

THE EFFECT OF FERTILIZATION AND GRAZING APPLICATIONS ON ROOT LENGTH AND ROOT BIOMASS OF SOME RANGELAND GRASSES

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ABSTRACT

It is important to know the effects of applications such as fertilization and grazing on the vegetation improvement of certain species. This study was conducted to examine the effect of grassland improvement by fertilization and grazing on root length and biomass of various grassland grasses (*Festuca ovina* L., *Koeleria cristata* (L.) Bertol, *Chrysopogon gryllus* (L.) Trin., *Bothriochloa ischaemum* L. Keng) of the Tokat province of Turkey in the years 2008 and 2009. Great variations were observed among grass species in all applications. All different fertilization and ungrazed applications increased root length and root biomass parameters. Root lengths and root biomass of the species varied from 8.16 to 14.27 cm and from 0.73 to 4.73 g, respectively. The longest root lengths and root biomass results were obtained from ungrazed land+ 75 kg ha⁻¹ N+P₂O₅ fertilization application.

Key Words: Belowground biomass, Fertilization, Rangeland, Grazing,

INTRODUCTION

Stockbreeding depends mainly on grasslands that have been overgrazed and grassland productivity has decreased in Turkey (Bakoglu et al., 1999a; Turk et al., 2014). A major portion of forage was supplied from low quality sources due to the insufficient production of quality forage crops (Koc et al., 2012). The requisite methods of rangeland improvement and management should be applied in order to increase their productivity and overgrazing should be decreased. In rangeland improvement, it is incredibly important to know the effects of many applications such as fertilization and protect from grazing regimes on rangeland vegetation in light of vegetation health and sustainability.

Based on the results of different practices under different conditions, it is quite difficult to determine the effects of pasture grazing and fertilization on rangeland vegetation. Current studies show significantly different results. Some researchers reported that grazing has no effect on root biomass (McNaughton et al., 1998; Hejduk and Hrabě, 2003; Pucheta et al., 2004); however, some have reported increases (Milchunas and Lauenroth, 1993; Frank et al., 2002), and others have reported decreases in root biomass (Tewari and Joshi, 1985; Milchunas and Lauenroth, 1989; Biondini et al., 1998; Johnson and Matchett, 2001; Gao et al., 2008; Bagchi and Ritchie, 2010; Gao et al., 2011; Nippert et al., 2012; Yan et al., 2013). Similar results can be seen in fertilization studies.

Ladwig et al. (2012) and Balogianni et al. (2014) indicated that fertilization does not affect root biomass. According to Glab and Kacorzyk (2011), fertilization leads to a decrease in root biomass. On the other hand, many researchers found that fertilization on rangeland leads to an increase in root biomass (Tewari and Joshi, 1985; Gonzalez et al., 2002; Beebe et al., 2002; Hejduk and Hrabě, 2003; Rajaniemi et al., 2003; Heggenstaller et al., 2009).

Considering recent studies, the effects of fertilization and grazing on rangeland vegetation should be investigated under different ecological conditions and the results must be evaluated to its own conditions. Therefore, the aim of the current study was to determine the effect of fertilization and grazing applications on root length and root biomass of some grasses in the natural rangelands of Turkey.

MATERIALS AND METHODS

The grasses included in the study were the natural grasslands of the Tokat province of Turkey (40°19' 23" N, 36°28' 50" E). These grasslands are located in nearly 750 meters above mean sea level and on the north aspect of the hills. Annual temperature means were 12.0 °C and 13.1 °C in the years 2008 and 2009, respectively. The long-term temperature mean is 12.4 °C. Total precipitation in 2008 and 2009 and long-term precipitation values were 471.2 mm, 592.9 mm, and 448.2 mm, respectively. The soil was

sandy-loam, non-saline, and had pH of 7.65; the available phosphorous was 0.85 kg da⁻¹, available potassium was 55.3 kg da⁻¹, and organic matter was 3.61%.

The experiment was conducted in 2008 and 2009 according to a randomized complete block design with three replicates. The plot area in the experiment was a 50 m² (5x10 m) block and plot spaces were 1 m. A total of six applications were implemented, which included: grazed (G), ungrazed (UG; protected from grazing and unfertilized), ungrazed + 50 kg ha⁻¹ P₂O₅ (UG+F₁), ungrazed + 75 kg ha⁻¹ P₂O₅ (UG+F₂), ungrazed + 50 kg ha⁻¹ N + P₂O₅ (UG+F₃), and ungrazed + 75 kg ha⁻¹ N+ P₂O₅(UG+F₄). The experimental area was fenced by barbed wire on March 1, 2007 for grazing preservation during the experimental period. Control plots for the grazing application were outside of this fenced area. Fertilizer was applied on April 1 in the years 2007, 2008, and 2009.

During study, ten plant samples from each dominant species (*Festuca ovina* L., *Koeleria cristata* L. Bertol, *Chrysopogon gryllus* (L.) Trin., *Bothriochloa ischaemum* (L.) Keng) with their roots were obtained from all plots at the end of the vegetation period using a spade. All

samples were washed in a bucket. Root lengths and weights of the washed samples were measured. The average root lengths and biomass were calculated for each plant. Then, the plants were cut from root necks. The roots were dried at 70 °C for 48 h to determine the root biomass. The obtained data were analyzed by using SAS Version 8.0 (SAS Institute, 1999) statistical program and LSD values were calculated.

RESULTS AND DISCUSSION

Root Length

In both years of the experiment, root lengths were also statistically different concerning both grass forage species and applications (Table 1). The longest root length was measured (11.42 cm) in the *C. Gryllus* species and the shortest root length was 9.90 cm in *K. cristata* in 2008; whereas the longest root length was measured (12.91 cm) in the *C. gryllus* species and the shortest root length was 11.21 cm in *K. cristata* in 2009. In addition, the longest root length (12.97 cm) in the first year was measured in the plots with UG+F₄ application and the shortest root length (8.08 cm) was measured in the G application. In the second year of the experiment, root lengths varied from 8.24 (G) to 15.57 cm (UG+F₄) (Table 1).

Table 1. Effect of applications on root length of some grass species (cm plant⁻¹)

| Applications | <i>Festuca ovina</i> | <i>Koeleria cristata</i> | <i>Chrysopogon gryllus</i> | <i>Bothriochloa ischaemum</i> | Means |
|-----------------------|-----------------------|--------------------------|----------------------------|-------------------------------|---------------------|
| 2008 | | | | | |
| G* | 8.77 hij [†] | 6.87 k | 8.97 hij | 7.73 jk | 8.08 e [‡] |
| UG | 10.63 d-g | 8.30 ijk | 11.17 c-f | 8.97 hij | 9.77 d |
| UG+F ₁ | 9.97 e-h | 9.83 fgh | 11.30 cde | 10.20 e-h | 10.32 d |
| UG+F ₂ | 12.20 abc | 11.97 bcd | 12.87 ab | 11.40 cde | 12.11 b |
| UG+F ₃ | 11.20 c-f | 9.54 ghi | 11.77 bcd | 11.90 bcd | 11.10 c |
| UG+F ₄ | 13.57 a | 12.87 ab | 12.43 abc | 13.00 ab | 12.97 a |
| Means | 11.06 AB ⁿ | 9.90 C | 11.42 A | 10.53 B | 10.73 |
| 2009 | | | | | |
| G | 8.87 m | 7.47 n | 9.17 lm | 7.47 n | 8.24 f |
| UG | 10.70 ij | 9.83 kl | 11.87 h | 10.43 jk | 10.71 e |
| UG+F ₁ | 11.37 hi | 11.47 h | 12.87 g | 11.37 hi | 11.77 d |
| UG+F ₂ | 14.00 de | 13.07 g | 15.00 c | 13.43 efg | 13.88 b |
| UG+F ₃ | 12.97 g | 11.20 hi | 13.10 fg | 13.83 def | 12.77 c |
| UG+F ₄ | 16.63 a | 14.23 d | 15.47 bc | 15.97 ab | 15.57 a |
| Means | 12.42 B | 11.21 D | 12.91 A | 12.08 C | 12.16 |
| Mean of 2-year | | | | | |
| G | 8.82 l | 7.17 m | 9.07 kl | 7.60 m | 8.16 f |
| UG | 10.67 i | 9.07 kl | 11.52 gh | 9.70 jk | 10.24 e |
| UG+F ₁ | 10.67 i | 10.65 i | 12.08 fg | 10.78 hi | 11.05 d |
| UG+F ₂ | 13.10 de | 12.52 ef | 13.93 bc | 12.42 ef | 12.99 b |
| UG+F ₃ | 12.08 fg | 10.37 ij | 12.43 ef | 12.87 def | 11.94 c |
| UG+F ₄ | 15.10 a | 13.55 cd | 13.95 bc | 14.48 ab | 14.27 a |
| Means | 11.74 B | 10.55 D | 12.16 A | 11.31 C | 11.45 |

[†]Same letter(s) in the same columns and lines are not different. [‡]Same letter(s) in the same columns are not different. ⁿSame letter(s) in the same lines are not different.

*G: grazed

UG; ungrazed (protected from grazing and unfertilized)

UG+F₁: ungrazed + 50 kg ha⁻¹ P₂O₅

UG+F₂: ungrazed + 75 kg ha⁻¹ P₂O₅

UG+F₃: ungrazed + 50 kg ha⁻¹ N + P₂O₅

UG+F₄: ungrazed + 75 kg ha⁻¹ N+ P₂O₅

According to two-year means, the root lengths showed a statistically significant difference ($p < 0.01$) among the grass species (Table 1). The longest root length mean (12.16 cm) was in *C. gryllus*; while the shortest root length (10.55 cm) was determined in *K. cristata*. The effect of the applications on root length was statistically significant ($p < 0.01$). The root lengths increased with applications. The longest root length (14.27 cm) was in the UG+F₄ application, whereas the shortest root length (8.16 cm) was determined in the G application (Table 1).

Species \times application and year \times application interactions were statistically significant ($p < 0.01$) in the study. The significant interaction between years and applications indicates that the fertilizer applications did not have an effect on the root length increases in both years simultaneously. Therefore, the mean root length in the UG application was not statistically different from the mean root length in the UG+F₁ application in 2008; however, there was a statistically difference between root lengths in the UG and UG+ F₁ applications ($p < 0.01$) in 2009. On the other hand, the root lengths of *F. ovina*, *K. cristata*, *C. gryllus*, and *B. ischaemum* species were 11.06 cm, 9.90 cm, 11.42 cm, and 10.53 cm, respectively in 2008; while they were measured as 12.42 cm, 11.21 cm, 12.91 cm, and 12.08 cm, respectively, in 2009. It can be said that these differences were caused by precipitation during the experiment period, which implies that available fertilizer might increase owing to precipitation for plants (Table 1).

According to the results of the present study, plant root length increased significantly with fertilization, ungrazing, and the combination of the two compared with continuously grazed and unfertilized plots. Therefore, it is possible to claim that fertilization and ungrazing have a positive effect on root length. Indeed, heavy grazing reduces root growth and length (Johnson and Matchett, 2001; Nippert et al., 2012). In contrast to Glab and Kacorzyc (2011), the longest root length was obtained from non-fertilized control plots. According to Milchunas and Lauenroth (1989), grazing has little effect on the vertical development of root biomass, but has significant effects on the horizontal development. Frank et al. (2002) reported that herbivores have a positive effect on root growth and Bonin et al., (2013) reported that root length is increased by grazing on the soil surface. Results related to root length, and differences between other studies may be caused by different botanical compositions and ecological conditions in grasslands (Gibson et al., 1993; Pucheta et al., 2004) or different responses of species to different applications (Heggenstaller et al., 2009; Kohyani et al., 2009).

Root Biomass

Root biomass values were statistically different ($p < 0.01$) regarding both grass species and applications in both years. The highest root biomass (8.22 g) was measured in *F. ovina* and the lowest root biomass (0.49 g) was in *K. cristata* in 2008; whereas these values were 9.63 and 0.56 g in the same species in 2009 (Table 2). Evaluating the

effect of the fertilizer applications, the highest root biomass was 4.08 g with the UG+F₂ application and the lowest root biomass (0.73 g) was measured in the G application in 2008. The lowest and highest root biomasses varied from 0.74 g in the G application to 5.43 g in the UG+F₄ application in 2009 (Table 2).

According to the two-year means, root biomass showed a statistically significant difference ($p < 0.01$) regarding both the grass species and applications. The highest root biomass (8.79 g) was in *F. ovina*, while the lowest root biomass (0.52 g) was determined in *K. cristata*. The highest root biomass (4.73 g) was in the UG+F₄ application, whereas the lowest root biomass (0.73g) was determined in the G application. Root biomass increased in the ungrazed and fertilization combinations, but decreased in the grazing application (Table 2).

Species \times application, species \times year, application \times year, and species \times application \times year interactions were statistically significant ($p < 0.01$) in the study. The reason that the year \times interaction was statistically significant was due to different reactions of years to different fertilizer doses. As a matter fact, root biomass, which was determined in UG+F₁, was not statistically different from the root biomass in UG+F₃ and UG+F₄ applications in 2008; however, it was statistically different ($p < 0.01$) in 2009 (Table 2). The effect of the grass species on root biomass was statistically different in both years. In the first year the study, dry root weights of *F. ovina*, *K. cristata*, *C. gryllus*, and *B. ischaemum* species were 8.22 g, 0.49g, 1.09 g, and 1.80 g, respectively; these values were 9.63 g, 0.56 g, 1.27 g, and 2.57 g, respectively, in 2009. These high values in 2009 were caused by climate conditions, especially high precipitation. Furthermore, high temperature with precipitation in the second year increased the available fertilizer (Sun et al., 2008).

The results demonstrated that the effect of the applications on root biomass rise parallel to the effects on root length. While grazing reduced root biomass, fertilization and protection from grazing practices increased root biomass. Grazing had a negative effect on below-ground and above-ground biomass of the grasslands (Yan et al., 2013), and therefore the production of biomass decreased (Nippert et al., 2012; Gaoet al., 2008 and 2011). Controversially, some researchers reported that grazing does not affect root biomass (McNaughton et al., 1998; Pucheta et al., 2004). Root growth has been reported to be reduced by heavy grazing (-30%) (Johnson and Matchett, 2001) and the below-ground production of grassland plants was reduced by intensive grazing (-35%) (Bagchi and Ritchie, 2010). Schuster (1964) indicated that the root biomass of grasses in ungrazed pastures were significantly higher than those in medium or heavily grazed pastures, and increases in grazing pressure caused remarkable decreases in the root biomass of grasses. Furthermore, according to Rogers et al. (2005), medium or heavy grazing resulted in a reduction of total root biomass, but heavy grazing had a affected the decrease more significantly than medium grazing. Bakoglu et

al.(1999b) reported that the below-ground biomass of in *Koeleria cristata* these values ranged from 6.63 g to *Festuca ovina* ranged from 6.17 g to 23.34g plant⁻¹, while 20.74g plant⁻¹.

Table 2. Effect of applications on root biomass of some grass species (g plant⁻¹)

| Applications | <i>Festuca ovina</i> | <i>Koeleria cristata</i> | <i>Chrysopogon gryllus</i> | <i>Bothriochloa ischaemum</i> | Means |
|------------------------|----------------------|--------------------------|----------------------------|-------------------------------|---------------------|
| 2008 | | | | | |
| G | 1.42 h [†] | 0.22 m | 0.43 lm | 0.83 jk | 0.73 d [*] |
| UG | 3.49 d | 0.36 lm | 0.82 jk | 1.44 gh | 1.53 c |
| UG+F ₁ | 10.64 c | 0.46 lm | 1.29 h | 1.73 fg | 3.53 b |
| UG+F ₂ | 12.06 a | 0.55 kl | 1.40 h | 2.31 e | 4.08 a |
| UG+F ₃ | 10.47 c | 0.47 lm | 1.15 hi | 1.89 f | 3.50 b |
| UG+F ₄ | 11.22 b | 0.88 ij | 1.42 h | 2.61 e | 4.03 b |
| Means | 8.22 A [‡] | 0.49 D | 1.09 C | 1.80 B | 2.90 |
| 2009 | | | | | |
| G | 1.46 ij | 0.24 n | 0.45 mn | 0.78 lm | 0.74 f |
| UG | 3.48 f | 0.45 mn | 0.91 klm | 1.70 i | 1.64 e |
| UG+F ₁ | 10.90 d | 0.52 mn | 1.53 i | 2.40 h | 3.84 d |
| UG+F ₂ | 13.62 b | 0.61 lmn | 1.67 i | 3.16 fg | 4.77 b |
| UG+F ₃ | 12.26 c | 0.51 mn | 1.35 ijk | 2.86 gh | 4.24 c |
| UG+F ₄ | 14.45 a | 1.02 jkl | 1.72 i | 4.51 e | 5.43 a |
| Means | 9.63 A | 0.56 D | 1.27 C | 2.57 B | 3.44 |
| Mean of 2-years | | | | | |
| G | 1.44 hi | 0.23 m | 0.44 lm | 0.81 jk | 0.73 f |
| UG | 3.49 d | 0.41 lm | 0.87 j | 1.57 h | 1.58 e |
| UG+F ₁ | 10.77 c | 0.49 lm | 1.41 hi | 2.07 g | 3.68 d |
| UG+F ₂ | 12.84 a | 0.58 kl | 1.54 h | 2.74 e | 4.42 b |
| UG+F ₃ | 11.37 b | 0.49 lm | 1.25 i | 2.38 f | 3.87 c |
| UG+F ₄ | 12.83 a | 0.95 j | 1.57 h | 3.56 d | 4.73 a |
| Means | 8.79 A | 0.52 D | 1.18 C | 2.19 B | 3.17 |

[†]Same letter(s) in the same columns and lines are not different. ^{*}Same letter(s) in the same columns are not different. Same letter(s) in the same lines are not different.

^{*}G: grazed

UG; ungrazed (protected from grazing and unfertilized)

UG+F₁: ungrazed + 50 kg ha⁻¹ P₂O₅

UG+F₂: ungrazed + 75 kg ha⁻¹ P₂O₅

UG+F₃: ungrazed + 50 kg ha⁻¹ N + P₂O₅

UG+F₄: ungrazed + 75 kg ha⁻¹ N+ P₂O₅

In general, nitrogen fertilizers significantly increase the yield capacity of grasslands. Nitrogen is the main soil element that limits the productivity of grasslands. The efficiency of nitrogen depends on many factors such as climatic conditions, vegetation types, structure and form of soils, and the application frequency and quantity of fertilization (Sun et al., 2008). Heggenstaller et al. (2009) emphasized that nitrogen fertilization has a positive effect on yield and root biomass of grasses. In addition, some studies have reported that fertilization increases root biomass (Tewari and Joshi, 1985; Rajaniemi et al., 2003; Tomaškin et al., 2013); nevertheless, low dose fertilization increases root biomass and high doses cause a decrease (Holub et al., 2013). The data of the current study differed from other researchers (Pucheta et al., 2004; Glab and Kacorzyk, 2011; Ladwig et al., 2012; Balogianni et al., 2014), due to different environmental conditions and management applications (Nippert et al., 2012; Yan et al., 2013), different amounts of fertilizer (Holub et al., 2013) and different grazing intensity and ungrazing applications (McNaughton et al., 1998).

CONCLUSION

Fertilizer applications combinations with ungrazing affected root length and biomass of grass species positively. Results show that root length and biomass increased with fertilization and ungrazing of the grassland. Consequently, it is possible to suggest that grazing has an adverse effect on root biomass and 75 kg ha⁻¹ N+P₂O₅, as the most effective fertilizer dose, might be recommended to increase root length and root biomass of grasslands that have similar vegetation characteristics.

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