ГЛАСНИК ШУМАРСКОГ ФАКУЛТЕТА
BIBLID: 0353-4537, 2015, стр. 15-24

UDK: 630*307=111
Оригинални научни рад
DOI: 10.2298/GSF15S1015D

WORK EFFICIENCY IN THE OPERATIONS OF JUVENILE THINNING OF MIXED STANDS OF PEDUNCULATE OAK WITH HORNBEAM, ASH AND OTHER HARD BROADLEAVES WITH THE STIHL MS 260 CHAINSAW

Milorad Danilović, DSc, Associate professor, University of Belgrade - Faculty of Forestry (milorad.danilovic@sfb.bg.ac.rs)
Zoran Đorđević, Graduate engineer, SE "Vojvodinašume"
Slavica Antonić, MSc, Teaching assistant, University of Belgrade - Faculty of Forestry

Abstract: This paper presents the results of research of efficacy of the lightweight low power chainsaw Stihl MS 260 in the operations of juvenile thinning in preserved even-aged mixed stands of pedunculate oak with hornbeam, ash and other hard hardwoods. The investigations were carried out in the territory of FE "Sremska Mitrovica" in three sample plots of different ages. It is the first research of this kind based on the choice of optimal technological solution for the cleaning cuts of oak stands. Technology of work is based on cutting unwanted species at a certain height in order to favor pedunculate oak as the main species. In sample plot 1 the cutting through of undesirable species was carried out in one place and then third parties carried out their processing and transportation. In sample plots 2 and 3 workers cut the unwanted species in several places and stacked the timber on the ground so as not to interfere with the growth of pedunculate oak which does not tolerate shading. In this study, we applied time and work study. Group system of work was recorded. The group typically consisted of 4 workers and a foreman. Fuel consumption was recorded by the method of tank refuelling. The research results show that operating conditions have a significant impact on the effects of work with a chainsaw, as well as on the consumption of fuel and lubricants. The differences are mainly caused by different structures of cut timber.

Key words: cleaning cut, oak, chainsaw, felling at a certain height above ground

INTRODUCTION

FE "Sremska Mitrovica" manages forests on an area of 42.495.37 hectares and traditionally pays great attention to the establishment and tending of forests of pedunculate oak. This is best confirmed by the fact that the growing stock of the areas managed by this FE has increased 2.7 times in the period from 1952 to 2004. In other words, in 1952, the growing stock amounted to 4,642,771m^3 and in 2004 it amounted to 12,716,499 m^3. Pedunculate oak accounted for 49.07% or 6,239,697 m^3 of the total growing stock. Pedunculate oak is one of the most valuable species with respect to the price of assortments. It is therefore extremely important to apply appropriate silvicultural measures at different stages and different intensities.

Pedunculate oak is affected by a large number of site, stand and biotic factors. Proper planning of tending measures for pedunculate oak stands

or adjustment of their intensity to the aim of forest management and development dynamics of stands, enable the achievement of best results in long-term planned production processes (Dekanić 1964; Matić, 1989). One of the silvicultural measures that needs to be taken to ensure proper development of oak trees is juvenile thinning. This type of felling is performed to enable the creation of high quality, healthy and vital trees, as well as to produce maximum amounts of quality timber and at the same time ensure the use of multibeneficial forest functions. The main characteristic of cleaning cuts is negative selection of trees in a stand. The aim of removing phenotypically negative individuals from the upper layer of the stand is to enable good quality specimens from the lower layer to grow into the higher production layer of the stand, in addition to favoring the best individuals in the higher layer (Stojanović and Krstić, 2008).

When performing cleaning cuts, the removal of undesirable individuals can be performed in several ways: by cutting just above the ground, cutting at a certain height above the ground, tree topping, side-reduction of the crown and girdling (Saniga, 2007).

Cutting at a certain height above the ground consists of cutting trees at a height of 1-1.5 m above the ground. It is particularly applied to juvenile stands with a large number of trees, where cutting just above the ground is difficult to perform, or if simplification of work is supposed to be introduced (Stojanović and Krstić, 2008).

Due to the extreme heliophility of oak, the process of biological differentiation of trees at younger stages of stand development is characterized by mortality, movement of trees to a lower layer and a positive change in layers rarely occurs for trees from lower layers (Bobinac and Ferlin, 1996; Ferlin and Bobinac, 1999).

The area of juvenile stands of pedunculate oak in which annual cleaning is performed in FE "Sremska Mitrovica" ranges from 25 to 160 hectares on an annual basis, observed in the last 5 years. It is necessary to hire qualified chainsaw operators for these operations and skilled workforce that will assist the workers in the choice of woody species to be removed.

Labor costs in the opeartions of cleaning are high, since low productivity and a high share of physical labor are involved. Bearing in mind the organizational problems and the desire to reduce unit costs while maintaining the quality of implemented works, activities related to the selection of optimum technological solutions for the cleaning of pedunculate oak stands were initiated.

The aim of this study is to investigate the efficiency of work in the operations of juvenile thinning of pedunculate oak stands with the Stihl 260 MS chainsaw. In addition, the goal is to establish norms and standards of work for the proposed technology as the most important element in the development of plans of engagement of manpower, machinery and materials, i.e. to reduce labor costs in these operations and achieve greater productivity.

RESEARCH PROBLEM

Pedunculate oak as the main species in certain stand conditions is threatened by the accompanying tree species and therefore it is necessary to regularly carry out tending measures in the aim of liberation of oak species from the accompanying species (ash, maple, hornbeam and elm).

Vulnerability of pedunculate oak to accompanying species occurs as a result of natural laws i.e. the biological activity of certain tree species. The impact of man through measures such as cleaning cuts is aimed at creating a favorable stand structure in the future. Therefore, certain activities are needed to affect the development progress of a stand in order to achieve silvicultural objectives.

These activities cause disturbance of the natural laws in the stand, which obliges us to vigilance, as many open issues arise from that: the technology of work, thinning weight, rate of repetition, time of operation, labor costs, etc.

The task of the forestry profession is to bring the natural course of stand development and the silvicultural goal closer together.

Tending measures favor pedunculate oak as the main species, and other accompanying species are hampered in their development, i.e. the basic task of cleaning is to create conditions for pedunculate oak to transform from a depressed species (retarded in growth) to the one with a dominant position in the stand.

The aim of removing phenotypically negative individuals from the higher layer of the stand stand is to enable good quality specimens from the lower layer to grow into the upper layer of the stand, in addition to favoring the best individuals in the upper layer. All trees in the stand are classified into three categories: the first category includes trees with the best phenotypic characteristics, the second one trees and shrubs that help development of the first category, and the third one those trees which impede proper development of trees in the first and second categories. This group involves deformed trees, trees with top-drought and sick trees (Stojanović and Krstić, 2008).

The cutting of undesired species is performed at approximately half the height of pedunculate oak in order to:

- keep pedunculate oak in the stand,i.e. to be cleaned from branches in the future and
- maintain internal cohesion properties of the stand, as the remaining parts of trees prevent snowbreaks and snowthrows in the changed circumstances arising in the stand after felling.

In the future, the above silvicultural measure will enable the implementation of positive selection according to the principle of choice of future trees, which is a strategic orientation when it comes to the management of young forest stands of pedunculate oak in the area of Ravni Srem.

Work norms are established separately for each tree species depending on the average tree diameter at breast height (Nikolić and Jezdić, 2003). According to the available literature, up to now, there are no published results regarding work norms for the operations of cleaning cuts in pedunculate oak stands. According to (1996), interim norms have been developed for silviculture and tending in sessile oak stands.

MATERIAL AND METHOD

Recording of the effects of work of the Stihl MS 260 chainsaw in the tending of mixed stands of pedunculate oak, elm, ash and other species of hard broadleaves, i.e. juvenile thinning for the purpose of pedunculate oak liberation from the accompanying species was carried out in the area of FE "Sremska Mitrovica", FA"Višnjićevo", FMU 2710 Varadin-Županja, compartments 51, 52 and 53.

Figure 1. Cutting of undesired species with a STIHL 260 chainsaw

A young stand of pedunculate oak, hornbeam and ash is located on a flat terrain. Age of the mixed oak stands with accompanying species (Carpino-Fraxino-roboris ceratosum remote) in FMU 2710 Varadin-Županja, compartment 51 is 23 years (Figure 2). It is a mixed even-aged preserved stand established artificially (by acorn sowing).

In compartments 52 and 53, stand age was 15 years (Figure 1). Areas where these stands are located are not flood prone.

The total area where the recording of cleaning cuts was performed is 39,91 ha (29.3 ha 6.25 ha 4.36 ha). The recording was performed in winter periods of 2010 and 2013, during a total of 22 working days. The weather was without precipitation and air temperature ranged from a minimum of 0 ° C in the morning to a maximum of 16 ° C at 14 h.

Figure 2. Felling of trees in sample plot 1

The juvenile cleaning was conducted by a group of 4 trained workers under the supervision of the foreman who marked trees for removal. The ages of workers who worked in the group ranged from 33 to 40 years, i.e. their work experience in the jobs of felling with a chainsaw ranged from 4 to 14 years. The commitment of workers to work in all sample plots was average.

In sample plot 1 the chainsaw operators cut the trees just above the ground, and these trees were later processed and transported by third parties. In sample plot 2 the cutting was mainly performed at a certain height above the ground with several cuts and in sample plot 3 the cut timber had small dimensions, so it was necessary to perform cutting in several places in order to place the timber on the ground and keep it in the stand. The application of low-power (lightweight) chainsaws depends on the diameter of tree species and of the accessibility of undergrowth, i.e. its density, and particularly the presence of certain species such as hawthorn, wild rose, blackthorn in the lower layer. These species do not usually hinder the development of pedunculate oak, but make the movement of workers difficult, when they go through the forest during juvenile thinning. In certain situations, sickle or axes are used in addition to chainsaws, which depends on the diameter of the cut species, accessibility of the terrain or undergrowth density.

On the basis of previous experiences in the forest estate, it was shown that the greatest effects are achieved with lightweight chainsaws, when the diameter of the cut species ranges from 2 to 7 cm, although it can also be efficiently performed with other tools such as sickle and axe, especially in cases of thick undergrowth, as workers clear the pathway for themselves with a chainsaw (cutting down some individuals of bushes and weeds) along the route during felling. The power of the chainsaw Stihl MS 260 is 2.6 kW or 3.5 hp. Its weight without bar and chain is 4.8 kg. Its fuel tank capacity is 0.46 l and 0.29 l of lubricant. The level of vibration according to ISO 7505 is 3.6 m / s2on the front handle, and 4.1 m / s2 on the rear one. The sound pressure level Lpeq according to ISO 7182 is 99 dB (A) and sound power level Lweq according to ISO 9207 is 111 dB (A).

The dimensions of compartments in the lowland forests of hard broadleaves are 750 × 750 or 750 m × 450 m, and they are intersected with main and additional skid trails whose width is 3.5 m. The distance between the skid trails depends on the density and age of a stand. The younger and denser stands are characterized by smaller spacings. The distribution of skid trails is mainly symmetrical, i.e. the width and length of the compartment are divided into equal parts with skid trails. Accordingly, in the working field, workers occupy trails with a width of about 3 m, i.e they are at a safe distance from each other with a foreman in the middle.

RESEARCH RESULTS

The following parameters were recorded within the designed technological scheme: *time of cutting, the time of transition from one plot to another and downtime.*

The share of chainsaw operation time (technological time) in sample plot 1 in the total time spent on the cleaning cut amounted to 65.2%, 34.7% in sample plot 2 and 36.7% in sample plot 3.

The share of downtime in the total time amounted to 25.7% in sample plot 1. In sample plot 2 the share of downtime is 55.02% and in sample plot 3 it is 50.1%. In addition, the share of preparatory-final time ranges from 9.1% to 13.2%.

The structure of downtime during work is shown in figures 3, 4 and 5.

The share of downtime was affected by the operator's skill in working with the chainsaw, proper functioning of the chainsaw, organization of work, etc.

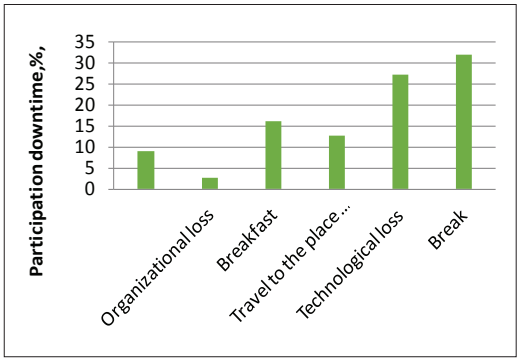

Figure 3. The structure of downtime in SP1

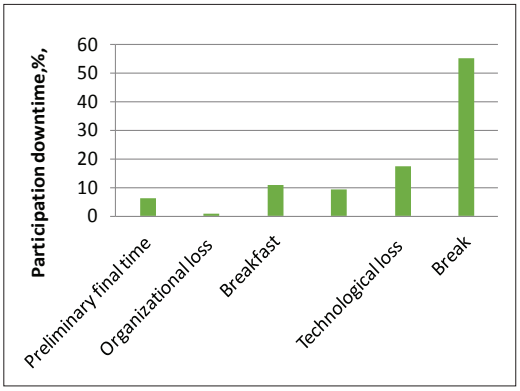

Figure 4. The structure of downtime in SP2

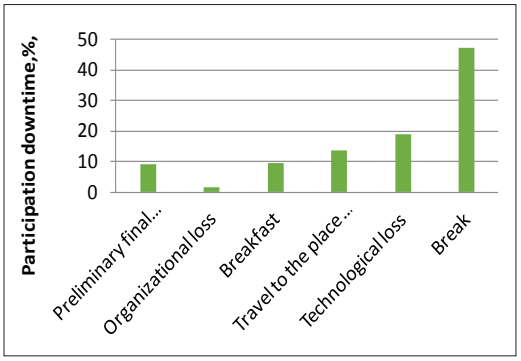

Figure 5. The structure of downtime in SP3

The share of woody species was determined in a number of sample plots. Every weekday a total of 5 sample plots were established, and they were distributed in a way that best represents the actual situation. The area in which the measurement of shrub vegetation was performed was 10 m2. The counting of species was performed in all sample plots and the recording list was filled in with those data. In this way, the shares of individual species were obtained. In addition,the diameters of the species cut were measured at the place of cutting. This was very important in order to identify the inputs for standards and norms of work in cleaning cut operations in the pedunculate oak stands.

The following tree species were registered in the sample plots: oak, hornbeam, elm, maple, poplar, ash, indigo bush and other hardwood species.

The number of species and diameters in sample plot 1 is shown by days, because thick timber is concerned with a great deviation between the minimum and maximum diameters. In other plots, there was no need for this, given that the differences in diameters at the place of cutting are small. Table 1 presents: the number of individuals of the species per hectare and average diameter for all species cut.

The results of measurements were collected from 110 sample plots. On average, the number of undesirable individuals cut per hectare was 533 in sample plot 1, and their average diameter was 17.4 cm. In sample plot 2 the number of undesirable individuals cut was 1360, and their average diameter was 2.9. In sample plot 3, 2468 of undesirable individuals were cut, and their average diameter was 2.7 cm.

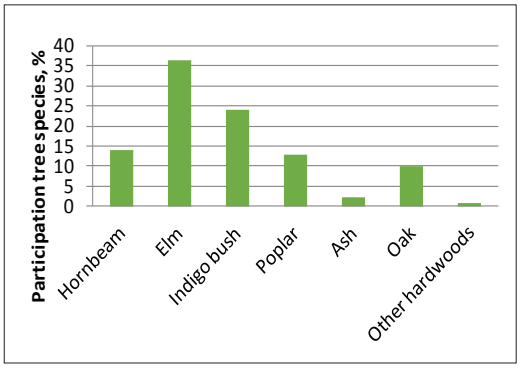

Figure 6. The shares of different tree species in the total number of cut tree species in sample plot 1

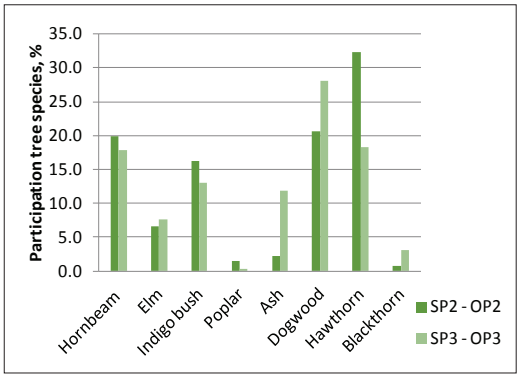

Figure 7. The shares of different tree species in the total number of cut tree species in sample plots 2 and 3

Table 1. The shares of cut species

Sample plot 1 (Compartment 51)															
Oak		**Hornbeam**		**Elm**		**Maple**		**Ash**		**Indigo bush**		**Other hard broadleaves**		**In total per 10 m²**	
Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter	Number of individuals per ha	Mean diameter
Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm
26.7	13	180	12.2	126.7	12.6	46.7	9.6	13.3	10	33.3	14.6	0	0	426.67	17.1
13.3	13.5	193.3	12.9	26.7	13	33.3	12.8	20	13.3	33.3	11.6	0	0	320	18.2
20	12.7	166.7	13.3	140	11.6	133.3	12	13.3	14.5	26.7	14.8	0	0	500	18.6
153.3	8.9	140	10.7	106.7	9.3	106.7	9.3	6.7	7	106.7	13.6	6.7	17	626.67	17.2
233.3	9	246.7	13.8	126.7	11.7	40	9.5	0	0	13.3	19	6	0	666	16.9
60	12.2	146.7	13.3	133.3	12	66.7	13.5	6.7	16	80	15.3	0	0	493.33	19.5
60	7.3	313.3	11.4	233.3	11	80	11.1	6.7	13	113.3	15.2	20	6.3	826.67	17
26.7	8.5	166.7	12.6	133.3	10.9	40	8.7	0	0	13.3	13.5	0	0	380	14.2
74.2	10.6	194.2	12.5	128.3	11.5	68.3	10.8	11.1	12.3	52.5	14.7	4.1	11.7	532.7	17.4

Sample plot 2 (Compartment 52)															
Hawthorn		**Hornbeam**		**Elm**		**Indigo bush**		**Ash**		**Dogwood**		**Other hard broadleaves**		**In total per 10 m²**	
Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm
Комада															
440	-	270	-	90	-	220	-	30	-	280	-	30	-	1360	2.9

Sample plot 3 (Compartment 53)															
Hawthorn		**Hornbeam**		**Elm**		**Indigo bush**		**Ash**		**Dogwood**		**Other hard broadleaves**		**In total per 10 m²**	
Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm	Individuals	cm
450	-	468	-	188	-	320	-	293	-	694	-	75	-	2468	2.7

The structure of cut species differs depending on the age of the stand. Sample plots 2 and 3 are characterized by a greater presence of bushy species compared to sample plot 1 where their share is small. This affected the effective operating time of the saws and the consumption of energy-generating products.

In addition to recording the time of operation on the cutting of woody species needed to produce norms of work, the consumption of fuel and lubricants was also recorded, as an important basis for the calculation of the costs of work on the cleaning operations. The recording was carried out by the method of tank refuelling.

The results of the conducted measurement are shown in Table 2.

Table 2. Consumption of fuels and lubricants

Sample plot	Unit of measurement	SP1	SP2	SP3
Fuel consumption	L·ha-1	1.78	5.17	12.42
Lubricant consumption		0.71	2.63	6.34

Fuel consumption was significantly higher in sample plots 2 and 3, as expected (Table 2). The vegetation concerned there is shrub vegetation, where it was necessary to make significantly more cuts. In addition, small diameters of 2 to 3 cm were concerned, and they had to be cut at full throttle. Otherwise, entrapment of the chain would occur. The consumption of lubricants was within the expected range, reaching about 50% of fuel consumption. Similar ratios were found in previous research (Bajić and Danilović, 2002; Nikolić and Jezdić, 2003)

On the basis of the basic norms of work, outputs of workers in cleaning cut operations with the Stihl MS 260 chainsaw were calculated in different conditions (Table 3).

Table 3. Output in the operations of juvenile thinning

Sample plot	Unit of measurement	SP1	SP2	SP3
Output	ha·dan-1	0.84	0.402	0.204

The workers' performance varies with changing stand conditions, i.e. with changes in stand density and cut diameters the performance of workers also varies, and consequently also unit costs.

This is the first research of this kind in this country, so it is necessary to make various recordings in different operating conditions, and then determine the appropriate inputs in the standards and norms of work.

DISCUSSION

In this paper, juvenile thinning as one of tending measures was observed through the use of technological solutions, which can increase productivity. The work on juvenile thinning of pedunculate oak is physically demanding, even when mechanized equipment is applied, as was the case in this study. In addition, low performance of equipment is concerned, i.e. high costs per unit of area. Investing in these activities represents an investment in the future of the stand, both in qualitative and quantitative terms, and economic benefits should be sought in the production cycle of the tended species. The selection of species and type of equipment for these activities is a complex issue that should be considered on the basis of assessment of different aspects of work, such as the technical, environmental, ergonomic and energy aspect. The technical aspect refers to the possibility of applying an asset with regard to its technical characteristics.

If technical, environmental and ergonomic conditions are met, then the problem is of economic nature. The application of specific equipment in order to increase labor productivity implies giving advantage to mechanized equipment over unmechanized one. Under specific conditions, such as stand conditions of oak stands aged 10 to 20 years, where cleaning cuts create conditions for stand development with the maximum use of its resources, the choice of equipment is usually made between lightweight chainsaws of small or medium power or clearing saws. Besides being intended for clearing, clearing saws are not always the best technical solution. The name itself may not always be a recommendation for the use of equipment. Solutions should be sought through

an assessment of the above aspects of applicability. In most operating conditions, the technical aspect of applicability is not dominant. However, when young stands of high density are concerned, this aspect should be considered from the aspect of worker safety. Application of chainsaws in the conditions of young oak stands, where the work is mainly cutting of thin branches and trunks can lead to adverse effects. Under these operating conditions, there are common jams and coming off of the chainsaw chain, as well as recurrent strokes. Working with clearing saws in young stands of high density can also lead to undesirable consequences, given that the space for manipulation is small. One of the reasons why this research was implemented is a desire to recommend the most favourable equipment for the cleaning cuts in oak stands to forestry professionals.

The results of these studies show that the effects of work of the STIHL MS 260 chain saws depend primarily on the structure of cut timber. In stands with a dense canopy the average diameter of a cut tree species is smaller compared to the stands with a sparse canopy, while the share of technological downtime is significantly higher. In addition, there is a significantly greater risk of injury. The problem associated with the load of workers due to the position of the saw was not analyzed.So, in order to provide full insight into the problem it is necessary to extend the research to the assessment of the significance of factors affecting the efficiency of chainsaw performance in the cleaning cuts of young oak stands.

Another problem, not so crucial, is of ecological nature and is mainly concerned with environmental pollutants emitting harmful gases from fuel combustion, as well as pollution by mineral oils used for chainsaw lubrication. Despite the fact that medium power motors are concerned, whose consumption of fuel and lubricants is low (Table 2) compared to the consumption of fuel and lubricants during regular cuts, in the aim of environmental protection, it is desirable to use ecological fuel, especially in young stands. This research indicates that with increasing stand age, there is an increase in performance per unit area during the operations of cleaning cuts using a chainsaw, while the consumption of fuel and lubricants is reduced. However, on the basis of these studies, it is not possible to draw conclusions concerning the choice of equipment. It is necessary to carry out comprehensive research into medium-power chainsaws and other (alernative) equipment in different stand and site conditions.

CONCLUSIONS

On the basis of the results of the research and analysis conducted, we reached the following conclusions:

- The share of effective time of chainsaw operation is considerably higher in older stands, such as sample plot 1, because of the larger diameters of trees.
- The share of downtime is greater in young stands due to small diameters of cut species, i.e. greater share of technological downtime (jams of chainsaw bar and chain, throwing off of the chainsaw chain).
- The structure of cut species varies with stand age. The share of shrub species is much greater in younger stands, which significantly affects the effective operating time of chainsaws and fuel consumption.
- Fuel consumption is significantly higher in younger stands, where the share of shrub vegetation is greater, and where it is necessary to make more cuts at full throttle in order to prevent entrapment of the chainsaw chain.
- Work performance in the operations of juvenile thinning of oak stands increases with an increasing stand age, which consequently increases unit costs.
- Since this is the first research of its kind in this country, it is necessary to expand it. Appropriate inputs to the norms and standards of work can be obtained on the basis of significance assessment of the impact factors.

REFERENCES

(1996): Привремене норме у области гајења шума и заштите шума. ЈП „Србијашуме“, Београд.

Бајић В., Даниловић М. (2002): Потрошња горива и мазива при сечи у младим храстово - грабовим састојинама, Гласник Шумарског факултета 86:59-66, Београд.

Matić S., (1989): Intenzitet prorede i njegov utjecaj na stabilnost, proiozvodnost i podmlađivanje sastojina hrasta lužnjaka, Glasnik za šumske pokuse 25: 261-278, Zagreb.

Deknić I., (1964): Metodi intenzivnog proređivanja sastojina visokog uzrasta, Dokumentacija za tehniku i tehnologiju u šumarstvu, 46:7-79, Beograd.

Bobinac M., Ferlin F. (1996): Characteristics of biological differentiation of trees in a young untended pedunculate oak stand. Proceedings of the 2nd International Conference on the Development of Wood Science/Technology and Forestry: 334–340, Sopron

Ferlin F., Bobinac M. (1999): Natürliche Strukturentwicklung und Umsetzungsvorgänge in jüngeren, ungepflegten Stieleichenbeständen. Allg. Forst-u. J. – Ztg., 170. Jg., 8. 137–142

Николић С., Јездић Д. (2003): Техничке норме и нормативи у шумарству. Друго проширено издање. ЈП ''Србијашуме''-Београд. ЈП '“Војводинашуме'' Нови Сад.