Original Research

Impact of Chosen Bare Root Nursery Practices on White Birch Seedling Quality and Soil Mites (Acari)

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Received: 12 February 2009
Accepted: 2 June 2009

Abstract

The aim of our study was to determine the influence of microirrigation and organic fertilization on the vitality of white birch (*Betula pendula* Roth) seedlings and the occurrence of soil mites (Acari) after edaphon inoculation. Nursery experiments were carried out in 2003-05. It was found that the studied factors influenced seedling vigour, soil properties and the occurrence of mites.

Keywords: microirrigation, fertilization, birch, seedling vitality, soil mites

Introduction

It has been noted that birches (*Betula* spp.) are pioneer species that rapidly colonize bare areas [1]. Birches usually improve soils by efficiently cycling nutrients. First generation birch stands on former *Calluna vulgaris* (heather) heathland have increased earthworm activity, soil pH, total P, base status, rates of N mineralization and cellulose decomposition, and diversity of ground flora. Surface soil N, P, K, Ca, Mg and Mn are increased [2]. Because of this, birch can play an important role in afforestation of post-arable and devastated areas.

One-year-old seedlings of birch are usually produced in forest nurseries. In some cases, production of older and larger seedlings is also justified. Such seedlings are aimed for afforestation under especially difficult conditions, e.g. on post-arable grounds characterized by the strong weeding [3, 4].

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One of the most important cultural practices in forest nurseries is irrigation, which is mostly conducted using sprinklers. Recently, water-saving irrigation systems have been tested to improve water management in forest nurseries [5, 6].

To achieve maximum productivity, white birch requires all necessary nutrients [2]. High productivity in forest nurseries is achieved, among other methods, by supplying organic fertilizers, e.g. composts [7].

Edaphic (soil) conditions of numerous nurseries are in general far from those characteristic for forest soils. Forest seedlings are often grown without typical groups of edaphon, especially saprophages. It is well-known that soil organisms influence soil fertility [8]. Therefore, their introduction can be considered an important ameliorative measure. Introduction of edaphon with forest litter to the soils of nurseries can positively affect biological balance and effectiveness of seedling production.

The purpose of the study was to determine the influence of micro-irrigation (microjet sprinkling and drip irrigation) and organic fertilization on the vitality of white birch (*Betula pendula* Roth) seedlings in two (one-year and two-year) production cycles, as well as on the occurrence of soil mites (Acari) after edaphon inoculation.

Materials and Methods

Two nursery trials were conducted in 2003-05 at the Forest Nursery in Białe Błota, Forest District in Bydgoszcz. The first two-year experiment was carried out in 2003-04 (2 cycles of one-year old seedling production), and the second – in 2004-05 (2 cycles of two-year-old seedling production).

These experiments were run on a brown podzolic soil formed from a loose sandy soil, in a *split-plot* system with four replications. Two different factors were compared. The first row factor – irrigation, was applied in three treatments (main plots): without irrigation (control), drip irrigation, and micro-jet sprinkling. The second-row factor – fertilization, was used in two variants (subplots): mineral fertilization (standard applied in forest nurseries), organic fertilization (compost).

Seed origin and seeding density were similar to standard nursery practices [3]. White birch seeds were obtained from the seed stand of the Forest District in Bydgoszcz.

The plot area was 4 m^2 and contained 4 rows (4 m length) of white birch seedlings. The total number of plots in each experiment was 24 (3 x 2 x 4).

Organic fertilizer was produced from 80% of sewage sludge (pH 8.72; DM content 56%; N_{total} 6.5%, P_{total} 0.85%, Ca 1.6%, and Mg 4.0% of DM) and 20% of highmoor peat. This compost was spread in the spring (dose: 100 t · ha^{-1}) and mixed with the topsoil (10 cm deep) before establishing the field experiments. Introduction of edaphon consisted of mixing topsoil (2 cm deep) with organic matter obtained from the surface of fresh coniferous forest after partial cutting. This substrate contained an abundant living soil mesofauna. The introduction was conducted directly before sowing every year.

Mineral fertilization applied in the standard nursery treatment [7] was as follows: 70 kg N · ha^{-1}, 70 kg P · ha^{-1}, 80 kg K · ha^{-1} and 4 kg Mg · ha^{-1}.

Drip irrigation was applied using 'T-Tape' drip lines (in-line emitters spaced 20 cm apart). Microjet sprinkling irrigation was done with the use of 'Hadar' micro-jets. Terms of irrigation and water rates were established according to 'Directives for irrigation of forest nurseries on bare areas' [6].

Soil Analyses

The experiment was carried out on a Cambic Arenosol [9] formed on fluvioglacial sand characterized by the following soil pedon: Ap-AB-BC-C. Soil samples were taken from the 0-15 cm surface layer of all experimental plots. Soils were air-dried at room temperature and passed through a 1 mm sieve.

The following physico-chemical and chemical properties were determined [10]:

- pH in water and in 1M KCl (1:2.5) was measured using a pH meter (model CPC-551 Elmetron);
- organic carbon (C_{org}) was determined by oxidizing the soil sample with a mixture of potassium dichromate and sulfuric acid, diluting the suspension with water and back titrating the excess dichromate with standardized ferrous sulfate solution (Tiurin method);
- total nitrogen (N_{total}) was determined by the Kjeldahl method;
- available potassium and phosphorus was determined by the Egner-Riehm method, by extraction of soil samples in solution of calcium lactate; P was determined by colorimetric method, with the use of UV-VIS spectrometer model Marcel Media, and K was determined by emission spectrometry method with the use of a Philips PU-9100X spectrometer;
- available magnesium was determined by the Schachtschabel method, by extraction of samples in solution of 0.0125 M $CaCl_2$, measurement of Mg content was determined by atomic absorption spectrometry, with the use of a Philips PU-9100X spectrometer;
- available microelements (zinc, copper, manganese) were determined by atomic absorption spectrometry, with the use of a Philips PU-9100X spectrometer, after their previous extraction from the soil samples in 1 M HCl;
- granulometric analysis was carried out according to the method of Bouyoucos in modification of Casagrande and Prószyński.

Growth Analyses

Plant growth was evaluated in late autumn. The height of seedlings (cm) and shoot diameter (mm) were measured.

Sampling and Observation of Soil Mites

To investigate the occurrence of mites, soil samples were taken twice a year (in May and October) in successive years. Samples of 17 cm^2 and 3 cm deep were taken from all plots in 3 replications (3 samples per plot). Mites were extracted during 7 days in high gradient Tullgren funnels. A total of 4353 mites (Acari) were identified to order, according to Hammen's systematics [11].

Statistical Evaluation

The data were statistically processed by analysis of variance [12]. The Fisher-Snedecor test was used to determine the significance of experimental factors, and the Tukey test was used to define significant differences between combinations. The data of mites were ln-transformed (x+1) prior to analyses [13].

Table 1. Air temperature, rainfall, water needs and water deficits in the vegetation period of white birch.

Year	Month						IV-IX
	IV	V	VI	VII	VIII	IX	
Air temperatures (t) (°C)							
2003	6.4	14.4	17.6	19.2	18.4	13.6	14.9
2004	7.5	11.3	14.7	16.4	17.9	12.7	13.4
2005	7.4	12.2	14.9	19.4	16.3	14.8	14.2
Mean for 2003-05	7.1	12.6	15.7	18.3	17.5	13.7	14.2
Rainfall (P) (mm)							
2003	13.3	12.1	34.3	88.8	17.8	11.2	177.5
2004	12.1	44.4	35.8	41.8	85.6	24.8	244.5
2005	23.8	69.5	30.7	40.2	20.9	17.9	203.0
Mean for 2003-05	16.4	42.0	33.6	56.9	41.4	18.0	208.3
Water needs (Et) of birch nursery according to Drupka method [5] (mm)							
2003	55	86	100	127	101	57	526
2004	53	76	87	108	96	55	475
2005	54	78	89	124	88	57	490
Mean for 2003-05	54	80	92	120	95	56	497
Water deficits (N = Et - P) in the vegetation period (mm)							
2003	41.7	73.9	65.7	38.2	83.2	45.8	348.5
2004	40.9	31.6	51.2	66.2	10.4	30.2	230.5
2005	30.2	8.5	58.3	83.8	67.1	39.1	287.0
Mean for 2003-05	37.6	38.0	58.4	62.7	53.6	38.4	288.7

Results and Discussion

Climatic Conditions, Water Needs and Irrigation

Mean air temperature during the vegetation period (April-September) in the study years was 14.2°C, ranging from 13.4°C to 14.9°C, in 2004 and 2003, respectively (Table 1). Mean monthly values of air temperature in 2003-05 varied from 7.1°C in April to 18.3°C in July.

Total rainfall from 1 April to 30 September, on average for 2003-05, amounted to 208.3 mm, ranging from 177.5 mm to 244.5 mm, in 2003 and 2004, respectively. Among the months of the vegetation period, July was characterized by the highest rainfall (56.9 mm), and April by the lowest (16.4 mm).

Water requirements of birch seedling nursery during the vegetation period (1 April – 30 September), determined as evapotranspiration (Et) according to Drupka method [6], amounted to 497 mm, ranging from 475 mm to 526 mm, in 2004 and 2003, respectively. Mean monthly amount of water needs varied from 54 mm in April to 120 mm in July.

Water deficits during the vegetation period (April-September), on average for 2003-05, amounted to 288.7 mm, ranging from 230.5 mm to 348.5 mm, in 2004 and 2003, respectively. Water deficits were noted in all months of the vegetation period. Among the months, June, July and August were characterized – on average for 2003-05 – by the highest water deficits (above 50 mm).

Seasonal irrigation rates were dependent on precipitation. The highest amounts of water were applied in the case of the one-year old seedling plantation in the vegetation period 2003 (Fig. 1). This year was characterized by highest air temperature, lowest amount of rainfall, and as a result – by highest water needs and water deficits.

Total amounts of water in drip irrigation and micro-jet sprinkling were higher in case of the one-year old seedling production cycle (2003-04) than those for the two-year old seedlings (years 2004-05) (Fig. 2). It can be explained by the different water requirements of the white birch seedlings during their first and the second growing seasons [6, 14, 15].

Soil Characteristics

Proper pH value of forest nurseries (acid or slightly acid) plays an important role in assimilability of nutrients by seedlings [16]. In our experiments the pH values were

Table 2. Soil characteristics under different irrigation and fertilization systems.

Soil characteristics	Treatments					
	Control		Drip		Microjet	
	MF	OF	MF	OF	MF	OF
pH H_2O	7.28	7.2	7.11	7.22	6.95	7.39
pH KCl	7.03	6.96	6.96	7	6.81	7.13
$C_{org.}$ %	1.24	2.04	1.11	1.86	1.25	1.69
N_{total} %	0.08	0.21	0.09	0.16	0.09	0.15
K_2O mg·100g^{-1}	4.31	3.84	4.11	2.69	3.56	2.5
P_2O_5 mg·100g^{-1}	3.19	2.3	3.22	2.17	3.56	2.15
Mg mg·100g^{-1}	2.51	1.16	1.86	1.15	2.35	1.26
Zn mg·kg^{-1}	0.44	0.27	0.41	0.25	0.54	0.32
Cu mg·kg^{-1}	0.19	0.23	0.31	0.11	0.26	0.13
Mn mg·kg^{-1}	24.17	21.3	25.2	18.3	22.5	16.2

MF, OF – without organic fertilization and with organic fertilization (compost), respectively.

neutral to alkaline (Table 2). Similar reactions were noted in our neighbouring nursery experiments on Scots pine seedlings, carried out simultaneously at the same forest nursery [17]. Optimal pH value for birch seedlings is estimated to be in the range 4.5-5.5 [18]. According to Perala and Alm [2] the pH optimum for *B. pendula* is between 4 and 5. In the treatments with organic fertilization it was found that the soil acidity increased more distinctly under micro-sprinkler irrigation than under drip irrigation, in comparison to plots without organic fertilization. Increase of pH due to organic fertilization is unfavourable for the birch seedlings.

The content of organic carbon (C_{org}) was higher on plots with organic fertilization than on plots without compost. The highest content was found on control plots (without irrigation). Irrigation decreased total C and N – probably because of decomposition.

To achieve maximum productivity, white birch requires all necessary nutrients, an optimum ratio of nitrogen NO_3^- and NH_4^+ sources in rhizosphere, and optimal total nutrient solution [18]. No major differences of total nitrogen were noted in the combinations without organic fertilization. Application of compost caused an increase of total nitrogen content on all three water treatments – control, drip and

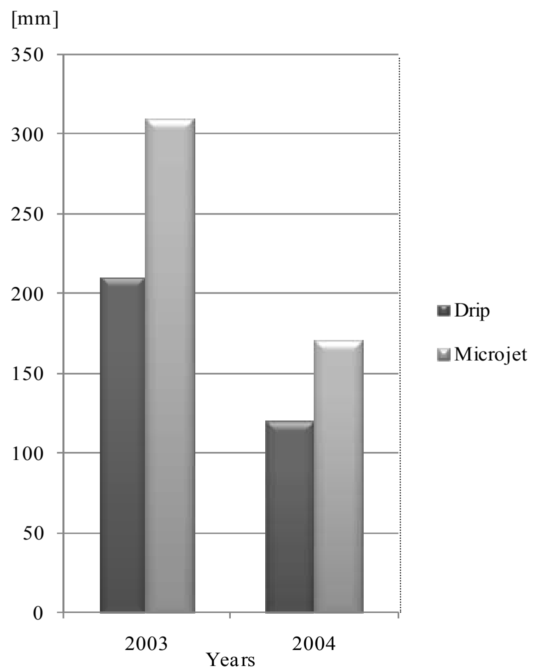

Fig. 1. Seasonal irrigation water rates for one-year-old seedlings.

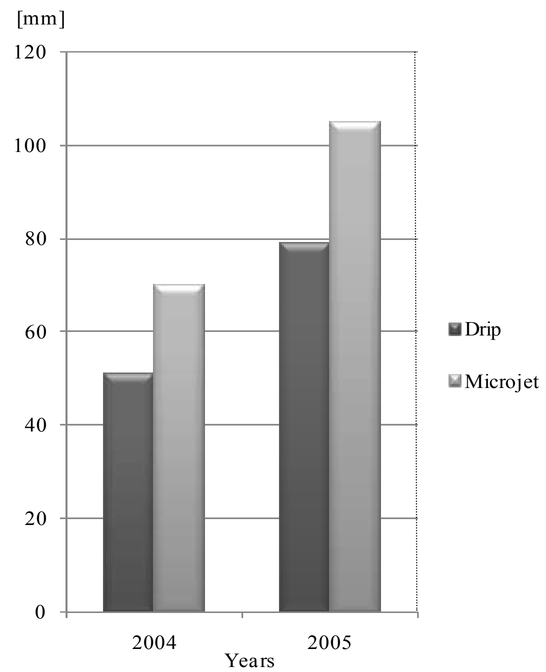

Fig. 2. Seasonal irrigation water rates for two-year-old seedlings.

Table 3. Influence of irrigation and fertilization on white birch seedling height and diameter.

Irrigation	Fertilization	One-year-old seedling*		Two-year-old seedling**	
		height (cm)	diameter (mm)	height (cm)	diameter (mm)
Control	MF	31.5	4.0	112.3	9.8
	OF	33.9	5.6	135.9	12.5
Drip	MF	55.4	6.7	127.5	11.1
	OF	80.3	9.1	173.1	14.5
Microjet	MF	61.7	7.3	130.1	14.7
	OF	85.0	10.0	175.5	16.3
Influence of irrigation (I)					
Control	-	32.6	4.8	124.1	11.1
Drip	-	67.8	7.9	150.3	12.8
Microjet	-	73.2	8.6	152.8	15.5
Influence of fertilization (II)					
-	MF	49.5	6.0	123.3	11.9
-	OF	66.4	8.2	161.5	14.4
$LSD_{0.05}$	(I)	3.617	0.753	12.574	1.725
	(II)	2.452	0.485	6.781	0.749
	(I) x (II)	4.789	0.973	15.102	1.932
	(II) x (I)	4.247	0.839	11.744	1.297

MF, OF – see Table 2.
*, ** - mean for 2003-04 and 2004-05, respectively.

microjet. On the other hand, N_{total} was higher on the control plots (without irrigation) fertilized with compost than those on the same treatments, but under irrigation.

The content of available K ranged from 2.5 to 4.31 mg $K_2O \cdot 100\ g^{-1}$. Irrigation decreased the K content independently of fertilization, from 4.31 and 3.84 mg $\cdot$ 100 g^{-1} to 4.11 and 2.69, and to 3.56 and 2.50 mg $\cdot$ 100 g^{-1}, for drip irrigation and microsprinkler irrigation, respectively (Table 2).

A similar tendency was noted in available P and Mg: lower concentrations of these nutrients were observed on all treatments with organic fertilization, as compared to those without compost, and – on the other hand – on plots with drip and microsprinkler irrigation, in comparison to the control plot (without irrigation).

At optimum levels, both zinc and manganese stimulate seedling growth [2]. The investigated soils were characterized by lower contents of Zn and Mn on plots fertilized with compost, as compared to those without organic fertilization. The same tendency – but only under irrigation – was noted also in Cu content.

Growth of Seedlings

To produce high-quality seedlings, the irrigation management should be optimized [19]. On the other hand, it should be noted that birches use water ineffectively [2]. Silver birch seedlings maintain turgor at high soil water potential only by closing stomata, which partially close at about – 15 x 102 kPa.

Irrigation significantly increased the height of one-year-old seedlings from 32.6 cm on control plots (without irrigation) to 67.8 and 73.2 cm, for drip irrigation and micro-jet sprinkling, respectively (Table 3). In the second growing season, irrigation significantly increased the height from 124.1 to 150.3 and 152.8 cm for drip irrigation and micro-jet sprinkling, respectively. One-year-old seedlings grown under micro-jet sprinkling were significantly higher than those on drip-irrigated plots, but there were no significant differences between seedlings irrigated with drip system and micro-jets during their second growing season, (although the sprinkled plants were slightly higher – by 2.5 cm – than those under drip irrigation). These results corroborate those of Klimek et al. [17] concerning the growth of Scots pine seedlings.

Irrigation significantly increased the diameter of seedlings during both growing seasons. Seedlings cultivated under micro-jet sprinkling were higher than those under drip irrigation, but a significant difference was detected only in the second growing season. Organic fertilization influenced significantly the growth of seedlings both in the first and in the second season. Seedlings fertilized with

Table 4. Abundance (10^3 individuals per m^2) of mites under different irrigation and fertilization systems.

Group of mites	Year	Treatments						I
		Control		Drip		Microjet		
		MF	OF	MF	OF	MF	OF	
Acaridida	I	0.18	0.03$^{(1)}$	-	-	0.03$^{(1)}$	-	0.017
	II	-	-	-	0.03	0.03	-	ns
	Mean	0.09	0.01$^{(1)}$	-	0.01	0.03$^{(1)}$	-	ns
Actinedida	I	2.06	1.20	2.06	2.43	3.24	1.51	ns
	II	1.45	1.35	2.11	2.38$^{(1)}$	3.36$^{(1)}$	4.59$^{(12)}$	<0.001
	Mean	1.76	1.28	2.08	2.41	3.30$^{(1)}$	3.05$^{(1)}$	<0.001
Gamasida	I	0.65	0.53	0.53	0.43	0.40	0.68	ns
	II	0.30	0.10	0.28	0.30	0.73	0.33	ns
	Mean	0.48	0.31	0.40	0.36	0.56	0.50	ns
Oribatida	I	2.83	2.08	3.96	1.61$^{(1)}$	3.86	6.52	0.042
	II	3.16	4.69	7.98$^{(12)}$	8.40$^{(12)}$	12.01$^{(12)}$	8.45$^{(1)}$	<0.001
	Mean	3.00	3.39	5.97$^{(1)}$	5.00	7.94$^{(1)}$	7.49$^{(1)}$	<0.001
Tarsonemida	I	0.13	-	0.13	0.13	0.20	0.63	ns
	II	-	-	0.10	0.20	0.10	0.10$^{(2)}$	0.034
	Mean	0.06	-	0.11	0.16	0.15	0.36$^{(1)}$	0.014
Acari total	I	5.84	3.84	6.67	4.59	7.73	9.33	0.025
	II	4.92	6.15	10.46$^{(12)}$	11.31$^{(12)}$	16.23$^{(12)}$	13.47$^{(1)}$	<0.001
	Mean	5.38	4.99	8.57	7.95	11.98$^{(1)}$	11.40$^{(1)}$	<0.001

MF, OF – see Table 2;
$^{(1)}$ – significant between control plot MF and variant at $p < 0.05$;
$^{(2)}$ – significant between I and II year, $p < 0.05$;
I – irrigation effect (p).

compost were higher than those in the control treatments (plots fertilized with mineral fertilizers only) by 16.9 cm and 38.2 cm, mean for the first and the second growing seasons, respectively.

White birch seedlings cultivated in treatments with organic fertilization had significantly increased diameter as compared to the control (with mineral fertilization only). The differences were 1.2 mm and 2.5 mm for one-year-old and two-year-old seedlings, respectively.

Seedlings grown in treatments with organic fertilization under irrigation, were characterized by increased height and diameter in comparison to those cultivated without irrigation (significant interaction between irrigation and organic fertilization). Similar results were obtained in the experiment on Scots pine seedlings [17].

Occurrence of Mites

Forest soil is usually characterized by a very abundant population of Acari. For example, in 26-year-old Scots pine forest the density of mites was 71,400-112,000 individuals per m^2 and in birch forest 99,300-133,500 individuals per m^2 [20]. The density of mites in the irrigated (sprinkler irrigation) traditional nursery was distinctly lower – 4,053 individuals · m^{-2} in two-year old white birch stands [21], which was twice as high as in the Scots pine plantation [22].

The density of mites in the experiment on Scots pine seedlings, which was simultaneously carried out, ranged from 2,090 to 12,870 individuals per m^2 [17]. In this study, the density of Acari was rather similar, from 4,990 to 11,990 individuals per m^2 (Table 4).

The density of mites was significantly influenced by irrigation only. Especially high average densities were noted on plots irrigated with micro-jets. In the first year of the experiment, differences between control (MF) and organic fertilizer were not significant. It should be noted that in the second year the density on irrigated plots was distinctly increased as compared to the first year. In the second year the differences between control and irrigation were significant.

Oribatid mites were the predominant order of mites – 64.7% of all Acari. For comparison, in Scots pine cultivation the predominant order of soil mites was Actinedida [17] that ranged from 16 to 53% of Acari, depending on treatment (variant). Predacious Gamasida were less numerous – 6% of Acari. Two other groups of mites, Acaridida and Tarsonemida, occurred sporadically.

The density of oribatid mites in the first year ranged from 1,610 to 6,520 per m^2, depending on treatment. In the second year the density increased distinctly. Especially high densities were noted on irrigated plots – 7,980-12,010 individuals per m^2. Irrigation was a factor influencing the density of oribatids. In a traditional forest nursery, without edaphon inoculation, the density of oribatids in irrigated cultivation of two-year-old birch was scarcely 620 individuals per m^2 [21]. On the contrary, in two-year-old Scots pine seedling cultivation [17], after similar treatment of edaphon inoculation on irrigated plots, the density of Oribatida was distinctly lower (3,290-6,350 individuals per m^2) than that in birch cultivation.

The relatively high density of oribatid mites in cultivation of birch, as compared to that of Scots pine, can be a result of edaphon inoculation as well as ecological conditions connected with rapid growth and manifold larger size of seedlings. Large seedlings shelter the soil and counteract overdrying of the surface soil layer, which can be harmful for soil fauna, especially for oribatid mites that are sensitive to drought [23]. In addition, birch seedlings already in the first year supply considerable amounts of organic matter (leaf litter), thus improving feeding conditions for saprophages.

In the first year of study, oribatid mites composed on average 53% of all mites. In the second year they composed 71% of all Acari. This percentage of Oribatida is characteristic for forest soils [24]. Soil saprophages are recognized as good bioindicators [25, 26]. Saprophage Oribatida mites are regarded as useful indicators of the degree of decomposition and biological properties of forest humus [27] as well as different sorts of industrial pollution [24].

Edaphon has a great influence on soil fertility because soil animals take part in decomposition of organic matter. Lack of soil fauna and also its low density or diversity of species, especially in forest soils, can exert a negative influence on soil-forming processes and functioning of whole ecosystems. It was confirmed in laboratory tests and in bare areas the with use of the litterbag method [8, 28].

It is known that long-lasting and intensive use of forest nurseries can decrease soil biodiversity, including ectomycorrhizal fungi [29], and it can cause the degradation of soils. On the basis of acarological studies, it has been concluded that after edaphon inoculation, especially in connection with irrigation, the biological condition of nursery soil was distinctly improved. It seems that edaphon inoculation connected with irrigation may be regarded as successful, especially in birch cultivation.

Conclusions

1. Studied irrigation systems significantly increased the height and diameter of white birch seedlings. Seedlings grown under micro-jet sprinkling were significantly higher than those under drip irrigation.
2. Fertilization of white birch seedlings with compost significantly increased the height and diameter of seedlings.
3. Interaction of irrigation with organic fertilization occurred. Irrigated white birch seedlings grown on plots fertilized with compost were characterized by increased height and diameter as compared to those cultivated under irrigation, but without organic fertilization.
4. Oribatid mites were the predominant order of mites – 64.7% of all Acari.
5. Irrigation increased the density of oribatid mites, especially in the second year of the study.

Acknowledgements

The authors gratefully acknowledge the considerable help provided by Białe Błota Forest Nursery and the forest inspectorate in Bydgoszcz, as well as 'Agromis' – Rafał Piasecki in these trials.

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