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INFLUENCE OF FERTILIZATION METHODS ON THE GROWTH OF NORWAY SPRUCE (*PICEA ABIES* (L.) KARST.) SEEDLINGS IN A FOREST NURSERY

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Abstract. The essence of conducting a forest nursery production is high quality planting material. Its essential element is rational fertilization of plants grown and conscious use of available methods and fertilizer application. Studies on the effects of fertilization on the growth of Norway spruce (*Picea abies* (L.) Karst.) can be used by foresters to properly choose the fertilizer needed to achieve the target of production. In the research foliar fertilization was applied, by the following means: "EM Naturally Active" (EM Naturalnie Aktywny – Greenland EM Technology) – liquid organic fertilizer with soil microorganisms, "Bioekor for conifers and ericaceous plants" (Bioekor dla iglaków i roślin wrzosowatych) – mineral foliar fertilizer in the form of a liquid concentrate trace elements and natural growth substances, "Ekolist standard" mineral foliar fertilizer in the form of a liquid concentrate. The study was conducted in 2009-2010 in the forest nursery situated in the Forest District Spychowo. Spruce seedlings transplanting was used. Experiments consisted of four objects repeated in four blocks. The fertilization was performed six times – 2009, and four – 2010. The measurements were performed three times. Annual growth of seedlings taken, from height of measurement was calculated. Analysis of the results obtained, did not show statistically significant differences for any of the applied methods of fertilization.

Key words: fertilization, seedlings, Norway spruce, effective microorganism, forest nurseries

INTRODUCTION

The Polish forest nursery tradition dates back to the interwar period. The first attempts were addressed only to the production of seedlings of Scots pine, and the nursery sheltered nature of plots under trees [Broda 1988]. Connecting element between the first

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attempts by forest seedlings from the interwar period to the present model of forest nursery is an indispensable need of planting fertilization produced. The main tasks of fertilization are the wealth and control of soil humus [Barzdajn 1993]. Additional activities are change both chemical and physical properties of soils, consequently affecting the status and living conditions of rhizosphere edaphone [Urbański 1999]. In selecting the right fertilizer for the needs of the plants used in the current (annual) soil analysis and scientific advice on the requirements of individual species of forest trees on annual uptake of nutrients [Szołtyk 2003].

In Japan, where agriculture is developed, soil fertilization technology with effective microorganisms (EM) [Higa 1991] is used. EM consists of mixed cultures of beneficial and naturally-occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plants. Research has shown that the inoculation of EM cultures to the soil/plant ecosystem can improve soil quality, and health, and growth, yield, and quality of crops. EM contains selected species of microorganisms including predominant populations of lactic acid bacteria and yeasts, and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms [Higa and Parr 1994]. Producers of EM confection claim that their use allows for the resignation of fertilization.

In forest nurseries essential source of soil nutrients is mineral fertilization with organic fertilizer applied periodically. Nursery intensive production, in addition to the above-mentioned fertilization, requires supplementary foliar fertilization [Wesoły and Hauke 2009].

The purpose of this paper is an attempt to answer the question whether EM fertilizer application is better than other, chosen, forms of foliar fertilization.

METHODS

The experiment was located in the nursery Piasutno, close to the Nożyce Lake, Forest District Spychowo (Forest Inspectorate Olsztyn). The forest nursery was established in the forest land in 1978. Soil in the forest nursery is described as brownish rusty soil on week loamy sand, site type fresh mixed coniferous forest and fresh mixed forest. The characteristic feature in the western region of Mazury is quite frequent occurrence of moderately warm days with high cloud cover and precipitation. The proximity of the lake affects more air relative humidity. Basic characteristics of the climate are as follows: average annual rainfall 611 mm, the mean annual air temperature 6.5°C, and the length of the growing period oscillates between 180-195 days.

The material used in the experiment are spruce seedlings, with production symbol 1/1 and 1/2. This species were chosen because of its their production in recent years in the nursery Piasutno.

In the spring of 2008, the seeds were sown in the nursery Mrągowo Forest District (Forest Inspectorate Olsztyn). Broadcast sowing into trough was used. After a year production, the seedlings were transported in special boxes to the nursery Piasutno intended for further culture of bare root system. The aim was to produce spruce seedlings of symbols 1/2 in 2011, and 1/3 in 2012. Transplantings were made in April 27, 2009.

Soil conditions at the place of transplanting were as follows:

- weakly acidic soils of pH 5.6
- assimilable form in mg/100 g soil: P_2O_5 – 18.8, K_2O – 4.5, Mg – 2.5

– N as % of total – 0.220
– C organic in % – 3.48
– ratio C:N – 16:1.

The designation sowing bend and the division into blocks and objects was made at the beginning of June 2009, then the first measurement was taken.

The experiment used four objects: foliar fertilization and control object, in a randomized complete block designs. The experiment was repeated four times. All fertilizers were prepared according to the instructions for use provided by the manufacturer on the packaging of concentrates.

All the objects were the same size. Each of the four blocks had a length of 162 meters and an area of 246 m^2. Each of the objects, which was 27 meters in length, had an area of 41 m^2. The following fertilizers were used:

1. "EM Naturally Active" (EM Naturalnie Aktywny, Greenland EM Technology) – liquid organic fertilizer with soil microorganisms (contains nitrogen in organic forms, and concentrated dose of Effective Microorganisms™ and Azotobacter). The experiment used 10% solution.
2. "Bioekor for conifers and ericaceous plants" (Bioekor dla iglaków i roślin wrzosowatych) – mineral foliar fertilizer in the form of a liquid concentrate (nitrogen (N) – 4.3%, phosphorus (P_2O_5) – 1.46%, potassium (K_2O) – 2.9%, trace elements and natural growth substances, carbohydrates, amino acids and simple proteins which prolong the effect of the fertilizer). In the experiment 1% solution was used.
3. "Ekolist standard" mineral foliar fertilizer in the form of a liquid concentrate (nitrogen (N) – 10%, potassium (K_2O) – 6%, magnesium oxide (MgO) – 2.7%). Organic fertilizer for use on the surface of the sowing bend. In the experiment 1% solution was used.
4. Control object, which did not use any fertilizer throughout the period of the research.

In 2009, the fertilization was performed six, in 2010, four times. The measurements were performed three times (VI, VII 2009; X 2010), on chosen characteristics of plants in each objects. All seedlings were measured in the third and fourth row sowing bend. Annual growth of seedlings was calculated, from height measurement.

The obtained measurement results were analysed statistically, using two-way analysis of variance without repetition. The results are presented in a table and graphic forms as standardized deviations from the mean for the experiment.

RESULTS

Statistical analysis, for each of the analysed parameters in two periods of measurement are shown in Tables 1-4. In none of the cases, statistically significant differences of the analysed traits have been proved.

No proved statistically significant differences of the compared objects gave the grounds for further statistical analysis. To illustrate the results of the experiment, diversity of individual objects are presented in units of standardized features for each of the three measurement periods (Fig. 1-2). In the case of height, the fertilized Ekolist it is worth mentioning that in all periods of measurement, the products scored above average experience. However, other objects showned the results below average. The second feature that was observed during seedling growth, over the period concerned the fact that there was no such an obvious trend as in the case of height.

Table 1. Analysis of variance of height of the second measurement
Tabela 1. Analiza wariancji wysokości drugiego pomiaru

Source of variance Źródło wariancji	*SS*	*df*	*MS*	*F*	Value-*p* Wartość *p*	Test *F*
Variants Obiekty	9.079069	3	3.026356	0.919106	0.46988	3.862548
Blocks Bloki	6.987819	3	2.329273	0.707401	0.571404	3.862548
Error Błąd	29.63446	9	3.292717			
Together Razem	45.70134	15				

Table 2. Analysis of variance of height increase for the second measurement
Tabela 2. Analiza wariancji przyrostu wysokości dla drugiego pomiaru

Source of variance Źródło wariancji	*SS*	*df*	*MS*	*F*	Value-*p* Wartość *p*	Test *F*
Variants Obiekty	2.783319	3	0.927773	1.542587	0.269655	3.862548
Blocks Bloki	5.896719	3	1.965573	3.268114	0.073127	3.862548
Error Błąd	5.412956	9	0.60144			
Together Razem	14.09299	15				

Table 3. Analysis of variance of height of the third measurement
Tabela 3. Analiza wariancji wysokości trzeciego pomiaru

Source of variance Źródło wariancji	*SS*	*df*	*MS*	*F*	Value-*p* Wartość *p*	Test *F*
Variants Obiekty	9.634869	3	3.211623	1.018675	0.428913	3.862548
Blocks Bloki	17.07692	3	5.692306	1.805508	0.216208	3.862548
Error Błąd	28.37471	9	3.152745			
Together Razem	55.08649	15				

Table 4. Analysis of variance of height increase for the third measurement
Tabela 4. Analiza wariancji przyrostu wysokości dla trzeciego pomiaru

Source of variance Źródło wariancji	*SS*	*df*	*MS*	*F*	Value-*p* Wartość *p*	Test *F*
Variants Obiekty	0.0757	3	0.025233	0.085917	0.966003	3.862548
Blocks Bloki	15.12545	3	5.041817	17.16688	0.000458	3.862548
Error Błąd	2.64325	9	0.293694			
Together Razem	17.8444	15				

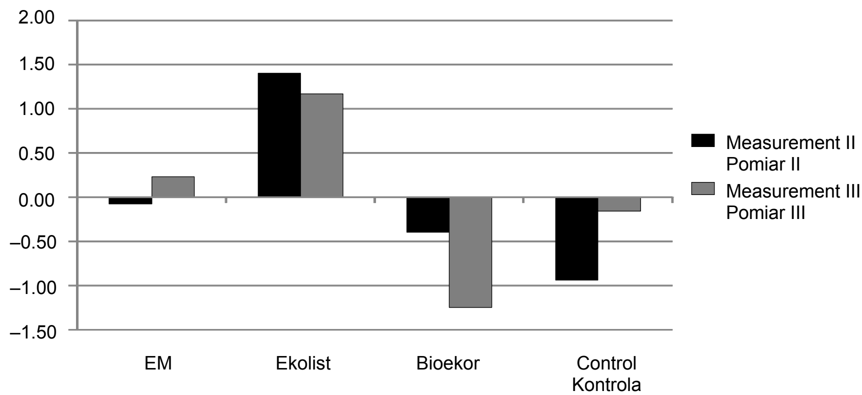

Fig. 1. Height of plants in standard deviation degrees
Rys. 1. Wysokość sadzonek w stopniach odchylenia standardowego

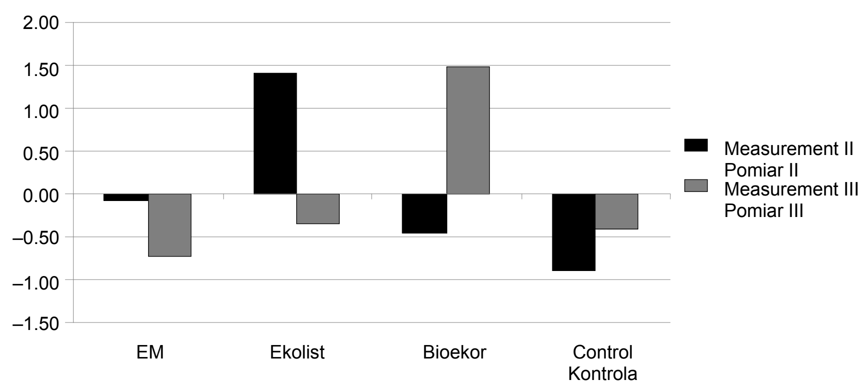

Fig. 2. Growth stages of seedlings in the standard deviation degrees
Rys. 2. Przyrost sadzonek w stopniach odchylenia standardowego

Only in the case of Ekolist fertilization the first measurement shows analogy, which result is also well above the average. The results obtained point to other objects of decreasing the growth of seedlings in each of the following measurements.

SUMMARY OF RESULTS

Most nutrients, are taken by plants via root system, providing the soil, enables normal plants growth. In nurseries significant losses of soil nutrients occur, mainly by removing the plants with roots, on which are located molecules of soil. For this reason, there is a need for soil fertilization, spring fertilization. Irrespective of mineral fertilization soil application, in many cases, there is a need for supplementary foliar fertilization. The best form of foliar fertilization of seedlings in the nursery, is the use of fertilizers with low nitrogen content [Wesoły and Hauke 2009].

The conducted two-year study on the effects of fertilizer spruce (*Picea abies* (L.) Karst.) plants in nursery conditions indicates that the selected fertilizers have similar effects on height growth and the number of plants, and differences between the applied fertilizers are not statistically significant at the production nursery of the species. Seedlings treated with Ekolist fertilizer were characterized by the highest growth, which influenced a higher content of nitrogen and other trace elements as compared to Bioekor. In the case of EM Naturally Active fertilizer we were unable to obtain information from the distributor of nitrogen concentration and the number of bacteria of the Azotobacter. Regardless of the fertilizer, the characteristics of spruce seedlings were very low-diversed. Unsatisfactory results were obtained for fertilizer EM Naturally Active. Numerous scientific publications [eg. Allahverdiyev et al. 2011, Javaid 2006] and business distributing informational materials EM preparations indicate a positive impact on the growth and vigor of the plants. The opposite conclusion was reached [Chen and Cheng 2013], EM application did not show significant effect on the growth of cherry (*Prunus campanulata* Maxim) seedlings.

The composition of the growth medium played the most significant role affecting the seedling growth. Soil conditions at transplanting area (C:N ratio – 16:1) indicate a high level of organic matter. Khaliq et al. [2006] in their study indicated that application of EM increased the efficiency of both organic and mineral nutrient sources. Moreover, EM can influence soil productivity when applied with NPK but less than with green manure and manure [Hussain et al. 1999].

In the literature, there are no publications on the treatment of EM tree seedlings in the bare root nursery. Therefore, it is difficult to compare our results. Khan et al. [2011] analysing the 3-month growth of *Dalbergia sissoo* seedlings, treated 2-times with different concentrations (0.1-10%) EM. At concentrations of 0.1%, 0.5%, 10%, and control there were no statistically significant differences between the variants in the analysis of the dry weight of shoots and roots. Similar concentrations of 10% EM were obtained in this experiment. Perhaps, for seedlings of woody plants, EM concentration of 10% is too high.

CONCLUSIONS

1. No statistically significant differences were proved between the influence of the type of fertilization. It does not allow to build a clear answer whether the use of effective microorganisms fertilizer is more beneficial than other forms of fertilization.

2. The results may give a more complete illustration of the impact of fertilization by their further verification in the form of research on the cultivation of spruce growth and subsequent development phases.

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WPŁYW RÓŻNYCH SPOSOBÓW NAWOŻENIA NA WZROST SADZONEK ŚWIERKA POSPOLITEGO (*PICEA ABIES* (L.) KARST.) W WARUNKACH SZKÓŁKI LEŚNEJ

Streszczenie. Istotą prowadzenia leśnego gospodarstwa szkółkarskiego jest produkcja wysokiej jakości materiału sadzeniowego, który zapewni ciągłość przemianie pokoleniowej w lasach. Nieodzownym jego elementem jest racjonalne nawożenie hodowanych roślin oraz świadome wykorzystanie dostępnych metod aplikacji i nawozów. Badania nad wpływem nawożenia na wzrost świerka pospolitego (*Picea abies* (L.) Karst.) mogą posłużyć praktykom szkółkarzom w odpowiednim doborze nawozów niezbędnych do osiągnięcia celu produkcyjnego. W doświadczeniu zastosowano następujące nawozy: „EM Naturalnie Aktywny" (Greenland Technologia EM) – płynny nawóz organiczny z mikroorganizmami glebowymi (zawiera azot w formach organicznych oraz skoncentrowaną dawkę Efektywnych Mikroorganizmów^{TM} i Azotobakter), „Bioekor dla iglaków i roślin wrzosowatych" – mineralny nawóz dolistny w formie płynnego koncentratu oraz „Ekolist Standard" – mineralny nawóz dolistny w formie koncentratu płynnego. Badania przeprowadzono w latach 2009-2010 w szkółce leśnej Nadleśnictwa Spychowo. Obiektem badań były szkółkowane sadzonki świerka pospolitego. Doświadczenie założono w układzie doświadczalnym bloków losowych kompletnych. Składało się ono z czterech obiektów (trzy nawozy i obiekt kontrolny) powtórzonych w czterech blokach. W trakcie badań wykonano trzykrotny pomiar wysokości sadzonek, a do analiz wykorzystano także wynikający z tych pomiarów przyrost wysokości. Analiza uzyskanych wyników, zarówno wysokości, jak i przyrostu wysokości, nie wykazała istotnych statystycznie różnic dla każdego z zastosowanych sposobów nawożenia.

Słowa kluczowe: nawożenie, sadzonki, świerk pospolity, efektywne mikroorganizmy, szkółkarstwo leśne

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