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THE GROWTH AND STATUS OF MYCORRHIZATION OF SEEDLINGS IN THE NATURAL REGENERATION OF SCOTS PINE CHEMICALLY TREATED AGAINST *LOPHODERMIUM* NEEDLE CAST*

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Abstract. The aim of the research was to evaluate the effect of two fungicides Falcon 460 EC and Gwarant 500 SC used to protect Scots pine against *Lophodermium* needle cast on the state of mycorrhizae and seedling growth. The subject of the research was natural regeneration of one-year-old pines in the Gostynin Forest Inspectorate. Falcon 460 EC was applied at a concentration of 0.15% and Gwarant 500 SC at a concentration of 0.5%, at a rate of 500 l/ha for both fungicides. The treatments were applied once or twice during the growing season. No occurrence of *Lophodermium* needle cast was detected either on treated or untreated pines. Only two mycorrhizal morphotypes were distinguished on pine seedling roots. The mycorrhization level of seedlings did not change after fungicide application. Both fungicides showed a limiting effect on the formation of complex structures: dychotomous and coralloid. None of the tested fungicides caused changes in seedling growth.

Key words: ectomycorrhiza, fungicide, natural regeneration, *Lophodermium* needle cast, Scots pine

INTRODUCTION

Implementation of the obligatory silviculture rules indicating the need to improve forest management based on ecological principles leads to more and more frequent applications of natural methods of forest regeneration. *Lophodermium* needle cast, a disease caused by fungal assemblages with the dominant *Lophodermium seditiosum* Minter, Staley et Millar pose a serious threat, frequently causing failure to natural re-

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generation [Andrzejczyk 2002]. In the case of a high threat to the natural regenerations of pine, chemical protective treatments should be contemplated. Such treatments have been carried out by the Pułtusk and Łuków Forest Inspectorates in the framework of their own experiments with a good result [Stocka 2000].

Fungicides used in pine protection against *Lophodermium* needle cast may cause microbiologic changes in forest environment which in turn will affect the level of seedling mycorrhization. Disturbances in the functioning of mycorrhizae, lowering of the level of mycorrhizal colonization, or changes in the composition of ectomycorrhizal fungi species resulting from the use of fungicides may have a negative effect on the growth of seedlings and their resistance to diseases lasting for even several succeeding vegetation seasons. Therefore, it is important to learn which fungicides may have a negative effect on the mycorrhizae of pine seedlings and their biometric parameters, and to what extent.

The aim of the research was to evaluate the effect of two fungicides Falcon 460 EC and Gwarant 500 SC, applied at the recommended rates and concentrations for the protection of naturally regenerated pine seedlings against *Lophodermium* needle cast, on mycorrhization level and seedling growth.

MATERIAL AND METHODS

The subject of the research was natural regeneration of Scots pine in the first and second year after seeding (2006 and 2007) established in the fresh coniferous forest habitat in compartment 120 in the territory of the Gostynin Forest Inspectorate. The regeneration area was established in a 60-m wide clear-cut strip. Soil preparation consisted in ploughing furrows using a LPz – 75 plough. The experiment had five treatments. The treatments embraced seedlings treated with Falcon 460 EC or Gwarant 500 SC, once or twice during the growing season. The untreated seedlings were used as control.

Ten permanent sample plots were established and arranged in two rows, with five plots in each row, at a distance of 20 m from one another and 10 m from the edge of the surrounding stands. The distance between the plots in rows was 25 m. Each sample plot consisted of five 5 × 5 metre squares representing five experimental treatments. The design of a sample plot is presented in Figure 1.

The first application of fungicides took place in mid July, the second – at the beginning of September. Falcon 460 EC was applied at a concentration of 0.15% and Gwarant 500 SC at a concentration of 0.5%, at a rate of 500 litres per hectare. The characteristic of the fungicides is presented in Table 1.

The assessment of seedling density was performed by the end of the first and second growing season. All seedlings on 1-m wide transects running through the centre of sample plots were counted and the heights of three randomly selected seedlings were measured separately in a furrow and on a ridge on each metre of the transect (only after the second growing season). In total, 1044 seedlings were measured. After the first growing season, 40 seedlings were collected from each experimental variant, 20 from the furrow and 20 from the ridge. 200 seedlings were collected altogether.

The laboratory work consisted in measurements of stem length and diameter at root collar of seedlings, counting of lateral shoots and determining the aboveground and root

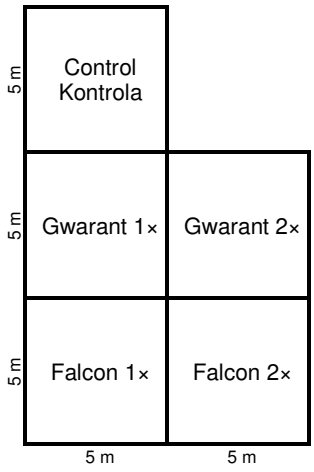

Fig. 1. Sample plot design. Control – untreated seedlings, Falcon 1× – seedlings treated one time with Falcon, Falcon 2× – seedlings treated twice with Falcon, Gwarant 1× – seedlings treated one time with Gwarant, Gwarant 2× – seedlings treated twice with Gwarant

Rys. 1. Schemat powierzchni próbnej. Kontrola – siewki kontrolne, Falcon 1× – siewki jednokrotnie traktowane Falconem, Falcon 2× – siewki dwukrotnie traktowane Falconem, Gwarant 1× – siewki jednokrotnie traktowane Gwarantem, Gwarant 2× – siewki dwukrotnie traktowane Gwarantem

dry mass after drying at a temperature of 105°C. The degree of root mycorrhization was assessed by counting the autotrophic and mycorrhizal tips categorised into morphotypes. 100 successive root tips (mycorrhizal and non-mycorrhizal) of each seedling were subject to assessment and the length of the long root section on which they occurred was measured. The length of seedling roots and the length of the long root section on which 100 assessed short roots occurred were determined using the Böhm [1985] method. The method consists in the random arrangement of roots on a grid of squares with sides of any length (in this case the square sides were each 0.5 cm) and specification of the number of lines intersecting the roots.

The root length was calculated from the formula:

$$L = 11/14 \cdot n \cdot a$$

Table 1. Fungicide description
Tabela 1. Charakterystyka fungicydów

Preparation trade name Nazwa handlowa preparatu	Active ingredient per 1 litre of the preparation Zawartość substancji czynnej w 1 litrze środka	Toxicity class Klasa toksyczności	Manufacturer Producent
Falcon 460 EC	spiroxamine 250 g spiroksamina 250 g tebuconazole 167 g tebukonazol 167 g triadimenol 43 g triadimenol 43 g	III	Bayer CropScience AG – Niemcy
Gwarant 500 SC	chlorothalonil 500 g chlorotalonil 500 g	IV	Arysta Agro Polska Sp. z o.o.

where:

L – root length, cm,

n – number of square grid intersections,

a – square side length (a = 0.5 cm).

The obtained data allowed calculation of a short root branching index determining their number per 1 cm of root length.

The assessment of the infestation of seedlings by the *Lophodermium* needle cast was conducted in the spring in the second year of seedling growth (2007).

The empirical data of biometrical parameters of seedlings and their densities, as well as the percentage of autotrophic and mycorrhizal tips and the branching index were subject to statistical analyses (analysis of variance and Duncan's test).

RESULTS

Only two mycorrhizal morphotypes were identified on seedling roots from the natural regeneration of Scots pine in the Gostynin Forest Inspectorate:

– pale, usually elongated mycorrhizae, smooth mantle or small quantity of white mycelium, a few white rhizomorphs,

– brown, irregularly shortened mycorrhizae, smooth mantle, sporadically with white single strands.

On average, the share of mycorrhizal root tips of pine seedling in the whole experiment was 60.3% and of autotrophic tips – 39.7%. No statistically significant differences were found between individual experimental treatments as concerns the share of autotrophic tips (p = 0.4230; Fig. 2).

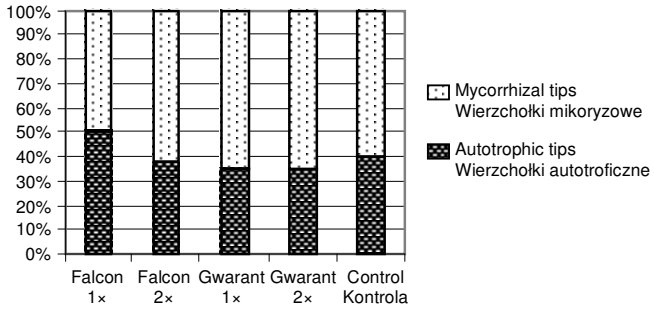

Fig. 2. Share of mycorrhizal and autotrophic tips of pine seedlings chemically protected against *Lophodermium* needle cast

Rys. 2. Udział wierzchołków mikoryzowych i autotroficznych jednorocznych siewek sosny chronionych chemicznie przed wiosenną osutką

The structure of mycorrhizal tip forms was best developed in seedlings from the control variant where the share of the complex multi-dichotomously branched and coralloid forms was highest while the share of simple mycorrhizae was lowest (Table 2).

Table 2. Structure of mycorrhizal tip forms in one-year-old pine seedlings, %
Tabela 2. Struktura form wierzchołków mikoryzowych jednorocznych siewek sosny, %

Treatment Wariant	Share of mycorrhizae, % – Udział mikoryz, %			
	single pojedynczych	dichotomous dychotomicznych	multi-dichotomous wielokrotnie dychotomicznych	coralloid koralowatych
Falcon 1×	75.6	19.5	4.0	0.9
Falcon 2×	69.3	20.2	8.8	1.7
Gwarant 1×	69.0	19.6	8.6	2.8
Gwarant 2×	68.5	21.0	9.0	1.5
Control – Kontrola	65.1	20.5	11.1	3.3
Mean – Średnia	69.5	20.2	8.3	2.0

The average root collar diameter in 1-year-old pine seedlings was 1.71 mm. Pines sprayed only once with Falcon 460 EC had significantly larger diameters at root collar (1.95 mm, $p = 0.0159$) than other chemically treated seedlings, however, they did not significantly differ from the untreated pines (1.77 mm). The variation in root collar diameter ranged from 24.5% to 39.6% (Table 3).

Pines sprayed once with Falcon 460 EC showed the largest shoot length – 6.5 cm, while pines sprayed once with Gwarant 500 SC – the lowest (6.1 cm). No differences in shoot length were found between the treatments ($p = 0.7453$). The variation coefficient value was 24.8% on average (Table 3).

Table 3. Biometrical parameters of the aboveground parts of pine seedlings
Tabela 3. Cechy biometryczne części nadziemnej jednorocznych siewek sosny

Treatment Wariant	Root collar diameter, mm Grubość w szyi korzeniowej, mm		Shoot length, cm Długość pędu, cm		Aboveground dry mass, g Sucha masa części nadziemnej, g		Number of lateral shoots, pcs Liczba pędów bocznych, szt.	
	x	v%	x	v%	x	v%	x	v%
Falcon 1×	1.95 b	39.6	6.5 a	24.3	0.48 b	64.3	1.8 a	96.8
Falcon 2×	1.66 a	28.9	6.4 a	26.4	0.38 ab	48.8	2.1 a	72.4
Gwarant 1×	1.52 a	24.5	6.1 a	23.2	0.30 a	55.6	1.6 a	90.0
Gwarant 2×	1.65 a	30.4	6.2 a	24.8	0.39 ab	60.1	1.9 a	74.0
Control – Kontrola	1.77 ab	34.5	6.4 a	25.7	0.43 b	65.1	1.7 a	104.2
Mean – Średnia	1.71	33.6	6.3	24.8	0.40	62.1	1.8	86.9

x – mean, v% – variation coefficient.

The same letter in columns denotes lack of statistically significant differences between means in Duncan's test at $p \leq 0.05$.

x – średnia, v% – współczynnik zmienności.

Ta sama litera w kolumnach oznacza brak różnic istotnych statystycznie między średnimi w teście Duncana przy $p \leq 0{,}05$.

The aboveground dry mass of seedlings treated once with Gwarant 500 SC was significantly lower (0.30 g, p = 0.0207) than in the case of untreated pines (0.43 g) and in pines treated once with Falcon 460 EC (0.48 g). It did not differ from the aboveground dry mass of seedlings from other treatments. The variation coefficient of this parameter was quite high – 62.1% on average (Table 3).

The average number of lateral shoots oscillated between 1.6 for the smallest pines treated once with Gwarant 500 SC and 2.1 for pines treated twice with Falcon 460 EC. However, the differences appeared to be not statistically significant (p = 0.7057). The variation of this parameter was very high, reaching as much as 104.2% for untreated pines (Table 3).

The average root length of pine seedlings in the experiment was 144.3 cm. No statistically significant differences in this parameter were detected between the treatments (p = 0.3009). The variation coefficient of this parameter ranged from 43.2% to 52.8% (Table 4).

Table 4. Biometrical parameters of one-year-old pine seedling roots
Tabela 4. Cechy biometryczne korzeni jednorocznych siewek sosny

Treatment Wariant	Root length, cm Długość korzeni, cm		Root dry mass, g Sucha masa korzeni, g		Root branching index pcs/cm Wskaźnik rozgałęzienia szt./cm	
	x	v%	x	v%	x	v%
Falcon 1×	154.4 a	52.8	0.18 b	98.1	4.8 a	33.1
Falcon 2×	142.2 a	43.2	0.12 a	44.7	5.1 a	28.2
Gwarant 1×	126.1 a	47.6	0.10 a	42.7	5.2 a	29.4
Gwarant 2×	157.0 a	49.6	0.15 ab	53.7	4.9 a	30.1
Control – Kontrola	141.8 a	48.3	0.14 ab	54.5	5.1 a	28.7
Mean – Średnia	144.3	48.9	0.14	73.1	5.0	29.7

Descriptions see Table 3.
Oznaczenia jak w tabeli 3.

Seedlings sprayed once with Gwarant 500 SC (0.10 g) and twice with Falcon 460 EC (0.12 g) featured the lowest root dry mass. Their root dry mass was statistically significantly lower (p = 0.0062) in comparison with pines treated once with Falcon 460 EC (0.18 g) and it did not differ from the root dry mass value in seedlings from the control treatment (0.14 g) and from those sprayed twice with Gwarant 500 SC (0.15 g). The variation coefficient was 73.1% on average (Table 4).

The branching index characterizing the number of mycorrhizal or autotrophic short roots per 1 cm of root length fell within the range of 4.9 – 5.2. The variation coefficient of this parameter was 29.7% (Table 4). A positive correlation was found between the percentage of autotrophic tips and the majority of biometric parameters of seedlings (except for root dry mass; Table 5). Pine seedlings with poorly developed mycorrhizae demonstrated better growth parameters.

The seedlings growing in furrows and on ridges differed statistically significantly in the percentage of autotrophic tips and size of all biometric parameters (except for root dry mass). The seedlings growing in furrows were significantly smaller and better mycorrhized in comparison with those growing on ridges (Table 6).

The average seedling height by the end of the second growing season was 13.9 cm. Like in the previous year, pines sprayed once with Gwarant 500 SC were lowest (12.9 cm). However, the differences in seedling height between the treatments were not statistically significant (p = 0.5865). The variation coefficient of this parameter for individual treatments was similar and equalled 39% (Table 7). Unlike in the previous year, the

Table 5. Correlation coefficient of the linear relationship between the share of autotrophic tips and biometric parameters of pine seedlings

Tabela 5. Współczynniki korelacji prostoliniowej zależności między udziałem wierzchołków autotroficznych i cechami biometrycznymi siewek sosny

Schare Udział	Root collar diameter Grubość w szyi korzeniowej	Shoot length Długość pędu	Aboveground dry mass Sucha masa części nadziemnej	Number of lateral shoots Liczba pędów bocznych	Root length Długość korzeni	Root dry mass Sucha masa korzeni
Autotrophic tips Wierzchołki autotroficzne	0.345**	0.303**	0.310**	0.186*	0.207*	0.054

* r significant at α = 0.05, ** r significant at α = 0.01.
* r istotny przy α = 0,05, ** r istotny przy α = 0,01.

Table 6. Biometrical parameters and share of autotrophic tips of one-year-old pine seedlings growing in the furrow or on the ridge

Tabela 6. Cechy biometryczne i udział wierzchołków autotroficznych jednorocznych siewek sosny rosnących w bruździe lub na skibie

Treatment Wariant	Root collar diameter mm Grubość w szyi korzeniowej mm	Shoot length cm Długość pędu cm	Shoot dry mass g Sucha masa pędu g	Number of lateral shoots pcs Liczba pędów bocznych szt.	Root length cm Długość korzeni cm	Root dry mass g Sucha masa korzeni g	Root branching index pcs/cm Wskaźnik rozgałęzienia szt./cm	Share of autotrophic tips % Udział wierzchołków autotroficznych %
Furrow Bruzda	1.45 a	5.6 a	0.29 a	1.3 a	110.7 a	0.13 a	4.3 a	15.8 a
Ridge Skiba	1.97 b	7.1 b	0.51 b	2.3 b	178.0 b	0.15 a	5.7 b	63.6 b
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0848	0.0000	0.0000

p – significance level. Other descriptions as in Table 3.
p – poziom istotności. Pozostałe oznaczenia jak w tabeli 3.

average height of pines growing in the furrows was greater (14.3) than of those growing on the ridges (13.5 cm). The proportion was reversed only in the case of seedlings treated twice with Falcon 460 EC. In this treatment, the heights of pines growing in the furrows were lower (13.7 cm) than of those from other experimental treatments and were highest in pines growing on the ridges (14.7 cm). The height variation coefficient for seedlings growing on the ridges (46.8% on average) was greater than for seedlings growing in the furrows (34.2% on average; Table 7).

Table 7. Height of pine seedlings after two years of growth in natural regeneration, cm
Tabela 7. Wysokość siewek sosny po dwóch latach wzrostu w odnowieniu naturalnym, cm

Treatment Wariant	Seedling height after 2 years, cm – Wysokość siewek po 2 latach, cm					
	in the furrow w bruździe		on the ridge na skibie		in treatment w wariancie	
	x	v%	x	V%	x	v%
Falcon 1×	14.5	37.2	14.3	43.7	14.4 a	39.9
Falcon 2×	13.7	33.7	14.7	47.5	14.1 a	39.8
Gwarant 1×	13.8	30.4	11.5	51.2	12.9 a	39.3
Gwarant 2×	14.6	36.0	13.3	43.4	14.1 a	38.9
Control – Kontrola	14.7	33.9	13.6	48.1	14.3 a	39.7
Mean – Średnia	14.3	34.2	13.5	46.8	13.9	39.7

Descriptions see Table 3.
Oznaczenia jak w tabeli 3.

Table 8. Density of pine seedlings in a natural regeneration, pcs/m^2
Tabela 8. Zagęszczenie siewek sosny w odnowieniu naturalnym, szt./m^2

Treatment Wariant	Seedling density, pcs/m² – Zagęszczenie siewek, szt./m²							
	in the first year – w pierwszym roku				in the second year – w drugim roku			
	in the furrow w bruździe	on the ridge na skibie	in treatment w wariancie		in the furrow w bruździe	on the ridge na skibie	in treatment w wariancie	
			x	v%			x	v%
Falcon 1×	63.6	14.8	39.2	138.3	23.3	6.4	14.9	109.6
Falcon 2×	55.2	15.4	35.3	113.5	20.9	6.1	13.5	93.7
Gwarant 1×	41.7	15.2	28.5	98.9	18.1	5.4	11.8	91.2
Gwarant 2×	58.5	17.4	38.0	114.1	27.4	7.2	17.3	107.3
Control – Kontrola	64.5	12.2	38.4	132.3	27.2	5.9	16.5	117.6
Mean – Średnia	56.7	15.0	35.9	123.3	23.4	6.2	14.8	103.9

Descriptions see Table 3.
Oznaczenia jak w tabeli 3.

In both growing seasons, the density of seedlings in the furrows was significantly higher (2006 – 56.7 seedlings/m², 2007 – 23.4 seedlings/m²) than when they grew on the ridges (15.0 seedlings/m² and 6.2 seedlings/m², p = 0.0000 in both growing seasons). The lowest density occurred in the treatment with a single application of Gwarant 500 SC, however, the differences in the value of this parameter between the treatments in both years of growth were not statistically significant (p = 0.1507). The variation coefficient value was very high and exceeded 100% for most of the variants (Table 8).

The inspection of natural regeneration carried out in the spring of 2007 (in the second year of seedling growth) did not show any symptoms of the *Lophodermium* needle cast disease in pine seedlings.

DISCUSSION

The experiment with the natural regeneration of Scots pine established in the territory of the Gostynin Forest Inspectorate did not allow assessment of the effectiveness of fungicides such as Falcon 460 EC and Gwarant 500 SC in the protection of pine seedlings against *Lophodermium* needle cast. Although the regeneration established in a clear-cut strip (60 m) where microclimate conditions, high moisture level and shading were favourable for the development of *Lophodermium* needle cast, no infestation symptoms were observed either in chemically treated or untreated pines. Other factors such as weather conditions or lack of inoculum source (no occurrence of needle cast was detected in the plantations of the Gostynin Forest Inspectorate) may have been a possible cause of this situation.

Gwarant 500 SC and Falcon 460 EC are chemicals successfully used in forest nurseries to protect seedlings from *Lophodermium* needle cast. Chlorothalonil, an active ingredient of Gwarant 500 SC, may have an inhibiting effect on mycorrhizal development [Hong 1976], cause no changes in their state [Aleksandrowicz-Trzcińska 2002] or, at lower concentrations, it may even stimulate growth of mycorrhizal associations [Trappe et al. 1984]. So far, Falcon 460 EC has not been tested for its effect on mycorrhizae. Neither have active substances of this fungicide such as spiroxamine, tebuconasole and triadimenol been tested, It has however been observed, that Falcon 460 EC used in forest nurseries for the protection of pine subject to controlled mycorrhization with the Polish biopreparation containing the fungus *Hebeloma crustuliniforme* (Bull.) Quél. (Poison Pie) has no inhibiting effect on mycorrhiza formation [Aleksandrowicz-Trzcińska 2007].

In the presented research, Gwarant 500 SC and Falcon 460 EC applied once or twice at recommended rates and concentrations did not cause changes in the level of mycorrhizal colonisation of pine seedlings. Both fungicides may have had have a limiting effect on the formation of complex dychotomous and coralloid forms, as a more favourable structure of mycorrhizal tip forms was noted in the unsprayed than in sprayed seedlings.

In the adopted program of pine seedling protection, the effect of the active substances contained in the tested fungicides (on the environment, soil microorganisms, mycorrhizae and host plant) applied twice in the growing season was not great in comparison with the effect of the chemicals used throughout the full protection program implemented in forest nurseries. Obviously, this fact had a bearing on the obtained results.

The analysis of seedling biometric parameters shows that the heights of pines treated once with Gwarant 500 SC in both growing seasons were lowest. For the majority of parameters, the differences between mean values were not statistically significant except for the aboveground dry mass when one-year-old seedlings treated once with Gwarant 500 SC were statistically significantly lower than the seedlings from the control. It is difficult to explain why a one-time application of Gwarant 500 SC caused poorer seedling growth not observed in the case of a twofold application of this fungicide. It is speculated that other factors were likely to be involved, especially in view of the fact that the density of seedlings in the variant with a one-time application of Gwarant 500 SC was lower than in other experimental variants. No literature reports on the inhibiting effect of chlorotalonil on seedling growth.

The place of seedling growth either in a furrow or on a ridge had a significantly greater effect (only in the first year) on the dimensions of biometric parameters and the level of pine mycorrhization than the application of chemical preparations against *Lophodermium* needle cast. The poor coniferous forest habitat in which natural regeneration was established and developed in the territory of the Gostynin Forest Inspectorate provided different conditions for mycorrhiza formation. Moreover, the availability of mineral nutrients was different in furrows and on ridges. This is the reason why seedlings growing on the ridges were statistically significantly higher and the mycorrhization level was four times lower in comparison with pines growing in the furrows.

After the removal of a humus layer (on podzolic and rusty soils its thickness usually reaches several centimetres) in the furrows, the seedlings grew on an exposed nutrient-poor eluvial or rusty horizon, while the seedlings growing on the ridges benefited from the rich humus layer [Andrzejczyk and Drozdowski 2003].

Concurrently, the research results showed that the possibility of the formation of mycorrhizal associations on the ridges was many times lower than in the furrows. This may have been the result of moisture content in the substrate. Surface drying is a quick process taking place on concave forms *i.e.* ridges, and the separation of the ridge surface from the soil substrate with a double sod layer containing raw humus (mor) prevents infiltration. The unfavourable moisture conditions prevailing on ridges may be the cause of a poor mycorrhization of seedling roots.

The availability of different inoculum forms seems to be of less importance. It is maintained that the density of sclerocial forms and mycorrhizal root tips is higher in the soil organic horizon than in the mineral one [Harvey et al. 1979]. However, many studies confirm that the inoculum level in the mineral soil of logged areas has no limiting effect on mycorrhizal colonization [Jones et al. 2003]. The roots growing in the mineral soil are well colonized even in habitats where ectomycorrhizae occur in larger numbers in the organic soil horizon [Harvey et al. 1996]. So, furrows provided favourable moisture conditions and sufficient inoculum density, while the high availability of root ectomycorrhizae ensured an adequate amount of mineral substances even under the nutrient-deficit conditions.

Pines growing on the ridges had better biometric parameters as a result of the high availability of easily assimilated mineral elements and low root mycorrhization. This relationship is also confirmed by a positive correlation between the proportion of autotrophic tips in seedlings and their biometric parameters indicating larger dimensions of both the aboveground parts and roots in poorly mycorrhized pines. The relationship is regarded as physiological and typically occurring in seedlings of up to 2-3 years of age

as a result of the necessity of providing nutrients by the plant to its fungal partner [Stenström and Ek 1990]. Better mycorrhized seedlings transfer larger quantities of photosynthates to the mycorrhizal partner than those poorly mycorrhized and attain smaller dimensions.

CONCLUSIONS

1. Falcon 460 EC and Gwarant 500 SC applied once or twice in the growing season to the natural regeneration of pine at recommended rates and concentrations against the *Lophodermium* needle cast did not cause changes in the level of mycorrhizal colonization of seedlings. Both fungicides had a slight limiting effect on the formation of complex dychotomous and coralloid structures.

2. None of the tested fungicides caused changes in seedling growth. Pines treated once with Gwarant 500 SC showed the smallest dimensions, however, differences between mean values of the majority of the examined parameters were not statistically significant; no relationships were detected in the seedlings sprayed twice with this fungicide.

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WZROST I STAN MIKORYZ SIEWEK SOSNY W ODNOWIENIU NATURALNYM CHRONIONYM CHEMICZNIE PRZED WIOSENNĄ OSUTKĄ

Streszczenie. Celem pracy była ocena wpływu dwóch fungicydów Falconu 460 EC i Gwarantu 500 SC, zastosowanych w ochronie sosny przed osutką na stan mikoryz i wzrost samosiewów. Obiektem badań były jednoroczne naturalne odnowienia sosny w Nadleśnictwie Gostynin. Falcon stosowano w stężeniu 0,15%, a Gwarant 0,5%, oba fungicydy w ilości 500 l/ha. Zabiegi wykonano jedno- lub dwukrotnie w sezonie wegetacyjnym. Nie stwierdzono występowania objawów osutki, zarówno na sosnach chronionych fungicydami, jak i kontrolnych. Na korzeniach sosen wyróżniono tylko dwa morfotypy mikoryz. Poziom zmikoryzowania nalotów nie uległ zmianie po aplikacji fungicydów. Oba fungicydy działały nieznacznie ograniczająco na tworzenie form złożonych: wielokrotnie dychotomicznych i koralowatych. Żaden z badanych fungicydów nie powodował zmian we wzroście samosiewów sosny.

Słowa kluczowe: ektomikoryza, fungicydy, odnowienie naturalne, osutka sosny, sosna zwyczajna

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