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Growth of Austrian pine (*Pinus nigra* Arnold) treated with soil conditioners on Loket spoil bank

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ABSTRACT: The effects of soil conditioners Frisol, TerraCottem, Bi-algeen, and fertilisers Silvamix Forte and Cererit on the welfare of Austrian pine were observed in a seven-year experiment on Loket spoil bank. Simultaneously the economic aspects of growing the Austrian pine until the stage of established plantation were examined. The application of products one year and a half after planting did not cause seedling mortality. The elongation growth of young plants conditioned by the application of Silvamix Forte and Frisol was statistically significant whereas these effects manifested themselves in the second year: they persisted till the end of the experiment for Silvamix Forte, and for three years in total for Frisol. The other products – TerraCottem, Bi-algeen and Cererit – also showed generally better, though statistically insignificant results as compared to those of the control plants. The elongation growth for all products culminated in the fifth year and then declined. The stem diameter growth for the best products reached its maximum in the second year. Regarding the overall height growth after seven years, the average number of the highest plants on the experiment location was on plots treated with Silvamix Forte; these plants exceeded the control plants by 46.2 cm. Pines treated with Frisol were higher by 23.4 cm. However, the application of soil conditioners and fertilisers to the given location proved economically ineffective because there was no need to improve the soil at the location, the same applies to mowing and hoeing since almost no forest weed grew there and the substrate surface remained well-aerated and porous.

Keywords: Frisol; TerraCottem; Bi-algeen; Silvamix Forte; Cererit; Austrian pine; soil conditioners; fertilisers; spoil banks; survival rate; growth; costs

Austrian pine (*Pinus nigra* Arnold) ranks among the tree species that have proved suitable for the reforestation of spoil banks in the Sokolov Lignite Basin region, where it is still used for these purposes. This practical reason brought us to our decision to select it as an experimental species for testing the soil conditioners of Frisol, Terracottem, Bio-algeen (known as Bi-algeen in the CR) trademarks, their manufacturers and dealers (www.gebruederfriedrich.de, www.terracottem.com, www.schulze-hermsen.de) recommend, among others, as suitable even for reclamation objectives. The manufacturers tested the products abroad, very often under diverse geographical, climatic and soil conditions – arid zones, deserts, high-elevation zones, or in experiments with other plant groups – grasses, vegetables, flowers, fruit and ornamental tree species, e.g. Van Cottem (1996), Labeke (1994), Fuchs (1995), Weissbacher (1995). The above-mentioned products have also been tested in this country and their application in agriculture (www.hareko.info, www.bioalgeen.cz), horticulture (Salaš et al. 1996; Řezníček, Salaš 1996; Bulíř, Dubský 1998; Salaš 2002, 2004; www.terracottem.cz), forestry (Kriegel, Jurásek 1992; Sarvašová 2001), and building construction (www.skanska.cz) is known. However, knowledge of the application to forestry reclamation of anthropogenic substrates in the Central European emission zones is missing in the subject literature. Therefore, the objective of this long-term experiment was to observe and examine the effects of selected soil conditioners on spoil banks and to compare these effects with those of selected domestic fertilisers regarding their impact on the growth of Austrian pine seedlings up to the stage of established plantation. The other objective was to

observe and assess, within this time period, the economic effectiveness of the reclamation process.

MATERIAL AND METHODS

The following soil conditioners and fertilisers were tested and assessed in an experiment with Austrian pine seedlings (2/1) pricked out in rows 1.5 m × 1 m: Frisol A (FR A), Frisol F (FR F), TerraCottem (TC), Bi-algeen S-90 (BA S), Bi-algeen granulate (BA G), Silvamix Forte (SF) and Cererit (CE). For brief specifications of these products and fertilisers refer to Bulíř (2005).

The experimental location established on Loket spoil bank is situated in the moderately warm B3 climatic zone, with an average annual air temperature of about 6.4°C, and an average total annual precipitation level of about 600 mm, of which 400 mm falls during the vegetation period. The basic meteorological data measured at the nearest weather station in the course of the experimental observations is shown in Table 1. The experimental location substrate consisted of quaternary soils with a portion of grey clay. The soil profile showed an off-white soil-like coarse sand at 0–2 cm; a light grey, slightly ferruginous, sandy soil at 2–10 cm; a tamped sandy grey-coloured substrate at 10–13 cm; and a ferruginous-grey sandy soil of various grading underneath. The substrate physical and chemical properties identified at the beginning of the experiment are shown in Tables 2 and 3.

A randomised block design with eight replications was used on the experimental plots in the location. Five seedlings were planted on each plot (experimental variant). The application of conditioners and fertilisers was carried out just once in the spring of 1998, one year and a half after the original planting of pine seedlings. The doses of single products are shown in Table 4. Granulate products (FR F, TC, BA G, CE) were evenly scattered around each planting hole and then slightly forced with a hoe into the root zone of seedlings. Two SF pellets were put in notches made in a regular pattern around the holes by the planter. Liquid products (FR A, BA S) were water-diluted and then applied to seedlings with a watering can.

Since the substrate remained aerated and no forest weed grew over, there was no need for either mowing or hoeing in the course of the experiment whatsoever, except the first two years. However, the plants were treated with the repellent Morsuvin in autumn each year to protect them from nibbling by animals. In the sixth year of the experiment after the application of products, the treatment with Mor-

Table 1. 1997–2004 average temperatures and average precipitation levels at the Karlovy Vary weather station

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Average temperatures													
1997	–4.6	1.3	3.8	4.0	12.0	14.5	15.5	17.6	12.4	5.3	1.6	–0.2	6.9
1998	–0.2	2.1	2.5	7.9	12.7	15.7	15.2	15.7	11.3	7.1	–0.5	–1.8	7.3
1999	–0.8	–2.6	3.4	7.1	12.4	13.5	17.7	15.6	15.4	6.8	0.6	–0.3	7.4
2000	–2.3	1.5	2.8	9.3	13.8	16.1	13.9	17.1	12.1	8.9	3.6	–0.3	8.0
2001	–2.4	–0.3	1.9	5.5	13.5	13.1	17.2	17.5	9.6	10.6	1.4	–3.5	7.0
2002	–1.6	2.6	3.2	6.1	13.4	16.6	17.0	17.5	10.9	6.3	3.1	–3.0	7.7
2003	–2.7	–4.7	3.3	6.4	13.7	19.1	17.7	19.7	12.4	3.4	3.3	–1.5	7.5
2004	–3.7	0.1	1.6	7.6	9.8	14.2	16.2	17.7	12.5	8.5	2.5	–1.6	7.1
Long-term average	–3.2	–2.2	1.3	5.7	10.9	14.2	15.8	15.1	11.7	7.0	1.6	–1.8	6.4
Average precipitation levels													
1997	9.7	59.5	43.2	33.6	30.1	47.8	85.7	53.4	32.9	59.3	15.8	51.2	522.2
1998	24.4	12.1	33.2	34.6	39.0	85.2	101.1	45.6	119.5	132.1	41.0	17.4	685.2
1999	43.0	63.7	34.9	22.7	58.3	67.7	43.9	50.0	42.4	25.4	31.6	30.8	514.4
2000	29.3	37.9	94.0	15.2	44.4	71.5	66.6	53.7	41.1	54.5	34.8	19.5	562.5
2001	33.7	19.2	92.7	46.1	36.0	45.3	73.2	41.4	96.3	28.9	47.4	61.4	621.6
2002	29.0	73.6	43.3	18.4	49.9	78.5	27.8	128.9	71.7	62.1	95.2	75.4	753.8
2003	29.9	5.0	8.3	27.4	58.6	59.1	78.2	12.7	23.5	55.8	14.4	27.7	400.6
2004	48.8	27.9	14.3	20.8	97.7	88.9	81.1	70.1	81.0	33.8	76.5	30.4	671.3
Long-term average	38.0	32.0	36.3	39.8	65.1	71.4	69.1	68.8	54.9	39.3	40.5	43.8	598.2

Table 2. Physical properties of the substrate on Loket spoil bank experimental location on June 16, 1998 (average of three probes)

Profile (cm)	Bulk density (g/cm^3)	Particle density (g/cm^3)	WPS (% vol.)	Porosity (% vol.)	AS (% vol.)
0–5	1.37	2.41	30.4	42.7	12.3
5–10	1.45	2.43	29.7	40.5	10.8
10–20	1.50	2.44	28.9	38.5	9.6
20–40	1.55	2.43	30.4	36.4	6.0
40–60	1.46	2.43	29.3	39.7	10.4

WPS – water pore space, AS – air space

Table 3. Chemical analysis of the substrate on Loket spoil bank experimental location on June 3, 1998 (average of three probes)

Profile (cm)	pH	EC (mS/cm)	Contents of nutrients (mg/100 g of substrate)				
			$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca
0–20	4.1	0.04	1.2	2.0	0	4.7	60
20–40	4.2	0.02	1.0	1.7	0	4.7	62
40–60	4.1	0.03	1.0	2.2	0	5.0	68

EC – electrical conductivity

Table 4. Doses of soil conditioners and fertilisers for Austrian pine on Loket spoil bank

Variant	Dose
FR	FR F 60 g/seedling + FR A 250 ml/5 l of water/5 seedlings
TC	30 g/seedling
BA	BA G 10 g/seedling + BA S 10 ml/5 l of water/5 seedlings
SF	40 g/seedling = 8 pellets
CE	15 g/seedling
CO	control – without application

suvin was stopped because the plants had already grown sufficiently.

The method of measuring the total annual height and stem diameter growth was used at the end of each vegetation period. A measuring stick was used to measure annual shoots. The stem diameter was measured with a slide gauge 5 cm above the root collar. All the measured data was analysed by two-way analysis of variance (ANOVA). Statistically significant differences between means were evaluated by Multiple Range Tests using the significance level $p < 0.05$; all this was done using the Statgrafic plus, version 1, programme.

For the economic assessment of costs the catalogues of descriptions and indicative prices of construction works 823-2 Reclamations (ÚRS Prague 1998–2003) were used, as well as the wholesale prices of seedlings and products taken from their manufacturers or distributors. The labour and material costs of planting and growing one seedling were accumulated for single years until the stage of established plantation (established culture). The accumulated costs were then recalculated to the cost per one hectare (6,700 seedlings).

The meteorological data on average monthly temperatures and total precipitation was acquired from the Karlovy Vary weather station of the Czech Hydrometeorological Institute in Prague. The pedological analyses were carried out in accordance with Novák in Valla et al. (1980) and Soukup et al. (1987).

RESULTS AND DISCUSSION

Survival rate of seedlings

All the plants set out remained healthy and vital at the experiment location till 2002. After 18 months from planting the application of soil conditioners and fertilisers to Austrian pine in selected doses

Table 5. 1998–2004 average annual height growths of Austrian pine on Loket spoil bank

Variant	1998	1999	2000	2001	2002	2003	2004
CO	12.6 a	15.2 d	18.3 b	22.3 c	22.6 b	13.9 c	14.4 bc
FR	11.3 a	28.4 a	25.7 a	26.9 ab	22.5 b	14.2 bc	14.3 bc
TC	11.4 a	19.1 bc	21.2 b	24.7 bc	28.4 b	12.4 c	13.5 bc
BA	12.1 a	17.0 cd	18.8 b	23.5 bc	24.2 b	16.6 bc	16.9 bc
SF	12.0 a	22.0 b	26.4 a	30.3 a	31.1 a	21.6 a	24.1 a
CE	12.0 a	20.2 bc	20.9 b	23.7 bc	24.4 b	18.5 b	18.7 b

(Table 4) thus did not cause any additional mortality to the plants. As recently as in summer of the above-mentioned year, deer destroyed one pine on the TC-treated plot while cleaning/casting antlers and a vandal cut down the two best growing pine trees (on the SF- and FR-treated plots) for Christmas. In this sense, the experiment confirmed the conclusions from other experimental locations (Bulíř 2005) where the losses of plants in the second vegetation year were not caused by the applied agrochemicals but by other factors. In this case, the mortality of seedlings was not affected by the warmer weather and lower average total precipitation level in years following the application of products (Table 1) but exclusively by wildlife and humans.

Growth parameters

The height and stem diameter growth in 1998 to 2004, as well as the total height and diameter of pines in this period, are shown in Tables 5 to 8.

No statistically significant impact on the height (longitudinal) growth in the year of application was identified for any of the tested products. In the second year after the application, the plants showed a statistically significantly better growth in all experimental variants except BA, compared to the control plants, whereas the longest annual shoots were measured for FR. The third and fourth years showed definite benefits of FR and SF with the SF dominance. The remaining products also showed better growth rates in comparison with the control plants, but these were not statistically significant. The statistically positive impact of FR on the height growth stopped in the fourth experimental year, whereas that of SF lasted even in the final (seventh) year of observation. The height growths for all products culminated in the fifth year, then they declined and remained at approximately the same level. The progression till the fifth year was probably influenced by the supplied nutrients and other similar components contained in the products, and also by above-average temperatures and primarily the higher precipitation level (Table 1). The growth decline that occurred from the sixth year was probably caused by the drop-off in nutrients or their depletion and/or leaking. The height growth dominance on the SF-treated plots that was maintained till the end of the experiment was probably influenced by the reserves of stored nutrients generated in the previous years because the positive effects persist for three years as described in literature (e.g. Kubelka 2001) and in another experiment (Bulíř 2005). The acquired knowledge for SF is similar to that of Remeš et al. (2004) from observations of the growth of spruce seedlings in the emission zone.

In the seven years of the experiment, the highest plants grew on the SF- and FR-treated plots. From the third year after application their total height was always statistically significant in comparison with the control plants, whereas there was no statistical significance for the remaining products (Table 6). In 2002, when the highest growth was measured in the whole experimental period, the pines on the SF-treated plots were 28.8 cm higher than the control plants on average. In the case of the FR-treated plots,

Table 6. Average overall height of Austrian pine on Loket spoil bank

Variant	1998 spring	1998 autumn	1999	2000	2001	2002	2003	2004
CO	26.0 a	38.6 a	53.8 b	72.1 c	94.4 b	117.0 c	130.9 c	145.3 c
FR	25.4 a	36.7 a	65.1 a	90.8 a	117.7 a	140.2 ab	154.4 ab	168.7 b
TC	23.7 a	35.1 a	54.2 b	75.4 bc	100.1 b	128.5 bc	140.9 bc	154.4 bc
BA	25.2 a	37.3 a	54.3 b	73.1 c	96.6 b	120.8 c	137.4 c	154.3 bc
SF	24.0 a	36.0 a	58.0 b	84.4 ab	114.7 a	145.8 a	167.4 a	191.5 a
CE	23.4 a	35.4 a	55.6 b	76.5 bc	100.2 b	124.6 c	143.1 bc	161.8 bc

Table 7. Average annual stem diameter growths of Austrian pine on Loket spoil bank

Variant	1998	1999	2000	2001	2002	2003	2004
CO	3.4 a	5.8 d	7.5 b	7.7 bc	5.8 b	5.4 a	4.2 a
FR	3.4 a	10.8 a	8.8 ab	8.7 abc	7.4 a	4.6 a	3.7 a
TC	2.7 ab	8.1 c	8.8 ab	9.3 a	7.3 ab	5.6 a	3.9 a
BA	2.1 b	8.7 bc	8.1ab	9.1 ab	6.2 ab	4.5 a	4.8 a
SF	2.9 ab	10.6 ab	9.1 a	9.8 a	7.3 ab	6.1 a	5.4 a
CE	2.8 ab	8.5 c	8.0 ab	7.2 c	6.4 ab	5.1 a	4.0 a

Table 8. Average overall stem diameter of Austrian pine on Loket spoil bank in the period 1998–2004

Variant	1998 spring	1998 autumn	1999	2000	2001	2002	2003	2004
CO	14.4 a	17.8 a	23.6 b	31.2 c	38.7 b	44.4 c	49.8 d	54.0 c
FR	14.0 ab	17.4 ab	28.2 a	37.0 a	45.7 a	53.0 a	57.2 ab	60.9 ab
TC	12.9 ab	15.7 bc	23.8 b	32.6 bc	41.9 ab	49.8 ab	55.4 abc	59.4 abc
BA	14.0 ab	16.0 abc	24.7 b	32.8 bc	41.9 ab	48.1 abc	52.6 bcd	57.4 bc
SF	12.7 ab	15.6 bc	26.2 ab	35.3 ab	45.1 a	52.3 a	58.4 a	63.7 a
CE	12.5 b	15.3 c	23.7 b	31.7 bc	39.0 b	45.3 bc	50.4 cd	54.4 c

the height difference was 23.2 cm in comparison with CO. The pines treated with other products were higher by 3.8 cm to 11.5 cm on average. However, these differences were not statistically significant, as has already been stated. At the end of the experimental period (2004), the average height differences between the most successful products (SF, FR) and the control were 46.2 cm and 23.4 cm, respectively. The total height of plants on the TC-, BA-, and CE-treated plots also exceeded that of the control ones, however, the differences were insignificant.

The stem diameter growths also became statistically significant in the second year after the application of conditioners and fertilisers. The measurement showed a positive effect of all the products. In the following years, only the SF-treated pines showed better growth for another two years; after a break also the TC- and FR-treated plants (Table 7). The most significant stem diameter growths were identified in the second through the fourth year. Thus, the dynamics of stem diameter growth did not correspond to that of the height growth. In contrast to the height (longitudinal) growth, the decline of the stem diameter growth occurred one year sooner.

The overall stoutest stems, identified through the test as being statistically significant in comparison with the control pines, were measured in pines on the FR- and SF-treated plots regularly as of the second and third year, respectively, till the end of the experiment (Table 8). In the year with above-average (2002) and below-average (2003) precipitation level, also TC, containing hydrogels holding water and

Table 9. 1996–2004 costs invested in the existence of 1 seedling

Year	Costs per product (CZK/seedling)					
	CO	FR	TC	BA	SF	CE
1996	10.57	10.57	10.57	10.57	10.57	10.57
1997	5.64	5.64	5.64	5.64	5.64	5.64
1998*	6.44	20.88	26.34	17.27	15.34	14.07
1999	1.49	1.49	1.49	1.49	1.49	1.49
2000	1.59	1.59	1.59	1.59	1.59	1.59
2001	1.55	1.55	1.55	1.55	1.55	1.55
2002	1.61	1.61	1.61	1.61	1.61	1.61
2003	–	–	–	–	–	–
2004	–	–	–	–	–	–
1996–2002	28.89	43.33	48.79	39.72	37.79	36.52
Index CO = 1.0	1.0	1.50	1.69	1.37	1.31	1.26

* The year when conditioners and fertilisers were applied

Table 10. Dynamics of Austrian pine established plantation according to years and product variants

Variant	Provision (%)			
	2000	2001	2002	2003
CO	–	62.5	75	100
FR	50	87.5	100	100
TC	12.5	75	87.5	100
BA	12.5	75	75	100
SF	37.5	75	100	100
CE	–	87.5	100	100

making it available to plants in dry periods, showed itself positive in this sense. At the end of 2004, the SF- and the FR-treated pines had thicker stems on average, by 9.7 mm and 6.9 mm respectively, than those of the control plants. The stems of pines on the remaining plots treated with conditioners and CE were also measured and were found to be thicker in comparison with CO, however, the measured data was not statistically significant.

The observations of the stem diameter growth showed that SF and FR were the best of the tested products – just as it was for height growth.

Economic evaluation

Table 10 shows the costs of planting Austrian pine on Loket spoil bank for the particular experimental years. From the very beginning, the tending given to the tree species on the experimental location covered only chemical protection against animals (repellent treatment) and one hoeing during the vegetation period in the first two years because there were hardly any weeds and the coarse-grained substrate had specific properties. Up to 2002, there was no mortality of seedlings, thus no improvement was needed.

The first established plantation plots on the experimental location were observed in 2002, i.e. in the fifth year after planting and in the third year after the first application of products. The number of established plots further increased in 2001 to 2002. All variants reached the stage of established plantation in 2003 (Table 9).

The data given in Table 10 shows that the conditioners and fertilisers shortened the time needed for reaching the stage of established plantation (culture). Nevertheless, the time reduction did not distinctly lower the relatively high input costs of conditioners and their application, representing the crucial part of the total costs (Table 11) in 1998. It was so because the specific properties of the substrate in the location allowed good aeration and wetting in the root zone of plants and prevented the grasswort vegetation from successful growing. Thus, there was no need for costly mowing and hoeing in any year. Even though no improvement of the experimental location was necessary in the course of the experiment, and no ordinarily practised tending of the tree species site needed to take place, the application of the tested products proved economically ineffective. Growing pines treated with TC was 69% more expensive than growing pines on the control plots. The very good and statistically more significant growth of the SF and FR variants observed over the years did not have an adequate economic response, either. Regarding FR and SF, the costs of growing pines up to the stage of established plantation were 48% and 29% higher, respectively, than the costs of growing the control plants.

Table 11. Loket spoil bank – recalculation of costs/ha (6,700 seedlings) according to the time to reach the established plantation stage. Establishment (1996) and growing (1997–2004) CZK costs

Variant	Establishment (1996) and growing (1997–2004) costs (CZK)										
	1996	1997	1998	1999	2000	2001	2002	2003	2004	1996–2004	index
CO	70,819	37,788	43,148	9,983	10,653	10,385	4,045	–	–	186,821	1.00
FR	70,819	37,788	139,896	9,983	10,653	5,179	1,348	–	–	275,666	1.48
TC	70,819	37,788	176,478	9,983	10,653	7,990	1,348	–	–	315,059	1.69
BA	70,819	37,788	115,709	9,983	10,653	9,321	2,697	–	–	256,970	1.38
SF	70,819	37,788	102,778	9,983	10,653	6,658	2,697	–	–	241,376	1.29
CE	70,819	37,788	94,269	9,983	10,653	10,385	1,348	–	–	235,245	1.26

CONCLUSION

The experiment carried out on Loket spoil bank in the Sokolov Lignite Basin mining district with Austrian pine (*Pinus nigra* Arnold) tested soil conditioners of the Frisol, TerraCottem, Bi-algeen trademarks and fertilisers of Silvamix Forte and Cererit trademarks. The effects of these agrochemicals were assessed by the method of measuring the growth of shoots and stem diameters and subsequently they were evaluated statistically. The seven-year experiment showed the statistically significant support of two products – Silvamix Forte and Frisol – to the growth of pine in both the above-mentioned parameters from the second year after their application. The effect of statistically better growth of shoots of the FR-treated pine persisted for three years and that of the SF-treated pine was evident for six years. The long-term positive impact of pelleted fertilisers can be explained by the formation of larger reserves of assimilatory nutrients in the first four years after application when the pine seedlings had a plenitude of the nutrients contained in this product. Measuring the overall average height and stem diameter proved that the pines treated with SF and FR showed a statistically more significant growth rate lasting till the end of the experiment in 2004. The result corresponds with the hypothesis on the existence of larger reserves of assimilated nutrients formed in the course of the more intensive growth period owing to the active effect of the product and availability to the plant after the effects of a conditioner or a fertiliser fade. TerraCottem, Bi-algeen as well as Cererit also improved the overall, though statistically insignificant, growth of pines. Although both SF and FR sped up reaching the stage of established plantation by one year in comparison with the control plants, their application at the given location incurred 29% and 48% higher costs, respectively. This discrepancy between the demonstrably better growth, the reduction of the time to reach the stage of established plantation and the higher costs was caused by the 100% survival rate of seedlings and the almost zero tending as a result of the specific quality of the substrate and location. It can be assumed that the economic effectiveness of soil conditioners and fertilisers for other types of substrates would be more favourable.

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Růst borovice černé (*Pinus nigra* Arnold) na Loketské výsypce pod vlivem půdních kondicionérů

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ABSTRAKT: V sedmiletém pokusu založeném na Loketské výsypce byl testován vliv půdních kondicionérů Frisol, TerraCottem, Bi-algeen a hnojiv Silvamix Forte a Cererit na prosperitu borovice černé. Souběžně byly sledovány ekonomické aspekty pěstování borovice do stadia zajištěné kultury. Aplikace přípravků jeden a půl roku po výsadbě nezpůsobila v použitých dávkách žádné úhyny rostlin. Výškové přirůstání dřevin statisticky průkazně ovlivnilo použití Silvamixu Forte a Frisolu, přičemž tyto efekty byly evidentní od druhého roku; u SF trvaly do konce pokusu, u FR celkem tři roky. U zbývajících preparátů – TerraCottem, Bi-algeen a Cererit – bylo dosaženo také vesměs lepších výsledků než u kontrolních rostlin, ale ne statisticky průkazně. Výškové přirůstání vrcholilo u všech přípravků v pátém roce, poté zesláblo. Tloušťkové přirůstání u nejlepších preparátů bylo největší ve druhém roce. V celkové výšce po sedmi letech byly na pokusné ploše průměrně nejvyšší rostliny na parcelách se SF, které kontrolní rostliny předčily o 46,2 cm. Borovice s podporou FR byly vyšší o 23,4 cm. Ekonomicky se nasazení kondicionérů a hnojiv na dané lokalitě ukázalo jako neefektivní, neboť plochu nebylo třeba vylepšovat, a také odpadlo ožínání a okopávání sazenic, protože zde nerostla téměř žádná buřeň a povrch substrátu zůstával vzdušný a propustný.

Klíčová slova: Frisol; TerraCottem; Bi-algeen; Silvamix Forte; Cererit; borovice černá; půdní kondicionéry; hnojiva; výsypky; ujímavost; růst; náklady

V experimentu založeném na Loketské výsypce v Sokolovském hnědouhelném revíru byly na borovici černé (*Pinus nigra* Arnold) testovány půdní kondicionéry obchodních značek Frisol (FR), TerraCottem (TC), Bi-algeen (BA) a hnojiva Silvamix Forte (SF) a Cererit (CE). Pokus byl založen na ploše kvartérních zemin s podílem šedého jílu a uspořádán metodou znáhodněných bloků variant v osmi opakováních. Každá parcela (varianta) zahrnovala pět sazenic. Celkový počet rostlin ve variantě byl tedy 40 kusů. Aplikace přípravků v dávkách uvedených v tabulce 4 se uskutečnila jeden a půl roku po výsadbě. Účinky uvedených agrochemikálií na růst borovice černé v počáteční fázi pěstování byly zjišťovány metodou každoročního měření přírůstků letorostů a přírůstků tloušťky kmínků. Získaná data byla následně vyhodnocována statisticky analýzou rozptylu dvojného třídění (ANOVA). Průkaznost rozdílu mezi průměry hodnot byla testována mnohonásobným srovnáváním na hladině významnosti $p < 0,05$. Vedle sledování vlivu půdních kondicionérů a hnojiv na prosperitu sazenic bylo dalším cílem pokusu kalkulování a srovnávání nákladů na pěstování borovice u jednotlivých preparátů, a to do stadia zajištěné kultury. Výpočty byly prováděny ve vazbě na růst a za pomoci standardních ceníků prací a materiálů používaných rekultivační praxí. Sedmiletá doba existence a hodnocení pokusu ukázala statisticky průkaznou podporu růstu borovice v obou sledovaných biologických parametrech u dvou preparátů – Silvamixu Forte a Frisolu, a to od druhého roku po aplikaci. Efekt statisticky lepších přírůstků letorostů trval u FR tři roky, v případě SF byl evidentní šest let. Dlouhodobý pozitivní účinek tabletovaného hnojiva vysvětlujeme vytvořením větších rezerv asimilátů v prvních čtyřech letech po aplikaci, kdy borovice měly k dispozici dostatek živin obsažených v tomto preparátu. Při měření celkové průměrné výšky rostlin a tloušťky jejich kmínků vykazovaly borovice statisticky průkazně lepší hodnoty růstu u SF a FR až do doby skončení pokusu v roce 2004. V tomto posledním roce hodnocení pokusu byly borovice s podporou SF vyšší průměrně o 46,2 cm a s podporou FR vyšší o 23,4 cm než borovice na kontrolních parcelkách. Výsledek koresponduje s hypotézou o existenci

větších rezerv asimilátů vytvořených během období intenzivnějšího růstu vlivem aktivního působení přípravku, disponibilních rostlině po odeznění účinků kondicionéru či hnojiva. TerraCottem, Bi-algeen i Cererit zlepšovaly také celkový růst borovic, nikoliv však statisticky průkazně. Pokus rovněž ukázal, že testované půdní kondicionéry a hnojiva ve zvolených dávkách nezpůsobily během jeho trvání žádný úhyn sazenic. Přestože SF i FR ve srovnání s kontrolními rostlinami urychlily vstup do stadia zajištěné kultury o jeden rok, jejich aplikace si vyžádala na dané lokalitě vyšší náklady o 29 %, resp. o 48 %. Uvedený nesoulad mezi prokazatelně zlepšeným růstem, zkrácením času do zajištění kultury a vysokými náklady způsobila 100% ujímavost rostlin a potřeba minimální péče, vyplývající ze specifické kvality substrátu a stanoviště. Lze se domnívat, že na jiných substrátech se ekonomická efektivnost půdních kondicionérů a hnojiv ukáže v příznivějším světle.

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