Pedological and microclimatic properties of some experimental plots of pedunculate oak (Quercus robur L.) plantations in Croatia

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PEDOLOGICAL AND MICROCLIMATIC PROPERTIES OF SOME EXPERIMENTAL PLOTS OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.) PLANTATIONS IN CROATIA

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Research was conducted on 12-year-old experimental plots representing artificially raised stands of pedunculate oak. One experimental plot is located in Central Croatia, where pedunculate oak was planted at different spacings on a site of pedunculate oak and common hornbeam on planosol. The pre-treatment vegetation consisted of a pure stand of common hornbeam. A similar experiment was also carried out in eastern Croatia (Slavonia), where pedunculate oak was planted identically to the former experiment on calci-mollic gleysol with meadow vegetation. In terms of synecology, this site corresponds to the association of pedunculate oak and great greenweed with remote sedge.

Pedological research in the experiments mentioned above showed that the planting arrangement did not have any significant effects on the properties of the topsoil. This is in line with the fact that the evolution of soil and its properties is very slow. Distinct spatial variability of pedological parameters of the topsoil of the pedosphere is another key factor in annulling the importance of potential differences in the soil arising from different planting spacing.

This variability, as well as micro-climatic characteristics, reflects the natural diversity of this forest ecosystem.

Micro-climatic properties of the sites in combination with water regimes in both localities point to pedogenetic processes, which will probably increase the differences among pedological parameters in experimental plots in the future.

Key words: pedunculate oak, soil, humisation, microclimate

INTRODUCTION

Regeneration of pedunculate oak stands and afforestation with pedunculate oak, thanks to its biological properties and ecological and economic characteristics, are intended for large and bare (formerly cleared and possibly prepared) areas. The forestry profession is well acquainted with the stress occurring in the ecosystem during the regeneration of pedunculate oak stands. This stress, related to drastic changes in the cycle of matter and energy, is manifested in the release of energy reserves. Energetic changes of particular proportions occur in the surface part of the pedosphere - in the humus - accumulative horizon (Korotaev 1988, Raulund-Rasmussen and Vejre 1993, Van Breemen 1995). Oxidation processes are intensified, and the humisation trend is mainly determined by micro-climatic and hydrological properties of the site, the young stand (young growth) and the quality and quantity of leaf litter constantly accumulating on the soil surface (Arrouays et al. 1995, Pastor & Post 1988, Schoenau & Bettany 1987). Micro-climatic changes taking place in the course of stand development (Seletković 1981, 1984, 1996), as well as the qualitative and quantitative stabilisation of organic matter production lead to a decrease in energy flow levels and to an equilibrium in the top part of the soil. These changes are in the function of crown closure of the young growth, or the number of plants per surface unit, provided the effects of silvicultural treatments, such as tending and cleaning, are excluded.

If non-forest soil and pastureland is left unploughed or untreated prior to afforestation, the ecosystem does not suffer any significant stresses. Changes in the topsoil are relatively slow, and humisation processes assume positive trends and become a direct function of the microclimate and the quality and quantity of dead organic matter (leaf litter and roots of grass vegetation). Micro-climatic changes, litter production and the retreat of grassy vegetation under similar other conditions (ecological conditions, silvicultural treatments) also depend exclusively on the number of plants per surface unit.

With regard to the changes occurring in the ecosystem during regeneration or the establishment of pedunculate oak stands, it should be borne in mind that soil is a biologically active system and represents the best buffer mechanism for the ecosystem. Biologically and energetically, the most active niche of the forest ecosystem is the surface part of the soil - the organic and humus-accumulative horizon. It is hard to decide on the extent to which changes in the matter and energy cycle are reflected in the soil in pedunculate oak stands. Research presented in this paper is based on the assumption that there is correspondence between changes (development) in the topsoil and those in the microclimate accompanying the growth of a pedunculate oak stand. The aim was to quantify pedological and micro-climatic properties dictated by the thickness of the crown canopy of the young growth and thicket, that is, by the number of planted pedunculate oaks per surface unit in the contrasting hydro-pedological and climatic conditions of pedunculate oak area in Croatia.

RESEARCH METHODS AND AREA

Research was carried out in experimental plots established 12 years ago in the Forestry Office of Vrbovec and Forestry Office of Strošinci (Fig. 1). Two-year-old

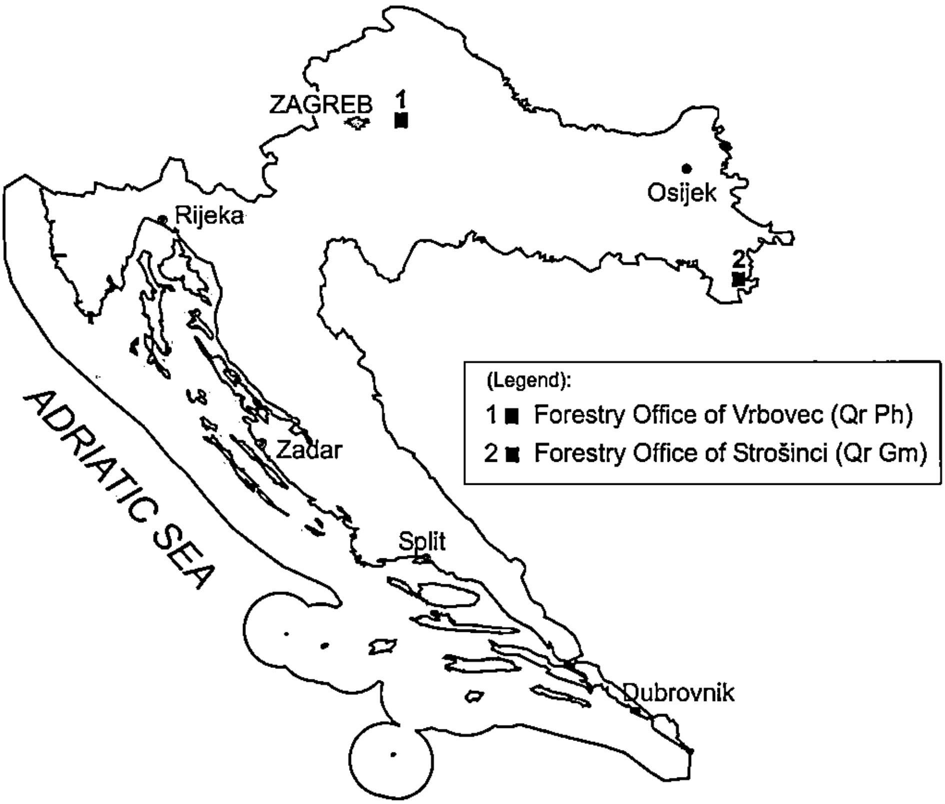

Figure 1. Experimental plot locations

seedlings of pedunculate oak were planted at different distances, and the experiment was established according to a random block system (Fig. 2).

Pedological and microclimatic research was done in the field in the summer of 1999. In both experiments, a pedological profile was opened in the middle of the plot with the largest spacing. Soil samples from each horizon were taken in order to obtain general pedological characteristics. The soil samples, forming the pedological base of this paper, are composed of seven individual samples taken at the depths of 0 - 10 cm below the O-horizon. In the Forestry Office of Vrbovec, control soil samples were taken from the stands of common hornbeam in the vicinity of the experimental plots (two composite samples). Sampling was done with a probe, and two composite samples were assembled in each plot (Fig. 2). The humus content was determined with the bichromatic method of total nitrogen according to Kjerdahl, and the pH was determined electrometrically in the soil suspension in water and in the 0.01 M $CaCl_2$. The extractability of organic matter (group humus content) was determined using Kononova's and Bjelchikova's method. Statistic analysis was based on the random block system of experimental plots.

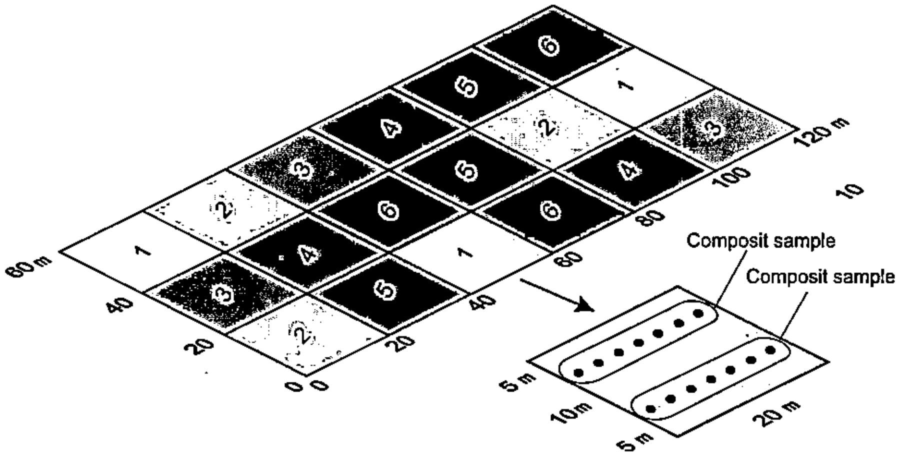

Figure 2. Schematic preview of experiment structure. Planting spacing: 1) 1.8 x 1.8 m (3000 ha^{-1}); 2) 1.4 x 1.4 m (5000 ha^{-1}); 3) 1.2 x 1.2 m (7000 ha^{-1}); 4) 1 x 1 m (10000 ha^{-1}); 5) 0.8 x 0.8 m (15000 ha^{-1}); 6) 0.7 x 0.7 m (20000 ha^{-1}).

Microclimatic research involved the measurement of air and soil temperature and the relative light intensity. Air temperature was taken with automatic thermographs Rotronic placed 2 m above the ground on pedunculate oak trees in medium stand conditions of the 1st, 3rd and 6th treatment. Soil temperature was measured with a geo-thermometer and the relative light intensity with digital light meters over the whole experimental plot. In the Forestry Office Vrbovec (QrPh), the measurements relate to the period from 14 September - 1 October 1999 and in that of Strošinci (QrGm) to the period from 6 July - 4 August 1999.

The experiment in the Forestry Office Vrbovec was established on the site of pedunculate oak and common hornbeam on haplic planosol at the NNW exposition, with an inclination of 5°. This was a pure hornbeam stand, which was felled prior to the experiment.

The experiment in the Forest Office Strošinci (QrGm) was done on the site of pedunculate oak and great greenweed with remote sedge on calci-mollic gleysol. The vegetation was of a grassland type.

In terms of climate, the studied area belongs to the temperate rainy climate characterised by a mean annual air temperature of about 10.5 °C and annual precipitation between 700 - 900 mm. Generally, the area of Strošinci (QrGm) is somewhat warmer and has less precipitation than that of Vrbovec (QrPh).

RESEARCH RESULTS

According to research, the soil in the QrPh experiment is haplic planosol, with a typical profile structure and properties characteristic for the soils of pedunculate stands in Central Croatia (Table 1). The soil in the QrGm experiment is mollic gleysol. This soil has a distinct clayey texture with a high humus and total nitrogen content per surface unit.

Table 1. Soil properties in experiment QrPh i QrGm.

No.	Horizont	Depth	2,0 - 0,2 mm	0,2 - 0,02 mm	0,02 - 0,002 mm	<0,002 mm	Texture	pH H_2O	pH $CaCl_2$	Humus	Nitrogen	C:N
			(%)							(g kg-1)		
QrPh												
1	A	0-12	2.0	57.5	31.2	9.3	loam	4.90	4.19	73.90	3.20	13.4
2	Eg	12-40	1.2	50.1	30.9	17.8	clay loam Ilovača	5.50	4.28	11.30	2.00	3.3
3	BgI	40-80	1.4	47.9	33.5	17.2	clay loam	6.12	5.20	5.10	1.70	1.7
4	BgII	80-105	1.1	46.6	31.3	21.0	clay loam	6.43	5.44	2.00	1.13	-
5	III	105-150	0.5	49.7	23.5	26.3	light clay	6.75	5.67	1.00	1.13	-
QrGm												
1	Amo,a,vt	0-45	1.31	30.09	37.30	31.30	light clay	6.91	6.46	48.00	2.90	9.6
2	Gso	45-85	1.69	19.51	37.50	41.30	light clay	8.05	7.37	10.30	0.90	6.6
3	Gso,ca	85-120	1.82	30.38	38.70	29.10	light clay	8.08	7.48	6.80	0.70	5.6
4	GsoGr,ca	120-150	1.14	38.56	32.20	28.10	light clay	8.30	7.69	7.70	0.80	5.6
5	Gr	>150	0.14	29.56	34.30	36.00	light clay	8.19	7.50	9.80	0.80	7.1

The variance analysis of humus and nitrogen, the pH values and the extractability of organic matter (group humus content) showed that the QrPh experiment (Fig. 3) was homogenous in total, which means that planting spacing did not affect the properties of the topsoil significantly. A high correlation between the humus and nitrogen content, as well as the pH values and humus and nitrogen content, was also noted.

The variance analysis in the QrGm experiment did not prove homogenous. In other words, statistically significant differences were observed in the properties of the surface part of the soil. The differences among individual treatments are explained by the differences in the nitrogen content (Fig. 4) with 97.3% probability. Treatment No. 3 stands out by having much higher nitrogen content than that in treatments 4, 5 and 6. Treatment No. 6 has considerably less nitrogen than plots 1 and 2. On the other hand, significant differences in the extractability of organic matter were noted in the blocks. Block C displayed much lower extractability of organic matter than that in blocks A and B. Significant differences among treatments concerning the nitrogen content can be explained with the effect of planting distances on a low nitrogen cycle. As the highest nitrogen content was observed in treatment 3 and the lowest in treatments 1 and 2, it is evident that the planting spa-

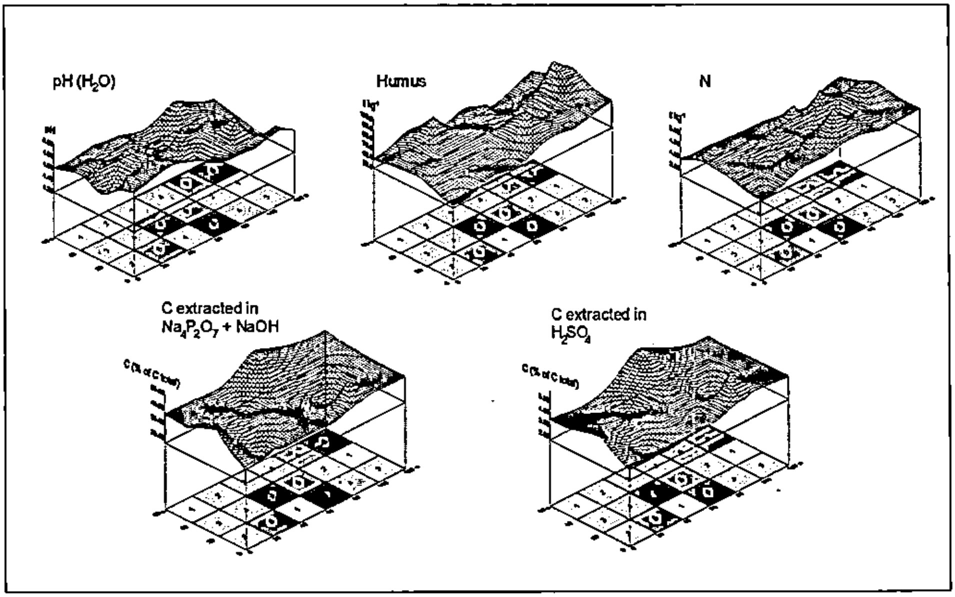

Figure 3. Experiment QrPh – soil parameters

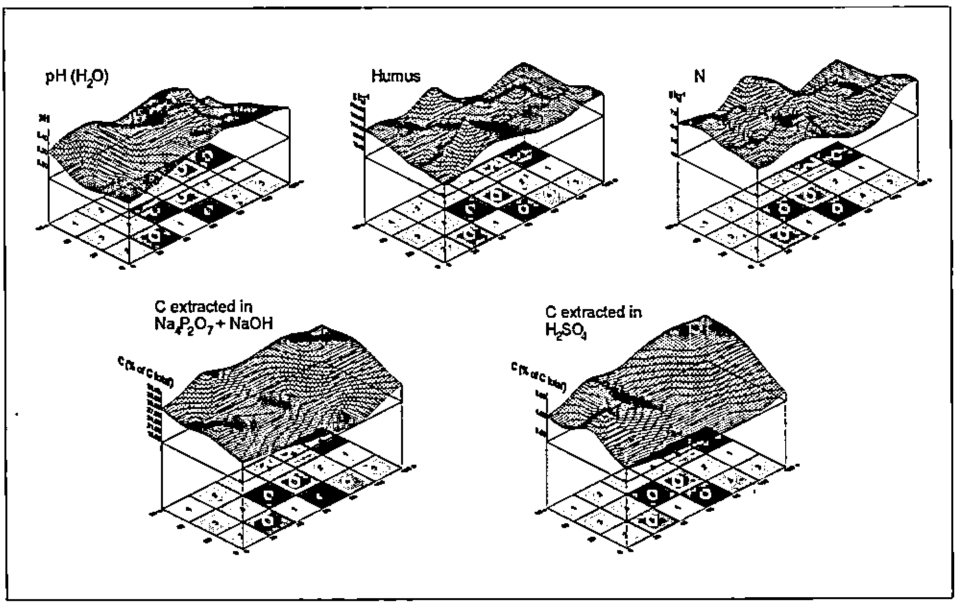

Figure 4. Experiment QrGm – soil parameters

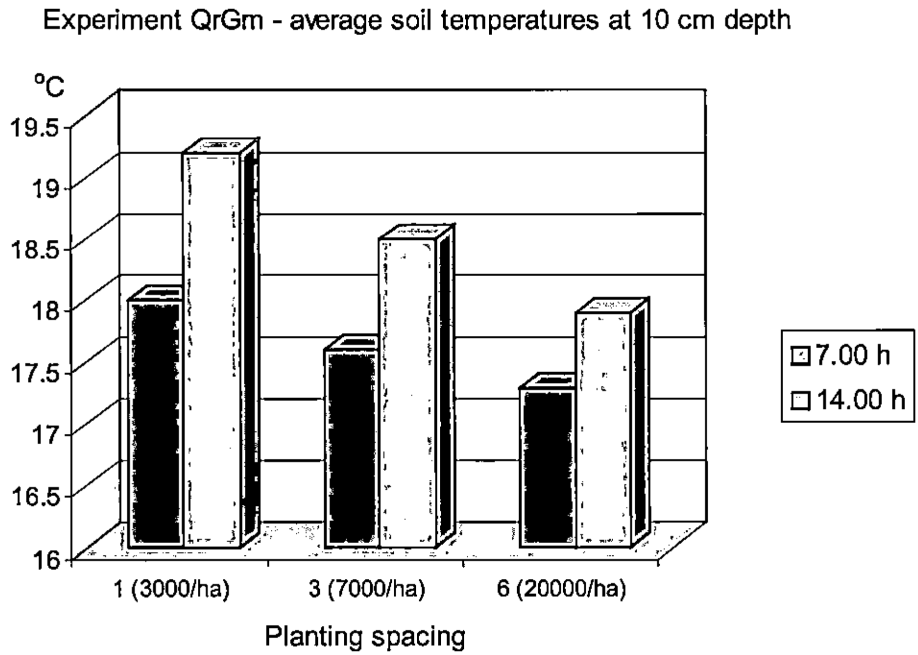

Figure 5. Experiment QrPh – average soil temperatures at 10 cm depth

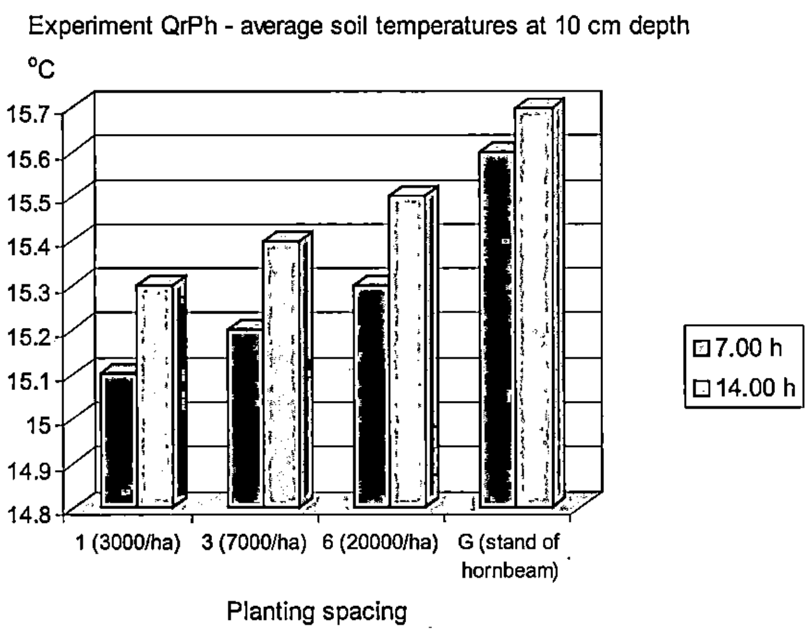

Figure 6. Experiment QrGm – average soil temperatures at 10 cm depth

cing - nitrogen content ratio is not of a linear character, and is therefore difficult to interpret. Differences among the blocks relating to the extractability of organic matter indicate uncontrolled impacts that could be linked to the accumulation regime and organic matter transformation (litter) on the soil surface and the role of tannin in the soil organic complex.

In the QrPh plot experiment (treatment 1), 12 years after planting there were 24,275 trees ha^{-1} (a very high content of common hornbeam, so young hornbeams prevail). The relative light intensity was only 1.58% on this plot. In experimental plot No. 3, there are 10,425 trees ha^{-1}, and the relative light intensity is 10.53%, while on plot No. 6 there are 10,725 trees ha^{-1}, with a relative light intensity of 8.58%.

There is an old stand of common hornbeam next to the experimental plots in which the value of light intensity was found to be 6.9%.

Air temperatures on these experimental plots differ to some extent from those in the experiment QrGm, but the difference is still small. A somewhat thicker canopy affected the values of both air and soil temperatures.

Soil temperatures at a depth of 10 cm, shown in Fig. 5, range from 15.1 - 15.5 °C in young stands, which corresponds to the mentioned uniform stand conditions in terms of the number of trees.

In the QrGm experiment, experimental plot No. 1 contained 2,575 trees of pedunculate oak ha^{-1} 12 years after planting, experimental plot No. 3 had 5,950 trees, and experimental plot No. 6 18,475 trees ha^{-1}. These are the only trees that formed the young stand.

Different values of relative light intensity were also measured in these stand conditions. In experimental plot No. 1 characterised with the rarest canopy, the relative light intensity was 77%. Experimental plot No. 3 with 5,950 trees showed a value of relative light intensity of 21%, and in experimental plot No.6 with the largest number of trees (18,475), the relative light intensity was only 2%.

Air temperatures have a characteristic daily pattern, but the differences among experimental plots are not particularly distinct. On the contrary, the differences are so minimal that they are almost uniform.

A higher correlation in terms of the number of trees was found when soil temperatures were measured at depths of 10cm (Fig. 6). Experimental plots with the smallest number of trees had the highest temperature. Thus, the mean morning temperature in experimental plot 1 was 18.0 °C, in plot No 3 it was 17.6 °C, and in plot 6 it was 17.3°C. Afternoon temperatures followed the 19.2 °C - 18.5 °C - 17.9 °C pattern.

DISCUSSION

One of the most important factors in ecosystem stability is the buffer soil potential. This research has shown that the buffer potential, the natural mechanism that protects the soil from rapid changes, proved decisive in comprehending the almost insignificant effects of the differences in stand characteristics on the properties of the soil, although two distinctly different sites were involved. Stands of pedunculate oak in Croatia are characterised by different hydro-morphous soils. In the central semi-humid and humid area, these are various gleyic soils and planosols, and in the eastern, semi-arid area gleyic soils prevail. Undoubtedly, the temperature and water regime of the sites has a profound influence on soil evolution (Amelung et al. 1997). In view of this, the importance of stable soil properties and the "coexistence" of soil and vegetation can be appreciated.

Very slight differences in the properties of the soil in only one of the experiments, and some microclimatic differences on the other hand, point to a chain that firmly links all the niches of the ecosystem and mitigates the sharp borders. This chain is microbiological activity. Products of organic matter transformation depend directly on microbiological activity. Differences in the nitrogen content, displayed in the treatments in the QrGm experiment, can be explained by this factor.

The degree of structural unit condensation of the humus matter and condensate polymerisation is manifested in the extractability of organic matter. The differences in the extractability of organic matter in experiment QrGm could be attributed to the influence of oak litter (tannin) on the quality of the humus. Although these differences can seemingly be explained by the influence of the blocks, we believe that the impact of wind on litter distribution should be taken into account in cases when a stand is located in an open area (grassland).

The aim of this paper was not to study the impacts of vegetation type on the soil and microclimate. However, this issue normally arises within the framework of a discussion on a general law. In this sense, the results of the research lead to a complex conclusion based on the fact that vegetation is a pedogenetic and microclimatic factor. The effect of vegetation on microclimate can be measured even when there are very small differences in the crown canopy (floor coverage). The influence of vegetation on the soil is far more complex because it is determined by a number of factors (quality and quantity of organic matter, microclimate, soil properties, etc.). In relation to a hypothetical zero state, the extent of this influence depends on the closeness of the vegetation and soil properties in a pedogenetic sense. The worse the physiographic properties of the soil, the more degraded the soil, and the weaker the pedogenetic link between the soil and the vegetation under analysis are, the higher the influence on the soil can be. Although both experiments dealt with in this paper were established in the natural distribution area of pedunculate oak in Croatia in very different ecological conditions, the soils have all the properties that correspond to the pedogenetic characteristics of pedunculate oak. In such conditions, in the stand established on haplic planosol after the removal of forest vegetation, the planting distance of pedunculate oak seedings did not affect the soil properties 12 years after planting. Certain effects on the soil (nitrogen in the soil) in the stand erected on calci-mollic gleysol with grassy vegetation can directly be attributed to microbiological activity, that is, to recorded microclimatic differences (particularly soil temperatures and relative light intensity).

CONCLUSIONS

The following conclusions can be drawn from the study of pedological and microclimatic characteristics in the two experiments involving the pedunculate oak in Croatia:

1. After the establishment of pedunculate oak stands, in the stages of pole and young growth, a considerable influence of planting spacing can be expected on the soil properties and microclimatic characteristics of the site. In other words, planting spacing influences the evolution of the forest ecosystem. During artificial regeneration of pedunculate oak stands, the effect of the planting arrangement on the balanced development of the forest ecosystem is not always important, with the exception of regeneration on sites with degraded soils.
2. Predictable effects are manifested particularly through the air and soil temperature regimes and through the nitrogen cycle in the ecosystem.
3. The extent of the effect of stand parameters on the soil during stand regeneration depends on the closeness of vegetation and soil properties in the pedogenetic sense and on the degree of soil degradation.

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PEDOLOŠKE I MIKROKLIMATSKA OBILJEŽJA HRASTA LUŽNJAKA (*Quercus robur* L.) NA NEKIM POKUSNIM PLOHAMA U HRVATSKOJ

Istraživanja su provedena u 12-godišnjim pokusnim plohama na kojima su umjetno podignute sastojine hrasta lužnjaka. Jedan se pokus nalazi se u središnjoj Hrvatskoj gdje je na staništu hrasta lužnjaka i običnoga graba na pseudogleju posađen hrast lužnjak s različitim razmacima. Prethodnu vegetaciju činila je čista sastojina običnoga graba. Sličan pokus postavljen je i u istočnoj Hrvatskoj (Slavonija). Tu je na ritskoj crnici s livadnom vegetacijom posađen hrast lužnjak po planu kao u prijašnjem pokusu. Ovo stanište sinekološki odgovara zajednici hrasta lužnjaka i velike žutilovke s rastavljenim šašem.

Pedološka istraživanja u navedenim pokusima pokazala su da razmaci sadnje nisu značajno utjecali na značajke površinskoga dijela tla. Ovo se slaže s činjenicom da je evolucija tla i njegovih svojstava vrlo spora. Izrazito visoka prostorna varijabilnost pedoloških parametara površinskoga dijela pedosfere također je bitan čimbenik anuliranja značaja potencijalnih razlika u tlu ovisno o razmaku sadnje.

Ova varijabilnost, kao i mikroklimatska obilježja odraz su prirodne raznolikosti takva šumskoga ekosustava.

Mikroklimatska obilježja staništa u konstelaciji s vodnim režimom jednoga i drugoga lokaliteta usmjeravajući su čimbenici pedogenetskih procesa koji će se u budućnosti vjerojatno odraziti na povećanje razlika između pedoloških parametara na pokusnim plohama.

Ključne riječi: hrast lužnjak, tlo, humizacija, mikroklima