Impact of soil conditioners on the growth of European ash (*Fraxinus excelsior* L.) on dumps

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ABSTRACT: The effects of soil conditioners TerraCottem, Frisol, Bio-algeen and fertilisers Silvamix Forte and Cererit on the survival rate and growth of European ash seedlings until the stage called established plantation were observed on two experimental plots with different anthropogenic substrates. Eight-year experiments showed that under the given conditions the tested agents fulfilled the declared effects only partially. The application of TerraCottem was statistically insignificant both in the survival rate and in the growth. In the applied dose, Frisol manifested itself as an agent that may cause problems with the survival of plants, but at the same time also as a preparation improving the overall growth of young plants statistically significantly. Its effective dosage largely depends on the soil character. Bio-algeen had a very good effect on the survival rate of plants, but it did not surpass the control plants in the initial growth of plants. Silvamix Forte did not cause the mortality of seedlings and influenced the growth of plants statistically significantly for 1–3 years. In the applied dose, Cererit caused a high mortality of seedlings. The application of soil conditioners and Silvamix Forte did not markedly accelerate the growth and development until the stage of the established plantation. Until that time, the costs of the application of conditioners were higher by 4–13% as compared with the costs in the control plants.

Keywords: TerraCottem; Frisol; Bio-algeen; Silvamix Forte; Cererit; European ash; soil conditioners; reclamations; dumps; anthropogenic substrates; survival rate and growth; costs

The current market in agricultural preparations offers, among others, the products such as TerraCottem, Frisol, Bio-algeen, which may be designated as soil conditioners on the basis of information provided by manufacturers and distributors. Under this designation, we generally understand artificially produced preparations of a natural or synthetic character that improve chemical, physical and biological properties of soils in order to achieve better growth and production of cultivated plants. The domains of the practical application of soil conditioners, as stated by their manufacturers [www.terracottem.com, www.gebruederfriedrich.de, www.schulze-hermsen.de], include the improvement of degraded soils and anthropogenic substrates. In the Czech Republic, reclamations are realised particularly in regions damaged by surface and deep mining of mineral resources or power generation in thermal power plants – in the North-Bohemian Lignite Mining District (SHR), in Sokolov region and Ostrava-Karviná region.

Dumps, waste piles, evaporation ponds, disposal and dumping sites of any kind are mostly reclaimed by agricultural and forestry methods. As mentioned by Štýs (2001), only the SHR includes almost 5,400 hectares under reclamation, out of which 3,310 are forestry hectares. Reforestation is the most widely used form of reclamations here and the European ash (*Fraxinus excelsior* L.) ranks among the most frequently used target species.

A large scope of devastated areas, particularly in the SHR, as well as high financial costs of reclamation force both the specialists in practice and the researchers to search for new materials, tools, technologies and methods that would accelerate and facilitate the reclamation process and reduce its costs. An improvement of the soil environment in the root zone of plants is one of the ways of making the biotechnological stage of the reclamation process more effective. This opens a space for the application of soil conditioners. Considering the fact that soil conditioners are relatively new and expensive foreign preparations, it seems reasonable, according to the principle of preliminary caution, to test them under our conditions and to verify their declared effects and efficiency before their general application.

Neither foreign data on the effects of conditioners on the vegetation acquired under conditions not typical of this country (deserts, arid areas, high-elevation zones), e.g. Weissbacher (1995), Fuchs (1995), Van Cottem (1996) nor the instructions of manufacturers and dealers composed on the basis of tests with other groups of plants – grass, fruit trees, vegetables, flowers, ornamental woods [www.terracottem.cz, www.gebruederfriedrich.de] provide a sufficient guarantee of success of their application to seedlings of forest tree species grown on anthropogenic soils in pollution-damaged areas of this country. The results of experiments carried out in the Czech Republic with ornamental woody plants on natural soils (Bulíř 1997; Bulíř, Dubský 1998) or in plant nurseries (Puhlová, Šmelková 1998) or in pots (Salaš 2002, 2004) must be seen from the same perspective.

The objective of this paper was a long-term experimental verification of effects of the above-mentioned soil conditioners and their comparison with domestic fertilisers in relation to the survival rate, initial growth and costs of the cultivation of European ash (*Fraxinus excelsior* L.) until the stage of the established plantation in different climatic conditions and soil environments.

MATERIAL AND METHODS

The following soil conditioners and fertilisers were tested and assessed in an experiment with European ash (2/0) in a continuous sequence of 8 years:

Frisol (FR) – German product, two types of product were tested: **Frisol A (FR A)** – liquid concentrate, organic fertiliser with a long-term effect, containing 50% of organic substances, 9% of total nitrogen, 11% of total P_2O_5, pH 1.5, and **Frisol F (FR F)** – granulate, organic fertiliser from soil fungi and bacteria containing 80% of organic substances, 8% N, 2% P_2O_5, 2% K_2O, 1% MgO, microelements and vitamins, pH 5.3.

TerraCottem (TC) – Belgian product, mixture of synthetic and natural hydroabsorbent polymers (39.5%), mineral and organic fertilisers (10.5%), out of which 5.9% N, 0.9% P_2O_5, 3.9% K_2O, microelements (B, Cu, Fe, Mn, Mo, Zn), root growth activators (0.25%) and base material – volcanic rock (49.75%).

Bio-algeen (BA) – German product, distributed in the Czech Republic under the trademark **Bi-algeen,** product from sea algae (*Ascophyllum nodosum*) containing polyuronic acids, amino acids, vitamins, phytohormones, microelements. Three types were tested: **Bi-algeen granulate (BA G), Bi-algeen S-90 (BA S 90)** – liquid concentrate, **Bi-algeen root concentrate (BA kk)** – liquid or pasty concentrate.

Silvamix Forte (SF) – Czech product, modern pelleted, slowly dissolvable fertiliser containing 17.5% N, 17.5% P_2O_5, 10.5% K_2O, 9% MgO.

Cererit (CE) – Czech combined fertiliser, three-component granulate containing 8% N, 13% P_2O_5, 11% K_2O, 2% MgO and microelements (B, Cu, Mo, Zn).

The tests of the effectiveness of the above-mentioned preparations were conducted on two plots with different climatic and soil characteristics – the Střimice dump and the evaporation pond of Prunéřov Power Plant (EPRU) – see Tables 1, 4–7. A randomised block design with four replications was used in both experimental plantings. Ten seedlings were planted in each variant. The experimental plots were established in spring 1997. The application of preparations was carried out simultaneously with the planting of the species in the following doses (see Table 2).

The tending of experimental plots in 1997–2002 followed a model that is applied in the reclamation practice, i.e. the plants were hoed twice, mown twice and treated with the repellent Morsuvin each year during the vegetation period. In addition, all the trees were fertilised with 10 g NPK/plant in 2002 (the sixth year). Since 2003, the tending of the plots was differentiated. On Střimice dump, one hoeing

Table 1. Basic climatic and soil characteristics of experimental locations

Characteristics	Střimice dump	EPRU evaporation pond
Climatic zone	Moderately warm B 2, avg. annual air temperature: 8.7°C, avg. annual total precipitation: 438 mm	Moderately warm B 3, avg. annual air temperature: 8.2°C, avg. annual total precipitation: 422 mm
Substrate	Mostly grey clays covered with a 5–10 cm layer consisting of a mixture of cellulose fibres, clay and peat	Power plant light ash covered with a 20–45 cm layer of grassed podzolic soils

Table 2. Doses of tested soil conditioners and fertilisers in experimental locations

Preparation – version	Dose
Frisol – FR	FR A 150 ml/3 l of water /2 seedlings + FR F 300 g
TerraCottem – TC	40 g
Bio-algeen – BA	short soaking of seedling roots in the solution of BA kk 1:100 + BA G 10 g + BA S 90 2 ml/l water
Silvamix Forte – SF	40 g = 8 tablets
Cererit – CE	70 g
Control – CO	without application

and repellent application were omitted in that year and there was no hoeing and no repellent application in the locality of EPRU evaporation pond. In 2004, the trees on both plots were fertilised with 15 g NPK/plant, one additional mowing was performed on Střimice dump.

The assessment of experimental plots was performed each year and was aimed at the survival or, as the case may be, at the mortality of plants, their height and diameter growth. The dynamics of the survival of plants in the location was assessed only in course of the first vegetation period according to the scale:

1 – wilting or already wilted plant,
2 – living, not awakened or partially wilted plant,
3 – living plant.

In the following years, only mortality and its causes were observed. The measuring of annual height increment, total height and total stem diameter was performed always at the end of the vegetation period. A measuring stick was used to measure height increment and plant height, stem diameter was measured with slide gauge 5 cm above the root collar. All the data sets were tested for normality and analysed by two-way analysis of variance (ANOVA) using the Statgraphics plus programme, version 1. The significance level $p < 0.05$ was used; significant differences between means were evaluated by Multiple Range Test.

For the economic assessment of costs, we used the catalogues of descriptions and indicative prices of construction works 823-2 Reclamations (ÚRS Prague 1997–2004) as well as the prices of materials provided by manufacturers or exclusive distributors and wholesalers. The costs of the cultivation of

Table 3. Survival rate and numbers of living plants on experimental plots. The same letters are not significantly different within one factor and parameter according to Multiple Range Test, $p < 0.05$

Var.	Degree	Střimice dump					EPRU evaporation pond				
		20. 6. 1997	16. 9. 1997	21. 4. 1998	25. 9. 1999	18. 9. 2004	16. 6. 1997	15. 9. 1997	20. 4. 1998	20. 9. 1999	19. 9. 2004
FR	1	19	2	38 a	37 a	37 a	17	19	14 b	14 b	13 b
	2	7	0				21	11			
	3	14	38				2	10			
TC	1	11	1	39 a	39 a	39 a	8	7	33 a	33 a	31 a
	2	17	0				1	1			
	3	12	39				31	32			
BA	1	2	0	40 a	40 a	40 a	0	1	39 a	39 a	35 a
	2	15	0				2	0			
	3	23	40				38	39			
SF	1	5	1	38 a	38 a	38 a	2	2	38 a	36 a	35 a
	2	23	0				4	0			
	3	12	39				34	38			
CE	1	36	28	12 b	11 b	11 b	32	35	5 b	5 b	5 a
	2	4	0				8	0			
	3	0	12				0	5			
CO	1	2	2	38 a	38 a	38 a	9	7	33 a	33 a	30 a
	2	6	0				10	0			
	3	32	38				21	33			

Table 4. Physical properties of substrates in experimental locations (average of three probes)

Profile (cm)	Střimice dump					EPRU evaporation pond				
	bulk density (g/cm^3)	particle density (g/cm^3)	WPS (% vol.)	porosity (% vol.)	AS (% vol.)	bulk density (g/cm^3)	particle density (g/cm^3)	WPS (% vol.)	porosity (% vol.)	AS (% vol.)
0–5	0.92	2.33	40.9	60.5	19.6	1.40	2.51	41.2	44.2	3.0
5–10	1.33	2.41	42.7	44.8	2.1	1.49	2.53	38.4	41.1	2.7
10–20	1.38	2.45	43.7	45.7	2.0	1.47	2.49	38.4	41.0	2.6
20–40	1.66	2.58	34.3	35.7	1.4	1.49	2.51	37.5	40.6	3.1
40–60	1.51	2.51	38.4	39.8	1.4	1.40	2.53	33.8	44.7	10.9

WPS – water pore space, AS – air space

Table 5. Chemical analysis of the substrate on Střimice dump from 26. 5. 1997 and EPRU evaporation pond from 12. 5. 1997 (average of three probes)

Profile (cm)	Střimice dump							EPRU evaporation pond						
	pH	EC (mS/cm)	contents of nutrients (mg/100 g of substrate)					pH	EC (mS/cm)	contents of nutrients (mg/100 g of substrate)				
			N-NH_4	N-NO_3	P	K	Ca			N-NH_4	N-NO_3	P	K	Ca
0–20	7.0	0.46	11.3	2.7	0.6	18.0	520	5.8	0.08	6.7	3.3	1.3	18.3	258
20–40	6.7	0.23	8.3	2.8	0.3	15.8	289	5.5	0.07	6.7	3.3	0.6	11.9	180
40–60	6.7	0.28	5.3	4.0	0.6	15.2	227	5.2	0.07	5.3	2.5	0.3	12.3	114

EC – electrical conductivity

1 plant in respective treatment variants and years included work operations and specified materials according to the realised technology. To determine the effectiveness of the conditioner application, the costs were calculated per 1 hectare (6,700 plants) and related to the period the plants needed for the achievement of the stage called **established culture**. These costs also included the costs necessary for the compensation of the plant losses to ensure the original number of trees calculated per hectare. The percentage of dead seedlings determined at the end of the first vegetation period was taken as a basis of the loss. The same percentage was used for the compensation of losses in the already compensated stand in next years until the number of growing (living) plants achieved the planned number of 6,700 pieces.

The meteorological data on average monthly temperatures and total precipitation are from the stations nearest to the experimental plots and were provided by the Czech Hydrometeorological Institute in Prague.

Table 6. Average temperatures (in the months) and total precipitation on Střimice dump (Kopisty u Mostu station)

Year	Average air temperature (°C)					Average total precipitation (mm)				
	I–III	IV–VI	VII–IX	X–XII	annual	I–III	IV–VI	VII–IX	X–XII	annual
1997	1.4	12.8	17.6	3.8	8.9	86.2	108.8	137.0	78.0	410.3
1998	3.5	14.9	16.6	3.3	9.6	55.3	93.0	154.3	125.1	427.7
1999	2.1	13.8	18.5	4.5	9.7	94.5	125.1	112.5	86.1	418.2
2000	2.9	15.5	16.9	5.8	10.3	155.1	115.0	126.0	84.6	480.7
2001	1.1	13.0	16.7	4.4	8.8	133.5	129.0	176.6	96.6	535.7
2002	2.9	14.3	17.4	2.9	9.4	85.9	129.5	280.3	195.2	690.9
2003	0.4	15.0	18.0	2.8	8.9	44.3	95.2	91.4	53.0	283.9
2004	0.8	13.1	17.0	4.1	8.8	93.9	131.1	141.7	106.8	473.5
Long-term average	1.3	12.8	16.6	4.3	8.7	73.9	125.3	150.0	85.2	437.6

Table 7. Average temperatures (in the months) and total precipitation in EPRU evaporation pond (Tušimice station)

Year	Average air temperature (°C)					Average total precipitation (mm)				
	I–III	IV–VI	VII–IX	X–XII	annual	I–III	IV–VI	VII–IX	X–XII	annual
1997	1.2	12.1	17.0	3.6	8.5	68.0	100.3	138.3	70.0	376.6
1998	3.2	14.3	16.3	3.4	9.3	55.8	86.5	168.1	122.3	432.7
1999	2.2	19.8	18.1	4.3	9.5	64.0	109.3	155.4	76.5	405.2
2000	2.8	15.1	16.4	5.7	10.0	100.4	94.2	166.4	97.6	458.6
2001	1.2	12.8	16.8	4.6	8.8	109.5	78.5	121.8	77.9	387.7
2002	3.2	14.0	17.4	3.6	9.6	64.5	149.2	240.1	182.4	636.2
2003	0.4	14.7	18.2	3.5	9.2	27.1	84.8	97.3	40.4	249.6
2004	1.0	12.4	16.7	4.3	8.8	70.9	138.3	134.7	82.2	426.1
Long-term average	0.5	12.2	16.2	4.1	8.2	67.7	127.9	147.9	82.5	422.1

Chemical analyses of dry soil samples were carried out in accordance with the methods of investigation of horticultural soils (Soukup et al. 1987). Electrical conductivity and pH value were estimated in water extract 1 w:10 v, contents of available nutrients were estimated in Göhler leaching extract (0.52 M CH_3COOH, 0.05 M CH_3COONa) 1 w:10 v.

Physical properties of soil samples were determined (Valla et al. 1980) in cylinders 100 cm^3 in volume at the beginning of experiments.

RESULTS AND DISCUSSION

Survival rate of seedlings

Table 3 shows the responses of bare-root seedlings to applied conditioners and fertilisers. In the course of the first vegetation period marked differences in the plant survival were observed in the individual treatments, particularly in the onset of budbreak and in growth rate. On Střimice dump, all the applied preparations, and particularly FR and TC, delayed the budbreak if compared with the control plot. The application of BA and SF also suppressed, even if less markedly, the beginning of budbreak. CE had an unambiguous effect. The applied dose caused the death of seedlings very quickly after planting. In EPRU evaporation pond, the initial suppression of budbreak was not as marked as on Střimice dump. FR and CE were exceptions, while enormous losses became evident soon after the application of CE. On plots with FR, the losses were proven only at the end of the vegetation period when the living, vital seedlings could be distinguished with certainty from wilted seedlings.

The final assessment of seedling survival performed in spring 1998, precisely one year after planting, showed statistically significant differences if compared with all the remaining preparations in the case of variants with CE and, in EPRU evaporation pond, also in the case of FR. The selected doses of CE and FR were probably too high for the local soil and climatic conditions, as illustrated in Tables 4–7, and therefore they caused an excessively high mortality of seedlings. In the next years, the conditioners and the fertilisers did not have any effects on the losses. The decrease in the number of plants in the period 1998–2004 in EPRU evaporation pond was partly caused by cutting the low trees during the mowing of high grass and plants and partly by damage to roots caused by mice. The experiment showed that higher doses of FR suppressed the survival in light soils and soils with higher aeration, but they did not cause abnormal mortality of seedlings in total assessment. However, the same doses led to statistically significant losses of seedlings in heavy-textured soils with lower aeration (EPRU). Cererit caused high losses in both localities, evident very soon after its application. The remaining tested preparations had a positive, even if statistically insignificant effect on the survival rate of seedlings. The plots with the application of BA showed the best results in this respect on both experimental plots.

Growth parameters

Due to a low number of plants on plots with CE and, in the case of EPRU also with FR, these variants were not compared with the others. Tables 8–11 contain the results depicting total height of plants and total stem diameter over the years of the experiment duration, including their statistical evaluation. On Střimice dump, two preparations – FR and SF – had statistically significant positive effects on the

Table 8. Střimice dump, European ash – total height (cm) in 1997–2004. Results of ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Multiple Range Test, $p < 0.05$

Var.	1997 spring	1997	1998	1999	2000	2001	2002	2003	2004
FR	32.9 a	35.1 a	50.7 a	64.5 a	80.0 a	95.3 a	118.9 a	169.7 a	205.7 a
TC	32.8 a	33.9 a	47.6 ab	55.5 b	67.6 bc	78.3 bc	98.1 bc	145.4 bc	177.9 b
BA	31.5 a	35.4 a	42.2 c	50.9 b	61.7 c	71.8 c	84.6 c	127.1 c	164.1 b
SF	31.0 a	34.3 a	51.3 a	63.4 a	75.5 ab	86.7 ab	103.4 b	151.5 ab	181.9 b
CO	30.0 a	32.6 a	42.6 bc	51.8 b	65.6 c	78.6 bc	101.2 b	147.9 b	177.0 b

Table 9. Střimice dump, European ash – total stem diameter (mm) in 1997–2004. Results of ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Multiple Range Test, $p < 0.05$

Var.	1997 spring	1997	1998	1999	2000	2001	2002	2003	2004
FR	9.9 a	10.0 a	11.1 a	13.3 a	15.1 a	17.8 a	27.1 a	32.1 a	40.1 a
TC	8.9 bc	8.9 bc	10.0 b	11.7 b	13.1 b	16.1 a	20.9 b	25.6 b	32.6 b
BA	7.8 d	8.0 d	8.7 c	10.5 c	11.9 bc	13.4 b	17.3 c	21.5 c	28.5 c
SF	9.2 ab	9.3 ab	10.3 ab	12.0 b	13.3 b	16.5 a	22.4 b	26.5 b	31.3 bc
CO	8.1 cd	8.2 cd	9.0 c	10.0 c	11.4 c	13.5 b	20.8 b	26.1 b	32.1 bc

elongation (height) growth if compared with the control plantations. The effects of FR became evident since the second year (1998) and they have persisted until now. The positive effects of SF became evident also in the second year and ceased in the fourth year when the nutrients were probably depleted. This means that they persisted for 3 years. In the remaining preparations, the effects were never statistically significant in this respect. As far as the diameter growth is concerned, the situation is analogical. TC also had positive effects on this parameter, namely from the second to the fifth year. We may generally say that in the given location the ash plants grew relatively slowly. In the best preparations, the highest annual increment was measured in the second year – despite the below-average precipitation in the period of intensive growth – and then always after fertilisation. Over the eight years, the plants treated with SF and FR grew on average by 151 cm and 173 cm, respectively, and the control plants by 147 cm.

In EPRU evaporation pond, the total height of plants if compared with the control was statistically significant in TC in the first year and in SF in the second year. No significant effects were reported in the following years. The positive effects of SF on growth were evident also in this location even if the data show that the plants were smaller if compared

Table 10. EPRU evaporation pond, European ash – total height (cm) in 1997–2004. Results of ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Multiple Range Test, $p < 0.05$

Var.	1997 spring	1997	1998	1999	2000	2001	2002	2003	2004
TC	37.0 a	45.0 a	57.2 ab	66.2 b	77.0 b	89.7 b	130.5 b	159.8 b	189.6 a
BA	33.5 b	39.4 b	50.4 c	67.2 b	77.7 b	89.4 b	134.6 ab	166.6 ab	193.4 a
SF	35.5 ab	41.3 ab	60.3 a	77.1 a	92.9 a	107.0 a	155.1 a	192.5 a	209.0 a
CO	33.8 ab	39.6 b	52.6 bc	72.4 ab	89.5 a	99.4 ab	136.7 ab	166.7 ab	189.3 a

Table 11. EPRU evaporation pond, European ash – total stem diameter (mm) in 1997–2004. Results of ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Multiple Range Test, $p < 0.05$

Var.	1997 spring	1997	1998	1999	2000	2001	2002	2003	2004
TC	10.4 a	10.5 a	11.2 a	12.9 a	15.1 b	16.4 bc	20.9 b	27.6 b	33.5 b
BA	10.1 a	10.2 a	10.6 a	11.4 b	15.1 b	15.8 c	22.7 ab	29.9 b	34.9 b
SF	10.4 a	10.6 a	11.0 a	12.7 a	17.4 a	18.2 ab	25.0 a	34.7 a	40.0 a
CO	9.6 a	10.0 a	10.7 a	12.5 ab	16.5 ab	18.8 a	25.3 a	31.7 ab	37.5 ab

Table 12. Střimice dump – costs invested in the existence of 1 seedling on the experimental plot in 1997–2004

Year	Costs per preparation (CZK/seedling)				
	CO	FR	TC	BA	SF
1997	29.81	43.75	48.71	39.58	37.71
1998	23.34	23.34	23.34	23.34	23.34
1999	26.09	26.09	26.09	26.09	26.09
2000	28.79	28.79	28.79	28.79	28.79
2001	27.55	27.55	27.55	27.55	27.55
2002	37.35	37.35	37.35	37.35	37.35
1997–2002	172.93	186.87	191.83	182.70	180.83
Index CO = 1.0	1.00	1.08	1.11	1.06	1.05
2003	22.80	22.80	22.80	22.80	22.80
2004	17.62	17.62	17.62	17.62	17.62
1997–2004	213.35	227.29	232.25	223.12	221.25
Index CO = 1.0	1.00	1.07	1.09	1.05	1.04

with the plot on Střimice dump. In the first year characterised by below-average precipitation the positive effects were reported also in TC, containing hydrogels releasing the retained water for plants during the periods of insufficient natural rainfall. However, this effect was not reported in the following years. The statistical evaluation of diameter increment shows that over the eight years none of the tested preparations achieved better results in this respect than the control. A short efficient support of the elongation growth or no support (diameter) may be explained, among other things, by the fact that the grass-herb layer in which the ashes were planted participated in the use of nutrients and the nutrients were thus depleted more quickly. The conclusion may analogically be related also to the remaining tested preparations. As on Střimice dump, the best average annual results were reported in SF, namely in the second year, despite below-average precipitation and above-average temperatures in the period of intensive growth. A high increment was reported after fertilisation in 2002, while it was not so marked two years later. Since the beginning of the experiment, the ash plants grew on average by 174 cm in SF variants and by 156 cm on control plots.

Economic effectiveness

Tables 12 and 13 show the costs of planting and of the tending of one plant on both experimental plots over the particular years. From planting to 2002, when the stage of established plantation was stated on the basis of the plant state, the costs related to one plant were identical in both locations. The tables show that in this period the application of preparations increased the individual costs by 5–11%. The total costs for the same period, if calculated per 1 ha and including the costs of compensation of losses, more or less copied this difference (Tables 14, 15). The highest costs were incurred in the case of the application of TC, the lowest costs in the case of SF and BA. Even if the height growth of ash on Střimice dump was statistically significant in the long term on plots with FR, as it was in the case of SF for a period of three years, the above-mentioned preparations did not substantially reduce the time necessary for the establishment of the plantation. The plants achieved

Table 13. EPRU evaporation pond II – costs invested in the existence of 1 seedling on the experimental plot in 1997–2004

Year	Costs per preparation (CZK/seedling)			
	CO	TC	BA	SF
1997–2002	172.93	191.83	182.70	180.83
2003	16.00	16.00	16.00	16.00
2004	9.52	9.52	9.52	9.52
1997–2004	198.45	217.35	208.22	206.35
Index CO = 1.0	1.00	1.10	1.05	1.04

Table 14. Střimice dump – total costs of the cultivation of ash from the foundation of the plot in 1997 to the stage of established plantation, calculated per 1 ha (6,700 seedlings) and by 2004

Var.	Improvement (%)	Provision (year)	1997–2002		1997–2003		1997–2004	
			CZK	(%)	CZK	(%)	CZK	(%)
FR	5	2002	1,261,505	108.5	1,414,265	107.5	1,532,319	106.9
TC	2.5	2002	1,290,487	111.0	1,443,247	109.7	1,561,301	108.9
BA	0	2003	1,224,090	105.3	1,376,850	104.7	1,494,904	104.3
SF	5	2002	1,218,576	104.8	1,371,336	104.3	1,489,390	103.9
CO	5	2002	1,162,426	100.0	1,315,186	100.0	1,433,240	100.0

Table 15. EPRU evaporation pond – total costs of the cultivation of ash from the foundation of the plot in 1997 to the stage of established plantation, calculated per 1 ha (6,700 seedlings) and by 2004

Var.	Improvement (%)	Provision (year)	1997–2002		1997–2003		1997–2004	
			CZK	(%)	CZK	(%)	CZK	(%)
TC	17.5	2002	1,329,725	113.0	1,436,925	111.9	1,500,709	111.3
BA	2.5	2002	1,227,754	104.3	1,334,954	103.9	1,398,738	103.8
SF	7.5	2002	1,222,404	103.9	1,329,604	103.5	1,393,388	103.4
CO	20.0	2002	1,177,069	100.0	1,284,269	100.0	1,348,053	100.0

this state almost simultaneously in all the variants within six years after planting, even if the ashes supported by FR were the highest and they nearly approached the establishment already in course of the fifth year. The long-term statistical significance of height growth, if compared with control plants, was not determined in any of the tested conditioners or fertilisers in EPRU location. The stage of the established plantation in this grass-covered area was stated in all the variants equally in six years after planting. If compared with control plants, the costs in the case of the application of preparations were higher by 4–13%.

On the basis of the observation of this aspect, we may draw a conclusion that in tested doses and periods of application, the tested conditioners and fertilisers did not substantially reduce the time necessary for the achievement of the stage of established plantation since when the requirements for further interventions and thus the costs rapidly decrease. Their application increased the costs by up to 13%. If we accept, for the purpose of the objectivity of the experiment assessment, a 10% tolerance in the potential dispersion of total costs given by the work with trees as a variable biological material, the errors during the measurement of plants or the assessment of the established plantation, we may state that all the preparates, with the exception of TC, are within the degree of the cost tolerance defined in this way.

CONCLUSION

Two long-term experiments with European ash, based on anthropogenic substrates in pollution-damaged zones showed that the selected soil conditioners manifested their declared effects only partially. In the applied dose, Frisol manifested itself as an agent that may cause problems with the seedling survival, but at the same time, also as a preparation improving the overall growth of young plants statistically significantly. Its effective dosage heavily depends on the soil character. TerraCottem did not show any beneficial effects on the survival rate and growth of plants in different soil environments. The application on dumps was ineffective. The application of Bio-algeen had a positive effect on the plant survival. This preparation did not surpass the control in the plant growth. Silvamix Forte, as a pelleted fertiliser, did not reduce the survival rate and managed to increase the growth statistically significantly for 1–3 years. From the economic aspect, the conditioners and Silvamix Forte did not markedly accelerate the growth and development until the stage of established culture.

References

BULÍŘ P., 1997. Supportive factors of growth and their influence on woody plants. In: Biological and Technical Development in Horticulture 2. Brno, Mendel University of Agriculture and Forestry: 292–296.

BULÍŘ P., DUBSKÝ M., 1998. Vliv moderních chemických preparátů Bio-algeen a TerraCottem na prosperitu okrasných dřevin. Acta Pruhoniciana, *66*: 15–36.

FUCHS J., 1995. Wissenschaftliche Exaktversuche zur Frage des Aufkommens und Wachstums von Fichtenpflanzen bei schwierigen Aufforstungen. Im Einklang mit der Natur. Salzgütter, Gebrüder Friedrich: 1–14.

PUHLOVÁ I., ŠMELKOVÁ Ľ., 1998. Vplyv hydroabsorbentu TerraCottem na rast semenáčikov smreka obyčajného (*Picea abies* L. Karst.) a buka lesného (*Fagus sylvatica* L.). Lesnictví-Forestry, *44*: 10–15.

SALAŠ P., 2002. New technologies and improvement of nursery stock quality. Horticultural Science, *29*: 153–160.

SALAŠ P., 2004. Use of waste material in cultivation substrates. Acta Universitatis Agriculture et Silviculture Mendelianae Brunensis, LII (2): 43–52.

SOUKUP J. et al., 1987. Vyšetřování zahradnických půd a substrátů. Aktuality. Průhonice, VÚOZ.

ŠTÝS S., 2001. Rekultivace Severočeského hnědouhelného revíru v proměnách času. In: CD-Rom. Sanace a rekultivace krajiny po těžbě uhlí. Teplice.

VALLA M. et al., 1980. Cvičení z půdoznalství II. [Učební texty VŠZ Praha.] Praha, SNP.

VAN COTTEM W., 1996. Hydroabsorbční polymery – nové možnosti využití. In: Využití hydroabsorbentů pro potřeby zahradní architektury, zahradnické produkce a lesnictví. Lednice na Moravě, MZLU: 3–13.

WEISSBACHER J., 1995. Der Einsatz organischer Dünger bei Hochlangenaufforstungen. Im Einklang mit der Natur. Salzgütter, Gebrüder Friedrich: 1–10.

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Vliv půdních kondicionérů na růst jasanu ztepilého (*Fraxinus excelsior* L.) na výsypkách

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ABSTRAKT: Na dvou pokusných plochách s odlišnými antropogenními substráty byl sledován vliv půdních kondicionérů TerraCottem, Frisol, Bio-algeen a hnojiv Silvamix Forte a Cererit na ujímavost a růst sazenic jasanu ztepilého do stadia nazývaného zajištěná kultura. Osmileté pokusy ukázaly, že testované prostředky naplnily deklarované účinky v daných podmínkách jen částečně. Aplikace TerraCottemu byla statisticky neprůkazná jak v aspektu ujímavosti, tak růstu. Frisol se v použité dávce projevil jako prostředek, který může způsobovat problémy při ujímání sazenic, ale současně i jako preparát zlepšující, a to statisticky průkazně, celkový růst mladých rostlin. Jeho účinné dávkování je silně závislé na charakteru půd. Bio-algeen působil velmi dobře na ujímání sazenic, v počátečním růstu rostlin ale nepředčil kontrolní rostliny. Silvamix Forte nezpůsoboval úhyn sazenic, růst rostlin statisticky průkazně ovlivňoval 1–3 roky. Cererit v dané dávce vyvolal velkou mortalitu sazenic. Použití půdních kondicionérů ani hnojiva Silvamix Forte výrazně neurychlilo růst a vývoj do stadia zajištěné kultury. Náklady při aplikaci kondicionérů byly do této doby vyšší o 4–13 % proti nákladům u kontrolních rostlin.

Klíčová slova: TerraCottem; Frisol; Bio-algeen; Silvamix Forte; Cererit; jasan ztepilý; půdní kondicionéry; rekultivace; výsypky; antropogenní substráty; ujímavost a růst; náklady

Půdními kondicionéry rozumíme uměle vyráběné prostředky přírodní nebo syntetické povahy, které zlepšují chemické, fyzikální a biologické vlastnosti půd za účelem dosažení lepšího růstu a produkce pěstovaných rostlin. Jednou z oblastí uplatnění takových preparátů v praxi jsou (podle jejich výrobců a distributorů) rekultivace degradovaných půd a antropogenních substrátů. Rozsáhlá rekultivační činnost probíhá v ČR zejména v regionech dotčených povrchovou i hlubinnou těžbou nerostných surovin a ukládáním odpadů, konkrétně v Severočeském hnědouhelném revíru (SHR), na Sokolovsku a Ostravsko-karvinsku. Pro představu – jen v SHR je rozpracováno 5 400 ha rekultivací, z toho 3 310 ha lesnických. Půdní kondicionéry zde tedy mohou při rekultivaci území sehrát významnou úlohu, prokáže-li se v místních podmínkách jejich efektivnost.

K rekultivačnímu zalesňování se v SHR používá velmi často jasan ztepilý (*Fraxinus excelsior* L.). Tento druh byl proto zvolen jako experimentální dřevina k ověření a srovnávání vlivů vybraných půdních kondicionérů (TerraCottem – TC, Frisol – FR, Bio-algeen – BA) a hnojiv (Silvamix Forte – SF, Cererit – CE) na ujímavost sazenic a jejich počáteční růst při současném sledování nákladů pěstování do stadia zajištěné kultury. Ověřování a srovnávání efektů jednotlivých preparátů s kontrolou (varianty pokusu) probíhalo na dvou půdně a klimaticky odlišných lokalitách – Střimické výsypce a odkališti elektrárny Prunéřov (EPRU) (tab. 1 a 4–7). Pokusné plochy s jasanem 2/0 byly založeny metodou znáhodněných bloků ve čtyřech opakováních na jaře 1997. V každé variantě bylo vysazeno 10 sazenic. Aplikace přípravků proběhla souběžně s výsadbou dřevin v dávkách uvedených v tab. 2. Péče o pokusné plochy probíhala až do roku 2002 na obou plochách stejným způsobem, a to podle modelu, který používá rekultivační praxe. Sazenice byly dvakrát ročně okopány, dvakrát ožnuty a na podzim natřeny Morsuvinem, v roce 2002 (šestý rok) navíc přihnojeny 10 g NPK na sazenici. Od roku 2003 se péče o plochy diferencovala. Na Střimické výsypce se v tomto roce vynechala jedna okopávka a nátěr repelentem, na EPRU se okopávka již neprováděla, stejně tak i nátěr repelentem. V roce 2004 byly dřeviny na obou plochách přihnojeny 15 g NPK na sazenici, na Střimické výsypce se uskutečnilo ještě jednou ožnutí.

Monitorování a hodnocení ploch probíhalo každoročně a bylo zaměřeno na ujímavost, resp. úhyn sazenic a jejich přirůstání do výšky a tloušťky kmínku. Dynamika ujímavosti sazenic na stanovišti se vyhodnocovala pouze v průběhu prvního vegetačního období podle třístupňové stupnice (1 – usychající nebo suchá; 2 – živá, neprobuzená nebo částečně suchá; 3 – živá). V dalších letech se zjišťoval již jen úhyn a jeho příčiny. Měření ročních výškových přírůstků, celkové výšky a celkové tloušťky kmínku se uskutečňovalo vždy na konci vegetačního období. K měření výškových přírůstků a výšky rostlin byla použita měřicí lať, tloušťka osy se měřila posuvným měřítkem 5 cm nad kořenovým krčkem. Data o ujímavosti rostlin, výškovém a tloušťkovém růstu byla statisticky hodnocena analýzou rozptylu dvojného třídění v počítačovém programu Statgrafic plus, verze 1.

K ekonomickému hodnocení nákladů byly používány katalogy popisů a směrných cen stavebních prací 823–2 Rekultivace (ÚRS Praha 1997–2004) i ceny materiálů od výrobců, resp. výhradních distributorů nebo velkoprodejců. Náklady na pěstování jedné sazenice v jednotlivých variantách ošetření a jednotlivých letech se sčítaly za pracovní operace a specifikované materiály podle realizované technologie. Pro zjištění efektivity použití kondicionérů se náklady poté přepočítaly na hektar (6 700 sazenic) a vztáhly se k době, kterou dřeviny potřebovaly k dosažení stadia nazývaného zajištěná kultura. Do těchto nákladů byly zahrnuty i náklady na potřebné vylepšování porostu vlivem ztrát do původního počtu dřevin přepočítaných na 1 ha. Za základ ztrát bylo vzato procento uhynulých sazenic, zjištěné na konci prvního vegetačního období. Stejný procentuální údaj byl použit pro vylepšování výpadků u již vylepšovaného porostu v dalších letech, dokud počet rostoucích (živých) rostlin nedosáhl předpokládaného počtu 6 700 kusů.

Ujímavost a mortalita sazenic na sledovaných dvou plochách je prezentována v tab. 3. Na Střimické výsypce všechny přidané preparáty proti kontrole (KO) zpožďovaly rašení, zvláště pak FR a TC. Aplikace BA a SF rovněž tlumila rašení, avšak méně znatelně. Zvolená dávka CE způsobila velmi rychle po výsadbě rapidní úhyn sazenic. Na odkališti EPRU nebyly počáteční útlumy rašení tak výrazné jako na Střimické výsypce, výjimku tvořily FR a CE. Definitivní vyhodnocení ujímavosti sazenic provedené přesně rok po výsadbě, na jaře 1998, ukázalo statisticky signifikantní rozdíly proti všem zbývajícím přípravkům u variant s CE, na lokalitě EPRU pak také u FR. Zvolené dávky CE a FR byly zřejmě k místním půdním a klimatickým podmínkám příliš vysoké, a proto vedly k nadměrné mortalitě sazenic. Pokles počtu sazenic v dalších letech trvání pokusu kondicionéry ani hnojiva již neovlivnily. Ztráty byly způsobeny částečně posekáním při ožínání vysoké buřeně, zčásti požerem kořenů myšovitými hlodavci. Pokus ukázal, že na lehčích a vzdušnějších půdách vyšší dávky FR sice zpomalily ujímání, avšak v celkovém hodnocení nezpůsobily abnormální úhyny sazenic. V těžších půdách s nižší vzdušností (EPRU) však stejné dávky vedly ke statisticky prokazatelným výpadkům sazenic. Cererit na obou lokalitách způsobil velké ztráty, které byly patrné velmi brzy po jeho aplikaci. Ostatní testované přípravky měly na ujímavost sazenic spíše pozitivní vliv, avšak statisticky neprůkazný. Nejlepší výsledky na obou pokusných plochách v tomto ohledu vykazovaly parcely s aplikací BA. Růstové parametry dřevin jsou zachyceny v tab. 8–11. Na Střimické výsypce měly – ve srovnání s kontrolními výsadbami – statisticky průkazný pozitivní vliv na dloužívý (výškový) růst dva přípravky – FR a SF. Vliv FR byl zřejmý od druhého roku (1998) a trvá dodnes. Pozitivní účinky SF nastaly rovněž ve druhém roce a skončily v roce čtvrtém, kdy došlo pravděpodobně k dočerpání živin. Trvaly tedy tři roky. U zbývajících přípravků nebyl vliv v tomto ohledu nikdy statisticky signifikantní. Analogická je průkaznost i v tloušťkovém přirůstání. Na odkališti EPRU byla proti kontrole statisticky průkazná celková výška rostlin u TC v prvním roce a u SF ve druhém roce. V dalších letech již průkaznost nebyla zaznamenána. Ve srážkově podprůměrném prvním roce se dobře projevil i TC obsahující hydrogely, které uvolňují zadrženou vodu rostlinám právě v obdobích absence přirozených srážek. V dalších letech však tento efekt nebyl zjištěn.

Statistické vyhodnocení tloušťkového přirůstání ukazuje, že žádný z testovaných preparátů během osmi let nebyl v tomto kritériu lepší než kontrola. Kratší efektivní podporu dlouživého růstu nebo žádnou (tloušťka) lze vysvětlit mj. tím, že na čerpání živin obsažených v tomto hnojivu se spolupodílelo také husté travobylinné patro, do kterého byly jasany vysázeny, a živiny tak byly rychleji zužitkovány.

Náklady na výsadbu a péči o jednu rostlinu na obou pokusných plochách v jednotlivých letech obsahují tab. 12 a 13. Z nich vyplývá, že aplikace přípravků zvýšila individuální náklady v tomto období o 5–11 %. Celkové náklady za stejnou dobu v přepočtu na 1 ha při započítání nákladů na vylepšování nezdarů pak tuto diferenci víceméně kopírovaly (tabulky 14 a 15). Nejvyšší náklady byly při použití TC, nejnižší pak u SF a BA. Přestože výškový růst jasanu na Střimické výsypce byl na parcelkách s FR dlouhodobě statisticky průkazný (a po dobu tří let také se SF), tyto přípravky zásadně nezkrátily dobu potřebnou na zajištění kultury. Tento stav docílily rostliny téměř současně ve všech variantách po šesti letech od výsadby, i když jasany s podporou FR z nich byly nejvyšší a k zajištění se značně přiblížily již v pátém roce. Na lokalitě EPRU nebyla zaznamenána ve výškovém růstu dlouhodobá statistická průkaznost proti KO u žádného testovaného kondicionéru ani hnojiva. Stav zajištěné kultury byl shledán na této zatravněné ploše ve všech variantách rovněž po šesti letech od výsadby. Náklady při aplikaci přípravků zde stouply o 4–13 % proti kontrolním rostlinám. Ze sledování tohoto aspektu můžeme vyvodit závěr, že testované kondicionéry ani hnojiva ve zkoušených dávkách a termínu aplikace zásadně nezkrátily čas potřebný k dosažení stadia zajištěné kultury.

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