Effect of hydrogel application on survival and growth of pine seedlings in reclamations

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ABSTRACT: In this study results of hydrogel application in reclamations are presented. The application of hydrogel affected the survival of pine seedlings during two vegetation periods after planting. Double application of STOCKOSORB AGRO (gel) on the root system after lifting caused an about 19% higher survival rate compared to control variants. The application of 7 g/planting hole of STOCKOSORB MICRO granules caused overdosage and plant mortality. The application of hydrogel granules is simple but it is very complicated not to cause the overdosage because of the very high swelling capacity of hydrogel. Research should be carried out to determine suitable hydrogel application rates for different environmental conditions and tree species. To design a technology with regard to the economic effectiveness of application will be a very important task.

Keywords: reclamation of sand pit; hydrogel STOCKOSORB; Scots pine seedlings

Soil and moisture conditions are key factors for vegetation establishment in reclamations of lands after mining. These factors play a more important role if the area is under extreme environmental conditions. Záhorská lowland belongs to the most extreme areas in Slovakia and it is characterized by drought and warm climate.

Besides high average temperature and precipitation deficit this area is negatively affected by wind. Light sandy soil is damaged by wind erosion (Serdel 1973). These factors affect artificial forest regeneration and reclamation. Therefore it is needful to draw up new or modified procedures for the improvement of soil moisture conditions. The aims of these procedures should be to increase planting stock survival and field performance after planting.

In the last years, a new generation of hydrogels was developed, highly cross-linked polyacrylamides with 40% of the amides hydrolyzed to carboxylic groups. According to Bouranis et al. (1995) these hydrogels are able to absorb and store water up to 400 times their own weight, and consequently, reduce water stress for the trees. Hydrogels of STOCKOSORB belong to these new hydrogels.

Different hydrogel fractions are used commensurate with an application – STOCKOSORB Powder (fraction size < 0.2 mm, for the root system protection during planting, handling, storing and transporting). STOCKOSORB AGRO and MICRO (0.2–0.3 mm) are used for direct application to planting holes before planting. These hydrogels are frequently used for afforestation in semi-arid areas (Roldan et al. 1996; Tognetti et al. 1997). On the other hand, little information is available about the use of these hydrogels under environmental conditions in Central Europe.

The aim of this study was to determine the effect of hydrogel STOCKOSORB application on the survival and growth of pine (*Pinus sylvestris* L.) seedlings in the reclamation of a sand pit.

MATERIAL AND METHODS

Pieskovňa I – Plantation 2002

On March 5th 2002 one-year Scots pine (*Pinus sylvestris* L.) seedlings were lifted from a nursery bed. Directly after lifting (in the forest nursery), the seedlings were bundled (100 seedlings/bundle). The bundles were treated with STOCKOSORB AGRO (granule size 0.2–0.3 mm; 60 g of STOCKOSORB AGRO was stirred into 10 litres of water – *variant II*) + control (untreated) bundles – *variant I*. Before planting (onto the reclamation plot), a part of the treated bundles was dipped into STOCKOSORB AGRO gel again – *variant III*. The seedlings were planted to a randomized block on the same day as they were lifted. In this randomized block the rows were used as variants (100 seedlings/variant) and three replications were used. The seedling distance was 1.5 m between the rows and 80 cm within the rows.

Planting was carried out on a plot after sand mining, which had finished 2 years ago. The area is located 6 km south of the town of Malacky. The reclamation plot after mining was about 10 m below the level of the surrounding field. After mining no reclamation measures were taken. Soil samples were taken after planting (layer 5–20 cm) and the soil analysis was carried out.

Data on shoot height and root collar diameter was processed by the analysis of variance, and Tukey's HSD test was used for the separation of treatment means at the 5% level.

Pieskovňa II – Plantation 2003

Near by a plot that was afforested in 2002, the planting of pine seedlings was carried out in spring 2003. In autumn 2003, a reclamation measure was taken. The topsoil layer (20 cm) which was removed before mining was brought back. Unfortunately, the results from the soil analyses are not available.

On March 25th 2003 pine seedlings were lifted from a nursery bed. Next, the seedlings were bundled (100 seedlings/bundle). The bundles were treated with STOCKOSORB POWDER (70 g STOCKOSORB POWDER was stirred into 10 litres of water) + control bundles. The planting was carried out on the same day as the seedlings were lifted. The following variants were used:

- control plants – variant 1,
- application of STOCKOSORB MICRO (granule size: 0.2–0.8 mm) granules to a planting hole (7 g/planting hole) – variant 2,
- application of STOCKOSORB MICRO gel* to a planting hole** directly before planting – variant 3,
- root system treated with STOCKOSORB POWDER gel in the nursery – variant 4 (*70 g STOCKOSORB MICRO was stirred into 10 l of water, **150 g MICRO gel/planting hole).

The same plot design of planting procedure and evaluation of survival and biometrical parameters as on Pieskovňa I site were used.

RESULTS

Pieskovňa I – Plantation 2002

Soil analyses

The results of soil analyses are presented in Table 1. Physical and chemical properties of the soil are mainly related to the texture of the substrate. The very high value of dry matter in the samples indicates a very low content of hygroscopic water and very low water-holding capacity. Soil reaction (pH) can be classified as optimal for the planted trees. Organic carbon content and total nitrogen content are very low. Soil organic

Table 1. The results of soil analyses

Plot	Soil traits							
	dry matter (%)	pH_{H_20}	C_T[1]	N_T[1]	Mg_M[2]	Ca_M[2]	K_M[2]	P_M[2]
Pieskovňa I	99.83	5.87	0.029	0.002	34.7	127.8	23.1	8.08

[1]% weight of dry matter, [2]mg/kg dry matter
pH – soil reaction potentiometric method (pH electrode), C_T – organic carbon (dry combustion method at > 900°C), N_T – total nitrogen (dry combustion method), Mg_M, Ca_M, K_M, P_M – available nutrients in Mehlich extract, ICP AAS (colorimetry for P)

Table 2. Survival, height and root collar diameter of seedlings after the first vegetation period (autumn 2002)

Variant	Survival (%)	Height ± $s_{\bar{x}}$ (cm)	Root collar diameter % ± $s_{\bar{x}}$ (mm)
I	59	$12.2 \pm 3.6^{a/b}$	2.8 ± 0.6^{a}
II	73	10.3 ± 2.9^{b}	3.0 ± 0.5^{a}
III	78	12.7 ± 4.0^{a}	4.6 ± 1.8^{b}

Different letters show significant differences

Table 3. Survival, height and root collar diameter of seedlings after the second vegetation period (autumn 2003)

Variant	Survival (%)	Height ± $s_{\bar{x}}$ (cm)	Root collar diameter ± $s_{\bar{x}}$ (mm)
I	20	–	–
II	69	15.6 ± 5.1[a]	6.9 ± 2.0[a]
III	68	14.9 ± 5.8[a]	5.9 ± 1.0[a]

Different letters show significant differences

matter content is hardly one hundredth of the optimal content in forest soils. Contents of available nutrients (P, K, Ca, Mg) are very low as well. The measured values are 5 to 10 times lower than optimal values.

These results of the analyses indicate extreme physical and chemical properties of soil. According to the properties, it is only a sandy substrate very slightly changed by soil-forming processes, not a soil in fact. The substrate is very extreme even for the region Záhorská lowland, where soils are developed on aeolian sands.

The most important is the deficiency of organic matter and clay, which causes very low sorption capacity and water-holding capacity.

Seedling survival and growth

The survival and biometrical parameters of pine seedlings in the first vegetation period after planting are presented in Table 2. The hydrogel application had a positive effect on seedling survival (the seedlings treated with STOCKOSORB AGRO reached 14% and 19% higher survival rate compared with control seedlings).

In autumn 2003 (after the second vegetation period) the same evaluation of seedling survival and biometrical characteristics as in autumn 2002 was carried out (Table 3). The survival rate of the control variant decreased to 20%. Therefore the measurement of seedling height and root collar diameter was not carried out. On the other hand, the seedlings treated with hydrogel had 69% and 68% survival, respectively.

Pieskovňa II – Plantation 2003

Seedling survival and growth

The same procedure of evaluation of seedling survival and growth as in Pieskovňa I was used in Pieskovňa II. There were not found any significant differences in the survival and growth of seedlings between three vegetation periods as expected from the application of hydrogel granules. In this variant the seedling survival was about 20% lower than in the other three variants (Tables 4 to 6).

Table 4. Survival, height and root collar diameter of seedlings after the first vegetation period (autumn 2003)

Variant	Survival (%)	Height ± $s_{\bar{x}}$ (cm)	Root collar diameter ± $s_{\bar{x}}$ (mm)
1	85	11.3 ± 3.0[a]	3.4 ± 1.0[a]
2	64	11.2 ± 3.0[a]	3.3 ± 0.9[a]
3	84	11.0 ± 2.9[a]	3.3 ± 0.8[a]
4	85	11.0 ± 3.0[a]	3.1 ± 0.8[a]

Different letters show significant differences

Table 5. Survival, height and root collar diameter of seedlings after the second vegetation period (autumn 2004)

Variant	Survival (%)	Height ± $s_{\bar{x}}$ (cm)	Root collar diameter ± $s_{\bar{x}}$ (mm)
1	81	16.4 ± 4.8[a]	5.7 ± 1.7[a]
2	64	14.5 ± 5.8[a]	5.5 ± 2.5[a]
3	84	16.5 ± 5.6[a]	5.8 ± 2.0[a]
4	83	16.4 ± 5.5[a]	5.9 ± 1.7[a]

Different letters show significant differences

Table 6. Survival, height and root collar diameter of seedlings after the third vegetation period (autumn 2005)

Variant	Survival (%)	Height ± $s_{\bar{x}}$ (cm)	Root collar diameter ± $s_{\bar{x}}$ (mm)
1	79	28.6 ± 8.4[a]	13.4 ± 4.1[a]
2	63	25.2 ± 9.3[b]	13.3 ± 4.9[a]
3	84	28.5 ± 8.5[a]	13.6 ± 4.4[a]
4	83	27.6 ± 8.3[a]	14.0 ± 5.0

Different letters show significant differences

DISCUSSION

The results of the application of STOCKOSORB hydrogel for the reclamation of lands after sand mining in Zahorie are presented in this study. There are very extreme environmental conditions and it is needful to use the tree species that are better adapted to these conditions. In autochthonous forest ecosystems oak and pine dominated expecting more moist sites where lime was dominating (Serdel 1973). The Scots pine is adapted to these extreme conditions and it could be used for reclamations as a pioneer tree species.

On the other hand, the water-holding capacity is crucial for the survival of plants (Parker 1974). The application of hydrogel could increase the water-holding capacity, which is very important in reclamations. The hydrogel application increases the water potential and decreases evaporation by reducing the hydraulic conductivity of soil (Aggelides, Kollias 1984; Aggelides, Bachtalias 1989) and has a positive effect on survival and growth in reclamations (Bood 1990; Brofas et al. 2004).

Pieskovňa I – Plantation 2002

The application of hydrogel affected the survival of pine seedlings during two vegetation periods after planting. Double application of STOCKOSORB AGRO on the root system after lifting caused an about 19% higher survival rate in comparison with the control variants. The differences in survival were higher after the second vegetation period. The survival of the control variant decreased to 20%.

Pieskovňa II – Plantation 2003

Research on the application of STOCKOSORB MICRO and POWDER began in 2003. STOCKOSORB POWDER is recommended for the root system protection during seedling handling and transporting. The STOCKOSORB MICRO is added to the substrate or soil for water absorption in the root zone.

In the first vegetation period after STOCKOSORB application the lowest survival rate was found out after the application of STOCKOSORB MICRO granule into the planting hole (64%). This high mortality was caused by hydrogel overdosage (7 g/planting hole – application with a dessert-spoon). After rain the hydrogel granule swelled and the seedling was pushed up. The application of hydrogel granules is simple but it is very complicated not to cause the overdosing because of the very high swelling capacity of hydrogel. If the granules are able to absorb an amount of water 400 times higher than their own weight (Bouranis et al. 1995), then 7 grams of the granules could absorb theoretically 2 litres of water. It is not clear what the optimum dose of the STOCKOSORB granule per planting hole is like and it would be very complicated to apply a lower dose of STOCKOSORB than 7 grams. The solution of this problem could be to mix hydrogel granules into soil and to apply this soil to planting holes, but this application is time-consuming and costly. In addition, if it does not rain after planting, there will not be any water for absorption and the application of hydrogel will not have any effects on survival.

Therefore it is better to apply hydrogel to the planting hole. After this application water for seedlings is directly available, which can significantly reduce the transplanting shock.

A difference in the seedling survival and growth was found between two planting sites. On Pieskovňa I site the survival 59% and 20% was found in the control variant after the first and second vegetation period, respectively.

On the other hand, the survival on Pieskovňa II site in the control variant was 79% after the third vegetation period. The plantation plots were beside each other and therefore these differences were highly probably caused by soil conditions. On Pieskovňa I site there were extreme soil conditions which affected the seedling survival and growth during two vegetation periods after planting.

The positive effect of STOCKOSORB application is reported by many authors: (*i*) for reclamations of mining soils (Brofas et al. 2004), (*ii*) for afforestation in semi-arid areas (Hüttermann et al. 1999; Oscroft et al. 2000), (*iii*) in forest nurseries and reforestation in Central Europe (Jurásek 2001; Sarvaš 2003a,b, 2004; Sarvaš, Tučeková 2003a,b).

On the other hand, the application of STOCKOSORB did not improve the survival and growth on Pieskovňa II site. The reasons for it could be as follows:

(1) The planting was done on the same day as lifting and handling, transporting (only 2 km) and planting was done very carefully so the root system of untreated seedlings was not damaged,
(2) the afforestation programme with a year old pine seedlings that have traditional survival about 85% and the seedlings are very well adapted to climate conditions in Zahorie.

Generally, the hydrogel was developed for arid and semi-arid areas but highly probably its use will also be needful for environmental conditions in Central Europe. Therefore research should be carried out to determine suitable doses for different soil types. To design a technology with regard to the economic efficiency of applications will be a very important task.

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Ujatosť a rast semenáčikov borovice pri melioráciách po aplikácii hydroabsorbentu

ABSTRAKT: V príspevku sú prezentované výsledky aplikácie hydroabsorbentu pri melioráciách. Aplikácia hydroabsorbentu ovplyvnila ujatosť a následné prežívanie vysadených borovicových semenáčikov počas dvoch vegetačných období po výsadbe. Dvojnásobná aplikácia hydroabsorbentu STOCKOSORB AGRO (gelovitá forma) na koreňový systém po vyzdvihnutí semenáčikov zo záhonu lesnej škôlky spôsobila o 19 % vyššiu ujatosť v porovnaní s kontrolným (neošetreným) variantom. Aplikácia STOCKOSORB MICRO (7 g/jamka) zapríčinila predávkovanie a následnú mortalitu vysadených semenáčikov. Aplikácia hydroabsorbentu vo forme granúl je jednoduchá, ale je veľmi náročné dodržať optimálne dávkovanie. Je potrebné uskutočniť ďalší výskum zameraný na určenie vhodnej aplikácie hydroabsorbentu pre rôzne prírodné podmienky a dreviny. Veľmi dôležitým aspektom bude navrhnutie vhodných technologických postupov s ohľadom na celkovú efektívnosť aplikácie.

Kľúčové slová: meliorácie piesčitých pôd; hydroabsorbent STOCKOSORB; semenáčiky borovice lesnej

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