Asian Journal of Chemistry Vol. 19, No. 3 (2007), 2341-2348

Effects of Nitrogen and Potassium Fertilization on Yield and Nutritional Quality of Rangeland

MEVLÜT TÜRK* NECMETTIN ÇELIK†, GAMZE BAYRAM† and EMINE BUDAKLI†
Department of Field Crops, Faculty of Agriculture
Süleyman Demirel University, Isparta, Turkey
Fax: (90)(246)2371693; Tel: (90)(246)2114629; E-mail: mturk72@ziraat.sdu.edu.tr

This research was conducted to investigate effects of nitrogen and potassium on yield and quality of rangelands in Turkey between 2001 and 2003. The research was set up as randomized complete block design with three replications. Four different nitrogen doses (0, 50, 100 and 150 kg ha^{-1}) and three different potassium doses (0, 50 and 100 kg ha^{-1}) were applied and their effects on rangeland was investigated. Ammonium nitrate and potassium sulphate was used as nitrogenous and potassium fertilizers. All of potassium fertilizer and 50% of nitrogenous fertilizer were be applied in Fall and the remaining amount was used in Spring. Effects of fertilizer applications on dry matter yield, crude protein concentration, crude cellulose ratio, crude ash ratio, magnesium, calcium, potassium concentrations and tetany ratios were investigated. Averaged over two years, nitrogen doses increased dry matter yield, crude protein concentration, crude cellulose ratio, crude ash ratio, potassium concentration and tetany ratio, while nitrogen doses decreased magnesium concentration. Potassium doses increased crude protein concentration, potassium concentration and tetany ratio, while it decreased magnesium and calcium concentration. According to results of this study, the highest dry matter yield was obtained from in $N_{150}K_0$ (9.93 g kg^{-1}) and $N_{150}K_{50}$ (10.01 g kg^{-1}) treatments. $N_{150}K_{100}$ application has the highest crude protein concentration (141.3 g kg^{-1}). The highest crude cellulose ratio (49.90 %) was obtained from in $N_{150}K_{50}$. Tetany ratios (K/Ca+Mg) exceeded the critical level in $N_{50}K_{100}$, $N_{100}K_{100}$ and $N_{150}K_{100}$ treatments.

Key Words: Rangeland, Nitrogen, Crude protein concentration, Potassium, Tetany ratio.

INTRODUCTION

Turkey has 12.5 million hectares of rangeland, many of which have deteriorated due to intensive livestock grazing. Large amounts of forage needed for feeding 11 million cattle and 29 million head sheep populations is provided by these rangelands[1]. In Turkey, the most important problem of raising livestock is the shortage of feed stuff and in fact only one-third

†Department of Field Crops, Faculty of Agriculture, Uludag University, Bursa, Turkey.

section of needed forage can be supplied. Often supplementary feed is required to compensate animals for pasture deficiencies. Inappropriate management contributes to these deficiencies.

The most practical and effective method to increase dry matter production in rangelands is to use appropriate and adequate fertilization in these areas[2]. Even though this practice has demonstrated a potential to significantly increase both amount and quality of forage around the world, it is not yet widely applied in Turkey. The primary reason is that the price of fertilizer is high or changes frequently. A second reason is that many rangelands experience high climatic variability every year that affects the results of this practice. These reasons represent high risks to the ranchers. It is believed that in general, the response of rangeland to applied fertilizer depends on 1) kind of fertilizer, 2) rates and application method, 3) density and type of vegetation, 4) soil type and soil fertility and 5) abiotic factors such as evaporation and precipitation[3].

If sufficient and balanced fertilization is performed in regions getting feasible precipitation, it is possible to increase the yield of rangelands twice or higher[4-7].

Species composition, plant available nutrients and water, climate and other agronomic factors influence production and quality characteristics[8]. Measurement of the nutritional value of the diet of grazing animals is difficult. Grazing animals commonly have available to them a wide range of potential food in the form of different plant species, each with its particular physical and chemical characteristics and each with different densities and growth forms. From this available forage, the grazing animal exercises a high degree of selection, the mechanisms of which appear to be based on subtle chemical and physical differences affecting smell, taste and touch.

The most important disease for livestock is grass tetany caused by mineral matter imbalance in feeds. Nitrogen and potassium fertilizing used to enhance rangeland yield has increased[9] the risk for tetany by increasing K/Ca+Mg ratio up to 2.2. Because, there is an antagonistic relationship between K and Mg. The yield decrease or mortality in livestock fed by feeds which are rich in K can be observed due to the fact that Mg is blocked. The concentrations of Ca, Mg and K are important for ruminants and must be higher than 3.1, 1 and 6.5 g kg^{-1} for beef cattle, respectively[10].

Because little information is available concerning the diets of grazing animals in Marmara region of Turkey, the present study was conducted to investigate the effects of N and K fertilization on dry matter yield, forage quality and nutritional value of the rangelands. The study also focuses on the determination of the tetany ratios (K/Ca+Mg) which may cause yield decrease and/or mortality in livestock.

EXPERIMENTAL

The experiment was conducted at the Agricultural Research and Experiment Center of Agriculture Faculty, at Uludag University, Bursa between 2001 and 2003. Bursa is located on the Marmara region of Turkey. The growing season of herbaceous vegetation begins in mid-March and ends in June at Bursa. Average temperature and relative humidity were 14.9ºC and 68.7 % in 2002; 14.3ºC and 68.7 % in 2003, 14.8ºC and 68.9 % in long years (1928-1999), respectively. While the long years (1928-1999) precipitation was 699 L/m^2, the annual precipitations were 894 and 653.5 L/m^2 for 2002 and 2003, respectively (Table-1). The experimental soil was clayey, non saline, poor in lime and organic matter, medium in potassium and had a neutral pH.

TABLE-1
ANNUAL AND SEASONAL TOTAL PRECIPITATION (L/m^2) AT BURSA, TURKEY

Years	Period	
	Growing Season (February-June)	Annual (October-September)
2001-2002	332.8	894
2002-2003	299.5	653.5
Long years (1928-1999)	290.6	699

Some major soil characteristics determined by the method described by Rowell[11] were found to be as follows; the soil texture is clay; organic matter is 1.1%; total salt is 0.1%; lime is 4%, sulphur is 12 mg/kg, extractable P by 0.5 $NaHCO_3$ extraction is 4.8 mg/kg; exchangeable K by 1 N ammoniumacetate extraction is 120.7 mg/kg; pH is 7.1 in soil saturation extract and EC is 1.51 mS/cm in the same saturation extract.

Fertilizer applications were randomly assigned to 12 plots within each of 3 blocks. Each treatment plot was 2 × 3 m (width and length) with a distance of 1 m between each plot. Treatments were repeated in the same plot for 2 years, 2002 and 2003. Nitrogen was applied as ammonium nitrate with rates of 0, 50, 100 and 150 kg N ha^{-1}. Potassium was applied as potassium sülfat (K_2SO_4) with rates of 0, 50 and 100 kg K ha^{-1}. Fertilizers were broadcasted by hand and then buried by a rake without disturbing the vegetation. Half of the N and all of K were applied at the beginning of November. The remaining N was applied at the beginning of rapid growth period of vegetation (mid-March).

Herbaceous vegetation was annually harvested within 6 m^2 area when grass plants reached full flowering stage at the beginning of June. Vegetation was handclipped at ground level. And then, green forage production per 6 m^2 area was recorded.

Samples taken from 1 m^2 area of each plot were oven-dried at 60ºC for 48 h and dry weight ratios were calculated. Dry matter yield of each plot was calculated through the values of green forage production and dry-weight percentage. However, crude protein concentration, crude cellulose ratio, crude ash ratio, Mg, Ca, K concentration and tetany ratio were determined. Crude protein ratios of harvested plots were determined by micro-Kjeldhal (N × 6.25) to determine crude protein concentration of each plot[12]. Crude cellulose ratios of samples were determined using soxhlet methods.

Samples were analyzed for Ca, Mg, K using an atomic absorption spectrophotometer using an air-acetylene flame. The three macronutrients (Ca, Mg and K) were expressed as g/kg of dry matter and the cation ratio K/(Ca+Mg) was calculated on a milliequivalent basis[13].

A randomized complete block experiment design was used in this study. The data was analysed using Minitab and Mstat programs. Differences among treatments were tested by LSD method (level of significance $P < 0.05$).

RESULTS AND DISCUSSION

Means of 2 years of experimental period, N applications significantly increased dry matter yield. The dry matter yield in control plots was 6.42 t ha^{-1}, while it increased up 9.93 t ha^{-1} in the $N_{150}K_0$-treatment. The effect of K applications on dry matter yield was found no significant (Fig. 1).

As shown in Fig. 1, N and K applications had a significant effect on crude protein concentration. Averaged of two years, crude protein concentration was 99.1 g kg^{-1} in control plots, while it increased up to 141.3 g kg^{-1} in the $N_{150}K_{100}$-treatment.

According to averaged of two years, the highest crude cellulose ratio was obtained from $N_{150}K_{50}$ treatment with 49.90 %, while the smallest crude cellulose ratio was obtained from control plots with 28.47 %. Fertilizer treatments significantly increased crude cellulose ratio (Fig. 1).

The highest crude ash ratio (14.57 %) was determined in $N_{100}K_{50}$-treatment, while the lowest crude ash ratio (11.37 %) was obtained from N_0K_{100}-treatment. The increase in nitrogen doses caused an increase in crude ash ratio. 50 kg ha^{-1} K treatment had the higher crude ash ratio than 100 kg ha^{-1} K treatment (Fig. 1).

Fertilizer treatments significantly decreased Mg concentrations. Mg concentration was 4.17 g kg^{-1} in control plots, while Mg concentration was 1.33 g kg^{-1} in $N_{150}K_{100}$ treatment (Fig. 2).

The highest Ca concentration (17.33 g kg^{-1}) was obtained from $N_{50}K_0$-treatments, while the smallest Ca concentration (6.33 g kg^{-1}) was obtained from N_0K_{100} treatments. The increase in K doses resulted in a decrease in Ca concentrations. 50 kg ha^{-1} N application significantly increased Ca concentration, but 100 and 150 kg ha^{-1} N application decreased Ca concentrations, except in 100 kg ha^{-1} K treatment (Fig. 2).

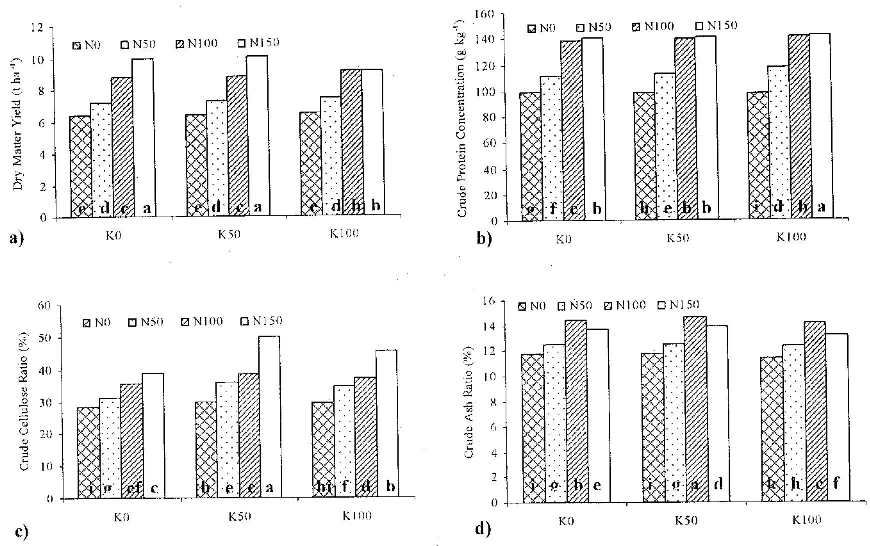

Fig. 1. Dry matter yield (a), crude protein concentration (b), crude cellulose ratio (c) and crude ash ratio (d) on a rangeland with different fertilization treatments as mean of the two experimental years. Values with different letters within columns differ significantly at the level of $p < 0.05$

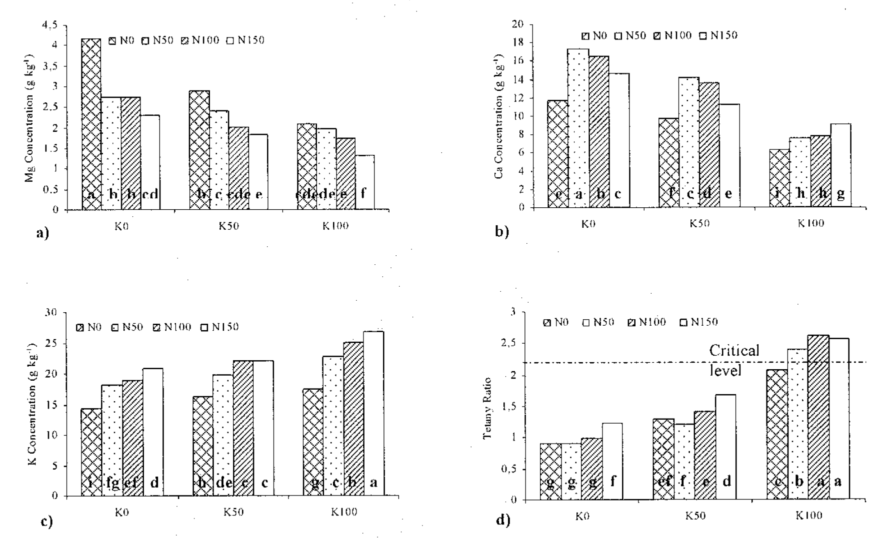

Fig. 2. Mg concentration (a), Ca concentration (b), K concentration (c) and tetany ratio (d) on a rangeland with different fertilization treatments as mean of the two experimental years. Values with different letters within columns differ significantly at the level of $p < 0.05$

The application of N and K had a significant effect on K concentrations. K concentration in control plots was 14.43 g kg^{-1}, while it increased up 26.87 g kg^{-1} in the $N_{150}K_{100}$-treatment (Fig. 2).

The tetany ratios are presented in Fig. 8. The effects of N and K applications on tetany ratios were highly significant in averages of two years. In plots without K, tetany ratios changed from 0.905 to 1.229. But, K applications increased significantly tetany ratios. In plots receiving 100 kg ha^{-1} K, tetany ratios changed from 2.083 to 2.626 (Fig. 2).

Application of N fertilization increased dry matter yield from 6.42 to 10.01 t ha^{-1} in present study. Because, N doses affected significantly yields of grasses, such as *Avena fatua* L., *Bromus japonicus* L., *Lolium perenne* L., in rangelands. Many studies have shown a doubling or more dry matter yields from fertilizer N applications[4-7,14,15].

Increases in N and K doses caused increase crude protein concentrations in the present study. Increases of crude protein content due to N applications has been reported in numerous studies[3,16-18]. Forage quality can be described as the conversion of consumed forage to animal products. One of the main criterions is the crude protein concentration of the forage[16]. Digestibility of hay increases with the increase in crude protein concentration[19]. Forage with high quality in terms of animal feeding should contain 125 g kg^{-1} crude protein[20]. Except N_0 and N_{50} fertilizer treatments, the forage quality obtained from the present study in terms of crude protein was similar to this value. Crude protein production depends on dry matter yield in plots and crude protein concentration in plants, which changes according to plant species. In fact, fertilization with N and K not only affects crude protein production but also botanical composition in rangelands. Therefore, it can be said that the higher crude protein yield was due to the increase in doses of fertilizers, which directly affects dry matter yield in plots.

Fertilizer treatments increased crude cellulose ratios, in agreement with Mc Donald *et al.*[21], but not with Grimes[22] and Doyle[23]. The reason for the differences in crude cellulose ratios could be due to the availability of different grass ratios in botanical composition, since the increase in N doses increases grasses proportion and crude cellulose ratios.

Nitrogen doses increased crude ash ratios. This result was in accordance with the result reported by Altin[24].

A linear decrease in Mg concentration was seen with K and N fertilization rates, as has been reported in other studies[25-28]. The determined Mg level in this study was higher than the recommended daily requirements of 1 g kg^{-1} for beef cattle[10]. All fertilizer treatments exceeded the Ca concentration of 3.1 g kg^{-1} recommended for beef cattle[10]. The increase in K concentration from 18.13 to 23.05 g kg^{-1} with increasing K fertilization rates, is quite similar to the results reported Barbarick[29] and Lloveras *et al.*[30]. Smith[25] found that the K concentrations of the tissue increased from 8.9 to 20.5 g kg^{-1} when K fertilization rates increased from 0 to 448 kg K ha^{-1}. All treatments had higher K concentration than recommended daily requirement (6.5 g kg^{-1}) for beef cattle[10]. A forage researcher considering altering the mineral concentration of grasses should investigate whether increased concentration of a particular element in the plant would result in an increase in another element. Both Ca and Mg had negative association with K and the cation ratio in grasses and in legumes[18,31]. This indicates that breeding for higher Ca or Mg concentration may lead to lower concentration of K. However, it is important to note that weather, soil and water may influence chemical ratios which in turn may cause hypomagnesaemia[32].

Forage and animal scientists are aware of the importance of the concentrations of Ca, Mg, K and K/(Ca+Mg) ratio in diets for ruminants. A ratio between K and Ca+Mg of more than 2.2, expressed on an equivalent basis, has been considered to be an indicator of potential grass tetany[9,33-35]. In present study, means of K/(Ca+Mg) ratio exceeded the critical 2.2 level in $N_{50}K_{100}$, $N_{100}K_{100}$ and $N_{150}K_{100}$ treatments. This higher ratio may have been due to high potassium levels. Mayland and Hankins[36] reported that high N and K doses increases the risk of contracting grass tetany in early spring. Grass tetany causes yield decrease or mortality in livestock. The application of Mg fertilizer can decrease risk of grass tetany[37]. In present study, the tetany ratio in N_0K_{100} application was close to the critical level. The ratios in other fertilizer treatments were less than the critical level.

Conclusion

The results of this study showed that nitrogen application increased dry matter yield, crude protein concentration, crude cellulose ratio, crude ash ratio, K concentration and tetany ratio, while it decreased Mg concentration. On the other hand, K applications increased crude protein concentration, K concentration and tetany ratio, while it decreased Mg and Ca concentration. Tetany ratios (K/Ca+Mg), which may cause yield decrease and/or mortality in livestock, exceeded the critical level in $N_{50}K_{100}$, $N_{100}K_{100}$ and $N_{150}K_{100}$ treatments.

REFERENCES

1. I. Aydin and F. Uzun, *Eur. J. Agron.*, **23**, 8 (2005).
2. E. Cazzato, P. Ventricelli and A. Corleto, *Rivista-di-Agronomia*, **33**, 257 (1999).
3. H.O. Rubio, M.K. Wood, A. Gomez and G. Reyes, *J. Range Manage.*, **49**, 315 (1996).
4. J.R. Wight and A.L. Black, *J. Range Manage.*, **32**, 345 (1979).
5. J.F. Power, *Agron. J.*, **77**, 189 (1985).
6. S.K. Barnhart, R.D. Voss and J.R. George, Fertilizing Pasture, Iowa State University, University Extension, Pm-869 (1997).
7. D.E. Elliott and R.J. Abbott, *Aust. J. Exp. Agric.*, **43**, 553 (2003).

8. J.S. Jacobsen, S.H. Lorbeer, H.A.R. Houlton and G.R. Carlson, *J. Range Manage.*, **49**, 340 (1996).
9. C.B. Elkins, R.L. Haaland and C.S. Honeland, Proceedings of the 13th International Grass Congress, 18-21 May, Vol. 2, pp. 1505-1507 (1977).
10. NRC, Nutrient Requirements of Domestic Animals, No. 4, Nutrient Requirements of Beef Cattle, Washington : NAS : NRC, revised edn. 6, (1984).
11. D.R. Rowell, Soil Science: Methods and Applications, Longman, Harlow (1996).
12. Technicon, Individual/Simultaneous Determination of Nitrogen and/or Phosphorus in BD Acid Digests, Industrial Method No. 334-374, Tarrytown, New York: W/B Technicon Industrial Systems (1977).
13. J.H. Cherney and G.C. Marten, *Crop Sci.*, **22**, 227 (1982).
14. J.F. Power and J. Alessi, *Agron. J.*, **63**, 277 (1971).
15. D.W.L. Read and G.E. Winkleman, *Can. J. Plant Sci.*, **62**, 415 (1982).
16. R.L. Gillen and W.A. Berg, *J. Range Manage.*, **51**, 436 (1998).
17. G.F. Lima, L.E. Sollenberger, W.E. Kunkle, J.E. Moore and A.C. Hammond, *Crop Sci.*, **39**, 1853 (1999).
18. M.R.M. Losado, G.A. Rodriguez and R.A. Rodriguez, *J. Range Manage.*, **57**, 280 (2004).
19. P.J. Van Soest, Composition and Nutritive Value of Forages, The Science of Grassland Agriculture, Iowa State University Press, Ames, IA (1973).
20. G. Yildiz, in eds.: A. Ergun and S.D. Tuncer, Feeding the Beef Cows, Animal Nutrition and Nutrition-Related Diseases, Ozkan Press, Ankara, pp. 137-175 (2001) (in Turkish).
21. P. McDonald, R.A. Edwards, J.F.D. Greenhalgh and C.A. Morgan, Grass and Forage Crops, Animal Nutrition Longman Scientific and Technical, England, pp. 434-444 (1995).
22. R.C. Grimes, *J. Agric. Sci.*, **69**, 33 (1967).
23. J.J. Doyle, *J. Range Manage.*, **32**, 162 (1979).
24. M. Altin, The Effects of Nitrogen, Phosphorus and Potassium Fertilization on Yield, Crude Protein Ratio, Crude Ash Ratio and Botanical Composition of Range and Meadow in Erzurum, Turkey conditions, Atatürk University Publish No. 326, Agricultural Faculty Publish No. 159, Erzurum, Turkey, p. 141 (1975).
25. D. Smith, *Agron. J.*, **67**, 60 (1975).
26. R.S. Rominger, D. Smith and L.A. Peterson, *Agron. J.*, **68**, 573 (1976).
27. D.W. James, C.J. Hurst and T.A. Tindall, *J. Plant Nutr.*, **18**, 2447 (1995).
28. D.M. Ball, M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, D.H. Putnam, D.J. Undersander and M.W. Wolf, Understanding Forage Quality, American Farm Bureau Federation Publication, 1-01, Park Ridge, IL (2001).
29. K.A. Barbarick, *Agron. J.*, **77**, 442 (1985).
30. J. Lloveras, J. Ferran, J. Boixaders and J. Bonet, *Argon. J.*, **93**, 139 (2001).
31. S.P. Kidambi, A.G. Matches and T.C. Griggs, *J. Range Manage.*, **42**, 316 (1989).
32. H.F. Mayland, in ed.: K.L. Johnson, Crested Wheatgrass: Its Values, Problems and Myths, Symp. Proc. Utah State Univ., Logan, pp. 215-266 (1986).
33. A. Kemp and M.L. t'Hart, *Neth. J. Agric. Sci.*, **54**, 17 (1957).
34. G.M. Ward, *J. Dairy Sci.*, **49**, 268(1966).
35. H.F. Mayland and D.L. Grunes, *J. Range Manage.*, **27**, 198 (1974).
36. H.F. Mayland and J.L. Hankins, in ed.: K. Launchhbaugh, Mineral Imbalances and Animal Health: A Management Puzzle Anti-Quality Factors in Eangeland and Pastureland Forages, Idaho Forest, Wildlife and Range Experiment Station University of Idaho, Moscow, ID 83844-1130, pp. 54-62 (2001).
37. E.B. Rayburn, Forage Management, West Virginia University, Extension Service (2005); http://www.caf.wvu.edu

(*Received*: 4 July 2006; *Accepted*: 4 November 2006) AJC-5252