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COMPETITION BETWEEN SESSILE OAK SEEDLINGS AND COMPETING VEGETATION UNDER A SHELTERWOOD

SUMMARY

The paper presents the results of research on competitive relations between sessile oak seedlings and the most important competing species of woody vegetation, as well as ground flora that grows under a shelterwood, after the preparatory - seed cut of the shelterwood cutting. The research was conducted in sessile oak (*Quecus petraea* /Matt./Liebl.) stand in the area of northeastern Serbia. The studied stand is located at 320 to 350 m above sea level, with a slope up to 25° and western exposure. In terms of phytosociology, the stand is defined as an association of sessile oak with hairy sedge (*Carici pilosae – Quercetum petraeae* B. Jov. 1989). After the preparatory-seed cut, 124 trees per ha remained in the stand, with a basal area of 11.9 m^2/ha and a volume of 129.1 m^3/ha. The obtained results in the paper indicate the competitive relations between sessile oak and the most important competing woody species, as well as the species of ground vegetation. The most common competing woody species are silver linden (*Tilia tomentosa* Moench.) and hornbeam (*Carpinus betulus* L.), while other species (*Fraxinus excelsior* L., *Fraxinus ornus* L., *Crataegus monogyna* Jacq., *Acer campestre* L., *Cornus mas* L.) are represented individually. In addition to a significant presence, competing species of woody vegetation are characterized by very intensive development, which significantly reflects on the presence and development of sessile oak seedlings. In contrast, eight-year-old sessile oak

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seedlings have outgrown blackberries in the studied stand, which no longer competes with them. The obtained results indicate that during the regeneration of sessile oak forests, special attention must be focused on the presence and dynamics of the development of competing vegetation, as well as that the success of the regeneration largely depends on controlling this factor.

Keywords: competition, forest regeneration, sessile oak, shelterwood cutting, seedlings

INTRODUCTION

Natural regeneration of sessile oak forests is one of the most important issues in forestry, considering the presence of these forests, ecological specificity, productivity, as well as the quality of products obtained by their use.

Despite the numerous problems and aggravating circumstances that accompany the process of natural regeneration of sessile oak forests (irregular seed production, competing vegetation, sensitivity to extreme temperatures, etc.), natural regeneration offers numerous advantages over artificial regeneration, which should be practiced only in situations where natural regeneration is lacking. In addition to preserving indigenous genetic diversity (Burczyk et al. 2006), natural regeneration enables the process of natural selection from a large number of individuals during the development of a future stand (Kohler et al. 2020), thus significantly increasing its stability and resistance to negative abiotic and biotic factors.

In situations when the canopy of sessile oak forests is interrupted, if there is a lack of sessile oak seedlings, as well as if the land is weedy or the presence of competing species is too large, it is necessary to carry out auxiliary measures to the natural regeneration of sessile oak forests, which include silvicultural treatments that are focused on the removal of competing species, as well as which involve a combination of natural and artificial regeneration (Stojanović and Krstic, 2000).

One of the key phases that largely determine the outcome of the natural regeneration of sessile oak forests is the phase of the initial development of the young seedlings when its survival is most endangered (Harmer et al. 2005; Annighöfer et al 2015; Krstic et al. 2017; Krstic et al. 2018; Kanjevac 2020; Kanjevac et al. 2021). By regulating the canopy of the stand, i.e., by the controlled addition of light in this phase, the development of the seedlings can be significantly influenced, which indirectly reflects on its qualitative characteristics (Govedar 2006).

Competition by woody species and ground vegetation is one of the key factors that burden the process of natural regeneration of sessile forests and significantly hinders the development of sessile oak seedlings in the first years (Mölder et al. 2019). In accordance with the above, a large number of authors point to the endangerment of sessile oak seedlings in relation to weed species such as *Rubus* spp. (Modrow et al. 2020; Kanjevac et al. 2021), or species that better tolerate shade, such as beech (*Fagus sylvatica* L.), hornbeam (*Carpinus*

betulus L.), silver linden (*Tilia tomentosa* Moench.), etc. (Otto et al. 2009; Ligot et al. 2013; Kanjevac et al. 2020). These species have the potential to outgrow and eventually suppress sessile oak seedlings if light conditions are unfavorable over a long period (Ligot et al. 2013). In this regard, many authors emphasize the importance of removing competing vegetation (especially shoots and root suckers of woody vegetation) during the regeneration process (vön Lupke 1998; Ligot et al. 2013; Kanjevac et al. 2020), as well as pre-commercial thinning after the regeneration process (Ammer and Dingel 1997; Mölder et al. 2019).

Considering the previously stated ascertainments, the aim of this paper is to analyze competitive relations between sessile oak seedlings and competing vegetation that develop under the protection of the parent stand.

MATERIAL AND METHODS

The research was performed in a stand of sessile oak (Quecus petraea / Matt./Liebl.) in the area of northeastern Serbia in the management unit "Ujevac" within the State Enterprise "Srbijašume" Belgrade (44°25´N; 21°52´E). The average annual temperature at the study sites in the reference period 1981-2010 was 10.3°C (17.0 °C in the growing season), and the average annual precipitation was 679 mm (59.4% in the growing season). According to Thornthwaite climate classification (Thornthwaite, 1948), the studied area belongs to the subhumid moist climate (C_2), while according to Lang's classification (Lang, 1915) it also belongs to the subhumid climate i.e., the climate of low-altitude forests.

The studied stand is located at 320 to 350 m above sea level, with a slope up to 25° and western exposure. In terms of phytosociology, the stand is defined as an association of sessile oak with hairy sedge (*Carici pilosae – Quercetum petraeae* B. Jov. 1989). The soil is deep eutric cambisol, formed on neutral and basic eruptive rocks, weakly skeletal, with good properties.

Before performing silvicultural treatments, the total number of trees in the stand ($d_{1.30}$ > 5.0 cm) was 520 per ha, while the basal area amounted to 22.5 m^2/ha, and the total volume to 229.4 m^3/ha, where the share of sessile oak by volume was 63.6%, silver linden (*Tilia tomentosa*) 29.5%, common ash (*Fraxinus excelsior*) 2.7%, hornbeam (*Carpinus betulus*) 2.2%, and service tree (*Sorbus torminalis*) 2.0% (Kanjevac, 2020). After the preparatory-seed cut, 124 trees per ha remained in the stand, with a basal area of 11.9 m^2/ha and a volume of 129.1 m^3/ha, where, in addition to sessile oak trees, individual trees of common ash and service tree remained in the stand after the cutting (Kanjevac, 2020).

The combination preparatory and seed cut was conducted in 2013 when the undergrowth of accompanying tree species (silver linden, hornbeam, common ash) was removed, together with individual dead sessile oak trees. The canopy of the stand after this cut is incomplete (0.5-0.6). An experimental field of 0.25 ha (50x50 m) was set up within the stand, where the characteristics of the number and growth of seedlings (root collar diameter and height) of sessile oak and main competing species were studied on 30 sample plots of 1 m^2. In the autumn of

2017, the shoots and root suckers which appeared after the removal of the undergrowth of accompanying tree species were removed, so that the age of the competing woody species at the time of measurement was 3 years and the seedlings were predominantly of coppice origin. Considering that the majority of seedlings originated from the mast year of 2012, at the end of the vegetation period 2020 the number and growth characteristics of eight-year-old seedlings of sessile oak were studied.

RESULTS AND DISCUSSION

The average number of eight-year-old sessile oak seedlings per square meter was 5.6, the maximum was 11 and the minimum was 0 (Table 1). When it comes to competing species, the most common are silver linden whose average number of seedlings is 1.1 per square meter and hornbeam 0.5 seedlings per square meter, while other species (*Fraxinus excelsior*, *Fraxinus ornus*, *Crataegus monogyna*, *Acer campestre*, *Cornus mas*) are represented by 0.4 seedlings per square meter (Table 1). Overall, the average number of seedlings of competing species per square meter was 2.0, the maximum was 5 and the minimum was 0 (Table 1).

Table 1. The number of seedlings of sessile oak and the main competing species (per square meter)

Stat. paramet	***Quercus petraea***	***Tilia tomentosa***	***Carpinus betulus***	***Other species***	***Σ competing species***
min	0	0	0	0	0
max	11	3	2	2	5
mean	5.6	1.1	0.5	0.4	2.0
std. error	0.65	0.26	0.18	0.15	0.30
cv (%)	54.3	106.2	157.3	199.9	68.3

The average surface presence of blackberries per square meter in the studied stand is 19.3%, while the maximum is 80% and the minimum is 0%.

This indicates a pronounced presence of the main competing species of woody vegetation and ground flora. Kanjevac et al. (2021) also pointed out the pronounced presence of competing species in the regeneration layer of sessile oak forests in the area of northeastern Serbia. Also, a large number of authors point out competing vegetation as one of the key factors that threaten the success of the natural regeneration of sessile oak forests (Kohler et al. 2020).

The average height of eight-year-old sessile oak seedlings in the studied stand is 86.8 cm, while the minimum height is 21.0 cm and the maximum is 262.0 cm (Table 2). The main competing species are characterized by higher average values of height, which for silver linden is 95.5 cm (the minimum height is 43.0 cm, and the maximum is 160.0 cm), and for hornbeam is 125.8 cm (the minimum height is 81.0 cm, and the maximum is 203.0 cm) (Table 2). The blackberry,

which is the most represented of the species of ground flora, is characterized by an average height of 9.2 cm, with a maximum value of height 20.0 cm and a minimum 5.0 cm.

In addition to the fact that the blackberry can outgrow the sessile oak seedlings and thus significantly reduce the available amount of light, blackberry is also known to affect forest regeneration by forming dense thickets that overgrow and eventually press seedlings to the ground under heavy snow (Krstic et al. 2017; Kohler et al. 2020). Blackberry mostly occurs in places with greater canopy openness, i.e., the available amount of light, whereby it prefers deep and moist soils, rich in nutrients (Krstic et al. 2017; Kanjevac et al. 2021). The presence of blackberries is significantly dependent on the initial number of seedlings during the regeneration of sessile oak forests, which is why it is often considered that the initial number of seedlings per unit area is one of the key factors influencing the success of the regeneration of sessile oak forests (Kuehne et al. 2020; Kanjevac et al. 2021).

Table 2. Growth characteristics of seedlings of sessile oak and the most common competing woody species

Element	**Statistical parameter**	**Species**		
		Q. petraea	***T. tomentosa***	***C. betulus***
height (cm)	min	21.0	43.0	81.0
	max	262.0	160.0	203.0
	mean	86.8	95.5	125.8
	std. error	6.06	6.29	14.60
	cv (%)	66.7	34.8	34.8
root collar diameter (mm)	min	2.0	4.0	4.0
	max	24.0	20.0	14.0
	mean	8.0	9.1	9.2
	std. error	0.53	0.77	1.02
	cv (%)	62.9	43.8	35.1

The average value of the root collar diameter of eight-year-old sessile oak seedlings in the studied stand is 8.0 mm, while the minimum value is 2.0 mm and the maximum is 24.0 mm (Table 2). The main competing species are characterized by higher average values of root collar diameter, which for silver linden is 9.1 cm (the minimum is 4.0 mm and the maximum is 20.0 mm), and for hornbeam is 9.2 cm (the minimum is 4.0 mm and the maximum is 14.0 mm) (Table 2).

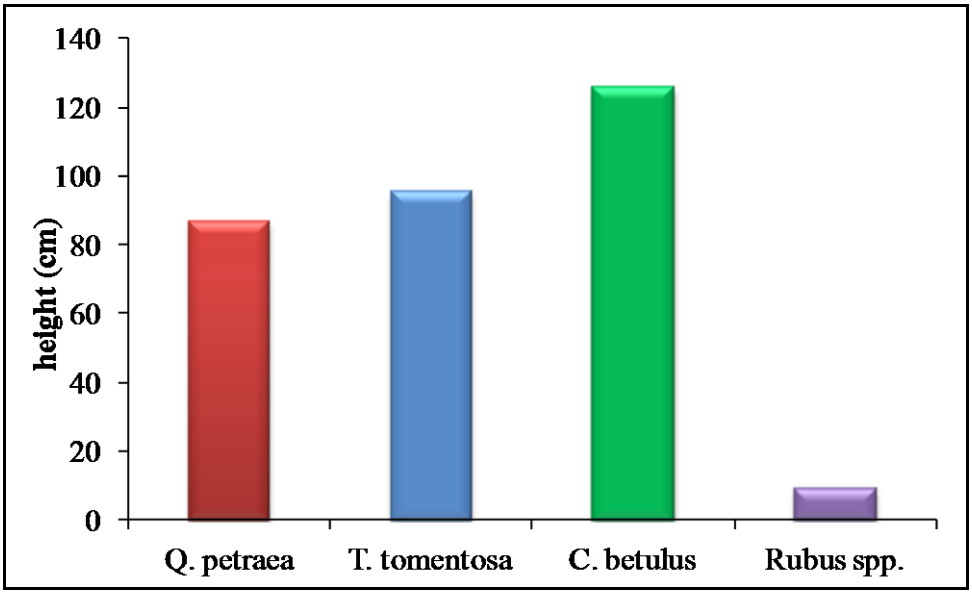
Competition between species and individuals is an ecological mechanism that affects the structure, diversity and functioning of plant communities (Robakowski and Bielinis, 2011). In oak forests, competition in the regeneration layer is a significant variable that controls the regeneration effect of these forests, and it is also known that tree species, shrubs, and ground vegetation interfere with

oak development (Annighöfer et al. 2015). The competition for the light of the seedlings of woody species at an early age is of great importance in silviculture. The competition for light and other ecological factors important for natural regeneration can occur between species or individuals of the same species and significantly depends on the bioecological characteristics of the species, as well as population density, which is one of the key factors when it comes to natural regeneration of forest and seedling development.

Due to the well-known fact that oaks are light-demanding species, any change in the parent stand leads to improved light conditions, which contributes to the development of sessile oak seedlings. However, improved light conditions can affect other species that are considered competitive in the case of oak regeneration.

Accordingly, sessile oak stands cannot be successfully regenerated if the silvicultural intervention is concentrated only on the trees of the parent stand, but it is necessary to apply auxiliary measures that will be concentrated on competing species that have the potential to overcome sessile oak seedlings (vön Lupke 1998; Ligot et al. 2013; Kanjevac et al. 2020, 2021).

Figure 1. Sessile oak seedlings and competing species in the studied stand



Graph 1 The average heights of seedlings of sessile oak and the most common competing woody species and species of ground vegetation

In addition to a significant presence, competing species of woody vegetation are characterized by very intensive development, which significantly reflects on the presence and development of sessile oak seedlings (Figure 1, Graph 1). Numerous authors state that competing vegetation can inhibit the growth of sessile oak seedlings through allelopathy or by reducing the available resources necessary for their growth and survival (Kozlowski et al. 1991; Löf, 2000). Since the eight-year-old sessile oak seedlings in the studied stand are characterized by slower growth compared to the seedlings of competing species, it is necessary to provide an additional amount of light by additional removal of the mature trees (final cut of shelterwood cutting), which will intensify the growth of sessile oak seedlings. In addition, auxiliary measures are needed to regulate the composition of the species in the regeneration layer, which will reduce the negative impact of competing vegetation on the development of sessile oak seedlings.

Accordingly, natural regeneration as an element of the close-to-nature silviculture concept is of immeasurable importance because adequate silvicultural treatments can modify the future structure of forests, influence the interaction between species, encourage wood production, and also encourage the production of numerous ecosystem services (Ammer, 2008).

CONCLUSIONS

Regeneration of sessile oak forests is one of the most important issues in modern forestry, burdened with numerous aggravating factors that have the potential to decisively influence the final outcome.

The obtained results in the paper indicate the competitive relations between sessile oak and the most important competing woody species, as well as the species of ground vegetation. The most common competing woody species are silver linden (*Tilia tomentosa*) and hornbeam (*Carpinus betulus*), while other species (*Fraxinus excelsior*, *Fraxinus ornus*, *Crataegus monogyna*, *Acer campestre*, *Cornus mas*) are represented individually. The number of eight-year-old sessile oak seedlings in the studied stand is 56.000 individuals per ha, while the number of seedlings of all competing species is 20.000 individuals per ha. The average surface presence of blackberries per square meter in the studied stand is 19.3%.

In addition to a significant presence, competing species of woody vegetation are characterized by very intensive development, which significantly reflects on the presence and development of sessile oak seedlings. In contrast, sessile oak seedlings have outgrown blackberries in the studied stand, which no longer competes with them.

The obtained results indicate that during the regeneration of sessile oak forests, special attention must be focused on the presence and dynamics of the development of competing vegetation, as well as that the success of the regeneration largely depends on controlling this factor.

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