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FOREST REGENERATION UNDER STANDARDS OF PEDUNCULATE OAK (*Quercus robur* L.)

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Abstract

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Work objective was to establish reasons to the impaired vitality of woody and herbaceous vegetation growing under standards of pedunculate oak (*Quercus robur* L.). The paper analyzes the influence of insolation, root competition, soil moisture content and chemical composition of soil on the growth of pedunculate oak seedlings under standards. The analyses included three standards of pedunculate oak aged over 150 years, growing at an altitude of 160 m a.s.l. Controls were plots occurring at a distance of 20 m from the standards. Conclusions following out from the analyses are as follows: The number of seedlings emerged under the standards was lower than the number of seedlings emerged in the open area. Shoot height as well as root collar diameter of seedlings under the standards were lower than in the control seedlings. Total cover of herbaceous layer and height of herbs under the standards were lower than in the open area. The impaired vitality of woody and herbaceous vegetation resulted from a great amount of the fine roots of pedunculate oak standards, withdrawing water up to the wilting point. The amount of photosynthetic active radiation (PAR) under the standards was sufficient for the growth of plants.

pedunculate oak, standard, phytocoenology, root competition, soil moisture, photosynthetically active radiation

INTRODUCTION AND WORK OBJECTIVE

Similarly as many other countries, the Czech Republic fears the natural regeneration of pedunculate oak (*Quercus robur* L.) because seedlings emerging under the parent stand are dying. Reasons to the dieback may be seen in the lack of photosynthetically active radiation, moisture or nutrients, or even in the occurrence of phytotoxic substances in the soil. Pedunculate oak seedlings need a lot of light. According to Lust and Speleers (1990), self-seeded plants can cope with the shade from the parent stand for about two years. In agreement with their findings, Alent'et (1994) points out that self-seeded oak plants usually die within 2–3 years under a full shelter of the parent stand. By contrast, Úradníček and Chmelař (1995) observed young oak plants surviving under a fully closed parent stand for 4–8 years.

Czech authors studying in details the microclimate of floodplain forests are Litschman and Hadaš (2003). They compared climatic characteristics of the stand, the clearcut and the stand-clearcut boundary. Their results indicate that a locality inside the forest stand exhibits the lowest amplitudes of air temperature and humidity during the day, while localities on the boundary between the forest stand and the clearcut have highly extreme conditions in which soil temperature may sometimes exceed 40–45 °C and soil moisture content may fall to 20% (to the wilting point on clay-loam soils). It is therefore necessary to bear in mind that by combining two sites (in our case forest and clearcut), a third site may come to existence the microclimate of which is neither an intersection nor a consolidation of the microclimates of these sites but may have entirely different features, dissimilar to either of the original two sites. Conditions like these may develop under tree standards, too. Čermák, Matyssek and Kučera (1993) observed that drought-stressed trees aged 115 years responded to irrigation within a few minutes and remained undamaged. However, the situa-

tion is different in seedlings, which are highly sensitive to the lack of water (Burton and Bazzaz, 1995; Valladares and Pearcy, 2002). In 2002, Hadaš and Hybler (2003) measured soil bulk density at a depth of 10 cm on the clearing and under the stand and found its values decreasing on the clearing in summer below 30 %; only a heavy precipitation could increase it above 40 %.

Nevertheless, there are other factors, which can affect regeneration under the forest stand. Decisive for trees in terms of nutrition and water uptake are fine roots. By the term of fine roots, most authors understand the morphological category of roots with a diameter below 2 mm (Matzner, Murach and Fortmann, 1986; Puhe, Persson and Börjesson, 1986; Weiss and Agerer, 1986). Santantonio and Hermann (1985), Clemensson-Lindell (1994) and other went for a diameter limit below 1 mm. Through fine roots, the trees withdraw water and nutrients from the soil and may compete for them. Wilson (1988) concluded that root competition might impair growth more than the competition of above-ground parts. The occurrence and growth of seedlings may be affected by the root competition of standard tree.

Apart from the competition of roots, the tree vitality and growth can be considerably affeted by root exudates. Philips and Fahey (2007) suggested that root secretions and exudates can have a severe impact on the soil microedaphon and its respiration that has not a negligible influence on the deposition of C-substances in the soil and hence on the growth of trees.

The work objective was to find out reasons to the impaired vitality of woody and herbaceous vegetation growing under the standards of pedunculate oak (*Quercus robur* L.).

METHODS AND MATERIAL

The research included three standards of pedunculate oak (*Quercus robur* L.) aged over 150 years, growing at an altitude of 160 m a.s.l. in floodplain forests managed by the Forest Enterprise of LČR (Forests of the Czech Republic) in Židlochovice (48° 45' N and 17° 1' E) in the group of forest types 1L – Elm Floodplain. Radius of the horizontal crown projection of standard trees ranged from 3 to 7 metres. In some cases, a comparison was made with the mature, fully closed stands of pedunculate oak (density 1.0) growing on the same site.

Phytocoenological research

The phytocoenological research was conducted under three standards (in tables denoted as V), on three open plots (in tables denoted as K), and in three mature stands of pedunculate oak (in tables denoted as P).

Phytocoenological relevés were made on three transects 20 × 20 m. In phytocoenological releves on the site under the standard, the transect centre was represented by the trunk of the standard tree. Studied was the vernal aspect (21–24 April, 2008).

The height of thirty herbs was measured on transects under the standard and on the open plots on 4 August 2008. The thirty representatives were selected at random from the continuous herb layer.

Simulation of acorn seeding

Regarding the fact that the oak standards did not give crop in 2007, it was decided to simulate the seeding by the manual sowing of acorns. On 16 November 2007, a plot was staked out under each of three standards, sized 1 × 20 m. Two plots were in the EW aspect and one in the NS aspect. Weeds were removed from all plots and the soil was scarified by hoe. Forty-nine acorns were sown per each square metre at spacing of 15 × 15 cm, i.e. 980 acorns were sown by hand on each sample plot sized 20 m^2. Each acorn was worked into the soil by pushing. The sown out acorns were covered with wire mesh in order to protect them from game. Each plot was divided into two parts – one up to a distance of 10 m from the tree foot (hereinafter denoted as "under the standard") and the other one at a distance of 10–20 m from the tree foot in the open area (hereinafter denoted as "open area").

Measurement of photosynthetically active radiation

The amount of PAR was measured on the three sites by using data-loggers with sensors (Minikin QT made by EMS Brno). The sensor denoted in results as "standard" was placed vertically on a rod and carried along the circular line (r = 3 m), in the centre of which the standard occurred. The sensor denoted as "open area" was fixed on a tripod 1.7 m above the ground surface and placed 20 m from the standard in the open area so that it would not be shaded by anything and fully exposed to solar radiation. The sensor denoted as "stand" was placed vertically on a rod and carried at random across the closed mature oak stand (density 1.0).

Data were recorded within an interval of two hours at a period from 06.00 to 18.00 o'clock, in a synchronic manner at intervals of 5 sec for 10 minutes in each variant. The measurements were taken on a cloudless day not to have them affected by possible sun shading with clouds.

Establishing the biomass of fine roots under the standard and in the open area

Soil pits were dug out at half the crown projection (hereinafter denoted as "under the standard") and 20 m from the standard outside the reach of standard's crown (hereinafter denoted as "open area"). Sampler of 5 cm in diameter was used to lift from all analyzed plots 16 horizontal soil cores from depths of 30–40 cm and 70–80 cm. Soil cores from the respective depths were subsequently homogenized. Six samples were taken from the homogenates, each at 100 ml of bulk volume. After the separation of fine roots and their additional cleaning by hand, these were dried out and their weight was established.

Biomass of fine roots was established at the beginning of the growing season (February 2008) and during the growing season (June 2008).

Soil moisture under the standard and in the open area

The placement of moisture meters made it possible to compare the course of soil moisture in the open area and under the standard. Soil moisture meters Virrib were installed on 7 February 2008 at half the crown projection (hereinafter denoted as "under the standard") and 20 m from the standard outside the reach of standard's crown (hereinafter denoted as "open area"). There were three moisture meters installed – one in vertical direction (depth 15–40 cm) and two in horizontal direction (depths 40 and 70 cm).

Chemical properties of the soil

Soil samples for chemical analyses were taken at half the standard's crown projection (hereinafter denoted as "under the standard"), at a distance of 20 m from the standard (hereinafter denoted as "open area"), and from the closed mature oak stand (denoted as "stand"). Representativeness of the place of excavation was determined on the basis of bioindicators and preliminary dugouts. Soil for the chemical analyses was sampled at depths of 30–40 cm and 70–80 cm according to standard procedures (Zbíral, 2002). Available nutrients (phosphorus, potassium, calcium and magnesium) were extracted from the soil samples by using Mehlich II solution and detected on atomic absorption spectrophotometer. Sorption complex parameters were established by the additive method with pH/H_2O and pH/KCl being detected according to the methodology developed by Zbíral (2002).

Statistical analysis

Data sets with two samples were subjected first to the double sampling F-test of variance. In case of the agreement of variances, mean values were tested by using the double sampling t-test with corresponding variances. In case that the agreement of variances was not confirmed by the F-test, mean values were tested by using the double sampling t-test with non-corresponding variances.

RESULTS AND THEIR EVALUATION

Shoot height and seedling counts under the standard and in the open area

The number of seedlings emerged on each open plot by 20 August 2008 was considered 100%. The number of seedlings emerged under the three standards as at the same date amounted to 58–66% of seedlings emerged in the open area, on average 61%. The average height of seedlings under the standard was 10.50 cm and the average diameter of root collar was 1.98 mm. In the open area, the average height of seedlings was 13.03 cm and the average diameter of root collar was 2.18 mm. It follows that the height of seedlings under the standard as well as the diameter of their root collars were statistically significantly lower than in the seedlings growing in the open area.

Phytocoenological research

Table I shows that phytocoenological relevés under the standards and in the open area hardly differed in terms of the species composition. However, they differed in the total cover of herbaceous layer with the degree of coverage under the standard being on average by ca. 30% lower than in the open area. Phytocoenological relevés of the undergrowth in the closed oak stand highly differed from all other relevés with the total cover of herbaceous layer being by up to 75% lower than on the open plots. More light-demanding species occurring under the standards and in the open areas (*Ficaria bulbifera*, *Trifolium pratense*) gave ground to more shade loving species (*Rubus caesius*, *Urtica dioica*).

The double-sampling t-test with non-corresponding variances demonstrated a significantly lower height of the continuous herbaceous layer under the standard (39.45 cm) as compared with the open area (148.56 cm).

Measurement of photosynthetically active radiation

The amount of photosynthetically active radiation affecting seedlings under the standard was distinctly lower than the amount of photosynthetically active radiation affecting seedlings in the open area (Fig. 1). However, in no case it dropped to values recorded in the closed stand of pedunculate oak (Tab. II). Welander and Ottosson (1998) observed that one- and two-year old oak seedlings could grow at 1–2% of full light. However, the amount of light under the standard was 61% of full light. The amount of photosynthetically active radiation under the standard was therefore sufficient for young seedlings and thus, it could not be the cause either to the low number of emerged seedlings or to their lower height.

Establishing the biomass of fine roots under the standard and in the open area

The root system of pedunculate oak standards reached to a depth of 110 cm (groundwater table boundary). Measuring the biomass of fine roots at two different depths we found out that the amount of fine roots under the standard was considerably higher than on the other plots (Tab. III). The results suggested that a markedly greater competition between the seedlings and the standard occurred under the standard.

The double sampling t-test with corresponding variances indicated that the biomass of fine roots under the standard was statistically significantly higher at the depths of 30–40 cm and 70–80 cm than the biomass of fine roots in the open area. Highlighted values denote the significance.

I: *Phytocoenological releves – vernal aspect (under the standards (V), in the open area (K) and inside the stand (P)*

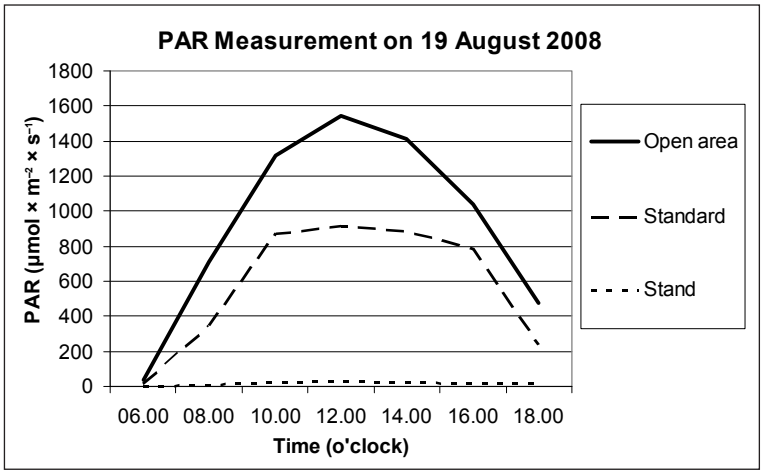
Site		V	V	V	K	K	K	P	P	P
Altitude (m a.s.l.)		160	160	160	160	160	160	160	160	160
Expozition		-	-	-	-	-	-	-	-	-
Slope (o)		-	-	-	-	-	-	-	-	-
Aspect		vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal
Total cover (%)		70	70	60	100	100	95	30	25	25
Layer	**Species**									
Tree	*Quercus robur* L.	+5	+5	+5				+5	+4	–4
	Fraxinus angustifolia Vahl.								1	–2
Shrub	*Acer campestre* L.	1		1	1			–2	–2	1
	Cornus sanguinea L.					+		1		1
	Crataegus sp.									
	Fraxinus angustifolia Vahl.									
	Rosa canina L.				+		+			
	Quercus robur L.	–2	1	1				–		
	Sambucus nigra L.								+	–
Herbaceous	*Aegopodium podagraria* L.		+		–	+	–			
	Aster lanceolatus Willd.	1	–2	1	–2	+2	+2	+	+	
	Brachypodium sylvaticum Huds.		1		–2	1	1			
	Carex riparia Curtis.	–	–	–	–		–		+	
	Crataegus sp.							+		+
	Cirsium arvense L.			–						
	Deschampsia cespitosa (L.) Beauv.	–	+					–		–
	Ficaria bulbifera Holub.	–2	–2	+2	–2	1	–2	–	–	
	Fraxinus angustifolia Vahl.							1	+	+
	Galium aparine L.	+	+	1	–2	1	1			
	Geum urbanum L.					–	–		–	+
	Glechoma hederacea L.		+		+	+		1		1
	Impatiens parviflora D.C.						–			–
	Iris pseudacorus L.			–			+			
	Lamium maculatum L.		–	–				+		+
	Lapsana communis L.	–	–			–			–	
	Lysimanchia nummularia L.	–		–		–		–	–	
	Persicaria hydropiper L.									
	Poa trivialis L.	–		–	–	–				
	Rubus caesius L.	+	+	+	+	–	+	–2	–2	–2
	Symphytum officinale L.	–			–				–	
	Viola reichenbachiana L.	+		+	–	1				
	Taraxacum officinale Weber	1	1	–2	1	–2	–2			
	Trifolium pratense L.	1	+2	–2	–2	–2	1			
	Tripleurospermum inodorum L.		–		–	–	–			
	Urtica dioica L.							–2	1	1
	Vicia cracca L.		–2			1				

Soil moisture under the standard and in the open area

Results from the measurement of soil moisture at 15–40 cm and at 70 cm are presented in Figs 2 and 3, respectively. The figures clearly show that soil moisture under the standard was lower than soil moisture in the open area. During the growing season, soil moisture was decreasing both under the standard and in the open area, from mid-June getting near the wilting point (20%) under the standard at lesser depths (15–40 cm). The difference between soil moisture under the standard and in the open

II: *Average amounts of photosynthetically active radiation in the open area, under the standard and inside the stand*

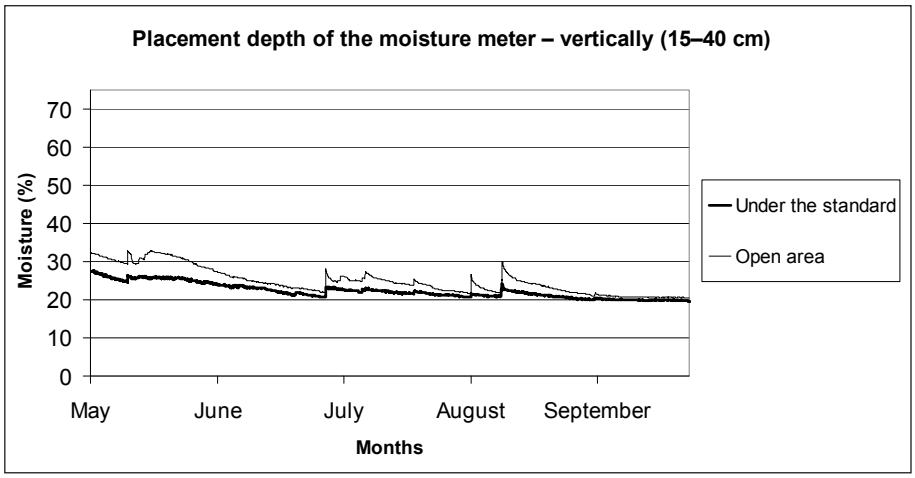
	PAR (µmol × m^{-2} × s^{-1})						
	06.00	**08.00**	**10.00**	**12.00**	**14.00**	**16.00**	**18.00**
Open area	34.38	712.44	1318.81	1544.19	1412.50	1041.03	476.23
Standard	15.31	344.95	869.65	911.49	886.30	782.42	233.95
Stand	1.03	6.84	20.00	26.76	21.98	17.12	11.04



1: *Amounts of photosynthetically active radiation under the standard, in the open area and inside the stand*

III: *Biomass of fine roots under the standard and in the open area*

February 2008				
Depth (cm)	**30–40**		**70–80**	
Site	open area	under the standard	open area	under the standard
Weight of fine roots (g×100 ml^{-1})	0.0019 ± 0.0002	0.0151 ± 0.0012	0.0005 ± 0.0001	0.0319 ± 0.0019
June 2008				
Depth (cm)	**30–40**		**70–80**	
Site	open area	under the standard	open area	under the standard
Weight of fine roots (g×100 ml^{-1})	0.0047 ± 0.0017	0.0220 ± 0.0016	0.0057 ± 0.0007	0.0368 ± 0.0024



2: *Soil moisture values at a depth of 15–40 cm*

area was approx. 5%. At a depth of 70 cm, soil moisture under the standard was by 10% lower than soil moisture at the same depth in the open area. Only soil moisture under the standard was getting near the wilting point from mid July.

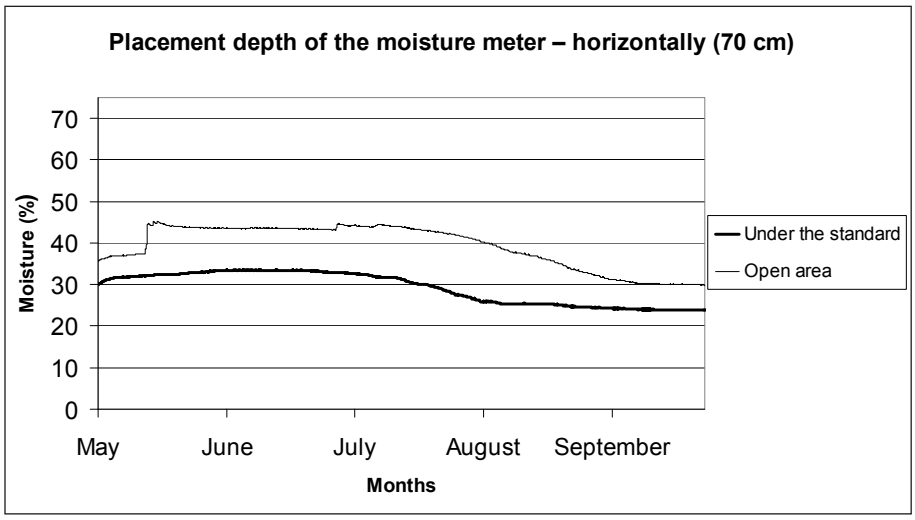
Chemical properties of the soil

Tab. IV shows that soil reaction on all surveyed plots was at a level of neutral soils. Equable were also the values of exchangeable soil bases, hydrolytic acidity, maximum sorption capacity and sorptive saturation. The contents of calcium and magnesium in all soil profiles on all sites did not differ either. The site under the standard showed high to very high levels of other available nutrients (N, P, K). As compared with other sites (open area and stand), the soil under the standard exhibited very high contents of oxidizable carbon and humus. These facts relate to the low soil moisture content in both horizons under the standard. A possible explanation may be that due to the lack of soil moisture, the seedlings and the other undergrowth cannot absorb nutrients from the soil, which consequently accumulate under the standard.

CONCLUSION

Work objective was to establish reasons to the impaired vitality of woody and herbaceous vegetation growing under standards of pedunculate oak (*Quercus robur* L.). Conclusions from the research results are as follows:

- The number of seedlings emerged under standards was lower than the number of seedlings emerged on sites other than under the standard. The height of seedlings under the standard as well as the diameter of their root collars was statistically significantly lower than in seedlings in the open area.
- The herbaceous layer degree of coverage under standards was lower than in the open area. The height of herbs under standards was considerably lower than the height of herbs in the open area.
- The amount of photosynthetically active radiation under the standard was sufficient for young seedlings and therefore, it was not considered a cause to their lesser height or lower counts.
- The amount of fine roots under the standard was considerably higher than on sites other than under



3: *Soil moisture values at a depth of 70 cm*

IV: *Chemical parameters of the soil*

Indication		Content of exchangeable soil bases mmol×kg^{-1}	Hydrolytic acidity mmol×kg^{-1}	Maximum sorption capacity mmol×kg^{-1}	Sorptive saturation %	Mehlich II				Kjeldahl	Springel-Klee		pH KCl	pH H_2O
Site	Depth (cm)					P	K	Ca	Mg	N	C	Humus		
						mg×kg^{-1}				%				
Under the standard	30–40	291.00	14.65	305.65	95.21	323	99	4740	593	0.31	3.67	6.33	6.1	6.9
	70–80	336.85	8.25	345.10	97.61	354	103	4560	593	0.29	3.46	5.96	6.3	7.1
Open area	30–40	226.90	12.45	239.35	94.80	36	52	3253	467	0.09	1.26	2.17	5.5	7.0
	70–80	301.40	15.45	316.85	95.12	45	62	3847	560	0.07	1.18	2.04	5.7	7.0
Stand	30–40	243.70	5.70	249.40	97.72	48	76	3767	620	0.14	1.47	2.54	6.6	7.5
	70–80	284.30	14.30	298.60	95.21	96	88	4107	587	0.11	1.40	2.41	6.2	7.1

the standard where much greater competition between the standard and seedlings or herbs was observed to exist.

- Soil moisture under the standard was much lower than in the open area and often reached the wilting point. The lack of soil moisture distinctly affected the growth of herbs and might even make the growth of pedunculate oak seedlings impossible.
- The contents of N, P, K, oxidizable carbon and humus were markedly higher under standards than in other soils.

SOUHRN

Obnova lesa pod výstavky dubu letního (*Quercus robur* L.)

V České republice (stejně jako v mnoha jiných zemích) existuje obava z realizace přirozené obnovy dubu letního (*Quercus robur* L.) především proto, že semenáčky objevující se pod mateřským porostem odumírají. Důvodem odumírání může být nedostatek fotosynteticky aktivního záření, vláhy či živin.

Cílem práce bylo zjistit příčiny snížené životaschopnosti dřevinné a bylinné vegetace rostoucí pod výstavky dubu letního (*Quercus robur* L.).

Šetření probíhala na plochách uprostřed průmětu koruny a 20 m od paty kmene. Fytocenologický výzkum byl realizován pod třemi výstavky, na třech volných plochách a ve třech mýtních porostech dubu letního. Na transektech pod výstavkem a na volné ploše byla 4. 8. 2008 změřena výška třiceti bylin. Těchto třicet reprezentantů bylo vybráno náhodně v souvislém bylinném patru. Množství fotosynteticky aktivní radiace bylo měřeno pod výstavkem, na volné ploše a pod plně zapojeným porostem pomocí datalogerů se senzory (Minikin QT firmy EMS Brno). Množství biomasy jemných kořenů bylo zjišťováno pod výstavky a na volné ploše na počátku vegetačního období (únor 2008) a ve vegetační době (červen 2008). Pod výstavkem a na volné ploše byla měřena v různých hloubkách půdní vlhkost. Analýzy chemických vlastností půdy byly realizovány pod výstavkem, na volné ploše a v zapojeném mýtním dubovém porostu. Z realizovaných analýz lze vyvodit následující závěry:

- Počet vzešlých semenáčků pod výstavky je nižší než počet vzešlých semenáčků na ploše mimo výstavek. Výška semenáčků pod výstavkem i tloušťka jejich kořenových krčků je statisticky průkazně nižší než u semenáčků na volné ploše.
- Pokryvnost bylinného patra je pod výstavky menší než na volné ploše. Výška bylin pod výstavky je výrazně nižší než výška bylin na volné ploše.
- Množství fotosynteticky aktivní radiace pod výstavkem je pro mladé semenáčky dostačující, a není tedy příčinou jejich menší výšky ani nízkého počtu vzešlých semenáčků.
- Pod výstavkem se nachází výrazně vyšší množství jemných kořenů než na plochách mimo výstavek. Pod výstavkem dochází k výrazně vyšší kompetici, resp. konkurenci kořenů výstavku a semenáčků či bylin.
- Vlhkost půdy je pod výstavky nižší než na volných plochách a často dosahuje bodu vadnutí. Vlhkost půdy výrazně negativně ovlivňuje růst bylin a až znemožňuje růst semenáčků dubu letního.
- Obsah N, P, K, oxidovatelného uhlíku a humusu je pod výstavky výrazně vyšší než na půdách mimo výstavek.

dub letní, výstavek, fytocenologie, kořenová konkurence, půdní vlhkost, fotosynteticky aktivní záření

SUMMARY

Similarly as in many other countries, there are fears in the Czech Republic from the natural regeneration of pedunculate oak (*Quercus robur* L.) because seedlings emerging under the parent stand are dying. Reasons to the dieback may be seen in the lack of photosynthetically active radiation, moisture or nutrients.

Work objective was to establish reasons to the impaired vitality of woody and herbaceous vegetation growing under standards of pedunculate oak (*Quercus robur* L.).

The measurements were taken on plots in the centre of crown projection and 20 m from the tree foot. The phytocoenological research was made beneath three standards, on three open plots and in three mature stands of pedunculate oak. The height of thirty herbs was measured on transects under the standard and on the open plots on 4 August 2008. The thirty representatives were selected at random from the continuous herb layer. The amount of photosynthetically active radiation was measured under the standard, in the open area and inside the fully closed stand by using data-loggers with sensors (Minikin QT made by EMS Brno). The biomass of fine roots was established under the standards and in the open area at the beginning of the growing season (February 2008) and dur-

ing the growing season (June 2008). Soil moisture was measured at different depths under the standard and in the open area. Analyses of the chemical properties of soil were made under the standard, in the open area and inside the closed stand of pedunculate oak. Conclusions from the research results are as follows:

The number of seedlings emerged under standards was lower than the number of seedlings emerged on sites other than under the standard. The height of seedlings under the standard as well as the diameter of their root collars was statistically significantly lower than in seedlings in the open area.

The herbaceous layer degree of coverage under standards was lower than in the open area. The height of herbs under standards was considerably lower than the height of herbs in the open area.

The amount of photosynthetically active radiation under the standard was sufficient for young seedlings and therefore, it is not considered a cause to their lesser height or lesser counts.

The amount of fine roots under the standard was considerably higher than on sites other than under the standard where much greater competition between the standard and seedlings or herbs was observed to exist.

Soil moisture under the standard was much lower than in the open area and often reached the wilting point. The lack of soil moisture distinctly affected the growth of herbs and might even make the growth of pedunculate oak seedlings impossible.

The contents of N, P, K, oxidizable carbon and humus were markedly higher under standards than in other soils.

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