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Influence of the mineral rock alginite on survival rate and re-growth of selected tree species on agricultural land

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ABSTRACT: The objective of this work is to evaluate the effect of alginite on the growth parameters of seedlings of Douglas-fir, Scots pine and line mixture of pedunculate oak, red oak and Norway maple (broadleaves) on former agricultural land with an unfavourable hydrophysical regime. The research plot consists of 36 sub-plots, each sub-plot has a size of 400 m^2. The following doses of alginite were applied: control (variant A without alginite), 0.5 kg of alginite (B) and 1.5 kg of alginite (C) when planting both conifers and mixtures of broadleaves. Number of seedlings on the sub-plots was 400 individuals, only in the case of Douglas-fir the number was 200 individuals. Therefore every combination of tree species and the amount of alginite had 4 replications. The parameters of growth and development of individual trees (height, increment and mortality) show that after 2 years, both doses of alginite had statistically positive effects on height increments.

Keywords: afforestation; soil improvement; stimulator; plantation growth

In the Czech Republic the afforestation process of agricultural land has been in progress with varying intensity since the early 19th century. The most extensive afforestation projects were implemented in the 1920's in connection with land reforms and especially in the 1950's in the mountains. Spruce (*Picea abies*) was planted on the majority of the area, but also other tree species such as European larch (*Larix decidua*), black alder (*Alnus glutinosa*), speckled alder (*Alnus incana*) and Scots pine (*Pinus sylvestris*) were used (Hatlapatková et al. 2006). In the late 19th and early 20th century approximately 18,000 ha of non-forest areas were afforested in the Czech Republic (Kacálek, Bartoš 2002). The research of newly established forest stands on agricultural land is particularly important in the areas with great losses of seedlings during the afforestation due to the unfavourable effects of environmental factors. This is observed on the monitored research plots located in the Labe region.

The failures in afforestation are generally determined by unfavourable soil and habitat conditions. These are often caused by severe stand conditions, occasionally connected with anthropic influence (Vacek, Podrázský 1994; Borůvka et al. 2005; Balcar et al. 2012a, b), causing the poor condition of forest plantations and even of older stands (Vacek et al. 2009). Therefore, forest species have evolved a number of mechanisms allowing the re-forestation under unfavourable conditions (Vacek et al. 2012).

In forestry practice, both chemical and biological reclamation techniques were used to facilitate the recovery of forests (Podrázský 1994, 2006a, b; Kacálek et al. 2009; Balcar et al. 2011; Kuneš et al. 2011). Amelioration treatments involved the

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applications of lime or basalt-rock grit (Kuneš et al. 2009) or special slow-release fertilizers (Kuneš et al. 2004; Kuneš et al. 2013a, b). Also, a number of broadleaved trees have a favourable effect on the forest soil conditions in mountain conditions (Podrázský et al. 2004).

Natural conditions of the area of interest are relatively unfavourable, especially climate, i.e. the growing season with higher air temperatures and low precipitation (Tužinský 2013). This means that one of the most important factors for successful afforestation on research areas is the hydrothermal regime of the soil, particularly its surface layers, which is often the limiting factor in the juvenile stages of trees.

These problems could partially be solved using an appropriate method of soil preparation or the application of supporting materials. The harmful influence of microclimate would be limited. Consequently, more favourable conditions for rainfall accumulation in the root zone would provide a sufficient amount of soil air. The root system is much more sensitive to evapotranspiration of water than the aboveground tree sections. The water deficit stress can damage this part of the plant faster. For this purpose incorporating alginite into the soil was used. According to Vass et al. (2000), the shortage of water in the soil caused a reduction of nutrition which is a critical parameter in afforestation.

Objectives of the study

The first prerequisite for successful afforestation on non-forest land is the awareness of ecological and environmental conditions, the consistency of preparatory work before afforestation. In our case, it is agricultural unused land with unfavourable nutrient and hydrophysical regime. In 2013 the soil amelioration was done on these plots by alginate application, and the afforestation was subsequently carried out. The main goals of the research were: to monitor the growth and development of various species (Scots pine, Douglas fir, pedunculate oak, red oak, Norway maple) and to evaluate the effect of alginite on the growth and prosperity of the plantations.

Alginite

Alginite is an organomineral rock with rich deposits near Lučenec (Slovak Republic) with prospective wide use. Alginite is derived from fossil algae, which in the volcanic changes of the Pannonian lake system 3–4 million years ago, along with eroded rocks created coherent sediments (Kulich et al. 2001). Alginite as an organic ingredient suitable for use in forestry was described for the first time by Vass et al. (1997, 1998). Alginite, which fills a former inland sea at Pincina, is a grey to dark grey laminated, clayey rock rich in organic substances, weakly strengthened organogenic sedimentary rock with a form of disintegrating clay (Vass 2005). It was formed from algae in the aquatic environment. Therefore, it contains a high content of phosphorus, potassium, calcium and magnesium. It also contains a number of important trace elements and other substances that act as soil activators (Gregor, Bublinec 1999).

In the rock the dark and light laminae of 0.5 to 2 mm in thickness are alternating. Dark laminae are rich in Botryococcus remains whose funnel cell covers consist of organic material similar to sporopoleminium. The light lamina is formed from clay material and contains repositories of diatoms formed by opal (Vass 2005). Small resources of alginite cannot be used for energy purposes. The physicochemical features and high amount of humus presume alginite for use in agriculture, forestry, horticulture and park design. Alginite can be used as a carrier of organic waste, which absorbs organic odours and facilitates waste recycling. For its convenient hydrophysical features it has been monitored as a substrate used as a support for the tree plantation re-growth, including forest tree species.

MATERIAL AND METHODS

The influence and use of alginite in afforestation have been studied in the research area near the town of Odolena Voda (15 km N of Prague, Czech Republic). The research plot is situated in the locality called "U Lomu", GPS coordinates: N 50°13.95', E 14°25.58'. The locality has the following site characteristics: former agricultural land, located in a warm, moderately dry area with an average annual temperature of 8–9°C and the sum of temperatures above 10°C in the growing season from 2,600 to 2,800°C. The average annual precipitation is 500 to 600 mm, the probability of a dry growing seasons is 20–30%.

The experimental plot is located on a gentle slope with a western aspect. The soil type is modal eubasic to mesobasic Cambisol, slates are the soil-forming substrate. The soil is deep to moderately

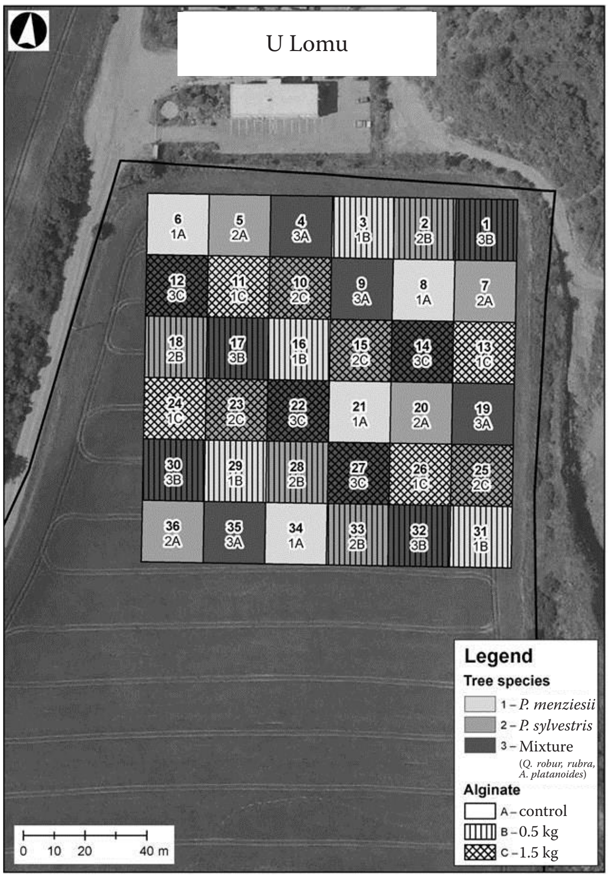

Fig. 1. Design of the research plot "U Lomu"

deep, moderate grain size, heavy, slightly skeletal with good water capacity.

The experimental plot was established in the spring 2013 with a total of 36 sub-plots with dimensions 20 × 20 m (Tužinský 2013). The spacing of seedlings was 1 × 1 m, Douglas-fir (*Pseudotsuga menziesii*) 1 × 2 m. Ameliorative material (alginite) was added and mixed with the soil during outplanting. Used trees: Douglas-fir, Scots pine and line mixture of pedunculate oak (*Quercus robur*), red oak (*Quercus rubra*) and Norway maple (*Acer platanoides*) were used. Two treatments with ameliorative material were used: 0.5 kg or 1.5 kg alginite to each seedling (planting hole). In the sub-plots, 400 seedlings, in the case of Douglas-fir 200 plants were planted. The design of the experimental plot is shown in Fig. 1.

The homogeneity of variances was assessed by Levene's test. To assess the effect of alginite application on the height growth of seedlings, multi-factor analysis of variance (ANOVA) was used. To assess not only the effect of alginite on height development, but also a possible interaction between trees and alginite, that means whether some of the tree species respond better to this product (mix) than the other tree species.

RESULTS AND DISCUSSION

The results of afforestation on the research plot in the form of biometric indicators, height, increment of Scots pine (*Pinus sylvestris*), Douglas-fir (*Pseudotsuga menziesii*), pedunculate oak (*Quercus robur*), red oak (*Quercus rubra*) and Norway maple (*Acer platanoides*) seedlings are summarized in Table 1 and graphically represented in Figs 1–3.

The highest increment was observed in Scots pine (*Pinus sylvestris*), with minimum differences between the control plots and the plots with the dose of alginite. Increments of other species varied from 6 to 9 cm, significantly higher was Norway maple (*Acer platanoides*) and red oak (*Quercus rubra*) on the plots with the dose of 0.5 kg alginite per seedling (Table 1).

The relative height increment of Scots pine was not affected by the two alginite treatments. In Douglas-fir relative height increment was larger in the control treatment. These results suggest that the application of alginite has not shown a positive effect on the height growth of conifers. However, the broadleaved species had a significantly higher relative height increment after the application of 0.5 kg alginite. A higher dose of alginite (variant C, 1.5 kg per seedling) had neither positive nor negative effect on the relative height increment of broadleaved species (Fig. 2).

Tree species composition was based on the growth characteristics of tree species in relation to site conditions, including anticipated changes in the development of soil properties (Tučeková, Halák 2011).

The reasons for mortality are not explicit in biometric measurements, particularly high mortality of Scots pine (*Pinus sylvestris*) and red oak (*Quer-*

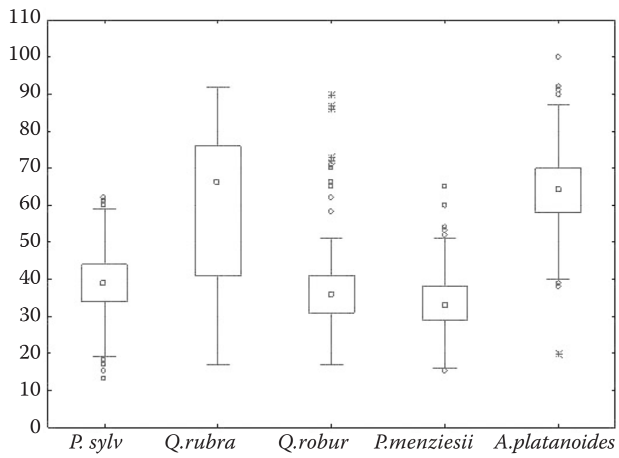

Fig. 2. Box plot of heights in 2013 confirming the priority of *Quercus rubra* and *Acer platanoides* growth in variant B (alginite 0.5 kg per plant)

Table 1. Influence of alginite on the height increment of seedlings and the effect of alginite application on mortality and initial growth in the locality

Variant	Tree Species	Quantity (indd)	Height (cm) 2012	Height (cm) 2013	Increment 2012–2013 (cm)	Relative increment (%)	Mortality (%)
A	*P. sylvestris*	1,549	25.3 ± 5.1	38.9 ± 8.4	13.6 ± 6.1	55.5 ± 25.1	24.9
B		1,571	26.8 ± 5.6	38.8 ± 8.1	13.7 ± 6.2	56.7 ± 26.6	22.7
C		1,524	25.3 ± 5.3	41.2 ± 8.5	**14.5 ± 5.7**	56.0 ± 23.0	28.8
A	*Q. rubra*	534	61.0 ± 16.4	70.6 ± 13.9	9.6 ± 9.1	20.7 ± 25.1	19.3
B		347	48.9 ± 21.2	60.6 ± 19.6	**11.7 ± 9.8**	**34.4 ± 31.3**	25.6
C		418	54.0 ± 19.2	61.4 ± 19.2	7.4 ± 7.2	17.2 ± 12.9	19.1
A	*Q. robur*	519	28.3 ± 6.0	35.8 ± 6.5	7.5 ± 4.3	28.9 ± 19.7	1.2
B		410	27.9 ± 10.0	37.3 ± 10.0	**9.4 ± 5.1**	**39.3 ± 25.9**	3.9
C		623	34.6 ± 13.5	42.3 ± 13.6	7.8 ± 4.1	26.7 ± 19.0	3.2
A	*P. menziesii*	778	25.9 ± 6.2	33.0 ± 6.6	7.1 ± 2.5	**29.2 ± 12.9**	0.8
B		753	27.9 ± 6.6	34.0 ± 7.2	6.0 ± 2.4	22.7 ± 11.1	2.7
C		748	26.2 ± 6.4	32.1 ± 6.6	5.9 ± 2.2	24.2 ± 11.1	2.0
A	*A. platanoides*	468	52.2 ± 10.7	61.3 ± 11.2	9.1 ± 5.5	18.8 ± 14.3	2.6
B		398	52.4 ± 10.3	64.7 ± 9.9	**12.3 ± 7.0**	**26.0 ± 19.8**	1.8
C		516	55.4 ± 8.4	64.0 ± 9.4	8.6 ± 4.7	15.9 ± 9.4	1.6

A – control, B – 0.5 kg of alginite, C – 1.5 kg of alginite; in bold – significantly different at $P = 0.05$

cus rubra) seedlings, in changed soil conditions in terms of vegetation, i.e. conversion of non-forest land into forest land. The mortality of the seedlings of both above-mentioned tree species was on average nearly 24% higher compared to the other tree species. Particularly surprising is the highest mortality of Scots pine (*Pinus sylvestris*) in the plots with a dose of 1.5 kg alginite per seedling (Fig. 3). Apart from the genetic predisposition of plants, high mortality can be caused by the lower physiological resistance of seedlings. It will be important to observe the trends of mortality and biometric growth parameters during the next period of research with applied single dose of alginite.

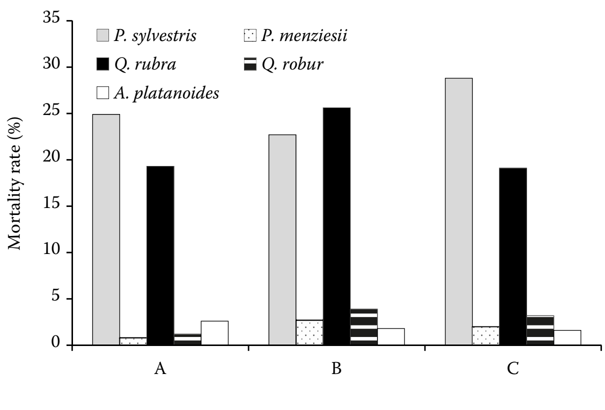

Fig. 3. Mortality of tree species according to alginite dose (variants A, B, C)

A – high alginite dose (1.5 kg of alginite to the planting hole during planting), B – medium alginite dose (0.5 kg), C – control

On the research area in the locality the results of afforestation are influenced by the environmental habitat conditions besides the ecological conditions. The basic requirements for acquiring and widening the knowledge of the ecological conditions of afforestation on agricultural lands are the characteristics of afforested plots. In particular, the characteristics and parameters of soil, soil profile description, soil reaction, available plant nutrients and others (Podrázský, Štěpánek 2002; Podrázský, Ulbrichová 2004; Kacálek, Bartoš 2005).

The afforestation success in the research plot was linked with considering the soil and other vegetation cover (forest tree species) and genetic components of afforested tree species. The application of alginite, a loamy rock rich in organic matter (Bublinec, Gregor 1997; Vass et al. 1997, 1998), was initiated by the need to improve the physical properties of soils, hydro-pedological characteristics, water holding capacity, hydraulic conductivity, presence of capillary and physiologically available water. Alginite can be used as a soil conditioner which binds and neutralizes the toxic effects of micronutrients as a result of its absorption capacity and which interacts positively with nutrient cycles and humus formation. These characteristics indicate that alginite is suitable for wider use, particularly on agricultural soils poor in minerals. In the past such soils were often affected by periods with a deficit of available water (Gregor, Bublinec 1999).

Field and pot experiments investigating the fertilization of nonstructural and light sandy soils, conducted by ÚKSUP Bratislava (Kubíková, Halás 1999) at the Záhorská lowland, showed that alginite use increased the grain yield of maize by more than 40% in the first year in comparison with the unfertilized research plot. The average rate increased by 45% in the second year after fertilization with one third of the recommended dose of nitrogen. In the first year the average height of maize increased by nearly 19% in comparison with the control variant, in the second year by 27%.

A positive effect of alginite on the height and diameter growth of Scots pine (*Pinus sylvestris*) and sessile oak (*Quercus petraea*) seedlings in a water deficient area of the Záhorská lowland was reported by Vass et al. (2005).

The success of afforestation on abandoned agricultural land with an unfavourable hydrophysical regime in the locality is primarily limited by the soil moisture. Tree species are threatened by inadequate supply of available water. The greatest moisture deficit is found in the surface layers of soil, where the highest density of active seedling roots is found (Tužinský 2004). Retaining fully functional and undamaged root systems, by preventing damage due to drought, is an important factor in improving the survival rate of plantations, recovery from post-planting shock and achieving faster height growth. Successful early establishment of planted seedlings and rapid initial growth will also minimize the harmful effects of weeds, resulting in lower costs of plant care.

Limiting factors of drought with deteriorated water regime can be expected on research plots in Odolena Voda – U Lomu mainly in the summer months. This is also seen in the climatic conditions during the growing season of 2013. In warm July with rainfall deficit, during 4 days only 41 mm of water fell, and during 2 days less than 5 mm (ČHMÚ Praha – Kbely, NCDC – The National Climatic Data Centre).

The period of rapid water dispensing for evapotranspiration is the period between July 4 and July 28 with only 2.8 mm of rainfall (July 24) and maximum daily temperatures of 22–36°C. This means that the physiological supply of available/usable water decreased significantly in the surface layer with the maximum occurrence of active roots. The growth parameters are relatively favourable for deciduous tree species such as maple (*Acer platanoides*) and pedunculate oak (*Quercus robur*). This can be caused by the ameliorative effect of alginite, improved soil water accumulation, increased water retention and slower moving capillary water above the critical soil moisture constant, limiting transpiration and wilting point (Reicosky, Ritchie 1976; Gregor, Bublinec 1999; Tužinský 2004).

CONCLUSIONS

The objective of the research in the first years after outplanting was the analysis of the growth rate of planted seedlings, their increment, height, health status on the research plot in the locality without and with the application of alginite.

In the following years the research will focus on the development of soil features, particularly physical and hydrophysical properties by monitoring the diversity of relations between individual trees and in stand mixtures comparing the growth of the used recovery species.

In the presumed single application of alginite during long-term continuous research and trends of the monitored growth parameters evident data are expected in the area of the interactions between the optional changes in hydrophysical and biochemical features of soils and the reaction of forest tree species by their physiological processes.

This research will be based on previous work aimed at supporting existing targets for afforestation of non-forest and agricultural land. Earlier studies evaluated tree growth and soil properties on selected plots identified for afforestation (Švarc 1954; Šindelář 1994; Černý et al. 1995; Kacálek, Bartoš 2005).

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