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BRACONID WASPS: A BIOLOGICAL CONTROL METHOD FOR THE COMMON FURNITURE BEETLE (COLEOPTERA: ANOBIIDAE)

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Abstract The aim of our research was to develop and test a biological control method for *A. punctatum*. After mass rearing of the host-specific braconid wasp species *Spathius exarator* (L.), laboratory control tests of the parasitism rate were conducted. Praxis tests of the efficiency of the braconid wasps were performed in six churches for the duration of two years. Monitoring of success was based on exit holes from wasps and *A. punctatum*. Laboratory control tests with defined numbers of living *A. punctatum* larvae in small lumbers showed 79% parasitism by braconid wasps after three months and 98% parasitism after ten months. The results of the praxis tests revealed a steady increase of emerging braconid wasps in all churches; up to 80% less new exit holes of *A. puncatum* were counted in 2013 compared to 2012. The results demonstrate the biological control of *A. punctatum* with the braconid wasps.
Key words *Anobium punctatum*, *Spathius exarator*, church, museum pests.

INTRODUCTION

A. punctatum belongs to the family of Anobiidae, derives originally from Europe and has spread worldwide (Pinniger and Child, 1996). It causes huge economic damage by the destruction of wood, especially in attics, stairs and in antiques of churches and museums. The eclosion of *A. punctatum* occurs between April and August, preferentially in May and June (Vite, 1952) and can be identified by a circular hole on the wood surface with a diameter of about 1 -2 mm (Becker, 1983). The beetles lay 20-60 eggs primarily in soft- and sapwood with wood moisture over 10% (Becker, 1940; Hickin, 1963; Cymorek, 1982). The *A. punctatum* larvae eat their way through the wood and thereby produce dust heaps typically found under active infested wood. The development of the larvae takes between two and five years (Becker, 1940; Hickin, 1963).

The methods of control range from local insecticide or thermal treatment to fumigation with carbon dioxide, nitrogen and sulfuryldifluoride. Especially in extensive infected buildings, such as churches or museums, these treatments often are impossible or unwanted. A new approach lies in the biological pest control with natural enemies. Several antagonists of *A. punctatum* are known, but remained unstudied for about 50 years (Becker, 1954). Thus, the aim of our work was to rear and test the host-specific parasitic wasps *S. exarator*, which are described as one of the most common natural enemies of *A. punctatum* (Becker, 1942). The development of a single wasp proceeds on *A. punctatum* larvae of different larval stages and the eclosion of the adult wasps happens through an own gnawed exit hole on the wood surface with an average diameter of 0.5 mm (Lyngnes, 1956).

MATERIAL AND METHODS

Laboratory Tests

After successful mass rearing of the braconid wasps, the parasitism rate was tested on twelve small lumbers (10 cm x 5 cm x 3 cm) with the same batch of living *A. punctatum* larvae, prepared by the Federal Institute for Materials Research and Testing (Berlin, Germany). At given times, parasitic wasps were added to half of the twelve lumbers (test samples). Other six lumbers without the addition of wasps served as a control (control samples). Table 1 shows the detailed overview of dates and numbers of added wasps. From December to February no further parasitic wasps had to be added, because the reproduction occurred internally. From March to July wasps were added again. About ten months after the first addition of wasps the experiment was finished.

Table 1. Overview of the addition of parasitic wasps to the test sample.

Date	Parasitic wasps
7.11.12	10 ♀, 5 ♂
26.11.12	10 ♀, 5 ♂
18.3.13	10 ♀, 5 ♂
30.5.13	10 ♀, 5 ♂
6.7.13	10 ♀, 5 ♂

The conditions in the laboratory were adjusted to 18h light, 6 h darkness, 21°C room temperature and 75% relative humidity. Once a month all wood dust heaps per lumber were counted and removed. In addition all new *S. exarator* exit holes per lumber, which match the number of parasitized *A. punctatum* larvae, were documented. At the end of the experiment, the wood moisture was measured with a wood moisture meter GMH 3810 (Greisinger Electronic). To determine the exact number of living and dead larvae, the lumbers were disintegrated with a pry bar.

The number of exit holes of wasps in addition to the number of living *A. punctatum* larvae at the end of the experiment result in the total number of vital larvae at the onset of the experiment. With this number, the parasitism rate per month was calculated in percent.

Praxis Tests

To test the ability for parasitism outdoor, six different infested churches were treated with the braconid wasps six to eight times a year within duration of two years. Monitoring of success was based on the intensity of the infestation of *A. punctatum* in contrast to the effectiveness of the parasitic wasps. Heavily infested wood surfaces were bond with commercial wrapping paper and 10% tylose glue (Noldt, 2007). After each treatment, the new exit holes of *A. punctatum* and braconid wasps, distinguished by the diameter, were marked with colored pens and counted.

DATA ANALYSIS

Statistical analysis was done with Microsoft Excel. The correlation between the parasitism rate and the number of wood dust heaps was calculated with Pearsons´correlation and the significance of the correlation (one-tailed) was determined with the software of Soper (2014). The difference of exit holes from A. *puncatum* between 2012 and 2013 was calculated using a one-tailed two-sample-t-test for dependent samples. P-values of $p \leq 0.05$ were considered significant and marked with *.

RESULTS AND DISCUSSION

Laboratory Tests

The measurement of wood moisture of the lumbers gave an average value of 13.7 ± 0.77 % relative humidity. This moisture provides optimal conditions for the development of *A. punctatum* larvae.

To evaluate the parasitism rate, the exact number of living *A. punctatum* larvae at the onset of the experiment was determined and is listed in Table 2. This value is an addition of the number of exit holes of wasps and the number of living *A. punctatum* larvae at the end of the experiment.

Table 2. Number of living larvae and exit holes in the lumbers.

	Number of exit holes of wasps	Living *A. punctatum* larvae at the end	Living *A. punctatum* larvae at the beginning
Control sample	0	38 (+1 adult beetle)	39
Test sample	39	1(+2 pupae of parasitic wasps)	42

The control samples with its 38 living *A. puncatum* larvae and one emerged adult beetle at the end of the experiment proved optimal life conditions for *A. punctatum*. In the test samples 42 living *A. punctatum* larvae were present in the lumbers at the onset of the experiment. At the end, only one *A. punctatum* larva survived and two partial developed wasp pupae rested in the lumbers. Moreover, 39 exit holes of the wasps were detected, corresponding to the number of parasitized larvae. The increase of parasitized *A. punctatum* larvae per month is shown in Figure 1, together with the number of monthly counted wood dust heaps.

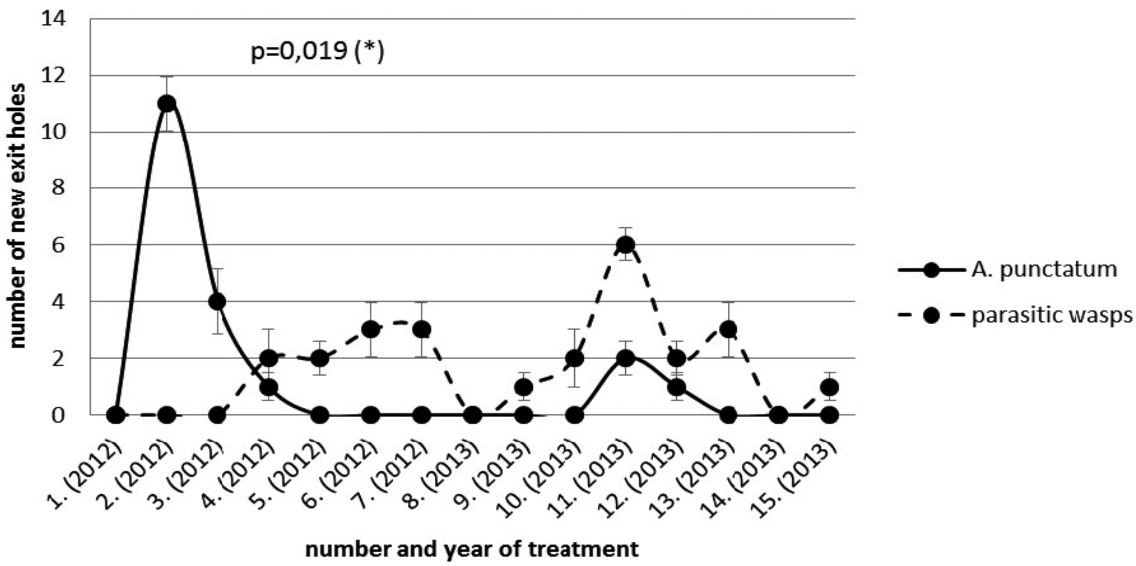

Figure 1. Parasitized *A. punctatum* larvae (round dots) and numbers of wood dust heaps (triangular dots) in the test samples. Standard derivation results from differences between the six lumbers. The correlation coefficient after Pearson was -0.85 with a significant correlation between the two curves (p=0,016). The arrow indicates the date of the initial addition of the parasitic wasps at 7.11.12.

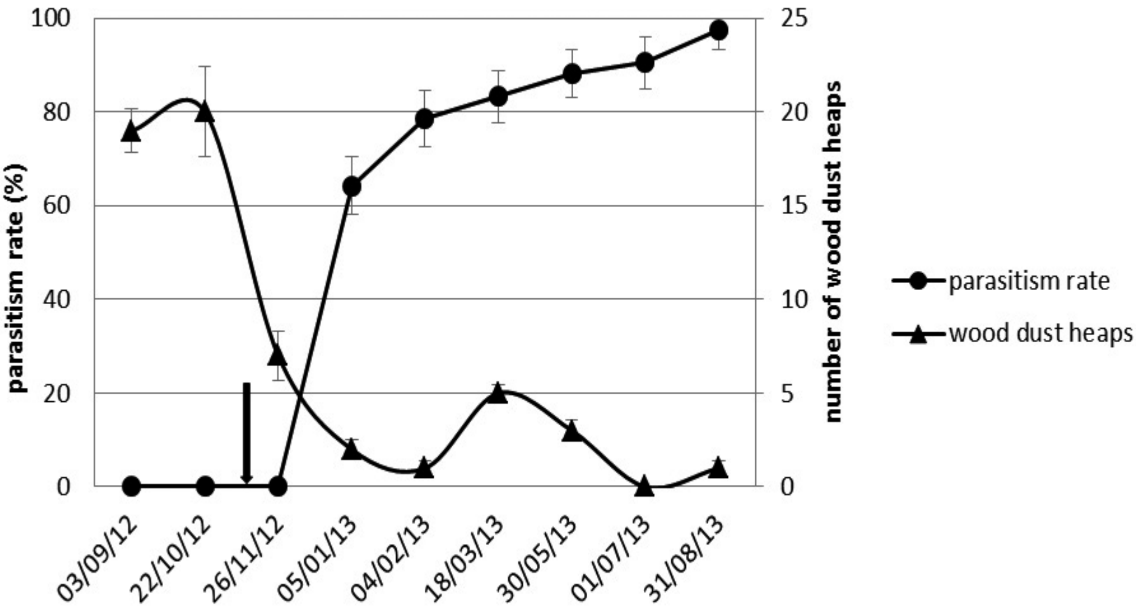

Figure 2a. Church N. Number of exit holes of *A. punctatum* (continuous line) and of parasitic wasps (dotted line) of pews in the church N. (a) and S. (b), masked with wrapping paper. Values are given as total amount of exit holes from four parts of the pew (0.7 m^2) (a) and from two different parts of the pews (together approximately 0.15 m^2) (b) with the mean standard derivation. Statistical analysis between the numbers of exit holes of *A. punctatum* from 2012 and 2013 was carried out with a one-tailed two-sample t-test for dependent samples.

Three months after the first addition of *S. exarator*, 79% of the *A. punctatum* larvae were parasitized. At the end of the experiment, an almost complete parasitism was achieved with 98% killed *A. punctatum* larvae. The increase of parasitized larvae showed a high negative correlation with the decrease of wood dust heaps with a correlation index of r=-0.85. The statistical analysis revealed this value as significant (p=0,016).

Praxis Tests

In 2012 and 2013 six different churches were treated with parasitic wasps against *A. puncatum*. Monitoring of success was performed by counting new exit holes from braconid wasps and *A. punctatum* as described above. Representative results from two different churches were shown in Figure 2a and b.

Figure 2a shows the summarized number of new exit holes of *A. punctatum* and parasitic wasps on four infested parts of the pews in the church N., masked with wrapping paper. Two hatching phases of *A. punctatum* can be identified. The first happened between the first and fourth treatment (from June to August 2012), the second hatching phase was between the tenth and twelveth treatment (June to August 2013). The number of emerged *A. punctatum* decreased from 16 beetles in 2012 to 3 beetles in 2013, according a significant reduction of 81% (p=0,019). During the entire treatment period 25 *A. punctatum* larvae were parasitized in the monitored area, as identified by the exit holes of the wasps.

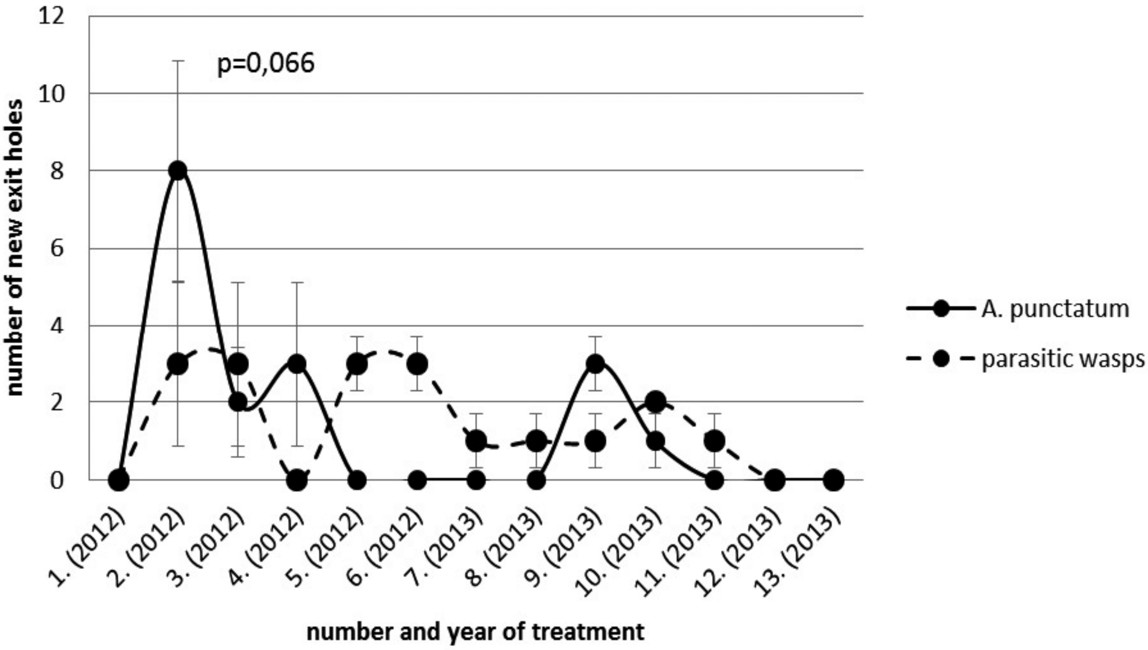

Figure 2b shows the number of summarized exit holes on two parts of the pewage in the church S. In 2012, a total number of 13 hatched *A. punctatum* were counted, with a peak between the first and third treatment. In 2013, four *A. punctatum* hatched, corresponding to a 70 % reduction (p=0,066). This reduction was caused most likely by the parasitism of the braconid wasps, which killed 17 *A. punctatum* larvae in different stages of development in the monitored area.

CONCLUSIONS

The results of the laboratory tests show a fast, effective parasitism of *A. punctatum* by the host-specific *S. exarator*. Moreover, the praxis tests in several churches proved successful parasitism of *A. punctatum*. This tests lead to a reduction of up to 80% hatched *A. punctatum* beetles within strong infested areas in the second year of treatment. Therefore it can be reasoned that the biological treatment with suited braconid wasps is an effective, easy-to-apply method for large-area *A. punctatum* infested objects. However, the further development of infestation by *A. punctatum* and the need for additional, selective treatments remains to be investigated in the following years.

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