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PROPERTIES OF HORNBEAM (*CARPINUS BETULUS* L.) SEEDLING ONTOGENY DURING THE FIRST VEGETATION PERIOD IN STAND CONDITIONS

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The properties of hornbeam seedling ontogeny were analysed during the first vegetation period in identical site, and in different environmental conditions, based on the divergence of the unique and complex biological properties. In different environmental conditions, we confirmed the statistically significant differences among the biological properties of seedlings: hypocotyl length, length of above-cotyledon-axis, thickness epicotyl, number of leaves, i.e. number of buds. During the first vegetation growth period, in favourable environmental conditions, hornbeam has the marked capacity of elongation of the "above-cotyledon-axis". In this way it becomes ontogenetically adapted to the site and climate conditions.

Key words: *Carpinus betulus L.*, biological properties, one-year old seedlings, ontogeny, stand conditions

INTRODUCTION

The genus *Carpinus* L. (family *Betulaceae)* in the North hemisphere consists of 26 species (TATIĆ I BLEČIĆ, 2002). Hornbeam (*Carpinus betulus* L.) is

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a deciduous woody mesophyte, which in our conditions usually occurs in mixed stands with oaks and beech (JOVANOVIĆ *et al.*, 1997). In Europe, hornbeam has more than 18 forms (STIPCOV *et al.*, 1997). Regarding light demand, it is classified in the transition group of species between sciophytes and semi-sciophytes (KOJI? *et al.*, 1994). In our region, hornbeam phyto-ecology has been studied by several authors (TUCOVIĆ, 1966, Dinić, 1971, 1975a, 1975b). The morphological characters of seedlings and their variability were reported by SLAVNIĆ and ŠILJAK (1972), STILINOVIĆ (1985, 1987), JOVANOVIĆ (2000). In the European literature, there are also special monographs on hornbeam (BUGALA *et al.*, 1993). As a species with a specific ecological plasticity, marked regenerative capacity and high biomass productivity, hornbeam is becoming an increasingly valued species (STIPCOV *et al.*, 1997). By silvicultural measures in mixed stands with oaks, it is maintained in the underwood layer and it represents the necessary species in the process of production of technically valuable oak wood. However, because of its more frequent yield, sciophylous seedlings, higher resistance to unfavourable effects, hornbeam is a very expansive species in mixed stands. When it is too abundant during the stand regeneration stage on the regenerated areas, it is a weed species from the silvicultural aspect. The aim of this paper is to point to hornbeam seedling development and properties in stand conditions in the youngest stage of ontogenetic development.

MATERIAL AND METHODS

The characteristics and development of hornbeam seedlings during the first vegetation period were studied in different stand conditions on the site of pedunculate oak and hornbeam forest in terrestrial conditions of *Tilio-Carpino-Quercetum roboris,* in the lowlands on deluvium (NP Fruška Gora, "GJ Gvozdenjak lice", compartment 43). The microrelief and microclimate, on the one hand, and the deep soil, on the other hand, make this site very productive both for pedunculate oak and for hornbeam (JOVIĆ *et al.*, 1992).

The study was performed in the zone of a circular felling area, elliptic in shape, area about 0.10 ha, formed in the part with the domination of old hornbeam trees with abundant yield. Hornbeam trees were felled by the end of 1999, in the year of abundant seed crop. Hornbeam seed dormancy and germination after the year of abundant seed crop in 1999 developed in contrasting conditions. The extremely dry period in the spring 2000 conditioned the absence of hornbeam seed germination. The seedlings were formed abundantly during 2001. In the central part of the circular felled area, the number of seedlings was more than 300 pcs/m^2.

The development of hornbeam seedlings was monitored on micro sample plots on a 25 m long transect, from the central part of the circular felled area to the completely closed canopy in the north-east direction. By the end of the vegetation period, 50 one-year-old seedlings with undisturbed growth were taken for the analysis, each from the micro plot in the central part of the circular felling unit (site C) 5 m far from the forest edge in the direction of the closed canopy part (site B) and 10 m far from the forest edge in the completely closed part (site A). The seedlings were then morphometrically analysed. The seedlings in the central part of the circular felled unit developed during the summer under the direct sunlight during the period from 11 to 17h, and in the fringe part of the stand, the seedlings were exposed to lateral and diffuse light.

The following arbitrarily measured quantitative properties were analysed - they were ocularly visible as the biological entities on the seedlings:

1. hypocotyl length - from the base of cotyledon leaf to the widest part of root collar zone, i.e. the first lateral root (H_y),
2. length of the "above-cotyledon-axis"-from the base of cotyledon to the base of terminal bud ("Ep"),
3. thickness of epicotyl - in the middle of internodes from the base of cotyledon to the primary leaf (d_{Ep}),
4. number of leaves (B.L.),
5. number of buds (B.P.)
6. number of large vegetative buds (B.K.P.)

The following basic statistical parameters were calculated for the measured quantitative characters and the complex of different properties of seedlings in individual environmental conditions: arithmetic mean (x), limits (min-max), standard deviation (S_D) and variation coefficient ($C_V\%$). The significance of differences between the means of individual seedling properties was tested by the analysis of variance, and the differences between the means of individual samples were tested by LSD-test at the significance level 0.05.

RESULTS AND DISCUSSION

Hornbeam cotyledons are raised above the surface of the ground (epigeal germination: SCHÜTT AND WERNER, 1978). The aboveground part of the completely developed seedling usually consists of: hypocotyl, cotyledons, above-cotyledon internode-epicotyl, primary leaf alternating with cotyledons, and often 1-2 alternating leaves. Cotyledons are egg-like with short stalks, oppositely arranged on hypocotyl, leathery, thick and naked, with entire leaf margin, and sagittate at the base. The veins on cotyledons are marked on both sides of the leaf; they are rough and finely branched. Cotyledons are dark green and shiny on the adahial side, and whitish-grey on the abaxial side. Primary leaf is similar to the leaves of the mature plant, it alternates with cotyledons and it alternates with the following leaves. Above-cotyledon internode-epicotyl (internode from the base of cotyledon to the base of primary leaf) is poorly made. Axillary buds are formed in the axil of cotyledon leaves and the following leaves (ANIĆ, 1983; STILINOVIĆ, 1985; JOVANOVIĆ, 2000).

Table 1 presents the statistical parameters of the analysed properties of hornbeam seedlings in the same site conditions and different environmental conditions at the end of the first vegetation period. The seedlings from the completely closed canopy (site A) at the end of the first vegetation growth period have the phenotype of sciomorphic structural form, with a more elongated hypocotyl and a short "above-cotyledon-axis". Compared to the seedlings formed in more shaded conditions, the seedlings in more favourable light conditions (sites B and C) have different morphological properties. At the end of the first vegetation growth they have different morphological structure, primarily conditioned by the changes of the "above-cotyledon-axis" development. The seedlings formed in the transition zone and in the central part of the circular felling unit regularly have a shorter hypocotyl and a longer "above-cotyledon-axis", i.e. greater total height, thicker epicotyl, greater number of leaves and buds, compared to the seedlings formed in the conditions of the completely closed canopy (Figure 1). The results of t-test confirm the statistically significant differences between the analysed seedling properties in different environmental conditions, at the significance levels 0.05 and 0.01.

Table 1. Properties of one-year-old hornbeam seedlings in different stand conditions, The analysis of variance and LSD-test at the level of significance 0.05

Statistical parameter	Site	Growth element						
		$H_{Yugoslavia}$	E_p	H_t	d_{Ep}	*B.L.*	*B.P.*	*B.K.P.*
			[cm]		*[mm]*		*[kom]*	
	A	5.86	1.67	7.53	0.71	3.20	3.74	1,32
ξ	B	4.97	6.03	10.99	1.60	6.86	7.46	3,42
	C	4.38	21.38	25.76	2.69	9.84	12.28	7,40
	A	4.5	0.6	6.0	0.5	2	2	1
Min	B	3.5	4.2	8.7	1.2	5	5	2
	C	2.6	13.0	17.3	1.9	6	8	3
	A	7.5	2.8	9.9	0.9	5	6	2
Max	B	6.0	7.7	13.5	2.0	9	9	5
	C	5.0	34.0	39.0	3.2	17	22	13
	A	0.73	0.56	0.87	0.10	0.83	1.16	0,47
S_D	B	0.70	1.06	1.13	0.19	1.29	1.25	0,88
	C	0.56	5.38	5.25	0.36	2.40	3.01	1,85
	A	12.5	33.7	11.6	14.4	26.0	30.9	35,7
$C_V\%$	B	14.2	17.6	10.3	11.8	18.9	16.7	25,8
	C	12.8	25.2	20.4	13.4	24.4	24.5	25,0
F		61,78	528.75	475.72	841.92	203.88	229.90	322.90
p		3,36E-20	0.000	0.000	0.000	0.000	0.000	0.000
signif.		***	***	***	***	***	***	***
LSD 0.05	A	a	c	c	c	c	c	c
	B	b	b	b	b	b	b	b
	C	c	a	a	a	a	a	a

*** Significance of differences at the level higher than 0.001

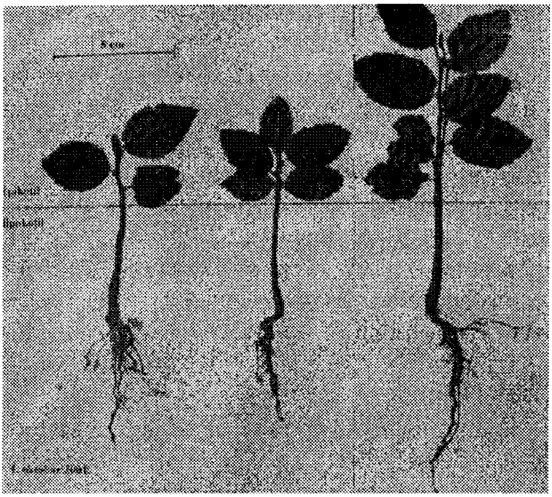

Fig. 1. - Development of one-year-old hornbeam seedlings in different environmental conditions. (Erdevik, GJ Gvozdenjak-Lice, Compartment 43, Oct 2001, photo M. Bobinac)

Low light conditions lead to the development of a specific, sciomorphic structural form and sciophytes are characterised by small-diameter stems, long internodes, low total amount of leaves, etc. (STEVANOVIĆ and JANKOVIĆ, 2001). The differences between the same biological properties of one-year-old hornbeam seedlings in different environmental conditions are expressed in the order of their development. In the conditions of closed canopy, hornbeam seedlings have longer hypocotyl and reduced "above-cotyledon-axis". Growth reduction characterises the sciophytes, primarily aiming at the long survival (GRIME and HUT, 1975; GRIME, 1981). The seedlings in the central part of the circular felling unit have a significantly elongated "above-cotyledon-axis". This indicates that hornbeam has different adaptive capacity in the phases of hypocotyl formation and "above-cotyledon-axis" formation, depending on environmental conditions. During the juvenile stage of ontogeny, in the more lighted felled units, and under other more favourable conditions, hornbeam has the capacity to elongate the "above-cotyledon-axis" and in this way it adapts to site and weather conditions. The range between the average effects on seedling development in closed canopy and completely lighted felled unit, points to the hornbeam development potentials depending on ecological factors. This can be, to some extent, controlled by silvicultural measures. The length of "above-cotyledon-axis" is the most prominent indicator of the changes of seedling development on the felled unit compared to the conditions of the more or less closed canopy. Different values of the study seedling properties in different conditions and the deviations resulting from the "response" of the development process to the effect of environmental factors, indicate that some ecological factors have the dominant effect on the formation of biological properties. Different ecological demands of hornbeam in the initial development, defined by the adaptive potentials, determine also the hornbeam heliophyte and sciophyte degree. Thus, in the interactive relation with other site factors, hornbeam adaptive potentials define significantly the strategy of natural regeneration of forest ecosystems with hornbeam.

CONCLUSION

Based on the divergence of hornbeam seedling biological properties during the first vegetation period in the same site conditions, but in different environmental conditions, we can conclude as follows:

In the juvenile stage of ontogeny, hornbeam has the capacity of marked adaptation to site and weather conditions.

Seedlings in the completely closed canopy part of the stand represent the phenotype of sciomorphic structural form, and the seedlings in the central part of the circular felled unit have significantly different biological properties. The significance of differences between the same biological properties depends on the order of their formation. The most noticeable differences are in the development of "above-cotyledon-axis".

More intensive growth of "above-cotyledon-axis" in the seedlings from the central part of the circular felled unit results in the higher seedlings at the end of the first vegetation period, more numerous leaves and thicker epicotyl part.

The different values of the study seedling properties, in the conditions of closed canopy and circular felled unit, point to hornbeam development potentials depending on ecological factors. This can be, to some extent, controlled by silvicultural measures.

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OSOBINE ONTOGENEZE SADNICA GRABA (*CARPINUS BETULUS L.*) U PRVOM VEGETACIONOM PERIODU U SASTOJINSKIM USLOVIMA

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Izvod

U prvom vegetacionom periodu, u identičnim stanišnim, a različitim sastojinskim uslovima, analizirane su osobine ontogeneze sadnica graba na osnovu divergencije u vrednostima jedinstvenih i kompleksnih bioloških osobina. Utvrđeno je da sadnice graba iz različitih sredinskih uslova ispoljavaju divergencije u vrednostima analiziranih bioloških osobina. Veća značajnost razlika između identičnih bioloških osobina sadnica ispoljava se prema sledu njihovog nastanka, a najizraženije razlike su u razvoju "nad-kotiledone ose". Sadnice iz potpuno sklopljenog dela sastojine karakteriše dužina hipokotila 5,8 cm i sileptički formirana "nad-kotiledone ose" 1,6 cm, sadnice iz prelazne zone karakteriše prosečna dužina hipokotila 4,9 cm i "nad-kotiledone ose" 6,0 cm, a sadnice iz centralnog dela kružne sečine karakteriše prosečna dužina hipokotila 4,3 cm i "nad-kotiledone ose" 21,3 cm. Ve?i intenzitet rasta "nad-kotiledone ose" kod sadnica na sečini uslovio je značajno veću visinu sadnica na kraju prvog vegetacionog perioda, veću debljinu epikotila, brojniji asimilacioni aparat i veći broj krupnih pupoljaka, u odnosu na sadnice iz prelazne zone i sklopljene sastojine. Raspon između prosečnih efekata rasta u uslovima sklopljene sastojine i sečine ukazuje na razvojne mogućnosti graba u zavisnosti od faktora ekološke prirode koji se u značajnoj meri mogu kontrolisati uzgojnim merama. Različiti ekološki zahtevi graba u početnim fazama razvoja, definisani adaptivnim sposobnostima, određuju i stepen heliofitnosti i skiofitnosti ove vrste. Time, u interaktivnom odnosu sa drugim faktorima na staništu, adaptivne mogućnosti graba u značajnoj meri opredeljuju strategiju prirodnog obnavljanja šumskih ekosistema u kojima je zastupljen grab.

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