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PRELIMINARY RESULTS OF STUDIES ON THE EFFECTS OF ORGANIC FERTILIZATION AND MULCHING ON THE GROWTH OF ONE-YEAR OLD EUROPEAN LARCH (*LARIX DECIDUA* MILL.) SEEDLINGS AND OCCURRENCE OF SOIL MITES UNDER MICRO-SPRINKLER IRRIGATION IN TWO SYLVAN-NATURAL REGIONS OF POLAND

Summary

The aim of the study was to determine the influence of organic fertilization and mulching on the seedling vigour of European larch (*Larix decidua* Mill.) and occurrence of soil mites (Acari) in forest- and post-arable soils. Two different nursery experiments were carried out in the vegetation period of the year 2005 on light soils at two sylvan-natural regions of Poland. The first trial was conducted at Białe Błota near Bydgoszcz – on a brown podzolic soil. The second experiment – at Lipnik near Stargard Szczeciński – on an acid brown soil. The higher was the rainfall amount during the vegetation period, the lower was the seasonal irrigation rate supplied to European larch seedlings. Because of this the seasonal irrigation water rate applied at Białe Błota was higher than that at Lipnik. European larch seedlings grown on the forest soil were characterized by the increased height and the fresh mass than those cultivated on the post-arable ground. Seedlings grown in the forest soil on treatments mulched with litter were characterized by the increased height and the fresh mass of above-ground parts as compared to those cultivated on control plots (without mulching). Mulching with litter increased the number of mites, especially oribatid mites, as well as their species diversity. It can be recognized as the result of the positive influence of the mulching on the biological properties of the studied soils.

Key words: one-year old European larch seedlings, sewage sludge, bark, sawdust, Acari, Oribatida, micro-sprinkler irrigation

INTRODUCTION

Post-arable grounds and other soils changed by industrial or agricultural activities, are very often characterized by lack of suitable phyto- and zoo-edaphon which can secure the proper growth of forest trees. Similar situation is noted on soils of older forest nurseries where a decrease of biological diversity is also detected [Aleksandrowicz-Trzcińska 2004]. It is potentially possible to use the edaphon for intensification of soil processes and also for increase of biological balance on a post-arable land and grounds of degraded forest nurseries. Because of this, an inoculation of edaphon derived from a forest soil to the soils of nurseries as well as to post-arable grounds seems to be justified. This treatment should advantageously influence growth conditions of young trees. According to the opinion of Szujecki [1996], saprophage organisms play especially important role in an edaphon inoculation. In forest soils, the saprophage oribatid mites (Acari, Oribatida) are especially abundant [Klimek 2000]. They play a number of important tasks in soils.

An organic matter is a soil component being decisive in case of a soil suitability for seedling cultivation at forest nurseries [Niski 1992]. Proper seedling growth on a soil in forest nurseries is very often determined by supply of organic fertilizers as, e.g., composts. In these investigations compost produced from treated sewage sludge with admixture of bark or sawdust was applied. Usage of treated sewage sludge is justified from an ecological point of view [Siuta and Wasiak 2001].

The aim of the study was to determine the influence of mulching and organic fertilization on the seedling vigour of European larch (*Larix decidua* Mill.) and occurrence of soil mites (Acari) in forest- and post-arable soils.

MATERIAL AND METHODS

Two different field experiments were carried out in the vegetation period of the year 2005 on the light soils at two sylvan-natural regions (table 1). The first trial was conducted at Białe Błota near Bydgoszcz – on a brown podzolic soil; the second experiment - at Lipnik near Stargard Szczeciński - on an acid brown soil.

Table 1. Geographical location and soil conditions of the nursery experiments

Specification	Białe Błota	Lipnik
Geographical location		
North latitude (N)	φ = 53° 06’ 00’’	φ = 53° 20’ 37’’
East longitude (E)	λ = 18° 56’ 35’’	λ = 14° 58’ 14’’
Altitude (m)	71	25
Soil conditions	brown podzolic soil	acid brown soil

The experiments were run in a *split-plot* system with four replications. Two different factors were compared. The first row factor was fertilization, used in the two following treatments: N_1 – treated sewage sludge (⅔) + bark (⅓) and N_2 – treated sewage sludge (⅔) + sawdust (⅓). The second row factor was mulching, used in the two variants: C – without mulching (control) and S – mulching with litter.

The plot area was 2 m^2. Total number of plots in each experiment was 16 (2 factors x 2 treatments x 4 replications).

Organic fertilizer was produced on the base of treated sewage sludge (⅔) and Scots pine bark (⅓) or sawdust (⅓). This fertilizer was applied with a dose of 100 $t \cdot ha^{-1}$ in spring and mixed with the topsoil (10 cm deep) before European larch seed time.

Mulching with litter obtained from fresh coniferous forest was done – after emergence of European larch seedlings – with the dose of 100 $m^3 \cdot ha^{-1}$.

Irrigation was done with the use of micro-sprinklers "Nelson". Terms of irrigation and water rates were established according to [Pierzgalski et al. 2002].

In October the growth of plants was evaluated. The height of seedlings was measured as well as the fresh mass of above-ground parts and roots were determined.

The soil samples for investigation on mites were taken three times a year (in May, August and October). The samples of 17 cm^2 area and 3 cm deep were taken from all plots in 3 replications. There were 36 soil samples for each treatment (variant of the experiment). The mites were extracted from the material in high gradient Tullgren funnels, and next they were preserved and prepared. Oribatid mites (including the juvenile stages) were determined according to species. Total number of mites was also determined. In general, 1914 mites (Acari) were examined, including 985 Oribatida. The density of mites (*N)* was calculated for 1 m^2 of soil area. Species diversity of oribatid mites was determined with the use of general species number (*S)*, mean number of species in a sample (*s)* as well as the Shannon index of species diversity (*H)* [Magurran 1988]. The data of mites were ln-transformed prior to the analyses [Bruchwald 1997].

Potential evapotranspiration (*Etp*) was determined using Szarov's formula [Ostromęcki 1973]:

$$Etp = \alpha \, \Sigma t$$

where:

- α – coefficient (mm/(24 hours and 1°C)) modified according to Grabarczyk's proposal for conditions of Poland (0.25 in April, 0.24 – May, 0.23 – June, 0.21 – July, 0.20 – August, 0.19 – September) [Grabarczyk 1989],
- Σt – sum of mean daily air temperature in a particular month of the vegetation period (°C).

Additionally, the rainfall deficiency *N* = *Etp* – *P* was given [Ostromęcki 1973].

RESULTS AND DISCUSSION

Course of weather, evapotranspiration and irrigation

Air temperature in experiment at Białe Blota

Mean air temperature value in the vegetation period 2005 at Białe Błota was 14.2 °C. It was lower by 0.2 °C than the long-term average. Mean monthly values of air temperature varied from 7.4°C to 19.4°C, in April and in July, respectively (Table 2). July was characterized by the highest decade values of air temperature which varied from 18.5 °C to 20.2 °C, in the 3rd and 2nd decade, respectively. Among all the months of the vegetation, September was characterized by the highest deviation from a long-period average (+ 12.1 %)

Table 2. Air temperature of the vegetation period 2005 at Białe Błota and Lipnik (°C)

Specification	Months of the vegetation period					
	IV	V	VI	VII	VIII	IX
Białe Błota						
1st decade	6.9	10.0	12.3	19.5	15.3	18.1
2nd decade	9.1	9.1	15.2	20.2	16.0	13.6
3rd decade	6.2	17.1	17.3	18.5	17.4	12.9
Mean 1-3	7.4	12.2	14.9	19.4	16.3	14.8
Deviation from the long-period average (%)	-6.3	-6.9	-6.9	+4.9	-8.9	+12.1
Lipnik						
1st decade	8.0	11.7	13.4	18.8	15.8	18.6
2nd decade	10.8	9.9	15.3	20.2	16.8	14.4
3rd decade	8.8	17.9	18.7	19.3	17.1	13.4
Mean 1-3	9.2	13.1	15.8	19.4	16.6	15.5
Deviation from the long-period average (%)	+27.8	+4.8	-0.6	+11.5	-2.4	+17.4

Air temperature in experiment at Lipnik

Mean air temperature value in the vegetation period 2005 at Lipnik was 14.9 °C. It was 0.7 °C higher as compared to that at Białe Błota. All the months of the vegetation period, excepting July, were characterized by higher temperature in comparison to values noted at Białe Błota. Mean monthly values of temperature ranged from 9.2 °C to 19.4 °C, in April and July, respectively. In July, the decade values of temperature varied from 18.8 °C to 20.2 °C, in the 1st and in the 2nd decade, respectively.

Rainfall in experiment at Białe Błota

The sum of rainfall in the vegetation period 2005 amounted 203 mm. It was lower by 76 mm from the long-term average value. The mean monthly rainfall amount in the vegetation period varied from 17.9 mm in September to 69.5 mm in May (Table 3). There were three rainfall-free decades during this vegetation period: 1st decade of July, 3rd of August and 1st of September.

Table 3. Rainfall amount of the vegetation period 2005 at Białe Błota and Lipnik (mm)

Specification	Months of the vegetation period					
	IV	V	VI	VII	VIII	IX
	Białe Błota					
1st decade	3.8	46.6	20.9	-	19.3	-
2nd decade	1.5	13.2	6.1	2.5	1.6	7.9
3rd decade	18.5	9.7	3.7	37.7	-	10.0
Total 1-3	23.8	69.5	30.7	40.2	20.9	17.9
Deviation from the long-period average (%)	-13.4	+72.4	-41.4	-36.3	-65.2	-60.0
	Lipnik					
1st decade	6.6	28.2	13.2	14.4	40.1	-
2nd decade	-	14.1	12.5	14.7	3.4	20.0
3rd decade	7.1	25.2	-	47.1	9.7	5.8
Total 1-3	13.7	67.5	25.7	76.2	53.2	25.8
Deviation from the long-period average (%)	-63.8	+32.1	-58.0	+20.6	-2.4	-45.0

Rainfall in experiment at Lipnik

The total rainfall from 1 April to 30 September amounted 262.1 mm. This amount was higher by 59.1 mm than that at Białe Błota. Among the months of the vegetation period, July was characterized by the highest rainfall amount (76.2 mm), and April by the lowest one (13.7 mm). There were also three rainfall-free decades during the vegetation period: 2nd decade of April, 3rd decade of June and the 1st decade of September.

Potential evapotranspiration

The sum of *Etp* calculated using Szarow's formula in the vegetation period (1 April - 30 September) amounted 561 mm and 594.7 mm, in Białe Błota and Lipnik, respectively (Table 4). As can be seen from the results presented, the vegetation period at Lipnik was characterized by the higher *Etp* values also in all the particular months. Among the months of the vegetation season, June, July and August were characterized by the *Etp* values higher than 100 mm. The highest *Etp* values - both in Białe Błota as well as in Lipnik - were obtained for July, and they amounted 126 mm and 126.5 mm, respectively. Among the all particular decades, the 3rd decade of May was characterized by the highest value of *Etp* which amounted 45.1 mm and 47.3 mm in Białe Błota and Lipnik, respectively.

Table 4. Potential evapotranspiration in the vegetation period 2005 at Białe Błota and Lipnik (mm)

Specification	Months of the vegetation period					
	IV	V	VI	VII	VIII	IX
	Białe Błota					
1st decade	17.2	24.0	28.3	40.9	30.6	34.4
2nd decade	22.7	21.8	35.0	42.4	32.0	25.8
3rd decade	15.5	45.1	39.8	42.7	38.3	24.5
Total 1-3	55.4	90.9	103.1	126.0	100.9	84.7
	Lipnik					
1st decade	20.0	28.1	30.8	39.5	31.6	35.3
2nd decade	27.0	23.8	35.2	42.4	33.6	27.4
3rd decade	22.0	47.3	43.0	44.6	37.6	25.5
Total 1-3	69.0	99.2	109.0	126.5	102.8	88.2

Water deficits

The difference *Etp – P* for the vegetation season was higher in Białe Błota than in Lipnik, and amounted 358 mm and 332.7 mm, respectively (Table 5). Among the months of the vegetation season, the highest water deficits (80 mm and more) were calculated in Białe Błota for July and August and in Lipnik - for June. As can be seen from the results presented in Table 5, April, May and June were characterized by the higher water deficits in Lipnik than in Białe Błota, whereas in case of July, August and September the water deficits were higher in Białe Błota as compared to those in Lipnik. There were two decades without water deficits in Białe Błota (3rd decade of April and 1st decade of May) and the three decades in Lipnik (1st decade of May, 3rd decade of July and 1st decade of August).

Table 5. Difference (Etp – P) in the vegetation period 2005 at Białe Błota and Lipnik (mm)

Specification	Months of the vegetation period					
	IV	V	VI	VII	VIII	IX
	Białe Błota					
1st decade	13.4	-22.6	7.4	40.9	11.3	34.4
2nd decade	21.2	8.6	28.9	39.9	30.4	17.9
3rd decade	-3.0	35.4	36.1	5.0	38.3	14.5
Total 1-3	31.6	21.4	72.4	85.8	80.0	66.8
	Lipnik					
1st decade	13.4	-0.1	17.6	25.1	-8.5	35.4
2nd decade	27.0	9.7	22.7	27.7	30.2	7.4
3rd decade	14.9	22.1	43.0	-2.5	27.9	19.7
Total 1-3	55.3	31.7	83.3	50.3	49.6	62.5

Irrigation

Amounts of irrigation water were dependent on the course of rainfall and rainfall amounts during the vegetation period. The higher was rainfall amount, the lower was seasonal irrigation rate supplied to the European larch seedlings. Therefore, seasonal irrigation water rate applied at Białe Błota was higher (210 mm) than that at Lipnik (140 mm).

GROWTH OF SEEDLINGS

Height of seedlings

The European larch seedlings grown on the forest soil at Białe Błota were characterized by increased height (21.73 cm) than those cultivated on the post-arable land at Lipnik (10.35 cm) (Table 6). The best results, both on forest soil as well as on post-arable ground, were obtained for treatment SN_2. Seedlings on plots mulched with litter and fertilized with treated sewage sludge (⅔) with sawdust admixture (⅓), reached the height 25.42 cm and 12.36 cm, on forest- and post-arable soil, respectively. A positive effect of fertilization with sewage sludge with peat admixture on the growth of Scots pine seedlings was also noted in our previous investigations [Rolbiecki *et al*. 2005a,b,c; Rolbiecki *et al*. 2007 a,b].

Table 6. Influence of organic fertilization and mulching on the European larch seedling height (cm)

Specification	Mulching		Mean
	S	C	
Białe Błota			
N_1	25.27	17.57	21.42
N_2	25.42	18.65	22.04
Mean	25.35	18.11	21.73
Lipnik			
N_1	5.50	10.03	7.76
N_2	12.36	13.53	12.94
Mean	8.93	11.78	10.35

N_1, N_2 - treated sewage sludge (⅔) + bark (⅓), treated sewage sludge (⅔) + sawdust (⅓), respectively;

S, C - mulching with litter and without mulching (control), respectively

Białe Błota: $LSD_{0,05}$: N_1, N_2 – n.s.; S, C – 2.202; interaction – n.s.

Weight of seedlings

The fresh mass of the above-ground parts of European larch seedling was higher on the forest soil (6.95 g) as compared to that on the post-arable land (1.80 g) (Table 7). The mass of seedling was more differentiated on the post-arable land at Lipnik than on the forest soil at Białe Blota, and ranged from 0.73 to 3.0 g and from 6.24 to 7.72 g, respectively. For forest soil, better results were obtained at treatment S (mulching with litter) as compared to variant C (without mulching), and amounted 7.61 g and 6.28 g, respectively. The difference between them was statistically significant. On the other hand, the tendency for the post-arable ground was opposite.

Table 7. Influence of organic fertilization and mulching on the fresh mass of above-ground parts of a European larch seedling (g)

Specification	Mulching		Mean
	S	C	
Białe Błota			
N_1	7.51	6.24	6.87
N_2	7.72	6.33	7.02
Mean	7.61	6.28	6.95
Lipnik			
N_1	0.73	1.00	0.86
N_2	2.50	3.00	2.75
Mean	1.61	2.00	1.80

Explanations – see Table 6; Białe Błota: $LSD_{0,05}$: N_1, N_2 – n.s.; S, C – 0.340; interaction – n.s.

Roots of seedlings grown on the forest soil were characterized by higher fresh mass than those cultivated on post-arable land (Table 8). The root fresh mass of seedling amounted, on average, 3.19 g and 0.92 g, respectively. On the forest soil, seedlings grown on treatments S (mulching with litter) were characterized by the significantly higher root mass in comparison to those on control plots (treatment C), amounting 3.42 g and 2.96 g, respectively. Similar results were noted in case of simultaneous experiment with Scots pine cultivation [Rolbiecki R. *at al*. 2007b].

Table 8. Influence of organic fertilization and mulching on the fresh mass of roots of a European larch seedling (g)

Specification	Mulching		Mean
	S	C	
Białe Błota			
N_1	3.52	3.02	3.27
N_2	3.32	2.91	3.11
Mean	3.42	2.96	3.19
Lipnik			
N_1	0.20	1.00	0.60
N_2	1.50	1.00	1.25
Mean	0.85	1.00	0.92

Explanations – see Table 6; Białe Błota: $LSD_{0,05}$: N_1, N_2 – n.s.; S, C – 0.333; interaction – n.s.

Occurrence of soil mites

In forest soils, there are about 70 % of oribatid mites in gatherings of all mites [Klimek 2000]. It was found that oribatid mites can feed on ectomycorrhizal fungi [Schneider *et al*. 2005], and because of this they can stimulate the growth of these fungi and their expansion. In addition, they are - among others - good bioindicators of biological properties of forest humus [Seniczak 1979].

The density of mites on the investigated treatments varied from 0.73 to 11.94 thousand individuals · m^{-2} (Table 7). The density of mites in both the regions of the study considerably increased – after edaphon introduction - on treatments SN_1 and SN_2, as compared to the plots without mulching. It was found on the base of the statistical analysis that only mulching significantly influenced on the density of mites. Organic fertilization with the use of different components did not effect on this index. After mulching, the density of these arthropods was many times higher on plots at Lipnik than at Białe Błota.

Table 9. Abundance (*N* in 1000 individuals · m^{-2}) of mites, number of species (*S*), average number of species in a sample (*s*) and Shannon index (*H*) for gatherings of Oribatida under different fertilization systems on experimental sites at Białe Błota (B) and Lipnik (L) in cultivation of European larch

Index – group of mites	Object	Experimental treatment				Mulching effect (p)
		CN_1	SN_1	CN_2	SN_2	
N – Acari total	B	1.58	3.49	2.56	3.86	<0.001
	L	0.73	8.65*	1.40	11.94*	<0.001
N – Oribatida	B	0.03	0.85	0.08	1.35	<0.001
	L	0.03	5.49*	0.05	9.58*	<0.001
S – Oribatida	B	3	23	4	19	-
	L	5	27	5	33	-
s – Oribatida	B	0.10	1.28	0.10	1.10	<0.001
	L	0.17	3.45*	0.23	4.52*	<0.001
H – Oribatida	B	0.64	2.57	1.24	2.14	-
	L	1.30	2.20	0.92	2.17	-

(1) significant between B and L at p = 0.05

On variants with mulching (S), oribatid mites were distinctly predominant in gatherings of mites, and on control plots (C - without mulching) – other mites were more abundant. Mulching was the treatment which had distinctly positive influence on the number as well as on the species diversity of Oribatida. In the experiment at Białe Błota 25 species of oribatid mites were noted, and in that at Lipnik – there were 36 species of these mites. On control plots, the low number of these mites was noted – from 3 to 5. This index was increased to 23 species and to 19 species - at treatments SN_1 and SN_2, respectively. In experiment carried out at Lipnik there were 29 and 30 species, respectively.

After mulching, the increase of the number of species (*S*) as well as of the average number of species in a sample (*s*) was much higher at Lipnik than that noted at Białe Błota. Differences between SN_1 and SN_2 treatments of the two regions were statistically significant.

Better results of mulching with litter (edaphon inoculation or the so-called 'zoo-melioration') at Lipnik can be connected with the course of rainfall and temperature, especially with higher humidity during the vegetation season (Table 3). Similar arrangement of the number and the diversity of species of the studied arthropods were noted for Scots pine cultivation [Rolbiecki R. *at al*. 2007b].

CONCLUSIONS

1. European larch seedlings grown on the forest soil were characterized by the increased height and the fresh mass than those cultivated on the post-arable ground.
2. Seedlings grown in the forest soil on treatments mulched with litter were characterized by the increased height and the fresh mass of above-ground parts as compared to those cultivated on control plots (without mulching).
3. Mulching with litter increased the number of mites, especially oribatid mites, as well as their species diversity. This can be recognized as the result of the positive influence of the mulching on the biological properties of the studied soils.

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