http://www.balticforestry.mi.lt
ISSN 1392-1355
eISSN 2029-9230

Baltic Forestry 2022 28(2): 641
Category: Research article
https://doi.org/10.46490/BF641

Growth and survival of Scots pine saplings under controlled grazing in forest plantation areas of the high altitude rangelands

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Bilgili, A., Koç, A., Güllap, M.K., Ağyürek, C. and Okutucu, M.A. 2022. Growth and survival of Scots pine saplings under controlled grazing in forest plantation areas of the high altitude rangelands. *Baltic Forestry* 28(2): article id 641. https://doi.org/10.46490/BF641.

Received 9 April 2022 **Revised** 28 July 2022 **Accepted** 21 November 2022

Abstract

This study was carried out to determine the effects of controlled cattle grazing in Scots pine (*Pinus sylvestris* L.) plantation that in the edge of forest areas because animal husbandry has a significant role and forage gap is a main problem in the area. For this purpose, the study was carried out in a Scots pine plantation with an average of 2,160 m altitude in the forest edge rangeland area between 2012 and 2015. The study area was divided into 12 plots in total, with each plot 0.2 ha in size. The experiment was laid out in a randomized complete block design with three replications in a split plot arrangement keeping Scots pine sapling height (0–60 cm, 61–90 cm and > 90 cm) and four grazing treatments (Ungrazed, grazed in June, grazed in July, grazed in August). The relative diameter and height increments were determined along with the survival percentages for the saplings. According to the results; overall, less than 1% of saplings were found to be damaged as a result of the treatments. In all the grazing plots, the Scots pine saplings had more diameter and height increment than the ungrazed plots on average. In conclusion, controlled cattle grazing in July and August can provide both good quality forage for regional livestock and positive contributions to the growth of saplings, provided that saplings have more than 60 cm in height.

Keywords: Scots pine, plantation, sapling, growing, forest, grazing

Introduction

Natural resources, such as forests, shrubs, and grasslands, have been a valuable contribution to the livelihood of smallholder farmers (Debie and Singh 2021). Rangelands serve humans in various aspects such as providing food for livestock, plant and animal genetic resources, preventing of erosion, developing and protecting of water resources, biodiversity and medicinal plant heritage (Sandhage-Hofmann 2016). If rangeland degradation can be prevented, deforestation will also be prevented (Reis et al. 2010). However, rangelands have lost their productivity and biodiversity due to excessive and uncontrolled grazing. Because of converting true rangelands to arable land, grazing land has been shrinkage due to developing and expanding agricultural machinery in Turkey and consequently decreased their productivity (Koç et al. 2000). As a result of this, animal owners have been directed to alternative grazing areas and especially the people living on the edge of the forest had to use forest gap lands and understory. However, these areas are not compatible with grazing as open rangelands (Uluocak 1977), these areas can provide substantially feed for livestock and wild herbivores if planned properly, even making carefully management plans can contribute to increasing tree or sapling growth in forests or plantation areas (Kolb 2006). Seedlings in forest could be damaged due to grazing of livestock, but if done with care, grazing could be an integral part of forestry management (Varga et al. 2020).

In many countries around the world, livestock grazing practices in forest areas and cattle grazing have been used in traditional forest management systems for centuries (Clason and Sharrow 2000). The practice of grazing livestock is effectively used to improve the planting and growth of pine plantations for the natural regeneration of coniferous forests in both the west and south of America (Vallentine 2001) and is common in western Canada (Kaufmann et al. 2017).

A silvopastoral grazing system is an approach that has recently gained importance for the management of degraded rangelands in industrialized countries (Nair et al. 2021).

In many parts of the world, the forest understory is used for livestock grazing (Morecroft et al. 2001, Watkinson et al. 2001, Kramer et al. 2006, Moser and Schütz 2006, Evlagon et al. 2010, Mancilla-Leytón et al. 2012, Hjeljord et al. 2014, Osem et al. 2015). Livestock grazing requires managing the timing and duration of grazing to avoid browsing young tree saplings (Lemus 2014). If the number of livestock is balanced by the amount of feed produced from the area and the type of animal to be grazed is chosen well, serious grazing damage generally does not occur to the forest or plantations (Vieira et al. 2007).

In some studies, grazing reduces unwanted plant species (De Bruijn and Bork 2006, Lemus 2014), improves plant competitiveness (Gratzer et al. 1999, Norbu 2000), facilitates interspecific competition and species succession (Zhang et al. 2022) and provides important ecological, social and economic benefits. Cattle generally do not graze on leafy cones or conifers, and reduce the competition between trees and herbaceous plants; thus, the harmful effect of grazing is alleviated or disappears (Clason and Sharrow 2000). As a matter of fact, in silvopastoral systems, in which forest production occurs together with livestock grazing, trees can grow faster than in traditional management systems (Clason and Sharrow 2000). Mayer and Stöckli (2005) reported that young trees can grow faster in grazed forests. Grazing can enhance tree growth by controlling grass competition for moisture, nutrients, and sunlight (Lemus 2014). It can be said that moderate grazing improves tree growth, so that under forest grazing is an efficient management plan for sustainable forestry (Ainalis et al. 2010).

In Turkey, there is no evidence-based on the results of scientific research that provides the right answers to questions about how long to graze, in which region, in which months, by which livestock species and numbers in forest gap lands, understory or plantations. Determination of livestock grazing practices is very important in forest gap lands and forests, especially in pine plantations in highland forests in Turkey. The information about the effect of grazing will contribute to decision making about the grazing of these forests.

This study aimed to determine the effect on the sapling survival and growth of cattle grazing on Scots pine plantations, which is the common tree species in the region, in the highland forest of North-eastern Anatolia.

Materials and methods

Material

This research was conducted on a plantation area in the Oltu district of Erzurum province with an average altitude of 2160 m and a location was between 40°38'36.04" N and 41°55'54.02" E. The area is covered with forest gaps, rangelands and forest (Figure 1). The Scots pine, a Europe-Siberian element, is a common species in the experimental area as in Northeastern Anatolia forests. One-year-old Scots pine saplings were planted in the experimental area in 2007 (2.0 m × 1.2 m spacing) and protected by a barbed-wire fence against grazing. In total 10 heifers (two old years) were selected from village herds used to graze in the experiment.

According to the station records, the nearest meteorological station located in Oltu town center; the average temperature is 10°C, an average annual total rainfall is 342.3 mm and the average relative humidity is 60% in the research area. Based on long-term averages, the highest temperature occurs in July and August (22.7–22.8°C). May is the humid month of the year with precipitation of 54 mm. While an average of 251 mm of precipitation was recorded in the first experimental years (2012), it was 238.6 mm, 303 mm and 322.4 mm, during the following years, respectively. The dry season extends from July to October (Figure 2).

The soil samples taken from the experimental area were analysed (Soil Survey Laboratory Staff 2009) in the laboratory of Forest Soil and Ecology Research Institute. According to soil analysis results, experimental area soils are clay textured, containing 4.15% organic matter, and 4.46% lime with 26.3% Na and pH of 6.63. The corresponding available K and P contents were 287 and 50 ppm, respectively.

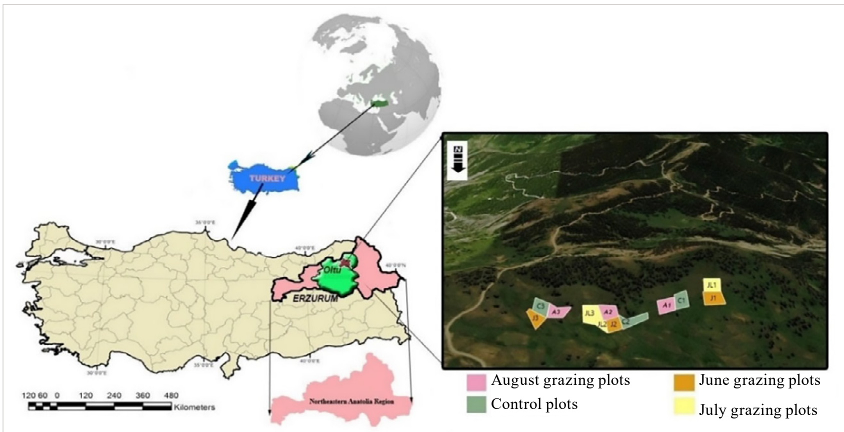

Figure 1. Location of the study area where in rangelands and forest areas in the Oltu district of Erzurum

Methods

The experiment was laid out in a randomized complete block design with three replications in a split plot arrangement keeping Scots pine sapling height (0–60 cm, 61–90 cm and > 90 cm) and four grazing treatments

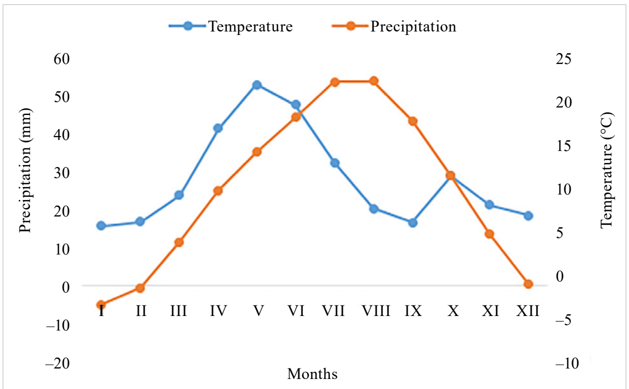

Figure 2. Overview of the climate diagram of the study area (meteorological station Oltu-Erzurum, 1965–2015)

(ungrazed, grazed in June, grazed in July, grazed in August). Each parcel covered an area of 0.2 hectares and was surrounded by barbed wire. In total, 150 Scots pine saplings were selected with fifty saplings from each height group in every plot. Each sapling was numbered with sapling labels that stainless-steel plates and water-resistant. A total of 1,800 Scots pine saplings were selected in 12 plots. During the four-year study period, sapling height, diameter and survival measurements were made on a total of 7,200. The experiment was conducted for 4 years from 2012 to 2015. Grazing applied in the study was carried out in 2012 and 2014 and rested in 2013 and 2015 years. However, all measurements were made during the resting years as well. During the treatment month, grazing was applied for up to half of the grazable species consumed in the middle of the month. It was taken 4 or 5 days for every treatment (Figure 3).

Figure 3. Photograph of the grazing practice in the research area and the placement of the cages in the plots

To determine the percentage of grazed forage amount during the grazing season in the study area, 6 wire cages (1 m × 1 m) were placed in each sub-plot, excluding the ungrazed plots (Figure 3). In this way, a total of 54 wire cages were use. After grazing, the forage in six paired areas (0.5 m × 0.5 m = 0.25 m^2) inside and outside of each cage (0.5 m × 0.5 m) were cut at the ground level in all plots. Then, these samples were dried at 68°C for up to reaching a constant weight in the laboratory and weighed. The amount and rate of grazing per unit area were calculated in proportion with each other for the forage amount in and out of cages (Gökkuş et al. 2000). The samples were taken from the plots after grazing treatment.

In the first year of the experiment, saplings were counted before beginning of the grazing and it was repeated every years after end of the grazing season, thereafter the percentage of survival of the saplings was determined by proportioning the live sapling number to the total sapling number of beginning the experiment. The height and diameter of the saplings were measured in spring and autumn. Relative height and diameter calculations were made for the obtained height and diameter measurements. The height and diameter were measured on same saplings every year using ruler and caliper, respectively. The height and diameter measurements of the saplings were made by the same person, from the places marked in the saplings every year (root collar diameter).

All data were performed to compatability test for normal distribution, thereafter, subjected to Analysis of Variance (ANOVA) based on general linear models for repeated measurements using SPSS for Windows statistical software (SPSS Inc., Chicago, IL). The differences among means were separated using Duncan's Multiple Range Test.

Results

Grazing percentage

Although total production (in cage) was higher in the first year (2,666 kg ha^{-1}) than in the second grazing experimental year (2,116 kg ha^{-1}), both grazed amount and grazing percentage did not change significantly between the years. The mean grazing percentage was 32.6% and it did not change significantly between the years (Table 1). Forage utilization percentage ranged between 37.8% and 29.7% among the treatments but these changes were not significant statistically. Utilization percentage was the same in grazed plots in June both years while it was changed in the other grazed plots between years (Figure 4). Hence, years × treatment interaction was statistically significant ($p < 0.05$).

Although there were no significant differences among treatments with respect to forage production (caged production), the harvesting (grazing) rate was changed significantly among treatments depending on years. The highest harvesting percentage occurred in the plots grazed in Au-

Table 1. Changes in forage amount and grazing percentage (%) among treatments and years

Grazing Plots	2012 CI Forage (kg ha^{-1})	2012 CO Forage (kg ha^{-1})	2012 GA (kg ha^{-1})	2012 GP (%)	2014 CI Forage (kg ha^{-1})	2014 CO Forage (kg ha^{-1})	2014 GA (kg ha^{-1})	2014 GP (%)	Mean GP (%)
June	2560	1772	788	30.8	2036	1453	582	28.6	29.7
July	2574	1945	629	24.4	2099	1342	757	36.1	30.3
August	2865	1513	1352	47.2	2213	1586	627	28.3	37.8
Mean	2666	1743	923	34.1	2116	1460	655	31.0	32.6
Treatment × Year			*	*			*	*	*

Notes: CI – In of Cage, CO – Out of Cage, GA – Grazed Amount, GP – Grazing Percentage. * Statistical difference at $P < 0.05$.

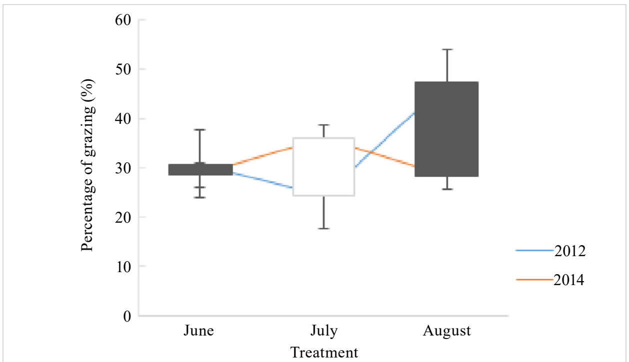

Figure 4. Year × treatment interactions of grazing percentage

gust in the first year, it occurred in the plots grazed in July in the second year (Table 1, Figure 4). This difference was responsible for year × treatment interaction.

Survival percentage of saplings

Although the differences between the years were statistically significant ($p < 0.05$) concerning sapling survival percentage, actually, these differences can be negligible because they did not exceed 0.6% between years (Table 2). There were no significant differences among grazing treatments related to sapling survival percentage. The plots having shortest sapling height showed less survival percentage than the others. The interactions between year × sapling height × treatment were statistically insignificant.

Table 2. Survival percentages (%) of Scots pine saplings for 2012–2015

		Sapling height 0–60 cm (n = 2,400)	Sapling height 61–90 cm (n = 2,400)	Sapling height > 90 cm (n = 2,400)	Mean
Treatments	June	98.5	99.7	100	99.4
	July	99.4	100	100	99.8
	August	99.8	99.7	99.8	99.8
	Ungrazed	99.5	99.5	100	99.7
	Mean	99.3 B	99.7 A	100 A	99.7
Years	2012	100	100	100	100 a
	2013	99.0	99.5	100	99.5 b
	2014	98.7	99.5	100	99.4 b
	2015	99.5	99.8	99.8	99.7 ab
	Mean	99.3 B	99.7 A	100 A	99.7

Notes: n – number of saplings measured. Means followed by differ letter in a column and row shows significant differences at $P < 0.05$ (lowercase letters) and $P < 0.01$ (capital letters) levels, using Duncan's multiple range test.

Sapling height increment

The height increments of Scots pine saplings were statistically very significant between the years ($p < 0.001$) and sapling height ($p < 0.001$). The difference among the treatments was statistically insignificant. While the interactions of treatment × sapling height were statistically significant ($p = 0.014$), the interactions of year × sapling height were also statistically significant ($p < 0.001$).

There was an average of 24.3 cm sapling height increment in the experiment area. According to the general aver-

Table 3. Mean height increment of Scots pine saplings in 2012–2015

	Sapling height	Sapling height increments (cm) 0–60 cm (n = 2,400)	61–90 cm (n = 2,400)	> 90 cm (n = 2,400)	Mean
Treatments	June	16.6 ± 2.421	22.8 ± 3.291	30.2 ± 3.936	23.2 ± 3.211
	July	19.6 ± 3.358	25.8 ± 3.871	33.9 ± 4.439	26.5 ± 3.885
	August	19.2 ± 3.526	23.3 ± 3.893	33.6 ± 4.090	25.4 ± 3.818
	Ungrazed	16.8 ± 2.835	21.0 ± 3.320	28.9 ± 3.742	22.2 ± 3.298
	Mean	18.1 ± 1.417 C	23.2 ± 1.673 B	31.7 ± 1.90 A	24.3 ± 1.653
Years	2012	12.5 ± 0.284	17.3 ± 0.749	25.0 ± 0.692	18.3 ± 0.491 C
	2013	16.4 ± 0.732	20.9 ± 0.997	29.6 ± 1.529	22.3 ± 1.002 B
	2014	16.7 ± 1.002	21.0 ± 1.038	28.7 ± 1.374	22.1 ± 1.109 B
	2015	26.7 ± 1.396	33.7 ± 1.385	43.4 ± 1.535	34.6 ± 1.390 A
	Mean	18.1 ± 1.417 C	23.2 ± 1.673 B	31.7 ± 1.90 A	24.3 ± 1.653

Notes: Values are means ± standard errors. n – number of saplings measured. Means followed by different capital letters in the rows and columns significant differ at $P < 0.01$ level by Duncan's multiple range test.

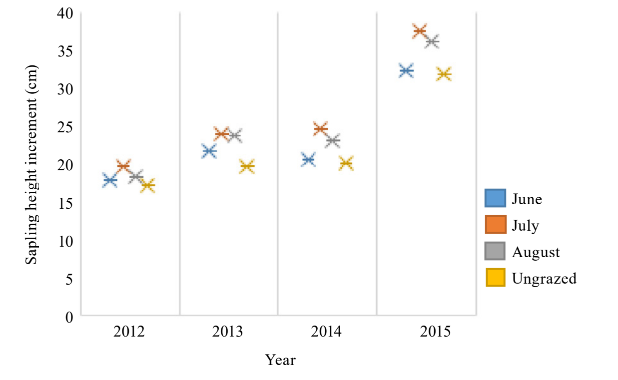

Figure 5. Height increments of Scots pine saplings according to treatment

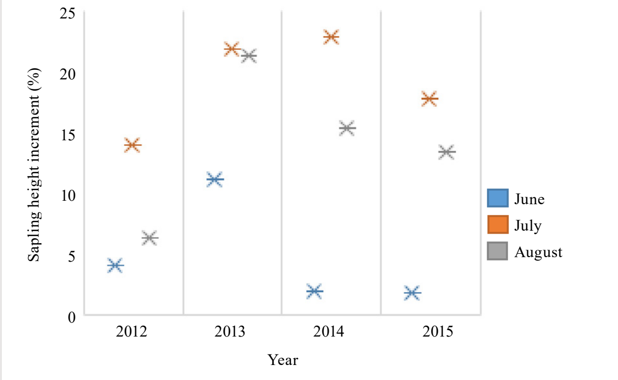

Figure 6. Sapling height increment percentage (%) compared to the ungrazed treatment

age of years (2012–2015), the highest sapling height increment (34.6 cm) occurred in 2015. According to the average for the years, while the saplings in the > 90 cm height had the highest sapling height increment at 31.7 cm, the lowest sapling height increment was recorded as 18.1 cm for the 0–60 cm sapling height. According to the average of the years, while the difference between the treatments was insignificant, the highest sapling height increment was recorded for the July grazing treatment at 26.5 cm and the lowest sapling height increment was recorded in the ungrazed treatment at 22.2 cm. While the highest sapling height increment in all study years occurred in July grazing treatments, the lowest height increment was detected in ungrazed treatments. The largest height increment of saplings was determined in July grazing treatments in the three different sapling heights, followed by August grazing treatments, during the research years (Table 3, Figure 5).

In general, for mean and sapling height, the largest sapling height increment occurred in July grazing treatments (26.5 cm) and the lowest sapling height increment was detected in ungrazed treatments (22.2 cm) (Table 3). So, the sapling height increment in July grazing treatments was detected to increase 19.2% more than the ungrazed treatment (Figure 6).

Sapling diameter increment

The diameter increments of Scots pine saplings were statistically very significant between years ($p = 0.001$) and sapling height ($p < 0.001$). The difference among the treatments was statistically insignificant. The interactions of year x sapling height were statistically very significant ($p < 0.001$). The interactions of year × treatment, treatment × sapling height and year × treatment × sapling height were statistically insignificant.

There was an average 0.77 cm sapling diameter increment in the experimental area. According to the general mean for the years (2012 to 2015), the highest sapling diameter increment (1.05 cm) occurred in 2015. According to the average for the years, while the saplings in the > 90 cm height had the highest sapling diameter increment at 1.02 cm, the lowest sapling diameter increment is recorded as 0.55 cm in the 0–60 cm sapling height. According to the average for the years, while the difference between the treatments was insignificant, the highest sapling diameter increment was recorded in June and July grazing treatments at 0.79 cm and the lowest sapling diameter increment was recorded in the ungrazed treatment at 0.75 cm (Table 4, Figure 7).

The highest diameter increments were found for saplings with > 90 cm height in the experimental years, followed by saplings with 61–90 cm height and the lowest diameter increments were for saplings with 0–60 cm

Table 4. Mean diameter increment of Scots pine saplings in 2012–2015

	Sapling height	Sapling diameter increments (cm)			
		0–60 cm (n = 2,400)	61–90 cm (n = 2,400)	> 90 cm (n = 2,400)	Mean
Treatments	June	0.53 ± 0.074	0.76 ± 0.090	1.09 ± 0.036	0.79 ± 0.067
	July	0.54 ± 0.070	0.80 ± 0.080	1.02 ± 0.060	0.79 ± 0.070
	August	0.57 ± 0.116	0.75 ± 0.106	0.99 ± 0.067	0.77 ± 0.095
	Ungrazed	0.54 ± 0.172	0.72 ± 0.158	0.98 ± 0.139	0.75 ± 0.156
	Mean	0.55 ± 0.009 C	0.76 ± 0.017 B	1.02 ± 0.025 A	0.77 ± 0.010
Years	2012	0.39 ± 0.018	0.59 ± 0.031	0.90 ± 0.045	0.63 ± 0.025 C
	2013	0.47 ± 0.040	0.70 ± 0.040	1.00 ± 0.048	0.72 ± 0.041 B
	2014	0.46 ± 0.024	0.67 ± 0.038	0.95 ± 0.046	0.69 ± 0.033 B
	2015	0.86 ± 0.073	1.07 ± 0.040	1.23 ± 0.054	1.05 ± 0.054 A
	Mean	0.55 ± 0.009 C	0.76 ± 0.017 B	1.02 ± 0.025 A	0.77 ± 0.010

Notes: Values are means ± standard errors. n – number of saplings measured. Means followed by different capital letters in the rows and columns significant differ at $P < 0.01$ level by Duncan's multiple range test.

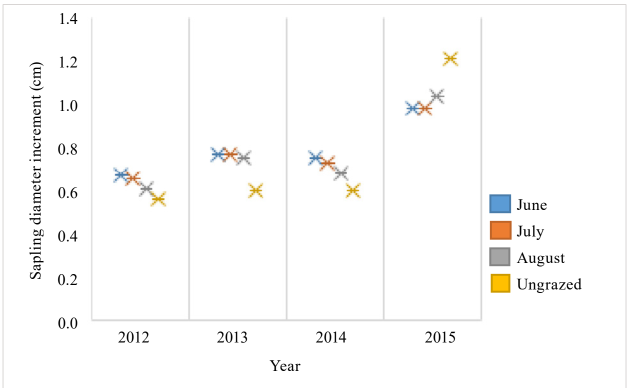

Figure 7. Diameter increments of Scots pine saplings according to treatments

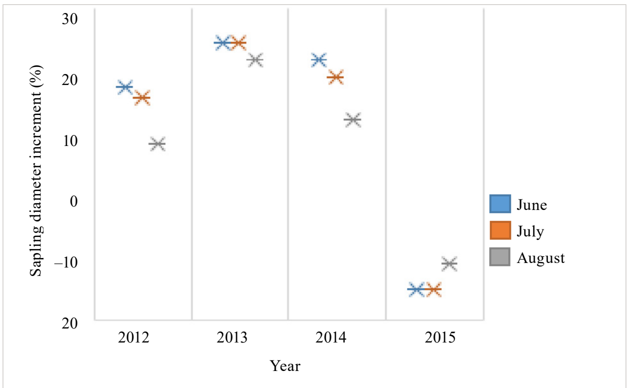

Figure 8. Sapling diameter increment percentage (%) compared to the ungrazed treatment

height. In general, for mean and sapling height, the largest sapling diameter increment occurred in June and July grazing treatments (0.79 cm) and the lowest sapling diameter increment was detected in ungrazed treatments (0.75 cm) (Table 4). On average, sapling diameter increment was detected as 5.3% in June and July in grazing treatment more than ungrazed treatment (Figure 8).

Discussion

Grazing percentage

Harvesting percentage and amount of forage are mainly related to grazing intensity rather than production in both years and treatments (Holechek et al. 1998, Hanselka et al. 2001, Penati et al. 2014). The grazing intensity was not a factor in the experiment so some extent of differences occurred between years and plots, therefore, its intensity showed some variation both between years and treatments. Although the second sampling year (2014) received more precipitation than the first sampling year (2012), forage production was higher in the first sampling year. This situation may be mainly originated preceding years autumn precipitation distribution because production performance of cool season grasses, which are the dominant herbaceous plant in the experimental area and need vernalization to produce reproductive tillers, strongly related to preceding years autumn precipitation (Koç 2001).

The highest harvesting percentage occurred in the plots grazed in August in the first year, and it was occurred in the plots grazed in July in the second year. This difference was responsible for year × treatment interaction. This differences mainly originated from grazing intensity severity rather than production differences, because harvesting index are a result of proportion of consumed forages to total available production (Hanselka et al. 2001, Patton et al. 2007, Penati et al. 2014).

Climate change has the potential to impact the quantity and quality of forage (Giridhar and Samireddypalle 2015). As a matter of fact, in this study, irregular rains and delayed melting of snow from the surface in some years due to climatic fluctation have caused low grass production in rangeland areas.

Survival percentage of saplings

Overall, less than 1% of saplings were found to be damaged on average in both years and treatment. These results implied that cattle grazing in suitable season and intensity did not have a side effect on Scots pine plantations. Indeed, Currie (1978) found that damage from cattle grazing on the survival of Scots pine saplings was less than 1% and Newman and Powell (1997) found that only 2% of lodgepole pines on plantations were damaged. These results support the findings obtained in relation to the survival percentage of the saplings in this study. The other studies conducted in the other countries (Lewis et al. 1988, Pitt et al. 1998, Mayle 1999, Mayer et al. 2005, Vandenberghe et al. 2007) reported that the negative effect of cattle grazing on survival percentage Scots pine saplings decreased as the sapling height increase. Our findings are also consistent with these results, but this mortality ratio can be negligible because mortality ratio are less than 1%. This less mortality ratio of Scots pine plantation under cattle grazing may be related to grazing preference of cattle. Because pine needles are unpreferred by cattle due to lower feeding value and unpleasant taste (Roder et al. 2002, Mayer et al. 2005). This finding give promised results for rural development programs in forest line because pine plantation areas can be grazed by cattle herds. This treatment can contribute to increase animal production and consequently, contribute to improve livelihoods condition of forest line settlers.

Sapling height increment

Krueger and Vavra (1984) and Doescher et al. (1989) recorded similar growth in their study about the growth of Douglas pine. Cleary (1978) reported similar results with 20% height increment with sheep grazing. The height increments of Scots pine saplings were better in the grazing plots than the ungrazed plots for all of the sapling height. The height increment of saplings in July and August may be due to the lowering of the transpiration surface of the herbaceous layer depending on grazing and due to Scots pine saplings having more moisture. Krueger and Vavra (1993) found that there was better height growth of conifer species in areas with grazing by cattle and large wild animals in research study on forest plantations, supporting the results we obtained about the growth of sapling height. In addition, in this study, it was reported that the increase in the growth performance of seedlings as a result of increased nutrient cycling and moisture availability originated from grazing. Jaindl and Sharrow (1988), Doescher et al. (1989), Sharrow et al. (1992), Gratzer et al. (1999) and Darabant et al. (2007) reported that forest grazing could increase tree growth due to the reduction of herbaceous biomass in rangelands. The results of these studies support our results.

Sapling diameter increment

Jaindl and Sharrow (1988) reported that grazing of conifer plantations increased tree diameter growth. Sharrow et al. (1989) find similar results with 7% diameter increment with sheep grazing. The diameter increases obtained in our study were similar to those obtained by Krueger and Vavra (1993) for douglas pine. It was determined that the diameter increase of the Scots pine saplings was higher for the grazing plots than in the ungrazed plots for all the sapling height. As a matter of fact, Krueger and Vavra (1993) and Darabant et al. (2007) found that the diameter growth of coniferous tree species is better in areas with grazing in forest plantations. This research study supports the results for the growth of saplings in our study.

While the people of the region benefit by grazing these areas in a controlled manner (in terms of time, animal variety and number of animals, etc.) in line with the permissions of the forest management directorates, there will be an increase in sapling growth as the competition of saplings in plantation areas with herbaceous plant species will decrease (Clason and Sharrow 2000, Norbu 2000). In addition, since it will help to reduce fuel load in the understory with controlled grazing, low intensity fires can be prevented from turning into large fires (Davies et al. 2010, Strand et al. 2014, Svejcar et al. 2014). In this perspective, our study is important in terms of both sustainable forestry and sustainable animal husbandry.

Conclusion

The height and diameter increase of Scots pine saplings were higher in grazing plots than in non-grazing plots for all sapling heights. Overall, less than 1% of saplings were found to be damaged as a result of the treatments. According to the results of our study, it was concluded that cattle grazing may be appropriate in Scots pine plantations which sapling height above 60 cm, two cattle per hectare and in similar forage yields to the area of research, in July and August months. For the timing of grazing treatment, attention should be paid to annual bark development and resin periods for Scots pine saplings. It will be appropriate to graze heifers or dairy cows accustomed to in-forest or edge areas in order to prevent damage to Scots pine sapling.

Grazing is not recommended in these areas in early June or earlier because the saplings were sensitive to damage of the top and side branch shoots, and the soil was more moist during this period and liable to compaction. It is also considered appropriate to make plans for grazing in the appropriate period, with appropriate animal type and number considering ecological structure differences, different forage yields, quality of forage and saplings in the area. For this reason, controlled grazing before August and September, which are risky periods for fires high altitude areas where prevailed continental climate, will reduce a possible fire risk, especially in the research area or similar ecological areas.

Acknowledgments

This work was supported by the [General Directorate of Forestry, Republic of Turkey] under Project [number: 01.6905/2012-2016]. The authors are indebted to General Directorate of Forestry for providing funding for the study. We would like to thank all Eastern Anatolia Forestry Research Institute staff who contributed to the field measurements. Three-year results of this study were used in Adnan BİLGİLİ's PhD thesis.

Competing Interests: The authors have no competing interests to declare that are relevant to the content of this article.

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