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INFLUENCE OF MICROIRRIGATION AND ORGANIC FERTILIZATION ON THE GROWTH OF SCOTS PINE (*PINUS SYLVESTRIS* L.) SEEDLINGS AND THE OCCURRENCE OF SOIL MITES IN A POST-ARABLE LAND OF TWO DIFFERENT SYLVAN-NATURAL REGIONS

Summary

The aim of the study was to determine the influence of microirrigation (microjet sprinkling and drip irrigation) and organic fertilization (compost prepared on the base of sewage sludge) on a seedling vigour of one-year and two-year old Scot pine seedlings (*Pinus sylvestris* L.), cultivated on a post-agricultural ground with the use of zoo-melioration in two different regions. Field experiments were carried out on an experimental field in Kruszyn Krajeński (loose sandy soil of quality class VI) near Bydgoszcz and in Lipnik near Stargard Szczeciński (sandy soil of quality class IVb). The first row factor was irrigation used in three treatments: without irrigation (control), drip irrigation, microjet sprinkling. The second row factor was fertilization, used in two variants: mineral fertilization (standard applied in forest nurseries), organic fertilization (compost).

The irrigation significantly increased the height and the diameter of the Scot pine seedlings. There were no significant differences in the characters of the growth between the two irrigation systems. Fertilization of Scot pine seedlings with the compost increased significantly the height of seedlings. Interaction of irrigation with organic fertilization of Scot pine seedling height and diameter was noted. Pine seedlings grown on the plots fertilized with compost under irrigation conditions were characterized by increased height and diameter. Better effects were obtained in Lipnik than in Kruszyn Krajeński. Joint effect of organic fertilization and microjet sprinkling positively influenced the density and the species number of Oribatida in Kruszyn Krajeński. The obtained results indicated that the amelioration measures used can positively influence the growth of Scot pine seedlings on a post-agricultural ground.

Key words: micro-irrigation, post-arable land, sewage sludge, Scots pine seedlings, amelioration with soil animals, Acari, Oribatida

INTRODUCTION

Irrigation is one of the most important amelioration measures. The use of irrigation enables systematic supply of water to young plants and securing adequate moisture for edaphon. Seedlings of trees should be grown on soils characterized by advantageous physical and biological properties and rich with nutrients. Introduction of edaphon to soils, especially those on post-arable land, being connected with organic fertilization and irrigation should considerably improve soil conditions which are decisive for quality of seedlings.

Soil processes and soil fertility is determined by edaphon [Górny 1975]. Therefore, edaphon can be used for intensification of soil-forming processes. Reconstruction of soil fauna can be performed by improvement of living conditions and stimulation of native populations of soil animals as well as by introduction of new, desirable species [Mazur and Tracz 1996].

In contrast to soils of Scots pine forests, oribatid mites living in arable land create not numerous gatherings which are characterized by relatively low species differentiation. This disadvantageous situation can be improved by mulching which can be treated as zoomelioration (amelioration with soil animals). According to the opinion of Mazur and Tracz [1996], zoomelioration can consist in the improvement of living conditions for native populations of soil animals or with the use a new species introduction.

The purpose of this paper was to determine the influence of micro-irrigation and organic fertilization on the growth of Scots pine (*Pinus sylvestris* L.) seedlings as well as on the occurrence of soil mites in a post-arable land of two different sylvan-natural regions.

MATERIAL AND METHODS

Two-year field experiments were carried out in the years 2003-2004 on a post-arable ground at two sites (Table 1):

1/ Kruszyn Krajeński near Bydgoszcz – on a loose sandy soil belonging to quality class VI (very weak rye complex).

2/ Lipnik near Stargard Szczeciński - on a sandy soil belonging to quality class IVb (good rye complex).

The experiments were run in a *split-plot* system with four replications [Bruchwald 1997]. Two different factors were compared. The first row factor – irrigation, was used in the three following treatments: without irrigation (control), drip irrigation, microjet sprinkling. The second row factor - fertilization, was used in two variants: mineral fertilization (standard applied in forest nurseries), organic fertilization (compost). The plot area was 4 m^2 and contained 4 rows (4-m length) of Scots pine seedlings. Total number of plots in each experiment was 24 (3x2x4).

Table 1. Data on location of the field experiments with Scots pine seedlings

Specification	Kruszyn Krajeński	Lipnik
Geographical location	φ = 53° 04' 00'' λ = 17° 51' 33''	φ = 53° 20' 37'' λ = 14° 58' 14''
Height above sea-level (m)	65	25
Soil conditions: Order Suborder Great group Subgroup	 Mollisols Udolls Hapludolls Typic Hapludolls	 Alfisols Udalfs Hapludalfs Typic Hapludalfs

Drip irrigation was made with the use of drip lines „T-Tape" (in-line emitters spaced 20 cm apart). The microjet irrigation was made with the use of microjets "Hadar". The terms of irrigation and water rates were established according to "Directives for irrigation of forest nurseries on an open areas" [Pierzgalski *et al*. 2002].

Organic fertilizer was produced on the base of sewage sludge (80%) and highmoor peat (20%). This fertilizer was spread (dose: 100 $t \cdot ha^{-1}$) in spring and mixed with the topsoil (10 cm deep) before establishing of exact field experiments. Zoomelioration measures consisted in the mixing of topsoil (2 cm deep) with an organic matter obtained from the surface of partial cutting in the habitat of a fresh coniferous forest. This substrate contained very abundant living soil mesofauna. This measure was conducted directly before seeding.

In late autumn the growth of plants was evaluated. The height of seedlings and shoot diameter were measured.

The soil samples for investigation on mites were taken twice a year (in May and October). The samples of 17 cm^2 and 3 cm deep were taken from all plots in 3 replications. Mites were extracted from the material in high gradient Tullgren funnels. Oribatid mites (including the juvenile stages) were determined to species. Other mites were determined to order. In total, 3194 mites (Acari) were examined, including 1116 Oribatida. The density of mites, N, was calculated for 1 m^2 of soil. The 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 using the Shannon index of species diversity H [Magurran 1988].

The experimental data has been statistically processed by analysis of variance [Bruchwald 1997]. The Fisher-Snedecor test was used to determine the significance of influence of experimental factors and the Tukey test was used to define significant differences between the combinations.

RESULTS AND DISCUSSION

Climatic conditions and course of irrigation

The mean air temperature during the vegetation period (April-September) in the years of the study was similar to the multi-annual average, both in Kruszyn Krajeński as well as in Lipnik (Table 2). The experimental site in Kruszyn Krajeński was characterized by lower temperatures and rainfall amounts as compared to those in Lipnik.

Table 2. Weather conditions of the field experiments with Scots pine seedlings

Specification	Kruszyn Krajeński		Lipnik	
Air temperature (°C)				
Year of study:	First	Second	First	Second
April	6.4	7.5	9.4	9.2
May	14.4	11.3	13.0	13.1
June	17.6	14.7	16.0	15.8
July	19.2	16.4	17.9	19.4
August	18.4	17.9	19.9	16.6
September	13.6	12.7	13.9	15.5
Mean for April - September	14.9	13.4	15.0	14.9
Rainfall (mm)				
Year of study:	First	Second	First	Second
April	13.3	12.1	20.7	13.7
May	12.1	44.4	39.5	67.5
June	34.3	35.8	61.0	25.7
July	88.8	41.8	69.8	76.2
August	17.8	85.6	47.2	53.2
September	11.2	24.8	33.5	25.8
Total for April - September	177.5	244.5	271.7	262.1

The seasonal irrigation rates were dependent on rainfall . Total rates of water in drip irrigation and micro-jet sprinkling were higher in Kruszyn Krajeński than those in Lipnik (Table 3). The differences were connected with rainfall conditions of both of the experimental sites.

Table 3. Amounts of seasonal irrigation water rates (mm)

Specification	Kruszyn Krajeński		Lipnik	
	Drip	Microjet	Drip	Microjet
First year	200	290	110	130
Second year	141	187	83	140
Mean	170	238	97	135

Growth of seedlings

One-year old seedlings

The emergence of Scots pine seedlings grown on control plots (without irrigation) at Kruszyn Krajeński was incomplete. One-year old seedlings were very short and their height was, on average for period of the study, 2.1 cm only (Table 4). Organic fertilization was in such conditions completely ineffective.

Table 4. Influence of irrigation and fertilization on the one-year old Scots pine seedling height [h] and diameter [ø] in the experiments at Kruszyn Krajeński and Lipnik, 2-year mean

Irrigation	Fertilization	Experiment			
		Kruszyn Krajeński		Lipnik	
		h (cm)	ø (mm)	h (cm)	ø (mm)
Control	N_1	2.1	0.9	4.1	1.5
	N_2	2.1	0.8	5.4	2.1
Drip	N_1	11.6	1.7	7.6	3.0
	N_2	12.5	1.9	8.6	2.7
Microjet	N_1	10.8	1.6	7.7	3.0
	N_2	11.9	1.8	9.5	3.4
$LSD_{0.05}$	(I)	0.596	0.237	0.522	0.122
	(II)	0.428	n.s.	0.439	0.136
	(I) x (II)	0.812	0.250	0.760	0.236
	(II) x (I)	0.741	0.137	0.758	0. 231

N_1, N_2 – without organic fertilization and with organic fertilization (compost), respectively

The use of irrigation created possibilities for full emergence of seedlings. Irrigation caused a significant increase of their height and diameter which ranged from 10.8 to 12.5 cm and from 1.6 to 1.9 mm, respectively. Better results, both height and diameter, were obtained on the drip-irrigated plots. The differences between the seedling height on the drip-irrigated plots and the height of those with microjet-sprinkling were not significant.

The height and diameter of seedlings grown on the non-irrigated plots at Lipnik were higher than those at Kruszyn Krajeński, and amounted to 4.7 cm and 1.8 mm, respectively. This was certainly caused by higher rainfall amount during the period of the study. Both the irrigation systems significantly increased the height and diameter of seedlings. But these results were lower than those at Kruszyn Krajeński. It can be explained by lower irrigation rates which were used at Lipnik as a result of higher rainfall amount.

Better results of the use of micro-irrigation were obtained in other experiments which were carried out simultaneously at the Białe Błota Forest Nursery [Rolbiecki R. *et al*. 2005]. The one-year old seedlings grown on the forest soil were characterized by increased height and diameter as compared to adequate results of the experiments on post-arable soils.

Two-year old seedlings

The results obtained from the experiments with two-year old seedlings were also better on the sandy soil at Lipnik than on the loose sandy soil at Kruszyn Krajeński (Table 5). These seedlings were characterized by higher height and diameter both on control as well as on irrigated plots.

Table 5. Influence of irrigation and fertilization on the two-year old Scots pine seedling height [h] and diameter [ø] in the experiments at Kruszyn Krajeński and Lipnik, 2-year mean

Irrigation	Fertilization	Object			
		Kruszyn Krajeński		Lipnik	
		h (cm)	ø (mm)	h (cm)	ø (mm)
Control	N_1	8.0	3.2	22.3	5.4
	N_2	7.2	3.0	24.3	8.1
Drip	N_1	13.9	4.3	30.6	7.3
	N_2	15.3	4.7	29.9	7.6
Microjet	N_1	12.2	3.0	30.7	6.8
	N_2	16.2	4.8	31.6	7.1
$LSD_{0.05}$	(I)	2.113	0.387	2.136	1.000
	(II)	n.s.	0.503	1.937	0.714
	(I) x (II)	n.s.	0.872	1.128	1.236
	(II) x (I)	n.s.	0.800	1.098	1.312

Explanations – see Table 4

An interaction of irrigation system and organic fertilization on Scots pine seedling height and diameter was observed on both of the experimental sites. The pine seedlings grown on the plots fertilized with compost under irrigation conditions were characterized by increased height and diameter.

Positive influence of micro-irrigation systems on the growth of Scots pine seedlings cultivated on the post-arable land is confirmed by the results of the previous studies concerning the use of sprinkler irrigation in forest nurseries [Babiński and Białkiewicz 1992, Hilszczańska 2002, Pierzgalski *et al*. 2002].

The use of micro-irrigation in other simultaneous experiments at the Białe Błota Forest Nursery was more effective [Rolbiecki R. *et al*. 2007]. The two-year old Scots pine seedlings grown on the forest soil were characterized by increased height and diameter in comparison to results of these experiments conducted on the post-arable soils. Significant interaction of irrigation and organic fertilization was also observed. There were no significant differences in the seedling height between the two irrigation systems studied (drip irrigation and micro-jet sprinkling).

Occurrence of mites

The soil mites (Acari), especially Oribatida, are abundant in soil of Scots pine forests – from 100 to 200 thou. individuals·m^{-2} [Klimek 2000], but in forest nurseries the density of these mites is lower [Rolbiecki R. *et al*. 2005, Rolbiecki S. *et al*. 2005]. The density of mites on the investigated plots on the post-arable land at Kruszyn Krajeński ranged from 3.51 to 7.27 thou. individuals·m^{-2}, but at Lipnik was lower and more uniform equalized (2.31–4.26 thou. individuals · m^{-2}) (Table 6). On most of the plots at Kruszyn, Actinedida were most abundant, and the plots at Lipnik were characterized by the domination of saprophage Oribatida. The number of the mites was relatively balanced and there were no significant differences between particular treatments of the experiment. At Kruszyn, the difference in the average number of oribatid mites between the control plots (without irrigation and organic fertilization) and the plots irrigated with microjets and fertilized with compost were statistically significant. It shows a distinct positive influence of organic fertilization and microjet sprinkling (interaction) on these mites. Similar results were obtained at the forest nursery [Rolbiecki R. *et al*. 2005, Rolbiecki S. *et al*. 2005].

Table 6. Abundance (*N* in 1000 individuals · m^{-2}) of mites, number of species (*S*), average number of species (*s*) and Shannon index (*H*) for gatherings of Oribatida under different irrigation and fertilization systems at Kruszyn Krajeński (K) and Lipnik (L)

Index – group of mites	Object	Irrigation					
		Control		Drip		Microjet	
		N_1	N_2	N_1	N_2	N_1	N_2
N – Acari	K	4.14	9.38	4.52	5.84	3.51	7.27
	L	2.31	3.61	4.26	3.06	3.31	3.16
N – Acaridida	K	0.98	1.76	0.25	0.30	-	0.40
	L	0.08	0.48	0.20	0.25	0.18	0.38
N – Actinedida	K	1.83	2.53	1.40	1.43	1.71	2.43
	L	0.48	0.63	0.80	0.60	0.75	0.93
N – Gamasida	K	0.78	1.96	1.83	2.46	0.95	1.71
	L	0.48	0.98	0.93	0.58	0.53	0.25
N – Tarsonemida	K	0.03	1.03	0.03	0.15	0.08	0.10
	L	0.10	0.13	0.13	0.03	0.28	0.05
N – Oribatida	K	0.53	2.11*	1.00	1.51	0.78	2.63*
	L	1.18	1.40	2.21	1.61	1.58	1.56
S – Oribatida	K	6	10	10	11	9	13
	L	15	11	16	10	15	11
s – Oribatida	K	0.58	2.13*	1.00	1.13	0.92	1.58*
	L	1.33	1.71	1.92	1.54	1.67	1.54
H – Oribatida	K	1.29	2.15	2.05	1.54	1.89	1.58
	L	2.22	1.90	1.94	1.95	1.97	2.00

* significant difference at $p = 0.05$

In the investigated area at Lipnik 24 species of oribatid mites were found, and this number ranged from 11 to 16 as dependent on the experimental treatment. At Kruszyn 20 species of oribatid mites were found and their number ranged from 6 to 13 on particular treatments. *Oribatula tibialis* (Nicolet) predominated in the gatherings of oribatid mites on the control plots (without irrigation) at Kruszyn, but on the irrigated plots *Tectocepheus velatus* (Michael) was the most abundant. This species – *Tectocepheus velatus* (Michael) – was the most abundant on all the plots at Lipnik. Both the species are eurytopic but they prefer also forest soils, especially soils of Scots pine forests [Klimek 1999, 2000]. Among Oribatida such species like *Chamobates cuspidatiformis* (Trägårdh), *Scutovertex sculptus* Michael, *Oppiella minus* (Paoli), *Oppiella nova* (Oudemans) were also relatively abundant. The species composition of Oribatida on the investigated area indicated that the amelioration measures caused positive results, and some of species – representatives of forest soil fauna – are able to adapt under proper conditions (soil moisture and additional organic matter) too difficult for them conditions of post-arable soils.

CONCLUSIONS

1. Irrigation significantly increased the height and diameter of Scots pine seedlings in both the experiments. Better results were obtained at Lipnik than at Kruszyn Krajeński. There were no significant differences in the investigated parameters of seedling growth between the two irrigation systems studied (drip irrigation and micro-jet sprinkling). Fertilization of seedlings with the compost from sewage sludge with peat admixture significantly increased the height under irrigation conditions only. An interaction of irrigation system and organic fertilization in effect on Scots pine seedling height and diameter was observed.
2. It was found – on the basis of acarologic study – that in the case of plots with microjet sprinkling and organic fertilization joint effect, the species number and the density of Oribatida increased at Kruszyn Krajeński, but at Lipnik the factors did not influence significantly these indices.
3. The obtained results indicated that the amelioration measures which were used in the experiments can advantageously influence the Scots pine seedling production on post-arable ground.

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