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SHOOT DAMAGE AND RADIAL INCREMENT OF TREES IN SCOTS PINE (*PINUS SYLVESTRIS*) STANDS AFFECTED BY A ONE-YEAR'S OUTBREAK OF PINE SHOOT BEETLES *TOMICUS PINIPERDA* AND *T. MINOR* (*COL., SCOLYTIDAE*) IN SOUTHERN POLAND

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ABSTRACT

The level of shoot damage and the annual radial increment were estimated in Scots pine stands affected by a severe maturation feeding of pine shoot beetles *Tomicus piniperda* (L.) and *T. minor* (Hart.). Studies were conducted on sample plots situated about 60 and 500 m from sawmill timber storage sites during 2001-2005. In both investigated stands the radial increment in 2003 was smaller than that in 2002. There was no significant difference between the damaged stand and the control stand in respect of its relative value. The relative value of radial increment during the period 2003—2005 showed that a severe maturation feeding of pine shoot beetles had no effect on weakening of increment dynamics of trees in the edge part of the stand.

Key words: *Pinus sylvestris, Tomicus piniperda, T. minor,* shoot damage, growth.

INTRODUCTION

Pine shoot beetles, *Tomicus piniperda* (L.) and *T. minor* (Hart.), are widely distributed in the Palearctic Region, inhabiting different pine species within boundaries of their natural ranges [21, 17, 7]. They infest those parts of trunks of felled or strongly weakened trees where the bark is thick [15, 9]. Their feeding under the bark may lead to death of stands growing on burns [5], stands affected by outbreaks of phylophagous insects [1, 4], or stands growing around centers of their reproduction [19]. Harmfulness of pine shoot beetles is intensified by feeding of adults of the old as well as young generation in pine shoots [11, 12, 18, 23, 10]. This feeding results in reduction of the assimilation apparatus of trees, and in consequence leads to greater or smaller losses in growth of trees [19, 13, 14, 6, 2]. Some investigations showed that losses in increment, amounting to 20—40 %, occurred during several years following a one-year's outbreak [20], while in other cases smaller losses were observed, even when intensity of attack was high [8, 16].

The purpose of this study was to estimate the level of shoot damage, and to characterize the value of the annual radial increment in Scots pine stands affected by a one-year's outbreak of pine shoot beetles. A lack of such studies conducted in stands of older age classes, growing during their entire growth period within the influence of reproduction centers of pine shoot beetles, justified the undertaking of these investigations.

MATERIAL AND METHODS

The study area was situated in Zagnańsk in southeastern Poland (longitude 20° 45' E; latitude 50° 55' N; altitude 350 m). Investigations were carried out in Scots pine stands growing about 50 m away from sawmill timber storage sites which have been in operation since 1916. In 1996, in place of the state owned large sawmill, smaller private sawmills were created, which are sawing timber day by day. Also a high demand for bark prevented its storage in the storage sites. However, problems with lumber market in 2002 caused that over 500 m^3 of pine timber was stored in timber yards during summer. This caused a mass migration of beetles from the timber storage sites to Scots pine stands surrounding the sawmill area. The migration was evidences by a high amount of fallen shoots damaged by adults of pine shoot beetles in the edge parts of stands [3].

Research was conducted during the period 2001—2005 on two permanent sample plots, in stands growing under similar environmental conditions. The first plot was situated in the edge part of the stand, characterized by severe crown damage caused by a long-term beetle feeding in pine shoots (damaged stand). A strong deformation of tree tops, including damage of leaders, greatly limited height growth of trees in this stand. The second plot, a control one, was situated in the stand growing outside the reach of beetles (control stand). Trees in this stand had crowns typical for healthy pines. In both plots, each 0.2 ha in size (40 × 50 m), all trees were numbered, and their dbh outside bark was measured at N–S and E–W directions, exact to 0.5 cm. Also height of all trees was measured, accuracy to 0.5 m. The stand data are presented in Table 1. Since 2001, a permanent checking of beetle numbers, based on amount of damaged fallen shoots, is being conducted in the investigated stands. Fallen shoots are collected once a month during the period from August to December, and also in spring of the next year after melting of snow, on strips, 25 m long and 1 m wide, running from a sample tree in four cardinal points.

Table 1. Characteristics of Scots pine stands of Zagnańsk in 2004

Variable	Stand	
	Damaged	Control
Distance from beetle source, m	60	500
Trees per 0.2 ha	222	149
Mean dbh, cm	17.4	22.8
Mean height, m	9.9	18.5
Site type	degraded fresh coniferous forest	fresh coniferous forest
Stand age, years	85	85

In November 2005 a sample of 30 trees (every 10^{th} numbered tree) was selected in each investigated stand. From each tree in a sample, an increment core was taken on its northern side, 1.3 m above the ground, using the Suunto increment borer. Width of annual rings on each core was measured, accuracy to 0.01 mm. Annual radial increments produced in 2002 (r_o), 2003 (r_1), 2004 (r_2), and 2005 (r_3) were analyzed. The increment (r_1) was produced during the first, (r_2) during the second, and (r_3) during the third year after the outbreak. For each tree a relative value of radial increment (z_{ij}) was determined, expressing its magnitude during the period (r_{ij}) within the magnitude of increment produced in 2002 (r_{oj}):

$$z_{ij} = \frac{r_{ij}}{r_{oj}}$$

where:

i – increment year (i = 1, 2, 3),
j – number of a tree with measured increment (j = 1, 2, ..., 30).

The relative radial increment of the stand during the assumed increment years (r_i) was an arithmetic mean of relative increments of measured trees. Significance of difference between the damaged and the control stand in respect of the relative radial increment of trees during the assumed increment years was tested by the Student's t-test. The analyses were carried out using "Statistica 6.1" [22].

RESULTS

The amount of fallen damaged pine shoots in 2002 indicated an intensive maturation feeding of pine shoot beetles in the edge part of the stand (Table 2). The number of damaged shoots was almost 10 times higher than in 2001. The amount of fallen damaged shoots during the remaining years was typical for the number of adult beetles occurring in stands growing under natural conditions.

Table 2. The mean amount of dropped shoots per 1 m^2 in the investigated stands

Stand	Year				
	2001	2002	2003	2004	2005
Damaged	2.91	26.4	0.73	0.43	0.26
Control	0.24	0.35	0.23	0.11	0.11

The radial increment produced during the first year after intensive beetle feeding was in both investigated stands smaller than that produced in 2002. Its relative value in the damaged stand was smaller in comparison with the control stand (Table 3). In 2004 the radial increment produced in both stands was greater, assuming a greater relative value in the control stand. In 2005 there was a slight decrease of the radial increment in the control stand, and increase in the damaged stand. In compared increment years the relative values of the radial increment in the damaged stand were not significantly different from those in the control stand.

Table 3. Relative radial increment of trees in the damaged stand and the control stand during the study period. P < 0.05 indicates significant statistical differences, Student's t-test

Year increment	Stand	Mean ± standard error	*P*
2003	Damaged	0.81 ± 0.05	*0.3226*
	Control	0.89 ± 0.06	
2004	Damaged	1.12 ± 0.08	*0.4249*
	Control	1.24 ± 0.12	
2005	Damaged	1.05 ± 0.09	*0.4777*
	Control	0.94 ± 0.11	

DISCUSSION

Most of studies conducted in stands affected by the long term outbreaks of pine shoot beetles showed significant losses in the radial increment of trees. The losses showed a tendency to decrease with increase of distance between the stand and the beetle reproduction center. In Scandinavia reduction of the radial increment during a 5-year period varied from 3 to 60% [13, 14]. In the New York State (USA) a 7-year basal area increment in a strongly damaged stand was by 37% smaller in comparison with a medium damaged stand [6]. In Poland the increment losses in stands of younger age classes during the period of 6 years varied from about 20 to about 40% [19], while in stands of older age classes during the period of 10 years were about 50% [3]. Less univocal were the results of studies conducted in stands affected by a one-year's outbreak of pine shoot beetles. Some of them showed losses in the diameter increment varying from 20 to 40% [20], while other showed smaller losses, even at a high density of attack [8, 16].

The present study showed a very limited effect of severe maturation feeding of pine shoot beetles on increment losses in the stand damaged in 2003. This was shown by a smaller value of increment produced in 2003 in the control stand, and statistically insignificant differences between mean values of annual increment in both investigated stands. The value of a relative increment produced during consecutive years showed that a severe maturation feeding of pine shoot beetles had no effect on weakening of increment dynamics of trees in the edge part of the stand.

Different authors give a different level of damage which would significantly affect the tree growth. In stands affected by secondary outbreaks of pine shoot beetles this level is from several [2, 19] to about a hundred of shoots per 1 m^2 [16, 14]. In stands affected by a one-year's outbreak, studied by Nilsson [20], there were significant increment losses at the presence of 100—150 damaged shoots per one tree, while according to other studies at the presence of several hundred such shoots [16, 13]. In the present study the approximate number of damaged shoots in the edge part of the stand was 240 per one tree (26.4 fallen shoots per 1 m^2 × 2000 m^2 / 222 trees in a plot), and it did not cause any significant losses in the radial increment of trees in stands affected by a long-term feeding of pine shoot beetles in pine shoots.

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