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UDK: 630*231:630*232

Original scientific paper
Izvorni znanstveni članak

REGENERATION OF NARROW-LEAVED ASH STANDS (*Fraxinus angustifolia* Vahl) IN CENTRAL CROATIA

POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA (*Fraxinus angustifolia* Vahl) U SREDIŠNJOJ HRVATSKOJ

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Received – *Prispjelo*: 15.6.1997. Accepted – *Prihvaćeno*: 8.10.1997.

The research was conducted in lowland forests of Central Croatia, in the forest basin of Česma. Methods of regenerating narrow-leaved ash stands were studied, and the classification of young growth was made in terms of micro-relief, site, and regeneration methods. Narrow-leaved ash was found to regenerate in three groups of sites. The first group are micro-depressions, the second are micro-depressions in transition into micro-elevations, and the third are micro-elevations. Two regeneration methods were applied: the shelterwood method and the clearcutting method. The shelterwood method proved successful in regenerating narrow-leaved ash stands growing in the sites of the first group, as well as in those stages of the second group in which pedunculate oak cannot regenerate. Narrow-leaved ash stands growing in the sites of the third group and in those of the second group where the rejuvenation of pedunculate oak is possible were regenerated with shelterwood fellings followed by the artificial regeneration of pedunculate oak. It is unwise to regenerate ash stands of any group with the clearcutting method, because the ensuing results are poor and lead to site degradation. Clearcutting is a treatment which inhibits the progressive, and enhances the regressive, succession processes in narrow-leaved ash eco-systems.

Key words: narrow-leaved ash (*Fraxinus angustifolia* Vahl), natural regeneration, artificial regeneration, micro-relief, site, shelterwood method, clearcutting method

INTRODUCTION
UVOD

Narrow-leaved ash forests make up over 27,296 ha of lowland forests in Croatia. Their growing stock amounts to 6,245,000 m^3, and the annual increment is 210,485 m^3. Forests of narrow-leaved ash are mainly distributed in the Posavina region between Sisak and Spačva. The largest and the most beautiful tracts are found in the Posavina forests of Lipovljani, in Javička Greda near Jasenovac, and in Kamare near Novska. Going eastward, the areas under these forests decrease considerably (Matić 1971, Glavač 1959).

The economic, ecological, biological, social and other characteristics of narrow-leaved ash stands depend primarily on the properties of their sites. In Croatia, these lowland sites fall into three categories, called wet micro-depressions, unsoaked micro-depressions and micro-elevations. Their local names (*bara, niza* and *greda*) in fact reflect the water regime and the micro-relief with minimal relative height differences of occasionally only 10 cm (Dekanić 1962). Wet micro-depressions, the most important of the three, are those depressions which are frequently inundated with stagnant flood or precipitation water for longer periods of time, with average levels of groundwater in the growing period ranging between 50 and 100 cm. Unsoaked micro-depressions are drier than wet ones owing to the fact that precipitation water and, less frequently, flood water remain there for shorter periods. Average groundwater levels are about 150 cm in the vegetation period. Micro-elevations are the driest sites. They are mildly raised elevations out of reach of flood water. The average levels of groundwater in the growing period are about 200 cm (Mayer 1996, Dekanić 1962).

Between wet micro-depressions, unsoaked micro-depressions and micro-elevations there are transitional stages, such as, for example, a wet micro-depression gradually turning into a proper swamp, a wet micro-depression turning into an unsoaked micro-depression, a swampy hollow in an unsoaked micro-depression, a raised micro-depression, a transition from a micro-depression towards a micro-elevation, a low terrace, a low micro-elevation, and a micro-elevation in a micro-depression, etc.

In terms of principal tree species, the sites in Posavina can be divided into oak and ash sites. It is of primary importance for forestry practice to differentiate between the two, but also to take into account the transitional sites. In the course of forest tending, it is the properties of a site which determine the goals of forest management, the methods of regeneration, and the regulation of species composition. Narrow-leaved ash grows successfully in all the above-mentioned sites. In a wet micro-depression it forms pure stands, while in an unsoaked micro-depression it thrives in mixed stands with pedunculate oak and black alder, where its participation in the mixture can be between 20% to 26% of the stand's growing stock (Dekanić 1962). On a micro-elevation, it is mixed with pedunculate oak and common hornbeam, and participates in the composition in a proportion of up to 20% of the growing stock.

The least favourable site conditions for the growth of forest trees are found in wet micro-depressions, slightly better conditions are in unsoaked micro-depressions, while the most favourable ones exist on micro-elevations. Due to its ecological characteristics and biological properties, narrow-leaved ash is capable of tolerating various site conditions, including highly unfavourable swampy conditions. This is the reason that wet micro-depressions are inhabited by pure ash stands. In other sites, more favourable conditions allow the growth of other tree species, in particular the pedunculate oak, which results in the establishment of mixed stands. Stands of narrow-leaved ash growing in wet micro-depressions have very low economic value compared to the other stands in which it occurs (Matić 1971, Dekanić 1962). However, their ecological and social value is high.

According to Glavač (1959), Prpić (1971) and Dekanić (1971, 1970), the ecological optimum of narrow-leaved ash differs from the physiological one. The ecological requirements and biological properties enable it to reach its ecological optimum, that is, the largest participation in the mixture, in a wet micro-depression. Its biological stability and fast growth help it to suppress other water-tolerant tree species, such as black alder and willow. In contrast, narrow-leaved ash achieves its physiological optimum or its growth optimum in better-quality sites: unsoaked micro-depressions and micro-elevations. This means that, although the participation of narrow-leaved ash is dominant in a wet micro-depression, its production potential is very poor. Because of the competition, its participation in a stand mixture is lower in a micro-depression or a micro-elevation, but the quality of trees is much better (Plavšić 1965, 1960, 1956; Plavšić and Klepac 1960).

Recent research into the ecological, biological and silvicultural properties of narrow-leaved ash has shown that its characteristics as a pioneering tree species stem from its wide ecological valency in relation to the most important ecological factors in lowland forests. An abundant and frequent crop of light and slightly winged seed allows it to regenerate naturally and to inhabit wet and unsoaked micro-depressions and micro-elevations (Matić 1971). The trees fructify very early, at the age of between 20 and 30 years. As narrow-leaved ash grows very fast when young, it avoids the negative impacts of flood water, ice and frost, thus taking a dominant position in and above the soil and suppressing other tree species. Since its requirement for soil oxygen is very modest, it successfully invades wet micro-depressions, wet clearings and fields, and forms the so-called swampy borderline between a forest and a swamp.

According to Seletković (1984) and Prpić (1971), in the seedling and sapling stage, narrow-leaved ash can tolerate a kind of shade with less than 3% of full sun. However, the need for light increases with age. At the young-tree stage, terminal leaves develop only when the share of available light exceeds 6% of full sunlight. At the age of about thirty, narrow-leaved ash becomes a distinct heliophyte. At the age of about thirty, narrow-leaved ash becomes a distinct heliophyte. It is susceptible to late frost and spring colds.

Large-scale fellings of old pedunculate oak stands in the past gave rise to the problem of regenerating lowland forests as early as the last century. If a site was not abundantly seeded with acorns after the final cut, narrow-leaved ash and lowland elm, then seen as tree species of little economic value, were instantly established and spread (Matić 1971).

In connection with this problem, Kozarac (1895, 1886, 1886a) wrote papers describing the laws in mixed stands of pedunculate oak, narrow-leaved ash and lowland elm. Based on the fact that narrow-leaved ash had a wide ecological valency with regard to its occurrence in lowland forests, he divided the forests in Posavina into four groups.

- oak stands with a participation of 10% of other species in dry, unflooded sites;
- stands in which narrow-leaved ash participated at 30 to 40% of the growing stock in the composition, while the remaining proportion was made up of pedunculate oak. Both species succeeded equally, and the humidity of the site satisfied both species equally;
- stands in which narrow-leaved ash and pedunculate oak were either equally represented or where there was more ash than oak. Both species were of poorer quality, and the soil was mostly humid;
- pure ash stands on permanently humid sites.

This classification, based on the stand species composition ratio and on hydrological and pedological properties of a site, was the forerunner of the present classification of lowland forests and sites. According to Kozarac, oak and ash are two species whose regular occurrence is more or less dependent on site humidity. In a more humid site ashes suppress oaks, while in the stands of the third type, where both species participate equally in the mixture, the very high transpiration of narrow-leaved ash and its bio-draining role enhances the growth of oak (Fukarek 1955).

In recent times, the problem of regenerating narrow-leaved ash in Croatia has been dealt with by Dekanić (1970, 1961), and Matić (1971). In the cited papers, the authors state the basic principles of regenerating pure stands of narrow-leaved ash in wet micro-depressions, and mixed stands of pedunculate oak and narrow-leaved ash in unsoaked micro-depressions and micro-elevations. They focus on the relationship between these two species in the course of regeneration and on the necessary silvicultural measures to be taken for each stand.

According to these authors, narrow-leaved ash growing in wet micro-depressions should be regenerated naturally with the shelterwood method in two steps: the seed cut and the final cut. In places threatened by ice and excess water, an additional cut should be carried out between the seed and the final cut. In such cases, the trees left over for the final cut take the role of a water pump, prevent excessive bogging, and take on themselves the burden of ice, thus enabling the young seedlings and saplings to survive and develop more easily. The rotation of such stands should last up to 80 years. After this period, certain undesirable changes take place: the increment decreases, crowns desiccate, fructification becomes weaker, and dark heartwood occurs as a result of reduced crowns (Benić 1956).

Natural regeneration of narrow-leaved ash is successful in sites with narrow-leaved ash and summer snowflake, provided that stands are intensively tended from their early period (Dekanić 1962, 1962a, 1962b). If they are not, then the short, narrow and partially desiccated crowns are responsible for poor fructification. According to Matić (1971), this phenomenon is confined to smaller, isolated ash stands in depressions within a complex of pedunculate oak stands. The reason for this lies in extensive management practices in which silvicultural treatments, instead of being directed individually towards smaller groups of trees or sections, are applied uniformly to different tree species.

Shelterwood cuts in pedunculate oak and narrow-leaved ash stands in unsoaked micro-depressions should be accomplished in such a way as to favour the regeneration of the weaker species: the pedunculate oak (Dekanić 1961). Shelterwood cuts are done in two steps - the seed and the final cut. In the seed cut, all the trees competing with pedunculate oak are removed. Later on, in the course of tending the young growth sprouting after the final cuts, attention should focus on pedunculate oak. Otherwise, the biologically stronger narrow-leaved ash might assume dominance in the stand, suppress the oak and turn the stand into a pure ash stand. If there is a dominance of narrow-leaved ash over pedunculate oak in the mixture, then the shelterwood method should be accompanied by artificial regeneration involving the introduction of acorns or pedunculate oak seedlings.

Matić (1993) considers the quantity of the young growth of a principal species to be the basic prerequisite for the successful regeneration, establishment and tending of a forest. He points out that each regeneration and reforestation activity should be aimed at forming a young stand in as short a period as possible. Its composition should stop the processes of site degradation and turn the processes of regression into those of progression. In order to achieve this aim, it is very important to obtain the optimal amount of growth of the principal tree species, which should neither be too high nor too low. He recommends the use of 7 - 10 kilograms of seeds, or 5,000 to 10,000 seedlings per hectare for artificial regeneration with narrow-leaved ash (Matić 1994).

Research into the natural regeneration and growth of narrow-leaved ash in sites of pedunculate oak is of particular importance in desiccated and decline-afflicted pedunculate oak stands. Such degraded lowland ecosystems are best regenerated with narrow-leaved ash. The procedure of "biological preparation and/or site improvement" is based on the artificial regeneration of stands with the shelterwood method, and on the introduction of narrow-leaved ash and other pioneer tree species (Matić 1996, 1989, Matić *et al.* 1996, Matić *et al.* 1996, Matić *et al.* 1994, Matić and Skenderović 1993).

The successful management of a lowland forest depends on a thorough knowledge of the ecological and biological properties of forest trees, the structures of forest stands, and the conditions in a site. Narrow-leaved ash has wide ecological valency with regard to the ecological factors important for its growth and regeneration, and good elasticity with regard to site conditions. Therefore, silvicultural treatments should satisfy different stand and site conditions; hence the choice of different regeneration methods.

This paper discusses two methods of regenerating narrow-leaved ash stands: the method of shelterwood cutting and the method of clearcutting in strips. In the former method, regeneration was analyzed after the seed and the final cut. In both methods, regeneration was analyzed in terms of the proliferation of young growth, its structural characteristics and site conditions. Site conditions were observed by establishing a series of experimental plots along a levelled land profile on which wet and unsoaked micro-depressions and micro-elevations were sighted. An additional study of pedological relations and climate was made, as well as the description of hydrological and geological features of the area.

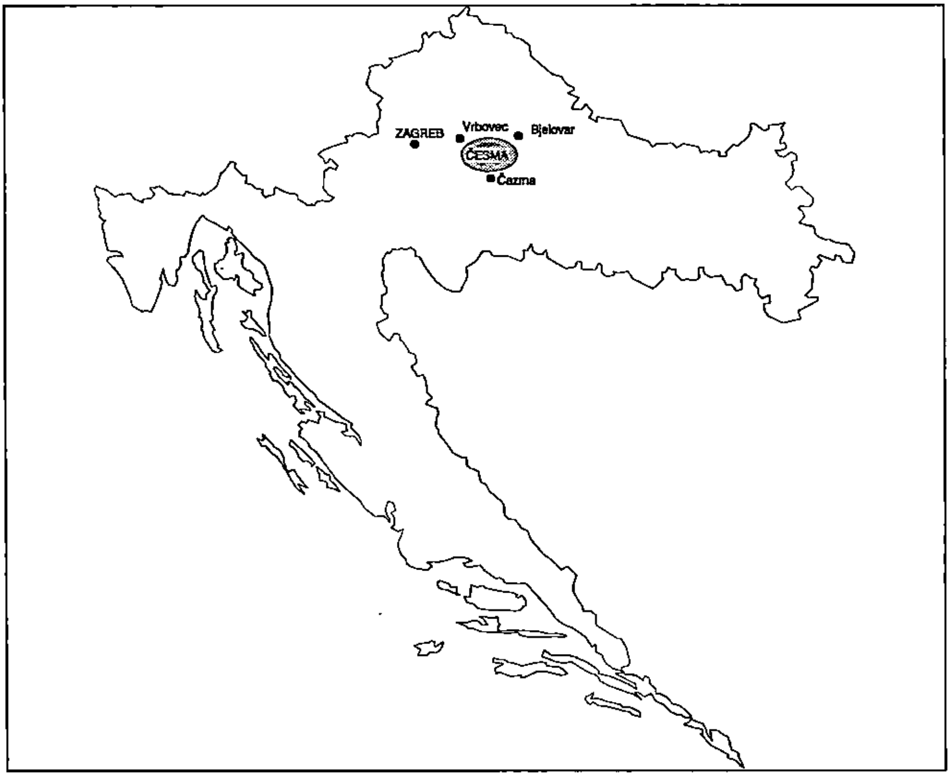
RESEARCH AREA
PODRUČJE ISTRAŽIVANJA

TOPOGRAPHIC, HYDROGRAPHIC AND GEOMORPHOLOGIC FEATURES
TOPOGRAFSKA, HIDROGRAFSKA I GEOMORFOLOŠKA OBILJEŽJA

The research was conducted in a part of the forest basin "Česma", managed by the Forest Enterprise Vrbovec (Map 1). The forest basin "Česma" is a constituent part of the Bjelovar plain which, together with upper and a part of central Posavina, belongs to a wider geographic unit of Central Croatia. The relief of the region is characterized by the denudation-accumulation, and the accumulation-tectonic type (Bognar 1979). This region contains the majority of narrow-leaved ash forests in Croatia. The northern edge of the basin runs along the southern slopes of the mountain Bilogora, and the southern one along the slopes of Moslavačka Gora. The basin of "Česma" is the area of the lowest elevation and an accumulation point of the water running down the southern slopes of Bilogora and the northern slopes of Moslavačka Gora.

The studied Management Unit of "Česma" covers an area of 1,750 ha. It is located between 103 and 107 m above sea level (Mayer *et al.* 1996), sloping in the north-south and west-east direction. The approximate coordinates encircling the basin extend from 16^0 36' to 16^0 49' of eastern longitude, and from 45^0 49' to 45^0 52' of northern latitude.

Map 1. Location of the "Česma" basin
Karta 1. Položaj bazena "Česma"



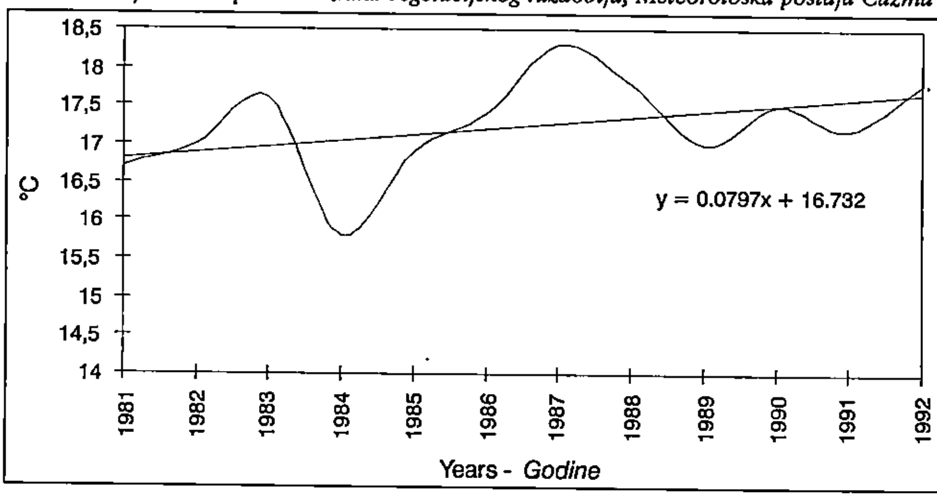
CLIMATE OF THE REGION
OBILJEŽJA PODNEBLJA

The area of Česma belongs to climatic category C, which is characterized by a temperate rainy climate without dry periods. Rainfall is evenly distributed over the whole year, with the driest part of the year falling in the cold season. The warm half of the year is marked by two precipitation maximums. The first maximum occurs in spring (May), and the second in late summer (July or August), with a dry period between them. The temperatures in the coldest month are above -3 ^{0}C, the summers are fresh with a mean monthly temperature in the warmest month under 22 ^{0}C. This type of climate belongs to the Cfwbx" type (Seletković and Katušin 1992).

The mean annual air temperature for the observed period is 10.7 ^{0}C. The marginal values of the mean air temperature range are 0.0 ^{0}C (January) and 21.0 ^{0}C (July). From a silvicultural and ecological-phytocoenological standpoint, extreme air temperatures are very important because they indicate the least favourable temperatures to which the vegetation cover, and particularly the sensitive seedlings and saplings, are exposed. The absolute minimal air temperatures are below zero in all months except for the June-September period. The values range from -22.3 ^{0}C (January) to 6.8 ^{0}C (July). The highest absolute maximum air temperatures were recorded in July and August, and their bordering values range between 16.9 ^{0}C (January) and 36.0 ^{0}C (August).

In the last ten years, mean air temperatures have risen considerably in the vegetation period (Figure 1).

Figure 1. Average vegetative air temperature, Meteorological station Čazma
Slika 1. Prosječna temperatura zraka vegetacijskog razdoblja, Meteorološka postaja Čazma

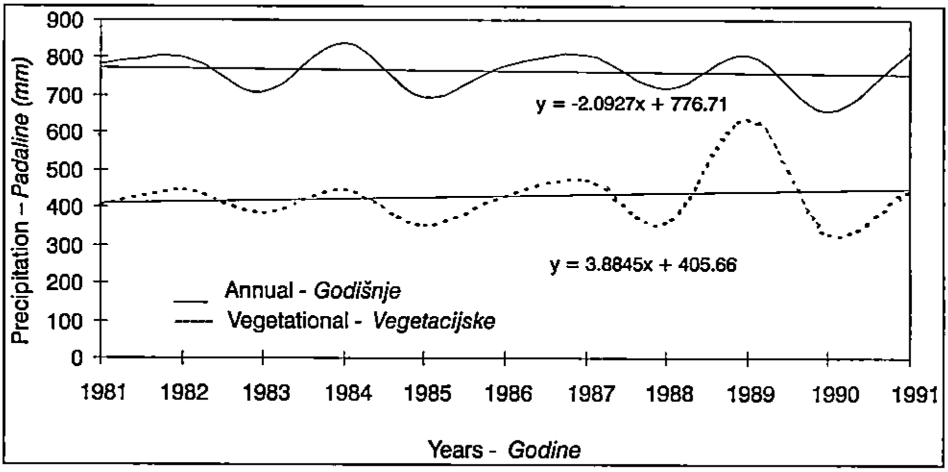


Minimal daily air temperatures of less than 0 ^{0}C (cold days) occur 89 times a year on average. Such days can occur in the vegetation period as well (April).

The average annual rainfall for the period 1981 to 1991 is 771.2 mm. A downward trend in the quantity of annual and vegetation precipitation has been noted in the last ten years (Figure 2). The average precipitation in the growth period is 428.9 mm, which is 56% of the total annual precipitation. Maximum quantities occur in June, and minimum ones in January. Another precipitation maximum occurs in the October-November period. A sudden increase in the quantity of rainfall at the beginning of the vegetation period from April to June should be pointed out.

On average, there are 26 frost days per year. The highest number of frost days occurs in the autumn. Frost is very rare in April, and completely absent in May. Days with a snow cover thicker than 1 cm (38 days a year on average) follow a similar pattern. Although not very likely, snow may also occur in April (Bertović 1971).

Figure 2. Annual and vegetational totals of rainfall, Meteorological station Čazma
Slika 2. Godišnje i vegetacijske padaline, Meteorološka postaja Čazma



GEOLOGICAL FEATURES
GEOLOŠKA OBILJEŽJA

The appearance of Quaternary deposits marks a significant point in the geological history of the Česma basin and the edges of Bilogora and Moslavačka Gora. The higher terrace parts of the basin and the mountain slopes are formed of Pleistocene deposits of typical loess, where periglacial features display manifold invasions of the glaciers into these regions. Loess is predominantly non-carbonate and of a lighter mechanical composition (loam and clayey loam), except in relief depressions where loess has retained its carbonate content due to permanent humidity and the absence of descendent water flows (Bogunović 1979).

The lowest water valleys were formed by deposits of the Holocene period. These are (Mayer 1996):

- alluvial deposits of the floodplains and old flows formed when river beds shifted,
- organogenic swampy sediments of flooded and non-flooded areas consisting of dark green and dark grey clay, clayey silt and fine-particle sand,
- deposits in disused river beds, with the sediments composed of silt, swampy clay and plant material.

The sediments of the Holocene period have a predominantly heavier mechanical composition in which clays of montmorillonite type dominate. These exhibit considerable properties of expansion, thereby causing soils to swell when wet, and to crack when dry.

PEDOLOGICAL FEATURES
PEDOLOŠKA OBILJEŽJA

Pedological characteristics of the studied plots were determined by field analyses of the three basic pedological profiles and by chemical and mechanical analyses of soil samples (18 samples) (Table 1).

The pedological profile 1/96 is located in Plot 4, on the eastern edge of the Management Unit "Česma", Compartment 66c. It lies directly along the Velika stream, with a mean elevation point of 104.69 m above sea level. The plot is situated in a wet micro-depression. The geological base consists of tightly compacted and poorly permeable organogenic - swampy sediments of mainly green and dark grey clay, clayey silt (dust) and fine-particle sands.

The profile 1/96 belongs to the type of partially drained swampy amphigley humic non-carbonate vertic soil with a stratigraphic formula Aa - Gr - Gso - Gso,r - Gr.

The humic-accumulative layer is 7 cm thick and is marked with blue-grey hydromorphous humus formed under the conditions of stagnation and saturation with surface water. The gleyic reduction horizon (Gr) reaches a depth of up to 30 cm. Due to its heavy mechanical composition (clay participates of up to 71.5 per cent) and poor permeability, surface water stagnates and reduction processes prevail in the first two horizons.

The gleyic oxidation horizon (Gso) occurs between 30 and 50 cm. It differs morphologically from the overlying horizons by the presence of yellowish-orange concretions of oxidized iron. The occurrence of three-valency iron indicates the presence of oxidation conditions in this soil horizon and the absence of contact between the surface and ground water.

The oxidation layer is followed by a transitional oxidation-reduction layer (Gso,r) to a depth of 70 cm. The gleyic reduction horizon (Gr) occurs at a depth between 70 and 95 cm, where this part of the profile is saturated with high groundwater. The groundwater table measured on 5th October 1995 was -30 cm.

The studied area is located in the wet micro-depression of the lowest terrace along the Velika stream. Before the water courses of the rivers Velika and Česma were regulated with hydro-engineering operations, the area had frequently suffered from floods. Part of the flood water was contributed by the downslope water arriving from some elevated agricultural areas located to the north-west of the plot. High embankments were built along the banks of the Velika and the Česma, and their flows were directed into canals in order to stop them from frequently flooding over. A major change in the water regime of the Česma lowland forests took place when a canal network was built along the forest road, by which the lateral influx of surface water from nearby farms was re-directed into the Česma.

Today, a large part of the lowland Česma forests is flooded in the late autumn or early spring periods (Mayer *et al.* 1996). Vegetational floods take place only during very wet vegetational periods. Mayer *et al.* (1996) cite that the average vege-

Table 1. Results of chemical and mechanical analyses of soil in the Management unit "Česma"
Tablica 1. Rezultati kemijskih i mehaničkih analiza tla u gospodarskoj jedinici "Česma"

Character code-*Oznaka uzorka*			Chemical properties of soil - *Kemijska svojstva tla*								Mechanical composition of soil determined in Na-pyrophosphate-*Mehanički sastav tla određivan u Na-pirofosfatu*				
Compt. *Odsjek*	No. of profile *Broj profila*	Depth - *Dubina*	$CaCO_3$	pH		P_2O_5	K_2O	Humus	Total N- *Ukupni N*	C : N	2.0 - 0.2	0.2 - 0.02	0.02 - 0.002	<0.002	Texture category *Teksturna oznaka*
		cm	%	H_2O	*n*-KCl	mg/100 g of soil (AL-method)		%	%		mm				
66c	1/96	0 - 7		5.6	4.7	14.5	34.2	30.7	1.2	14.9	2.4	23.8	30.0	43.8	Light clay-*Laka glina*
		7 - 30		6.2	4.8	4.9	18.7	4.5	0.21	12.6	0.0	19.9	8.6	71.5	Heavy clay-*Teška glina*
		30 - 50	0.42	6.4	5.1	22.9	11.0	2.0	0.09	14.0	1.3	8.8	31.1	58.8	Heavy clay-*Teška glina*
		50 - 70		6.6	5.1	11.4	11.7				0.2	3.5	39.5	56.8	Heavy clay-*Teška glina*
		70 - 95		7.0	5.3	17.1	9.8				0.7	6.0	47.4	45.9	Heavy clay-*Teška glina*
72c	2/96	+3 - 0		6.8	6.4	25.4	67.2	52.2	1.85	16.4					
		0 - 25		6.2	5.3	8.2	16.3	20.5	0.71	16.8	2.1	21.5	33.7	42.7	Light clay-*Laka glina*
		25 - 60		6.7	5.1	3.7	6.1	2.1	0.10	12.2	0.2	28.7	35.1	36.0	Light clay-*Laka glina*
		60 - 80	1.25	7.4	6.0	7.7	4.7				0.1	39.1	39.3	21.5	Clayey loam-*Glin. ilov.*
		80 - 100	5.48	8.1	7.4	3.5	3.8				1.9	46.5	38.0	13.6	Loam-*Ilovača*
		100 - 135	2.53	8.0	7.3	5.4	4.8				0.9	49.1	31.8	18.2	Clayey loam-*Glin. ilov.*
71a	3/96	+3 - 0		6.7	6.3	165.4	120.0	43.9	1.51	16.9					
		0 - 17		5.8	4.8	4.1	12.1	9.1	0.49	10.8	1.1	34.9	39.9	24.1	Clayey loam-*Glin. ilov.*
		17 - 40		6.2	4.3	2.5	4.1	1.3	0.08	9.8	1.0	33.3	40.6	25.1	Light clay-*Laka glina*
		40 - 70	1.66	7.7	6.3	6.6	4.8				0.1	42.9	38.7	18.3	Clayey loam-*Glin. ilov.*
		70 - 90	1.66	8.0	7.0	10.0	4.6				0.6	46.0	35.6	17.8	Clayey loam-*Glin. ilov.*
		90 - 115	5.40	8.1	7.3	6.4	6.3				0.1	47.8	32.6	19.5	Clayey loam-*Glin. ilov.*
		115 - 135	3.74	8.1	7.4	4.1	6.3				0.2	41.7	36.0	22.1	Clayey loam-*Glin. ilov.*

tational water levels for the piezometric pipes placed at a depth of 4 m in partially drained amphigleyic soils ranged from - 69 and -130 cm in the studied period between 1988 and 1994. In the vegetational period, the duration of dry pipes was between 22 and 50% at a depth of 0.5 m. In the growing period, groundwater rarely drops below 4 m in depth.

The pedological profile 2/96 is located in Plot 2, which extends over the central part of the Česma floodplain forests, at a point where the northern elevated terraced part and the lowest southern part meet. The mean elevation of the terrain is 104.85 m above sea level, and the plot was placed in an unsoaked micro-depression which is about 1 m beneath the surrounding low terraces. The geological base is formed of loess of the Pleistocene period which is carbonate in the deeper part of the profile. The clayey loam to loamy texture makes the loess a favourable substrate with good hydro-physical properties.

The studied profile 2/96 belongs to the type of partially drained humic noncarbonate epigley with a stratigraphic formula Of - Aa - Gr - Gr,so - Gso,r - Gso.

The organic horizon consists of a decomposition-affected layer about 3cm thick, but the primary structure of plant remains is still visible.

The humic accumulative horizon (As) is found at a depth of 25 cm. This is a non-structured, bluish-grey hydromorphic humus variant. A slightly lower humus content indicates partial draining and faster decomposition of organic substance.

The gleyic reduction subhorizon (Gr) is located between 25 and 60 cm in depth. It is dominated by bluish-grey microzones. The morpho-chromatic signs are an indication of stagnant surface water in this layer.

The transitional subhorizon (Gr,so), at a depth of between 60 and 80 cm, is dominated by reduction microzones, but orange-yellow secondary oxidation zones also occur.

The transitional subhorizon (Gso,r), marked by the presence of oxidizing conditions, or brownish-red microzones, is at a depth of between 80 and 100 cm.

The depth between 100 and 135 cm is taken up by the oxidizing gleyic subhorizon (Gso). Since this part of the profile is not exposed to long-lasting saturation with groundwater, oxidizing conditions prevail.

The 25-cm thick surface layer is of a somewhat heavier mechanical composition (light clay) with 42.7% clay. A favourable soil texture and the presence of carbonates contributing to the formation of structural aggregates constitute good hydro-physical soil properties. The water-table measured on 5th October 1995 was -78cm.

Epigleyic soils are characterized by stagnant surface water in the upper layers, due to which reduction processes take place. Surface water consists of water from floods, rainfall and downslope water. The network of canals and forest roads has reduced or completely obstructed the passage of water from the upper terraces into the lower ones.

Mayer *et al.* (1996) noted that the mean vegetational levels of groundwater in epigleyic soils ranged between -141 and -206 for the period 1988 to 1994, while the duration percentage of dry pipes placed at 0.5 m in depth was between 13 and 37% in the vegetational period. The increased duration of dry pipes at a depth of 0.5 in the vegetation period was a combined result of hydrotechnical draining operations, in particular of the newly-built forest roads and canals, and a series of dry growing periods.

Plot 3 with the profile 3/96 is situated on a low micro-elevation in the central part of the Česma floodplain forests, Compartment 71a. The mean elevation is 105.22 m above sea level. The geological base consists of carbonate loess from the Pleistocene period, and has a relatively favourable clayey loamy texture.

Pedological profile 3 belongs to the partially drained pseudogley-gley type with a stratigraphic formula Of - Aa - g1 -g2 - g3 - Gr - Gr,so.

The 3 cm-thick organic horizon (Of) is made up of partially decomposed forest cover in which a primary duff structure is visible.

The humus-accumulative horizon (Aa) reaches a depth of 17 cm. It is affected by hydromorphism and mottling, and is bluish-grey in colour.

The thickly mottled pseudogleyic horizon (g1) was formed by stagnant surface water. It is characterized by an interchange of wet and dry phases and an increased clay content. It is from 17 to 40 cm deep.

The thickly mottled pseudogleyic horizons g2 and g3 have a lower clay content than the neighbouring horizons. Their depth ranges from 40 to 70 cm, or from 70 to 90 cm.

The gley horizon (Gr) is blue-grey in colour and was formed under the conditions of saturation with groundwater. Reduction processes prevail. This horizon is from 90 to 115 cm deep.

The transitional gley horizon (Gr,so), 115 to 135 cm deep, is characterized by occasional oxidizing conditions.

The entire depth of the profile has very favourable textural properties (clayey loam to light clay) and good hydric soil properties. The water-table measured in the profile on 2nd October 1995 was -85 cm.

The rhizospheric humidity of pseudogley-gleyic soils is composed of precipitation, downflows and groundwater. Surface water comes in the form of flood and downflows. The regulation of the Česma and Velika waterflows (Mayer 1996, Rauš *et al.* 1996) and the construction of a network of forest roads and canals has tipped the balance towards a dry condition. As a result of shorter-lasting and less frequent floods, the surface is now covered with water only for short periods during maximum autumn-winter floods.

A much lower evapotranspiration rate and ample rainfall is the reason for a high water-table in the autumn-winter period. According to the research by Mayer (1996, 1995), the mean vegetational water levels in the piezometers placed at a depth of 4 m for the period from 1988 to 1994 in the pseudogley-gleyic soils of the Česma range between -208 to -247 cm. The lowest water levels in the vegetation season fall below 4 m in depth. Due to a drop in groundwater in the vegetation period deep below the rhizospheric layer, there is no contact between the root systems of forest trees and groundwater, nor is there any contact with the capillary uptake layer.

All the water needed for the life of forest trees in the vegetation period, especially in its second part, is provided by rainfall, so that the availability of water for vegetation plays a fundamental role in the vitality of a stand. The rate of the duration of dry pipes at 0.5 m in depth on pseudogley soils is between 49 and 80%. In very dry years, the values reach as much as 100% .

HYDROLOGICAL CHARACTERISTICS
HIDROLOŠKA OBILJEŽJA

The construction of powerful flood defence systems with retentions and accumulations, the extensive hydromeliorative operations on agricultural and forest land, and the building of a dense road network, accompanied by a rapid worsening in the quality of water, have caused major changes in the water regimes of soils and in the regimes of groundwater, floodwater and other surface water.

Observing the forest basin Česma, Mayer *et al.* (1996) note that "since the sixties, all the surrounding agricultural land has been gradually consolidated, hydromeliorated and protected from the floods coming from the river Česma and the rivulet Glogovnica, so much so that the water regimes of the forests of Varoški lug, Česma and Bolčanski lug have undergone various changes. In the first phase, the water courses of the Česma, the Velika and the Glogovnica were directed into straight deep beds cutting across the meanders of the formerly natural flows. In the second phase, embankments were built in order to stop the polluted water from entering the forests. As a result, the forest of Varoški lug found itself completely out of reach of floods, while the forest of Česma was turned into a retention area. At the same time, economic considerations forced forestry experts to agree to the construction of a network of communications and drainage canals, so that easier access could be given to these flood forests. Surface water was directed from one section to another by a system of different-sized culverts. Doubts surrounding the ecological effectiveness of all these water-regulating solutions were only increased when dieback of trees set in at the beginning of the eighties."

Infrastructural facilities and the regulation of the Česma and the Velika water courses have significantly disrupted the natural hydrological regime of the forest Česma (Rauš *et al.* 1996). The same authors state that the course of the river Česma was considerably changed after being regulated. The old curving flows, only traces of which have remained in the forest and in the clearings in the form of a water-storage meander, have been replaced by long and straight river beds. Despite being regulated, the river Česma still floods the forests. The first to be flooded are the lowest parts inhabited by the forest of black alder and narrow-leaved ash. Then, as the water level rises, floods reach the forest of pedunculate oak and greenweed. However, the forest of pedunculate oak and common hornbeam is flooded only occasionally.

Mayer (1995) monitored the water level from 1988 and found that the ground and surface water dynamics was under a strong draining influence of the canal network. Since the river beds of the Česma and the Velika were deepened and regulated, floods have been reduced in frequency and in duration. The Česma basin is flooded during late autumn and in early spring (Mayer *et al.* 1996), while in the growing period floods are absent. From an ecological standpoint, late winter floods are very important because they ensure the presence of groundwater, so that the forest can make use of the necessary water at the beginning of the growing period.

In general, the hydro-technical operations in the Česma floodplain forests have caused the basin to dry, but also to bog locally. This, combined with a series of dry vegetation periods, has resulted in an increased desiccation of lowland forests and in a transition of the forest vegetation towards drier associations.

FOREST VEGETATION
ŠUMSKA VEGETACIJA

According to Rauš (1993, 1980), and Rauš *et al.* (1996), there are seven phytocoenoses (associations and subassociations), representing seven different ecosystems, in the studied area of the Management Unit "Česma". These are:

- typical forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris typicum* Rauš 1971),
- forest of pedunculate oak and common hornbeam with beech (*Carpino betuli-Quercetum roboris fagetosum* Rauš 1971),
- forest of pedunculate oak with greenweed and remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae* Ht. 1938),
- forest of pedunculate oak and greenweed with quaking sedge (*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht. 1938)
- typical forest of narrow-leaved ash and summer snowflake (*Leucoio-Fraxinetum angustifoliae typicum* Glav. 1959),
- typical forest of black alder with buckthorn (*Frangulo-Alnetum glutinosae typicum* Rauš 1971),
- forest of black alder, elm, and narrow-leaved ash (*Frangulo-Alnetum glutinosae ulmetosum laevis* Rauš 1971).

The phytocoenology of the stands of narrow-leaved ash in Croatia was first described by Glavač (1959) under the name "forest of narrow-leaved ash and summer snowflake" (*Leucoio-Fraxinetum angustifoliae*). The same author differentiates between two associations (Glavač 1962).

The first association is a typical forest of narrow-leaved ash and summer snowflake (*Leucoio-Fraxinetum angustifoliae typicum*). It grows in wet micro-depressions and is therefore exposed to long-lasting floods and high levels of groundwater (Fukarek 1962, 1956; Rauš 1993, 1975, 1975a; Rauš *et al.* 1996, 1992).

The second association is the forest of narrow-leaved ash with summer snowflake and black alder (*Leucoio-Fraxinetum angustifoliae alnetosum glutinosae*). It inhabits the border of a flood zone, that is, a transitional area between a wet and an unsoaked micro-depression. It is also influenced by high levels of groundwater. The hydrological properties of this subassociation are more favourable than those of the first one, and so the trees are taller and of much better form (Glavač 1962).

The initial, optimal and terminal stages in the development of ash forests are determined by the degrees of humidity and the floral compositions (Glavač 1959). The initial phase is found in extremely wet, boggy micro-depressions, where narrow-leaved ash has a very poor appearance. The tree bases are wide, the stems are crooked, and the bottom parts are bent under the impact of ice. The canopy is not complete and the trees are stunted in growth. Regeneration is difficult because in winter periods the young growth is exposed to long-standing water and ice. The optimal stage is found in a wet micro-depression in which water stagnates for shorter periods. This is the habitat of a typical ash forest. The stems are straighter and the trees are much taller. The canopy is closed, while the bases of the trees are still quite prominent. The terminal stage is found in a transitional zone between a wet and an unsoaked micro-depression and in various water-logged hollows in a depression. Apart from ash, stands are also inhabited by black alder and pedunculate oak. Some species in the shrub and ground layers indicate that the conditions might be favourable for the growth of pedunculate oak.

In forest communities growing in micro-depressions, narrow-leaved ash is represented in a forest of pedunculate oak with greenweed and remote sedge (*Genisto elatae-Quercetum roboris caricetosum remotae* Ht. 1938) and in a forest association of pedunculate oak and greenweed with quaking sedge (*Genisto elatae-Quercetum roboris caricetosum brizoides* Ht. 1938). In these ecosystems, narrow-leaved ash has an important economic, ecological and social role.

Narrow-leaved ash is present on micro-elevations, although only to a lesser degree because of strong competition from other tree species, in particular from pedunculate oak. This kind of site supports the forest of pedunculate oak and common hornbeam (*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969).

PLAN OF RESEARCH
PLAN ISTRAŽIVANJA

After inspecting the Management Unit "Česma" in the Vrbovec Forest Office, suitable compartments were chosen and experimental plots established. The compartments included a wet micro-depression, an unsoaked micro-depression, and a micro-elevation. The regeneration methods used were the shelterwood and the clearcut method.

Four experimental plots were established in the compartments. The success of regeneration with the shelterwood method was observed in Plot 1 and Plot 2, which were placed in Compartment 72c containing stands where seed cuts were carried out.

The success of regeneration in terms of the quantity and structure of the young growth, as well as of site conditions, was explored in Plots 3 and 4. Plot 3 was set up in Compartment 71a, containing the early stage of a young growth which was raised with the shelterwood method. Plot 4 was placed in Compartment 66c, in a stand of an early young growth established by the clearcutting method in strips.

The research plan included several stages during and after regeneration. This is the reason that experimental plots were placed into several compartments with similar structural and site properties. Field work was carried out during 1995 and 1996.

MEASUREMENTS
IZMJERE

Plots 1 and 2 were 0.25 ha (50 x 50 m) in size. Plot 1 was located in a wet micro-depression, and Plot 2 in an unsoaked micro-depression. The diameters and heights of the trees left over from the old stand were measured. The young growth was measured in strips of 100 m^2 (2 x 50 m). Four strips were placed in each plot. The young growth was classified according to the tree species and the height classes of 25 cm.

Plot 3 and Plot 4 were strips of 10 m in width and 100 and 200 m in length. Plot 3 was 1,000 m^2 (10 x 100 m), and Plot 4 is 2,000 m^2 (10 x 200 m) in size. The micro-relief and the sites of the plots were determined by way of terrain levelling. The levelling was done with a level line in the direction of the slope (from micro-elevations towards unsoaked and wet micro-depressions). The distance between the points was 20 m. Measurements were carried out in the subplots arranged linearly along the levelled terrain profile. Each subplot was 200 m^2 in area. The sides were 20 m long (the distance between two points of the level line), and 10 m wide (5 m from the left and the right point of the level line). Plots 3 and 4 were the sums of surface areas of the subplots.

Five subplots, labelled 3/1, 3/2, 3/3, 3/4, and 3/5, were placed in Plot 3. Ten subplots, labelled 4/1, 4/2, ..., 4/9, and 4/10, were established in Plot 4. In both terrain profiles, the subplots were labelled in the following way: the first plot was placed on the highest micro-relief position (micro-elevation), that is, the highest elevation. The difference in height between the first point 3/1 and the last point 3/5 was 67 cm. As shown in Table 2 and Figures 5 and 7, all the characteristic micro-relief forms and sites of lowland forests were represented in the profiles of 100 and

200 m in length. The young growth of the principal tree species growing in the subplots along the profile was measured and categorized into height classes.

Table 2. Micro-relief and sites on plots 3 and 4
Tablica 2. Mikroreljef i staništa na plohama 3 i 4

Plot *Ploha*	Subplot *Podploha*	Distance *Udaljenost* *(m)*	Average elevation of terrain *Srednja kota terena* m n.m.	Topography *Topografija*
3	3/1	- 20	104.83	Lower micro-elevation - *Niska greda*
	3/2	20 - 40	104.83	Lower micro-elevation - *Niska greda*
	3/3	40 - 60	104.83	Transition lower micro-elevation/unsoaked micro-depression - *Prijelaz niska greda/niza*
	3/4	60 - 80	104.66	Unsoaked micro-depression - *Niza*
	3/5	80 - 100	104.36	Wet micro-depression - *Bara*
4	4/1	- 20	105.22	Lower micro-elevation - *Niska greda*
	4/2	20 - 40	105.43	Transition lower micro-elevation/micro-elevation - *Prijelaz niska greda/greda*
	4/3	40 - 60	105.42	Transition micro-elevation/lower micro-elevation - *Prijelaz greda/niska greda*
	4/4	60 - 80	105.27	Unsoaked micro-depression - *Niza*
	4/5	80 - 100	105.09	Depression in unsoaked micro-depression - *Udubina u nizi*
	4/6	100 - 120	105.50	Wet micro-depression - *Bara*
	4/7	120 - 140	104.82	Wet micro-depression - *Bara*
	4/8	140 - 160	104.70	Wet micro-depression - *Bara*
	4/9	160 - 180	104.62	Wet micro-depression - *Bara*
	4/10	180 - 200	104.50	Wet micro-depression, basin bed, lowest elevation - *Bara, dno bazena, najniže kote*

Soil samples for chemical and mechanical analyses were taken from characteristic sites of the studied localities. Data on hydro-relations in the Management Unit "Česma" were obtained by monitoring the regimes of ground and surface water in the period 1988 to 1994 (Mayer *et al.* 1996).

DATA ANALYSIS
OBRADA PODATAKA

Based on the measurements in the experimental plots, a structural analysis of the stands and the sites was made. The following factors were analyzed: the structural characteristics of the stands before the shelterwood and clearcutting treatments, the old stand and the young growth after the seed cut in a wet micro-depression, the old stand and the young growth after the seed cut in an unsoaked micro-depression, and the young growth after the shelterwood cut and the clearcut on different sites.

The prevailing site conditions in the Management Unit "Česma" are described in the section "Research area". The pedological and hydrological relationships in the studied localities are analyzed in more detail in the subsections "Pedological characteristics" and "Hydrological characteristics". The sites of experimental plots were defined on the basis of their position in the micro-relief, and on the basis of pedological, hydrological and phytocoenological conditions. The Vegetation and Pedological Maps of the Management Unit "Česma" on a scale of 1 : 10,000 were used, as well as the Hydro-pedological Overview Map on a scale of 1 : 50,000, and the Flood Map of the area.

The data was processed and presented on a PC 386/80 using the programmes Word for Windows 6.0, Excel 5.0 and Corel Draw 4.0.

RESULTS OF THE RESEARCH
REZULTATI ISTRAŽIVANJA

REGENERATION METHODS
METODE POMLAĐIVANJA

Regeneration with the shelterwood method
Pomlađivanje oplodnim sječama

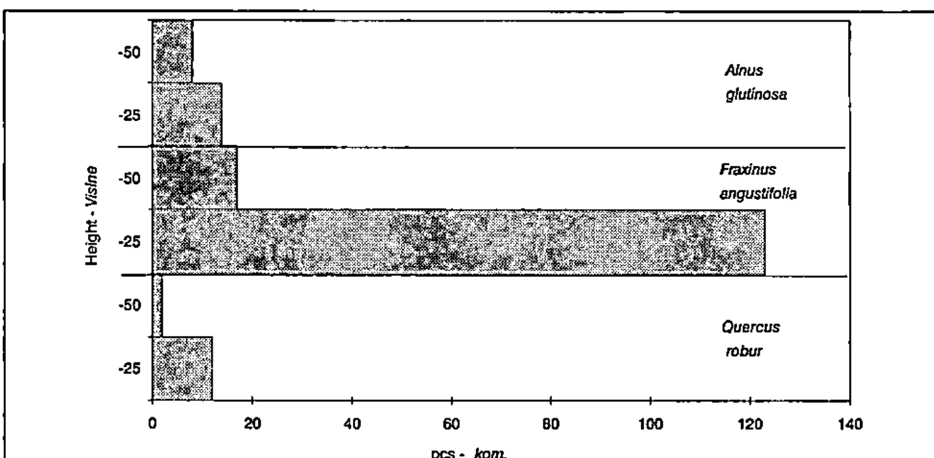
The shelterwood method will be described using the example of Plots 1 and 2. Plot 1 is located in a wet micro-depression containing a pure stand of narrow-leaved ash with some individual black alders in the lower storey. Before the regeneration, the growing stock was 375 m^3/ha at an age of 95 years. Plot 2 is situated in an unsoaked micro-depression. Before the regeneration, it contained a mixed stand of narrow-leaved ash and pedunculate oak, with lowland elm and maple in the lower storey and the understorey. The stand was 95 years old, and the growing stock was 410 m^3/ha.

In Plot 1, the preparatory cut was accomplished in 1990. The intensity of the cut was 16% of the stand's growing stock before the cut. Three years after the initial cut, the site was prepared (the shrubs and undergrowth were removed) for sowing 800 kg/ha of pedunculate oak acorns. That same year, a seed cut was carried out, removing 13% of the growing stock left over after the initial cut. 80 trees per hectare and a growing stock of 274 m^3/ha remained in the stand after the seed cut. The final cut was made in the winter of 1995. Table 3 shows the state of regeneration after the seed cut. Narrow-leaved ash was the most numerous (3,500 seedlings per hectare): in contrast, there were only 350 seedlings of pedunculate oak per hectare. There were 550 seedlings of black alder per hectare. At this stage, the majority of the seedlings of narrow-leaved ash were 25 cm high at the most (Figure 3). The young growth of narrow-leaved ash and black alder was regenerated naturally from the seeds of old trees left over in the regeneration area after the preparatory cut. The seedlings of pedunculate oak originated from the acorns sown artificially.

Table 3. Number of young growths after seeding cut, plot 1, area 400 m^2
Tablica 3. Brojnost pomlatka nakon naplodnog sjeka, ploha 1, površina 400 m^2

Plot - *Ploha: 1,* Subplot area - *Površina repeticije:* 100 m^2, Compartment - *Odsjek:* 72c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec				
Subplot - *Repeticija*	*Quercus robur*	*Fraxinus angustifolia*	*Alnus glutinosa*	Total - *Ukupno*
I	2	52	2	56
II	3	17	5	25
III	8	33	7	48
IV	1	38	8	47
Total - *Ukupno*	14	140	22	176
Per ha	350	3500	550	4400

Figure 3. Number of young growths by heights after seeding cut, plot 1, area 400 m^2
Slika 3. Brojnost pomlatka u odnosu na visine nakon naplodnog sjeka, ploha 1, površina 400 m^2

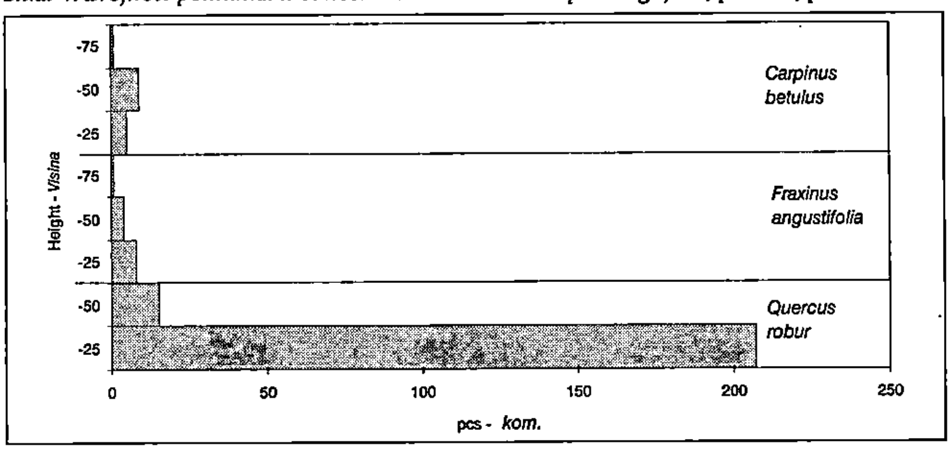


In Plot 2, regeneration was carried out similarly to that in Plot 1. A preparatory cut was made in 1990. The intensity of the cut was 16% of the stand's growing stock before the cut. In 1993, the site was prepared (the shrubs and undergrowth were removed) and 1,000 kg/ha of pedunculate oak acorns were sown. That same year, a seed cut removing 19% of the growing stock left after the preparatory cut was made. 93 trees per hectare and 280 m^3/ha of the growing stock remained in the stand after the seed cut. The final cut was accomplished in the winter of 1995. Table 4 shows the state of regeneration of the stand after the seed cut. Pedunculate oak was the most numerous (5,550 seedlings per hectare) and narrow-leaved ash the least (325 seedlings per hectare). There were 375 seedlings of common hornbeam per hectare, but no seedlings of black alder. The majority of pedunculate oak seedlings belonged to the height class of up to 25 cm (Figure 4). The seedlings of narrow-leaved ash originated from the seeds of the old trees that had remained in the regeneration area after the preparatory cut. The young growth of common hornbeam was also of natural origin, stemming from the seed of the trees growing in the neighbouring strips. The pedunculate oak seedlings were grown artificially by sowing acorns, although some naturally-grown seedlings were also found (advance regeneration in the height class of up to 75 cm).

Table 4. Number of young growths after seeding cut, plot 2, area 400 m^2
Tablica 4. Brojnost pomlatka nakon naplodnog sjeka, ploha 2, površina 400 m^2

Plot - *Ploha:* 2, Subplot area - *Površina repeticije:* 100 m^2, Compartment - *Odsjek:* 72c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec				
Subplot - *Repeticija*	*Quercus robur*	*Fraxinus angustifolia*	*Carpinus betulus*	Total - *Ukupno*
I	67	6	2	75
II	52	3	6	61
III	41	1	5	47
IV	62	3	2	67
Total - *Ukupno*	222	13	15	250
Per ha	5550	325	375	6250

Figure 4. Number of young growths by heights after seeding cut, plot 2, area 400 m^2
Slika 4. Brojnost pomlatka u odnosu na visine nakon naplodnog sjeka, ploha 2, površina 400



Regeneration with the clearcutting method
Pomlađivanje čistom sječom

Regeneration with the clearcutting method will be shown in the example of regeneration in Compartment 66c containing Plot 4. The compartment is situated immediately along the river Velika, so the site is predominantly boggy and exposed to flooding and high groundwater levels. Going away from the river, the micro-relief gradually rises. The sites alternate from a wet micro-depression to an unsoaked micro-depression to a micro-elevation. Accordingly, the composition ratio of species also changes. A pure narrow-leaved ash stand inhabiting the wet micro-depression gradually transforms into a mixed stand of narrow-leaved ash, black alder and pedunculate oak in the micro-depression, while a stand of narrow-leaved ash and pedunculate oak with some examples of common hornbeam grows on the micro-elevation.

At the end of the rotation period, at 91 years of age, the growing stock was 334 m^3/ha. Narrow-leaved ash was the main producer in the stand structure, since it constituted the dominant storey both in the wet and unsoaked micro-depression and in the micro-elevation. Pedunculate oak made up the dominant storey in the micro-depression and on the micro-elevation. Black alder developed in the lower storey of the stand in the wet micro-depression. Lowland elm and maple thrived in the lower storey and the understorey of the stand in the unsoaked micro-depression, while common hornbeam grew on the micro-elevation.

The stand was regenerated with a combination of natural and artificial regeneration using clearcuts in the form of strips. The strips were about 50 cm wide. The sum of two mean heights of the seedlings was also 50 cm. The strips were cut vertically to the terrain gradient on three occasions: in 1987, 1992, and 1994. After the cut, the site in each strip was prepared and pedunculate oak seedlings were planted. A total of 155,700 seedlings of pedunculate oak, or 8,300 pieces per hectare, were planted in the 18.75-hectare area in the period between 1987 and 1994. At the same time, weeds were removed with machines each year, and the seedlings were protected against mildew. The success of this regeneration method is described in the section "Structure and development of the young growth after the clearcuts".

SUCCESS OF REGENERATION
USPJEH POMLAĐIVANJA

Structure of young growth after the shelterwood cuts
Struktura pomlatka nakon oplodnih sječa

The structure of the young growth after the shelterwood cuts is shown in Table 5 and in Figures 5 and 6. They refer to Plot 3 in Compartment 71a containing the early stage of a young stand. The stand was formed with the shelterwood method, in the manner described in the section "Regeneration with the shelterwood method".

At the end of the rotation period, at 95 years of age, the stand's growing stock was 470,00 m^3/ha. The dominant storey of the stand in the wet micro-depression was made up of narrow-leaved ash, while in the unsoaked micro-depression and on the micro-elevation it consisted of narrow-leaved ash and pedunculate oak. In the wet micro-depression, the lower storey was made up of black alder, in the micro-depression it consisted of maple and lowland elm, and on the micro-elevation it contained common hornbeam. In the wet micro-depression the understorey did not develop, while in the unsoaked micro-depression it consisted of lowland elm and maple, and on the micro-elevation, of common hornbeam. The preparatory cut was accomplished in 1990 with an intensity of 30% of the growing stock before the cut. The following year, the site was prepared (the weeds and shrubs were removed), and 500 kg/ha of acorns were sown. A seed cut was made in 1992. About half of the growing stock left on the regeneration area after the preparatory cut was felled. The final cut was made in 1994.

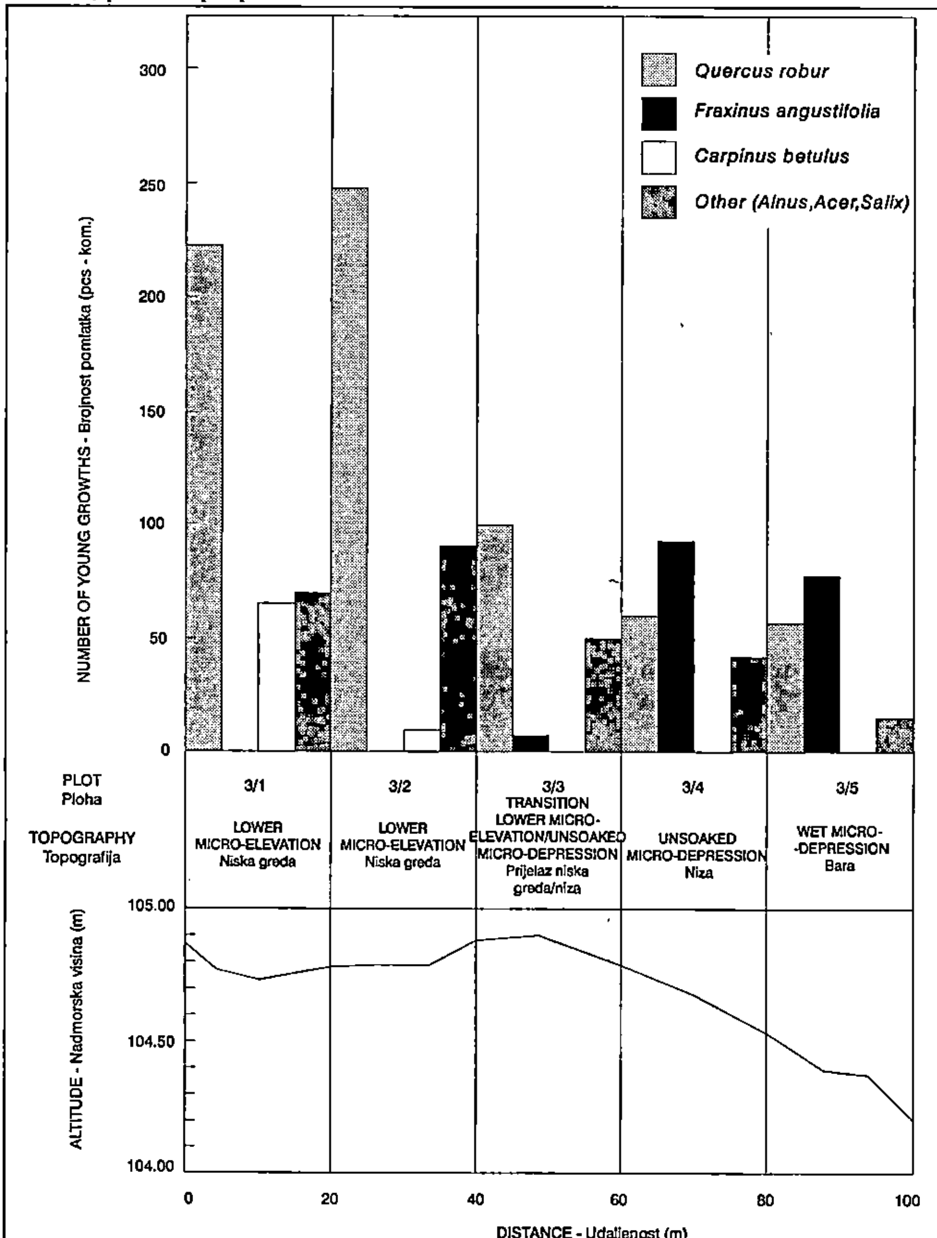
Table 5 shows the results of regeneration in relation to the micro-relief, site and tree species. In the developmental stage of a younger stand, there were 12,040 plants of the main tree species per hectare. Of this, 6,870 plants per hectare, or 57%, were pedunculate oaks, 1,770 plants per hectare, or 15%, were narrow-leaved ashes, 740 plants per hectare, or 6%, were common hornbeams, while 2,660 plants per hectare, or 22%, were other tree species (black alders, maples and willows). Except for pedunculate oak, the young growth of all the other tree species were of natural origin. Pedunculate oak seedlings originated from sown acorns and were only partially of natural origin. On average, the seedlings of pedunculate oak and narrow-leaved ash were the most numerous per hectare, while those of common hornbeam and other tree species were the least numerous. The distribution of the young growth in individual plots on the levelled terrain profile indicates the manner in which seedlings occurred in relation to the micro-relief and site conditions (Figure 5).

Table 5. Number of young growths by plots on the profile after final cut, plot 3, area 1000 m^2
Tablica 5. Brojnost pomlatka po plohama na profilu nakon dovršnog sjeka, ploha 3, površina 1000 m^2

Plot - *Ploha:* 3, Total area - *Ukupna površina:* 0.1 ha, Compartment - *Odsjek:* 71a, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec					
Plot number - *Oznaka plohe*	*Quercus robur*	*Fraxinus angustifolia*	*Carpinus betulus*	*Other (Alnus glutinosa, Acer campestre, Salix sp.)*	Total - *Ukupno*
3/1	223	-	66	69	358
3/2	248	-	8	91	347
3/3	99	6	-	50	155
3/4	60	93	-	41	194
3/5	57	78	-	15	150
Total - *Ukupno*	687	177	74	266	1204
Per ha	6870	1770	740	2660	12040

Figure 5. Number of young growths by micro-relief after shelterwood method, plot 3, area 1000 m^2, subplot area 200 m^2

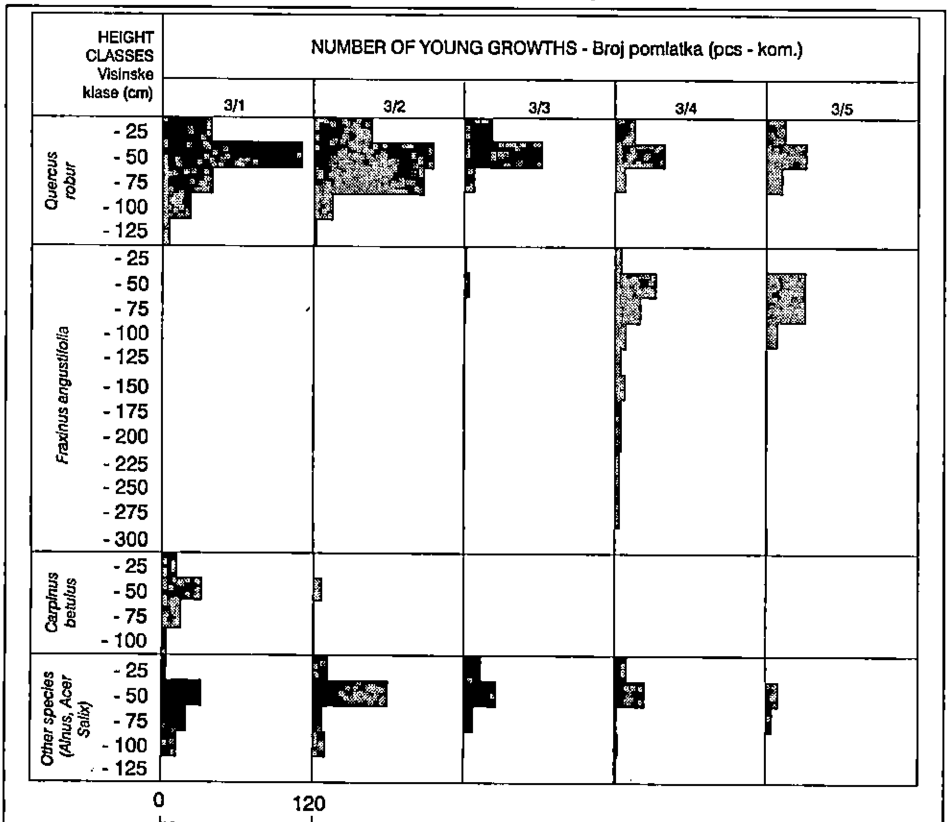
Slika 5. Brojnost pomlatka u odnosu na mikroreljef nakon oplodnih sječa, ploha 3, površina plohe 1000 m^2, površina podplohe 200 m^2



The analysis of the presence of pedunculate oak seedlings in the entire terrain profile shows that they occur most frequently in Plots 3/1 and 3/2, or on the lower micro-elevation. Although the location of Plot 3/3, situated on a transition from a micro-elevation to a micro-depression, is favourable for oak, the number of plants decreases. In Plots 3/4 and 3/5, which are micro-depressions, oak seedlings are very rare. Oak plants reach 125 cm in height on micro-elevations, and 75 cm in micro-depressions (Figure 6). The majority of the plants, stemming from artificially sown acorns, are about 50 cm tall. Plants taller than 50 cm in micro-depressions, or 75 cm in micro-elevations, have grown naturally from the acorns of old trees growing in the regeneration area.

The second most represented tree species is narrow-leaved ash. Its seedlings are present to a large extent only in wet micro-depressions and hollows. It participates at a rate of 48% in plot 3/4, and at 53% in Plot 3/5. The seedlings of narrow-leaved ash are of natural origin. Ash bears seeds almost every year. The light,

Figure 6. Height distribution of young growths by subplots on plot 3
Slika 6. Razdioba pomlatka po visinama na podplohama plohe 3



winged seeds with a high germination power regenerate easily throughout the regeneration period. In addition, young plants are shade-tolerant in their early years and grow very fast. This is the reason that the young growth ranges in height between 25 and 300 cm.

Common hornbeam occurs only on micro-elevations. Other species (maple, black alder, willow) are represented equally in all plot profiles, with maple growing on micro-elevations and willow and alder in micro-depressions. These species also bear frequent and abundant light seeds and are easily regenerated in favourable sites.

Strucutre of young growth after the clearcutting method
Struktura pomlatka nakon čiste sječe

The structure of the young growth after the clearcutting method is shown in Table 6 and in Figures 7 and 8. The figures refer to Plot 4, located in Compartment 66c, in a younger stage of a young stand. The formation of the stand was described in the section "Regeneration with the clearcutting method".

Table 6 presents the results of the applied regeneration method in terms of micro-relief, site and tree species. The stand in the early stage of young growth contains 10,630 plants of the principal tree species per hectare. Of this, 150 plants per hectare, or 2%, are pedunculate oaks, 8,650 plants per hectare, or 81%, are narrow-leaved ashes, 875 plants per hectare, or 8%, are black alders, and the remaining 955 plants per hectare, or 9%, are made up of willows, maples, and common hornbeams. On average, the best represented seedlings per plot are narrow-leaved ash, while common hornbeam and other tree species are the least numerous.

Table 6. Number of young growths by plots on the profile after clearcut, plot 4, area 2000 m^2
Tablica 6. Brojnost pomlatka po plohama na profilu nakon čiste sječe, ploha 4, površina 2000 m^2

Plot - *Ploha:* 4, Total area - *Ukupna površina:* 0.2 ha, Compartment - *Odsjek:* 66c, Management unit - *Gospodarska jedinica:* Česma, Forest enterprise - *Šumarija:* Vrbovec					
Plot number *Oznaka plohe*	*Quercus robur*	*Fraxinus angustifolia*	*Alnus glutinosa*	*Other (Acer campestre, Salix sp., Carpinus betulus)*	Total *Ukupno*
4/1	16	5	14	31	66
4/2	0	13	18	61	92
4/3	3	4	14	14	35
4/4	0	93	36	22	151
4/5	7	41	42	6	96
4/6	0	620	13	12	645
4/7	2	566	17	16	601
4/8	0	89	2	7	98
4/9	0	72	11	0	83
4/10	2	227	8	22	259
Total - *Ukupno*	30	1730	175	191	2126
Per ha	150	8650	875	955	10630

Figure 7. Number of young growths by micro-relief after clearcut method, plot 4, area 2000 m^2, subplot area 200 m^2

Slika 7. Brojnost pomlatka u odnosu na mikroreljef nakon čiste sječe, ploha 4 površina plohe 2000 m^2, površina podplohe 200 m^2

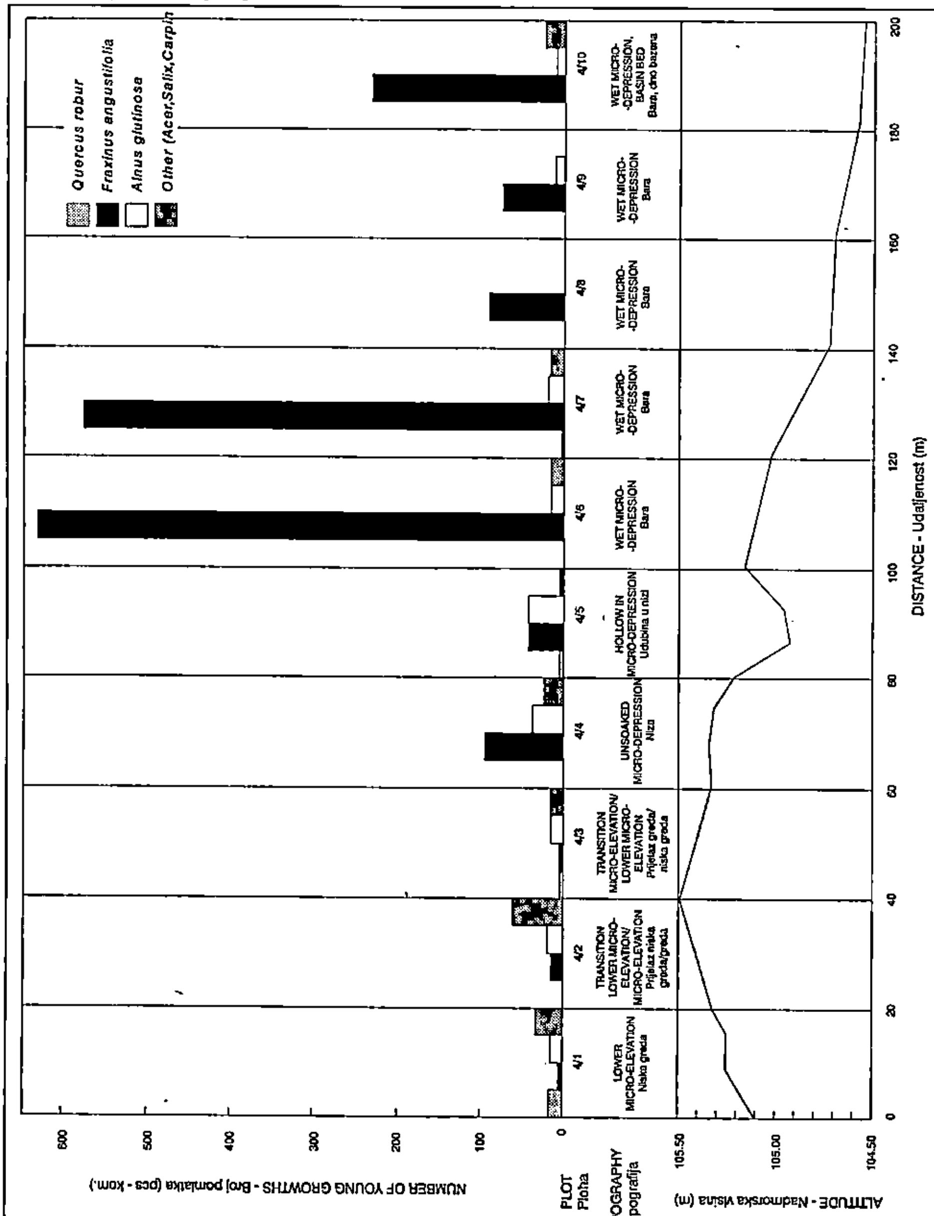
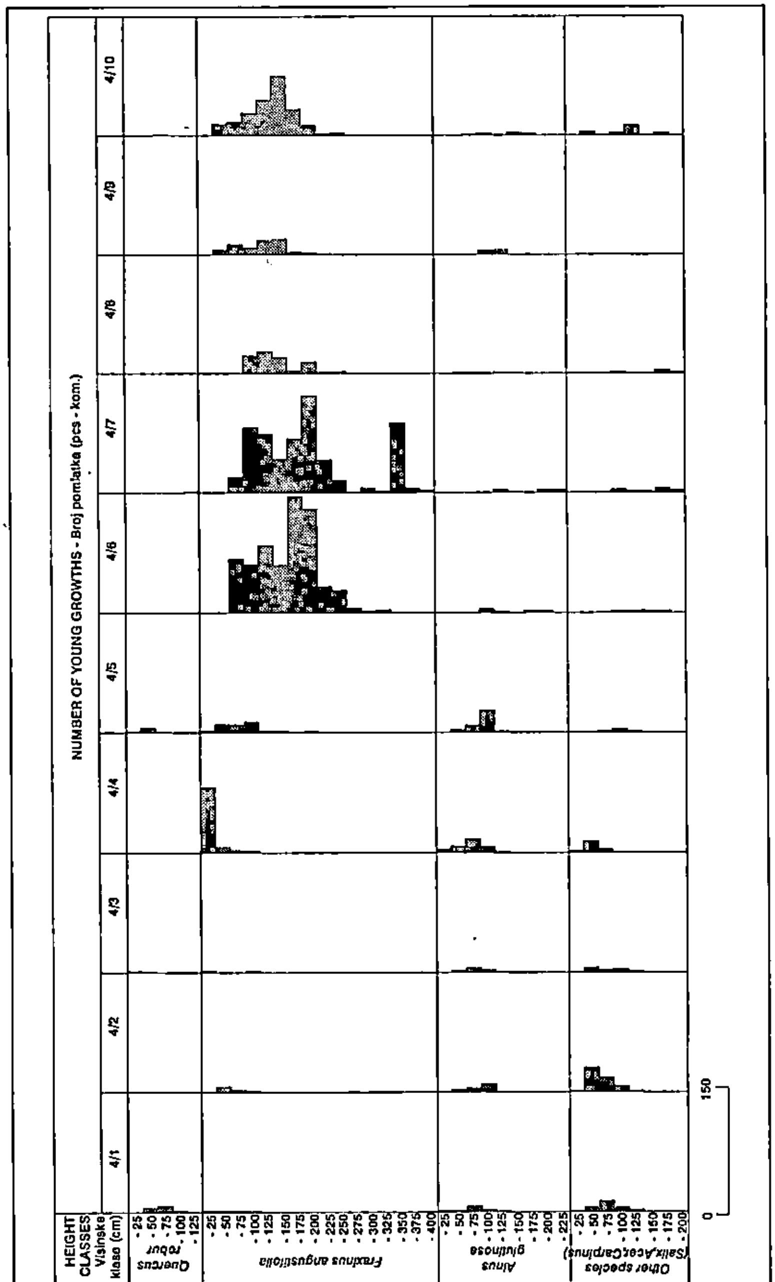


Figure 8. Height distribution of young growths by subplots on plot 4
Slika 8. Razdioba pomlatka po visinama na podplohama plohe 4



The distribution of seedlings of the above-mentioned species in the plots shows that their arrangement depends on the micro-relief and site conditions (Figure 7). Pedunculate oak was not successfully regenerated. On the whole, 150 oaks per hectare in the regeneration area is a negligible quantity in view of the fact that 8,300 seedlings per hectare were used to regenerate this stand.

8,650 narrow-leaved ash trees per hectare are found in the studied profile. This species is best regenerated in the wet micro-depression (Plots 4/6 - 4/10) and in the unsoaked micro-depression (Plots 4/4 and 4/6). It is not so well represented in the plots placed on the micro-elevation. The widest height range of the young growth of narrow-leaved ash is displayed in the wet micro-depression, then in the unsoakead micro-depression, and finally on the micro-elevation.

The seedlings of black alder are found in equal numbers in all the sites. Of other tree species, common hornbeam and maple regenerated well on micro-elevations and willow in micro-depressions.

The young growth of all the mentioned tree species is of natural origin, except pedunculate oak, which was regenerated artificially.

DISCUSSION
RASPRAVA

SITES OF NARROW-LEAVED ASH
STANIŠTA POLJSKOGA JASENA

In the forest basin "Česma", narrow-leaved ash occurs in three groups of sites. The first group consists of wet micro-depressions, the second of micro-depressions in transiton towards micro-elevations (micro-depression, a transition from a lower depression to micro-depression), and the third of micro-elevations (micro-elevation, low micro-elevation, transition from a lower micro-elevation towards micro-elevation). For the purpose of managing lowland forests in Croatia, sites were determined according to the meso-relief where landforms differ in height by some 20 m. The maps used are on a scale of 1 : 5,000 and 1 : 25,000. Our research has shown that sites of narrow-leaved ash should be differentiated at the micro-relief level. Micro-relief creates landforms less than 1 m in height which are cartographically presented on a scale of 1 : 500 to 1 : 5,000. Apart from wet micro-depressions, unsoaked micro-depressions and micro-elevations, micro-relief also allows the detection of transitional sites which influence the success of regeneration. Plots 3 and 4 are examples of relatively small areas (the length of profiles is 100 and 200 m) within the same compartment containing three groups of lowland forest sites (Table 2, Figures 5 and 7). In these areas, the old stands of narrow-leaved ash were replaced by mixed stands of narrow-leaved ash and pedunculate oak after regeneration. The differences in the micro-relief and in the sites, combined with the regenerating methods used, have resulted in the growth of new stands developed on the principles of tree growth in lowland forests. A practising forester should take into account these principles, increase the intensity of management, and avoid the application of uniform silvicultural treatments over larger areas.

The sites are determined by their position in the micro-relief (Figures 5 and 7), and by the pedological, hydrographic and phytocoenological conditions. Their characteristics depend on the water regime, which has been considerably disrupted by the construction of infrastructural facilities and the regulation of the water courses in the study area. As a result of hydro-technical operations in the lowland forests of the Česma and the Velika, the basin has generally become much drier, with scattered swampy patches. The dynamics of ground and surface water is strongly influenced by the network of draining canals. The frequency and the duration of floods has been reduced after the Česma and the Velika beds were regulated and made deeper. The Česma basin is flooded from late autumn to early spring, but floods are completely absent in the growing period. The draining of the basin, combined with a series of dry vegetation periods, has resulted in increased dieback, disturbances in stand structures and a succession of forest vegetation towards some drier associations. In such changed ecological and economic conditions, it is of utmost importance to carry out regeneration treatments properly.

REGENERATION OF NARROW-LEAVED ASH STANDS WITH THE SHELTERWOOD METHOD
POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA OPLODNIM SJEČAMA

Regeneration with the shelterwood method in three cuts (preparatory, seeding and final cut) has given rise to successful natural regeneration of narrow-leaved ash in the wet micro-depression, a partially successful one in the unsoaked micro-depression, and an unsuccessful one on the micro-elevation, as shown by the results of regeneration (Table 5, Figure 5), but also by the course of seed cuts (Tables 3 and 4). As the regeneration area may be seeded with numerous light seeds of narrow-leaved ash even before the regeneration period, the height of the young growth can vary considerably (Figure 6). During the seeding cut, most young plants reach 25 cm in height, and represent the nucleus of a future stand. Some young plants may reach heights of over 75 cm during and after the cuts, and may be individually distributed across the regeneration area, thus becoming examples of advance regeneration (Figures 3 and 4). These will have to be removed in the first years of the rotation because their height will obstruct the growth and development of the new growth.

With time, the sites of old stands of narrow-leaved ash may be affected by increased desiccation for the reasons described in the sections "Pedological conditions", "Hydrological conditions", and "Site conditions of narrow-leaved ash". This refers particularly to the stands growing in wet hollows and micro-depressions. Such sites gradually turn into oak sites, which is indicated by the presence of the plants characteristic of drier sites: oak and hornbeam seedlings, shrubs and herbaceous plants (Figure 4). This justifies the use of artificial regeneration in the form of sowing seeds and planting acorns of pedunculate oak. In doing so, stand forms change from pure ash stands to mixed stands of pedunculate oak and narrow-leaved ash (Tables 4 and 5). Still, even in new stands, the young growth of different species follows the basic principles of growth in appropriate sites. So, narrow-leaved ash grows more abundantly in micro-depressions, and pedunculate oak on micro-elevations (Figure 5). If site conditions in narrow-leaved ash stands are unchanged, then all attempts to introduce pedunculate oak artificially will be unsuccessful (Figure 3). A site that is a typical ash one is indicated by the occurrence of naturally regenerated young growth and undergrowth of black alder, narrow-leaved ash and the herbaceous plants of ash sites. In this case, narrow-leaved ash should be naturally regenerated (Table 3, Figure 3).

The examples described above show that narrow-leaved ash can be successfully regenerated in a natural way with shelterwood cuts. The conditions in the site, in particular the hydropedological and phytocoenological ones, and the structure of undergrowth and young growth sprouting during shelterwood cuts, determine the possibility of artificial regeneration with oak.

The preparatory cut creates suitable conditions for regeneration in a stand. When poor-quality and superfluous trees are removed, the crowns receive more space and light and trees of good quality are distributed evenly over the regenerated area. In our examples, a preparatory cut removing 16% of the stand's growing stock proved successful (Plots 1 and 2). As the stand in Plot 3 had a larger growing stock, the intensity of the cut was 30%. In general, the intensity of the preparatory cut depends on several factors, such as the structure of the stand, the state of the growing stock, the vertical and horizontal distribution of trees in the stand, and the state of the soil, etc. Ash stands have a poorly developed lower storey and no understorey. This is the reason that trees from the lower storey and some from the dominant storey should be marked for the preparatory cut. The stands we selected for artificial regeneration had a prominent understorey and abundant undergrowth. In the course of the seed cut, some of the trees in the understorey and some undergrowth were left standing because of their role in regulating the microclimate in the stand before the seed cut and in preventing excessive weeds.

It is not necessary to conduct a preparatory cut in properly tended stands, as their structure has adapted to future regeneration procedures during the rotation period. Likewise, preparatory cuts are not carried out in stands with a reduced growing stock, since the procedure would open the canopy too much and thus expose the sensitive ash site to weeds and excess water.

The seeding cut is accomplished 2-3 years after the preparatory cut. The examples (Plot 1 and 2) show that the intensity should not exceed 20% of the growing stock left in the stand after the preparatory cut. If there is a larger amount of growing stock, then the cutting intensity could be 50% (Plot 3). The seeding cut brings abundant light to the soil for the seeds to germinate and the seedlings to develop. In choosing trees for the seed cut, it is important to ensure that the remaining trees are evenly distributed for the final cut. At this stage, all the residual intermediate and co-dominant trees should be removed. The crowns of the remaining trees protect the new seedlings against adverse ecological factors, such as frost, hail or heat. In floods or freezing conditions, their stems bear the load of ice and thus shelter the young growth from the damage incurred when floods retreat but when hanging ice remains.

A stand is seeded in the period between the preparatory and the seed cut (the seeding period). Narrow-leaved ash stands are naturally regenerated with ash seeds and artificially regenerated with sown or planted acorns. Forestry regulations of the Republic of Croatia relating to artificial regeneration prescribe that 700 -1,000 kg of acorns per hectare be sown, and 400 - 600 kg of acorns per hectare be planted. Artificial regeneration can also be accomplished by planting 10,000 - 15,000 oak seedlings per hectare. During the seeding period in our study, the site was adequately prepared to enable a good establishment and germination of seeds. The preparations involved removing shrubs and weeds (Plots 1,2,3) and, in some cases, using a machine to loosen the soil to 19 cm in depth, surface draining, erecting fences to protect the seedlings from game and cattle, controlling rodents, etc.

As a rule, the final cut is carried out when the young growth is so firmly established that it does not need the protection of the old trees. In our examples, the final cut was accomplished two year after the seeding cut. The length of the period between the seeding cut and the final cut depends primarily on the regime of floods and on climatic conditions. If floods are frequent, abundant and long-lasting, and if frost and ice remain on the old trees for long periods, the seedlings need the prolonged protection of old trees. With regard to the climatic and hydrological conditions in the Management Unit "Česma", such long-term protection of the young growth was not necessary. Therefore, the stands were successfully regenerated within the regeneration period of 5 years.

In conclusion, we should point out that the described examples of regenerating stands of narrow-leaved ash should take into account the general influence of the hydro-technical operations undertaken in their vicinity. A changed regime of floods and a general drop in the water-table in the basin have led to partial desiccation in the sites and have directed regeneration towards the formation of stands more suitable for drier sites. In this sense, the amount of narrow-leaved ash in the new stands corresponds to the altered conditions. The shelterwood method has enabled narrow-leaved ash to regenerate naturally in the sites which optimally satisfy its ecological requirements and biological properties, that is, in the sites where it can reach its ecological optimum and where competition from pedunculate oak and other tree species is minimal.

REGENERATION OF NARROW-LEAVED ASH STANDS WITH THE CLEARCUTTING METHOD
POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA ČISTOM SJEČOM

The clearcutting system of regenerating stands of narrow-leaved ash proved unsatisfactory because it resulted in poor regeneration both in terms of the quantity and the structure of the young growth (Table 6, Figure 8). This refers particularly to the attempts to regenerate the site artificially with pedunculate oak. After planting 8,300 oak seedlings per hectare, only 150 individuals per hectare were found in the stand. The others gave way to weeds spreading vigorously over the regeneration area after the clearcut, despite several removal operations. The weeds developed in all micro-relief forms, from micro-elevations to micro-depressions. Additionally, as the regeneration area was suddenly exposed to the sun, precipitation and wind, the site conditions became unsuitable for a successful development of young oak plants.

After the clearcut, the barren regeneration area was promptly invaded by pioneer tree species (Figure 7). Micro-depressions became dominated by narrow-leaved ash, sporadically interspersed with willows, while micro-elevations were regenerated with common hornbeam and maple. Black alder regenerated equally poorly in all sites. The mentioned species are characterized by abundant yearly crops of light, winged, wind-borne seeds. As the rate of seed germination is very high and the fast-growing plants tolerate unfavourable site conditions, they belong to pioneer tree species.

The structure of the young growth in the areas regenerated with the clearcutting method shows that the applied silvicultural treatments have disrupted the progressive development of the stand and the site and have led to site regression. The bare areas left after the clearcut were gradually invaded by pioneer species. Despite the introduction of pedunculate oak seedlings, there is very little oak in the area.

CONCLUSIONS
ZAKLJUČCI

The following conclusions are based on the data involving the structural properties of the stands, the structural properties of young growth, and the site characteristics and ecological conditions in the studied area:

1. Narrow-leaved ash is regenerated in three groups of sites in the forest basin of "Česma". The first group of sites are micro-depressions (wet micro-depressions, hollows in micro-depressions). The second group are micro-depressions in transition towards micro-elevations (unsoaked micro-depression, transition from a low micro-elevation to an unsoaked micro-depression). The third group of sites are micro-elevations (micro-elevation, low micro-elevation, transition from a low micro-elevation to a micro-ele-

vation). The success of regeneration depends on the group of sites to which a regeneration area belongs and on the method of regeneration.

2. Shelterwood cuts (preparatory, seeding, and final cut) proved successful in regenerating stands of narrow-leaved ash growing in the sites of the first group and in the sites of the second group in which the developmental stage of the site did not allow pedunculate oak to regenerate. Stands of narrow-leaved ash thriving in the sites of the third group and in those of the second group in which pedunculate oak can be regenerated, were regenerated with shelterwood cuts in combination with the artificial regeneration of pedunculate oak.
3. Regenerating stands of narrow-leaved ash with the clearcutting method resulted in poor regeneration and site degradation. The clearcutting method is a treatment which stops progressive changes and starts regressive changes in the ecosystem, thus making ineffective all simultaneous attempts to alter stand forms.
4. In regenerating stands of narrow-leaved ash, sites should be differenced at the micro-relief level. Micro-relief creates landforms less than 1 m in height, which are presented in maps on a scale of 1 : 500 and 1 : 5,000. Apart from wet and unsoaked micro-depressions and micro-elevations, other transitional stages responsible for the success of regeneration are also present in the micro-relief.

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POMLAĐIVANJE SASTOJINA POLJSKOGA JASENA (*Fraxinus angustifolia* Vahl) U SREDIŠNJOJ HRVATSKOJ

SAŽETAK

Poljski jasen u šumskom bazenu Česma uspijeva na trima skupinama staništa. Prvu skupinu staništa čine mikroudubine (bara, udubina u nizi), drugu mikroudubine na prijelazu prema mikrouzvisinama (niza, prijelaz niske grede prema nizi), a treću skupinu staništa čine mikrouzvisine (greda, niska greda, prijelaz niske grede prema gredi). U gospodarenju nizinskim šumama u Hrvatskoj staništa se razlučuju na razini mezoreljefa kojega čine visinske razlike do 20 m, a kartografski se prikazuje u mjerilu od 1 : 5000 do 1 : 25000. Naša istraživanja pokazuju kako je u slučaju pomlađivanja sastojina poljskoga jasena potrebno razlikovati staništa na razini mikroreljefa. Mikroreljef čine visinske razlike do 1 m, a kartografski se prikazuje u mjerilu od 1 : 500 do 1 : 5000. Osim bare, nize i grede na razini je mikroreljefa moguće razlikovati i prijelazna staništa, koja također utječu na uspjeh pomlađivanja. Plohe 3 i 4 pokazuju kako se na relativno maloj površini (profili duljina 100 i 200 m), u istom odsjeku, nalaze tri skupine staništa nizinskih šuma (tablica 2, slike 5 i 7). Stare su sastojine na tim površinama bile sastojine poljskoga jasena, a nakon pomlađivanja nastale su mješovite sastojine poljskoga jasena i hrasta lužnjaka. Razlike u mikroreljefu i staništima, osim načina pomlađivanja, uvjetovale su ustrojstvo novih sastojina prema načelima pridolaska vrsta drveća u nizinskim šumama. Šumar praktičar trebao bi uzeti u obzir te zakonitosti, intenzivirati gospodarenje i izbjegavati ujednačenost gospodarskih zahvata na većim površinama.

Staništa su određena položajem u mikroreljefu (slike 5 i 7), te pedološkim, hidrografskim i fitocenološkim prilikama. Njihova svojstva ovise o režimu voda, koji je u istraživanom području većinom narušen izgradnjom infrastrukturnih objekata i regulacijom vodotoka. Izvedeni hidrotehnički zahvati u nizinskim šumama Česme i Velike uzrokovali su pojačanu isušenost šumskoga bazena, a samo lokalno zabarivanje. Dinamika je podzemnih i površinskih voda pod jakim utjecajem drenažne kanalske mreže. Poplave su zbog produbljivanja i kanaliziranja korita Česme i Velike smanjene po učestalosti i duljini trajanja. Česmanske su šume plavljene od kasne jeseni do ranoga proljeća, dok u vegetaciji poplave izostaju. Odvodnjenost bazena uz pojavu niza sušnih vegetacija uzrokuje pojačano sušenje, poremećaje u strukturi sastojina i sukcesiju šumske vegetacije u smjeru suših zajednica. U takvim promijenjenim ekološkim i gospodarskim uvjetima značajno je pravilno pomlađivanje sastojina.

Metoda pomlađivanja oplodnim sječama u tri sijeka (pripremni, naplodni, dovršni sijek) omogućila je uspješno prirodno pomlađivanje poljskoga jasena u bari, djelimice uspješno u nizi, a neuspješno na gredi. To pokazuju rezultati nakon pomlađivanja (tablica 5, slika 5), ali se uočava i u tijeku oplodnih sječa (tablice 3 i 4). Pomladna se površina naplođuje laganim i brojnim sjemenom poljskoga jasena i

prije pomladnoga razdoblja, pa razdioba visina pomlatka poljskoga jasena može imati širok raspon (slika 6). U tijeku oplodnih sječa najveći dio pomlatka postigne visinu do 25 cm. S tim pomlatkom treba računati kao s budućom sastojinom. Pojedine biljke koje svojom visinom dominiraju postati će predrast (slike 3 i 4).

S vremenom se stare sastojine poljskoga jasena mogu naći u uvjetima povećane isušenosti staništa zbog razloga koji su opisani u poglavljima "Pedološke prilike", "Hidrološke prilike" i "Staništa poljskoga jasena". To pogotovo vrijedi za sastojine koje uspijevaju u mikroudubinama - bari i nizi. Takva staništa prelaze u skupinu hrastovih, što pokazuje pojava hrastovoga podrasta, pomlatka običnoga graba, grmlja i zeljanica koje obilježavaju suše stanište (slika 4). Stoga je opravdano umjetno pomlađivanje sastojine sjetvom i sadnjom žira hrasta lužnjaka. Takvim se načinom obavlja izmjena sastojinskog oblika, jer se od čiste jasenove sastojine pomlađivanjem dobiva mješovita sastojina hrasta lužnjaka i poljskoga jasena (tablice 4 i 5). Ipak, i u toj novoj sastojini pomladak pojedinih vrsta prati temeljnu razdiobu prema staništima, pa je poljski jasen brojniji u mikroudubinama, a hrast lužnjak na mikrouzvisinama (slika 5). Ako su stanišni uvjeti u sastojinama poljskoga jasena ostali nepromijenjeni, tada će pokušaji umjetnoga pomlađivanja hrasta lužnjaka biti neuspješni (slika 3). Da je stanište ostalo jasenovo, pokazuje pojava prirodnoga pomlatka i podrasta crne johe, poljskoga jasena i zeljastih biljaka koje obilježavaju jasenovo stanište. U tom je slučaju potrebno prirodno pomladiti poljski jasen (tablica 3, slika 3).

Opisani primjeri pokazuju kako oplodne sječe omogućuju uspješno pomlađivanje poljskoga jasena, pri čemu eventualno umjetno pomlađivanje žirom određuje stanje staništa, i to ponajprije hidropedološke i fitocenološke prilike te struktura podrasta i pomlatka koji se pojave tijekom oplodnih sječa.

Pripremnim se sijekom u sastojini stvaraju povoljni uvjeti za pomlađivanje. Sječom loših i prekobrojnih stabala razmiču se krošnje, povećava se priljev svjetla, ravnomjerno se raspoređuju kvalitetna stabla po pomladnoj površini. Intenzitet pripremnoga sijeka od 16 % obujma drva u sastojini prije sječe pokazao se uspješnim u našim primjerima (plohe 1 i 2). Na plohi 3 intenzitet pripremnoga sijeka iznosio je 30 % od obujma drva u sastojini prije sječe jer je sastojina imala veći obujam. Općenito, intenzitet pripremnoga sijeka ovisi o strukturi sastojine, i to ponajprije o stanju drvne zalihe, okomitom i vodoravnom rasporedu stabala u prostoru sastojine, stanju tla i dr. U jasenovim je sastojinama slabo izražena nuzgredna etaža, a podstojne etaže nema. Zbog toga za pripremni sijek treba doznačivati stabla nuzgredne etaže i potrebna stabla iz dominantne etaže. U sastojinama koje smo odlučili pomlađivati umjetnim načinom podstojna je etaža izražena, a brojniji je i podrast. U tom slučaju pri doznaci treba za naplodni sijek ostaviti dio stabala podstojne etaže i podrast jer mogu koristiti za regulaciju mikroklime u sastojini prije naplodnoga sijeka i onemogućavati bujanja korova.

Pripremni sijek nije potreban u sastojinama koje su se pravilno njegovale, pa se njihova struktura tijekom ophodnje prilagodila budućemu postupku pomlađivanja. Isto tako pripremni se sijek ne izvodi u sastojinama sa smanjenom drvnom zalihom jer bi u tom slučaju sklop stabala bio previše otvoren, a osjetljivo bi se jasenovo stanište zakorovilo i zamočvarilo.

Naplodni se sijek izvodi 2 - 3 godine nakon pripremnoga sijeka. Na primjerima (plohe 1 i 2) pokazalo se kako intenzitet ne bi trebao biti veći od 20 % obujma koji je u sastojini ostao nakon pripremnoga sijeka. Kod povećanog obujma prije sječe intenzitet može iznositi i do 50 % (ploha 3). Naplodnim se sijekom postiže dovoljno svjetla na tlu za uspješno klijanje sjemena i razvoj pomlatka. Pri doznaci stabala u naplodnom sijeku značajno je postići ravnomjeran raspored stabala koja će ostati u sastojini za dovršni sijek. Ako je ostalo stabala iz podstojne etaže ili podrasta, tada ih treba ukloniti. Krošnje ostalih stabala štite pomladak od nepovoljnih ekoloških čimbenika, ponajprije od mraza, tuče i vrućina. Njihova debla u slučaju poplave i smrzavanja drže teret leda na sebi i tako onemogućuju oštećivanje pomlatka kada se poplavna voda povuče, a led ostane visiti.

U razdoblju između pripremnoga i naplodnog sijeka (naplodno razdoblje) sastojina se naplođuje. U slučaju prirodnoga pomlađivanja sastojina poljskoga jasena naplođuje se njegovim sjemenom, a u slučaju umjetnoga pomlađivanja sjetvom ili sadnjom žira. Prema sadašnjim propisima u šumarstvu Republike Hrvatske za umjetno pomlađivanje sjetvom potrebno je 700 - 1 000 kg žira po hektaru, a za sadnju 400 - 600 kg žira po hektaru. Umjetno pomlađivanje može se obaviti i sadnjom sadnica. Tada se koristi 10 000 - 15 000 sadnica hrasta po hektaru. Tijekom naplodnoga razdoblja pokazalo se opravdanim obaviti pripremu staništa za prihvat i uspješno klijanje sjemena. Ona obuhvaća uklanjanje grmlja, korovnih zeljanica (plohe 1, 2, 3), a u nekim slučajevima i rahljenje tla do dubine od 10 cm rotacijskom frezom, površinsku odvodnju, podizanje ograda zbog zaštite pomlatka od divljači i stoke, uništavanje glodavaca...

Dovršni se sijek najčešće izvodi kada se na pomladnoj površini pomladak razvije do mjere kada mu nije potrebna zaštita starih stabala. U našim je primjerima dovršni sijek obavljen dvije godine nakon naplodnoga sijeka. Razdoblje između naplodnoga i dovršnoga sjeka ovisi ponajprije o režimu poplava i klimatskim prilikama. Ako su poplave česte, obilne i dugotrajne, te ako su česti mrazovi i led koji se dugo zadržava na starim stablima, potrebna je duža zaštita starih stabala. U istraživanom području gospodarske jedinice Česma s obzirom na klimatske i hidrološke prilike takva dugotrajna zaštita pomlatka nije potrebna. Stoga je pomlađivanje sastojina uz pomladno razdoblje od 5 godina uspješno obavljeno.

Na kraju treba istaknuti kako opisane primjere pomlađivanja sastojina poljskoga jasena treba promatrati u sklopu općeg utjecaja hidrotehničkih radova u njihovu okolišu. Zbog izmijenjenoga režima poplava i općega pada razine podzemnih voda u Gospodarskoj jedinici djelomično je isušeno istraživano stanište pa se pomlađivanje usmjerilo prema stvaranju sastojina karakterističnih za sušnija staništa. U tom je smislu poljski jasen u strukturi novih sastojina prisutan onoliko koliko mu pripada u izmijenjenim uvjetima. Oplodna sječa omogućila je njegovo uspješno prirodno pomlađivanje na staništima koja ponajviše odgovaraju njegovim ekološkim zahtjevima i biološkim svojstvima, odnosno tamo gdje postiže svoj ekološki optimum i gdje je konkurencijska sposobnost hrasta lužnjaka i ostalih vrsta umanjena.

Čista se sječa pokazala nepovoljnim načinom pomlađivanja sastojina poljskoga jasena zbog slaboga pomlađivanja s obzirom na brojnost i strukturu pomlatka (tablica 6, slika 8). To se posebno odnosi na pokušaj umjetnoga pomlađivanja hrastom lužnjakom. Nakon sadnje 8 300 sadnica hrasta po hektaru u sastojini je pronađeno samo 150 biljaka po hektaru. Ostale su biljke propale u borbi s korovom koji se nakon čiste sječe bujno razvio na pomladnoj površini bez obzira na višekratnu žetvu. Korov se razvio na svim mikroreljefnim oblicima, od mikrouzvisina do mikroudubina. Osim toga pomladna je površina ostala naglo otvorena suncu, padalinama i vjetru, čime su stanišni uvjeti postali nepovoljni za uspješan razvoj mladih hrastovih biljaka.

Nakon čiste sječe ogoljelu pomladnu površinu počele su osvajati pionirske vrste drveća (slika 7). U mikroudubinama prevladava poljski jasen, pojavljuje se vrba, a na mikrouzvisinama se pomlađuju obični grab i klen. Crna se joha podjednako slabo pomlađuje na svim staništima. Za navedene je vrste karakteristično da gotovo svake godine urode velikim količinama laganoga, okriljenog sjemena koje vjetar lako prenosi. Klijavost je sjemena visoka, biljke brzo rastu, podnose nepovoljne stanišne uvjete, pa ih zbog svega toga ubrajamo u pionirske vrste drveća.

Iz strukture pomlatka na površini pomlađenoj čistom sječom vidljivo je kako su provedeni uzgojni zahvati prekinuli progresivni razvoj sastojine i staništa te izazvali regresiju staništa. Čistom sječom ogoljelu površinu postupno su počele osvajati pionirske vrste, dok je hrasta lužnjaka malo, iako su unošene sadnice.

Ključne riječi: poljski jasen (*Fraxinus angustifolia* Vahl), prirodno pomlađivanje, umjetno pomlađivanje, mikroreljef, stanište, oplodne sječe, čista sječa