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INITIAL RESULTS OF PLANTATIONS OF *LARIX EUROPAEA* L. ESTABLISHED FOR RECULTIVATION

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Abstract

The aim of the present study was to study success and development of coniferous trees for the needs of intensive plantations for biomass production, used in the recultivation process of mine-spoilt banks of opencast mines in the Kolubara basin. For this purpose, an experiment with European larch seedlings, aged 2+0, which lasted for four years in plots with seven repetitions was set. The distance between the rows with the seedlings was 1 m, and 2.5 m between the plants in a row. Out of the initial 1,000 seedlings 90.5% and 77.4 % survived in the first and second year after planting, respectively. At the later stages, the decay of the plants almost stagnated (up to 74.8%). From autmn 2007 to spring 2010 total height increment of seedlings was 1.17 m. Total root collar diameter increment was nearly1.9 cm. The highest increment was reported during the last vegetation of seedlings (in spring 2010): diameter increment was about 1.2 cm and height increment was about 0.9 m.

Differences between seedlings from sludge treated and untreated, control deposols (measured in spring 2010), were significant. Treated seedlings showed better results in mean root collar diameter as well as in mean height of seedlings (2.5 cm and 1.7 m, respectively) in comparing with untreated (control) ones (1.9 cm and 1.0 m, respectively). The results obtained justify the future more intensive establishment of plantations of this fast-growing conifer species. European larch also appears to be suitable for growing on mechanically damaged substratum.

Key words: European larch, survival of seedlings, growth, increment, recultivation.

Introduction

The European larch (*Larix europaea* Lam. et DC.) is a conifer naturally prevalent in disjunct areas in the high mountain massifs of Central Europe. The mode of distribution promotes the existence of a number of geographic races, subspecies and varieties (Vidaković 1982). Larch is a pioneer-species. The formation of heartwood begins at a very early age, and therefore, it has a large proportion of heartwood even at a relatively young age. This makes it usable for purposes where chemically treated wood was used earlier (Bergstedt and Lyck 2007).

Due to its rapid growth and height increment, as well as resistance to air pollu-

tion and tolerance to different soil types, the European larch is widely prevalent beyond its areal, in artificially established plantations at different altitudes (in forest plantations, parks, forest parks, etc.).

The provenances from Poland and Sudetes Mountains showed the best results, as well as the second generation of Danish sources (Brandt 1977 and Bornebusch 1948, ex Bergstedt and Lyck 2007). Since the first experiments conducted at waste dump sites of opencast mines in Indiana, USA (cited in Dražić 2002), European larch has performed successfully in many other forest plantations. It was due to the improvement of soil characteristics resulting from rapid accumulation of leaf litter, for instance in Germany and Pennsylvania, as well as in height and width increment, for instance in Denmark (Medvick 1973, Illner et al. 1967, Miles et al. 1973 and Schlatzer 1973, respectively, all cited in Dražić 2002), Bulgaria (Milev et al. 2004) and Serbia (Dražić 2002, Šmit et al. 1997, etc.). Apart from the European larch, other *Larix* species were also used for afforestation (Lukkarinen et al. 2009) with variable success among provenances.

Sludge is frequently used to improve the characteristics of sandy (Gál 1984), and degraded soils (Dželetović et al. 2009, and references therein), since it simultaneously influences both physical and chemical characteristics of soil, combined with fast plant growth (Hall and Coker 1983). The distribution and availability of heavy metals presents an open issue (Tsadilas et al. 1995). But there was no evidence that toxic materials and heavy metals would accumulate in the trees at higher quantities of sludge (Gál 1984). The effects of heavy-metal-containing sewage sludge on the soil microbial community were also examined (Bååth et al. 1998). Community tolerance to specific metals increased the most when the same metal was added to the soil. There were also indications of co-tolerance to metals whose concentration had not been elevated by the sludge treatment. Therefore, it is expected that the sludge treatment will have positive impact not only on the growth of larch seedlings, but also on other flora on degraded soil, as well as chemical and physical characteristics of deposol.

The aim of the study was to investigate the success of the development of the larch trees for the needs of the short-rotation intensive plantations for biomass production in the recultivation process of mine-spoilt banks of opencast mines.

Matherial and Methods

The experiment was set in the Kolubara basin, Baroševac locality, with European larch seedlings, aged 2 + 0. It lasted for four years. The distance between rows with seedlings was 1 m, and 2.5 m between the plants in a row, in seven replications (plots, 6 x 25 seedlings in one plot). The distance between the seedlings enabled the mechanical processing during the cycle of the plantation establishment. The care measures were regularly applied in the seedlings, including supplementary fertilization.

The plantations were established on a soil substratum belonging to the sandy loam class, with slight acid reaction (pH = 4.9) and low humus concentration (0.94%). C/N ratio was low (2.62), concentration of phosphorus was also low

(< 1 mg.g^{-1} of substratum), but concentration of potassium was medium (13.2 mg per 100 g of substratum). In the spring of the first year after planting, the initial nourishment was carried out with 30 g of NPK mineral fertiliser per seedling in order to ensure the highest planting rate and initial growth. The nourishment of one part of seedlings was carried out with sludge, which, according to its texture composition, comes under a loam class. It was characterised by a mild alkaline reaction of soil solution. The pH of sludge was 7.3, while substitution pH was 6.6. The concentration of total humus was exceptionally high (73.48%), the concentration of total nitrogen was low (0.64%), the C/N ratio was high (66.6) and the concentration of phosphorus (5.5 mg per 100 g of substratum) and potassium (8.6 mg per 100 g of substratum) were within the low limits. Determining the success of development of European larch seedlings on the sample plot was done by using literature sources on the same and other fast-growing conifers, established on similar and different substrata.

Results

Out of the initial about 1,000 seedlings, 90.5% and 77.4 % survived in the first and second year after the transplatation, respectively, At the later stages, the decay of the plants almost stagnated (74.8%, Table 1). Total height increment of seedlings (from autmn 2007 to spring 2010) was 1.17 m. Total root collar diameter increment of seedlings was 1.86 cm. During the first two years after the transplation (2007 and 2008) the

Table 1. Survival, growth and increment of larch seedlings (2007–2010).

Parameters	Spring 2007	Autumn 2007	Autumn 2008	Spring* 2009	Spring 2010	Total Increment 2007–2010
Total number of seedlings	1009	913	781	781	755	
Survival, %	100	90.5	77.4	77.4	74.8	
Height, m (**X** ± Sx)		**0.34** ± 0.40	**0.38** ± 0.50	**0.58** ± 1.14	**1.51** ± 2.56	
Height increment, m			0.04	0.20	0.93	1.17
Root collar diameter, cm (**X** ± Sx)		**0.51** ± 0.05	**0.87** ± 0.12	**1.22** ± 0.18	**2.37** ± 0.32	
Root collar diameter increment, cm			0.36	0.35	1.15	1.86

* Measurements in 2009 were done after the beginning of vegetation period.

average root collar diameter and its increment were quite low. The highest increment was reported during the last vegetation of seedlings (in spring 2010): diameter increment was about 1.2 cm and height increment was about 0.9 m.

Differences between seedlings from sludge treated and untreated, control deposols (measured in spring 2010), were significant (Table 2). Treated seedlings showed better results in mean root collar diameter as well as in mean height of seedlings (2.51 cm and 1.68 m, respectively) in comparing with untreated (control) ones (1.94 cm and 0.97 m, respectively). Furthermore, height of seedling showed several times greater variability than root collar diameter, both in treated and control seedlings (expressed by the standard deviation, Table 2).

Discussion and Conclusion

The obtained results of height and width growth and increment were compared to the previously analysed increment of larch plantations also planted on deposols of opencast mines in the Kolubara basin, plot D (Dražić 2002). The dynamics of diameter development of larch seedlings in this sample plot was approximately the same as the development dynamics of an average stand stem in a larch plantation planted on deposol of heavier mechanical composition, but significantly lower than those planted on deposol of lighter mechanical composition. These differences obviously depend on the mechanical and chemical properties of deposols. In terms of height and height increment, larch seedlings had lower height and height increment in comparison to the previously planted larch plantations, regardless of mechanical composition of deposol. However, it should be considered that these larch plantations were planted more thickly and have not been thinned.

The average larch height increment (up to the 16th year) on deposols of opencast mines in the Kolubara basin was 0.88 m and volume increment 4–10.37 $m^3.ha^{-1}$ (Šmit and Veselinović 1996). Larch has also shown the largest average volume increment, as compared to *Pinus nigra* and *Pinus sylvestris*, as well to numerous broadleaves. Having in mind these data, along with the fact

Table 2. Differences between sludge treated and untreated (control) larch seedlings (2010).

Measured properties	Root collar diameter, cm		Height, m	
Treated / Control	Treated	Control	Treated	Control
No of seedlings	571	183	571	183
Minimum value	0.90	0.70	0.12	0.29
Maximum value	5.90	4.20	3.80	3.20
X ± Sx	**2.51 ± 0.35**	**1.94 ± 0.34**	**1.68 ± 2.66**	**0.97 ± 2.63**
S ± Ss	**8.34 ± 0.25**	**8.20 ± 0.24**	**63.45 ± 1.88**	**62.90 ± 1.86**

X – mean; **Sx** – standard error of the mean;
S – standard deviation; **Ss** – standard error of the deviation.

stated by Dražić (2002) that the larch, in period between the 6th and 13th year, shows relatively consistent ascending development, and that the medium stand tree experiences abrupt growth between fifth and ninth year, it could be assumed that the larch trees analysed in this study will continue their intensive growth and development, in particular the ones treated with sludge. When studying the impact of sludge quantity on development of *Larix laricina* seedlings Couillard and Grenier (1989) did not found whether the different sludge quantity influenced the seedling growth, but they concluded that there was a significant, positive correlation between the growth of seedlings and the phosphorus and nitrogen content of their tissues, as well as that these elements originated from the wastewater sludge. The obtained results in this study justify the future more intensive establishment of plantations of this fast-growing conifer species. European larch also appears to be suitable for growing on mechanically damaged substratum.

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