

## The influence of stand and habitat characteristics on the occurrence of pine sawflies *Diprion pini* L. and *Gilpinia virens* (Klug) (Hymenoptera, Diprionidae) in selected areas of northern Poland

Piotr Gawęda,<sup>1</sup> Wojciech Grodzki<sup>2</sup> 

<sup>1</sup>Forest Protection Unit in Gdańsk, ul. Polanki 125/9, 80–322 Gdańsk, Poland; <sup>2</sup>Forest Research Institute, Department of Mountain Forests, ul. Fredry 39, 30–605 Kraków, Poland

\*Phone no. +48 12 2528212, e-mail: W.Grodzki@ibles.waw.pl

**Abstract.** Pine sawflies (Hymenoptera: Diprionidae) belong to the most common pests of Scots pine *Pinus sylvestris* L. in the area of the Regional Directorates of State Forests in Toruń and Gdańsk. The two most destructive species, *Diprion pini* L. in the area of Puszcza Bydgoska and *Gilpinia virens* (Klug) in Bory Tucholskie, were investigated in this study. Our main aim was to characterise the two species in the Bydgoszcz Forest District in RDSF in Toruń and Kaliska in RDSF in Gdańsk, respectively, based on data gathered during outbreaks between 1991 and 2011.

For this purpose, a geometric database was created, containing information about the year of outbreak, number of larvae observed after tree felling as well as selected stand and site features including stand age and species composition, stocking index, canopy closure, site index, humidity and fertility.

By analysing the occurrence of both species in relation to stand and site features, we were able to determine their environmental requirements, which are quite different from one another. *D. pini* preferred older stands, with a stocking index between 0.8–0.9, growing on fresh and dry coniferous sites, while species composition (share of pine), canopy closure or site index did not have any influence on its abundance. *G. virens* preferred middle-aged pure pine stands, with relatively open canopies, on fresh coniferous sites and poorer soils. The stocking index did not affect its occurrence.

**Keywords:** defoliating insects, *Pinus sylvestris*, outbreaks, environmental requirements

### 1. Introduction

Sawflies (Diprionidae), insects of the Hymenoptera order, are among the most important defoliating pests. Among the defoliating pests of the pine *Pinus sylvestris* L., they occupy a high position in terms of the total area of protective treatments performed since the 1950s in the forest districts of the Regional Directorates of State Forests (RDSF) in Toruń and Gdańsk. Sawflies are characterised by the complexity of the occurrence of different species and the variability of biology and ecology (e.g., the fact that an extended cocoon stage changes the timing of *imagines* swarms in different years of gradation occurrence). The share of particular species also changes in subsequent years of observation, and, so does their significance in a given area. Sawflies are characterised by their unpredictability of occurrence and intensity of the

damage they cause in the stands. Gradations also quickly cease in the face of resistance by the natural environment. These insects are considered to be the most difficult to predict – therefore, searching for regularities in their development can be useful for practices to protect the forest.

Of the discussed group of insects, the most important in the Toruń RDSF is the pine sawfly *Diprion pini* (L.), and in the Gdańsk RDSF – *Gilpinia virens* (Klug). Both species are trophically related mainly to Scots pine, although they can also feed on other pine species (Géri, 1988; Górnaś, 1989; Barre et al., 2002). The biology of *G. virens* is less well known than that of *D. pini*. One or two generations of these sawflies may occur per year, depending mainly on the atmospheric conditions (Upper Lus, 1989). They winter cocoons located in different places, with the pine sawfly locating its cocoons in groups in bark cracks in the root neck of the pine,

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and *G. virens* in moss patches, even outside the outline of the crown (Gawęda, 2012). The larvae feed on pine needles in spring (1<sup>st</sup> generation) and in summer and autumn (2<sup>nd</sup> generation). However, when the spring swarm is spread over time, different stages of the same species can be found in the field (Gawęda, 2011). According to the authors' observations, two generations of *D. pini* occurred during one year, but in summer, the swarm of *imagines* producing the second generation may be joined by those that have just hatched – after a much extended period of time – from overwintering cocoons. Given the highest fecundity of females of this species among all the sawflies, especially those swarming in the summer, the number of second-generation larvae can be even up to four times higher than the first generation (own observations).

One can find a number of papers in the literature discussing the dependence of *D. pini* occurrence on environmental conditions, especially on the species composition of stands and the presence of deciduous admixtures (Géri, Goussard, 1984; De Somviele et al., 2004); however, they do not refer to the stands of northern Poland. On the other hand, publications on *G. virens* in this regard are scarce, limited to the references in textbooks (Escherich, 1942; Górnas, 1989; Szujecki, 1995). Therefore, a deeper understanding of the sawfly's preference in terms of the habitat characteristics of the forest may facilitate better forecasting of outbreaks. In the Toruń RDSF, out of the seven species of sawfly for which protective treatments are performed, *D. pini* accounts for 65% of the total area of these treatments. In the Gdańsk RDSF, on the other hand, four species of sawfly threatened the forest, of which *G. virens* accounted for 74% of the total treatment area for this group of insects.

The aim of this study was to determine the influence of selected environmental parameters on the occurrence (number of larvae) of *D. pini* and *D. virens* sawflies.

## 2. Methods

### Study area

The study area encompassed two extensive areas: Puszcza Bydgoska (Bydgoszcz Forest District for the research on *D. pini*) and Bory Tucholskie (Kaliska Forest District for the research on *G. virens*). These areas are characterised by poor habitats and frequent occurrence of gradations of various insect pest species. The species composition is dominated by pine.

### Data set

The study analysed the influence of selected stand and habitat characteristics on the average number of sawfly larvae. For this purpose, a database was created, organised in accordance with the system of forest sub-compartments (stands) in forest

compartments containing the number of larvae of these insects in tree crowns and selected elements of stand characteristics. The data on the occurrence of both species were from years of their gradation: *D. pini* in the Bydgoszcz Forest District in 1991, 1992, 2005 and 2011, and *G. virens* in the Kaliska Forest District in 1992, 1995, 1996 and 1997. Data on the number of sawfly larvae were obtained from forms provided by the forest inspectorates to the Forest Protection Team in Gdańsk. The forms were filled out after the trees were felled on a tarpaulin (IOL 1988, 2004). Stand age was determined on the basis of properly updated data contained in the forms. The remaining data on the characteristics of the stand and the habitat in these sub-compartments were taken from the relevant forest management plans (PUL 1991a,b, 2002). The following information was included in the database: forest district, sub-district, year of gradation, compartment, sub-compartment, stand and habitat characteristics with division into appropriate classes (IUL 2012) provided in Table 1 and the number of larvae from the tree felled on the tarpaulin in a given sub-compartment (individuals). The database contained information on 1255 sub-compartments, including 560 from Bydgoszcz Forest District and 695 from Kaliska Forest District. In the case of habitat moisture, however, no representative sample was collected for statistical analyses, as *D. pini* was found in stands of dry and fresh habitats, while *G. virens* – almost exclusively in fresh habitats. The total number of pine sawfly larvae in the analysed sections was 790 688 and of *G. virens* larvae – 97,825.



**Figure 1.** Location of the study areas within the boundaries of the regional directorates of State Forests: 1 – the Kaliska Forest District (RDSF in Gdańsk) in Bory Tucholskie Forest; 2 – the Bydgoszcz Forest District (RDSF in Toruń) in the Puszcza Bydgoska Forest

**Table 1.** Stand and site features used for the assessment of *D. pini* and *G. virens* preferences

Study variable	Classes – according to forest inventory data (PUL 1991a, b, 2001)	Number of classes
Share of pine	10% intervals, 100%=10	10
Age of pine	20-years intervals (I – 1–20 years, VI – 101–120 years)	6
Stocking index	every 0,1 based on tables (IUL 2012)	8
Canopy closure [%]	full (90–100), moderate (70–80), intermittent (50–60), loose (40), field assessment	4
Site fertility	coniferous forest (B), mixed coniferous forest (BM), mixed deciduous forest (LM), deciduous forest (L)	4
Site humidity	dry, fresh, wet, marshy	4
Bonitation class	Ia – IV,5 based on tables (IUL 2012)	9

### Statistical analysis

Due to the lack of normality of the variable distribution, the significance of the differences in the number of larvae in the classes of the feature in question was tested using the non-parametric Kruskal–Wallis test ( $K-W$ ) together with the *post-hoc* test. Statistical calculations and graphs were performed using Statistica 9 (Statsoft 2009).

### 3. Results

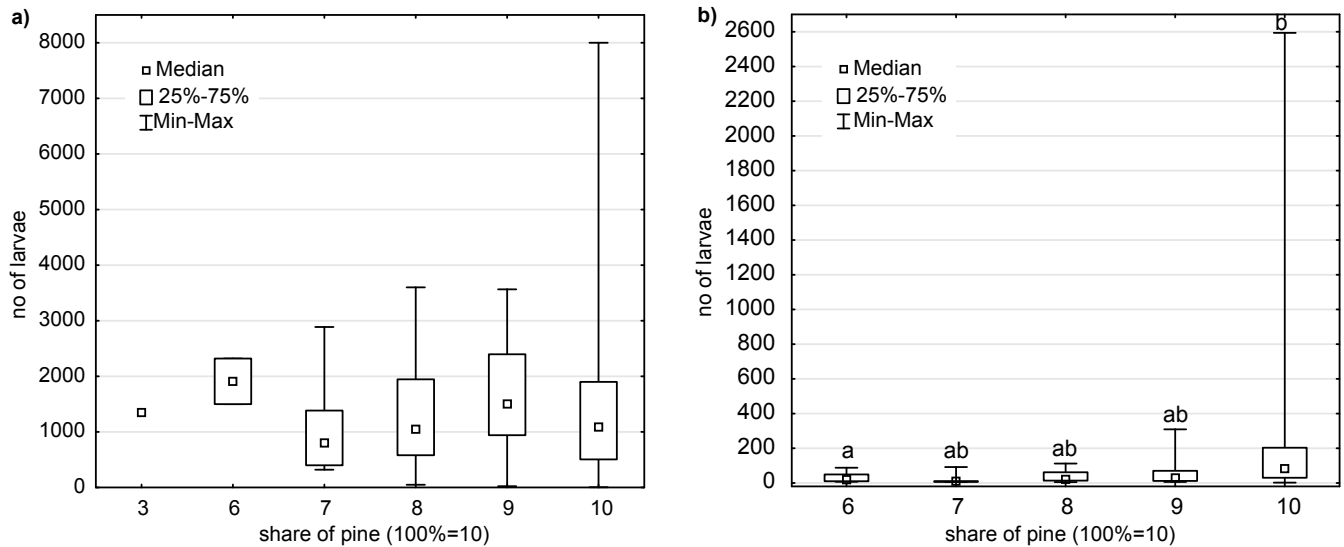
The occurrence of *D. pini* was limited to stands with the pine share defined as 3 (barely 1 stand) and 6–10. The average ( $\pm$  standard deviation) number of larvae in particular classes of pine share varied, from  $1095 \pm 873$  at a pine share of 7 to  $1910 \pm 580$  at 6, but the differences resulting from the pine share are not statistically significant ( $K-W$  test:  $p=0.56$ ) (Fig. 2a). The average number of *G. virens* larvae in particular pine classes ranged from  $25 \pm 38$  at 7 to  $148 \pm 191$  at 10 (Fig. 2b). The differences resulting from the pine share are statistically significant ( $K-W$  test:  $p<0.001$ ). However, they are only visible between the classes with a pine share equal to 6 and 10 ( $p<0.05$ ).

The average number of *D. pini* larvae in the tree crown increased with the age of the stand, from  $1061 \pm 960$  in the 2<sup>nd</sup> age class to  $1931 \pm 1671$  in the 6<sup>th</sup> age class (Fig. 3a). The differences resulting from age are statistically significant ( $K-W$  test:  $p<0.01$ ), but only between the 2<sup>nd</sup> and 4<sup>th</sup> and 5<sup>th</sup> age classes ( $p<0.05$ ). In the case of *G. virens*, the average number of larvae in the tree crown increased from  $68 \pm 78$  in the 2<sup>nd</sup> class to  $204 \pm 243$  in the 4<sup>th</sup> class and then dropped to  $146 \pm 158$  in 6<sup>th</sup> age class stands (Fig. 3b). The differences resulting from the stand age class are statistically significant ( $K-W$  test:  $p<0.001$ ), which is particularly noticeable within classes 3–5 ( $p<0.001$ ), as well as between classes 1 and 6 ( $p<0.05$ ).

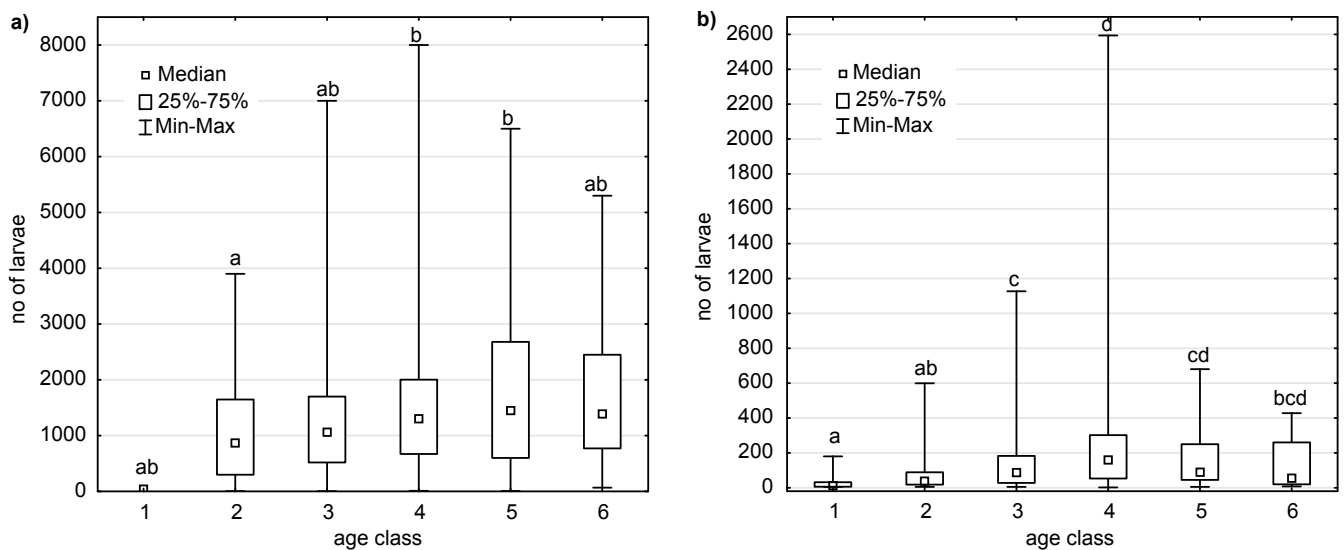
In terms of the stocking index, the average number of *D. pini* larvae was highest with a stocking index of 0.7 ( $1159 \pm 1107$ ) to 0.9 ( $1567 \pm 1384$ ), decreasing gradually with a declining stocking index and becoming significantly lower in classes above 1.0 (Fig. 4a). The differences resulting from the stocking index are statistically significant ( $K-W$  test:  $p<0.001$ ), but only between classes 0.8–0.9 and 1.1 ( $p<0.05$ ). In the case of *G. virens*, the average number of larvae was the highest in 0.5 ( $163 \pm 262$ ) and 0.7 ( $170 \pm 183$ ) stocking index classes, decreasing in higher classes and being the lowest in 1.2 (Fig. 4b). The differences resulting from the stocking index are not statistically significant ( $K-W$  test:  $p=0.15$ ).

The highest average number of *D. pini* larvae was found in moderate ( $1442 \pm 1287$ ) and intermittent canopy closure ( $1438 \pm 1218$ ), slightly lower in full canopy closure ( $1194 \pm 1054$ ), and the lowest in loose canopy closure, represented by only 1 stand (Fig. 5a). The differences resulting from a stand's canopy closure are not statistically significant ( $K-W$  test:  $p=0.64$ ). The average number of *G. virens* larvae was the highest also in loose canopy closures ( $388 \pm 486$ ) and much lower in the other classes, gradually decreasing to  $95 \pm 125$  for full canopy closure (Fig. 5b). The differences resulting from the stand short canopy closure are not statistically significant ( $K-W$  test:  $p=0.12$ ).

The average number of *D. pini* larvae in specific stand site index classes did not exhibit great variability – except for classes III,5 and IV,5 (Fig. 6a), with no statistically significant differences ( $K-W$  test:  $p=0.27$ ), which indicates the lack of clear preferences of *D. pini* in this respect. In the case of *G. virens*, on the other hand, the average number of larvae increased from  $41 \pm 45$  at site index Ia to  $192 \pm 294$  at III and  $183 \pm 151$  at site index class IV (Fig. 6b), which confirms its preference for less fertile stands. The effect resulting from the stand's site index class was statistically significant



**Figure 2.** Mean number of larvae of (a) *D. pini* and (b) *G. virens* related to *P. sylvestris* representation in the stand



**Figure 3.** Mean number of larvae of (a) *D. pini* and (b) *G. virens* related to *P. sylvestris* 20-years age class

(*K-W* test:  $p < 0.001$ ), but significant differences (at the level of at least  $p < 0.05$ ) occurred only between certain groups.

*D. pini* did not exhibit any particular preference for fertility class – the highest average number of larvae was found in mixed coniferous forest habitat, slightly lower in coniferous forest habitat and lowest in the mixed deciduous forest (Fig. 7a); the differences resulting from habitat fertility were not statistically significant (*K-W* test:  $p = 0.25$ ). On the other hand, *G. virens* preferred the sites with the poorest fertility – the average number of larvae was highest in coniferous sites

( $166 \pm 201$ ) and decreased with increasing habitat fertility to  $25 \pm 18$  in deciduous sites (Fig. 7b), but these differences were not statistically significant (*K-W* test:  $p = 0.53$ ).

#### 4. Discussion

Sawflies occurring in our forests, understood as a group of a dozen or so species, have not been thoroughly studied, and in many cases, there are gaps in the knowledge about their biology and ecology.

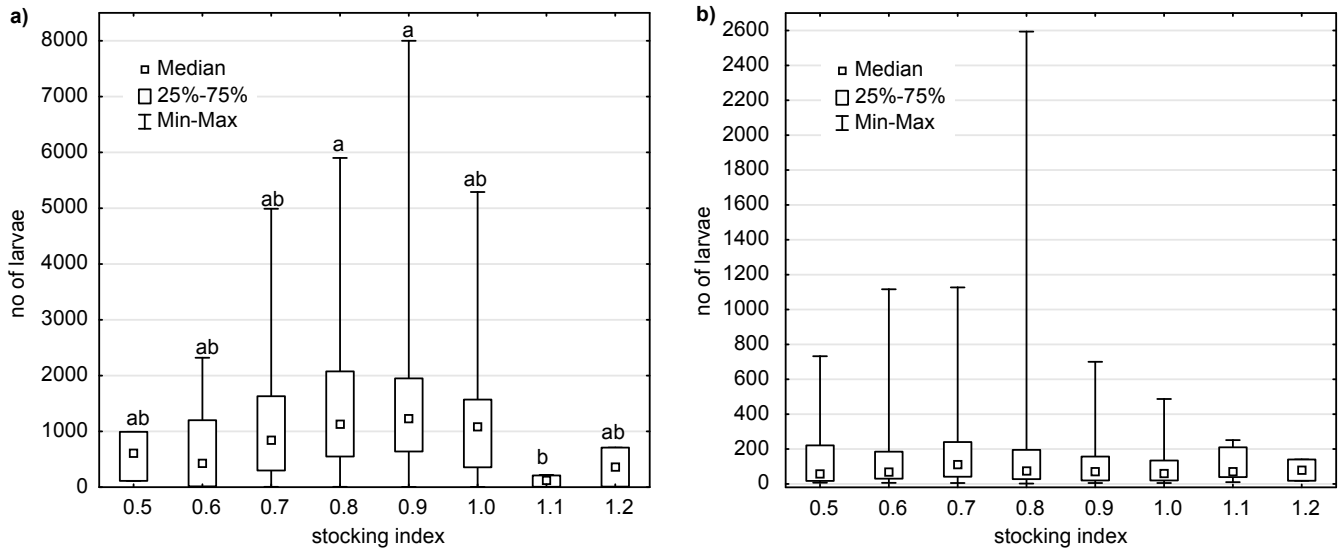


Figure 4. Mean number of (a) larvae of *D. pini* and (b) *G. virens* related to the stocking index

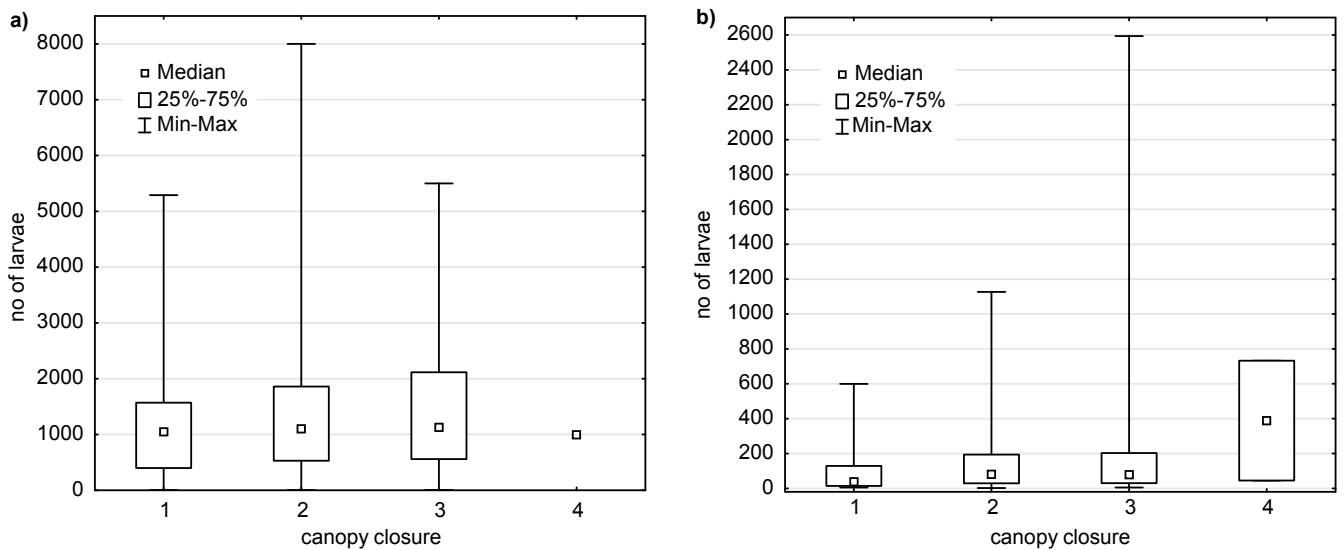


Figure 5. Mean number of larvae of (a) *D. pini* and (b) *G. virens* related to the canopy closure (1 – full, 2 – moderate, 3 – intermittent, 4 – loose)

In Europe, *D. pini* (Géri 1988) is considered to be the most important sawfly species from an economic point of view. In the northern zone of the European continent, there have been numerous gradations of this sawfly species, whereas there have been no mass appearances of *G. virens* (Hanski, 1989).

When analysing the influence of the selected stand features on the occurrence of *D. pini* and *G. virens*, differences in the habitat preferences of both species are noted. In the case of *D. pini*, the average number of larvae increased with stand age

class. Géri and Goussard (1984) also noted that *D. pini* prefers larger-sized trees, which is related to their more advanced age. De Somviele et al. (2004), studying the effects of *D. pini* larvae feeding in Finland during its gradation on 500,000 hectares between 1999 and 2000, found that the insect preferred older stands, while in younger ones, it damaged more trees intended for future harvest (thicker ones with more developed crowns). The second of the investigated species, *G. virens*, preferred stands in age class IV, while in older stands, a decrease in the number of its larvae was recorded. This would

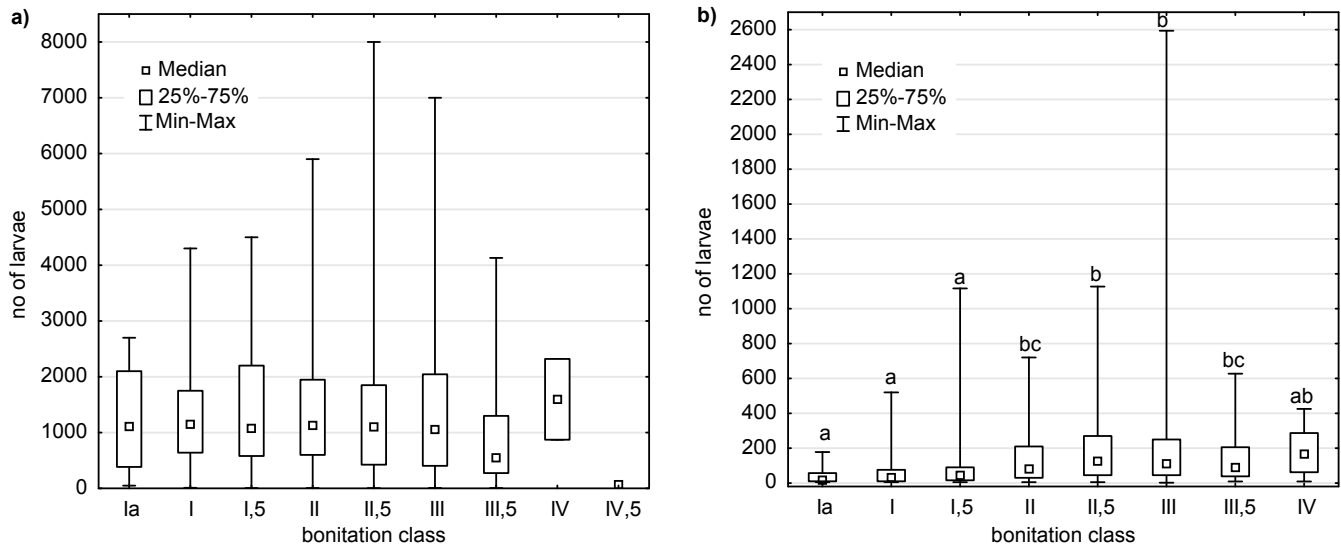


Figure 6. Mean number of larvae of (a) *D. pini* and (b) *G. virens* related to the stand bonitation

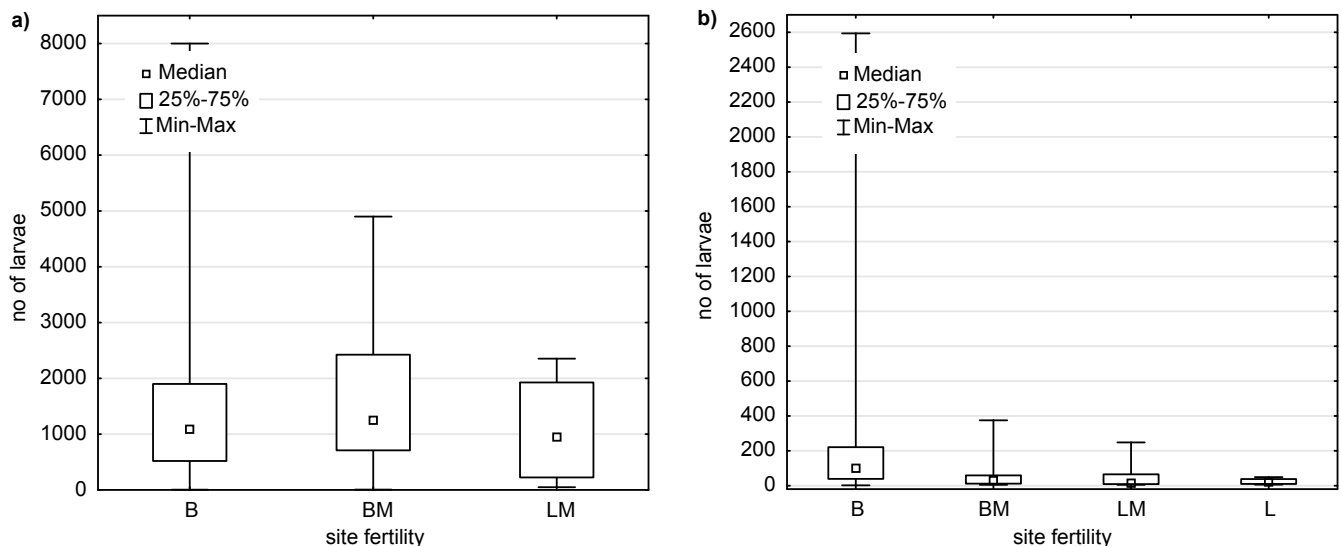


Figure 7. Mean number of larvae of (a) *D. pini* and (b) *G. virens* related to the site fertility: coniferous forest (B), mixed coniferous forest (BM), mixed deciduous forest (LM), deciduous forest (L)

indicate the different preferences of both tested species: *D. pini* to older stands and *G. virens* to medium age classes. Similar differences in preferences in this respect also occur in other, closely related insect species, for example, the pine web-spinning sawfly *Acantholyda posticalis* (Mats.), which usually prefers older stands, and the red-headed pine sawfly *A. erythrocephala* (L.), associated with younger stands (Kolk et al. 2009), although there are also known cases of changes in these dependencies (Button 1999).

The share of pine in the stand was not found to be a factor significantly influencing the number of occurring *D. pini* larvae, which may result from the fact that almost all the analysed stands had a high (at least 50%) share of this tree species. Géri and Goussard (1984) also did not find such a dependence. This indirectly confirms the information provided by Szujewski (1980) that in an area affected by the gradation, the number of wintering cocoons of *D. pini* and other defoliating insects is not significantly dependent on the presence of

deciduous species. In the case of *G. virens*, on the other hand, the share of pine in the stand proved to be a factor influencing the number of larvae, which was the highest in solid pine stands and decreased with the declining share of pine.

Both sawfly species were characterised by different habitat preferences regarding the stocking index of the stand. In the case of *D. pini*, the results indicate a preference of this species' larvae for stands with a stocking index at the level of 0.8 to 0.9, while in the case of *G. virens*, the differences resulting from the stand's stocking index was not found to be statistically significant. Sierpiński (1972) reports, according to Grimalskij (1971), that in 30-year old pine growing in poor habitats, the reduction of the stocking index from 1.0 to 0.7 had no significant impact on the occurrence of *D. pini*, while in fertile sites, it increased the resistance of stands to this insect species.

The canopy closure of the stand had no significant effect on the average number of larvae of both sawfly species, although according to Sierpiński (1972), referring to Schwerdtfeger's data (1957), the intensity of *D. pini*'s cocoon occurrence in autumn searches was higher with a looser canopy closure. Kielczewski et al. (1967) mentioned a much lower density of cocoons at full canopy closure of the stand, while Urban (1961) and Géri and Goussard (1984) pointed out the stronger defoliation due to the feeding of *D. pini* in less compact stands. Meanwhile, De Somviele et al. (2007) found a higher density of *D. pini* cocoons inside dense stands than in their fragmented edge zone, describing it as an edge effect. In the case of *G. virens*, on the other hand, a preference for stands with a looser canopy closure could be observed.

*D. pini* did not exhibit any preference for any specific site index of the stand, while the average number of *G. virens* larvae increased with higher site index classes, associated with increasingly less fertile stands. The data on the larval abundance of sawfly larvae was found to be insufficient to determine the preferences of these species with regard to habitat moisture. In general, however, it should be concluded that both sawflies appear to have a certain plasticity in terms of habitat characteristics, although in the case of *G. virens*, the results indicate that it tends to rather occur in poor habitats, as noted in the literature for *D. pini* (De Somviele et al., 2004).

## 5. Summary

1. The two studied sawfly species differed in their preference to some stand and habitat characteristics in the gradation areas.

2. The pine sawfly preferred older stands, with a stocking index from 0.8 to 0.9, while the share of pine, canopy closure or site index did not affect its abundance.

3. The *G. virens* sawfly preferred solid pine stands of medium age classes with a looser canopy closure and weaker site index in fresh coniferous habitat, while the stocking index did not significantly impact it.

## Conflict of interest

The authors declare the lack of potential conflicts of interest.

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### Authors' contribution

P.G. – concept, collection, data organization and analysis, text preparation; W.G. – concept, data analysis, text preparation.