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Possibility of using organic fertilization to grow pine plantations on former agricultural lands

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Abstract

In accordance with the National Program for Increasing Forest Cover it is planned to augment Poland's forest cover to 30% by 2020. This task involves afforestation of agricultural lands by pioneer species that have low habitat requirements, such as the silver birch or the Scots pine. Application of sawdust, clear cutting residues, compost bark and compost beneath tree roots contributed to better development of the assimilation apparatus. The use of mineral fertilizer stimulated tree growth as well as improved physical and chemical properties of soil.

Key words

Pinus sylvestris, organic remnants, transformation of soil, post-agricultural land

Introduction

The area of abandoned land in Poland used previously for agricultural production has been expanding over the last years. The land undergoes secondary succession with domineering pioneer tree species such as the Scots pine (*Pinus silvestris*) or the silver birch (*Betula pendula*) (Bernadzki, Kowalski 1982; Bernadzki, Kowalski 1983a). At the same time, following the National Program for Increasing Forest Cover fast-growing tree species are introduced onto abandoned agricultural lands. The goal of the Program (NPFIFC 2003) is to further augment existing forest area in Poland – 29.2% (CILP 2012) in order to reach 30% by the year 2020 (average forest area in Europe is 31.1%) and then to 33% by the year 2050 (world's average). Enlargement of the forest cover area will be mainly based on afforestation of former agricultural lands.

Former agricultural lands intended for afforestation are in the main covered with deep loose sand or slightly loamy sand. There occur less frequently gravel or clay soils. Fertility of these soils is characteristic of dry or fresh forest site types, and sometimes – of mixed forest. In general, post-agricultural soils are not suitable for agricultural production being barren due to long-term cultivation. The soils have insufficient content of nutrients, in particular – potassium and nitrogen, and at times – phosphorus and magnesium (Strzelecki, Sobczak 1972; Bernadzki, Kowalski 1983b). An additional undesirable feature is considerable soil compaction be-

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low a ploughing level. The latter results from former using heavy agricultural equipment as well building-up large amounts of sparingly soluble mineral compounds, which leached down from the outer soil layer. In consequence, deep growth of roots can be gradually more hindered, which in turn can contribute to impaired resistance of trees to the root rot?

This paper is an attempt to develop preventive activities aimed at triggering in former agricultural soils natural soil processes typical of forest soils (Oszako, Olejarski 2003). Research hypothesis was that adding organic material such as sawdust, clear cutting residues, bark compost and compost to the soil beneath tree roots on former agricultural land would improve soil physical and chemical properties. The aim of the study was to evaluate the effect of organic materials on enhancing development of pine plantations on former agricultural lands.

Material and methods

Description of experimental plots

The experiments were carried out on experimental plots in the Forest District Bielsk, which were set up on a former agricultural land (not used for cultivation before), with strongly acidic soil reaction (pH in KCI – 4.01). The area of each plot was 2 acres (10 m × 20 m). In 2001 (after soil was prepared for autumn), 1.5 m^3 of clear cutting residues (PZ), bark compost (Kk), sawdust (T) and compost for applying beneath tree roots (P) were scattered in lines on every acre of experimental plots (Oszako, Olejarski 2003) described in figure 1. The material came from pine cutting that took place in 2000. In the present study, the analysis focused on the growth of trees within the pine plantation 10 years later.

T-1	Pz-1	Kk-1	P-1	K-1
Pz-2	T-2	P-2	K-2	Kk-2

Fig. 1. Experimental pattern of plots and treatment codes: T – sawdust, Pz – clear cutting residues Kk-compost, bark, P – compost beneath roots, K – control

In the spring 2002, all the plots were planted with 7 lines of one-year-old Scots pine seedlings, with 25 trees in each line. The seedlings came from a local tree nursery. Nine years later measurements of annual height growth and 50 pairs of one-year old and 50 pairs of two-year old needles from 10 trees for each variant of the experiment were performed. The analysis concerned one- and two-year-old needles which were measured to know their length and after that were dried at 65°C to the moment when weight were constant (dry biomass).

In addition, 9 samples of mineral soil were taken from each experimental plot (from the ground level to 20 cm depth) with the use of metal cylinders with 100 cm^3 capacity. The soil samples were weighed before and after drying in order to obtain actual soil moisture and to determine soil density.

The data obtained was processed for statistic purposes. To compare the plots, the use was made of Kruskal-Wallis non-parametric ANOVA test. Statistical analyses were conducted with Statistica software v.10..

Results

Analysis of vitality of trees based on measurements of needle-cover

To determine pine tree vitality 50 pairs of needles were weighed. The highest average value was obtained on the plot treated with bark compost (Kk-2). The needles collected from this plot had the highest average weight – 7.3 g, whereas the lowest weight was identified on control plots (K-2). P-value was 0.000, which is indicative of statistically significant differences among the treatments. Having conducted an additional post-hoc analysis it was demonstrated that statistically significant differences were observed for the plots on which bark compost (Kk-2) and clear cutting residues (Pz-1) were applied as well as for the control area (K-2). The values of needle weight for the first two treatments are much higher than the other ones, whereas the weights determined on the plot K-2 were the lowest (fig. 2).

The weight of pine needles collected in 2011 turned out to be lower than that of pine needles collected in the year before. As it was the case last year, the heaviest needles were identified in the treatment with bark compost (Kk-1). Average needle weight on this plot was higher than that on the control plot (K). The lowest weight was identified for the needles collected from sawdust treatment (T-1). The post-hoc analyses proved that only the weights of the material obtained from bark compost treatment (Kk-1) significantly differed from the remaining experimental variants (fig. 3).

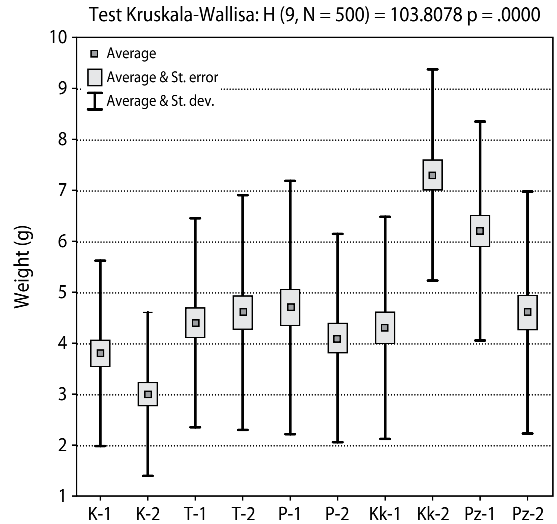

Fig. 2. Pine needle weight after treatment with organic material (in 2010)

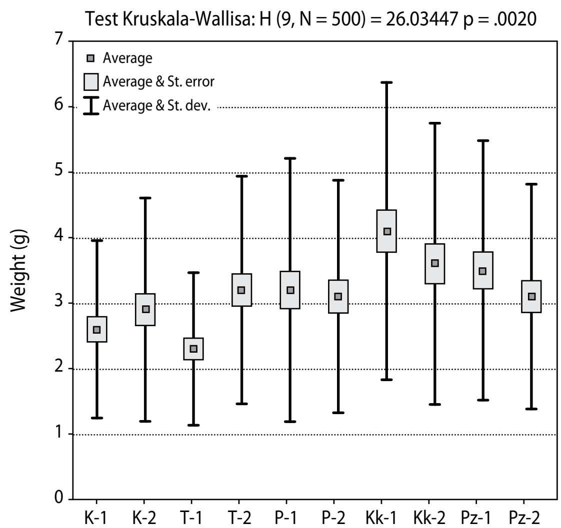

Fig. 3. Needle dry weight in Scots pine treated with organic material (needles collected in 2011)

The longest two-year-old pine needles collected in 2010 came from the plot fertilized with sawdust (T-1). Average needle length was 8.1 cm. In the control, average length was: 5.9 cm for K-1 and 5.3 cm for K-2 8.1, out of which the latter was the smallest when compared to all the treatments analyzed. The post-hoc analyses revealed that statistically significant larger needle average lengths were observed for T-1 sawdust treatment, bark compost (Kk-2) and clear cutting residues (Pz-1) ($P < 0.05$) (fig. 4).

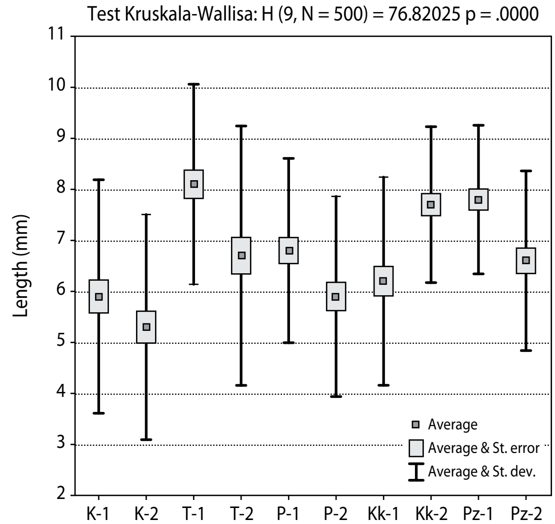

Fig. 4. Average needle length in Scots pine treated with organic material (collected in 2010)

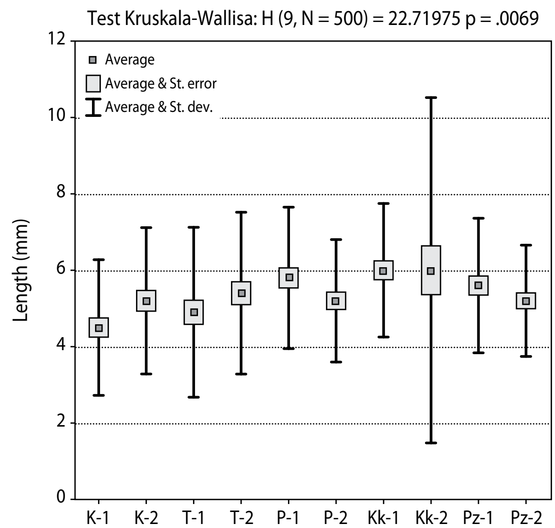

Fig. 5. Average needle length of needles in Scots pine treated with organic material (collected in 2011)

As for needle biomass, it was shown that needles collected in 2011 were shorter than those collected in the year before. The longest needles were collected on Kk-2 and Kk-1 (bark compost) plots. Average length of needles collected on these plots was 6 cm. The shortest needles were found on K-1 plot (control variant). Statistically significant larger average length of the needles was observed on the plots where bark compost and clear cutting residues were applied P < 0.05 (fig. 5).

Analysis of soil samples

The density of soil in the samples varied (fig. 6). The highest value (1.38 g/cm^3) was observed on the plot treated with compost beneath roots (P-2). The lowest value of soil density was identified in soil samples from the plots with bark compost (Kk) and clear cutting residues (PZ-1).

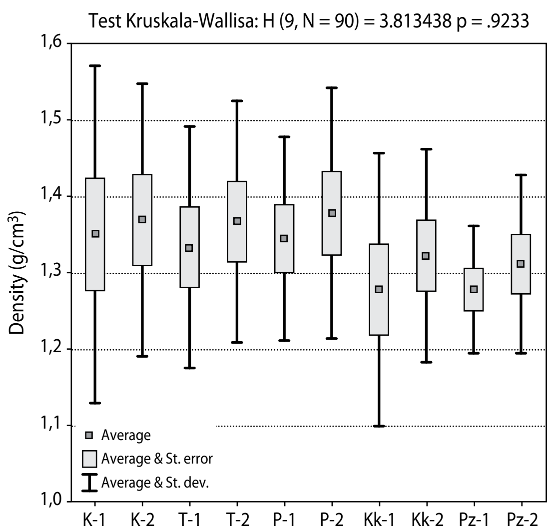

Fig. 6. The density of soil after treatment with organic material [g/cm^3]

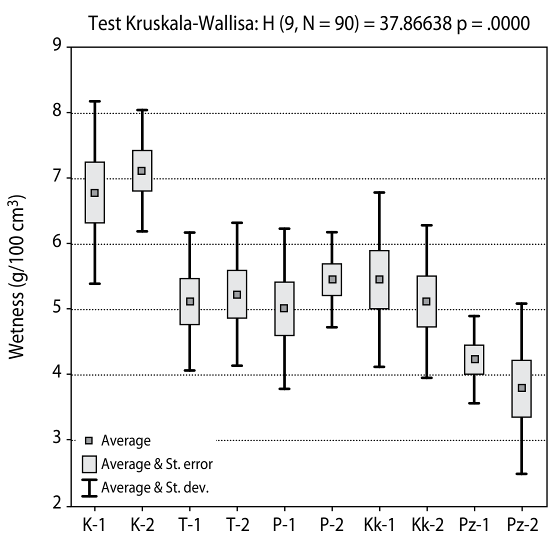

Fig. 7. Actual soil moisture [g/100 cm^3] after treatment with organic material

The values obtained amounted to 1.28 g/cm^3 in each case. The analysis using Kruskal – Wallis ANOVA test did not reveal significant statistical differences of the density of soil on respective experimental plots (P = 0.9233).

The highest soil moisture was observed on K-2, K-1 control plots (fig. 7). The value exceeded 6 g/100 cm^3, whereas the highest value was 7.2 g/100 cm^3 (control). The lowest soil moisture (3.8 g/100 cm^3) was observed on the plot with clear cutting residues (Pz-2). Significant statistical differences were found in control plots on which soil moisture was the highest as compared to variants in which e.g. clear cutting residues were applied P < 0.05.

Evaluation of height growth in years 2003–2011

The utmost growth was observed in trees growing on plots fertilized with compost (fig. 8), and next – in those treated with clear cutting residues and sawdust. When the trees analyzed were planted in 2003, their height was almost the same. However, 10 years later, significant differences of their height were found depending on the treatment applied. The trees on the plots fertilized with organic material grew faster than those on the control plots. The differences intensified with time, reaching even 72% in 2011 as in the case of the experimental variant treated with bark compost beneath roots. Good results in this regard were also achieved for treatments with clear cutting residues and sawdust, with differences at a level 61% and 54%, respectively.

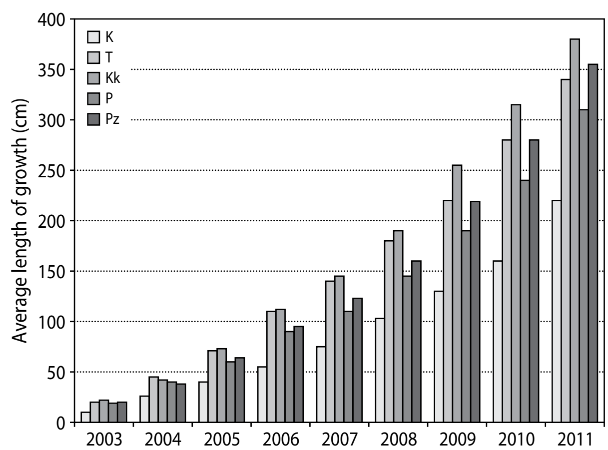

Fig. 8. Average length of growth [cm].of trees in the years 2003–2011

Discussion

In the plantations observed, soil features are significantly different from those in forest sites, therefore trees are often infected by the parasitic fungus *Heterobasidion annosum* (Fr.) Bref, which causes dieback of whole stands on post-agricultural lands. For that reason, it is important that the trees are in the best condition of health to be able to resist the disease. Better growth of Scots pine plantations on post-agricultural lands protect them against root and butt rot disease.

The analyses conducted revealed that trees developed significantly better (both in terms of annual height growth and biometric properties of needles) on the areas fertilized with organic materials. Out of 4 tested organic substances (sawdust, clear cutting residues, bark compost, compost beneath roots), the experimental variant fertilized with bark compost produced the best results in almost every case (the highest average values of analyzed parameters). Pines growing on plots had the highest increment of needle biomass and the highest increment of the length. Added bark compost did not improve significantly physical soil properties (in terms of moisture and density). The best effects with regard to soil density were achieved by applying compost directly beneath roots. As compared to the control, soil moisture was lower on every plot on which organic substances were applied. The improvement of tree vitality and physical soil properties plays a very important role in preventing the spread *Heterobasidion annosum*, which directly leads to the root rot (Oszako, Olejarski 2003). In Poland, root rot threat has been increasing, as former agricultural lands are reforested extensively under the National Program for Increasing Forest Cover (Sierota 1996, 1997; Małecka, Sierota 2003). Various attempts were made to prevent the development of pathogens of pine roots by applying biological preparations developed e.g. on the basis of non-pathogenic fungus *Phlebiopsis gigantea* decomposing pine trunks (Rykowski Sierota 1977; Łakomy 2001; Łakomy, Zarkowski 2000; Żółciak 2005, 2007; Żółciak, Sierota 2010), and by adding organic substance e.g. sawdust (Sierota, Kwaśna 1999; Kwaśna, Sierota 1999; Oszako, Olejarski 2003).

Conclusions

– Addition of organic materials to post-agricultural soil 10 years ago had a positive effect on the growth of planted bare-rooted Scots pine seedlings.
– The larger annual increments of shoots and length and biomass of needles (compared to the control plants) are readily visible.
– The addition of wood residues after clear cutting seems to have the higher positive effect on pine plantations grown on formal agriculture land.

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