

GROWTH OF SIX CONIFEROUS SPECIES IN DIFFERENT BIOCLIMATES IN CROATIA

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Abstract

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With the aim of determining a good selection of coniferous species for the establishment of cultures, the Forest Research Institute in Jastrebarsko began research work in 1960. Trial planting comprised three indigenous and three foreign species. The indigenous species included a Scotch pine (*Pinus sylvestris* L.), Black pine (*Pinus nigra* Arn.) and Norway spruce (*Picea abies* Karst.), and the foreign species were European Larch (*Larix decidua* Mill.), Weymouth pine (*Pinus strobus* L.) and Douglas fir (*Pseudotsuga menziesii* var. *viridis* Franco). These are economically the most interesting coniferous species that are often used in Croatia for establishing new cultures in non-forested areas and for reconstruction of lower quality stands of broadleaves. In spring of 1969 three comparative trials were established in three ecologically characteristic forest regions of Republic of Croatia.

A necessary condition for successful production could simply be expressed in this way: "The right species in the right place". It can be achieved when the basic indicators of productive ability of stands as well as bio-ecologic traits of the species are known. An absolute success may be expected only in the cultures where the highest degree of harmonisation of species requirements regarding stands has been obtained. This paper shows the results of the 32-year development of plants of the aforementioned species.

Key words: coniferous species, culture, survival, growth, height, DBH, wood volume, bio-ecological traits

Introduction

There are approximately 75 000 ha of coniferous cultures in Croatia. Another 330 000 ha of unoccupied forested and non-forested areas are available for possible forest harvesting. The largest areas available for establishing new coniferous cultures are located on the Mediterranean, Sub-Mediterranean and inland fern and heath areas (Matić et al., 1992). Continuous work on the selection of species and their provenance, as well as monitoring the

success (growth and increment, as well as biomass production) of certain species in different edaphic, climatic and habitat conditions enables us to achieve better results in harvesting coniferous cultures. For successful production one needs to adhere to the principle "The right species in the right place" (Orlić, 1979). This can be implemented only if the biological i.e. ecological characteristics of the species as well as the basic indicators of the productive capability of the stand (soil quality) are known. During the last 40 years many scientists in Croatia have conducted research in existing cultures and have published many studies (Komlenović et al., 1975; Komlenović, 1976, 1978; Orlić, 1979; Orlić, Ocvirek, 1993; Dokuš, Orlić, 1986; Orlić, Komlenović, 1988). A large number of researchers from different countries also study this topic (Malkönen, 1974; Lörgensen, 1976; Holmsgard, Bang, 1977; Schrober, 1978; Hansen, Baker, 1979; Perie, Munson, 2000; Lindstrom, 2002; Maeunier et al., 2002).

This paper shall demonstrate the results of research conducted on the success rate of six different species of conifers in comparative trials on three different locations in Croatia.

Research locations and methods

A series of comparative trials was set up in the spring of 1969 in three characteristic ecological forest areas in Croatia. The localities and their geographical position are given in Table 1 and Fig. 1.

The Lokve locality is situated in brake-tracts and heaths (Karlovac Forest Administration) in SW Croatia.

The climate is perhumid (Bertović, 1975). The Slatki potok locality is situated in NW Croatia in the hilly area of Bjelovar on agricultural land (Bjelovar Forest Administration). The climate is humid. The Durgutovica locality is situated in the East of Croatia on a once forested area (Vinkovci Forest Administration). The basic meteorological data is given in Table 2.

The research encompasses the economically most interesting coniferous species (indigenous and foreign) that are most commonly used in Croatia for establishing new cultures outside forest areas and for reconstructing degraded broad-leaf stands.

Planting material of known origin was used for the trial, with the same seed crop, identical nursery production and class of quality. The basic data on the origin and age of the seedlings is given in Table 3.

The trials were established in a randomised block design with three repetitions. Fig. 2 shows the layout of the trial. A total of 432 plants of every species (144 plants per lot)

Table 1. Geographical position of the localities

Forest – Locality	Latitude	Longitude	Altitude [m]
Durgutovica Vinkovci	45° 19'	18° 38'	110
Bjelovar, Slatki potok	45°46'	17°03'	142
Karlovac, Lokve	45°26'	15°17'	195

T a b l e 2. Meteorological data per station

Station/ Locality	Air temperature at 2 m [°C]		Amplitude of the mean annual temp.	Absolute max. temp.	Absolute min. temp.	Mean annual rel. air humidity [%]	Precipitation [mm]		
	Mean annual						Mean annual	Min. annual sum	Max. annual sum
Karlovac	11.2	9.9	12.3	37.0	-21.8	77	1061.5	896.5	1187.7
Bjelovar	10.8	9.8	11.8	36.9	-18.8	80	813.6	655.2	957.8
Vinkovci	11.8	10.5	14.2	36.7	-21.0	82	673.2	470.0	790.5

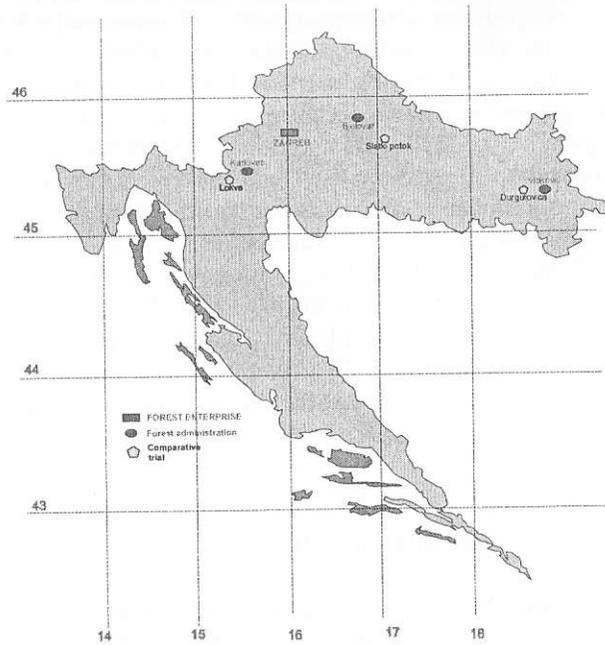


Fig. 1. Position of the localities.

were planted during the trial, and the total number of plants per trial was 2591. The size of each trial including the protective cover equalled 1.5 ha. The planting distance was 2.0x2.0 m (2500 plant/ha).

A series of research was conducted in these comparative trials: survival and height growth during the first five years, total height and breast height diameter by the end of the fifth year (Orlić, 1979), height and width growth and increment and survival 10 years upon establishment (Orlić, 1983), breast diameters and height after 23 and 26 years of age, stem wood, average and current increment, analysis of biomass and the concentration of nutrients in the plant matter (Komlenović, 1978; Orlić et al., 1991).

This study gives the results of the latest measurement taken in the spring of 2002 for each of the three localities aged 32 years. The basic meteorological data is given for

T a b l e 3. Species and age of research seedlings

Species	Symbol	Provenance	Age
Norway spruce (<i>Picea abies</i> K a r s t.)	OS	Ključ, BiH	2+2
Scotch pine (<i>Pinus sylvestris</i> L.)	OB	Visoč, BiH	1+2
Black pine (<i>Pinus nigra</i> A r n.)	CB	Titovo užice, Yugoslavia	1+2
European Larch (<i>Larix europea</i> L.)	EA	Kuleć, Brno, Czech R.	1+1
Weymouth pine (<i>Pinus strobus</i> L.)	AB	Ponovec, Slovenia	1+3
Douglas-fir (<i>Pseudotsuga menziesii</i> F r a n c o)	ZD	Vernonia Oregon, USA	2+3

Block

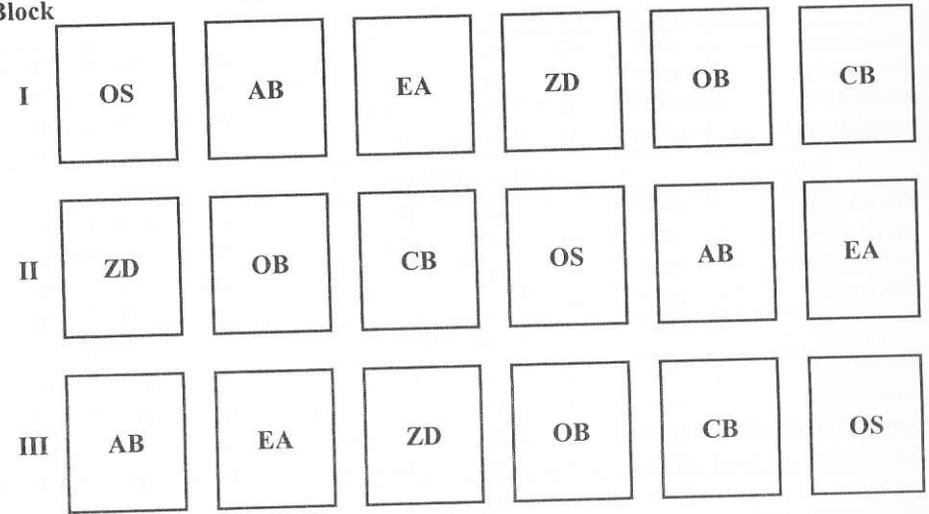


Fig. 2. Layout of the comparative trial.

each locality. An analysis has been conducted regarding survival per species and locality. Total height and breast height diameter were measured on each tree. The wood volume and average age increment were calculated on the basis of the collected data. One entry tables – tariffs were used for calculating wood volume. The statistical processing was conducted in Statistica and SAS 8.12 programmes. Descriptive statistic was done for all analysed variables. Difference between analysed species (*Picea abies*, *Pinus sylvestris*, *Pinus nigra*, *Larix europaea*, *Pinus strobus*, *Pseudotsuga mensiesii*) for height and DBH were testing using ANOVA for each location separately. If these difference was statistical significant ($p < 0.05$) Scheffe test for multiple comparison were used for testing which species make this difference (Sokal, Rahlf, 1995).

Research results and discussion

Survival

The survival rate of the plants was monitored in all the trials at 1, 10 and 32 years of age. The data is given in Table 4.

Table 4. Survival per species and locality

Data	Year	Species						Sum per locality
		OB	CB	OS	EA	ZD	AB	
Trial: Durgutovica								
Planted (pc)	1969	432	432	432	432	432	432	2592
Survival [%]	1969	71	88	93	73	80	83	81
Survival [%]	1978	58	85	84	69	60	70	70
Survival [%]	2001	15	35	75	27	49	60	43
Trial: Slatki potok								
Planted (pc)	1969	432	432	432	432	432	432	2592
Survival [%]	1969	86	91	100	96	86	96	92
Survival [%]	1978	84	85	82	41	16	78	64
Survival [%]	2001	46	53	73	31	16	55	45
Trial: Lokve								
Planted (pc)	1969	432	432	432	432	432	432	2592
Survival [%]	1969	81	91	99	90	95	98	92
Survival [%]	1978	76	74	97	73	65	96	81
Survival [%]	2001	9	16	79	39	34	57	38
Sum per species								
Planted (pc)	1969	1296	1296	1296	1296	1296	1296	7776
Survival [%]	1969	79	90	97	86	87	92	88
Survival [%]	1978	73	81	88	61	47	81	72
Survival [%]	2001	23	35	76	32	33	57	42

As can be seen in the Table 4, the data on survival varies per year but nevertheless certain regularities can be established. Throughout the monitored years the highest survival rate is recorded in Norway spruce and Weymouth pine. A high survival rate is registered with the Black pine in the Durgutovica and Slatki potok localities (35%, 53%), while the low survival rate in the Lokve locality (16%) is the result of grave damage due to snowbreakage and wind breakage. The lowest survival rate throughout the trial period was recorded for the European Larch, Douglas fir and Scotch pine. If we are looking at survival rates per species for the year 2001 we can notice that it ranges from 9% for the Scotch pine on the Lokve locality to 79% for the Norway spruce at the same locality.

The Weymouth pine and Norway spruce have a uniform survival rate on all three localities, which point to a wide ecological amplitude of these species. The European Larch and Douglas fir are species that haven't shown tolerance in regard to locality selection and they have the lowest survival rate in 2001 ranging from 32% to 33%. A survival rate of only 23% for the Scotch pine is the result of values ranging from 9% to 46%. As regards locality, the locality with the highest survival rate of 45% was Slatki potok.

Height growth

Table 5 gives an overview of mean heights per tree species and locality.

The European Larch (22.00 m) and Weymouth pine (22.14 m) are the leading species regarding height on the Slatki potok and Lokve localities. On the Durgutovica locality the Douglas-fir (23.76 m) is higher. The lowest heights were recorded for the Norway spruce and Black pine on all localities. This data corresponds to the data from earlier measurements (Orlić, 1979, 1983). The relation between

Table 5. Mean heights and standard deviation

Species	Height [m]					
	Durgutovica		Slatki potok		Lokve	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
OB	19.63	0.17	19.53	0.15	16.48	0.71
CB	17.81	0.04	16.43	0.11	14.60	0.67
AB	19.81	0.13	22.14	0.32	21.07	0.82
ZD	23.76	0.41	21.12	0.82	17.60	0.94
EA	21.02	0.32	22.00	0.03	21.02	0.49
OS	16.87	0.02	17.72	0.21	16.58	0.12

species is in accordance with their biological features and ecological requirements. The European Larch and Weymouth pine are superior species as regards the intensity of height growth during their young years in comparison to the Norway spruce and Black pine. Fig. 3 gives a graphical overview of the mean heights and a 95% reliability interval per species and locality.

It is evident from the graph that the Black pine has had the smallest growth, and the narrowest range of heights was recorded with the European Larch. The data collected on height was analysed using ANOVA for each location separately. It has been statistically proven that significant differences exist in localities (Table 6). Scheffe test for multiple comparison were used for testing which species make this difference (Fig. 4).

On the Lokve locality the species are divided according to the Scheffe multiple comparison test (Fig. 4) into three different groups. Significant differences exist between the Black pine and the other species. There is no major difference in height between the Weymouth pine and European Larch. These two species have the largest height values in this locality. The third group is composed of the Douglas fir, Norway spruce and Scotch pine. The graphical presentation shows the dominance of foreign species on this locality as regards height as well as the significant difference between the Douglas fir and the two other foreign species (Weymouth pine and European larch).

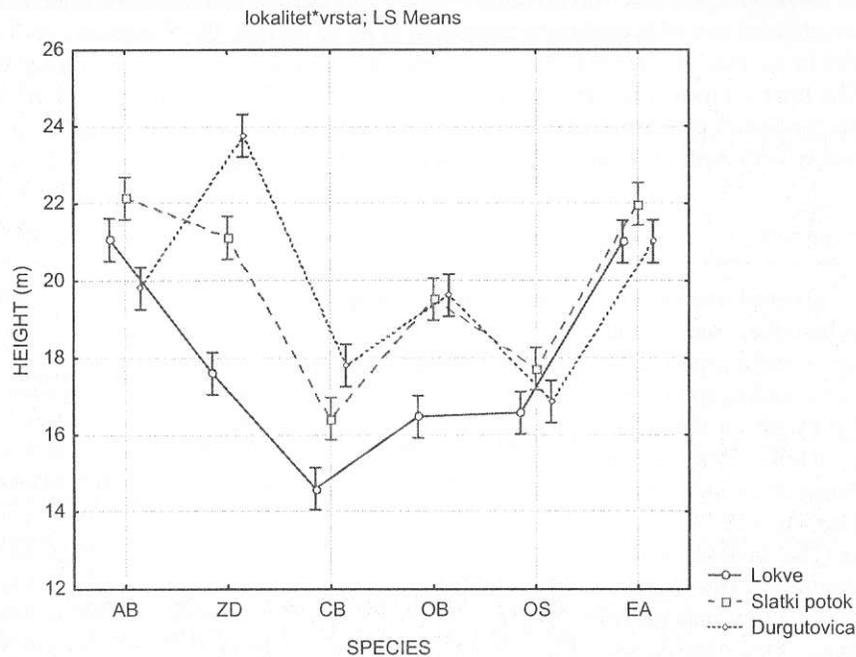


Fig. 3. Mean heights per species and locality.

Table 6. ANOVA for height and for each location separately

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Species-Lokve	5	103.5885833	20.7177167	44.71	< 0.0001
Species-Slatki potok	5	83.44702778	16.68940556	116.84	< 0.0001
Species-Durgutovica	5	89.37409444	17.87481889	331.66	< 0.0001

On the other hand, on the Slatki potok locality there are no significant height differences according to the Scheffe test between trees of foreign species (Waymouth pine, Douglas fir, European larch). The indigenous species are significantly different from one another. Each indigenous species differs in height from all of the foreign species. On the Durgutovica locality the species are divided into five groups also in accordance with the Scheffe test. Only the Waymouth pine and Norway spruce don't have significant differences. All the other species have significantly differ in height.

Diameter growth

At age 32 the Douglas fir and Waymouth pine had the highest average breast height diameter. Data is given in Table 7 and Fig. 5.

The Douglas fir has the widest range within one species on all the monitored localities. On the Slatki potok locality all the species except for the Black pine and Norway spruce have shown the highest values of breast height diameters. It has been statistically proven that significant differences exist in breast height diameters depending on localities (Table 8).

The data was analysed using a single analysis variance (ANOVA) and tested with the Scheffe multiple comparison test (Fig. 6).

According to the Scheffe multiple comparison test for breast height diameters (Fig. 6) on the Lokve locality there are no significant differences between the six species subject to the research, which is also proven by the border value of $F = 0.0416$. On the Slatki potok locality the species were divided into three groups according to the same test. The foreign species – Douglas fir and Waymouth pine – had the largest values for breast height diameter that did not significantly differ from each other. The European larch and the Scotch pine do not significantly differ from the Waymouth pine, but they do differ from the Douglas fir, Black pine and Norway spruce. When comparing groups A, B and C that are the result of the Scheffe test, none of the indigenous species

Scheffe Grouping	Mean	N	Species
Lokve	A	21.0733	3
	A	21.0167	3
	A	21.0167	3
	B	17.6033	3
	B	16.5800	3
	B	16.4767	3
C	14.6000	3	

Scheffe Grouping	Mean	N	Species
Slatki potok	A	22.1400	3
	A	21.9967	3
	A	21.1233	3
	A	21.1233	3
	B	19.5267	3
Durgutovica	C	17.7233	3
	D	16.4267	3

Scheffe Grouping	Mean	N	Species
Durgutovica	A	23.7633	3
	B	21.0233	3
	C	19.8067	3
	C	19.6267	3
	D	17.8067	3
	E	16.8700	3

Legend:

Symbol of species	Species
1	OB Scotch pine
2	CB Black pine
3	AB Waymouth pine
4	ZD Douglas fir
5	EA European Larch
6	OS Norway spruce

Fig. 4. Scheffe multiple comparison test, heights.

Table 7. Average values for breast height diameter and standard deviation [cm]

Species	Breast height diameter [cm]					
	Durgutovica		Slatki potok		Lokve	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
OB	22.37	0.76	21.03	1.14	22.03	2.40
CB	19.73	0.21	18.60	0.52	18.23	2.20
AB	20.53	0.71	24.67	2.05	22.97	2.74
ZD	23.13	1.45	28.23	2.87	20.50	2.50
EA	19.77	0.85	22.10	0.10	21.10	1.14
OS	16.37	0.06	17.87	0.68	17.37	2.40

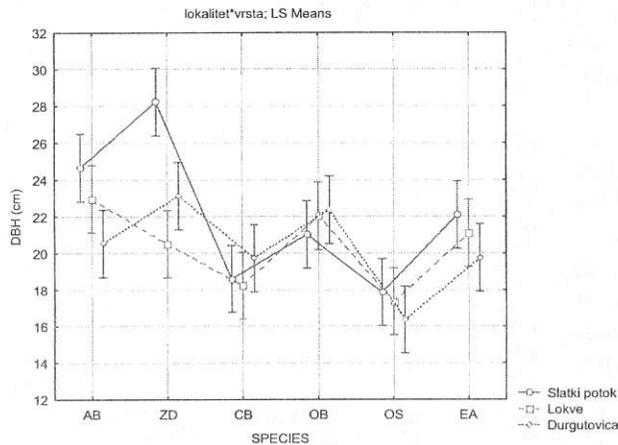


Fig. 5. Mean DBH per species and locality.

Table 8. ANOVA for DBH and for each location separately

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Species-Lokve	5	70.93333333	14.18666667	3.31	0.0416
Spec-Slatki potok	5	226.5383333	45.3076667	18.73	< 0.0001
Spec-Durgutovica	5	85.28500000	17.05700000	25.91	< 0.0001

Wood volume and basal area

This study has also conducted an analysis of wood volume according to tree species and locality. The data is given in Table 9 and Fig. 7.

The overview illustrates that the species with the most wood volume in all three localities is the Weymouth pine. The wood volume ranges from 569 m³/ha to 731 m³/ha. On the Durgutovica locality along side the Weymouth pine, the Douglas fir has the highest wood volume value. The Scotch pine (72 m³/ha) and Black pine (81 m³/ha) have an extremely low wood volume value on the Lokve locality. These results are related to the earlier mentioned snow breakage and wind breakage on this locality. On the Slatki potok locality, most of the monitored species (every species except the Douglas-fir) have had the highest wood volume values. When taking into consideration all the factors i.e. survival rate, height, breast height diameter and wood volume we can generally conclude that all the species grow best on the Slatki potok locality.

Scheffe Grouping	Mean	N	Species	
Lokve	A	22.967	3	3
Lokve	A	22.033	3	1
Lokve	A	21.100	3	5
Lokve	A	20.500	3	4
Lokve	A	18.233	3	2
Lokve	A	17.367	3	6

Scheffe Grouping	Mean	N	Species	
Slatki potok	A	28.233	3	4
Slatki potok	B A	24.667	3	3
Slatki potok	B C	22.100	3	5
Slatki potok	B C	21.033	3	1
Slatki potok	C	18.600	3	2
Slatki potok	C	17.867	3	6

Scheffe Grouping	Mean	N	Species	
Durgutovica	A	23.1333	3	4
Durgutovica	B A	22.3667	3	1
Durgutovica	B A C	20.5333	3	3
Durgutovica	B C	19.7667	3	5
Durgutovica	C	19.7333	3	2
Durgutovica	D	16.3667	3	6

Fig. 6. Scheffe multiple comparison test, DBH.

Table 9. Average values for wood volume and basal area

Species	Stem wood [m ³ /ha]			Basal area [m ² /ha]		
	D	SP	L	D	SP	L
OB	132.909	376.153	72.028	15.3667	43.0371	9.4093
CB	267.874	328.299	81.876	29.0675	38.5168	11.0114
AB	569.209	731.028	722.129	54.2332	64.4589	63.9395
ZD	582.074	250.522	236.475	51.7875	25.5264	27.1638
EA	229.492	360.456	414.495	21.7276	34.1106	38.6164
OS	361.823	422.172	415.265	40.4339	45.7723	46.7519

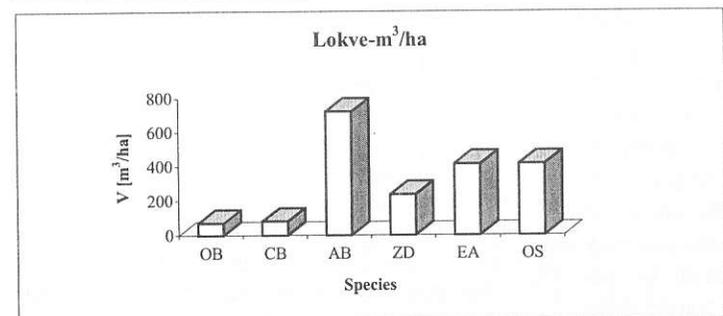
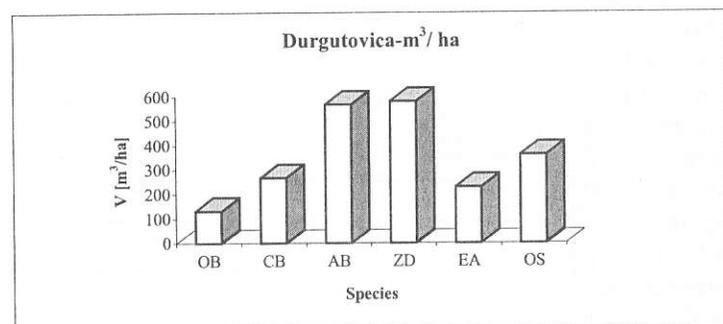
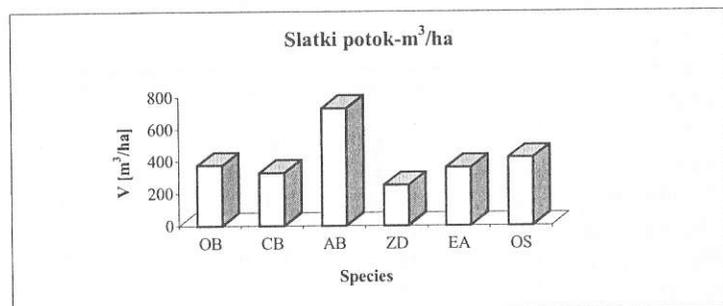


Fig. 7. Overview of wood volume per tree species and locality.

Conclusions

On the basis of the research conducted on the six different conifer species in their 32nd year over three localities we can conclude the following:

Throughout the monitored years (1,5,10,32) the highest survival rate was recorded for Norway spruce and Weymouth pine, and the lowest for European Larch, Douglas fir and Scotch pine.

The Weymouth pine and Norway spruce have a harmonized survival rate on all three localities. This indicates wide ecological amplitude of these species.

The European larch and Weymouth pine have the highest height values on the Slatki potok and Lokve localities, and on the Durgutovica locality they follow the values for the Douglas fir. The lowest values for height pertain to the Norway spruce and Black pine on all localities.

Statistical analysis has proven significant differences in breast height diameters and heights depending on tree species and locality, as well as the existence of interaction between locality and species.

The highest values for breast height diameter were in average achieved by Douglas fir and Weymouth pine, and the lowest by Norway spruce and Black pine.

The Weymouth pine has the highest average wood volume value on all three localities.

The Slatki potok locality has proven to be the best as regards growth success for all six species of conifers.

Different climatic conditions and productive capabilities of the stands as well as biological characteristics influence individual species on different localities.

Translated by A. Vahtarić

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Perić S., Orlić s., Ivanković M.: Rast šiestich ihličnatých druhov v rôznej bioklíme Chorvátska.

Vo výskumnom ústave v Jastrebarsku sme kvôli zisteniu dobrej selekcie ihličnatých druhov pre založenie kultúr začali na tomto probléme pracovať už od r. 1960. Pokusnú výsadbu sme začali s tromi pôvodnými a tromi cudzími druhmi. Pôvodnými druhmi boli *Pinus sylvestris* (L.), *Pinus nigra* (A r n.) a *Picea abies* (K a r s t.) a cudzími druhmi boli *Larix decidua* (M i l l.), *Pinus strobus* (L.) a *Pseudotsuga menziesii* (var. *viridis* F r a n c o). Z ekonomického hľadiska to boli medzi cudzími druhmi najzaujímavejšie, ktoré sa často používali v Chorvátsku na založenie nových kultúr v nelesných oblastiach a na rekonštrukciu nižšej kvality širokolistových porastov. Na jar 1969 tri porovnávacie výsadby boli založené v troch ekologicky charakteristických lesných regiónoch Chorvátskej republiky.

Pre úspešnú produkciu je dôležitá jedna podmienka, ktorú možno vyjadriť takto: „Správny druh na správnom mieste“. Môžeme to dosiahnuť vtedy, ak základné indikátory produkčnej schopnosti porastov ako aj biokologických vlastností druhov sú známe.

Absolútny úspech môžeme očakávať iba v kultúrach, kde sa dosiahne najvyšší stupeň požiadaviek harmonizácie druhov. V práci prezentujeme 32 ročný vývoj rastlín uvedených druhov.

INVERTEBRATE FAUNA IN HABITATS WITH DIFFERENT SOIL MOISTURE IN FLOODPLAIN MEADOWS OF THE RIVER MORAVA

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Abstract

Kalúz S., Čarnogurský J., Čejka T., Krumpálová Z., Majzlan O., Rychlik I.: Invertebrate fauna in habitats with different soil moisture in floodplain meadows of the river Morava. *Ekológia (Bratislava)*, Vol. 23, No. 1, 99–112, 2004.

During the research in floodplain of river Morava several groups of invertebrate fauna (Mollusca, Acari, Araneae, Collembola and Coleoptera) were studied. These animal groups were studied in various habitats with different soil moisture during the years 2000–2002. Standard methods of field research were used there. During the research the basic soil characters were observed (ammount of water, porosity, air content, specific weight of soil samples) and the ammount of rainfall was measured. Two the most wet habitats involved the lower number of invertebrate species with both the lowest density and the frequency. Mildly wet flooded meadow showed the richest communities of the majority of invertebrates. This habitat included mainly semihygrophilous species with the highest abundance, frequency and the highest number of species. Vertically the highest situated habitat was inhabited mainly by species requiring mildly wet or drier soils. The abundance and number of hygrophilous species decreased with the decreasing ammount of water in the soil. Community structure of invertebrates changed within the gradient of soil moisture and each habitat showed characteristic species living there.

Key words: habitats, fauna, floodplain, Acari, Araneae, Coleoptera (Carabidae), Collembola, Mollusca, moisture, river Morava, soil

Introduction

The attention of specialists to study various groups of animals has been focussed to the Slovak part of floodplain of the river Morava since 1992. While vertebrates are well stu-