

The effect of supplemental concentrate feed on live weight gain of yearling heifers over grazing season in subirrigated rangelands of East Anatolia

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Abstract: Animal performance declines considerably after summer dormancy during the grazing season in the steppe rangelands of East Anatolia. The aim of this study was to determine the growth performance of Holstein heifers grazed on rangeland and supported with concentrate. Forage amount, crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents of forage were sampled biweekly during the grazing season. In the experiment, heifers (250 ± 10 kg) were allocated to 1 of 3 feeding trials: 1) control, 2) grazing plus concentrate supplement fed at 1% of bodyweight once daily, and 3) grazing plus concentrate supplement fed at 1.5% of bodyweight once daily. The forage allowance increased from the beginning to the middle of July and thereafter continuously declined until the end of the season. CP content of forage declined from the beginning to the middle of July and thereafter it slightly increased until the end of the season. Both NDF and ADF content of forage increased from the beginning of August and thereafter declined. Bodyweight increased throughout the season, and the increases were considerably higher in the supplemented groups than in the control. Total live weight gain at the end of the grazing season was higher in the supplemented groups than in the control; however, there were no significant differences between the supplemented groups. According to the study results, concentrate supplement fed at 1% bodyweight after the start of summer dormancy can improve animal performance in the rangelands in this region.

Key words: Rangeland forage allowance and quality, Holstein heifer, performance, semiintensive conditions

1. Introduction

Due to high elevation and rough topography, rangelands cover large areas in the East Anatolia region and rangeland-dependent animal husbandry plays a significant role in regional agricultural production. Although there is no statistical record, subirrigated rangelands have a considerable share of the regional rangelands and play an unequal role in rangeland-dependent animal production (1). Feed quality of the rangelands, especially dry rangelands, drop under the maintenance level after the start of summer droughts in the region (2). Therefore, supplementation with different feeds such as high quality roughage or concentrate is a practical application to maintain animal performance during times of low-quality feed supply in the rangelands (3).

Forage quality varies throughout the year in the rangelands due to changing climatic conditions. In general, range plants reach grazing maturity stage in the second part of May, while forage production peaks in the middle of July and thereafter dries out due to summer dormancy. However, drying is delayed up to the beginning of autumn

in subirrigated rangelands; therefore, they supply green forage during the summer dry period in the region (1). While crude protein (CP) content decreases (4), cellulosic constituents such as neutral detergent fiber (NDF) and acid detergent fiber (ADF) increase (5,6) as plant growth advances and forage quality drops to the lowest value, which is insufficient to meet the maintenance needs of grazing animals (7), after drying out due to summer dormancy (2).

The live weight gain of grazing animals decreases parallel to the declining forage quality. Therefore, it is essential to give supplemental feed to grazing animals in order to maintain live weight gain after plants begin drying due to summer dormancy. A study conducted by Scholljegerdes and Kronberg (8) on the Northern Great Plain demonstrated that the daily live weight gain of heifers was significantly higher when supplemented with corn crack or ground flaxseed compared to the control during the summer dry period, whereas these differences were quite small during the wet period. As a result of changes in the live weight gain in response to supplement between

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seasons, treatment \times season interaction was significant. Similar results were also reported by other researchers (9–12).

Some studies have been conducted on seasonal changes in rangeland forage quality and animal performance in response to different applied supplements under feedlot conditions, although almost no data are available with regard to the effect of supplement on live weight gain of the cattle grazed in natural rangelands in high-altitude areas of the East Anatolia region of Turkey, while there are several studies related to small ruminants (13,14). The aim of this study was to evaluate seasonal changes of forage allowance and forage quality on subirrigated rangelands of the East Anatolia region, to determine seasonal changes of daily live weight of the animals grazed in these rangelands, and to enhance the effect of the supplement with concentrate feed on the daily live weight gain of grazing animals.

2. Materials and methods

This study was conducted at Atatürk University's ranch during the grazing season of 2010 in Erzurum (39°55'N, 41°61'E 1800 m a.s.l.), Turkey. Botanical composition of the experimental area was determined by loop method in the beginning of the experiment (15). According to canopy coverage, the experimental subirrigated rangeland vegetation consisted of 35% cool-season grasses such as *Hordeum violaceum*, *Poa pratensis*, and *Koeleria cristata*; 25% legumes such as *Astragalus onobrychis*, *Trifolium repens*, and *Lotus corniculatus*; and 40% plants from other families, such as *Plantago* spp., *Carex* spp., and *Galium* spp.. The area is characterized by a continental climate with a long-term average temperature and total precipitation of 5.0 °C and 425 mm, respectively. During the experimental year, total annual precipitation was 475.9 mm, and the average temperature was 7.9 °C (16). According to the long-term average, the distribution of precipitation is uneven, with the vast majority of annual precipitation occurring from October to the beginning of July; a similar precipitation pattern also occurred during the experimental year. The water table, which is recharged by subsurface flow, rises to almost the surface in the beginning of spring and drops to approximately 1 m below the surface at the end of the growing season (17). This is a significant water resource for plants up to the end of July, although it does not support plant growth, and especially that of grasses, after August. Grasses dried out in the beginning of August in the experimental area.

Some major soil characteristics determined by the method described by the Soil Survey Laboratory Staff (18) were found to be as follows: the soil texture was loam, organic matter was 3.3%, lime was 3.9%, electrical conductivity was 2.9 mmhos cm^{-1} , pH was 7.6 in the soil saturation extract, and the corresponding available

potassium (K) and Olsen phosphorus (P) contents were 650 and 20.5 kg ha^{-1} , respectively. The soils of the experimental site were poor in P, although rich in K.

Plant samples were taken by clipping 10 areas of 0.5 \times 0.5 m in size on every sampling date within the experimental rangeland at 15-day intervals before grazing began in the morning from 3 June to 18 September 18. Plant samples were oven-dried at 68 °C until reaching a constant weight to determine the forage allowance. After weighing, plant samples were ground to pass through a 2-mm sieve. The total N content of plant samples was determined by the Kjeldahl method and multiplied by 6.25 to give the CP content (19). NDF and ADF content were measured using an ANCOM fiber analyzer (ANCOM Technology, USA) following the procedure described by Van Soest et al. (20).

Holstein heifers (14 \pm 1 month of age with an initial bodyweight of 250 \pm 10 kg) were used to determine the growth performance in the experiment. The heifers were weighed and divided into 3 treatment groups: 1) control (no supplement), 2) daily supplementation with 1% bodyweight of concentrate feed in addition to rangeland, and 3) daily supplementation with 1.5% bodyweight of concentrate feed in addition to rangeland. After a 2-week adaptation period, supplemental feeding was done in a barn after the heifers returned from the rangeland every evening for 90 days between 18 June and 18 September. The concentrate mixture feed consisted of barley (42%), maize (24%), soybean meal (10%), wheat bran (4%), molasses (8%), limestone (3%), sunflower meal (8%), salt (0.9%), and premix (0.1%). Each kilogram of vitamin–mineral premix contained 12,000,000 IU of vitamin A, 180,000 IU of vitamin D₃, 12,000 mg of vitamin E, 1200 mg of vitamin C, 40 mg of thiamin, 225 mg of riboflavin, 250 mg of nicotine amid, 125 mg of vitamin K₁, 10,000 mg of iron, 6000 mg of manganese, 4500 mg of zinc, 1000 mg of copper, 120 mg of iodine, 130 mg of cobalt, 35 mg of selenium, 2000 mg of Ca-D-pantothenate, 450 mg of nicotinic acid, 1000 mg of choline chloride, 150,000 mg of sodium, 250,000 mg of phosphorus, and 350,000 mg of calcium. It contained 88% dry matter, 12% CP, 14% crude fiber, 9% ash, and 2500 kcal ME/kg. Each treatment group consisted of 10 heifers and the experimental animals grazed together with the ranch animals for 12 h. Supplemented groups were penned separately to give them supplemental feed every evening. After internal parasitic control and vaccination, the animals were adapted to fresh forage and concentrate feed for 2 weeks before starting the experiment, as for 6 months the animals were fed dry forage during the winter feedlot period. The animals were watered on rangeland and in the barn during the experiment.

The animals were taken from the rangeland and penned at approximately 19:00 hours and taken out to rangeland at approximately 07:00 hours every day. The

animals were weighed with live animal scales (WP-A-125 X 250-1500K.4L, Tunaylar, Turkey) after approximately 12 h of starvation biweekly before putting them to rangeland to determine bodyweight. To determine daily live weight gain, live weight increases between the 2 sampling periods were divided by the total number of days in the period.

Data were analyzed using the general linear model procedure as a completely randomized design for forage allowance, CP, NDF, and ADF and as a factorial arrangement in a completely randomized design for bodyweight and daily live weight gain using SAS statistical software (21). Means were separated using the least significant difference (LSD) test.

3. Results

3.1. Forage allowance and quality

The seasonal changes of the amount of forage allowance, CP, and NDF and ADF contents were significant ($P < 0.01$). Allowed forage in the experimental rangeland increased from the first (3 June) to the second sampling date (18 June) and declined significantly in the subsequent sampling period. It then increased again in the next sampling period and reached a peak value on 18 June (3.649 t dry matter ha⁻¹). Thereafter, it decreased continuously and finally dropped to 1.272 t dry matter ha⁻¹ at the end of the experimental period (Figure 1).

The CP content of forage was 14.03% at the beginning of the sampling and it declined regularly until 3 August (8.47%). Thereafter it showed slight increases until the last sampling date (Figure 2). The NDF content of forage was 46.82% on the first sampling date and reached 59.62% on 18 June, after which it declined significantly until the next sampling date and reached the highest value (68.60%) at the

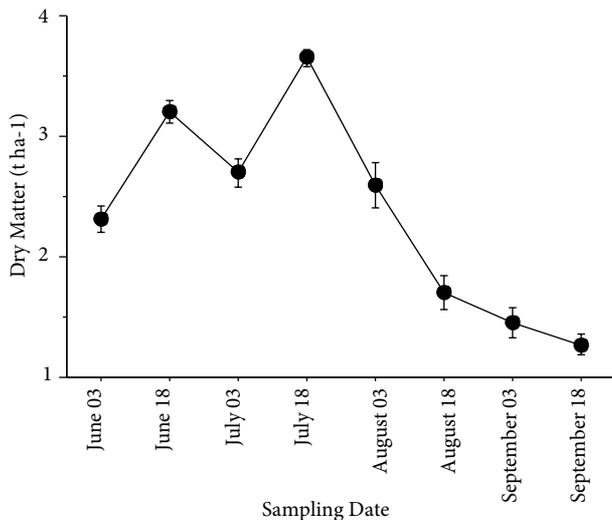


Figure 1. Seasonal changes in forage allowance on subirrigated rangelands (LSD: 0.341).

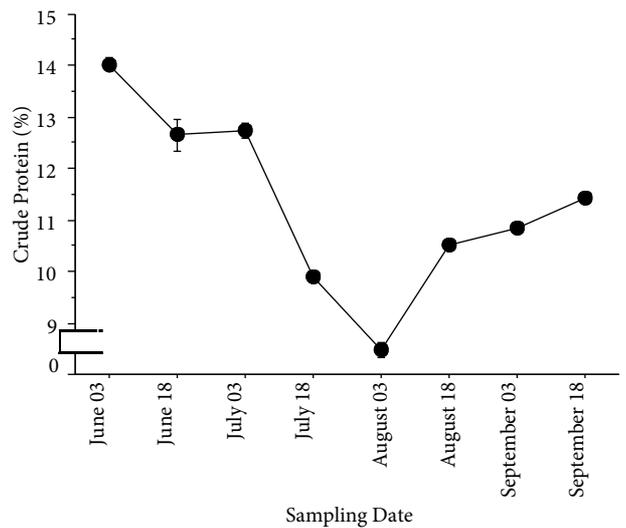


Figure 2. Seasonal changes in crude protein content (%) of allowed forage on subirrigated rangelands (LSD: 0.403).

beginning of August. Thereafter it declined continuously until the last sampling date (Figure 3). Similar changes were also observed for ADF content. The lowest ADF content (30.40%) was recorded at the beginning of the experiment, and the highest ADF content was recorded on 3 August (Figure 4).

3.2. Daily weight gain and concentrate consumed per kilogram of bodyweight gain

The average initial bodyweight of heifers was 249.1 kg, and it increased regularly until the end of the grazing season. There were significant differences between groups with respect to live weight gain, especially after the beginning

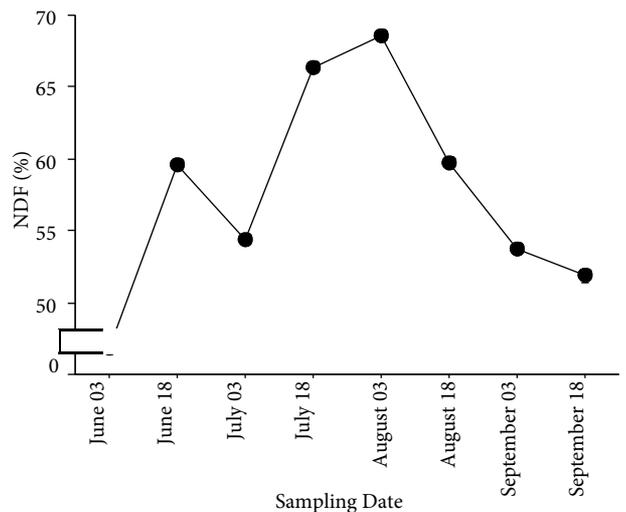


Figure 3. Seasonal changes in NDF content (%) of allowed forage on subirrigated rangelands (LSD: 0.691).

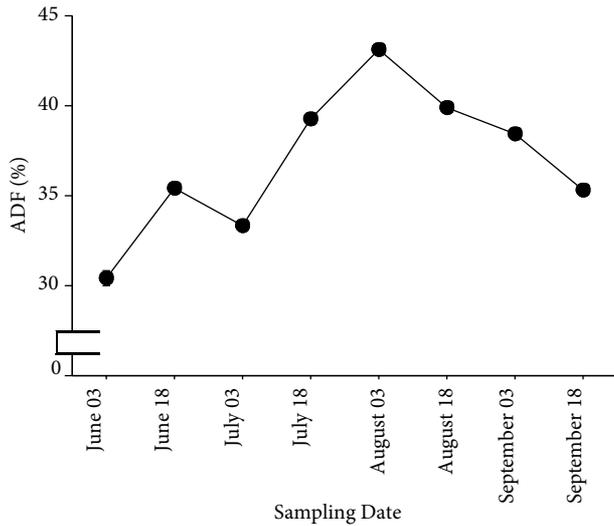


Figure 4. Seasonal changes in ADF content (%) of allowed forage on subirrigated rangelands (LSD: 0.651).

of July. Finally, the bodyweight of supplemented groups was significantly higher than that of the control group at the end of the grazing season (Figure 5). However, there were no statistically significant differences between the supplemented groups with respect to final bodyweight. From the beginning of the experiment (18 June) to 18 July, bodyweight was similar, at 276.8 kg in the control versus 296.4 and 290.3 kg in the experimental groups, although thereafter the bodyweight of the supplemented groups was higher than that of the control group. Therefore, season × application interaction was significant for bodyweight. Final bodyweight was 310.9 kg for the control group and

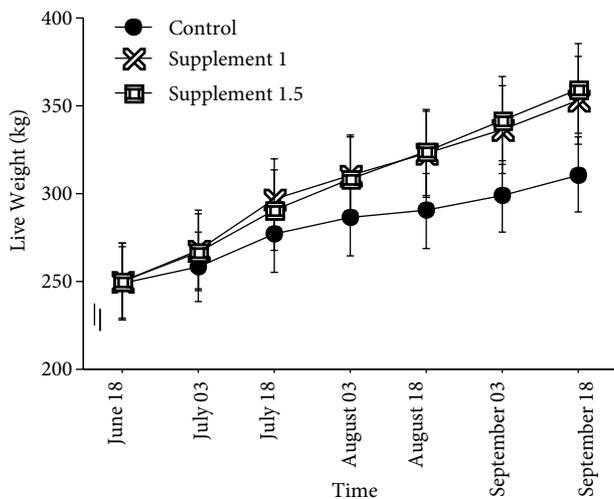


Figure 5. The effect of supplement levels on the bodyweight increases of heifers grazed on subirrigated rangelands (LSD: 12.45).

353.0 and 359.8 kg for the supplemented group with 1% and 1.5% concentrate of live weight groups, respectively.

Average daily live weight gain was 686, 1178, and 1224 g per heifer in the control group and groups supplemented with 1% and 1.5% concentrate of live weight, respectively. In addition, daily concentrate consumption was 2.97 and 4.45 kg per day at 1% and 1.5% bodyweight, respectively. The amounts of concentrate consumed per kilogram of live weight gain by heifers fed at 1% and 1.5% bodyweight were 2.60 and 3.63 kg, respectively. Daily live weight gain showed different trends among the groups during the season. Supplemented groups had consistently higher daily live weight gain on all sampling dates, although the differences were the highest on 18 August. Therefore, season × application interaction was significant for live weight gain in the experiment (Figure 6).

Total live weight gain at the end of the sampling period was 61.7 kg per heifer in the control group, while it was 102.9 and 110.1 kg per heifer when supplemented with 1% and 1.5% concentrate of bodyweight, respectively. The differences in live weight gain between the control and supplemented groups were significant ($P < 0.01$), although the differences between supplemented groups were insignificant (Figure 7). The heifers fed supplement with 1% concentrate of bodyweight had gained 41.2 kg more live weight than the heifers fed by only grazing at the end of the season. In this case, 1 kg of extra live weight gain was achieved by consuming approximately 6.5 kg of concentrate in the group fed by 1% bodyweight (data not presented). Differences between the supplemented groups in daily concentrate consumption and the amount of concentrate consumption in addition to grazing on rangeland per kilogram of weight gain were highly significant ($P < 0.01$;

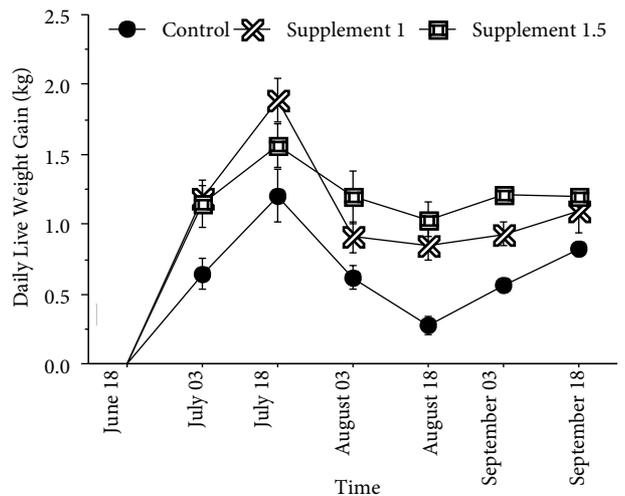


Figure 6. The effect of supplement levels on the daily live weight gain of heifers grazed on subirrigated rangelands (LSD: 0.335).

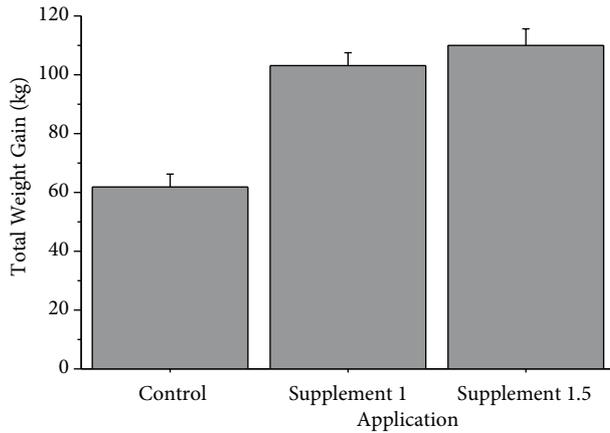


Figure 7. The effect of supplement levels on the live weight gain of heifers grazed on subirrigated rangelands.

Table). Heifers fed by concentrate at 1% bodyweight showed better performance between supplemented groups based on the amount of concentrate consumed in addition to grazing on rangeland per kilogram of weight gain (Table).

4. Discussion

In general, the forage allowance increased until the middle of August in the experiment. Since daily biomass accumulation of rangeland was higher than daily consumption by grazing, the amount of allowed forage increased in this period. Thereafter, allowed forage decreased until the last sampling date, due to decreasing biomass accumulation in rangeland plants because of increasing temperatures as well as decreasing soil moisture due to precipitation shortage and dropping of the water table in the region. The forage allowance trend in the rangeland reflected general characteristics of plants growing on subirrigated rangelands in the region: plant cover began drying out after the middle of July and in

the beginning of August on dry rangelands due to the cessation of spring precipitation in June (2). However, the biomass accumulation rate in the range plants slowed 2 weeks earlier than summer dormancy in the region (22). Allowed forage decreased in the beginning of July, mainly related to decreasing grass growth rates, as grasses reach the flowering stage toward the second part of June, and biomass accumulation rate decreased sharply in the grasses in the region (22). Conversely, summer dormancy began in grasses due to increasing temperature and moisture deficiency in the root zone. Legumes, with their large root system, can obtain moisture and still achieve sustainable yield compared to cool-season grasses during warm summer weather (23,24). Therefore, considerable increases in allowed forage were observed in the rangeland from the beginning to the middle of July in this experiment.

CP content decreased continuously until the beginning of August; thereafter, it showed an increasing trend in the allowed forage in the experimental rangeland. The decreases in CP content were related to the plant growing stage because, as the growth stage advanced, CP content decreased in plants (2,4). The increases in CP content after the middle of August were related to the regrowth of legumes, because legumes and other dicotyledonous plants begin regrowing as soon as the weather begins cooling after August in the region.

The NDF and ADF content of allowed forage in the experimental area increased until the middle of July, except for the third sampling period, and thereafter decreased continuously up to the end of the experiment. These general increases were related to the plant growing stage because as plant growth advanced cellulosic content increased (6,25). The decreases in NDF and ADF content on the sampling date of 3 July and after the beginning of August were related to the increasing contribution of legumes to the allowed forage because legumes always have lower NDF and ADF contents than grasses (26).

Table. Concentrate consumptions of heifers for daily and per kilogram live weight gain (kg).

Groups	Days						
	0-15	15-30	30-45	45-60	60-75	75-90	0-90
Daily consumption							
Control	-	-	-	-	-	-	-
1%	2.50	2.68	2.96	3.10	3.23	3.37	2.97
1.5%	3.75	4.00	4.36	4.62	4.86	5.13	4.45
Consumption per kilogram of live weight gain							
Control	-	-	-	-	-	-	-
1%	2.17	1.46	3.65	4.08	3.68	4.22	2.60
1.5%	3.88	2.72	4.20	5.13	4.01	4.26	3.63

As the season advanced, the bodyweight of heifers increased, although the trends were different among the groups. The heifers supplemented with concentrate at 1% or 1.5% of live bodyweight had higher bodyweight increases than the control group. Due to higher increases in bodyweight in supplemented heifer groups than the control, the supplemented groups had higher live weight gain at the end of the grazing season. The higher daily live weight gain of supplemented groups stemmed from higher feed consumption because higher feeding quality always causes higher live weight gain in grazed animals (13,14). Differences per kilogram of weight gain between the supplemented groups in daily concentrate consumption in addition to grazing on rangeland were highly significant ($P < 0.01$). Holstein heifers fed concentrate at 1% of bodyweight had better performance in the amount of concentrate consumed in addition to grazing on rangeland per kilogram of weight gain. They consumed less concentrate in addition to grazing on rangeland and gained more bodyweight than heifers fed concentrate at 1.5% of bodyweight.

Although the rate of both daily live weight gain and bodyweight decreased as the season advanced, the decreases were more pronounced in the control group. Therefore, season \times application interaction was significant. This situation originated from the decreasing forage quality as the season advanced. Similar results with forage quality decreasing live weight gains in grazed animals were reported by other researchers (27,28). In grazing experiments, as the forage quality decreased, the response to supplementation always increased (29). There was no additional daily or total live weight gain in the group fed with concentrate at 1.5% of bodyweight compared to those fed concentrate at the rate of 1% of bodyweight. This situation is probably related to forage intake and forage

quality, because as the supplement level increased forage intake by grazing declined (3), and when the animals grazed, appreciable quality forage could not show extra performance when a high level of supplementation was applied (30). In the experimental area, the CP content of the forage never dropped to a critical level (7%) for maintenance (7); therefore, no extra animal performance was recorded for the supplement level of 1.5% of bodyweight in the experiment. The study results showed that the decreases in live weight gain among grazing animals in the advanced season can be relieved by supplementing with 1% concentrate of bodyweight after range plants reach the generative stage, because the differences in live weight gain between the supplemented and control groups was small before this growing stage.

In conclusion, declining forage quality after summer dormancy is a significant obstacle in steppe ecosystem rangelands depending on animal husbandry, because animal performance declines sharply due to poor forage quality. Supplementing during the poor forage supply period can be a desirable practice to overcome this problem. According to the results from the present study, supplementing with concentrate at the rate of 1% of bodyweight in Holstein heifers after steppe rangeland plants reach the generative stage is an efficient practice to improve animal performance. Nevertheless, further studies on alternative supplement resources and supplement levels are needed to determine cheaper and more efficient supplementation for the beef industry in steppe ecosystems rangelands.

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References

- Koç A. The effects of topography and soil climate on some properties of rangeland vegetation. PhD, Atatürk University, Erzurum, Turkey, 2005.
- Koç A, Gökkuş A, Bakoğlu A, Özasan A. Temporal variation in chemical properties of plant samples during grazing season from Palandöken rangelands Erzurum. In: Proceedings of the International Animal Nutrition Congress. Isparta, Turkey; 2000. pp. 471–478.
- Greenquist MA, Klopfenstein TJ, Schacht WH, Erickson GE, Vander Pol KJ, Luebbe MK, Brink KR, Schwarz AK, Baleseng LB. Effects of nitrogen fertilization and dried distillers grains supplementation: forage use and performance of yearling steers. *J Anim Sci* 2009; 87: 3639–3646.
- Koç A, Gökkuş A. Annual variation above ground biomass, vegetation height and crude protein yield on natural rangelands of Erzurum. *Turk J Agric For* 1996; 20: 305–308.
- Linn JG, Martin NP. Forage Quality Tests and Interpretations. St Paul, MN, USA: University of Minnesota Extension Service; 1999.
- Erkovan Hİ, Güllap MK, Daşcı M, Koç A. Changes in leaf area index, forage quality and above-ground biomass in grazed and ungrazed rangelands of eastern Anatolia region. *Tarım Bilimleri Dergisi* 2009; 15: 217–223.
- Meen A. Forage quality on the Arizona strip. *Rangelands* 2001; 23: 7–12.
- Scholljegerdes EJ, Kronberg SL. Effects of supplemental ground flaxseed fed to beef cattle grazing summer native range on the Northern Great Plains. *J Anim Sci* 2010; 88: 2108–2121.
- Marsh R. A comparison between spring and autumn pasture for beef cattle at equal grazing pressures. *Grass Forage Sci* 1975; 30: 165–170.

10. Reid TC. Comparison of autumn/winter with spring pasture for growing beef cattle. In: Proceedings of the New Zealand Society of Animal Production. Palmerston North, New Zealand; 1986. pp. 145–148.
11. Cosgrove GP, Muir PD, Lambert MG. Nutritional options and implications for maximum growth rate of steers. In: Proceedings of the New Zealand Grassland Association. Palmerston North, New Zealand; 1996. pp. 277–222.
12. Petty SR, Poppi DP, Triglone T. Effect of maize supplementation, seasonal temperature and humidity on the live weight gain of steers grazing irrigated *Leucaena leucocephala*/*Digitaria eriantha* pastures in north-west Australia. *Journal of Agricultural Science Cambridge* 1998; 130: 95–105.
13. Macit M, Esenbuga N, Karaoglu M. Growth performance and carcass characteristics of Awassi, Morkaraman and Tushin lambs grazed on pasture and supported with concentrate. *Small Rum Res* 2002; 44: 241–246.
14. Macit M, Şahin S, Esenbuğa N, Karaoğlu M. Growth and carcass characteristics of three fat tailed pure breeds under grazing with concentrate supplementation. *Turk J Vet Anim Sci* 2003; 27: 331–337.
15. Koç A, Çakal S. Comparison of some rangeland canopy coverage methods. In: Proceedings of the International Soil Congress on Natural Resource Management For Sustainable Development. Erzurum, Turkey; 2004. pp. 41–45.
16. Republic of Turkey Ministry of Forest and Water Affairs. Turkish State Meteorological Service. 12th Regional Climate Center. Erzurum, Turkey; 2010.
17. Erkovan HI, Güllap MK, Daşcı M, Koç A. Effects of phosphorus fertilizer and phosphorus solubilizing bacteria application on clover dominant meadow: I. Hay yield and botanical composition. *Turkish J Field Crops* 2010; 15: 12–17.
18. Soil Survey Laboratory Staff. Soil Survey Laboratory Methods Manual. USDA-SCS. Soil Survey Investigations Report No: 42. Washington, DC, USA: USDA; 1992.
19. Jones DIH. Chemical composition and nutritive value. In: Handson J, Baker RD, Davies A, Laidlows AS, Leawer JD, editors. *Sward Measurement Handbook*. Kenilworth, UK: The British Grassland Society Press; 1981. pp. 243–265.
20. Van Soest PJ, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *J Dairy Sci* 1991; 74: 3583–3597.
21. SAS. SAS User's Guide. 4th ed. Version 9.1. Cary NC, USA: SAS Institute Inc.; 2003.
22. Bakoğlu A, Koç A, Gökkuş A. Variation in biomass and chemical composition of dominant rangeland plants during the growing season. I. Changes in biomass, root/shoot ratio, stem, leaf, flower ratios. *Turk J Agric For* 1999; 23: 487–494.
23. Mooso GD, Wedin WF. Yield dynamics of canopy components in alfalfa-grass mixtures. *Agron J* 1990; 82: 696–701.
24. Biever S, Fricke T, Wachendorf M. Determination of dry matter yield from legume-grass swards by field spectroscopy. *Crop Sci* 2009; 49: 1927–1936.
25. Messman MA, Weiss WP, Ericson DO. Effects of nitrogen fertilization and maturity of bromegrass on in situ ruminal digestion kinetics. *J Anim Sci* 1991; 69: 1151–1161.
26. Rayburn EB. Forage Quality-Fiber and Energy. Morgantown, WV, USA: West Virginia University Extension Service; 1997.
27. Potter EL, Cooley CO, Richardson LF, Raun AP, Rathmacher RP. Effect of monensin on performance of cattle fed forage. *J Anim Sci* 1976; 43: 665–669.
28. Squires VR, Siebert BD. Botanical and chemical components of the diet and live weight change in cattle on semi-desert rangeland in central Australia. *The Australian Rangeland Journal* 1983; 5: 28–34.
29. Koster HH, Cochran RC, Titgemeyer EC, Vanzant ES, Abdelgadir I, St-Jean G. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J Anim Sci* 1996; 74: 2473–2481.
30. Owensby CE, Cochran RC, Brandt RT, Vanzant ES, Auen LM, Clary EM. Grain supplementation on bluestem range for intensive-early stocked steers. *J Range Manage* 1995; 48: 246–250.