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Effects of regenerative cutting on the height growth of Turkey oak (*Quercus cerris* L.) saplings

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Abstract

Turkey oak (*Quercus cerris*) is distributed at the northern, western and southern Anatolia in Turkey. Although these forests are managed by shelterwood systems, degraded forests are subjected to artificial regeneration. In this context, the mature Turkey oak stands in Sipahiler Forests sub-district affiliated Sütçüler Forest District Directorate in Isparta, which did not have natural regeneration conditions, were artificially regenerated by acorn point sowing under the stand shelter. Although the regeneration was successful, the seedlings did not realize sufficient growth. In this context, regenerative cuttings (1- cutting all saplings in the plots from just above the ground level, 2- Cutting saplings from 10 cm height above the ground level, 3- Leaving only one individual at the each sowing plot (excluding the lateral stems) and pruning, 4-Leaving only one individual at the each sowing plot (excluding the lateral stems) without pruning and 5- Control without any cutting and pruning) were applied to the saplings and the 4 years' height growths of saplings were measured. The treatments were realized just before the vegetation period of 2014 and first measurements were done after the cuttings. To determine the height increment, second measurements were carried out after the vegetation period of 2017. As a result of these measurements, the height growth increment for each treatment was realized as follow: 75.25 cm for the saplings cut from ground level, 61.98 cm for the saplings cut from 10 cm height from ground level, 33.62 cm for the saplings of thinned and pruning, 32.80 cm for the saplings of thinned without pruning and 32.80 for the saplings of control. In final, the height growth of regenerative cutting saplings reached to those which were not subjected to cuttings. These results showed that regenerative cutting is promising to foster the growth of Turkey oak saplings. But for a better understanding, longer observation is needed to see the growth differences between the saplings subjected to regenerative cuttings and others, since the height of regenerative cutting saplings is not higher than the others yet.

Keywords: artificial regeneration, degradation, sapling, sprouting

Introduction

The oak genus has a wide distribution in the temperate and subtropic regions of the Northern hemisphere (Nixon 1993) and is represented by over 350 species (Yılmaz 2018). Seventeen oak taxa are naturally distributed in Turkey. These taxa are divided into 3 groups according to the anatomical structures of the wood, the ripening period of the fruit and the leaf characteristics (Yaltırık 1984). These are white oaks, red oaks, and evergreen oaks. Turkey oak (*Quercus cerris*) subjected in this work is one of the oak species under the red oak group.

Oak species are widely distributed in Turkey. In addition to their pure forests, they form mixed ones with other deciduous trees and coniferous as well (Mayer and Aksoy 1986). Especially the steppe forests in the inner and eastern Anatolia are characterized by oak species like *Quercus pubescens* and *Q. brantii* (Akman 1995)

Turkey oak is mainly distributed at the northern, western and southern parts of Turkey which are dominated by Black sea and Mediterranean climates respectively (Yaltırık 1984, Yılmaz 2018). In addition to the pure forests at the north it makes mixed stands with other oaks like *Q. frainetto* and *Q. petraea* and *Fagus orientalis* and the site conditions of these forests were well studied Tecimen et al. (2010, 2013). In the Mediterranean areas, Turkey oak generally forms mixed stands with *Pinus nigra* and shows local pure stands like in Alanya (Antalya), Sütçüler –Eğirdir (Isparta) and Dirmil (Burdur) provinces (Kavgacı et al.2018). Turkey oak also has a wide distribution along the Southern Europe and Balkan (de Rigo et al. 2016).

Like the other oak species, Turkey oak has the sprouting ability as well (Simeone et al. 2019, Odabaşı 1976). Due to that, some Turkey oak forests at northern Turkey were managed as coppice (Odabaşı 1976). But today, conversion studies of these forests to high forests have been still continued (Anon. 2006-2015). Differently from its northern distribution, Turkey oak stands in the Mediterranean parts of Turkey were not managed as coppice. The fact that these areas are generally dominated by sclerophyllous scrublands, forests, and coniferous forest as a result of the Mediterranean climate and the distribution of deciduous forests is limited may be the reason why the deciduous forests in the region were not attempted to manage as coppice. However, the Mediterranean landscape has been under the dense human use for centuries and Mediterranean ecosystems are accepted as man-made ecosystems (Perevolotsky 2005). Turkey oak forests were also affected by human use and mostly degraded, most of which have coppice structure supplying them to sustain during the years. These dense human use resulted in the broken stand structures. Due to that stand structure of Turkey oak forests in the Mediterranean areas is completely different from those in northern Turkey and natural regeneration conditions in these forests almost lost. This process makes artificial regeneration only one solution for the regeneration of degraded mature Turkey oak stands in the Mediterranean areas of Turkey.

As a result of this process, the mature Turkey oak stands in the Sipahiler Forests Province of Sutçüler Forest Enterprise in Isparta were artificially regenerated in 2009 by the method of acorn point sowing under the stand shelter. The regeneration success was high in the area. But during the technical visit to the regeneration area in 2013, it was seen that the growth performance of the saplings was not sufficient. As Turkey oak also has sprouting ability during the initial ages, it was decided to realize a study on the effects of regenerative cuttings on the growth of Turkey oak saplings in the area. Therefore, in this study, we hypothesized that regenerative cutting positively affects the growth of Turkey oak saplings.

Material and Method

This study was carried out in a Turkey oak stand in the Sipahiler Forest Sub-district of Sütçüler Forest Directorate affiliated Isparta Forest Regional Directorate (Fig. 1). The southern part of Sütçüler province is under the dense effect of Mediterranean climate while the northern part of the province consists of an intersection from the Mediterranean to continental climate (Sargın 2009). The study area is located on this intersection. The annual precipitation in Sütçüler province is 914.7 mm. The annual mean temperature is

13,03 °C. The coldest mount of the year is February with 3,3 °C, while July is the hottest mount of the year with 3,9°C. The highest part of the precipitation appears in December and November while it is the lowest in August and July (Büyükgebiz et al. 2008).

The altitude of the study area is about 1050 m. The Turkey oak stand belt in the area represents a transition from *Pinus brutia* forests at the lower vegetation zone to *P. nigra*, *Juniperus excalsa*, *J. foetidissima*, and *Cedrus libani* forests, which are the common tree species of the higher vegetation belt in the region. The scrub layer in the study stand is low and the herb layer is mainly dominated by perennial graminoids.

The topography of the stand was almost flat. It was a degraded forest with low canopy closure. Since natural regeneration conditions were lost, it was artificially regenerated. For this goal acorn point sowing under the stand shelter was applied in 2009. One acorn was sowed in the each sowing point with 1 m distances in a line. The regeneration success of the area was successful, but the saplings were not able to perform sufficient growth performance. In this context, it was thought that regenerative cutting can foster the sapling growth and a sampling design based on regenerative cutting was realized just before the vegetation period of 2014.

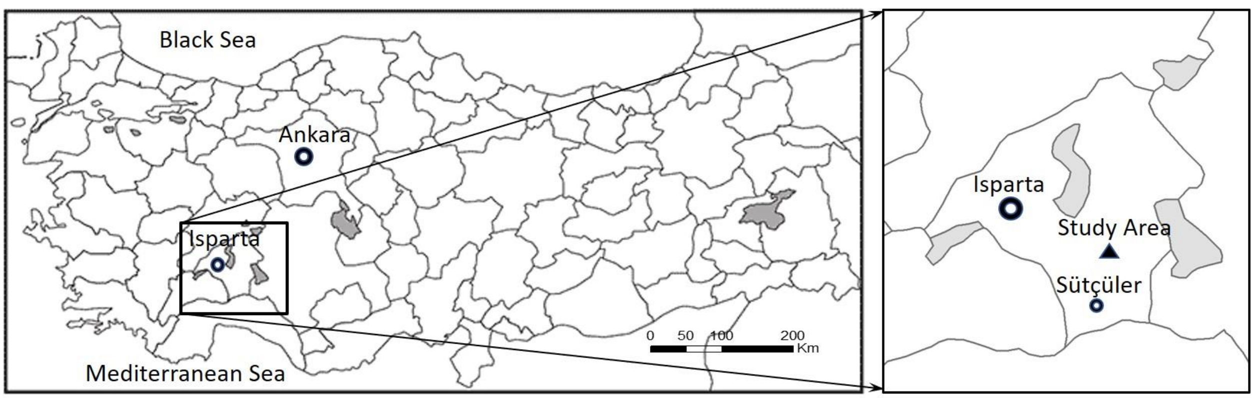

Figure 1. The geographical location of the study area.

The sampling design was set according to the randomized complete block design with 4 replication. Including the control, 5 different treatments were applied (Table 1). After the regenerative cutting in 2014, heights of saplings were measured in cm and recorded. These measurements were repeated after the vegetation period in 2017 to see the growth performances of each treatment.

Table 1. The treatments used for the regenerative cutting.

No	Treatment
1	Cutting all saplings in the plots from just above the ground level
2	Cutting saplings from 10 cm height above the ground level
3	Leaving only one individual at the each plot (excluding the lateral stems) and pruning
4	Leaving only one individual at the each plot (excluding the lateral stems) without pruning
5	Control parcels without any cutting and pruning

After the field measurements, the data were statistically evaluated. Normalization tests were applied to the data. Then, variance analyses were carried out for height increment and heights of 2017. As the difference appeared between groups, the Tukey test was applied to understand the level of difference between treatments.

Results

Regenerative cuttings on saplings were carried out just before the vegetation period of 2014. The heights of these saplings after the regenerative cutting application are shown in Table 2. The second measurement on the sapling was realized after the vegetation period of 2017 to see the effects of treatments. The height of the saplings after the 2017 measurement is submitted in Table 3. So, four years' height growth (cm) of saplings were observed in the study.

Table 2. The heights of the saplings after the regenerative cuttings in 2014. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	1.00	1.00	1.00	0.00	0.00
2	60	10.00	10.00	10.00	0.00	0.00
3	60	20.00	76.30	40.88	11.05	1.43
4	60	22.00	72.00	42.03	9.01	1.16
5	60	10.00	64.00	41.81	11.39	1.47

Table 3. The heights of the saplings after the second measurement in 2017. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	35.00	139.00	76.25	22.72	2.93
2	60	37.00	116.00	71.98	15.86	2.05
3	60	30.00	155.00	74.50	27.66	3.57
4	60	42.00	129.00	80.83	22.25	2.87
5	60	21.00	118.00	74.51	20.81	2.68

As a result of these measurements, the height growth increment for each treatment was realized as follow: 75.25 cm for the saplings cut from ground level, 61.98 cm for the saplings cut from 10 cm height from ground level, 33.62 cm for the saplings of thinned and pruning, 32.79 cm for the saplings of thinned without pruning and 32.70 for the saplings of control (Table 4). As the proportion of 2014 measurements to 2017 ones is observed, it is seen that the proportion of control is higher than all of the others (Table 5). But the proportion of the saplings cut from the ground level is lower than the others. It is followed by the saplings cut from 10 cm height. The heights of each treatment for the year 2014 and 2017 is shown in Figure 2.

Table 4. Height growth increment of the saplings. See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	34.00	138.00	75.25	22.72	2.93
2	60	27.00	106.00	61.98	15.86	2.04
3	60	3.500	102.00	33.62	21.52	2.77
4	60	1.00	79.00	38.79	19.47	2.51
5	60	3.00	84.00	32.70	19.20	2.47

Table 5. The proportion of the heights measured in 2014 and 2017 respectively (2014/2017). See the Table 1 for the explanation of the treatment legends.

Treatment	N Obs	Minimum (cm)	Maximum (cm)	Mean (cm)	Std Dev	Std Error
1	60	0.007	0.028	0.014	0.004	0.0006
2	60	0.086	0.270	0.145	0.032	0.0042
3	60	0.311	0.927	0.587	0.152	0.0196
4	60	0.288	0.976	0.548	0.155	0.0200
5	60	0.107	0.938	0.591	0.169	0.0218

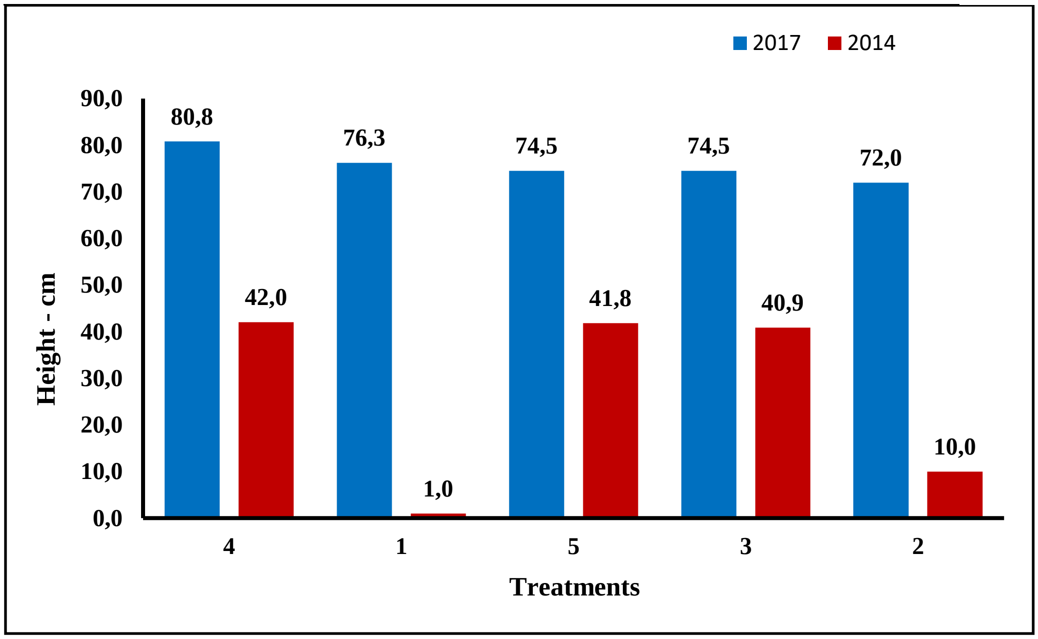

Figure 2. Sapling heights of treatments for 2014 and 2017 measurements. See the Table 1 for the meaning of treatment legends.

To understand whether there are differences between treatments or not, variance analysis was carried out for the measurements of 2017. According to the analyses, it was seen that there were no differences between treatments (Table 6). However, a clear difference occurred between treatments in terms of height increments (Table 7). The saplings cut from the ground level, which showed the highest height increment, was differentiated from other increments (Table 8). It is followed by the saplings of 10 cm height cut treatments as a different group. The other treatments were grouped and showed a similar height growth increment.

Table 6. Variance analysis of height of 2017 measurement.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	806.720	268.906	5.80	0.011
Treatment	4	173.091	43.272	0.93	0.477
Error	12	556.507	46.379		

Table 7. Variance analysis of the sapling height increments between 2017 and 2014 measurements.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	3	594.412	198.137	7.19	0.0051
Treatment	4	5850.140	1462.535	53.05	<.0001
Error	12	330.819	27.568		

Table 8. Tukey test results for the height growth increment. Means with the same letter are not significantly different. See the Table 1 for the meaning of treatment legends.

Treatment	N	Mean	Tukey Grouping
1	4	75.25	A
2	4	61.98	B
4	4	38.79	C
3	4	33.62	C
5	4	32.70	C

Discussion

The trees are generally known as single plants, erect woody trunks. However, some trees, especially those of Angiospermae, are able of sprouting, which is an induced response of trees to injury or a dramatic change in surrounding environmental conditions (Del Tredici 2001). Sprouting is an important adaptation ability of woody species against the environmental or anthropogenic effects (Retena et al. 2012) especially in Mediterranean type climate areas (Pausas 1999). In the Mediterranean basin, in which Turkey is located on the eastern side, fire, herbivore activity, and clear-cutting are common disturbances and plants have adaptive traits letting them survive after disturbances one of which is sprouting (Vergaquer et al. 2000). Girardclos et al. 2017 stated that sprouting ability is determined by the development, protection, and resourcing of available bud bank, after fire and other dramatic disturbance events such as flooding or wind storms.

Del Tredici (2001) pointed out that sprouting in trees occur in four different ways: collar sprouts from the base of the trunk, sprouts from specialized underground stems, sprouts from roots and opportunistic sprouts from layered branches. Oak species represent the different origins of sprouting. Turkey oak has also sprouts from the base of the trunk. Because of this characteristic, Turkey oak forests like other oak-dominated forests were managed as coppice for years although its wood quality is not high as much as other oak species (de Rigo et al. 2016) distributed in Turkey like *Q. petraea* and *Q. frainetto*.

Differently from the high forests, coppice sustains the same genetic structure for centuries resulting in the narrowing in the genetic diversity (Çalıkoğlu and Kavgacı 2001). Similarly, stand structure is degraded in coppice (Leibundgut 1984). Additionally, soil productive decrease, soil-plant water balance is broken, timber quality and product range are low in coppice (Odabaşı 1976, Kalıpsız 1984). These negative characteristics of coppice caused an action of conversion of coppice to high forests in Turkey (Anon 2006-2015). Similar actions on the conversion of coppice also common for other countries in which coppice is a common management system of deciduous forests (Amorini et al. 1996).

The sprouting ability of Turkey oak supplied it to sustain its distribution in Mediterranean areas in which human use was very intense for centuries and the climate is not suitable for deciduous tree species as much as sclerophyllous species and coniferous. The sprouting character of Turkey oak is common through all its life stages from juvenile age till mature one. Del Tredici (2001) indicated that the time of sprouting in the life cycle of a tree is more important than the morphological origin of the sprout and mentioned that sprouting in the early stages promotes the survival under a variety of stressful conditions.

Although it is different by species, oak-dominated forests are managed by shelterwood and clear-cutting systems (Jo Schweitzer et al. 2016). But clear-cutting needs special conditions like the sufficient amount of juveniles appearance under stand shelter and mesic site conditions. Due to that, the shelterwood system is more suitable and applicable for the natural regeneration of oak-dominated forests. Due to the biological and ecological characteristics of oak forests in Turkey, they were managed by the shelterwood system (Odabaşı et al. 2004). But as the natural regeneration conditions are lost, artificial regeneration is applied to the mature oak forests. One of the methods of artificial regeneration in the oak forests is the acorn point sowing under stand shelter. In this context, the degraded Turkey oak stands in the Sipahiler forest district in Sütçüler forest enterprise in Isparta Turkey were artificially regenerated by this technique. Although the regeneration was successful, the sapling did not perform sufficient growth. In this context, this study based on regenerative cutting to foster the growth of sapling was carried out.

At the end of the four years' growth period after regenerative cutting, the saplings cut from ground level and 10 cm height reached the other treatments and no difference between treatments appeared in terms of height. So, these two saplings showed a clear height growth increment and reached the other treatments. The saplings of ground-level cut showed the highest height increment. The treatments of thinning in the points did not differ from the saplings of control in terms of height increment.

The rapid growth of the saplings subjected to the regenerative cuttings showed the potential use of this applications to the slow-growing regenerations or degraded initial stage stands of Turkey oak. However, despite the rapid growth, these saplings reached the same heights to control at the end of the four years' observations. Therefore, to make a silvicultural suggestion for the managers, a longer period of observation is needed to see whether these saplings will continue their rapid growth against the other saplings or not.

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