

DEPENDENCE OF DOUGLAS-FIR MEAN HEIGHT ON GEOGRAPHIC ORIGIN OF CANADIAN PROVENANCES IN SEEDLING NURSERY CONDITIONS

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Abstract

Popović V., Lavadinović V., Bjelanović I., Lavadinović V.: Dependence of Douglas-fir mean height on geographic origin of Canadian provenances in seedlings nursery conditions. *Ekológia (Bratislava)*, Vol. 32, No. 3, p. 328–334, 2013.

Seed and seedling tests, performed with the aim of acquiring knowledge about the genetic potential of selected provenances, are generally one of the first trials in a complex system of comparative examinations to be conducted upon the introduction of alien tree species. This paper presents the results of the investigation of the dependence of the mean height of 14 Canadian origin Douglas-fir provenances, originating from latitude 49° 10' to 51° 35', longitude 11° 20' to 120° 10' and the altitude of 488 to 1,070 m, on the geographic origin.

Understanding the variations in the mean height of a seedling is of major importance for acquiring knowledge on genetic potential of selected provenances, which are one of the key parameters for the introduction of Douglas fir into relevant forest sites in Serbia.

Key words: Douglas fir, provenance, seedlings, mean height.

Introduction

The primary reason for the establishment of provenance test is to determine the economic justification for the introduction and to assess the risk arising from transfer of seeds from their natural, autochthonous zones of origin. Introduction must involve only those species that attain maximum production qualities and economic effectiveness in their natural area. Upon the transfer of seeds into forest sites with new ecological conditions, the genetic potential of species is tested by means of provenance trials. Another important reason for the establishment of provenance trials is to avoid risk and damage from the introduction of non-productive and non-adaptive provenances. Several years-long trials of introduced seed begin by a laboratory analysis of germination, measurement of tray plants, survival percentage of seedling nursery plants, establishment of a field trial and a years-long measurement of plant taxation elements until fruit bearing and collection of F2 generation seeds.

Douglas fir (*Pseudotsuga menziesii* Mirb. Franco) is abundant in North America, from west Oregon, across the Washington state, to British Columbia. Autochthonous forests of this type are one of the most productive forests in the world, which is the reason for a considerable interest that exists for establishment of this culture beyond the limits of its natural areal (Bradley et al., 1999). Owing to its extensive adaptability, ecological variations and potential value, Douglas fir is one of the most investigated and, at the same time, most important allochthonous conifer species in Europe (John, 1988; Linhart, 1990; Kleinshmit, Bestien, 1992; Schober, 1963). According to the available data, cultures of this species have been established in 26 European countries, on the surface area of 200,000 ha (Schober R.). The process of introduction Douglas fir in Europe was initiated in 1850, when first cultures were established. The success and productivity of the first established cultures differed, largely due to the unknown origin of the seeds used for production of seedlings for their establishment. Based on the studies conducted in North America as well as potential tests of this species in Europe, a detailed knowledge of the genetic potential of Douglas-fir provenances was acquired. The obtained results from the comparative tests had an impact on regionalisation and more proper selection of the seed sources in North America, which contributed to stability and overall quality of Douglas-fir cultures in forest sites outside its natural areal. The introduction of Douglas fir in the region of South-east Balkans began towards the end of 19th and at the beginning of 20th century. Initially, it was planted as a park-decorative species, and later as a species in forest cultures. (Kitić-Vrcelj, 1982). Two Douglas-fir provenance trials were established in Serbia in 1982, with the seed from the known North America seed sources, ranging from New Mexico to British Columbia. Trial facilities were created in Juhor near Jagodina and Tanda near Bor from the seedlings produced in the seedling nursery of the Institute of Forestry in Belgrade.

The results of the research conducted in the experimental facilities in Serbia, (Lavadinović, V. et al., 1995, 1996, 1997, 1999, 2001) proved that provenances from the higher latitudes of North America are characterised by genetic potential that makes them suitable for establishing their cultures in Serbia. The above-stated results directed the further research towards Douglas-fir provenances from Canada, of the latitude ranging from 49° 10' to 51° 35', longitude from 115° 20' to 120° 10' and altitude from 488 to 1070 m.

Material and work method

The paper presents the results of the seedling mean height measurement and their discrepancies, depending on geographic characteristics of the seed origin, in a plant juvenile development phase at the seedling nursery in Sremčica. The seed of 14 Douglas-fir provenances, originating from its natural areal in Canada and obtained through a forest seed centre „Canadian Forest Service” from British Columbia, was used for the production of seedlings for establishment of the trial. The seeds were sown in May 1999, while the trial was established in April 2002, at the seedling nursery in Sremčica. The planting was conducted in rows, one provenance in one row. The distance between the rows was 2 m, while the distance between seedlings in a row was 1 m. Figure 1 presents the spatial layout of provenance origins, while their geographic characteristics and original codes are presented in Table 1.

In October 2010, heights of all trial trees were measured by an altimeter VERTEX III, with the accuracy of 0.1 mm. The obtained data were processed by a computer programme STATGRAPHICS Plus. Statistical justification of differences between height arithmetic means was established by the Duncan test, with the probability of 95%. The impact of provenances' geographic origin on seedling height is determined by the Pierce linear correlation coefficient.

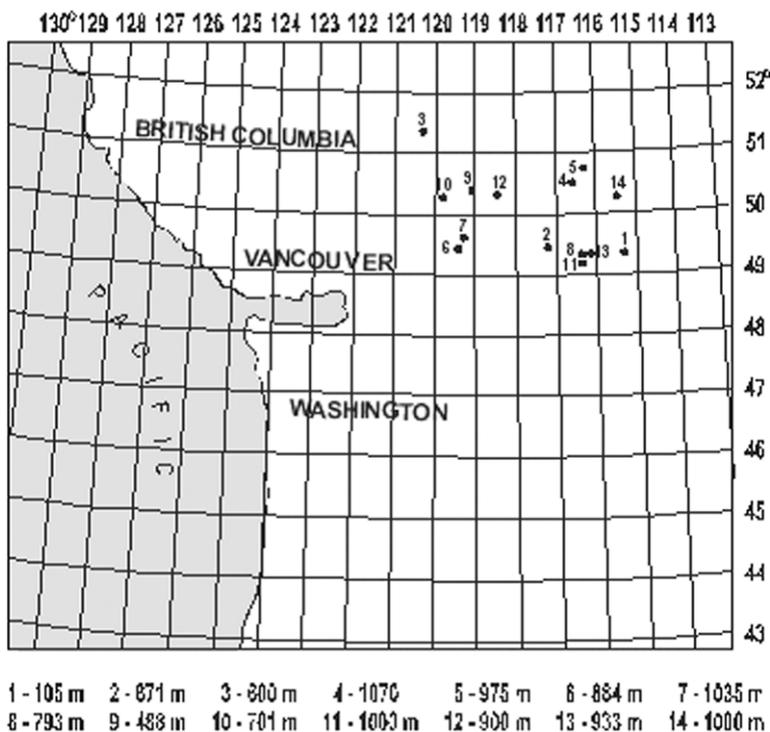


Fig. 1. Spatial layout chart of investigated provenances.

Table 1. Geographic characteristics of tested provenances.

Provenance		Location	Geographic		Altitude (m)
No.	Code		Latitude	Longitude	
1.	03333	Cranbrook	49° 25'	115° 20'	1050
2.	00848	Inonoaklin	49° 50'	118° 10'	671
3.	30667	Mann Creek	51° 35'	120° 10'	600
4.	05227	Gavia Lake	50° 56'	116° 35'	1070
5.	05226	Nine Bay	50° 58'	115° 32'	975
6.	03356	Trout Cr	49° 40'	119° 52'	884
7.	03360	Michell Cr	49° 54'	119° 37'	1035
8.	01198	Salmo	49° 15'	117° 30'	793
9.	30460	Mara Lk	50° 48'	119° 00'	488
10.	00278	Monte Crk	50° 37'	119° 52'	701
11.	03383	Sheep Creek	49° 10'	117° 15'	1000
12.	30461	Cooke Creek	50° 38'	118° 49'	900
13.	03389	Benton Creek	49° 12'	117° 25'	933
14.	05092	Sun Creek	50° 08'	115° 52'	1000

Results and discussion

A comparative analysis of the attained mean heights of Douglas-fir seedlings from 14 Canadian provenances was published for the purpose of establishing inter-provenance variability and its dependence on geographic characteristics of the seed origin.

Table 2. Mean heights of tested Douglas-fir provenances.

Provenance		Height (cm)	Provenance		Height (cm)
No.	Code		No.	Code	
1.	03333	188.4	8.	01198	146.5
2.	00848	312.9	9.	30460	282.7
3.	30667	271.9	10.	00278	193.4
4.	05227	217.5	11.	03383	222.4
5.	05226	182.2	12.	30461	294.8
6.	03356	149.4	13.	03389	217.2
7.	03360	158.1	14.	05092	175.0

Table 3. Analysis of variance.

	Sum of squares	df	Mean square	F	Sig.
Between groups	1597347.199	13	122872.861	36.941	0.000
Within groups	1769540.230	532	3326.203		
Total	3366887.429	545			

Table 4. Duncan test for the height of 14 Douglas-fir provenances

Provenance	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
8	17	146.471						
6	28	149.393						
7	64	158.078	158.078					
14	31	174.968	174.968	174.968				
5	53		182.208	182.208				
1	31			188.355	188.355			
10	49			193.429	193.429	193.429		
13	47				217.191	217.191		
4	39				217.513	217.513		
11	29					222.379		
3	29						271.897	
9	35						282.686	
12	36						294.833	294.833
2	58							312.948
Sig.		0.060	0.100	0.229	0.054	0.055	0.119	0.191

The largest mean height of 312.9 cm was attained by the trees of the second provenance (00848), followed by the twelfth with 294.8 cm (30461), while the smallest height of 146.5 cm was attained by the trees of the eighth provenance (01198), the sixth 149.4 cm (03356), the seventh 158.1 cm (03360) and the fourteenth 175.0 cm (05092), as can be seen in Table 2.

The obtained statistical data point out to the existence of genetic variability in selected Douglas-fir provenances, understanding of which is essential for the further success of introduction work.

The results of the variance analysis (Table 3) indicate the existence of statistically significant discrepancies at the level $p < 0.05$, between mean height of 14 Douglas-fir provenance trees.

By means of the Duncan test, statistically significant differences between mean heights of Douglas-fir provenances were determined at the reliability level $p < 0.05$ (Table 4). The provenances were grouped into seven homogenous groups, which confirmed the variations in mean heights of 14 Douglas-fir provenances. The provenances 2 and 12 belong to a homogenous group with the largest mean heights whereas the provenances 8, 6, 7 and 14 belong to a group with the smallest mean heights.

The impact of provenances' geographic origin on a Douglas-fir seedling height was examined by means of the Pierce linear correlation coefficient.

Table 5. Geographic location and mean height correlation matrix of 14 Douglas-fir provenances.

	Latitude	Longitude	Altitude	Height
Latitude	1.00	0.2897	-0.3803	0.3845
Longitude		1.00	-0.6337*	0.2538
Altitude			1.00	-0.5384*
Height				1.00

* Significant for $p < 0.05$.

On the basis of the Pierce coefficient values (Table 5), it can be concluded that there is a positive correlation between latitude and seedling height, but that correlation is not statistically significant. There is a positive correlation between longitude and seedling height as well, but that correlation is also not statistically significant. There is a negative correlation between altitude and seedling mean height, and that correlation is statistically significant. A similar correlation was also found in the tests involving seeds of the same provenances (Lavadinović V. et al., 2004) as well as in the tests involving the mean diameter (Popović V., Lavadinović V., 2011).

Based on the obtained results, it can be concluded that the size of the seedling height is increasing from east provenances to the west and from south provenances to the north. The size of the seedling height is decreasing with the increase of altitude, which is the most pronounced impact (Fig. 2).

Conclusion

In the juvenile development phase in seedling nursery conditions, the plants exhibit variations in growth characteristics. In order to draw more certain conclusions with respect to

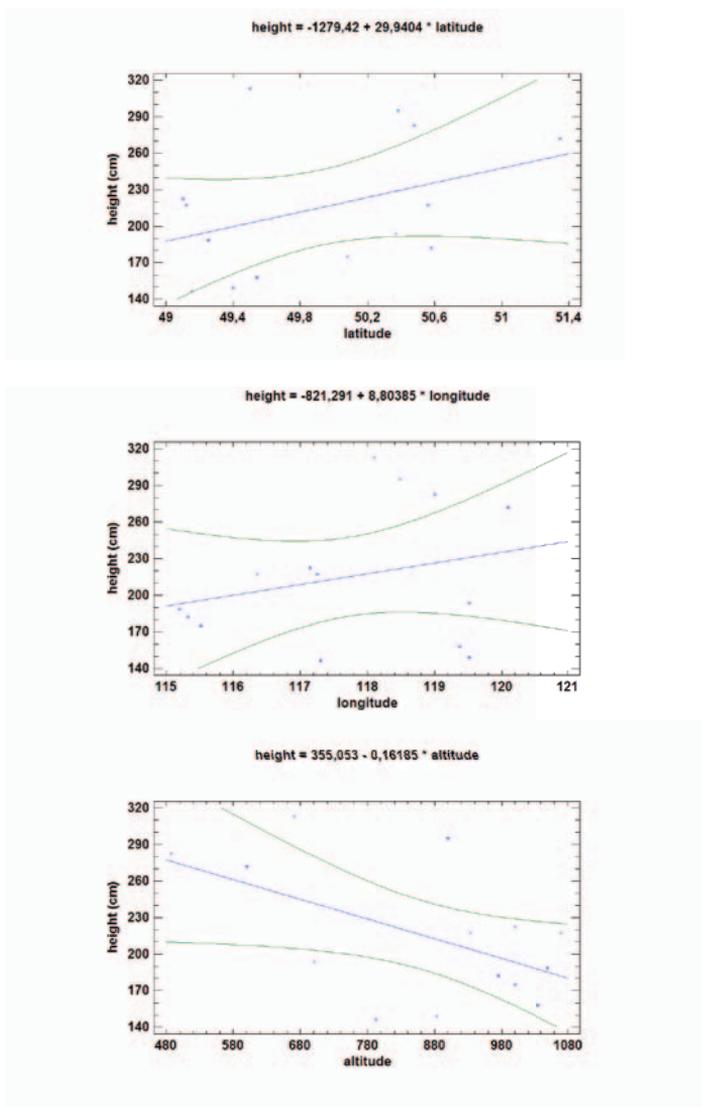


Fig. 2. Latitude, longitude and altitude impact on the seedling height.

which provenance exhibits better adaptability, it is necessary to monitor the development of older trees.

In this phase of juvenile plant development, the provenances 2, 12, 9 and 3 stood out as the best according to the attained mean heights, while the provenances 8, 6, 7 and 14 were ranked the worst. However, it is too early to propose those data as the underlying basis for the establishment of Douglas-fir cultures. The conducted research presents the basis for selection of a relevant Douglas-fir Canadian provenance for establishment of plantations in Serbia. In

order to conduct a more proper selection of provenances, it is necessary to continue to monitor the plant development and then, by consolidating several research results, recommend provenances that are most suitable for the establishment of Douglas-fir cultures in Serbia.

Acknowledgements

This paper was produced in the framework of the project 'Study of climatic change environment impact: monitoring impact, adaptation and mitigation' (43007), financed by the Republic of Serbia Ministry of Education and Science, in the framework of Integrated and Inter-disciplinary research programme for the period 2011–2014.

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