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The First Stages of Xylobiont Entomofauna Succession on European Silver Fir Logging Residues in Relation to Utilisation Method and Microenvironmental Conditions

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ABSTRACT

The effect of post-cleaning Silver fir logging residues treatment method on the occurrence of early arriving xylobiont insects was studied in 2013 in two stands of fresh upland broadleaved forest and fresh mountain broadleaved forest habitats. At each study site, branches and tree tops were arranged in four piles and scattered disorderly in two plots. It was demonstrated that fine woody debris of fir, regardless of the disposal variant and habitat conditions prevailing at the place of leaving the material, were the breeding and the feeding base for *Pityophthorus pityographus* (Ratzeburg, 1837), *Pityokteines vorontzowi* (Jakobson 1895), *P. curvidens* (Germar, 1824) and *Cryphalus piceae* (Ratzeburg, 1837) (Coleoptera: Scolytinae). It was noted that the attractiveness of fir branches and tree tops for phytophagous insects increased proportionally to the stage of decomposition of logging residues. The influence of forest habitat and the method of fir slash utilisation, as well as microenvironmental conditions, prevailing in the material surroundings, on the severity of branch and tree top infestation by insects was not confirmed. It was, however, proved that fine woody debris of fir was the place of the occurrence of saprophages and natural enemies of bark beetles, i.e. predators, parasites and parasitoids. The most abundant entomophagous insect species was *Phloeopora corticalis* (Gravenhorst, 1802) (Coleoptera: Staphylinidae), whereas saproxylobiont entomofauna was represented mostly by insects from the order Diptera and family Mycetophilidae.

Key words: Abies alba, fine woody debris, Coleoptera, beneficial insects, forest habitat, slash management

INTRODUCTION

Fine woody debris such as branches and tree tops, left in the forest after logging, are the habitat for numerous xylobiont insects species, including both cambio- xylophages harmful to the stability of stands (Grégoire *et al.*, 2004; Starzyk *et al.*, 2008a; Kacprzyk, 2012), entomophagous insects as beneficial in pest management (Kenis *et al.*, 2004; Hilszczański *et al.*, 2005; Johansson *et al.*, 2007) and saprophagous insects actively accelerating the process of organic matter circulation (Gunnarsson *et al.*, 2004; Lindhe and Lindelöw, 2004; Jonsell, 2008b; Zeniauskas and Gedminas, 2010).

Silver fir (*Abies alba* Mill.) is, next to European beech (*Fagus sylvativa* L.), one of the main forest-forming species in the Carpathians (Pawlaczyk *et al.*, 2005). In the Polish Carpathians the share of fir stands is estimated at ca. 20% but, according to

Jaworski and Pach (2014), having regard to the progressive climate change and loss of pure spruce stands, with simultaneous high production and adaptability of fir to different environmental conditions (Tinner *et al.*, 2013), the importance of this species in the considered region will increase in the future.

Silver fir stands, followed by spruce (*Picea abies* L. Karst.) stands are among the mountain forests most severely exposed to outbreaks of cambio- xylophagous insects although, as emphasised by Brauns (1975), the number of different groups of bark beetles is twice smaller in fir than in Scots pine (*Pinus sylvestris* L.) and Norway spruce. So far, little is known about the impact of disposal method of post-harvesting branches and tree tops of fir on the quantitative and qualitative diversity of occurring insects. The results obtained by Starzyk *et al.* (2008a) indicate, that in the case of accumulation of large number of cut-off or broken branches and tree tops in the stands, the material must be removed from the forest before swarming of most dangerous secondary insect pests, and in a situation where this is not possible it is advisable to leave the residues loosely on the surface in direct sunlight, to allow quick drying out of cambium and phloem. On the other hand, Ząbecki and Kacprzyk (2007) did not confirm that random scattering of spruce branches and tree tops on surfaces directly exposed to sun has the limiting impact on the development of bark beetles. In contrast, according to these authors, on surfaces with high (at least 0.5 m height) undergrowth vegetation in weakened Norway spruce stands this method can promote the colonisation of logging residues by cambiophagous insect pests to much greater extent than their pilling. Therefore, consideration of local environmental conditions seems reasonable when selecting the method of fine woody debris treatment. The effect of Silver fir logging residues (LR) treatment method on attractiveness for early successional xylobiont entomofauna was going to be examined. Additionally in this study the site conditions in the place of fir LR storage impact on the species insects composition were investigated. The following hypotheses were tested: 1) The spreading fir branches and tree tops on the forest floor reduces the attractiveness of the material for the cambio- xylophagous insects, (2) The frequency and infestation density of the fir LR by early colonizing insect species are determined by the physiological state of the material, which is associated with a forest habitat in the place of its storage and a utilisation method.

MATERIAL AND METHODS

The study was conducted in south-eastern Poland, in two, over 100 years old, Silver fir stands growing in areas of the Low Bieszczady Mountains (experimental site 1: 49°51’62” N; 22°31’91” E) and the Central Beskidian Piedmont (experimental site 2: 49°44’60” N; 22°29’77” E). The stand in the study site No. 1 overgrew the area at an altitude of 355 m above sea level, in the fresh upland broadleaved forest (FUBF) habitat. The second forest stand (study site No. 2) was located at a height of 445 m above sea level, in a fresh mountain broadleaved forest (FMBF) habitat. The local soils are derived from different parent material, i.e. siltstones for experimental site No.

1 and sandstones for experimental site No. 2. The soils were classified as Epidystric Cambisol and Hyperdystric Cambisol, respectively. Soils derived from different types of parent material had different texture. In the first research area it was silt, while in the second research area the soils were sandy loam. Mull type of humus was noted in both experimental sites.

Both stands were situated on the slopes of northern exposure. The health condition of test stands was good, as in the period of 2008-2013 neither dead lying trees infested by bark beetles nor severe drought were observed.

In the first half of May fir branches and tree tops left after logging conducted in the period of March-April, uninfested earlier by insects, were partially stored in 1.50 m-high piles, whereas the remaining LR were scattered disorderly on the forest floor over an area of 20x100 m in both sites. In total, four piles and 2 plots with material loosely scattered were established at each study site.

Also at each study site, both the material collected in piles and loosely scattered was located under partial cover of trees.

The minimum distance between the piles was 10 m, while the plots with material scattered disorderly were situated at a distance of minimum 30 m away from the piles. Entomological analyses were performed from early June to late September, at 2 week intervals. Each time, 15 branches and tree tops, taken randomly from the piles of three separate layers (5 pieces for each layer): external (depth of about 30 cm, measured from the top to the centre of the pile), middle (31-60 cm measured from the top to the interior of the pile) and bottom (at a depth of 60 cm, measured from the top to the interior of the pile) were inspected. At the same time, 15 pieces of material left loosely on the study plot were analysed. In total, 540 pieces of fir branches and tree tops, including 270 pieces for each of the LR disposal method were examined. The average dimensions of the analysed LR reached the length of 1.70 m and 7.15 cm for diameter measured at the half length of the material.

Physiological condition of each tree top and branch was assessed in relation to 4 characteristics (Table 1). Identification of insects and calculating the number of galleries were performed after debarking the entire length of the branch growing directly from the trunk. To determine the xylobiont insects associated with pioneer cambiophages colonising LR, 20 cm long pieces (N=60) from each layer of the pile and plot with material scattered disorderly were collected at random in the first half of December 2013. Then, the samples were taken to the laboratory where they were kept in plastic cylinders secured from the top with a fine-mesh curtain, for a period of five months, until hatching of insects. Thermal conditions prevailing in the storage material fluctuated around 20°C and 60% for relative air humidity. For insects whose species identification was not possible, lower taxon was assigned.

The prevalence of phloemophages on the analysed fir LR was characterised by the frequency expressed as the percentage of the analysed material colonised by a given species and by the infestation density, expressed as the number of exit holes or galleries of a given insect species per bark area. The Simpson diversity index (D) was used to compare the xylobiont entomofauna diversity (Simpson 1949) and the species richness (S) was given as the number of species per sample.

Table 1. Parameters and classification determining the physiological condition of the analysed Silver fir branches and tree tops.

Parameter	Degree	Criteria for evaluation
Bark decomposition (BDC)	1	bark fresh and strongly adherent to the wood
	2	bark dry and strongly adherent to the wood
	3	dry and loose bark
	4	moist and loose bark
Bark coverage (BC)	1	bark cover of 100%
	2	bark cover above 75% up to 100%
	3	bark cover above 50% up to 75%
	4	bark cover from 25% to 50%
	5	bark cover below 25%
Presence of needles (NP)	1	green needles
	2	yellow needles
	3	brown needles
	4	no needles
Phloem and cambium decomposition (PCDC)	1	phloem living and undecomposed
	2	phloem partly dead, partly decomposed
	3	phloem dead and completely decomposed

The relationships between the species of phloemophages and the physiological condition of the material as well as the study site habitat condition were presented using correspondence analysis (CA). The frequency of insects was statistically compared ($P \leq 0.05$) between LR treatment method and their location inside the pile using the chi-square test. The infestation density of fir LR by the most frequent species of bark beetles, taking into consideration the variant of the material treatment and position within the pile was examined using the Mann–Whitney U and Kruskal-Wallis tests. To demonstrate the effect of microenvironmental conditions on branch and tree top infestation density by the selected species of bark beetles, the general linear model (GLM) was used with study site localisation, variant of LR treatment and the physiological condition of the material as qualitative factors and temperature and relative humidity as continuous predictor variables. Kruskal-Wallis test was used to express the preferences of bark beetles for the physiological condition of fir LR. Statistical analyses were performed in STATISTICA software, Version 10.0 (StatSoft, Inc., Tulsa USA).

RESULTS

During the period of June-September 2013, fir branches and tree tops at the study sites were colonised by 4 species of bark beetles (Coleoptera) from the family Curculionidae, i.e. *Pityophthorus pityographus* (Ratzeburg, 1837), *Pityokteines vorontzowi* (Jakobson, 1895), *Cryphalus piceae* (Ratzeburg, 1837) and *Pityokteines curvidens* (Germar, 1824). Regardless of study site, the highest prevalence on the analysed material was observed for *P. pityographus*, that prefers branches and tree tops scattered disorderly on the forest floor rather than collected in piles (FUBF: x^2=9.968, df=1, p<0.05; FMBF: x^2=19.377, df=1, p<0.05) (Table 2). On the other hand, the presence of *P. pityographus* inside the piles differs between the tested areas. Nevertheless, the location of the material within the piles did not have significant influence on the occurrence of bark beetles (Table 3) (x^2=3.082, df=2, p>0.05). *P. vorontzowi*, in contrast to *P. pityographus* was more prevalent on the material collected in piles, than in the one scattered loosely on the study plot (Table 2) (FUBF: x^2=12.007, df=1, p<0.05; FMBF: x^2=34.020, df=1, p<0.05). The frequency index of *P. vorontzowi* reached the highest values in the lower pile layer, but the location of branches and tree tops inside the piles, similarly as in the case of *P. pityographus* did not influence significantly their attractiveness for this insect species in either of the study sites (Table 3) (FUBF: x^2=2.997, df=2, p>0.05; FMBF: x^2=3.173, df=2, p>0.05). The frequency of *C. piceae* and *P. curvidens* did not exceed 3% (Table 2).

Table 2. The percentage of Silver fir branch and tree top colonisation by phloemophages and the mean infestation density* by the most frequently occurring insect species (indiv.dm-2) (in parentheses), with regard to the utilisation method.

Forest habitat	Species	Logging residues treatment method	
		Pile	Scattered disorderly
Fresh upland broadleaved forest	*P. pityographus*	52.59 (0.35)	73.33 (0.34)
	P. vorontzowi	39.25 (0.32)	18.51 (0.23)
	P. curvidens	2.96	0.74
	C. piceae	2.22	0.00
No. of analyzed branches		135	135
Fresh mountain broadleaved forest	*P. pityographus*	48.88 (0.46)	75.55 (0.34)
	P. vorontzowi	41.48 (0.37)	10.37 (0.17)
	P. curvidens	2.22	0.00
	C. piceae	0.00	0.74
No. of analyzed branches		135	135

*Explanation: the mean values of infestation density indices were calculated for the cases where the presence of bark beetles on branches and tree tops was confirmed.

The correspondence analysis showed similar affinity of bark beetles to the LR in different physiological condition. The insects colonised mostly branches in the initiation phase (2 degree) of bark, cambium and phloem decomposition. However, *C. piceae*, *P. vorontzowi* and *P. pityographus* were related to residues collected in piles, whereas *P. curvidens* was mostly associated with branches scattered loosely on the forest floor (Fig. 1).

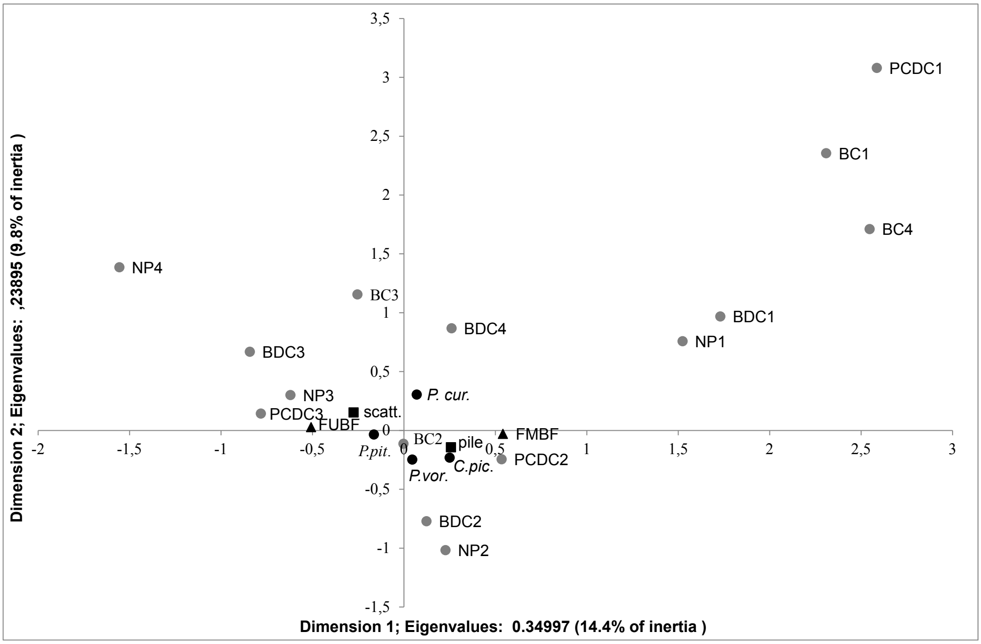

Fig. 1. Correspondence analysis (CA) showing the relationship between the prevalence of bark beetles and physiological condition of LR, their utilisation method and forest habitats. Species of bark beetles (*P. vor.-Pityokteines vorontzowi*, *P. cur.-Pityokteines curvidens*, *C. pic.-Cryphalus piceae*, *P. pit. -Pityophthorus pityographus*) are represented by black points, forest habitats-by black triangles, LR treatment method by black squares, physiological condition of the material (BDC-bark decomposition, BC-bark coverage, NP-presence of needles, PCDC-phloem and cambium decomposition) by grey points

It was observed that the mean LR infestation density by *P. pityographus* and *P. vorontzowi* was higher when the material was arranged into the piles rather than randomly spread over the study plot. However, only in the case of *P. vorontzowi* colonising fir LR in FMBF habitat the method of material disposal was a factor which significantly influenced the infestation density (Mann - Whitney U test: Z=-2.533, $p<0.05$) (Table 2).

There was a significant increase in LR infestation by bark beetles in deeper pile layers (Table 3) (Kruskall-Wallis test: *P. pityographus*, FMBF: H (2, N=56) =18.852, p=0001; *P. vorontzowi*, FUBF: H (2, N=72)=6.505, p=03870; FMBF: H (2, N=67) =21.445, p=0000).

It was demonstrated that the forest habitat, LR utilisation method and microenvironmental conditions had no impact on the infestation density by bark beetles. However, there was a significant correlation with physiological conditions of fir LR (Table 4).

Table 3. The percentage of Silver fir branch and tree top colonisation by phloemophages and the mean infestation density* by the most frequently occurring insect species (ndiv.dm-2) (in parentheses), with regard to the position of logging residues inside the pile.

Forest habitat	Insect species	Pile layer		
		External	Middle	Bottom
Fresh upland broadleaved forest	*P. pityographus*	60.00 (0.27)	46.67 (0.34)	51.11 (0.45)
	P. vorontzowi	31.11 (0.18)	37.77 (0.40)	46.66 (0.69)
	P. curvidens	2.22	0.00	4.44
	C. piceae	4.40	4.40	0.00
No. of analyzed branches		45	45	45
Fresh mountain broadleaved forest	*P. pityographus*	42.22 (0.21)	46.67 (0.33)	60.00 (0.39)
	P. vorontzowi	26.67 (0.15)	46.67 (0.33)	48.00 (0.55)
	P. curvidens	0.00	0.00	0.00
	C. piceae	1.22	0.00	0.00
No. of analyzed branches		45	45	45

*Explanation: the mean values of infestation density indices were calculated for the cases where the presence of bark beetles on branches and tree tops was confirmed.

Table 4. The results of multivariate analysis of variance based on the general linear model (GLM) for the infestation density of Silver fir fine woody debris by bark beetles, with regard to the forest habitat, LR treatment method and their physiological condition.

Effect	*P. pityographus*		*P. vorontzovi*		Total insects	
	F	*p*	F	*p*	F	*p*
Forest habitat	0.19	0.6604	0.24	0.6252	0.28	0.5989
BDC	4.96	0.0021	3.50	0.0197	18.16	0.0000
PCDC	3.58	0.0285	0.69	0.4993	11.22	0.0000
Forest habitat x LR treatment method	0.33	0.5638	0.68	0.4097	0.02	0.9657
Forest habitat x LR treatment method x BDC	0.75	0.5240	2.84	0.0152	2.54	0.0275
Forest habitat x LR treatment method x PCDC	0.69	0.5564	3.95	0.0036	5.40	0.0003
Forest habitat x Temperature	0.66	0.4181	2.77	0.0968	3.66	0.0562
Forest habitat x Temperature x Humidity	0.93	0.3358	1.29	0.2572	3.03	0.0824

The more advanced the process of LR bark and phloem decomposition, the higher infestation density of material by bark beetles was detected (Fig. 2).

A laboratory analysis of the LR fragments coming from piles and plots with material scattered disorderly showedthe presence of cambiophages such as the six-toothed spruce bark beetle (*Pityogenes chalcographus* L., 1761) (Coleoptera, Scolytinae) and xylophages represented by the greater horntail wasp (*Urocerus gigas* L., 1758) (Hymenoptera, Siricidae) (both male and female). The occurrence of saprophagous insects of the order Diptera and the family Mycetophilidae, being the most numerous group of early-arriving xylobiont entomofauna on the analysed fir LR, was also confirmed. Among the insect predators, the bark-gnawing beetles (*Nemosoma elongatum* L., 1761) (Coleoptera, Trogossitidae) and typical bugs such as *Scoloposcelis pulchella* (Zetterstedt, 1838) (Hemiptera, Anthocoridae) were recorded. The parasites of bark beetles were represented by insects of the family Braconidae (Hymenoptera), whereas on LR collected in piles in FUBF parasitoid the Ibaliid wasp (*Ibalia leucospoides* (Hochenwarth, 1785) (Hymenoptera, Ibaliidae) was observed (Table 5).

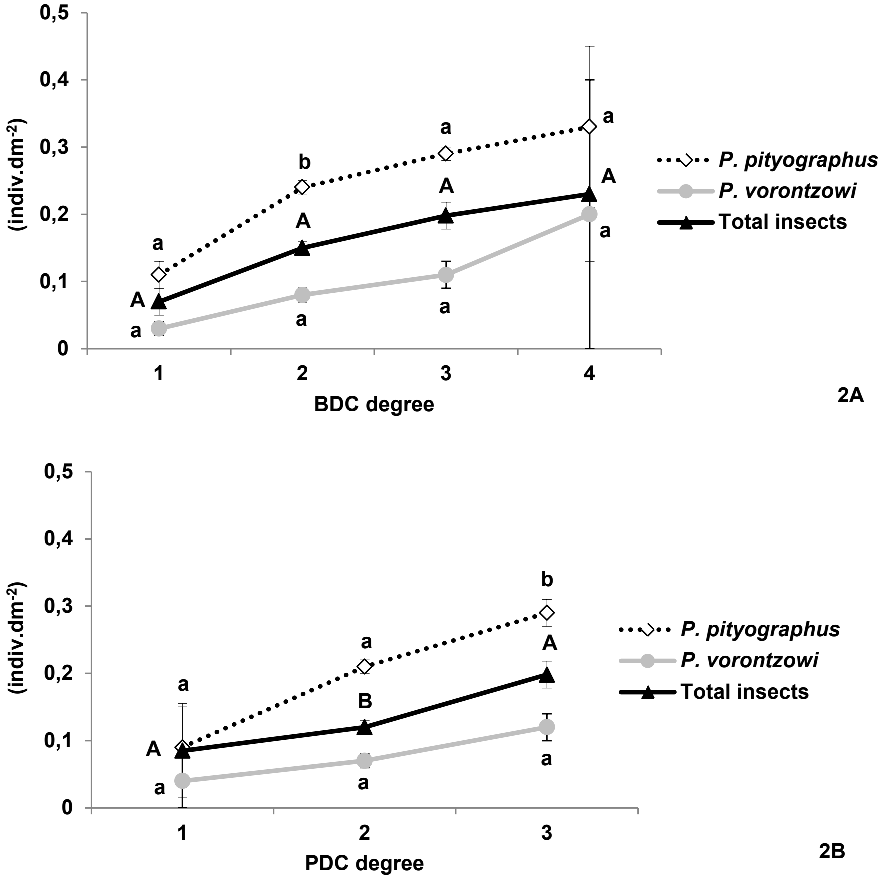

Fig. 2. Infestation density (mean ±SE) of Silver fir logging residues by the most numerous bark beetle species and total insects in different phloem, cambium (A) and bark decomposition (B) degrees. For each species, the values indicated by the same letter are not significantly different at p≤0.05.

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Table 5. List and percentage of collected individuals of bark beetles and accompanying insects in Silver fir fine woody debris in the study plots in south-eastern Poland.

Taxonomic group	Fresh upland broadleaved forest		Fresh mountain broadleaved forest	
	sacttered disorderly	collected in piles	sacttered disorderly	collected in piles
Diptera				
Diptera spp.	7.84	61.11	20.00	12.50
Mycetophilidae	62.74	-	-	-
Crypturgus hispidulus Thom.	-	-	-	1.25
Hymenoptera				
Hymenoptera spp.	-	-	6.15	1.25
Braconidae	-		5.56	-
Phloeopora corticalis Grav.	-	-	9.23	-
Ibalia leucospoides Hoch.	-	5.56	-	-
Urocerus gigas L.	-	11.11	-	-
Hemiptera				
Anthocoridae spp.	3.92	5.56	-	-
Cryptolestes ferruginesus Steph.	1.96	-	-	-
Scoloposcelis pulchella Zett.	-	5.56	-	-
Zeteotomus brevicornis Erich.	-	-	-	1.25
Coleoptera				
Nemosoma elongatum L.	-	5.56	-	1.25
Pityokteines vorontzowi (Jacobs.)*	15.68	-	63.08	77.50
Pityogenes chalcographus L.*	-	-	1.54	-
Pityophthorus pityographus Ratz.*	7.84	-	-	-
Total insects	51	18	65	80
Species richness (S)	6	6	6	6
The Simpson diversity index (D)	0.58	0.63	0.56	0.38

*Phloemophagous insect species infesting logging residues. Explanation: Frequency of insect occurrence expressed as the number of a given insect species per total number of insects collected x100

The parasites of bark beetles were represented by insects of the family Braconidae (Hymenoptera), whereas on LR collected in piles in FUBF parasitoid the Ibaliid wasp (*Ibalia leucospoides* Hochenwarth, 1785) (Hymenoptera, Ibaliidae) was observed (Table 5).

The similar saproxylic insect diversity (D) was observed in the case of LR scattered disorderly on the study plots, regardless of the forest habitat. In the case of branches and tree tops collected in piles, the difference between the index values was high (39.7%) in favour of LR left in FUBF habitat. No impact of forest habitat and LR disposal method on xylobiont entomofuana species richness (S) was proved (Table 5).

DISCUSSION AND CONCLUSIONS

The positive influence of post-harvesting LR on biodiversity of forest ecosystems in terms of soil enrichment in nutrients, preventing soil erosion and the creation of places for the development and shelter for many animal groups was demonstrated by numerous authors (Benson *et al.*, 1980; Bengtsson *et al.*, 1997; Proe *et al.*, 2001; Ecke *et al.*, 2002; Gunnarsson *et al.*, 2004; Jonsell, 2008a; Fossestøl and Sverdrup-Thygeson, 2009; Briedis *et al.*, 2011). Brin *et al.* (2011) shown that the presence of both large and small size fragments of residues left in the forest after logging operations, inhabited by various species of saproxylic insects, is an important biodiversity-increasing factor. On the other hand during considerable accumulation of breeding material in the form of branches and tree tops in the forest, insect pests may pose a threat to the vitality of the surrounding stands (Grijpma and Schuring, 1984; Hedgren *et al.*, 2003). Cambio- xylophages infesting LR following the breeding success on the studied material can colonise the tops of weakened and/or even healthy trees, playing an important role in the process of forest decline (Starzyk, 1996; Grodzki, 2004, 2010; Kacprzyk, 2014).

Based on the conducted entomological analysis of post-harvesting fir branches, 4 species of bark beetles were reported regardless of the forest habitat and the method of material disposal. The species identified on the analysed material are common cambiophagous insect pests of coniferous stands in the Carpathians, colonising the tops of trees (Starzyk *et al.*, 2008b). The observed lack of differences in the species composition of insects occurring on fir branches and tree tops between the applied disposal variants is quite unexpected. In stands with increased prevalence of cambio- xylophagous insects the colonisation is observed in the material of different physiological condition (Kacprzyk, 2014; Kacprzyk and Bednarz, 2015), whereas in healthy fir stands, with no bark beetles pressure, such as in the study sites, larger selection in choosing places for settlement by insects should be expected. Due to the absence of available breeding and feeding base for insects in the forest, the quality of dried LR becomes crucial for the bark beetles. However, all cambiophages identified on the fir branches and tree tops are thermophilic species with similar thermal and humidity requirements. We suggest that this, to some extent, blurs the differences in the species composition of bark beetles between the treatment methods of LR, that could have been observed in bark beetles characterised by different ecology of occurrence. Similar preferences of different species of bark beetles in relation to the physiological condition of the analysed material seem to also confirm it. At the same time, no differences were observed in the insect species composition colonising fir LR between forest habitats. It may indicate that the position above the sea level, the species composition of trees, geological structure and soil subtype are of secondary importance for early arriving entomofauna, especially for bark beetles characterised by high ecological plasticity in the material selection, as identified in the case of cambiophagous insects of fir LR.

The conducted study indicates that leaving fir branches and tree tops loosely on the forest floor was more favourable to the prevalence of *P. pityographus*, as the most numerous insect colonising fir LR, than collecting the material in piles. The opposite relationship was observed for the second most abundant species on the analysed LR, i.e. *P. vorontzowi*. Interestingly, the arrangement of the material in the pile does not have significant effect on the bark beetles frequency, while the location of branches and tree tops within the piles have a significant impact on the infestation density of LR by *P. voronztowi* and *P. pityographus*. For both insect species an increased density of galleries in deeper layers of piles was recorded. This is contrary to the results obtained by Kacprzyk (2014), who proved that spruce branches deposited in the upper layers of piles are more attractive for *P. pityographus* than those located in the bottom layers.

For the most frequently observed insect species the mean number of galleries does not exceed one per 1 dm^2 of bark area. Such low value of this index can probably confirm good health condition and vigour of trees in the study sites, where the current population of *P. pityographus* and *P. vorontzowi* does not pose a threat to the stability of the examined stands.. Moreover, low infestation density of fir branches and tree tops by bark beetles may result from the material location under partial cover of trees. A negative correlation between infestation density of spruce tops by cambio-xylophagous insects and stocking index of stands was proved by Röker (1986) and Kula *et al.* (2011). Also Kacprzyk (2014) observed that the variability of thermal conditions related to the location and the utilisation method of spruce LR significantly affects the infestation density of the material colonised by *P. chalcographus*, *P. pityographus* and *Dryocoetes autographus* (Ratzeburg, 1837) (Coleoptera: Scolytinae). In the presented experiment the effect of utilisation method and microenvironmental conditions on the infestation density of branches and tree tops by cambium-feeding insects was not significant. However, strong positive correlation between the density of bark beetle galleries on LR and advancement in the process of the material phloem and cambium decomposition was proved. It may result from the fact that the colonisation of the LR by insects increases with time and with progressing decomposition of the material.

No effect of utilisation method and site conditions in the place of fir LR storage on xylobiont entomofauna species richness was found. Nevertheless branches and tree tops collected in piles were characterized by a slightly higher share of beneficial entomophagous insects, in relation to the second LR treatment method. Moreover, entomophagous insects were more numerous on material left in FUBF forest site, than in FMBF forest site. The presence of saprophages, predators and parasitoids, beneficial to the environmental biodiversity, was proved. Saprophagous insects play an important role in forest ecosystems, as their adults and larvae - by the fragmentation of organic material-contribute to its decay and enrich the soil humus layer with valuable nutrients (Bańkowska, 1981; Soszyński *et al.*, 2000). Predatory insects and parasitoids are important in biological control of insect pests (Johansson *et al.*, 2007; Stojanović and Marković, 2007). In our study the group of beneficial insects was mostly represented by saprophagous insects from order Diptera and the family Mycetophilidae. The share of natural enemies of insect pests was relatively small and did not exceed 15%.

Grodzki (2010) emphasises, that there is still no detailed data on entomophagous organisms as regulators of the prevalence of Silver fir cambiophagous insect pests. Therefore, it seems to be necessary for conducted such experiments in a wider range by taking into account other environment conditions and longer period of leaving LR in the forest.

In conclusion, the low degree and colonisation intensity of fine woody debris of fir by cambiophagous insects coupled with frequent occurrence of saprophagous insect species, as well as parasites and predators, indicate that the fir branches and tree tops left after cuttings on the forest floor is desirable for the biodiversity protection and does not threat the stability of fir stands in the study sites.

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