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MONITORING *ARMILLARIA* ROOT ROT IN YOUNG (UP TO 20 YRS) SCOTS PINE PLANTATIONS IN ZIELONKA FOREST DISTRICT

Wojciech Szewczyk
Agricultural University of Poznań

Abstract. In Zielonka Forest District seven Scots pine plantations monitored in 1998-2001 for *Armillaria ostoyae* and *Heterobasidion annosum* disease development proved affected mainly by the former pathogen. Observations of 200 trees per plantation (every spring and fall) showed there was no correlation between the morphological features and over ground symptoms and infestation of pines by the pathogens in question and mortality of trees. The young stands were threatened more by *Armillaria* than by *Heterobasidion annosum* s.s., yet the infestation by *Armillaria* decreased with age of trees while the infestation by *Heterobasidion* increased.

Key words: *Pinus sylvestris*, *Armillaria*, *Heterobasidion*, root rot, monitoring

INTRODUCTION

The *Armillaria* spp. and *Heterobasidion annosum* (Fr.) Bref. cause the most important diseases of forest trees. These pathogens are ranked as one of the world's most dangerous causes of damages in tree stands [Orłoś 1948, Peace 1962, Gremmen 1970, Moriondo 1970, Hubbes 1980, Rykowski 1990, Hood et all 1991, Kile et all 1991, Mańka 1998, Mańka and Mańka 1998]. Both pathogens infested Scots pine stands in all ages, causing many gaps which are difficult to be productive again. Protection against these diseases is very difficult because of the way the pathogens spread. In the year 2000 the damages caused by *Armillaria* root rot in tree stands of the 1st class age occurred in the area of 19 thousand ha of National Forest and in the older tree stands it was 125 thousand ha. In the case of *Heterobasidion annosum* the area of the disease occurrence in all class age in even more and it amounts to 193 thousand ha [Sierota et al. 2000].

The Zielonka Forest District (Central-West Poland) has about 70% of forest area under Scots pine (*Pinus sylvestris* L.) stands, suiting the local forest site conditions. Young plantations (up to 10 yrs, established by planting) suffer a lot from root diseases:

Corresponding author – Adres do korespondencji: dr inż. Wojciech Szewczyk, Depatrment of Forest Pathology of Agricultural University of Poznań, Wojska Polskiego 71C, 60-625 Poznań, Poland, e-mail: wszew@au.poznan.pl

Armillaria spp., and *Heterobasidion annosum.* The threat from both pathogens has increased within the past 30 years.

The aim of the work was to evaluate root diseases impact and development, and to compare the damages in chosen plantations. Identifying the local species of *Armillaria* and intersterile groups of *H. annosum* was an additional point.

MATERIALS AND METHODS

Seven Scots pine plantations (7-13 yrs in 2002) were monitored from 1998 to 2001 for *Armillaria* spp. and *Heterobasidion* root rot. The plantations were situated on the following forest sites (according to Polish forest site typology; starting from the poorest one): fresh coniferous forest (div. 35b, 43f), fresh mixed coniferous forest (47k, 85c, 142d) and fresh mixed broadleaved forest (5a, 64c).

The rules monitoring in young Scots pine stands were worked out in the Department of Forest Pathology, University of Agriculture [Mańka 1953 a, b, 1954, Łakomy and Mańka 1998, Mańka and Jańczyk 1999]. It is based on regular observations of a group of marked trees. In every plantation, four groups of pines (50 trees each) were observed every spring and fall, and special attention was drawn towards infestation from *A. ostoyae* and *H. annosum*.

Isolates of *Armillaria* and *Heterobasidion* were tested with the Korhonen test [1978 a, b].

For comparison of tree mortality, analysis of variance was applied and for significant different values Tukey's multiple comparisons tests were applied.

RESULTS AND DISCUSSION

Armillaria ostoyae

On Figure 1 and 2 introduced number of dead trees infested by *Armillaria ostoyae*, appearing every year on investigative surface, in spring and fall is presented. The most diverse number of dead trees appeared every year in investigative surface 64c, the least diverse number appeared on investigative surface 85c. The number of dead trees alternatively grows and decreases in following years. This regularity papers both in spring and fall.

By means of two-way analysis of variations the influence of surfaces and years on the number of shocks was investigated (Table 1 and 2).

It was affirmed that essential differences of the number of trees infested by *A. ostoyae* do not appear in the investigated areas. However, in spring period the differences in the number of shocks are essential. The largest difference of the number of shocks appeared between 1998 (the largest number of new shocks) and 1999, however it did not cross the maximum admissible appointed in Tukey's procedure.

One can affirm, that essential statistical receipt of years and surface onto number of dead trees in autumnal periods appears. The largest difference of number of shocks appeared and 2001 between 1998, however the maximum admissible appointed in procedure difference Tukey's does not cross.

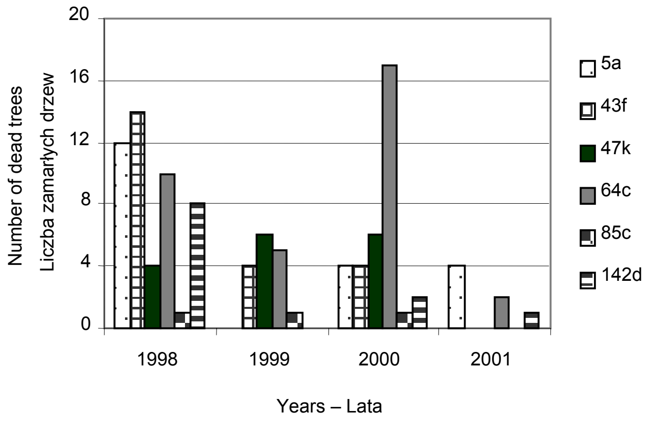

Fig. 1. Number of dead trees infested by *A. ostoyae* on experimental plots, in spring
Rys. 1. Liczba zamarłych drzew porażonych przez *A. ostoyae* na powierzchniach badawczych w okresach wiosennych

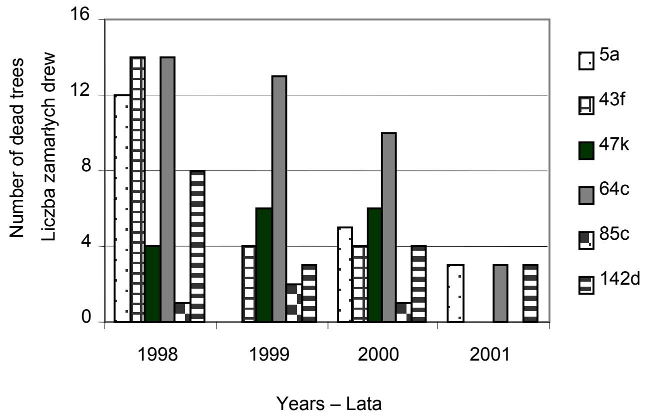

Fig. 2. Number of dead trees infested by *A. ostoyae* on experimental plots, in fall
Rys. 2. Liczba zamarłych drzew porażonych przez *A. ostoyae* na powierzchniach badawczych w okresach jesiennych

Surfaces: 85c 47k 5a 43f 142d 64c

On surfaces investigative in emissions 85c, 47k, 5a, 43f and 142d essential differences in number of appearing shocks in autumnal periods do not appear. On surfaces in 47k, 5a, 43f, 142d and 64c similarly. However the number of shocks by *A. ostoyae* on surfaces in 64c is indeed larger than on surfaces in 85c. Figures 3 and 4 show the number of dead trees infested by *H. annosum* of every year on investigative surfaces, separately for spring and fall. Figure 5 shows the number of dead trees was infested by *H. annosum* together for all the surfaces in investigated spring and fall period. In 1999 we can observe the largest height of dead trees both in spring and fall. From 1999 in spring periods the number of dead trees decreased, and in fall periods it kept at the same level.

Table 1. Two-way ANOVA for influence years and surface to number dead trees in spring
Tabela 1. Dwuczynnikowa analiza wariancji dla wpływu lat i powierzchni na liczbę porażeń w okresach wiosennych

Source of variation Zródło wariancji	Sums of squares Suma kwadratów	Degrees of freedom Stopnie swobody	Mean squares Średnie kwadraty	F calculated Empiryczna wartość statystyki F	p – value Wartość p	Critical value the F-test Wartość krytyczna testu F (α = 0.005)
Years Lata	0.0710	3	0.0237	5.6735**	0.0084	3.2874
Surfaces Powierzchnie	0.0452	5	0.0090	2.1648	0.1132	2.9013
Error Błąd	0.0626	15	0.0042			
Total Ogółem	0.1788	23				

Important influence of factor mean level of essentiality of test symbol ** extremely (0.01).
Symbolem ** oznaczono wysoce istotny wpływ czynnika (poziom istotności testu 0,01).

Table 2. Two-way ANOVA for influence years and surface to number of dead trees in fall
Tabela 2. Dwuczynnikowa analiza wariancji wpływu lat i powierzchni na liczbę nowych porażeń w okresach jesiennych

Source of variation Zródło wariancji	Sums of squares Suma kwadratów	Degrees of freedom Stopnie swobody	Mean squares Średnie kwadraty	F calculated Empiryczna wartość statystyki F	p – value Wartość p	Critical value the F-test Wartość krytyczna testu F (α = 0.005)
Years Lata	0.0592	3	0.0197	5.7228**	0.0081	3.2874
Surface Powierzchnie	0.0513	5	0.0103	2.9770*	0.0461	2.9013
Error Błąd	0.0517	15	0.0034			
Total Ogółem	0,1623	23				

Important influence of factor mean level of essentiality of test symbol * (0.05).
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Symbolem * oznaczono istotny wpływ czynnika (poziom istotności testu 0,05).
Symbolem ** oznaczono wysoce istotny wpływ czynnika (poziom istotności testu 0,01).

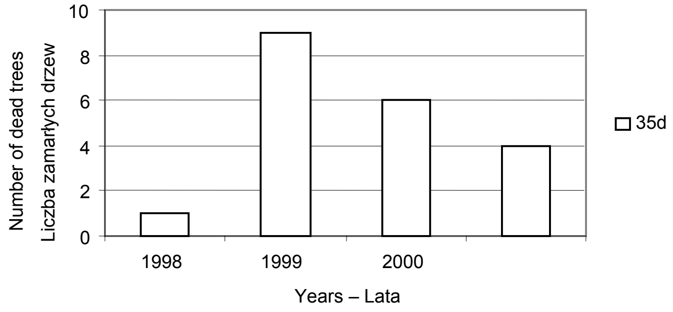

Fig. 3.Number of dead trees infested by *H. annosum* on experimental plots, in spring
Rys. 3. Liczba zamarłych drzew porażonych przez *H. annosum* na powierzchniach badawczych w okresach wiosennych

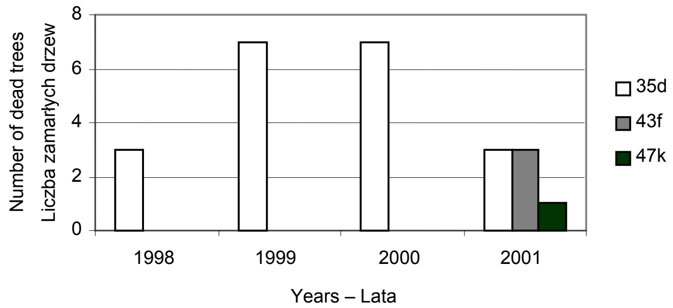

Fig. 4. Number of dead trees infested by *H. annosum* on experimental plots, in fall
Rys. 4. Liczba zamarłych drzew porażonych przez *H. annosum* na powierzchniach badawczych w okresach jesiennych

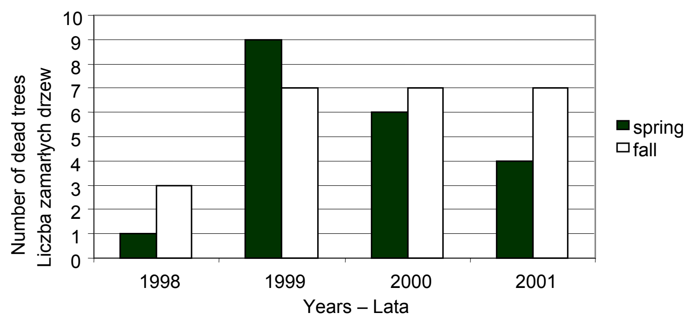

Fig. 5. Number of dead trees infested by *H. annosum* on experimental plots
Rys. 5. Liczba zamarłych drzew porażonych przez *H. annosum* na powierzchniach badawczych

Heterobasidion annosum

Variance analysis receipt of years was examined appearing number dead trees by *H. annosum* in spring periods. The investigation was passed only on the surface 35d on which the shocks by *H. annosum* appeared in investigated period (Table 3). Separate investigation was passed for fall periods (Table 4). Lack of essential receipt of years onto number of dead trees by *H. annosum* in spring periods can be affirmed. In the years 1998-2001 number appearing did not differ new shocks indeed. Lack of essential receipt of years onto number of new shocks by *H. annosum* in spring periods. In years 1998--2001 the number of new appearing dead specimens did not differ indeed.

Table 3. One-way ANOVA for influence years to number of dead trees in spring
Tabela 3. Jednoczynnikowa analiza wariancji wpływu lat na liczbę nowych porażeń w okresach wiosennych

Source of variation Zródło wariancji	Sums of squares Suma kwadratów	Degrees of freedom Stopnie swobody	Mean squares Średnie kwadraty	F calculated Empiryczna wartość statystyki F	p – value Wartość p	Critical value the F-test Wartość krytyczna testu F (α = 0.005)
Years Lata	0.0275	3	0.0092	0.4952	0.6924	3.4903
Error Błąd	0.2219	12	0.0185			
Total Ogółem	0.2494	15				

Table 4. One-way ANOVA for influence years to number of dead trees in fall
Tabela 4. Jednoczynnikowa analiza wariancji wpływu lat na liczbę nowych porażeń w okresach jesiennych

Source of variation Zródło wariancji	Sums of squares Suma kwadratów	Degrees of freedom Stopnie swobody	Mean squares Średnie kwadraty	F calculated Empiryczna wartość statystyki F	p – value Wartość p	Critical value the F-test Wartość krytyczna testu F (α = 0.005)
Years Lata	0.0207	3	0.0069	0.3621	0.7815	3.4903
Error Błąd	0.2287	12	0.0191			
Total Ogółem	0.2494	15				

DISCUSION

Armillaria root rot was the main disease in the plantations. The species present proved to be *A. ostoyae*. During four years of the research work on the investigative areas 162 pine decayed, paralyzed by *A. ostoyae* and 24 paralyzed by *H. annosum*. It makes 13.2% of all of observed trees determines. 64% of losses caused by *A. ostoyae* appeared in spring. In case of *H. annosum* of spring shocks and autumnal shocks were the same.

Smaller number of shocks from June to October can be explained by higher temperature of soil which oscillated even over 28°C, it often exceeded 30°C. According to Redfern and Philip [1991] a temperature over 30°C causes a set-back of rhizomorph growth. Mańka [1953] set this temperature at the level of 32°C and Rishbeth [1978] on the other hand claims that at the very level of 28°C rhizomorphs do not grow.

The age of pines shocked by *Armillaria* rot roots in its culmination was very similar: in 43f and 64c were 5 years old, in 47k pines reached the culmination at the age of 5 and 6, in 85c 6 and 7 and 5a and 142d – they were 9 years old. However in all of the examined areas observed at the age of 4, it was in the first year of the research work in this area. Distinct reduction of pine shocks at the age of 8 was observed by Redfern [1978] but according to Morrison [1993] the increase of losses from 1 to 35 per hectare in one year, observed at the age of at least 10. Culmination of losses caused by *A. ostoyae* was observed by Łakomy [1998] at various age – from 3 to 6 years after establishing of the tillage. In her research work Żółciak [1999] did not affirm any distinct preferences of *Armillaria* towards the age of the stands with the exception of *A. ostoyae* which preferred the stands of the I class age (89.4% of tests gathered in this class of age). According to Redfern [1978] and Garaway et al. [1991] species of *Armillria* are the most aggressive at stand growing in the sour soil. Mańka [1953 a] affirmed that optimum pH for the growth of *Armillaria* makes 4. Garraway et al. [1991] established this value at the level of 4.5 pH was very low in all the examined areas (below 4). The infest by *H. annosum* appeared especially in division 35b and additionally in the year 2001 on the investigated surface in divisions 43f and 47k. Development of the disease in the investigative surface in division 35b was quite aggressive. At the beginning 2 pines with the signs of dying were observed. During the second monitoring in autumn of 1998, one more tree was observed and the culmination of losses appeared in spring 1999, when 8 trees were shocked and in autumn 5 more were noticed. In the following years the situation stabililized and until the end of monitoring only 3 more pines died out. The age of pines with the culmination of shocks was 10 years in division 43f and 7 years in division 47k when the first losses were observed. According to Fedorow [1994] and Stenlid [1987] the largest number of losses appeared at the age of 18-20, Marinković [1974] on the other hand noticed large shocks of natural renegeration of pines at the age of 8-12. The range of temperature conducting the growth of *H. annosum* is conditioned on the isolate, but the isolates coming from various parts of the world, cold and warm, do not show big regional differences [Korhonen and Stenlid 1998]. Growth of the mycelium appears at the very temperature of about 0-2°C with the optimum between 22-28°C. The inhibition of the mycelium growth appears in the temperature of 32-37°C and death of the mycelium appears above 38°C in two hours [Korhonen and Stenlid 1998]. Korhonen also affirms that in the conditions of south Finland an infection may accomplish in winter as well. Temperature of the soil in the Zielonka Forest District fell below freezing point in Nov., Dec., Jan. and Feb. In the other mounths it never exceeded the top cut off temperature of inactivation of the mycelium growth. Ross [1970], investigating the temperature of the soil in the depth of 6 cal in the hottest period of the year, affirmed that it did not reach the level of inactivation of *H. annosum* but it with no doubt influenced on the growth of the infested roots. According to Rool-Hansen [Korhonen and Stenlid 1998] in the temperature of 12°C mycelium reaches 50% of the growth it can reach in the optimum temperature and about 21% of the growth in the temperature of 8°C [Cowling and Kelman 1964] *H. annosum* grows in the broad range of pH. Various isolates show big differentiation of reactions to pH [Korhonen nad Stenlid 1998]. Redfern [1984] informs, that big amount of sand, high pH and small amount of organic substrate in the soil causes the increase of dying trees as a result of *H. annosum* shock. According to Flemming and Hütterman [1981] pH which is optimal for production of spores amounts from 3.5 to 4. Germination on the other hand appears with the pH from 3 to 7.5 with the optimum between 4 and 6.5. That indicates the pH is conductive to development, creation and germination on the investigative surface. The source of infection and spreading of the pathogen are above all stumps and roots remaining after the previous generation of tree stands and number of shocked trees. On the investigative surfaces, division 35b fruitbody of *H. annsum* were affirmed to appear on the still remaining pine stumps though usually the fruitbody appeared on the shocked pines one year after the tree died.

More detailed investigation should be increased especially in the case of *H. annosum*. The older the tree stands are smaller in the number of *A. ostoyae* shocks on the other hand new shocks of *H. annosum* appear which previously did not occur.

CONCLUSION

The youngest stands were threatened more by Armillaria. With age the infestation by Armillaria decreased while the infestation by *Heterobasidion* increased.

The autumn observation proved more dependable than the spring one: in the course of several years it can be the basis for monitoring in young Scots pine plantations.

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MONOTORING OPIEŃKOWEJ ZGNILIZNY KORZENI W MŁODYCH DRZEWOSTANACH SOSNOWYCH NADLEŚNICTWA ZIELONKA

Streszczenie. Na terenie Nadleśnictwa Zielonka wybrano siedem wydzieleń w których w latach 1998-2001 były prowadzone obserwacje porażeń drzew przez *Armillaria ostoyae* i *Heterobasidion annosum*. Stwierdzono, że zamieranie drzew następowało głównie z powodu infekcji *A. ostoyae*. Ocena 200 drzew w każdym wydzieleniu wykazała brak korelacji między cechami morfologicznymi drzew a stopniem porażenia młodników przez wyżej wymienione patogeny. Wraz z wiekiem zmniejszała się liczba porażeń przez *A. ostoyae*, wzrastała natomiast przez *H. annosum.*

Słowa kluczowe: sosna, opieńka, huba korzeni, *Armillaria* spp. *Heterobasidion annosum*, monitoring

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