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EFFECTS OF SOIL PREPARATION ON THE SUCCESS OF ARTIFICIAL BEECH REGENERATION IN AREAS INFESTED BY WEEDS ON JUŽNI KUČAJ MOUNTAIN, SERBIA

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Abstract - This paper presents the results of research on the effects of prior soil preparation on artificial regeneration by mountain beech forests (*Fagenion moesiacae montanum*) in weed-covered plots on Južni Kučaj Mountain. Research was conducted on the survival of one-year-old containerized seedlings in weed-covered sites where different auxiliary measures had been carried out, i.e. the following methods of soil preparation: 1) control area, with no preparation; 2) living forest ground cover (blackberry) removed; 3) living forest ground cover removed and soil tilled to a depth of 10 cm; 4) only the soil tilled. The above treatments were performed with five repetitions each for further statistical processing. Analysis of variance showed no statistically significant difference at level $p < 0.05$ in initial seedling height, so that this did not considerably affect the influence of the different soil preparations on seedling growth. Half of the planted seedlings were treated with the chemical "Zeba" in order to establish and monitor its effects and needs for its use. The product has a sponge effect underground, meaning that it can absorb and retain moisture in the soil to be used later by the plants. The analysis carried out showed that only in certain elements were there statistically significant differences in one-year-old seedling height increment (annual shoot length).

Key words: Beech forests, Južni Kučaj, artificial regeneration, auxiliary measures, Serbia

INTRODUCTION

Beech forests in Serbia occur as special altitude belts where they comprise the greater number of basic groups of ecological units (Jović et al., 1991). Within these zones, beech forms four altitude belts: submountain beech forests (*Fagenion moesiacae submontanum*), mountain beech forests (*Fagenion moesiacae montanum*), beech-fir forests (*Abieti-Fagetum*) and subalpine beech forests (*Fagenion moesiacae subalpinum*). Submountain beech forests occur in the oak altitude belt, above which the beech builds a belt of regional climate vegetation.

It is known that there is a good natural rejuvenation of beech in stands characterized by a humid climate and under the canopy of crowns in old stands, and that a sudden opening up – breaking of the formation – does not suit it. The basic principles of natural beech regeneration have been described (Tschermak, 1950; Vyscot et al., 1978; Matthews, 1989; Stojanović and Krstić, 2000, etc.). A more detailed analysis – the modeling of natural beech regeneration depending on various factors – was performed by Madsen and Larsen (1996), and the analysis of the dependence of natural beech and fir regeneration on certain habitat factors and stand conditions was carried out by Krstić et al. (1997), Keren et al. (2011) and others.

Sparse and weed-infested stands represent a particular degradation stage that requires the appropriate ameliorative measures. In these stands, there is often weed infestation on the surface that creates unfavorable conditions for the appearance of offspring, and successful natural regeneration can only be expected with the use of auxiliary measures. Consequently, in plots where there is no possibility for natural regeneration, it is necessary to raise new artificial forests by planting seeds or saplings (Krstić and Stojanović, 2004). The need, feasibility and methods of artificial regeneration of degraded beech forests have been clearly shown by Krstić (2006). Potential woody species for the revegetation of degraded sites have been described by Kostić et al. (2012).

Isajev et al. (2002, 2010) presented data on the improvement of technological processes of targeted production of planting material for artificial cultivation, the possibility of introducing conifers into beech coppice forests in Serbia (Isajev et al., 2004), and the variability, breeding and reforestation of beech in Serbia (Isajev et al., 2005).

Stojanović et al. (1996) and Krstić et al. (2006, 2012) presented the task of silviculture and the need for enhancement of forest conditions in the future, particularly in terms of current climate change, as well as the importance of research on the problems of amelioration of degraded forests that have been conducted abroad. Aleksić et al. (2011) pointed out the silvicultural needs in the implementation of the National Forest Action Program in Serbia.

Beech forest stand conditions on Južni Kučaj, where the research was conducted, are characterized by very heterogeneous development and complete to incomplete tree canopy. This makes the natural regeneration of these forests far more complex than it should be. The major problem in the study site is blackberry (*Rubus sp.*), with stalks (vines/runners) that can reach lengths of several meters and a thickness of 2-3 cm, twining up to waist height. The blackberry completely covers the offspring that, because of deprivation of light and living space, withers. According to research done in beech and fir forests on Goč Mt. and current knowledge in similar stand conditions, only 10% of the total number of seedlings survive in the first growing season on weed-covered surfaces outside the canopy, and below the tree crowns a third of the plants survive. It is only after 3-5 years from the appearance of seedlings that successful natural regeneration can be said to have occurred (Krstić, 2000). Therefore, it is necessary to properly prepare the soil in order to create favorable conditions for natural regeneration. This has been done through numerous studies in forests of different tree species by Pintarić (1970) for fir, Stojanović and Josović (1984) for spruce, Krstić (1997) for Sessile oak, Krstić (2000) for fir and beech, etc. According to research by Krstić (2000), in plots where tillage was carried out, the number of beech samplings was about 2.5 times greater than on surfaces where only weeds had been removed.

Based on the above-mentioned, and with the aim of determining the impact of weed infestation on the possibility of renewing beech forests in circumstances where it is hindered, the following studies were conducted: 1) establishing and monitoring the survival of young beech on weed-infested surfaces and openings in forest formations where, after the application of various ancillary measures (soil preparation), one-year-old containerized beech seedlings were planted; 2) establishing and monitoring the survival of beech seedlings treated with the biodegradable product "Zeba", identifying its effects and the need for its use.

MATERIALS AND METHODS

Studies were carried out on the mountain massif Južni Kučaj, located in eastern Serbia, in the Timok forest area. The forests on the study site belong to a complex of mesophilic beech and beech-coniferous forest types, a group of environmental units: mountain beech forest (suballiance: *Fagenion moesiacae montanum*) in different brown soils. The bedrock consists of decaying crystalline schists. The soil is distric (acid) brown, middle-deep (40-80 cm), semi-loose, fresh, skeletoidal (10-30% of skeleton). The process of humification is favourable.

Studies were conducted on the site Brezovica, a plateau at the top of a ridge, at an altitude of 990 m, slope of terrain 5-7^o, with moderate northern terrain exposure. The main climate characteristics of this altitudinal belt (1000 m a.s.l.) over a multiannual period (1961-2000) are as follows: average annual air temperature 5.5^{o}C, in the growing season 13.1^{o}C; average annual precipitation 692 mm, of which 58.4% falls in the growing season. According to the Thornthwaite classification, the climate is slightly humid – B_1 (Krstić, 2005).

In the canopy openings, the surface is very overgrown, covered with blackberry 0.5 to 0.7 m in height. The opening where the research was conducted is oval in shape, with a long axis almost twofold times greater than the height (45 m) and width almost equal to the height of mature trees.

In the analyzed opening, there was a "block" of sample plots with different soil preparation. The characteristics of the sample plots were as follows: SP size is 8 x 8 m (0.64 are); the plot was divided into small lots measuring 2 x 2 m (scheme in Figure 1); in these lots, different soil preparation was carried out (four treatments, with four repetitions each). The layout of the sample plots is shown in Figures 2 and 3. The treatments were arranged so that in a single row or column there were not two of the same type. This made it possible to obtain an average value for the entire plot, which was important for further statistical processing: 1) control area, with no preparation; 2) ground vegetation (blackberries) removed by mowing; 3) area tilled to a depth of 10 cm, causing some damage to and breaking-up of the blackberry growth; 4) blackberry removed and ground tilled (Fig. 1).

One-year-old containerized beech seedlings of an average height of 10 cm, produced in the "Selište" nursery near Bor, were planted in the prepared plots. The seeds originated from a seed stand on Mt. Južni Kučaj, management unit "Zlotske šume" (compartments 36/e and 37/c). The distance between the planted seedlings was 0.7 x 0.7 m, i.e. 0.6 m. In this way, on each small lot (treatment) 9 seedlings were planted, 144 beech seedlings in total. This means that 22.500 seedlings were planted per hectare with the intention of simulating dense natural regeneration, giving each seedling the same living space.

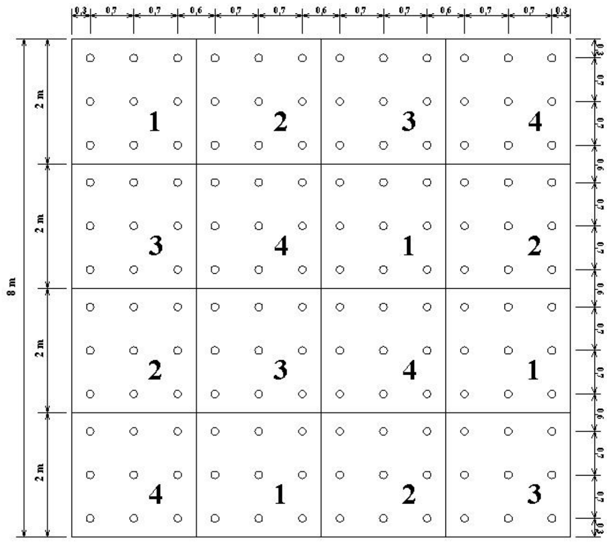

Fig. 1. Scheme of plot preparation and seedling arrangement (treatments)

Fig. 2. Sample area overgrown by blackberry

Half of the planted seedlings were previously treated with the biodegradable product "Zeba" in order to identify and monitor its effects and the need for its use. The product has a sponge effect –

Fig. 3. Sample area after completion of various treatments for soil preparation

it can absorb and retain moisture in the soil, which the plants can later use for their own purposes. It is made up of granules based on starch that, according to the catalogue data, have the capacity to absorb 500 times their own weight of water, which makes them "superabsorbent". In addition to use in agriculture, it is suitable for use in horticulture and reforestation by dissolving in water (2.4 g. per liter of water). The recommended amount for forest tree seedlings is 7.5 to 15 ml of solution per plant. The root of the seedlings was dipped into the solution before planting and then the stated amount was added into the holes dug for the seedlings and mixed with soil. Half of the seedlings were treated with the product. i.e. every other row. In this way, 6 rows with 12 seedlings each were treated, i.e. 72 out of a total of 144 seedlings. The different treatments (different soil preparation and treatment with chemical "Zeba") are marked as follows:

Containerized Seedlings Common
1) Control plot (no treatment)
2) Blackberry removed by mowing
3) Ground tilled to a depth of 10 cm
4) Blackberry removed and ground tilled

Containerized Seedlings treated with "Zeba"
5) Control plot (no treatment)
6) Removed blackberry by mowing
7) Ground tilled to a depth of 10 cm
8) Blackberry removed and ground tilled

The experiment was set up in autumn 2010, after the end of the growing season. The first count of plants and corresponding measurements on the sample plots were carried out in autumn 2011, after the first growing season.

In order to process the data and determine the differences between the compared treatments, variational and statistical methods were used – analysis of variance, test of equality of arithmetic population means, as well as cluster analysis.

RESULTS AND DISCUSSION

The emergence of abundant offspring is not a guarantee of successful natural regeneration of beech forests, which mainly depends on the preservation of offspring. Depending on the state of the stand and environmental conditions, due to a greater opening of canopy high weed infestation occurs, preventing regeneration and seedling survival and maintenance. The greatest obstruction is blackberry because it can reach "waist height".

Because of the open canopy and high weed infestation of some of the plots in the stand where the research was conducted, there has been no natural tree regeneration. According to Krstić and Stojanović (2004), the situation can be repaired in two ways: using extra measures to provide conditions for natural regeneration, or executing artificial regeneration by filling the gaps. According to Lavadinović and Krstić (2009), the Moesian beech represents a significant genetic resource in Serbia and has a very important role in biodiversity in Serbia (Mijović et al., 2012); therefore, it is certainly reasonable to use it for the artificial regeneration of beech forests. The reforestation of burned areas in beech forests and areas overgrown with blackberry was executed by sowing seeds in holes dug by hoe (Krstić et al., 2011). According to Krstić (2006), beech saplings with free roots or roots in turf, aged from 2+0, height 20-40

Table 1. Initial seedling height (cm) – descriptive statistics

Treatment	min	мах	Arithmetic mean	Standard error	Lower quartile	Upper quartile	No. of data
1	6.0	14.5	8.66	0.62	7.3	10.0	16
2	6.0	16.0	9.07	0.62	7.7	10.4	15
3	3.0	12.0	8.71	0.63	7.4	10.1	17
4	4.5	21.0	8.70	0.81	7.0	10.4	18
5	4.0	18.0	10.30	0.97	8.2	12.4	15
6	5.0	15.0	10.44	0.66	9.1	11.8	17
7	3.0	16.0	11.09	0.71	9.6	12.6	17
8	7.0	15.0	10.88	0.54	9.7	12.0	16
Average	4.81	15.93	9.72		9.2	10.2	131

Table 2. Annual seedling height increment (cm) – descriptive statistics

Treatment	min	мах	Arithmetic mean	Standard error	Lower quartile	Upper quartile	No. of data
1	5.5	17.0	10.09	0.76	8.5	11.7	16
2	8.0	18.0	12.30	0.76	10.7	13.9	15
3	3.0	19.0	11.15	1.03	9.0	13.3	17
4	4.0	16.0	10.72	0.82	9.0	12.2	18
5	3.5	21.0	12.27	1.10	9.9	14.6	15
6	7.5	17.5	12.88	0.69	11.4	14.4	17
7	7.5	16.0	11.35	0.56	10.2	12.5	17
8	4.0	22.0	13.3	0.99	11.2	15.5	16
Average	5.4	18.2	11.75		11.1	12.3	131

cm to 1+3 with height up to 120 cm, can be used for artificial regeneration; in deteriorated environmental conditions the height of seedlings must be at least 25-40 cm, and plant spacing 1.4 to 1.5 × 0.6 to 0.7 m (Krstić, 2006).

As mentioned above, one of the objectives of the study was to monitor and determine the survival of beech seedlings on weed-infested plots, establishing the effects of and need for different preparation treatments for plot regeneration. In the autumn of the following year, after the first growing season, the maximum height of blackberry on the treated surfaces was around 0.3 m and around 0.7 m on untreated ones.

Analysis of the data presented in Table 1 shows that out of the total number of seedlings planted (144), the number of plants analyzed was 131. This indicates that 91% of the seedlings survived the first year, i.e. one can expect to lose about 10%. This is certainly very favorable, given the statement by Korpel and Vinš (1965) that on overgrown plots in beech and fir stands, dominated by *Rubus* sp., less than 30% of natural offspring survive. On weed-covered plots on Mt. Goč where soil treatment was performed, the number of one-year-old plants (seedlings) of beech and fir was 4-5 times higher in comparison to plots with no treatment (Krstić, 2000). On plots overgrown with blackberry where the sowing of seeds in holes by hoe was executed, the survival rate after the first growing season under different site conditions was about 50% (Krstić et al., 2011).

It was also noted that there was a difference in the height of containerized seedlings used for reforestation. The smallest seedlings were only 3 cm in height, while the average minimum height was 5 cm. The maximum height was 21 cm, and the average maximum height was 16 cm. The total average height of all the planted seedlings was about 10 cm, and the maximum difference in their average height was only 2.4 cm. The borderline height, at which 25%

Fig. 4. Length of shoots on treated surface

Fig. 5. Appearance of the best seedlings on the Treat surface

of the seedlings were of small height, was 9.2 cm, and 25% of the seedlings had a greater height of 10.2 cm, confirming the statement that the average height of planted seedlings was about 10 cm.

By applying the Anderson-Darling Normality Test of data distribution, it was established that the schedule was normal in all three parameters analyzed. Assuming the requirement that the samples are randomly chosen, this is a precondition for undertaking the analysis of variance for testing the equality of the arithmetical means of the population (Lovrić, 2005).

The analysis of variance showed that there was no statistically significant difference at level $p<0.05$ in the initial height of seedlings planted in plots with different soil preparation. This was not significantly reflected on the effects resulting from various plot preparations on seedling growth.

Analysis of the annual height increment (shoot) of seedlings shows the following (Table 2): (i) the minimum height increment of shoots was 3 cm and the maximum 22 cm; (ii) the average value of the minimum length of shoots was 5.4 cm and the maximum 18.2 cm; (iii) the average length of shoots was about 12 cm. According to Krstić et al. (2011), the average height of one-year-old plants, on plots overgrown with blackberry where seeds were sown in holes, was 25.4 cm.

Table 3. Annual seedling height increment (shoot)

Treatment mark	Arithm. mean	Homogeneity 1	2
1	10.09	*	
4	10.72	*	*
3	11.15	*	*
7	11.35	*	*
5	12.27	*	*
2	12.30	*	*
6	12.88		*
8	13.31		*

Analysis of variance showed that only in certain elements were there differences in the one-year-old seedlings' height and shoot length (Table 3): (i) the difference in shoot length of seedlings planted in plots with different preparation methods was not statistically significant at level $p <0.05$, either among seedlings treated with "Zeba" or among untreated ones; (ii) for untreated seedlings, the biggest difference in average shoot length was 2.2 cm (18%) between the seedlings on the control plot and the plot from which blackberry was removed by mowing (treatments no. 1 and 2), but as mentioned, with no statistical significance. Although the length of the young shoots of fir was in proportion with the degree of illumination

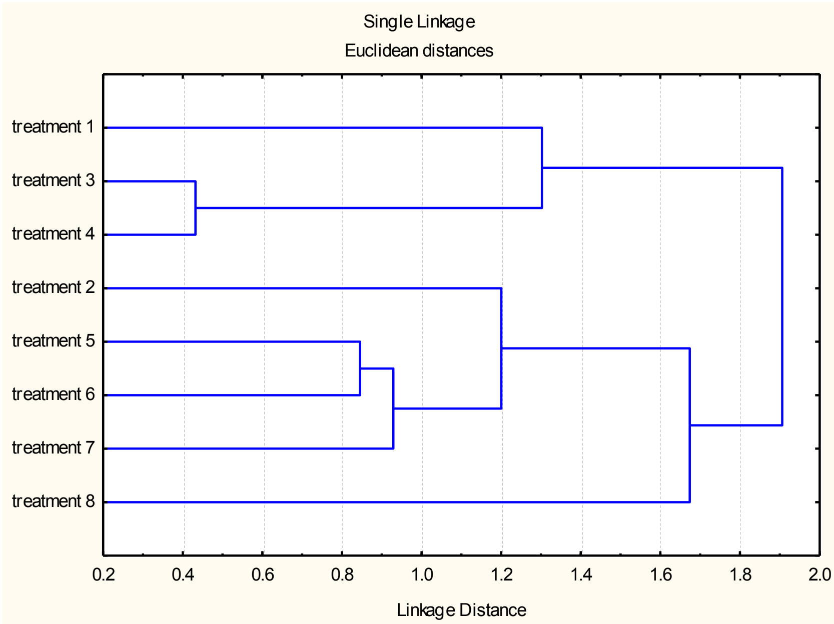

Fig. 6. Cluster analysis dendrogram based on initial seedling height and seedling height increment at one year

(Krstić and Macan, 1997), this was not observed in one-year-old beech seedlings on this occasion; (iii) for seedlings treated with "Zeba", the biggest difference in average shoot length of 1.9 cm (14%) was between seedlings on a tilled plot and those on a tilled plot from which the blackberry had been removed (treatments no. 7 and 8); this difference was also not statistically significant; (iv) there was a statistically significant difference in shoot length at the level of $p < 0.05$ only among seedlings treated with "Zeba" where blackberry had been removed by mowing and the soil tilled, and among untreated seedlings on the control plot (Table 3).

Based on the above, it can be concluded that the seedlings treated with "Zeba" had somewhat higher average values of shoots in the first growing season (Figure 6 – cluster analysis), but these were not so pronounced. Among other reasons, this was probably because the product was used in a beech forest at high altitude, where soil moisture is not deficient during the growing season.

Survival of natural offspring up to 5 years of age in overgrown plots was proportional to the degree (intensity) of soil preparation – 55-60% of plants survived in plots where tillage was carried out (Krstić, 2000).

CONCLUSION

In sparse beech stands, the surface is often overgrown with weeds, creating unfavorable conditions for the appearance of offspring, and there can be no successful natural regeneration without the use of additional measures. This is why it is necessary to raise artificial forests by planting new seeds or seedlings.

By studying the survival of one-year-old containerized beech seedlings planted in weed-covered plots where auxiliary measures had been carried out, i.e. the following methods of soil preparation (treatments) were applied: 1) control plot with no preparation; 2) living forest ground cover (blackberry) removed by mowing; 3) living forest ground cover removed and soil tilled to a depth of 10 cm, and 4) only tilled soil, the following was established: (i) in plots in stands with open canopy, weed infestation is of high intensity, particularly with blackberry which prevents successful natural regeneration; (ii) auxiliary measures (preparatory measures) contribute to a considerable increase in the number of offspring. In the first year, 91% of seedlings survived, i.e. a loss of about 10% of seedlings can be expected; (iii) the average length of shoots in the first growing season is about 12 cm; (iv) the difference in shoot length of seedlings planted on plots with different preparation methods is not statistically significant at level $p < 0.05$; (v) seedlings treated with the biodegradable product "Zeba", which has a sponge effect in that it can absorb and retain moisture in the soil, have somewhat higher average values of shoots in the first growing season; however, this also is not significant at $p < 0.05$.

For further survival of offspring it is necessary to ensure its maintenance (tending), which consists of increased light exposure and removal of blackberries by mechanical means, until such time as independence is established. Although technical literature offers recommendations for weed control by the use of chemicals (herbicides), given the importance of forests in water supply, i.e. the provision of healthy drinking water, this should not be done and is practically inapplicable. The solution must therefore be sought in mechanical weed control measures and the cutting of weeds.

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