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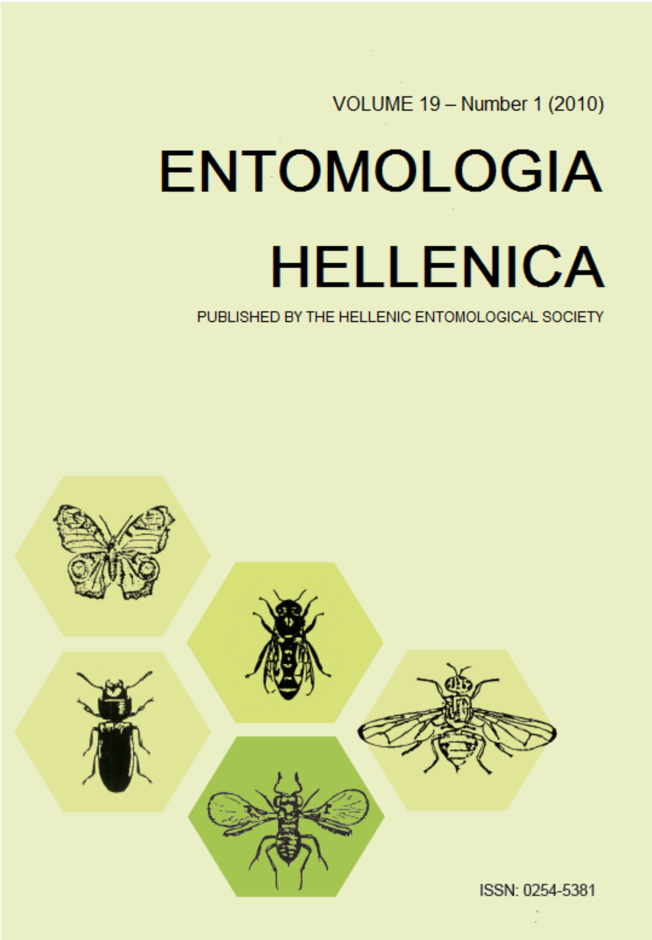

Pityogenes chalcographus (Coleoptera, Scolytinae) at the southernmost borderline of Norway spruce (Picea abies) in Greece

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Pityogenes chalcographus (Coleoptera: Scolytinae) at the southernmost borderline of Norway spruce (*Picea abies*) in Greece

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ABSTRACT

The six toothed bark beetle, *Pityogenes chalcographus* L. (Coleoptera: Scolytinae) is a widely distributed pest in Europe, infesting mainly Norway spruce (*Picea abies*) as well as other conifer species such as *Pinus* sp., *Abies alba, Larix deciduas, L. sibirica* and *Pseudotsuga douglasii*. Even though the distribution of this bark beetle coincides that of its main host tree, *P. abies*, the occurrence of *P. chalcographus* has never been recorded in the spruce forest of Elatia-Drama, Northern Greece, which is the southernmost area of the natural, autochthonous distribution of *P. abies*. In this study we installed five pheromone traps baited with chalcogran dispensers in the forest of Elatia. The total number of bark beetles attracted to these traps exceeded several thousands of individuals. Norway spruce trees growing in the natural forest of Elatia demonstrate low vigor, something that can be attributed to the marginal environmental conditions in concert with the effects of climate change. The combination of these factors inhibits the regular growth of spruce, rendering trees more susceptible to the attack of *P. chalcographus.*

KEYWORDS: *Pityogenes chalcographus*, Scolytinae, bark beetles, pheromone traps, Norway spruce, *Picea abies*, Greece.

Introduction

The genus *Pityogenes* belongs to the tribe Ipini, which comprises some of the most damaging forest pests. In Europe, it is represented by 13 polygamous species (Pfeffer 1995), which are distinguished from the other *Ipini* genera by the relatively small size (1.5-3.5 mm), the longitudinal ridge on the second half of the pronotum and the number of spines on the elytral declivity of males (1-3 spines). Within the genus *Pityogenes*, *P. chalcographus* is the most abundant species in Europe (Knizek et al. 2005). Its minute 1.5-2.5 mm size (Figure 1) and the distinctive red-brown color of the elytra in contrast with the black pronotum facilitate easy determination (Schwerdtfeger

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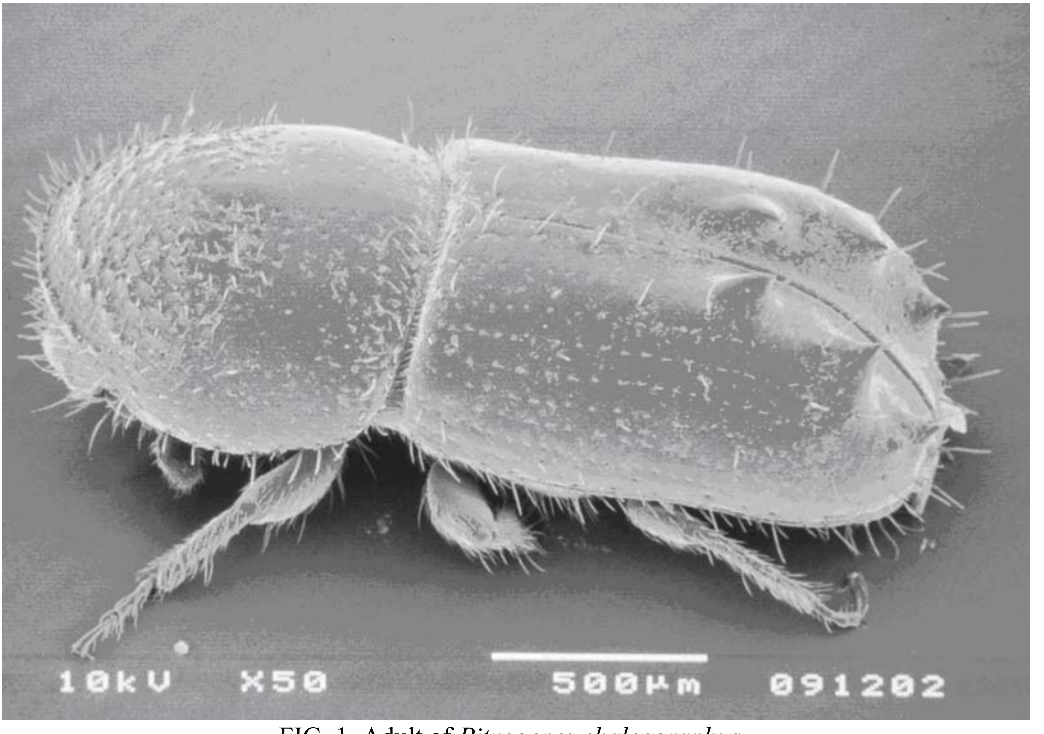

FIG. 1. Adult of *Pityogenes chalcographus*.

1929, Postner 1974, Wood and Bright 1992, Pfeffer 1995). In addition to color, *P. chalcographus* exhibits a very distinctive sexual dimorphism that is expressed in a dual form (Figure 2):

- males have three pairs of spines on the elytral declivity, whereas in females they are replaced by small knobs (Figure 2 A and 2 B)
- females have a deep depression in the center of the frons, that is absent in males.

P. chalcographus is a widely distributed pest in Eurasia that infests mainly *Picea abies* stands (Postner 1974, Pfeffer 1995). Field observations (Avtzis et al. 2008) and literature reviews (Schwerdtfeger 1929, Postner 1974, Pfeffer 1995) report that *P. chalcographus* can also develop on several pine species (*Pinus* spp.) as well as on the European larch, *Larix decidua*. Previous laboratory feeding experiments suggested that pine species are actually more preferred host trees than Norway spruce (Führer and Mühlenbrock 1983), but a recent laboratory experiment (Bertheau et al. 2009) revealed that in terms of larval development, Norway spruce is the most suitable host of *P. chalcographus*.

P. chalcographus is considered as an important spruce pest within Europe, responsible for damages of conifer forests during the last centuries (Ehnström et al. 1974, Christiansen et al. 1987, Christiansen and Bakke 1988, Eidmann 1992, Göthlin et al. 2000, Schroeder 2001, Bouget and Duelli 2004). Mass outbreaks are often in concert with *Ips typographus* (Coleoptera: Scolytinae) something that facilitates a successful colonization of the host tree (Schwerdtfeger 1929).

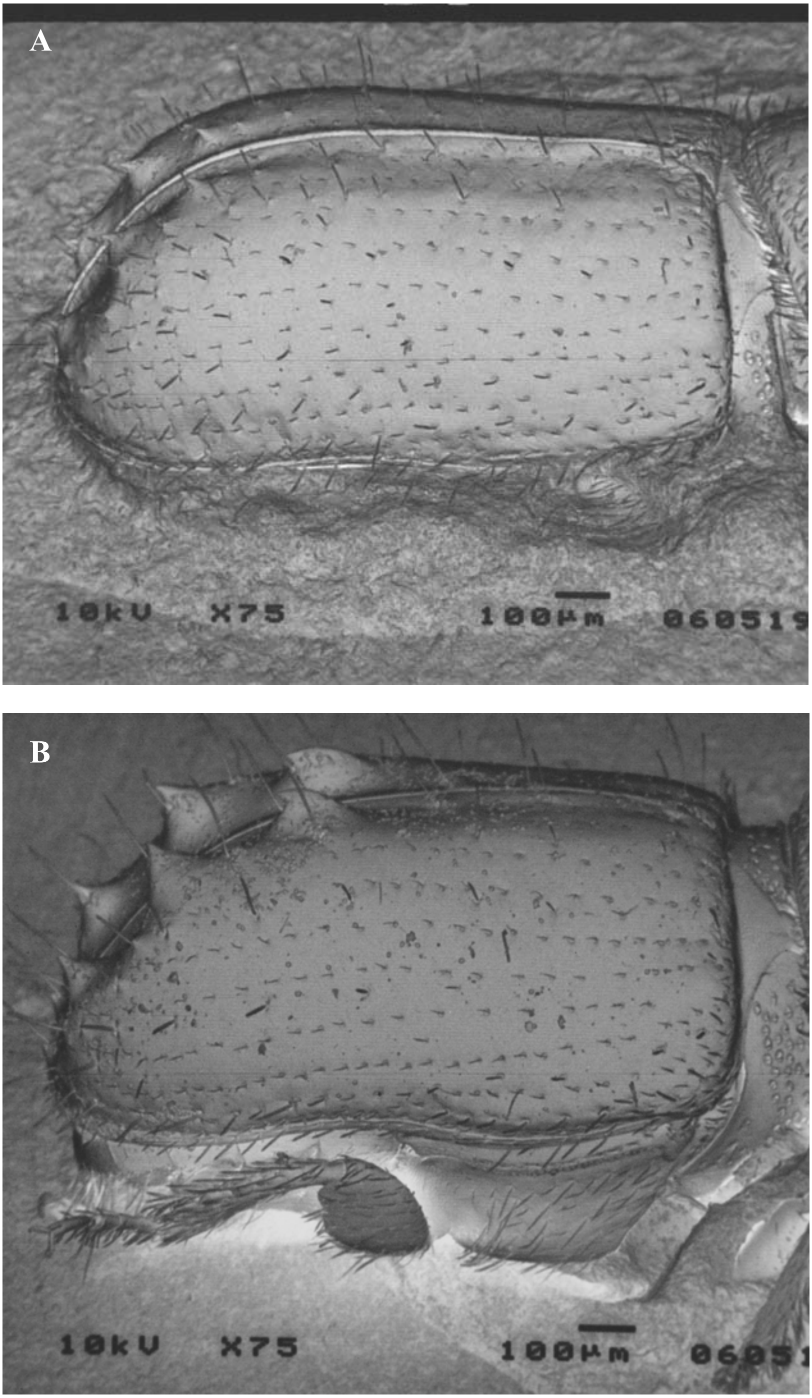

FIG. 2. Sexual dimorphism of *Pityogenes chalcographus*. The knobs on the elytral declivity of a female (A) are replaced by spines in males (B).

Pityogenes chalcographus is further associated with blue-stain fungi, mainly *Ophiostoma* spp. that help their insect vectors to overcome the tree's defence mechanisms (Kirisits 2004). Another interesting aspect of bark beetles concerns their chemical ecology (for review see Tillman et al. 1999, Byers 2004). The use of pheromones to efficiently aggregate on host trees is crucial to the success of most species associated with boreal conifers. Pheromone compounds are either derived from host-tree precursors or synthesized *de novo* by the beetles (Schlyter and Birgersson 1999, Tillman et al. 1999). *P. chalcographus* produces a two-component aggregation pheromone blend: Francke et al. (1977) isolated a spiroketal, chalcogran (2-ethyl-1,6-dioxaspirol[4,4]nonane) and Byers et al. (1990) isolated a methyl ester (methyl (E,Z)-2,4-decadienoate). However, individual compounds may exhibit either weak or no attraction. Together with the main components, a synergist may increase attraction up to manifold times (Borden 1985). In *P. chalcographus*, methyl (E,Z)-2,4-decadienoate synergized chalcogran and increased its attractivity 35 times in a field bioassay, while methyl decadienoate alone was unattractive (Byers et al. 1990). Communication via pheromones exhibits such high specificity that even slight changes in the ratio of enantiomeres have been associated with intraspecific differentiation (Lanier et al. 1972, Birch et al. 1980, Seybold et al. 1995).

The natural distribution of *P. chalcographus* coincides with that of its main host tree, *P. abies* (Avtzis et al. 2008), and thus, the six toothed spruce bark beetle can be found everywhere on spruce stands from Scandinavia to the Balkans (Knizek et al. 2005). The forest of Elatia (Drama, Greece) is the southernmost area of the natural, autochthonous distribution of Norway spruce in Europe (Arabatzis 1998) covering an area of 68,000 ha. Although it might be logical to assume that *P. chalcographus* has infiltrated in that forest as well, only Kailidis (1991) provides some information about *P. chalcographus*, without mentioning anything about geographic distribution, abundance or even sampling location.

The current investigation aimed to detect *P. chalcographus* in the southernmost European spruce distribution for the first time. For that reason, pheromone-baited traps were placed in the spruce forest of Elatia. In addition to the first report of *P. chalcographus* in Greece, this study provides a precise morphological and biological description of this bark beetle species, and assesses its potential as a pest species in Greece.

Materials and Methods

Five Theysohn® (Witasek, Austria) traps were baited with Chalcoprax® (Witasek, Austria) dispensers in order to attract *P. chalcographus* individuals. These traps were installed in the natural forest of Elatia, Drama, Greece (Table 1) in the beginning of July 2004 and removed at the end of September. Traps were set hanging on branches of Norway spruce trees at a height of about 1.5-2 m, and lures were changed once in mid August, whereas beetles caught were collected every two weeks. The estimation of the total number of individuals caught in the pheromone traps was achieved by comparing the total volume of the individuals in the traps with the volume of a known number of *P. chalcographus* individuals (a cylindrical container with 10,000 individuals).

For the investigations of *P. chalcographus* with the scanning electron microscope, several (more than 20) air-dried beetles were mounted on specimen stubs on carbon discs. The beetles were coated in a sputter coater with gold-palladium using a voltage of 2kV and a current intensity of 20mA for 90 sec under a vacuum of 10^{-2} to

10^{-3} mbar (Polaron E 5100, Hatfield, PA, USA). Electron micrographs were taken with a JEOL JSM 5200 scanning electron microscope (JEOL, Tokyo, Japan) and a Konica FT-1 analogue camera using a Fujichrome 100 color slide film; slides were scanned after exposure and processing.

TABLE 1. Exact location, elevation and distances between the five Theysohn ® traps installed in the natural Forest of Elatia.

Longitude (N)	**Latitude (E)**	**Elevation (m)**	**Trap**	**Distances between traps (km)**				
				1	**2**	**3**	**4**	**5**
41° 28 025	024° 19 278	1.554	**1**	---				
41° 28 443	024° 19 490	1.563	**2**	0.48	---			
41° 30 346	024° 18 992	1.475	**3**	2.60	2.16	---		
41° 29 584	024° 20 605	1.334	**4**	2.05	1.56	1.58	---	
41° 30 065	024° 18 296	1.551	**5**	2.40	2.06	0.67	2.00	---

Results and Discussion

The identification of individuals caught in the pheromone traps was based on the morphological features described above. Fifteen volumes of 10,000 individuals were counted giving a rough estimation of totally 150,000 individuals collected from all traps. This was to our knowledge the first time that *P. chalcographus* was trapped systematically in the spruce forest of Elatia, Drama.

Based on mass outbreak incidences, *P. chalcographus* attacks preferably weakened trees, since low defence of these hosts can be more easily overcome (Lieutier 2002, Sauvard 2004). The critical density of a bark beetle's population for an outbreak is mostly reached when an exogenous perturbation creates favorable conditions for population increase and, on the same time, lowers tree resistance (Berryman 1972). Mass outbreaks allow bark beetles to attack also healthy trees, inducing by this a positive feedback where population increase triggers increase of available hosts and in turn allows further population boost (Sauvard 2004). Fires, storms, snow breaks and severe drought are some of the agents that are likely to trigger mass outbreaks of phloem feeding beetles, with the latter one being most commonly observed in forest stands in Southern Europe (Mattson and Haack 1987, Bryant and Raffa 1995, Clancy et al. 1995, Paine et al. 1997, Raffa et al. 2008).

Situated at the southernmost area of its natural distribution, Norway spruce in the natural forest of Elatia (Drama-Greece) grows at a marginal environment in regard to temperature and humidity conditions, facing on the same time strong competition from beech and scots pine (Smiris 1985). Poor environmental conditions in similar cases have often been considered the essential prerequisite that triggered an increase in the bark beetle's population leading ultimately to mass outbreak (Thalenhorst 1958, Chararas 1962, Lekander 1972). *Picea abies* is generally considered a rather vigorous species when compared to other conifer species with regard to dominance or productivity indices, especially in the central parts of its natural distribution (Larsson et al. 1983, Waring and Pitman 1983, Hard 1985, Mulock and Christiansen 1986, Sandeness and Sollheim 2002). However, a marginal environment such as in Elatia inhibits Norway spruce from reaching high vigor. Weakened host trees release volatile chemicals (monoterpenes), which are supposed to play an active role in the primary attraction of bark beetles to a suitable host (Byers 2004). After bark beetles have landed on a weakened tree, it is without any doubt easier to overcome host resistance since the defense mechanisms of the host are already encumbered by exogenous factors (Vité and Wood 1961, Lorio and Hodges 1977, Dunn and Lorio 1993, Lorio et al. 1995, Croisé et al. 2001, Dreyer et al. 2002).

Climate change and its effects have become one of the major topics of research and discussion among experts in the last decades, something that underlines the gravity of the situation (Kellomäki et al. 2000, Führer and Csaba 2005, Martinic and Sporcic 2005, Bokhorst et al. 2007). Observations worldwide account for an increase in the mean temperature accompanied by decrease of rain precipitation (Diaz and Graham 1996, Easterling et al. 1997, Trenberth et al. 2003, Knutson and Tuleya 2004). As a consequence, trees weakened by drought and high temperatures become more susceptible to pests (Kalkstein 1976, Mattson and Hack 1987, Boyer 1995). Unfavorable environmental conditions are expected to cause sooner and in some cases more severely such effects, and therefore it can be hypothesized that Norway spruce at the southernmost area of its natural distribution is likely to already be facing the influence of climate change.

The combination of these two factors, namely the unfavorable environment in combination with climate change favors the current observation of the population level of *P. chalcographus* at the forest of Elatia (Drama – Greece). This outcome however should constitute the basis on which further experiments will be carried out, in order to evaluate even more accurately the potential of *P. chalcographus* as a possible threat not only for this marginal relict stand of Norway spruce, but of the endemic conifer species in Greece generally. The sheer fact, however, that *P. chalcographus* is able to attack beside Norway spruce, pine trees as well, should be taken into deep consideration, since Greece is mostly inhabited by pine species. A mass population outbreak of *P. chalcographus* at the forest of Elatia could potentially trigger a host shift on native pine species, something that will put under threat one of the major components of Greece's endemic flora.

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Το φλοιοφάγο έντομο *Pityogenes chalcographus* (Coleoptera: Scolytinae) στο νοτιότατο άκρο της φυσικής εξάπλωσης της ερυθρελάτης (*Picea abies*) στην Ελλάδα

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ΠΕΡΙΛΗΨΗ

Το φλοιοφάγο έντομο *Pityogenes chalcographus* L. αποτελεί ένα από τα κύρια βλαπτικά έντομα της υποοικογένειας Scolytinae, που είναι ευρέως εξαπλωμένο στην Ευρώπη. Ο κύριος ξενιστής του εντόμου είναι η ερυθρελάτη (*Picea abies*) ενώ επίσης μπορεί να αναπτυχθεί επιτυχώς σε αρκετά ακόμη είδη κωνοφόρων όπως το πεύκο (*Pinus* sp.), το έλατο (*Abies alba*), η λάρικα (*Larix decidua*) και η ψευδοτσούγκα (*Pseudotsuga douglasii*). Παρά το γεγονός ότι η φυσική εξάπλωση του εντόμου συμπίπτει με αυτή του κύριου ξενιστή του, το *P. chalcographus* δεν έχει καταγραφεί ούτε και παγιδευτεί στο δάσος ερυθρελάτης στην Ελατιά Δράμας, που αποτελεί το νοτιότερο άκρο της φυσικής, αυτόχθονης εξάπλωσης της ερυθρελάτης. Στα πλαίσια της έρευνας εγκαταστάθηκαν στο δάσος της Ελατιάς πέντε φερομονικές παγίδες, οι οποίες περιείχαν την προσελκυστική ουσία chalcogran. Ο συνολικός αριθμός των φλοιοφάγων εντόμων που συγκεντρώθηκαν μετά το πέρας της περιόδου που οι παγίδες ήταν στο πεδίο, ανήλθε σε αρκετές χιλιάδες ατόμων. Η ερυθρελάτη που αναπτύσσεται στο φυσικό δάσος της Ελατιάς βρίσκεται σε οριακό περιβάλλον όσον αφορά τις συνθήκες ανάπτυξής της, γεγονός που επιτείνεται και από την κλιματική αλλαγή, η οποία γίνεται ακόμη πιο εμφανής σε τέτοια περιβάλλοντα. Η συνδυαστική δράση αυτών των δύο παραγόντων μπορεί να καταστήσει την ερυθρελάτη ιδιαίτερα ευάλωτη στην προσβολή του *P. chalcographus,* γεγονός που θα μπορούσε εν δυνάμει να θέσει σε κίνδυνο και τα ενδημικά είδη πεύκου της Ελλάδας, καθώς το φλοιοφάγο αυτό έντομο έχει την δυνατότητα ανάπτυξης σε μια πλειάδα ξενιστών.