

# The Effect of Polypropylene Tree Shelters on Growth and Survival of Pedunculate Oak Seedlings (*Quercus robur* L.)

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## ABSTRACT

**Background and Purpose:** The declining and dieback of lowland oak forests as the result of global climate change, as well as the attack of various pathogenic organisms, industrial pollution, and other negative effects reduce acorn yield and will continue to do so in the future. As a result of this fact, the areas on which artificial regeneration will be applied by planting seedlings will have to be increased. The artificial regeneration process is more expensive than the natural one, so protection measures need to be applied to minimize the loss of young seedlings.

**Materials and Methods:** Experimental plots were set up in the forest area of Spačva Basin. A completely randomized block design experiment in four repetitions was used, in which four variants of planting and protection of oak seedlings were examined. We tested polypropylene tree shelters and hydrophilic superabsorbent based on maize starch. Heights of the plants were measured by measuring tape, and survival was registered by numbering of dead and living plants. For statistical purposes, we have used analysis of variance (repeated measure ANOVA), which allows us to prove statistically significant difference between morphological traits of studied variants.

**Results:** Two years after planting, the lowest level of survival was found in unprotected seedlings (79.5%), while tree shelters provided the best conditions for seedlings survival (88.75%). In the case with the hydrophilic granules Zeba the result is slightly worse. When analyzing average height in a particular case, significantly higher plants are recorded in cases where the polypropylene tree shelters are used. The average height, with tree shelters (128.27 cm), is more than three times higher than the unprotected seedlings (37.97 cm). The addition of hydrophilic granules did not show a statistically significant difference. In cases where the seedlings were not under the tree shelter protection, the effect of hydrophilic granules was also not statistically significant.

**Conclusions:** Sheltering accelerated the height growth of the planted oaks substantially and also provided best conditions for seedlings survival. During the research period the usage of Zeba did not justify the purpose for which it was applied. Although the first results are promising in order to gain a complete insight into the potential of tree shelters it is necessary to record the changes and maintain the experiment for a further 2-3 years with quantification of other harmful factors that may appear (drought, game etc.) after which a more reliable judgment regarding their usefulness could be provided.

**Keywords:** Spačva Basin, artificial regeneration, Zeba granules, polypropylene tree shelters, *Corythucha arcuata*, *Microsphaera alphitoides*, pedunculate oak

## INTRODUCTION

The decline of pedunculate oak (*Quercus robur* L.) in the last few decades has been intense in the whole territory of its areal [1-3], and Croatia is no exception [4, 5]. From

the total felled tree volume of pedunculate oak trees from forests of Spačva in the period from 1996 to 2006 almost 58% referred to dead and damaged trees [6]. Changes in the water regime (decrease in groundwater level or increase in humidity, or the so-called "swamping"), along with the

influence of droughts [6], water and air pollution, and tree defoliation due to insects or fungi, are the most important factors that cause dying of oak trees in Croatia [7, 8]. Most recently, new invasive species the oak lace bug (*Corythucha arcuata*), which has potential negative impact, has been spotted in pedunculate oak stands in Croatia [9], but changes in the vegetation cover have been recorded as well, in the form of movement to drier plant communities [10, 11]. Along with all the above mentioned facts, as well as the trend of average, maximum and minimum air temperature rise throughout Croatia [12] and models predicting decrease in quantities of rainfall in the wettest but also in the driest months [13], management of oak stands will require adaptation to the actual occurrence of climate change, both in Croatia and south Europe [14]. Reconstruction of these stands in the future will be a real challenge and an increase in the intensity of the forest works can be expected, as well as changes in the ways of management so far, in terms of adaptive forest management. The main characteristic of adaptive forest management is the flexibility and adaptation of all activities to the specific biological, ecological and structural features of forest ecosystems and the changes that occur in [15].

Global climate change and the attack of various pathogenic organisms lead to the decline of forests or dieback of trees in forest. Lowland forests of pedunculate oak and other lowland tree species are most intensively affected by these occurrences [16, 17]. This process manifests itself as the defoliation of tree crowns [18, 19]. With increased intensity of crown defoliation, the yield of acorn decreases as well [20]. Forest areas with increased intensity of defoliation or the share of areas with significantly defoliated crowns of oak trees are growing [18], and it is expected that the area on which artificial regeneration with seedlings will have to be applied will increase as well. The artificial regeneration process is more expensive than the natural one, so the loss of seedlings is not economically acceptable, because in that case the whole work would have to be repeated several times.

Competitiveness of weeds and game is the most harmful factor that reduces plant growth and survival. Dense weeds quickly overgrow seedlings, overshadow them, and reduce the intensity of photosynthesis, which affects plant vitality and height gain [21]. In addition, weeds are very competitive for water and nutrition to planted young seedlings. In winter, the overhanging parts of weeds mechanically press and bend the seedlings. The game cut off the tops of seedlings and thus reduce their competitiveness compared to the weeds surrounding them [22].

Polypropylene tree shelters, which in 1979 were introduced by the English forester Graham Tuley, can significantly reduce the negative impact of weeds and game. As reported by Jeffrey and Stephens [23] due to wild game browsing the leaves of unprotected black walnut, seedlings were higher at the start of the experiment than three years later, while the protected seedlings grew from 36.1 cm to 89.0 cm. Liović [24] states that 20% of unprotected plants had a cut-off top of the seedlings.

The use of the polypropylene tree shelters does not exclude the use of herbicides (used during preparation site for stand regeneration and for several sprayings after

planting), but fewer quantities are spent because the whole surface for regeneration is not needed to be sprayed. After the planting, once a year herbicide spray needs to be applied to the 1 m diameter around each tree shelter, which is economically and ecologically more favorable [25].

The use of the polypropylene tree shelters also reduces to some extent the onset of plant disease (powdery mildew) due to the specific climate within it [26]. Similarly, Liović [24] in his research states that 15% of unprotected control plants were browsed by oak defoliators while seedlings within the shelters were not damaged. The basic advantage of polypropylene tree shelters is the accelerated height increase of seedlings and their survival, as reported by many authors [24, 27-29]. The rapid height increase shortens the time of the plant growing in the shadow of weeds and has a significantly higher probability of survival.

Pedunculate oak seedlings and offspring were particularly sensitive to the conditions of weed competition because of their great demands for light. Therefore, in the first few years after planting, it is necessary to tend young oak plants, i.e. to release them from weeds. The procedure is not easy because of the fact that on eutrophic and wet soils the weeds grow rapidly and turn into lush (Figure 1). Therefore, during the year it is needed to tend them at least twice. Mechanical treatment with a large number of people is expensive and, because of young people leaving to work abroad, there is a problem of the lack of workers today. The use of herbicides on large surfaces is neither ecologically nor economically justified. Due to the problems mentioned above, the aim of this study is the implementation of forest regeneration methods into forestry practice which are not labor intensive and which include less use of pesticides.

## MATERIALS AND METHODS

Experimental plots were set up (November 2014) in the area of Forest Administration (FA) Vinkovci, Forest Office (FO) Županja, Management Unit (MU) Kragujna, Rašćica, Compartment (Comp.) 35a. This area belongs to the forest



**FIGURE 1.** Eutrophic and humid soil supports the rich growth of weeds.

area of Spačva Basin, one of the largest complexes of lowland pedunculate oak forests in Europe, where the management class of oak forests occupy 96% of them and spread over 40.000 ha (1/5 of all pedunculate oak forest stands in Croatia). Because of its specific hydrological characteristics, almost the whole area is situated on alluvial flat terrain with moderate micro-elevations. The main types of soil are accompanied by a topological gradient: pseudogley and pseudogley-gley dominate on river terraces, while different types of gley soil are found on micro-elevations and micro-depressions [30].

Research plots have been placed in relative forest soil area that had been for a long time overgrowing with scarce bushy vegetation, sometimes used as wild game feeding grounds. The scope of the experimental field encompasses the area of light-strips along the forest road that has been used for a long time for this purpose (Figure 2). There is also a trench along the forest road for the purpose of drainage (as the element of the road) with additional enlargement for its maintenance. Nearby old oak stands on micro-elevation belong to the forest community of common hornbeam and pedunculate oak forests (*Carpino betuli - Quercetum roboris*, Rauš 1969) located on the edge of the micro-depression area where the experimental plots are situated.



**FIGURE 2.** Trial location (FA Vinkovci, FO Županja, MU Kragujna, Rašćica, Comp. 35a).

The climate in this part of Croatia is continental. The average annual temperature is 11.4°C, the hottest month is August, with a moderate temperature of 21.8°C, while the coldest month is January, with an average temperature of -0.5°C. The average rainfall is 686 mm, with a maximum in June [31].

The object of the study are pedunculate oak seedlings used for the regeneration of oak forests in this area through various methods. In the study a completely randomized block design experiment in four repetitions was used, in which four variants of planting and protection of oak seedlings were examined (Figure 3).

Each repetition consisted of four variants: seedlings protected with polypropylene shelters with addition of hydrophilic granules Zeba (SŠHG), seedlings protected with polypropylene shelter (SŠ), seedlings without protection and Zeba (S), and unprotected seedlings with addition of Zeba (SHG).

Zeba (United Phosphorus, Inc.) is a superabsorbent based on maize starch whose high water absorption capacity (500 times their own weight) is used to improve the supply of water to seedlings during the dry season [32, 33]. Additionally, it is completely biodegradable. Numbers of seedlings are shown in Table 1.

Polypropylene shelters are cream-colored, green or brown, made of double layer polypropylene, resistant to UV rays. The upper edge of the tree shelter was bent outwards to avoid damage to the plants after it had overgrown. Due to the more economical and easier transport and storage, the shelters selected for this experiment are packed in 4 pieces, one in the other, so their diameters are between 8.3 and 10.8 cm. They are manufactured to be from 0.2 m high for

**TABLE 1.** Different cases and the number of seedlings of pedunculate oak.

Case	Number of seedlings (pieces)
SŠHG	280
SŠ	280
S	800
SHG	800
Total	2160



**FIGURE 3.** Completely randomized block design experiment in four repetitions.

the protection from voles and up to 1.8 m for the protection from wild game (common and roe deer). We used 1.2 m height shelters. The shelter is secured using a stake and is fastened with two plastic straps.

In order to reduce the negative impact of weeds, during the month of May around every shelter in the circle of 1 meter diameter all vegetation was sprayed with herbicide based on the glyphosate active substance (Figure 4). However, the weeds continued to grow lushly, so in 2016 herbicide was applied in diameter of 1 meter around each shelter again.

At the end of the vegetation period, for each seedling the total height were measured by measuring tape and the survival were established by numbering of dead/living plants.



FIGURE 4. Herbicide treatment around tree shelters.

Any biotic factors that occurred during the study period and that could negatively affect the growth and development of seedlings were just visually recorded without analyzing the impact on the growth and development.

With the aim of answering set research question, we have used analysis of variance (repeated measure ANOVA), which allows us to prove statistically significant difference between morphological traits of studied variants. In cases when statistically significant difference between variants was confirmed, it was necessary to determine which variants differed. Thus, differences gathered by repeated measures ANOVA were tested with „post hoc“ LSD test. Type I error (5%) was regarded as statistically significant. Furthermore, descriptive statistics was compiled for acquired data. Data analysis was conducted using Statistica software (StatSoft Inc. 2007) [34]. The condition of variance homogeneity is satisfied.

## RESULTS AND DISCUSSION

### Survival

The results are shown in tabular form (Table 2) and graphically (Figure 5). Planting which includes the protection and support by polypropylene tree shelters provided the best conditions for seedlings survival, so in that case 88.75% seedlings survived. In the case where Zeba were used the results are slightly inferior (87%) and it can be said that they do not justify its application. The lowest survival rate was in the case of unprotected seedlings (79.5%). Seedlings without protective shelters, but with the addition

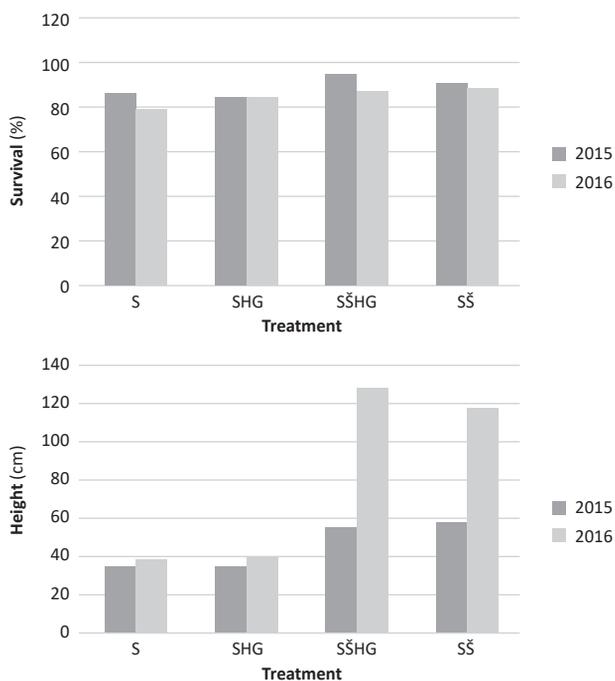


FIGURE 5. Survival and height of seedlings during research period.

of hydrophilic granules have about 5% better chances of survival. These results are in agreement with the results of Liović [35], in which the mortality rate of oak seedlings protected by shelters was 6% and unprotected seedlings 24%, but we must emphasize that Liović [35] did not study effects of Zeba. In Valkonen [36] sheltering improved the survival of planted seedlings of pedunculate oak a little, but the difference was not significant.

**TABLE 2.** Survival and height of seedlings at the end of 2015 and 2016 vegetation.

Case	Survival (%)	Height (ME ± SD) (cm)
<b>2015</b>		
SŠHG	95.57	54.94 ± 17.26
SŠ	91.97	56.64 ± 17.37
S	86.46	34.36 ± 9.70
SHG	85.54	34.71 ± 9.41
<b>2016</b>		
SŠHG	87.00	128.72 ± 33.42
SŠ	88.75	117.27 ± 41.27
S	79.50	39.04 ± 12.62
SHG	84.75	37.97 ± 12.01

ME - mean; SD - standard deviation

### Height

ANOVA showed statistically significant difference between variants height during research period (ANOVA:  $F=18.156$ ,  $p<0.001$ ). These points to the fact that variants do not act in a similar way during the investigated years. When analyzing the mean height in a particular case (Figure 5, Table 2), it was found that the results were higher in cases where polypropylene tree shelters are used. The average height with tree shelter protection is more than three times bigger than of the unprotected seedlings. The results are comparable to the measured plant heights after 2 years of research in the Lantagne [29]. In this experiment, control seedlings were three times lower than those protected by the shelters since the weed competition was significantly stronger. Namely the weeds around the shield were treated with a systemic herbicide that destroys overground parts of the weed but also the root of the weeds. On the other hand weeds on control unprotected seedlings were mechanically removed and shortly thereafter re-growth and compete for nutrition, water and light. Liović [35] presents similar results: 6 vegetation periods after planting, the average height of oak planters protected by shelters was over 200 cm and the height of unprotected seedlings 50 cm, while some seedlings reached a height of up to 4 m. In Valkonen [36] sheltering had accelerated the height growth of the planted oaks substantially. Other studies under different conditions had similar results regarding height growth and survival [29, 37, 38]. Such increase in height allowed a rapid outgrow of the weed competition zone (Figure 6) and brought all the benefits that have resulted in such heights. We believe that such a large difference in height between unprotected and

sheltered seedlings was due to the effective application of systemic herbicides that reduced the competition of weeds in protected plants for a long time.

The tendency of trees to grow taller with increasing water availability is common knowledge. There are also numerous studies about tree height and water availability [39-41]. Based on that studies and high water absorption capacity of Zeba we hypothesized that variants with added Zeba would be taller than variants without it. But our results showed that addition of hydrophilic granules affected the average height increase only by about 10 cm. In cases where the seedlings are not sheltered, the effect of hydrophilic granules is very small, around 2 cm.



**FIGURE 6.** Faster growth makes it possible to quickly leave the competition zone of weeds.

SŠHG significantly differs from SŠ ( $p<0.001$ ), S ( $p<0.001$ ) and SHG ( $p<0.001$ ). SŠ significantly differs from S ( $p<0.001$ ) and SHG ( $p<0.001$ ). There is no significant difference between S and SHG ( $p=0.315$ ).

### Biotic Factors

During the year 2015, attack of the oak lace bug (*Corythucha arcuata* Say) and the oak slug sawfly (*Caliroa annulipes* Klug.) have been recorded during the trial (Figure 7). Pesticides were not used.



**FIGURE 7.** Attack of the oak lace bug (green leaves of field maple for comparison).

During the year 2016, an attack of powdery oak mildew – (*Microspphaera alphitoides* Griff. et Maubl) that covered almost all plants that overgrew the height of the shelter was recorded (Figure 8). Fungicide protection measures were not implemented.



**FIGURE 8.** Attack of powdery oak mildew.

Inside the shelter powdery oak mildew is visually weaker or is not present (Figure 9). Stakes (with a bigger white mass on outer wood) decayed in two years, broke and the shelters fell, so the plants bent down as well (Figure 10). Fortunately, the plants did not break, so it was enough to replace the stake and reset the shelter.



**FIGURE 9.** Inside the shelter powdery oak mildew did not generally developed.



**FIGURE 10.** Prostrated plan.

## CONCLUSIONS

During the two-year period of research, in case where the polypropylene shelters were used, seedlings are found to be significantly higher than in non-sheltered cases. The average height of the shelter-protected seedlings (128.27 cm) is more than three times taller than of the unprotected seedlings (37.97 cm). Likewise, survival of unprotected seedlings that were most exposed to harmful factors was 79.5%, while planting within the shelter provided the best conditions for seedlings survival (88.75%). We believe that such a large difference in height between unprotected and sheltered seedlings was due to the effective application of systemic herbicides that reduced the competition of weeds in protected plants for a long time. During the observed study period, the use of the Zeba superabsorbent which is well-known for its water absorption capacities, did not significantly affect the growth and development of seedlings. In order to gain a complete insight into the potential of protection in terms of protecting planters from unfavorable factors, it is necessary to record the changes and maintain

the experiment for a further 2-3 years with quantification other harmful factors that may appear (drought, game etc.) after which a more accurate judgment on their usable value could be given. Also, one must be aware that using pedunculate oak for artificial regeneration without shelters requires repeated weed control measures for a longer time period– a costly burden that forest owners may tend to underestimate at the planning stage.

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