The bigger the tree the better the seed - effect of Sessile oak tree diameter on acorn size

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Abstract

Sessile oak (*Quercus petraea* L.) is one of the ecologically and economically most important tree species in Europe. Recently, the importance of this species has been particularly highlighted in the context of climate change, where it is expected that this species will play a significant role within its natural range and beyond. To regenerate and expand the range of the sessile oak forests, a large amount of healthy acorns is needed. The acorn production and the acorns themselves are endangered by a large number of abiotic and biotic factors. As oak trees of different sizes do not produce the same amount of seed of the same quality, we investigated how the sessile oak tree diameter affects the acorn size, insect infestation, and germination rate. On the other side, as the acorn size influences the attack rates of the most significant acorn pest – *Curculio glandium* (Marsham 1802), and the germination rates of both the damaged and healthy acorns we also investigated how the acorn dimensions influence the insect damage and germination rates, and how the insect damage influences the germination rates. We determined that the oak tree size influences some oak seed characteristics that are important for forest regeneration, while it does not affect others. A greater acorn yield was recorded on the bigger oak trees. The tree dimensions also had a significant influence on the acorn size. Greater average length, as well as greater average acorn diameter, were recorded on bigger trees. Although the tree size affects the acorn size, it does not influence the acorn insect predation rates or its germination rates. These parameters are affected by the acorn size itself. Bigger acorns had a greater germination rate. Insects preferred smaller acorns and had a significantly negative influence on the germination rate.

Keywords

Quercus petraea; generative regeneration; germination rate; acorn weevil

Contents

1 Introduction

Modern concepts of forest management point to the necessity of better knowledge of natural processes in forests and, accordingly, their support and intensification. The concept of ''close-to-nature silviculture'' that targets greater naturalness in forest management is an important goal in most of the European forestry sector at present (Petritanet al. 2012). Together with the beech, oaks (especially pedunculate oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* L.) have a special ecological and economic importance in Europe. Oak forests have a high capacity to provide numerous benefits for society: they provide high-value timber for industry, biomass for bio-energy production, key habitats for biodiversity, and valued environments for recreation and other cultural services (Löf et al. 2016). Recently, the importance of these species has been particularly highlighted in the context of climate change, where it is expected that these species will play a significant role within their natural range and beyond (Bolte et al. 2009; Hanewinkel et al. 2013; Kohler et al. 2020; Arsić et al. 2021).

Although oaks are species characterized by a wide ecological amplitude and suitable conditions for growth in most of their habitats, the problem of natural regeneration becomes more pronounced with time (Annighöfer et al. 2015). Many factors have a critical influence on the success of the regeneration of sessile oak forests: habitat conditions, microclimatic conditions including extreme high and low temperatures and light availability, competing woody and herbaceous vegetation, and browsing pressure (Mölder et al. 2019; Kohler et al. 2020). Most authors state that the disappearance of most types of these forest communities would occur if natural regeneration took place without human intervention (Shaw 1968; Reifand Gärtner 2007; Kanjevac et al. 2021). However, the natural regeneration of oak forests is always more favorable than artificial regeneration, since the best biological results are achieved in this way, the regeneration process is more stable and does not require large costs (Kanjevac et al. 2021). Considering the trend of increasing the area of the sessile oak forests, a significant issue is meeting the need for seeds for afforestation (Girard et al. 2021).

To enable the regeneration of the existing forests, and to artificially spread the range of *Q. petraea* in Serbia, a significant amount of healthy acorn is needed. The acorns are endangered by a great number of pests and diseases (Hirka 2003; Dobrosavljević et al. 2018). Different environmental conditions can threaten the abundance of acorn production and, in the next phase, the successful germination of seeds (Shröderet al. 2004; Kanjevac et al. 2017; Axer et al. 2021). The decrease in acorn production is often associated with late spring frosts, high humidity during pollination, and summer droughts (Wolgast and Stout 1977; Gradečki-Poštenjak et al. 2011). Considering the acorn quality indicators and the degree of damage, the proportion of acorns that could potentially germinate under natural conditions is only 1/4 to 1/3 of the total amount of acorns fallen after fruiting (Kanjevac et al. 2017). After germination, light availability, browsing, competing with ground vegetation, nutrient supply, and numerous pathogens affect the early establishment of oak regeneration (Ligot et al. 2013; Annighöfer et al. 2015; Kohler et al. 2020). The most significant acorn pests are the species from the genus *Curculio* and *Cydia* (Dobrosavljević et al. 2018). *Curculio* weevils are primary invaders and can attack oak acorns without prior damage, with infestation occurring in late summer as the acorns begin to mature (Lombardo and McCarthy 2009). They are always present in oak forests in lower numbers, but when their population reaches higher abundance, they can cause serious damage (Mihajlović 2008).

According to Viglas et al. (2013) trees of different sizes do not produce the same amount of seed of the same quality. To test this, we conducted the study with the aim of determining how the sessile oak tree diameter affects the acorn size, insect infestation, and germination rate. On the other side, according to Dobrosavljević et al. (2018), the acorn size affects the attack rates of the most significant acorn pest – *Curculio glandium* (Marsham 1802), and the germination rates of both the damaged and healthy acorns. That is why we also tried to determine how the acorn dimensions influence insect damage and germination rates, and how the insect damage influences germination rates.

2 Material and methods

The study was conducted in the Northeastern part of Serbia (Majdanpek) in three localities: Ujevac (44°25' N; 21°52' E), Crna reka (44°21' N; 21°55' E), and Ravna reka (44°26' N; 21°59' E). At each locality, the acorns were collected from three trees belonging to different diameter classes (25, 35 and 45 ± 2 cm). To avoid mixing of the collected acorns, the selected trees were separated at least 30 m from each other and at least 15 m from other trees around them. For the analyses, 30 acorns were randomly selected from the collected material per each diameter class, per each locality (270 acorns in total). The diameter and length of each of the selected acorns were measured. The acorns were then placed in plastic containers with moist sterilized sand at room temperature to determine the germination rates. The germination rate was determined in November, after 28 days. After germination, the acorns were dissected to precisely determine the infestation rates. Acorns were classified as infected if there were exit holes or insect larvae present in them. The insects that infested the acorns were identified to the genus level.

As the distribution of the analyzed parameters did not fit any of the standardized distributions (Kolmogorov–Smirnov test), nonparametric tests were used for further analysis. The Kruskal-Wallis Test (ANOVA by Ranks) was used to determine the influence of tree diameter on acorn size, infestation, and germination rate. For testing the influence of the acorn size on the infestation rate, acorn length and diameter were first grouped into classes. The length was separated into 9 and the diameter into 5 classes, with a class interval of 2 mm. Regression analysis was used to determine the influence of acorn size on the infestation and germination rates. Mann-Whitney U Test was used to determine the difference in germination rates between the infested and healthy acorns.

3 Results

The tree diameter significantly affected the number of acorns per m^2 (H =19.759, p = 0.000). The greatest number of acorns per m^2 was collected under the biggest trees (Figure 1).

The tree diameter significantly affected the acorn length (H = 32.599, p = 0.000) and diameter (H = 29.328, p = 0.000). Both acorn length and diameter grow bigger as the tree diameter grows (Figure 2).

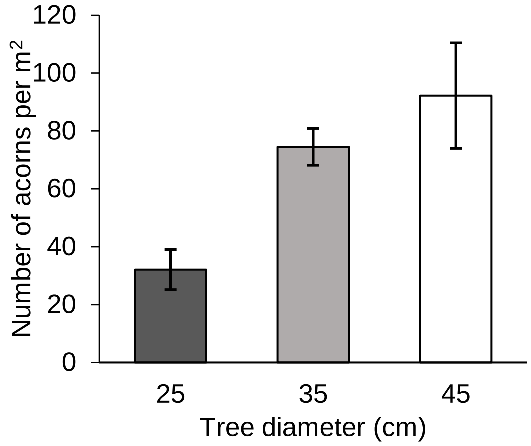

Figure 1. Influence of tree diameter on the number of acorns per m^2.

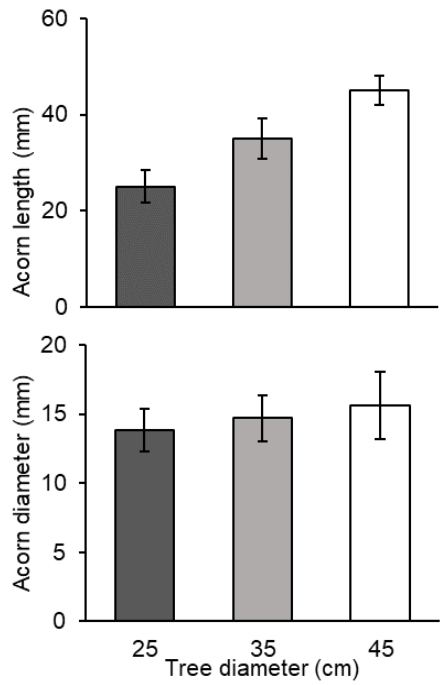

Figure 2. Influence of tree diameter on the acorn dimensions.

Insects infested 47.41 ± 14.32% of the acorns in total. Insects from the genus *Curculio* L. 1758 infested 34.07 ± 8.46% and from the genus *Cydia* Hb. 1825 16.67 ± 10.93% of the acorns. Insects from both genera together infested 3.33 ± 4.41% of the acorns. No significant influence of tree diameter on the infestation rate by insects (H = 3.759, p = 0.153) or germination (H = 3.237, p = 0.198) was determined (Figure 3).

Most of the collected acorns were mid-sized (Figure 4). Acorn length had a significantly negative influence on the infestation rates (R = 0.840, R^2 = 0.706, p = 0.005) and a significantly positive influence on the germination rates (R = 0.928, R^2 = 0.861, p = 0.000). Acorn diameter did not have a significant influence on the infestation rates (R = 0.741, R^2 = 0.549, p = 0.152) nor on the germination rates (R =

0.651, R^2 = 0.424, p = 0.234) (Figure5). Insect infestation significantly decreased the acorn germination rates (Z = 3.002, p = 0.003). The healthy acorns had an 81.05% germination rate while the infested ones reached 70.86%.

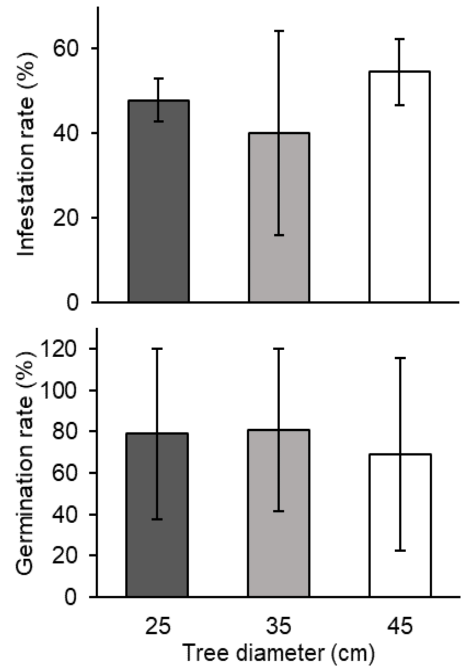

Figure 3. Acorn infestation rate and germination rate per tree diameter.

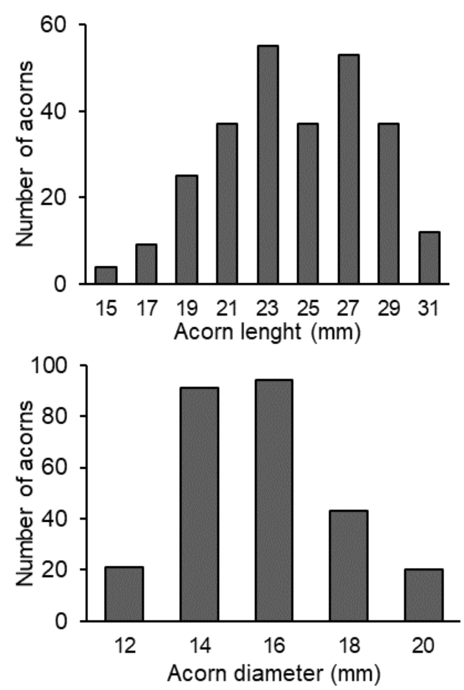

Figure 4. Acorn distribution by size intervals.

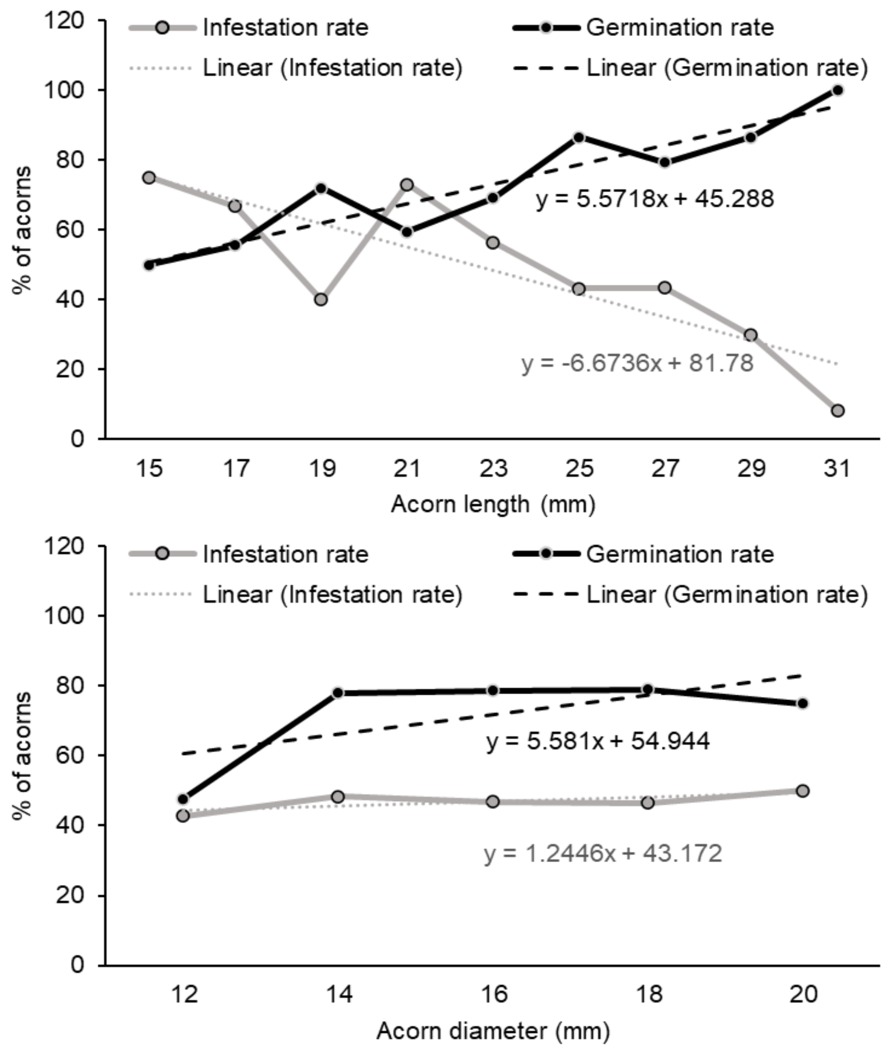

Figure 5. Correlation of acorn diameter and length with infestation and germination rates.

4 Discussion

In this study, we determined that the oak tree size influences some oak seed characteristics that are important for forest regeneration, while it does not affect others. A greater acorn yield was recorded on the bigger oak trees. Acorn production is expected to increase with the increase in tree diameter because the crown area, the area where acorns are produced, expands with the increase in diameter (Bechtold 2003). Similar observations were made by other authors who have dealt with this issue (Fernández-Santos et al. 2013). Also, some researchers suggests that oak stands may increase seed production after thinning, possibly as a result of reduced competition, increased light availability, and increased canopy exposure of individual trees over time (Perry et al. 2003). This is why the trees used for seed production have to be as big as possible but also healthy to produce a greater amount of acorn. Bigger trees also produced bigger seed which was less predated by insects. However, this should be taken into account with precautions because acorn production capacity varies with oak species (*Quercus*), individual trees (Popović et al. 2021), localities, as well as crop years (Rose et al. 2012).

The tree dimensions also influenced the acorn size. Greater average acorn length, as well as greater average acorn diameter, were recorded on bigger trees, as they spend less energy on their growth and more on their means of reproduction – the seed. Bigger trees also do not have to compete with other trees for space, so even more energy can be invested in the acorns. The seed size of the species is the result of the investment of the parent trees in the individual offspring (Leishman et al. 2000). Production of bigger seeds is a strategy to improve seedling success, as larger seeds have more resources (Ramos et al. 2013).

Although the tree size affects the acorn size, it does not influence the acorn insect predation rates or its germination rates. These parameters are affected by the acorn size itself. It is a general observation that larger acorns tend to show higher germination and lower acorn infestation (Ramos et al. 2013). A significant, strong correlation between acorn length and both infestation and germination rates were determined in this study. The mid-size acorns were infested the most. As the size of the acorns grew, their infestation rates diminished, while the germination rates got higher. This is probably a consequence that the infested acorns grow slower than the healthy ones, so they can never reach their size. The reason why the germination rates of the mid-size, and smaller acorns were lower than of the big ones was that the mid-size, and smaller ones were infested more. The significant influence of *Curculio* spp. on acorn germination rates was also determined in the study of Dobrosavljević et al. (2018). However, they determined that the *Curculio* spp. prefers bigger *Quercus cerris* L. acorns. The acorn diameter did not influence the infestation or the germination rates. Previous studies indicate that the size of acorns has a positive effect on the percentage of acorn germination, the growth of the above-ground part of seedlings, the percentage of survival of seedlings, a more favorable ratio between the mass of roots and the above-ground part, and faster recovery of seedlings from defoliation (Roth et al. 2011; Dobrosavljević et al. 2018; Popović et al. 2018; Clark and Schlarbaum 2018).

The germination rates of the infested acorns were significantly lower. This is not a surprise, as many other authors determined a negative effect of acorn infestation on germination (Forrester 1990; Hirka 2003; Csóka and Hirka 2006; Hou et al. 2010; Ramos et al. 2013). However, even if the germination rate of the infested acorns was significantly lower than that of the healthy ones, the germination rate of over 70% of the infested acorns is surprisingly high and significantly higher than the other authors determined on different oak species (Hirka 2003; Dobrosavljević et al. 2018). According to Forester (1990) and Hirka (2003), acorn size has a positive effect on germination as a single larva can consume only a certain amount of food to finish its development. In large acorns that amount comprises a smaller part than in small ones so the participation of the damaged volume is lower. Even if plants grew from the infested acorns, they would most probably be smaller and weaker than those that grew from the healthy acorns (Yi and Zhang 2008; Lombardo and McCarthy 2009).

5 Conclusions

Based on the obtained results, we can conclude that bigger trees produce more acorns per m^2. This result can be applied when choosing which trees should be left after the seed cut when regenerating forest with shelterwood cutting. Although the tree size does not affect the acorn germination rates, bigger trees produce bigger acorns. Those bigger acorns are less predated by carpophagous insects, and even if they are infested, the participation of healthy tissue in them is bigger, and chances that the cotyledons are damaged are lower. Bigger acorns also have a higher germination rate, and generally produce plants of greater quality. By reducing insect damage and increasing germination rates significant time and money can be saved. That is why, when possible, bigger acorns should be preffered over smaller ones in nursery plant production.

As studies of this type have a great practical value, they should be continued in multiple directions. The research could be conducted on different tree species, as not all seed is affected by predation the same way. As seed production and seed dimensions are affected by a large number of factors, the most important ones should be identified and monitored for multiple years. The plants produced from seed of different size with different degree of damage should also be monitored for multiple years to determine if the influence of these factors has a prolonged effect.

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