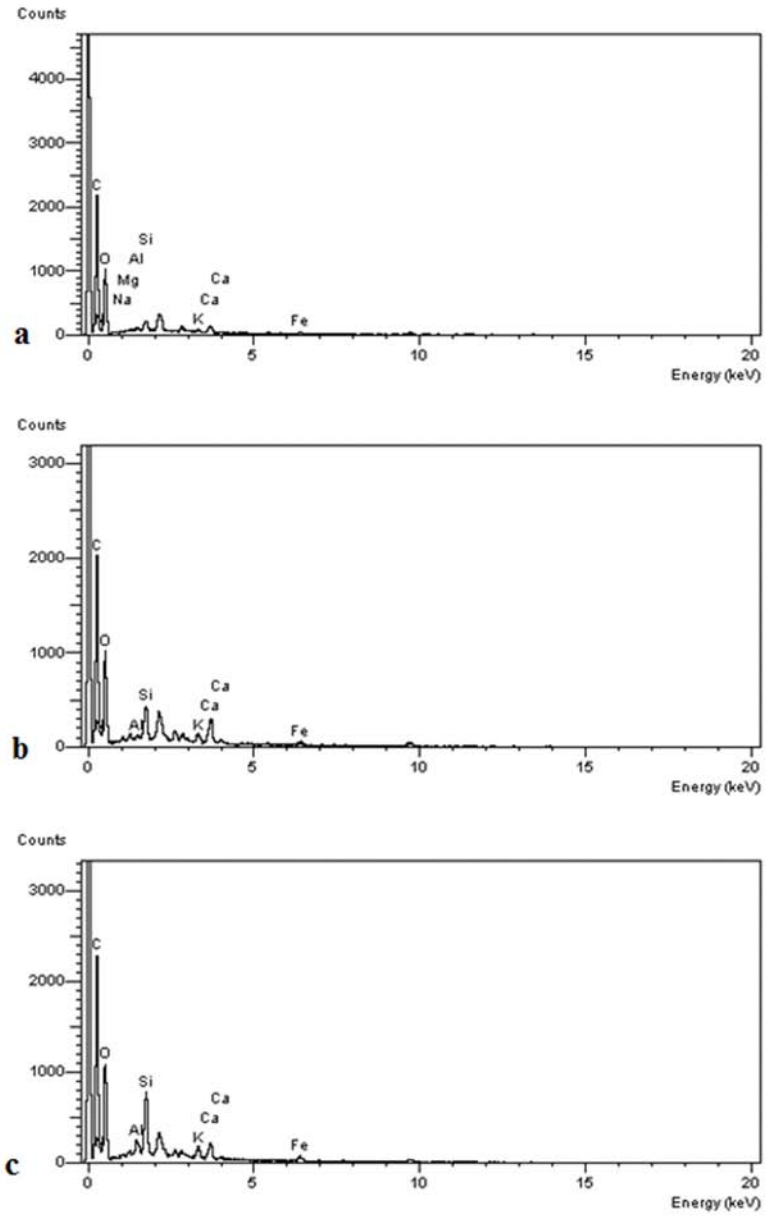

Fig. 2 (a-c). EDX spectra of elements embedded in the wall of the comb: *Polistes gallicus* (a); *Polistes dominulus* (b); *Polistes nimpha* (c).

gallicus, P. nimpha and *P. dominulus* were 5.73±1.26 µm, 9.04±1.58 µm and 8.7±2.44 µm, respectively (n=10 for each species). The oral secretions were seen as a thin membrane (SEM micrographs). The oral secretion on the surface of the *P. nimpha* nest was richer than that of *P. gallicus* and *P. dominulus*. The oral secretions on the surface of the *P. dominulus* nest were richer than that of *P. gallicus*. Some inorganic particles were seen after SEM (Fig. 1.a-f).

The elemental composition of the nest wall was analyzed by instrumental analysis. The nitrogen used for the production of the oral secretion by the wasps was an important component of the nest. The inor-

Element	Concentration (%)		
	P. gallicus	*P. dominulus*	*P. nimpha*
C	31.68	30.27	31.73
N	26.14	27.42	25.82
O	39.56	37.94	36.98
Na	0.09	-	-
Mg	0.09	-	-
Al	0.16	0.09	0.60
Si	0.63	1.50	2.53
K	0.29	0.54	0.60
Ca	0.70	1.71	0.96
Fe	0.66	0.52	0.80

Table 1. Elements and their concentration in a fragment according to EDX analysis

ganic particles collected from the near surroundings by the wasps were the source of the inorganic components in the nest wall. Oxygen, carbon and nitrogen were the major elements of the nest fragments of each species. Silicium, calcium, aluminum, potassium, and iron were determined in the nest wall fragment of each species. Magnesium and sodium were found in the fragment of the *P. gallicus* nest wall in a very low concentration. The concentration of silicium in the nest fragment of *P. nimpha* and the concentration of calcium in the nest fragment of *P. dominulus* were higher than the other inorganic elements. The concentrations of elements and EDX spectra are shown in Table 1 and Fig. 2 (a-c).

The percentage amounts of fiber and saliva in the nests of *P. nimpha, P. gallicus* and *P. dominulus* were calculated to be 42%, 77%, 78% and 58%, 23%, 22%, respectively (n=5 for each species).

DISCUSSION

The *Polistes* species prefer long vegetative fibers and plant hairs for nest material. The *Polybia* species utilize a great variety of nest materials (Wenzel, 1991). *Polybia paulista* uses minute vegetable chips, plant hairs and a small amount of mud or inorganic materials (Kudô et al., 2001). According to SEM observations of the nest materials of *Polistes chinensis* (Kudô et al., 1998) and *Polistes riparius* (Yamane et al., 1999), the nests consist of long woody fibers and inorganic particles.

Wasps lick the nest surface and smear it with oral secretion to protect it from the rain (Kudô et al., 2000). The nitrogen content is an index of the amount of oral secretion. The nitrogen content in *Polistes* nests varies considerably (Espelie and Himmelbach, 1990; Singer et al., 1992). *Polybia paulista* uses a small amount of oral secretion according to SEM observation and the nitrogen content was very low in its nest wall (1.59-2.14%) (Kudô et al., 2001). The nitrogen concentrations of *Polistes fuscatus* (McGovern et al., 1988), *Polistes annularis* (Espelie and Himmelsbach, 1990) and *Polistes metricus* (Singer et al., 1992) were 6.6%, 2.8% and 1.4-8.0%, respectively. The amount of plant materials and oral secretion in *Polistes riparius* nests were calculated to be 43-48% and 52-57%, respectively. The amount of plant materials and oral secretion in the nests of *Polistes chinensis* were calculated to be 35-40% and 60-65%, respectively (Yamane, 1999).

The nest architectures of *P. nimpha, P. gallicus* and *P. dominulus* were consistent with information in the literature (Jeanne, 1975; Evans and West Eberhard, 1970). The nests of *Polistes gallicus* were smaller than the nests of the other species. Nest size variations were observed to depend on nest site. The nests in sheltered place were larger than the nests in field. The variations in the edge length and diameter of the combs' cells were not observed to depend on nest site. These variations were correlated to the body size of the wasps, because they use their antennae to guide the construction of the hexagonal cells (Evans and West Eberhard, 1970).

Long vegetable fibers, plant hairs and inorganic particles were observed by SEM micrographs of the nests examined in this study. Plant fibers were arranged regularly and closely. Many inorganic particles were observed in the micrograph of *P. dominulus.*

The nitrogen concentrations in the nest walls of *P. nimpha*, *P. dominulus* and *P. gallicus* were found to be 25.82%, 27.42% and 26.14%, respectively. The nitrogen contents of the three species were higher than those mentioned in previous studies. The amount of inorganic components changed depending on type surroundings. The amount of plant materials in the nests of *P. dominulus*, *P. gallicus* and *P. nimpha* were calculated to be 78%, 77% and 42%, respectively. The amount of oral secretion in the nests of *P. dominulus*, *P. gallicus* and *P. nimpha* were calculated to be 22%, 23% and 58%, respectively. In addition, *P. nimpha* used more oral secretion relative to plant materials than *P. dominulus* and *P. gallicus*.

To conclude, there were no differences among the three species collected in the same ecological conditions in terms of nest material preference and nest architecture. As the amount of saliva and nitrogen concentration were species specific, there were differences in these measurements.

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