DEVELOPMENT-PRODUCTION CHARACTERISTICS OF DOUGLAS-FIR AND EASTERN WHITE PINE CULTURES IN SERBIA

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Abstract: *The Sustainable Development Strategy, by adopting the principles of the Convention on Biodiversity Protection, prohibits the introduction of allochthonous species in natural ecosystems. The utilisation of allochthonous species (provided they are not on the invasive species list) is allowed in intensive plantations with specific purpose wood production (with a view to decreasing pressure on ecosystems) and in public greenery. The Douglas-fir and eastern white pine are the species characterised by high productivity and, therefore, their utilisation in intensive plantantions is indisputable. The paper presents the study on the production characteristics of Douglas-fir and eastern white pine cultures planted at different forest sites. The results are based on 31 sample plots located in different site conditions, in cultures aged 40 years.*

Key words: intensive plantations, Douglas-fir, eastern white pine, rotation

1. INTRODUCTION

Pursuant to the Convention on Biodiversity Protection, the introduction of allochthonous species in natural ecosystems is prohibited, and their utilisation (provided they are not on the invasive spacies list) is permitted in intensive plantations with specific purpose wood production and public greenery.

The Douglas-fir and eastern white pine are the species characterised by high productivity and, therefore, their utilisation in intensive plantantions is indisputable. However, in Serbia, there are no comparative studies on production characteristics of Douglas-fir and eastern white pine cultures.

The purpose of this paper is to enable a production forecast in intensive plantations, depending on site conditions.

2. OBJECT AND METHOD OF RESEARCH

In several localities in Serbia, Douglas-fir and eastern white pine cultures have been studied- in15 Douglas-fir culture sample plots and 19 eastern white pine culture sample plots. The age of studied cultures is 40 years. The cultures have been planted by application of different methods of coppice and degraded forests reconstruction (cordon method – in rows of width of 12, 14 and 18 metres, under the canopy of parent stand planting method, clear cuts in larger area).

The studied cultures are established in the following sites:

Site 1. Artificially established Douglas-fir (Pseudotsuga mensienzii) stand (code G3.F21) planted in an Italian oak, Turkish oak and butcher's broom <Ruscus aculeatus> forest site (code G1.7612)

Site 2. Artificially established Douglas-fir (Pseudotsuga mensienzii) stand (code G3.F21) planted in a mesic Sessile oak and hornbeam <Quercus petraea> - <Carpinus betulus> forest site (code G1.A1C1)

Site 3. Artificially established Douglas-fir (Pseudotsuga mensienzii) stand (code G3.F21) planted in a mesic montane beech and wood rush <Luzula> spp. forest site (code G1.6921)

Site 4. Artificially established Douglas-fir (Pseudotsuga mensienzii) stand (code G3.F21) planted in an Italian oak, Turkish oak and hornbeam <Carpinus betulus> forest site (code G1.7615)

Site 5. Artificially established Douglas-fir (Pseudotsuga mensienzii) stand (code G3.F21) planted in a mesic monodominant montane beech forest site (code G1.6941)

Site 6. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in a mesic acidophilus Sessile Oak <Quercus petraea> (code G1.871) forest site

Site 7. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in an Italian oak, Turkish oak and hornbeam <Carpinus betulus> forest site (code G1.7615)

Site 8. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in a mesic monodominant montane beech forest site (code G1.6941)

Site 9. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in a mesic monodominant acidophilus beech forest site (code G1.6926)

Site 10. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in a mesic acidophilus Sessile oak <Quercus petraea> forest site (code G1.871)

Site 11. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in an Italian oak, Turkish oak and hornbeam <Carpinus betulus> forest site (code G1.7615)

Site 12. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in a mesic monodominant montane beech forest site (code G1.6941)

Site 13. Artificially established eastern white pine (Pinus strobus) stand (code G3.F22) planted in an Italian oak, Turkish oak and butcher's broom <Ruscus aculeatus> forest site (code G1.7612)

3. RESEARCH RESULTS

The majority of analysed cultures have been thinned during the growth, (some of them even more than once). With regard to a forest site indices correlation, (Ratknić, 1996), Douglas-fir sample plots are quite consistent (ecological units 5 and 7 correlate to the forest site index 26, while all other units correlate to the forest site index 30. Regarding eastern white pine cultures, ecological units 16 and 11 correlate to the forest site index 26, while all the others correlate to the forest site index 30.

The number of trees is conditioned by the applied reclamation method and conducted thinning felling. As for the Douglas-fir cultures, it ranges between 525 and 1,826 per hectar, while in eastern white pine cultures, it is from 222 to 2,561. This indicates that, when conducting thinning treatments, there were no clearly defined criteria concerning the optimum number of trees, time and the intensity of thinning.

By using the information on Douglas-fir and eastern white pine development in natural habitats, a regression model has been created based on a tree number dependence upon breast diameter (for site indices which correspond to conditions in Serbia, (Ratknić, M., Rakonjac., Lj., 2010). The potential number of trees in Douglas-fir cultures of the same age ranges between 1,359 and 3,386, while in eastern white pine cultures it ranges between 1,237 to 2,609 trees. The potential number of trees indicates that their number is much higher than the real one and it depends on the mean breast diameter. The highest tree number in Douglas-fir cultures has been recorded in the ecological unit G1.7615 (planted by cordon method in form of rows of different width). In rows of the same width in the ecological unit 2, the potential number of trees is 53.9% lower in comparison to the number of trees in the ecological unit 3. The highest tree number in eastern white pine cultures is recorded in the ecological unit 11. The potential number of trees, in rows of the same width, in the ecological unit 10 is 16.1% lower than in the ecological unit 12.

The potential volume has been determined on the basis of established dependence between volume (V), number of trees (N), medium diameter (d_g), medium height and age (S). A multiplicative form model has been used:

$$V = S^{a1} . N^{a2} . d_g^{a3} . h_g^{a4} . a_b$$

The potential volume for Douglas-fir has been obtained by the following regression equation:

$$\ln V = 0.004898 \ln S + 0.980968 \ln N + 1.726571 \ln d_g + 1.0086651 \ln h_g - \ln 9.345005$$

$$R^2 = 0.9988 \qquad S_t = 2.1\ m^3/ha$$

The potential volume for eastern white pine has been obtained by the following regression equation:

$$\ln V = 0.0048981 \ln S + 1.014275 \ln N + 2.079605 \ln d_g + 0.4555721 \ln h_g - \ln 9.605412$$

$$R^2 = 0.9989 \qquad S_t = 4.6\ m^3/ha$$

The basic taxation data on these cultures are given in the tables 1 and 2.

The mean diameter of Douglas-fir culture stand ranges between 17.5 to 41.5cm, while the mean diameters of dominant trees are on average 34.3% larger in comparison to the mean stand diameters. The medium diameter of eastern white pine culture stand ranges between 19.5 to 43.0 cm. The mean diameter of dominant trees is approximately 36.1% larger. In comparison to Douglas-fir cultures, eastern white pine reaches approximately the same breast diameter value of mean dominant trees.

The basal area total in Douglas-fir cultures ranges between 20.7 and 47.7 m^2 per hectar. In eastern white pine cultures the basal area total ranges between 8.8 to 80.5 m^2 per hectar. The significant decrease of the basal area total is the result of the applied reclamation method and thinning felling. The potential basal area (on the basis of calculated potential number of trees) per hectare is significantly larger than the real one.

Eastern white pine cultures established in the site G1.6911 have the basal area total ranging between 8.8 to 33.6 m^2 per hectare. The potential basal area, however, is quite consistent, and it ranges between 61.6 to 69.07 m^2 per hectare, so that this value should not be neglected in the process of different site data comparison. For that purpose, the data on eastern white pine cultures planted in sites G1.6926 i G1.871 can be illustrative. The sample in the site G1.6926 consists of two areas, one of which has been thinned (IV), and the other (III) not.The basal area total is larger in the unthinned area, while the potential basal area has approximately the same value (table 2). In the site G1.871, where apart from the unthinned area, there are areas I_2, with thinning of 30% (per number of trees), and I_3 (with thinning of 50% per number of trees) the real basal area correlates to the tree number decrease, while the potential basal area is quite consistent (from 77.17 to 78.50m_2).

Table 1. **Main data on Douglas-fir culture**

Diameter (cm)		Height (m)		SI	Number of trees		Basal area		Volume		Increment	
D	d	H	h		N_s	N_m	G_s	G_m	V_s	V_m	iv_s	iv_m
Site: G1.7612												
34,7	26,1	28,9	27,3	30	912	1706	36,5	70,3	336	647	13,6	26,1
34,7	26,8	28,9	27,6	30	1022	1634	43,2	71,1	397	653	16,4	26,9
34,7	25,3	28,8	26,9	30	1094	1799	41,5	69,5	380	636	14,4	24,1
Site: G1.A1C1												
40,0	29,9	29,6	26,7	30	615	1359	32,4	70,9	291	636	15,6	34,1
Site: G1.6921												
24,0	17,5	24,7	21,3	30	1147	3386	20,7	61,5	165	492	6,7	19,9
28,0	19,9	26,4	22,7	30	1000	2720	23,2	63,2	193	527	9,1	24,7
28,0	19,7	26,4	22,7	30	1157	2751	26,4	63,6	219	527	8,9	21,5
Site: G1.7615												
32,9	25,7	25,7	23,7	26	963	1923	34,9	71,7	247	544	8,8	19,4
37,1	29,3	26,3	24,6	26	614	1543	28,9	73,1	209	569	9,2	25,0
Site: G1.6941												
41,5	31,7	25,9	25,2	26	720	1435	38,4	77,5	260	584	14,8	33,2
38,5	28,3	25,6	24,4	26	1074	1739	45,6	75,7	305	563	14,4	26,5

In eastern white pine cultures, the volume ranges from 72 to 607 m_3 per hectare. The potential volume is significantly higher than the real one. In sites G1.7612 and G1.A1C1 the volume value is approximately 130m_2 higher than the potential volume of Douglas-fir cultures planted in the site G1.6921. The Douglas-fir culture, with the rows of the same width, in the site G1.A1C1 has 17.2% higher volume than the culture planted in the site G1.6921. The potential volume in certain fields is even 8 times higher than the real one, particularly after the utilisation of a circular method reconstruction. The potential volume is, similarly to the basal area, in the framework of the same ecological units, quite even (the eastern white pine cultures planted in the site G1.6911 are the most characteristic). The ratio between the lowest and highest real volume value is 1 : 3.0, and the ratio between the lowest and highest potential volume is 1 : 1.2.

The mean stem size, in terms of volume, in Douglas-fir cultures ranges between 0.143854 m^3 (30.6%) to 0.473171 m^3 (100%), and in eastern white pine cultures from 0.16844 (34.41%) to 0.489784 m^3 per hectare (100%) and, to a large extent, it reflects

the applied reclamation method and the difference in forest site characteristics.

The potential volume increment of Douglas-fir cultures ranges between 13.6 to 25.6 m^3 per hectare. The volume increment percentage of the real volume ranges between 3.5 to 5.6% (with the exception of the ecological unit 6). The potential volume increment of eastern white pine cultures is between 12.2 and 28.7 m^3 per hectare.

Table 2. **Main data on eastern white pine culture**

Diameter (cm)		Height (m)		SI	Number of trees		Basal area		Volume		Increment	
D	d	H	h		N_s	N_m	G_s	G_m	V_s	V_m	iv_s	iv_m
Site: G1.871												
37,3	29,9	26,8	25,3	30	855	1295	44,80	69,73	400	623	14,0	21,7
Site: G1.6911												
29,3	22,4	24,3	21,3	26	846	2058	24,93	63,20	200	507	13,9	35,1
24,0	19,5	21,9	19,7	26	564	2609	12,53	61,60	95	465	3,3	16,4
28,0	21,1	23,2	21,3	26	486	2283	12,80	63,47	100	496	3,2	15,9
30,7	19,9	24,8	19,9	26	1411	2590	32,80	62,53	253	483	8,4	15,9
Site: G1.6911												
29,3	21,1	24,1	20,5	30	1009	2344	26,27	62,80	208	497	6,3	14,9
30,7	23,9	24,9	22,7	30	766	1896	25,60	66,40	211	547	7,1	18,3
36,0	26,9	26,0	22,9	30	784	1544	33,60	67,60	285	575	10,4	20,9
33,3	24,3	25,6	22,1	30	576	1844	19,87	65,33	165	544	6,3	20,7
30,7	25,9	25,3	22,9	30	222	1653	8,80	69,07	72	565	2,8	22,0
Site: G1.6926												
36,7	30,3	28,3	25,8	30	1850	1844	80,00	82,67	612	632	19,7	20,3
40,0	32,5	29,0	27,0	30	1325	1639	66,00	84,83	513	660	22,0	28,3
Site: G1.871												
36,7	25,8	28,8	24,3	30	2561	2422	80,50	77,17	607	582	18,7	17,8
38,3	28,5	29,8	25,3	30	1641	1049	62,83	78,33	492	613	20,0	6,9
36,7	26,8	29,0	25,0	30	1481	2270	50,00	78,50	380	597	18,2	28,5
Site: G1.7615												
35,7	28,3	26,1	23,4	30	747	1597	32,71	74,29	260	590	9,6	21,7
38,6	32,6	26,6	23,9	30	523	1256	30,57	74,86	256	626	9,0	22,0
41,5	32,8	26,3	26,0	30	1030	1410	56,31	82,77	443	651	12,8	18,8
Site: G1.6941												
43,0	33,6	22,4	21,0	26	842	1237	50,37	90,37	324	582	23,7	42,5
Site: G1.7612												
37,3	28,9	28,3	24,4	30	1137	1367	56,27	68,53	497	605	18,8	22,9

The stands are experiencing the high productivity phase. The volume increment in certain forest sites culminates or it is approaching culmination. The culmination of the average volume increment of the eastern white pine cultures takes place between 20th and 40th year. The maximum production period of eastern white pine cultures is between 20th and 40th year and it lasts relatively shortly, with Douglas-fir having the absolute advantage in that respect, particularly in longer rotations. Eastern white pine should be possibly given the priority in shorter rotations. Eastern white pine is a species more or less sensitive to snowbreak, windbreak (the damage has an impact on stem quality), as

well as certain diseases (*Vercicladella procera, Crontium ribicola, Armilaria melea*), and, therefore, the preventive measures ought to be taken when selecting a forest site for establishing cultures. Culture vitality ought to be maintained by constant silvicultural treatments in order to reduce the attack of pathogenic organisms to minimum. The soil of heavier mechanical composition and micro habitats exposed to stronger humidity (the condition of ecological unit 15) ought to be avoided when planting the eastern white pine. Furthermore, the eastern white pine should not be planted in carbonated soils. In view of the all abovementioned restrictions, the absolute priority (when choosing between these two species) in forest reconstruction process ought to be given to Douglas-fir, strictly paying attention to the seed provenance.

4. CONCLUSION

Based on the comparison of current and average volume increment, it can be concluded that the cultures are experiencing a high productivity phase (although the average increment has not culminated yet). The period of high productivity lasts relatively long, which enables Douglas-fir, in long rotations and with appropriate tending measures, to fully exploit a forest site production potential.

The period of high productivity of eastern white pine lasts shortly, therefore, in long rotations it does not fully exploit the forest site production potential, which is most pronounced in medium aged stands, in which insufficient stocking is recognised, resulting from excessive reduction of tree numbers.

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