

The alpha-cypermethrin coated net for protecting Norway spruce wood against bark beetles (Curculionidae, Scolytinae)

Iwona Skrzecz^{1*}, Wojciech Grodzki¹, Mieczysław Kosibowicz¹, Dorota Tumialis²

¹ Forest Research Institute, Braci Leśnej 3, Sękocin Stary, 05-090 Raszyn, Poland

² University of Life Sciences, Faculty of Animals Sciences, Department of Animal Environment Biology, Ciszewskiego 8, 02-786 Warsaw, Poland

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Abstract: The study estimated the efficacy of a net coated with alpha-cypermethrin used to protect Norway spruce [*Picea abies* (L.) H. Karst] wood against bark beetle infestations. The inside of the net was coated with 100 mg/m² of alpha-cypermethrin. The studies carried out in 2010 and 2011 took place in southern Poland in the Beskid Żywiecki and Beskid Sądecki mountains in *P. abies* stands threatened by *Ips typographus* (Linnaeus, 1758). The research material consisted of wood logs taken off of 70–80-year-old *P. abies* trees. The logs were wrapped in the net in the early spring before spring swarming of bark beetles. The unwrapped logs were considered as the study controls. An evaluation of the treatments was performed after 2 months. The evaluation was based on the counting of bark beetle galleries found after removing the bark from the wrapped and unwrapped logs. There were no insect galleries on the wrapped logs. The net was a barrier, on which bark beetles died. About 10 dead *I. typographus* beetles were found on 0.01 m² of the net surface. On the bark from the unwrapped-control logs there were 3,156 galleries/entrance holes of bark beetles, in total, of which 73% belonged to *I. typographus*, 13% to *Pityogenes chalcographus* (Linnaeus, 1761), and almost 10% to *Xyloterus lineatus* (Oliv.). These results indicated the high efficacy of the net coated with alpha-cypermethrin used for the protection of Norway spruce wood against the bark beetles. At the same time, the net was found to have a negative effect on non-target entomofauna, mainly *Hylobius* spp., *Thanasimus formicarius* (L.), and *Tetropium castaneum* (F.). However, the use of a net did not affect other predatory (Carabidae) and parasitic (Ichneumonidae and Tachinidae) entomofauna.

Key words: alpha-cypermethrin, net, *Picea abies*, Scolytids, wood protection

Introduction

One of the most important problems in the Norway spruce stands is how to protect the processed timber stored in the forest, against the insects that infest the bark, phloem and wood. Among the most important species is the ambrosia beetle *Xyloterus lineatus* (Olivier, 1795) affecting wood. The European spruce bark beetle *Ips typographus* (Linnaeus, 1758) being a vector of the blue-stain fungi (Linnakoski *et al.* 2012), should also be mentioned. The total area of forests in Europe threatened by the European spruce bark beetle is estimated to be about 8 million ha (Grégoire and Evans 2004).

A set of methods exists for controlling the bark beetle populations and damage level. In the case of *I. typographus* and the accompanying species *I. amitinus* (Eichhoff, 1871) and *Pityogenes chalcographus* (Linnaeus, 1761), the most effective method is the identification and fast removal of infested trees before the emergence of a new generation of beetles that develops under the bark (Niemeyer 1997). This approach is usually supported by the use of trap trees and pheromone-baited artificial traps that catch swarming parent beetles. The traps, though, are often considered as not effective enough (e.g. Wes-

lien 1992; Grodzki *et al.* 2008). Conventional chemical insecticides are mostly used to protect stored timber (Wermelinger 2004; Koleva *et al.* 2012; Lubojacký and Holuša 2014) and systemic chemicals have been reported to protect single susceptible trees (DeGomez *et al.* 2006; Grosman and Upton 2006; Billings 2011). Emamectin benzoate and fipronil show substantial promise for preventing bark beetle attacks (Grosman and Upton 2006). At present in the USA, only the insecticides containing bifenthrin or permethrin are available for bark beetle prevention, and then only to protect trees in urban settings, but not in forests (Billings 2011).

In Central Europe the use of insecticides, including alpha-cypermethrin, in the protection of Norway spruce and Scots pine wood, is a method which has been used for over 25 years (Zahradník *et al.* 1996; Novotny and Zúbrik 2000). This substance has been used most often as an active ingredient of the insecticide Fastac 100 EC (formerly 10 EC) at 10% in 1 liter of formulation. It is recommended that this product be applied as a wood spray in a concentration of 0.3–0.5% before bark beetle attack.

According to the formal regulations of the Polish State Forests, the application of insecticides is very lim-

*Corresponding address:
i.skrzecz@ibles.waw.pl

ited; in the mountains it is not allowed at all due to water protection (Instrukcja ochrony lasu 2012). On the other hand, due to ecological limitations as well as expensive and lengthy procedures relating to the registration, the number of insecticides registered for wood protection has been decreasing each year. Insecticide use is also not recommended by certification authorities such as Forest Stewardship Council (FSC).

The control of bark beetles and the protection of stored timber in spruce stands is complicated and time-consuming, especially in outbreak conditions. In the mountains, it is much more difficult to apply control methods successfully and correctly. The difficulty is due to the shorter vegetation season, protection of watersheds, diversified terrain configuration, and related technical problems (Szabla 2013). For these reasons, there is a need for new methods which will enhance control effectiveness and reduce the work needed. One such method focused on the environmentally safe application of the insecticides, is described in this paper. The aim of this study, conducted from 2010 to 2011, was to estimate the efficacy of a net filled up with the alpha-cypermethrin used for wrapping Norway spruce wood to protect the timber from the bark beetles. Since *I. typographus* commonly occurs in spruce forests and infests stored fresh timber in the forest, this species was used as the main example for demonstrating the effectiveness of the tested method.

Materials and Methods

Study area

The experiments were located in the area administrated by the regional directorates of State Forests in Katowice and Kraków, in the Forest Districts Jeleśnia (coordinates: 49°32'N, 19°17'E) and Krościenko (49°26'N, 20°33'E) located in Beskid Żywiecki and Beskid Sądecki in the Western Carpathians. The climate in these areas is similar and characterised by a typical zonation associated with an increased altitude above sea level from about 500 to 1557/1266 m, respectively. The annual precipitation is approximately 800–1,100 mm, and is a function of elevation (being lowest at 500 m a.s.l., and highest at above 1200 m a.s.l.). The mean annual temperature is approximately 4–7°C, and is negatively correlated with elevation (Brzeźniak and Czemerda 2000).

The forests on the above-mentioned areas are classified as water-protective forests where the dominant species is the Norway spruce. The study was carried out in the *P. abies* stands threatened by bark beetles (Scolytinae), especially: the spruce bark beetle *I. typographus*, and accompanying, economically less important bark beetle species.

In both years, the experiments were located in spruce (*P. abies*) stands which were 70–90 years old. The stands were at three altitudes: 500, 800, and 1,100 m a.s.l.



Fig. 1. The logs wrapped in Storanet® and control (not wrapped) logs

Wood material and treatment

At the beginning of April 2010 and 2011 the Norway spruces (70–80 year old) were felled. They were made into logs 4 m in length, and 40–55 cm in diameter, with an average of 47.3±5.8 cm. The bark area of each log was between 2.1 and 2.5 m², with an average of 2.3±0.21 m². The logs were not initially infested by insects. Then, each year, at each of the 3 altitudes a.s.l., a set of 2 experimental piles was exposed: 1 pile of wood consisted of 5 logs (5 replications) wrapped in the net, and 1 pile of wood consisted of 5 logs not wrapped which was the control of the experiment. During the 2 year study, 60 logs of Norway spruce wood stacked in 12 piles were observed (2 piles × 3 altitudes × 2 years) (Fig. 1).

The treatments were started at the beginning of May of each year, before bark beetle swarming. For protecting the wood a product called Storanel[®] (producer BASF SE) was used, which is a polyester net (24 mesh/cm²) and the inside of the net contained 100 mg/m² alpha-cypermethrin. Additionally, a polymeric binder was used within the net. The binder prevented leaching of the insecticide by water and ensured insecticidal activity for 6 months. Each pile (both protected and unprotected) was baited with the synthetic pheromone Pheroprax Ampoule[®] (BASF) to attract the *I. typographus* beetles.

The experiments were located in protective mountain forests. In Poland, the spraying of insecticide is not allowed in such protective forests. Due to this regulation, standard insecticide was not used as a comparison.

Treatment evaluation

An evaluation of the treatment was performed after 2 months – in early July of each year. Before removing the Storanel[®], all insects found on the net's surface were collected to estimate the impact of treatment on non-target entomofauna. Next the Storanel[®] was removed and a 1 m² area on each treated and untreated log was debarked (2 areas of 0.5 m²/log on the log ends). Then, the bark beetle galleries and entrance holes were counted. The one-way ANOVA was used for the testing the differences between variants. The Tukey HSD (Honestly Significant Difference) test was used to distinguish homogeneous groups of galleries.

Results and Discussion

Treatment effectiveness

Although many studies are aimed at protecting the forest against insects, this problem is still relevant, especially in North and South America, Asia, and Europe. Early methods for killing bark beetles in America were pointed at the rapid utilisation of infested trees: burning or exposing infested logs to a solar heating source and then immersing them in water (Billings 2011). In European forests the measures most commonly applied for this purpose are clearing windthrows, felling of infested trees, and the use of trapping devices (Wermelinger 2004). The search for more efficient methods to protect the trees against bark

beetles led to the use of chemical sprays as well as injecting the insecticides into the stems of recently infested trees. Conventional chemical insecticides are mostly used to protect stored timber (Wermelinger 2004). The systemic chemicals have been reported to protect individual, susceptible trees (Bombosch and Dedek 1994; DeGomez *et al.* 2006).

The tested product Storanel[®] coated with alpha-cypermethrin allows precise application of insecticide, and due to a slow-release system, leads to the limitation of treatment replications. Furthermore, the active agent is not rinsed out from the net by water, which recommends the use of this net in mountain conditions.

The logs were wrapped in Storanel[®]. On the Storanel[®] surface many *I. typographus* beetles died due to contact with the net – approximately 10 specimens/0.01 m² were found (Table 1). There were no differences between the numbers of beetles found on those nets located at different altitudes (df = 49, F = 0.7807, p = 0.4637). It can be assumed, that the mortality of the beetles was actually higher because most of them flew away after contact with the net and died at a certain distance from the protected wood. Thus, due to the dispersion of contaminated insects (both active and passive by wind or water), a precise evaluation of their total mortality was not feasible. The net was not perforated by the insects. After the debarking of logs wrapped in the Storanel[®], no galleries of bark beetles were found in the cambium and wood.

Table 1. The number of *Ips typographus* beetles found on Storanel[®] with alpha-cypermethrin

Altitude a.s.l. [m]	Average number of beetles on 0.01 m ² of Storanel [®] ±SD
500	8.8±2.3
800	10.4±3.1
1,100	9.7±2.6

Different results were obtained on the control logs: there were 3,156 galleries/entrance holes all together (an average of 59±28.7 galleries/m²) of which 2,340 (74%) belonged to *I. typographus*, 411 (13.1%) to *P. chalcographus*, 310 (9.8%) to *X. lineatus*, 51 (1.6%) to *I. amitinus*, 45 (1.3%) to *Hylurgops palliatus* (Gyllenhal, 1813), and 5 (0.2%) to *Dryocoetes autographus* (Ratzeburg, 1837).

There were no differences found in the total number of bark beetle galleries at different altitudes (df = 49, F = 0.1483, p = 0.8626) (Table 2). Also the numbers of the *I. typographus* galleries were similar at different altitudes (df = 49, F = 2.0017, p = 0.1460) (Table 2). On the other hand, the numbers of galleries established by *P. chalcographus* varied according to the altitude (df = 49, F = 89.48946, p = 0.0007) and were the highest at 800 m a.s.l., twice lower at 500 m a.s.l., and the lowest at 1100 m a.s.l. This variability, however, seems to be related to local microclimatic conditions (humidity) rather than to the altitude (Grodzki and Plata 2008). *Xyloterus lineatus* entrance holes were only found in similar numbers (df = 49, F = 8.3985, p = 0.8941) on logs located at the lower

Table 2. The numbers of bark beetle galleries on experimental *Picea abies* logs

Altitude a.s.l. [m]	Variant	Average number of bark beetle galleries on 1 m ² of debarked area \pm SD			
		<i>Ips typographus</i>	<i>Pityogenes chalcographus</i>	<i>Xyloterus lineatus</i>	total bark beetle galleries
500	Storanet [®]	0	0	0	0
	unprotected	52.1 \pm 25.4	6.8 \pm 3.3a*	6.4 \pm 4.1	57.4 \pm 21.6
800	Storanet [®]	0	0	0	0
	unprotected	35.8 \pm 23.2	14.6 \pm 13.4b	7.2 \pm 3.8	57.0 \pm 17.2
1,100	Storanet [®]	0	0	0	0
	unprotected	43.7 \pm 23.6	3.4 \pm 0.8c	0	61.5 \pm 38.7

*different letters show statistical differences at $p \leq 0.05$

Table 3. Non-target insect species found on Storanet[®] with alpha-cypermethrin

Order	Family	Genus or species	Abundance*
Coleoptera	Cerambycidae	<i>Molorchus minor</i> (Linnaeus, 1758)	+
		<i>Oxymirus cursor</i> (Linnaeus, 1758)	+
		<i>Tetropium castaneum</i> (Linnaeus, 1758)	++
		<i>Rhagium inquisitor</i> (Linnaeus, 1758)	+
		<i>Pidonia lurida</i> (Fabricius, 1792)	+
	Carabidae	<i>Carabus linnaei</i> (Panzer, 1810)	+
		<i>Carabus sylvestris</i> (Panzer, 1793)	+
		<i>Pterostichus oblongopunctatus</i> (Fabricius, 1787)	+
		<i>Pterostichus</i> (Bonelli, 1810)	+
	Lycidae	<i>Dictyoptera aurora</i> (Herbst, 1784)	+
	Cantharidae	<i>Cantharis rustica</i> (Fallén, 1807)	+
	Cleridae	<i>Thanasimus formicarius</i> (Linnaeus, 1758)	++
	Elateridae	<i>Athous subfuscus</i> (O.F. Müller, 1764)	++
		<i>Melanotus</i> (Eschscholtz, 1829)	+
		<i>Ampedus pomorum</i> (Herbst, 1784)	+
Curculionidae	<i>Otiorhynchus tenebricosus</i> (Herbst, 1784)	++	
	<i>Hylobius pinastri</i> (Gyllenhal, 1813)	+++	
	<i>Hylobius abietis</i> (Linnaeus, 1758)	+++	
	<i>Polydrusus</i> (Germar, 1813)	+	
Silphidae	<i>Silpha carinata</i> (Herbst, 1783)	+	
Blattodea	Blattellidae	<i>Ectobius sylvestris</i> (Poda, 1761)	+
Hemiptera	Pentatomidae	<i>Palomena prasina</i> (Linnaeus, 1761)	+
Hymenoptera	Formicidae	<i>Camponotus herculeanus</i> (Linnaeus, 1758)	+
	Apidae	<i>Bombus</i> (Latreille, 1802)	+

*abundance of insects on 0.5 m² of the surface net: +++ – up to 5 specimens, ++ – up to 3 specimens, + – occasionally

(500 and 800 m a.s.l.) altitudes, in more humid storage sites, which are preferred by this species. The galleries established by other species were found only incidentally.

The use of Storanet[®] was also tested in neighbouring countries – in the Czech Republic and Slovakia. No information about the results from Slovakia has been published. The results from the Czech Republic showed the same, high protective effect of the net as obtained in Poland, and the impact on non-target insects was comparable as with the use of classic insecticides on sprayed trap logs (Geráková 2011). It should be pointed out, that Storanet[®] is the method of protection for already processed, fresh logs against the infestation by bark- and wood-boring insects (mainly *X. lineatus*, damaging wood quality) and the emergence of new beetles from infested logs. Sprayed logs acting as traps for killing insects, on the other hand, are focused on protecting

standing trees against insect attack. From this point of view, any comparisons of those methods in terms of forest protection is not available. In the experiments, no phytotoxic effect of the Storanet[®] on the Norway spruce wood was observed.

Effect of Storanet[®] on non-target organisms

Observations of insects found on the Storanet[®] showed the presence of 23 species and 4 genera belonging to the following groups (Table 3):

- insects trophically associated with *P. abies*: Coleoptera: Curculionidae (mainly Scolytinae), and Cerambycidae;
- predators feeding on insects associated with *P. abies*: Coleoptera: Cleridae, Carabidae, and Elateridae;

– accidentally killed insects: Hymenoptera: Formicidae, Apidae; Blattodea: Blattellidae; Hemiptera: Pentatomidae; Coleoptera: Carabidae, Silphidae.

All insects found on the Storanet® surface were killed by the contact with insecticide. The most abundant of the insects killed belonged to the genus *Hylobius* Germar, 1817 – up to 5 beetles/0.5 m² of the Storanet®. They were likely attracted by volatiles, mainly α -pinene and ethanol, released from the resin of cut trees (Tilles *et al.* 1986; Nordlander 1987).

The synthetic pheromone Pheroprax Ampoule®, as well as natural pheromones released by *I. typographus* beetles, attracted *Thanasimus formicarius* (Linnaeus, 1758) (up to 3 beetles/0.5 m² of the net surface). The *Thanasimus formicarius* beetles are one of the most common predators of spruce bark beetles in Europe (Kenis *et al.* 2004). Bakke and Kvamme (1978) observed that *T. formicarius* beetles respond to some compounds of the aggregation pheromones secreted by *I. typographus*. Similar results were obtained by Lubojacký and Holuša (2014) who studied the impact of the insecticide Vaztak 10 SC (an analog of Fastac 10 EC in Poland) which had been applied as a wood spray and which had caught non-target arthropods in Norway spruce stands. These authors confirmed that such treatments led to the death of the predators: *T. formicarius* and *T. femoralis* (Zetterstedt, 1828) which had been sitting on *P. abies* wood treated with alpha-cypermethrin based insecticides. However, the pheromone traps, commonly used in forest protection, also cause unwanted mortality of non-target insects including the predators *T. formicarius* and *T. femoralis* (Babuder *et al.* 1996; Grodzki 2007), but this unwanted mortality is not as high as in case of the use of trap logs sprayed with insecticide (Koleva *et al.* 2012; Lubojacký and Holuša 2014). *Tetropium castaneum* (Linnaeus, 1758) beetles were also often found on the net surface: 1–2 beetles/0.5 m² of the Storanet®. The *T. castaneum*, a pest of *P. abies*, prefers freshly felled trees and trees weakened by the biotic (insects, fungi) or abiotic (drought, air pollution, etc.) factors (Evans *et al.* 2004). However, in the case of a high population level, healthy trees can also be attacked. Other insects were found sporadically within the two years of the study. At the same time, no negative or positive effects on parasitic Ichneumonidae and Tachinidae as well as Lepidoptera, were observed.

In conclusion, the present study shows that use of a net containing alpha-cypermethrin, resulted in complete protection of *P. abies* trees and timber against bark and ambrosia beetle infestations. There were no insect galleries on logs which had been wrapped in the net, while numerous galleries were found on unprotected logs. The Storanet® can be recommended for use in forestry practice to protect timber, and as a barrier for beetles emerging from infested logs. On the other hand, the product is characterised by low selectivity, because besides the bark beetles it affects their predators that are natural regulators of pest populations.

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