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ORIGINAL ARTICLE

Two types of Norway spruce *Picea abies* (L.) H. Karst. infestation by the double spined bark beetle *Ips duplicatus* C.R. Sahlb. (Coleoptera: Scolytinae) in southern and north-eastern Poland

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Abstract

During an outbreak in the second half of the 1990s, the infestation pattern of *Ips duplicatus* C.R. Sahlb. on standing trees in the Silesian Upland (southern Poland), was seen to be different from the pattern observed in the north-eastern spruce range. The "southern" type can be characterised by (i) the abundance of *I. duplicatus* galleries in lower parts of stems (including the basal parts of stems), and (ii) co-occurrence and high spatial competition with *Ips typographus* L. The "southern" type of infestation seems to be temporal in nature, related to the high abundance of *I. duplicatus* during the progradation and culmination phase of its outbreak.

Key words

distribution, infestation, *Ips duplicatus*, *Picea abies*, standing trees

Introduction

One of the most important factors in Norway spruce *Picea abies* (L.) H. Karst. mortality is the infestation by bark beetles, among which the spruce bark beetle *Ips typographus* L. is the most frequent and aggressive species (Wermelinger 2004). This insect is a leading species in the complex of bark beetles which feed on spruce, and in most cases can be considered as the main or even exclusive agent of mortality. However, in specific conditions other species of bark beetles, usually known as "accompanying" species, can increase in frequency and become the main agents of tree death (Grodzki 1997b).

In Poland, the continuous distribution of Norway spruce is divided into two ranges: north-eastern and southern, separated by wide belt initially termed "spruceless" (Szafer 1921), but recently recognised as an area with a scattered distribution of this tree species (Boratyński 1998). *Ips duplicatus* C.R. Sahlb. is a bark beetle species distributed between the northern zone of Europe, Siberia, and Sakhalin, which feeds on spruces; mainly *P. abies*, but also on some other *Picea* and *Pinus* species (Pfeffer and Knížek 1995). In Poland *I. duplicatus*, considered as a dangerous pest of spruce (Schnaider and Sierpiński 1955), was regarded as common in the north-eastern range of *P. abies*, and sporadically observed in the southern range; the differ-

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ing abundance of this species in the north-eastern and southern parts of Poland was even considered as an argument proving the existence of two ranges of Norway spruce (Karpiński 1932). In the northern range of spruce *I. duplicatus* colonises mainly or exclusively the upper parts of the tree stems, the lower (thicker) parts of which is usually infested by *I. typographus* (Karpiński 1935). The co-occurrence of both species is regulated by competition mechanisms and preferences in the size of breeding material (Schlyter and Anderbrant 1993), as well as by the semiochemical mechanisms which relate to the negative response of both species to each other's pheromones (Schlyter *et al.* 1992).

In the second half of the 1990s a local outbreak of *I. duplicatus* affected the stands in the Silesian Upland in southern Poland (Grodzki 1997a), and in the adjacent area of the northern Czech Republic (Mrkva 1994). It was the first case of such an outbreak in this part of the Norway spruce distribution range. During the outbreak period (1991–1995), a volume of almost 1.5 million m^3 of spruce timber had to be removed from stands in the Silesia Upland due to bark beetle infestation (Grodzki 1997a). The conditions in southern Poland and the northern Czech Republic were favourable for the rapid proliferation of *I. duplicatus*: in the "northern" spruce range one generation (or exceptionally two) per year are usually produced (Schnaider and Sierpiński 1955), however in the "southern" range the species may produce up to three generations in a single growing season (Holuša *et al.* 2003).

In recognition of the importance of the pest and the damage caused, research was undertaken concerning possible methods of control (Grodzki 1997a). The results of the field investigations revealed that the infestation patterns in Silesian Upland differed from those observed in the northern range of spruce. The aim of this paper is to describe these two types of infestation, and to discuss the possible causes of the differences found.

Material and methods

The main study area was located in the southern range of the Norway spruce distribution – in the Silesian Upland, Forest District Strzelce Opolskie, in stands recently affected by the *I. duplicatus* outbreak. For comparison, results of experiments with standing trap trees performed in the north-eastern spruce range in Puszcza Romincka and Puszcza Knyszyńska, were also included.

1. Standing trees killed by bark beetles

   The analyses of standing trees infested by bark beetles were performed in the Forest District Strzelce Opolskie, Silesian Upland (southern spruce range) in 1996 and 2001, on the following dates and locations:
   - 24–25.06.1996: Forest Range Szymiszów, compartment (comp.) 65g, 61 year-old Norway spruce, 10 infested standing trees analysed after felling, performing analysis in four 0.5m sections: basal, middle (midway between stem base and crown base), upper (below the crown), and crown (middle of the crown).
   - 7.06.2001: Forest Range Zimna Wódka, comp. 11Ac, 95 year-old Norway spruce, 3 infested standing trees, analysed after felling, full stem analysis in 1m sections.

   In both cases the bark was removed from the entire surface of each section and the number of gallery systems (in practice: mating chambers) of individual bark beetle species was estimated per $1dm^2$ (decimetre squared) . In the first case the frequency of *I. duplicatus* and *I. typographus* was calculated in individual sections.

2. Standing trap trees

   The dissections of trees were made in:

   Southern spruce range:
   - 28.08.1999: Silesian Upland, Strzelce Opolskie, Szymiszów, comp. 65g, 20 standing trap trees, girdled in late autumn 1998, 4-sections analysis.

   North-eastern spruce range:
   - 15.06.2001: Puszcza Knyszyńska, Forest District Krynki, 5 various compartments, 20 standing trap trees girdled in the summer 2000, 4-sections analysis.
   - 2.08.2001: Puszcza Romincka, Forest District Gołdap, 5 various compartments, 20 standing trap trees girdled in the summer 2000, 4-sections analysis.

On all trees the presence of *I. duplicatus* galleries in individual sections was recorded, in order to calculate its frequency on the specific parts of the stems.

All trees were measured (DBH and height/length). The co-occurrence of two *Ips* species was characterised using linear regression and Aggrell's index (*Ag*), calculated following the formula:

$$Ag = \frac{N_{ab}}{N}$$

where:

N_{ab} – number of sections in which the species *a* and *b* occur,

N – number of all infested sections.

For statistical analyses of the occurrence of *I. duplicatus* on tree stems, a linear regression was applied, and nonparametric methods (median and Mann-Whitney test) were used to test for differences in the DBH of trees between study locations.

Results

Standing trees killed by bark beetles

The mean DBH of trees analysed in 1996 was 25.9 cm and ranged between 19–37 cm. The data collected showed that galleries of *I. duplicatus* occurred in all analysed sections of spruce trees, including the lowest parts of stems (Fig. 1A). Its frequency, which was relatively high (above 60%) in the basal parts of stems, increased to 100% in the section located just below the crown, then slightly decreased in the crown zone to just above 90%. The frequency of *I. typographus* on the same trees was much lower, reaching a little over 20% in the middle of the stem. When looking at the intensity of *I. duplicatus* attacks, the lowest infestation density was found in the basal parts of stems (2.19 per 1 dm^2) but increased with the tree height, reaching the value of 4.05 in the highest (middle of the crown) stem section (Fig. 1B); however the infestation density was not correlated with the section diameter ($r = 0.24$; $p = 0.18$; $n = 32$).

A similar but not identical pattern was found on the trees analysed in 2001, for which DBH ranged between 24–27 cm. There were no *I. duplicatus* galleries on the first lower three meters of stems (i.e. the species was absent in the parts of stems corresponding with the basal section), but from the fourth meter, where the species appeared at a density of 0.15 mating chamber/dm^2, the infestation density increased with the tree height up to a value of 1.53 at 24 meters (Fig. 2). The density of infestation by *I. duplicatus* was negatively correlated with section diameter ($r = –0.5426$, $n = 63$, $p < 0.01$), in accordance with the preferences of this species to thinner breeding material. Infestation by *I. typographus* was detected between one and seventeen meters of stem height, with the density decreasing slightly at greater height. *I. duplicatus* co-occurred with *I. typographus* in a 14 meter long zone of the tree stems, and the infesta-

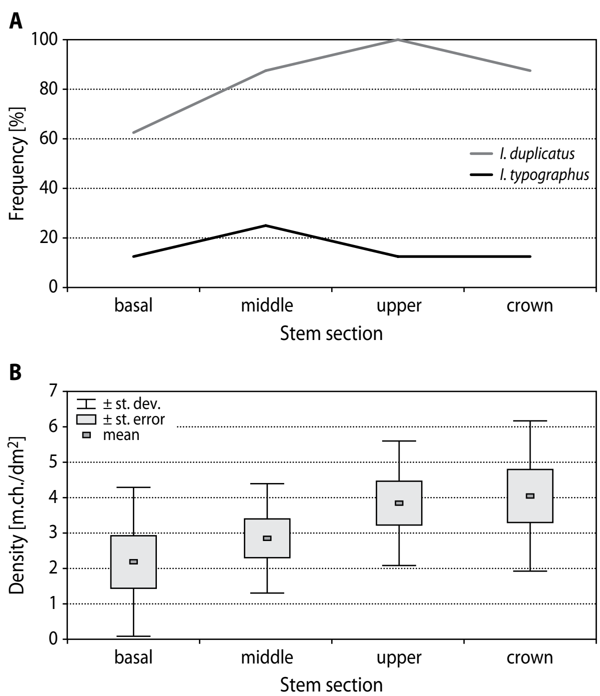

Fig. 1. Frequency of two *Ips* species (A) and infestation density of *I. duplicatus* (B) on attacked standing trees on Silesian Upland in 1996 (m.ch. – mating chambers)

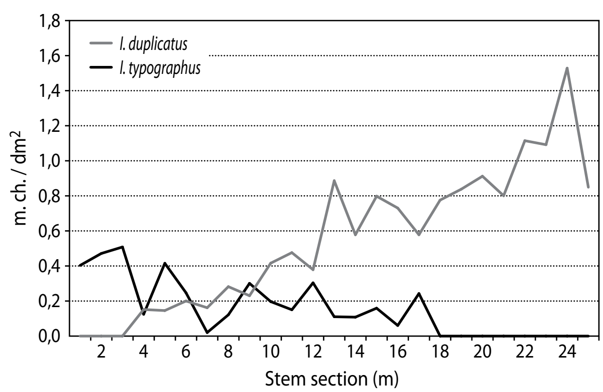

Fig. 2. Infestation density of two *Ips* species on attacked standing trees in 1-m stem sections, Strzelce Op. 2001 (m.ch. – mating chambers)

tion density by the two species was slightly negatively correlated (r = –0.3006, p = 0.017), which is suggestive of spatial competition. The requirements in the quality (size) of breeding material seemed to be similar in both species, as indicated by the Aggrell's index value *Ag* = 0.50 (0.41–0.58).

Standing trap trees

The experiments employing standing (girdled) trap trees, performed in Silesian Upland in 1999, revealed a similar infestation pattern in *I. duplicatus* (Fig. 3A), to that found on standing infested trees in 2001. This species was absent in the basal sections of trees and frequent in the middle and upper sections (67%), as well as in the crown zone (56%). The frequency of *I. typographus* was the highest (67%) in the basal and middle part of stem, and much lower in the upper (33%) and crown (11%) sections. The density of infestation by *I. duplicatus* was the highest in the upper part of stem (below the crown) and much lower in both middle of the stem and middle of the crown (Fig. 3B). No correlation was found between the density of infestation by *I. duplicatus* and section diameter (r = –0.29; p > 0.05), nor between the density of infestation by *I. duplicatus* and *I. typographus* (r = 0.33; p > 0.05). The co-occurrence of both species in the middle of the stem indicates spatial competition without any separation.

Comparison of the data collected in the three sites indicates differences in the infestation pattern between two parts of Poland, resulting from the much higher *I. duplicatus* frequency in the middle parts of stems in the "southern range" (Fig. 4).

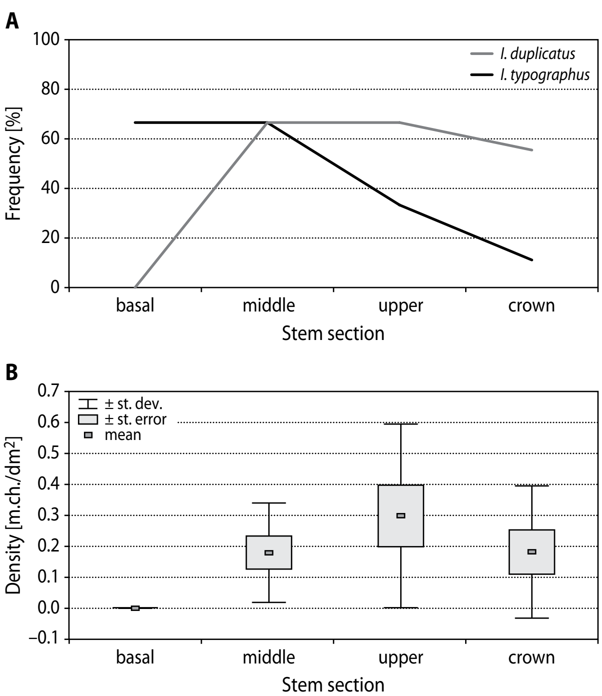

Fig. 3. Frequency of two *Ips* species (a) and infestation density of *I. duplicatus* (b) on standing trap trees on Silesian Upland in 1999 (m.ch. – mating chambers)

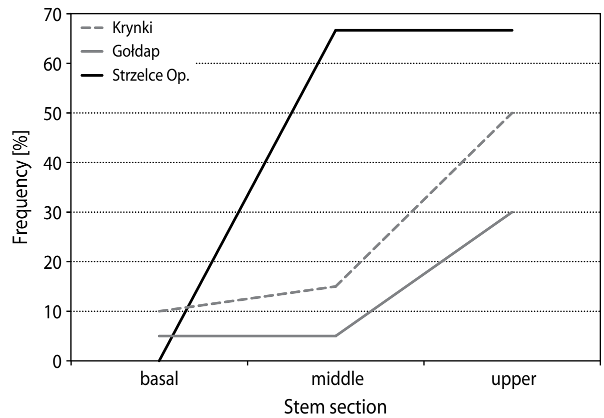

Fig. 4. Frequency of *I. duplicatus* in individual stem parts on standing trap trees in three study sites located in the north-eastern (Krynki, Gołdap), and southern (Strzelce Op.) range of spruce

No significant differences were found between individual locations in the DBH of trap trees analysed in individual study sites (only the trees infested by *I. duplicatus* were included in this analysis) (Fig. 5)

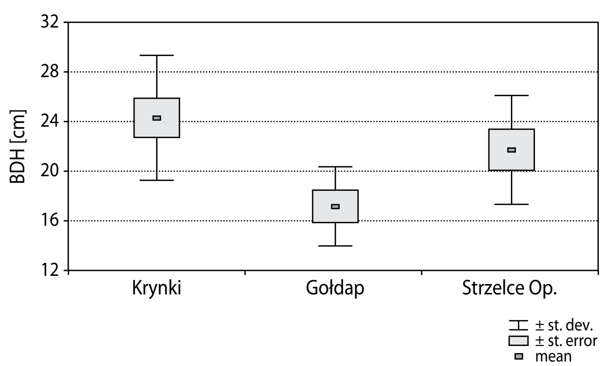

Fig. 5. DBH (diameter at breast height) of standing trap trees in individual study sites located in the north-eastern (Krynki, Gołdap) and southern (Strzelce Op.) range of spruce

(median test, $\chi^2 = 7.713962$, df = 2, p = 0.0211), nor between the north-eastern (pooled data) and southern Poland (Mann–Whitney test, U = 54.5, Z = –0.100223, $p > 0.05$).

Discussion

According to the data from the literature it is known that *I. duplicatus* infests the upper parts of stems and crown zone of Norway spruce trees, a species which also comes under attack from *I. typographus*. This model of infestation is common in the north-eastern range of the Norway spruce in Poland, where the species is regarded as abundant, and its occurrence was considered as a property that distinguished the two separated ranges of Norway spruce (Karpiński 1932). Even if the opinion about the existence of a "spruceless belt" in central Poland is a subject of discussion (Boratyński 1998; Latałowa and Van der Knaap 2006), the differences in the frequency and abundance of *I. duplicatus* remained genuine until its outbreak in southern Poland and the northern Czech Republic. As shown in the present paper, the infestation pattern in this "new" area is not the same as that known from the "old" area in north-eastern Poland (Karpiński 1935), or in Scandinavia (Schlyter and Anderbrant 1993). One can describe two types of Norway spruce infestation by *I. duplicatus*: "typical" (or "north-eastern") and "new" (or "southern"). The "southern" type can be characterized by (i) the abundance of *I. duplicatus* galleries in lower parts of stems (including the basal), and (ii) co-occurrence and high spatial competition with *I. typographus*.

(i) The differences in infestation of lower/basal parts of stems between the localities in the north-eastern and southern parts of Poland did not result from the DBH of attacked trees, as this parameter did not significantly differ between localities. *I. duplicatus* usually prefers thinner breeding material (Karpiński 1932, 1935; Mrkva 1994): in 2002 in the Forest District Hajnówka (Puszcza Białowieska, north-eastern spruce range), the galleries of this species on standing spruces were found above 25m from ground level (W. Grodzki, unpubl.). However, this parameter is probably not a factor limiting the infestation ability of *I. duplicatus* when its population level is high.

(ii) According to Gutowski and Kubisz (1995), *I. duplicatus* and *I. typographus* have completely different requirements regarding which parts of the stems they can infest, as expressed by Aggrell's index $Ag = 0$. This finding results most probably from the fact that the authors analysed only lying (windblown) trees, which are not usually infested by *I. duplicatus* (Sierpiński 1958). Contrarily, the results presented in this paper ($Ag = 0.5$) demonstrate the co-occurrence and/or competition of these two species on the same parts of stems, without the niche separation effect of the mechanisms described by Schlyter and Anderbrant (1993) which were observed in Scandinavia. The reason for the high competition potential between *I. duplicatus* and *I. typographus* in the Silesian Upland was probably the very high population level of the first species, as conditions favourable for rapid population growth (cf. Holuša *et al.* 2003) occurred at the time of its outbreak culmination. A similar mechanism was described in *Pityogenes chalcographus* (L.) after an *I. typographus* outbreak in the Western Sudetes (Grodzki 1997b). Such a conclusion can be supported by the results reported by Holuša *et al.* (2006): in the north-eastern Czech Republic (Moravia) in 2005 (i.e. in the retrogradation phase), *I. duplicatus* galleries were found only in the upper (crown) zone of infested trees, as in a "typical" infestation pattern.

The above described "southern" type of infestation seems to be of a temporal nature, related to the high abundance of the bark beetle during the progradation and culmination phase of its outbreak, and not resulting from special traits or features of *I. duplicatus* populations living in the two spruce ranges in Poland. Thus, the nature of the infestation could be used in the diagnostics of threat to forest caused by *I. duplicatus,* through the recognition of the progressive phase of its outbreak and/or high population level. This conclusion can be confirmed by the comparison of results obtained in 1996 (progradation), and 1999/2001 (beginning of retrogradation). Looking from a wider perspective, the temporal nature of the "southern" infestation type can be considered as an additional contribution that supports the opinion about continuous spruce distribution in Poland, without the "spruceless" belt (Boratyński 1998), as no differences between *I. duplicatus* populations from north-eastern and southern Poland have been detected by genetic studies (Lakatos et al. 2007).

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References

Boratyński A. 1998. O dysjunkcjach w zasięgu świerka. In: Biologia świerka pospolitego (eds.: A. Boratyński, W. Bugała). Bogucki Wydawnictwo Naukowe, Poznań, 79–90.

Grodzki W. 1997a. Możliwości kontroli liczebności populacji kornika zrosłozębnego *Ips duplicatus* C.R.Sahlb. na południu Polski. *Sylwan*, 11, 25–36.

Grodzki W. 1997b. *Pityogenes chalcographus* – an indicator of man-made changes in Norway spruce stands. *Biologia, Bratislava*, 52, 2, 217–220.

Gutowski J., Kubisz D. 1995. Entomofauna drzewostanów pohuraganowych w Puszczy Białowieskiej. *Prace Instytutu Badawczego Leśnictwa*, 783/789, 91–129.

Holuša J., Voigtová P., Kula E., Křístek S. 2006. Výskyt lýkožrouta severského (*Ips duplicatus* Sahlberg, 1836) (Coleoptera: Scolytidae) na LS Bruntál LČR, s. p., v roce 2004–2005. *Zpravodaj ochrany lesa*, 13, 1–46.

Holuša J., Zahradník P., Knížek M., Drápela K. 2003. Seasonal flight activity of the double-spined spruce bark-beetle *Ips duplicatus* (Coleoptera, Curculionidae, Scolytinae) in Silesia (Czech Republic). *Biologia, Bratislava*, 58 (5), 935–941.

Karpiński J.J. 1932. Geograficzne rozsiedlenie korników na ziemiach polskich i kwestja dwu zasiągów świerka w świetle badań ipidologicznych. *Sylwan* 3, 92–113.

Karpiński J.J. 1935. Przyczyny ograniczające rozmnażanie się korników drukarzy (*Ips typographus* L. i *Ips duplicatus* Sahlb.) w lesie pierwotnym. *Instytut Badawczy Lasów Państwowych, Rozprawy i sprawozdania ser. A*, 15, 1–65.

Lakatos F., Grodzki W., Zhang Q.-H., Stauffer C. 2007. Genetic comparison of *Ips duplicatus* (Sahlberg, 1836) (Coleoptera: Curculionidae, Scolytinae) populations from Europe and Asia. *Journal of Forest Research*, 12, 345–349.

Latałowa M., van der Knaap W.O. 2006. Late quaternary expansion of Norway spruce *Picea abies* (L.) Karst. in Europe according to pollen data. *Quaternary Science Reviews*, 25, 2780–2805.

Mrkva R. 1994. Lýkožrout severský (*Ips duplicatus* Sahlberg), nový významný škůdce smrku. *Lesnická práce*, 73 (2), 35–37.

Pfeffer A., Knížek M. 1995. Expanse lýkožrouta *Ips duplicatus* (Sahlb.) ze severské tajgy. *Zpravodaj ochrany lesa*, 2, 8–11.

Schlyter F., Anderbrant O. 1993. Competition and niche separation between two bark beetles: existence and mechanisms. *Oikos*, 68, 437–447.

Schlyter F., Birgersson G., Byers J.A., Bakke A. 1992. The aggregation pheromone of *Ips duplicatus* and its role in competitive mechanisms with *I. typographus* (Coleoptera: Scolytidae). *Chemoecology*, 3, 103–112.

Schnaider Z., Sierpiński Z. 1955. Z biologii kornika zrosłozębnego (*Ips duplicatus* Sahlb.). *Roczniki Nauk Leśnych*, 13 [*Prace Instytutu Badawczego Leśnictwa*, 144/149], 59–68.

Sierpiński Z. 1958. Zagadnienie zwalczania kornika zrosłozębnego (*Ips duplicatus* Sahlb.). *Sylwan*, 1, 68–75

Szafer W. 1921. Nieco o rozmieszczeniu geograficznem świerka w Polsce. *Sylwan*, 39 (7/9), 76–91.

Wermelinger B. 2004. Ecology and management of the spruce bark beetle *Ips typographus* – a review of recent research. *Forest Ecology and Management*, 202, 67–82.