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Nitrogen Effects on Crested Wheatgrass as Related to Forage Quality Indices of Grass Tetany[1]

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ABSTRACT

Nitrogen fertilization of forage is often accompanied by an increased incidence of grass tetany. A field experiment was established on two calcareous soils to evaluate the effects of N fertilizer on forage quality indices of grass tetany. Nitrogen, as NH_4NO_3, was applied at 0 and 150 kg N/ha in each of 2 years to separate plots. The crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult] forage was harvested at regular intervals in the Spring tetany period during 1968 through 1971. Forage was analyzed for inorganic cations, N, total water-soluble carbohydrates (TWSC), aconitic acid, higher fatty acids (HFA), dry matter, and ash alkalinity — a measure of total organic acids.

Nitrogen fertilizer increased the concentrations (equiv. basis) of forage Mg and Ca more than the increase in K, thus slightly reducing the K/(Ca + Mg) values when compared to the unfertilized forage. However, forage K/(Ca + Mg) values were usually less than the 2.2 value above which the incidence of grass tetany increases rapidly. The potential dietary benefits from the higher Mg concentrations may have been offset by increased concentrations of K, N, HFA, N/TWSC, and aconitic acid, since these parameters are associated with decreased Mg availability to cattle.

Low values for hypothetical blood serum Mg (calculated from forage N, Mg, and K concentrations) coincided with the occurrence of grass tetany in the field. The calculated serum Mg values were lower in the N-fertilized forage than in the control.

The aforementioned effects of N fertilization should not deter the judicious use of N for optimizing forage yields on semiarid ranges, since other research workers have found that grass tetany losses can be reduced by supplementing animals with Mg.

Additional index word: Hypomagnesemia.

HIGH rates of N fertilizer are often used, sometimes with K fertilizer, in order to increase yields on grass or mixed pastures. In humid areas, high rates of N fertilization have increased the concentrations of N in the forage, reduced the availability of dietary Mg, and increased the incidence of grass tetany of cattle (1, 2, 4).

A field study was established on crested wheatgrass [*Agropyron desertorum* (Fisch.) Sshult.] to evaluate the effects of N fertilization on forage chemical components that might be involved in the etiology of grass tetany under semiarid conditions. The study was continued for 4 years to evaluate the effects of residual N fertilizer, and to measure seasonal differences in the forage chemical composition. The data are discussed in relation to hypotheses concerning the etiology of grass tetany.

EXPERIMENTAL PROCEDURE

The two crested wheatgrass sites chosen for the study were located about 5 km from each other in northeastern Nevada. Both sites were on calcareous soils described in detail elsewhere (7). Forage grown on these sites was known to cause grass tetany during some Spring grazing periods (8).

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Table 1. Mean chemical composition of *Agropyron desertorum* during successive years as affected by 0 or 150 kg N/ha applied as NH_4NO_3 in either February 1968 or February 1969.

Component	Fertilized 1968								Fertilized 1969					
	1968		1969		1970		1971		1969†		1970		1971	
	N_0	N_{150}	N_0	N_{150}	N_0	N_{150}	N_0	N_{150}	N_0	N_{150}	N_0	N_{150}	N_0	N_{150}
Degrees of freedom‡	23		7		13		5		55		31		23	
K, %	1.63	1.78**	2.13	2.33**	1.74	1.86**	1.98	2.03	1.97	2.45**	1.81	2.00*	1.97	2.19**
Mg, %	0.10	0.11**	0.11	0.13**	0.10	0.11**	0.11	0.12*	0.11	0.16**	0.11	0.13**	0.11	0.13*
Ca, %	0.34	0.40**	0.41	0.52**	0.38	0.43**	0.39	0.38	0.41	0.51**	0.38	0.48**	0.38	0.44**
K/(Ca + Mg)	1.73	1.61**	1.89	1.69**	1.68	1.63	1.87	1.95	1.80	1.60**	1.70	1.57**	1.85	1.96*
P, %	0.25	0.25	0.30	0.27*	0.26	0.24**	0.28	0.29	0.29	0.30	0.25	0.24**	0.28	0.29*
Cl, %	0.48	0.50	0.45	0.48	0.37	0.37	0.40	0.31	0.44	0.45	0.39	0.36**	0.38	0.38
NO_3-N, ppm	140	360**	208	356**	138	218*	55	83	155	501**	134	372**	70	196**
N, %	3.27	3.95**	3.51	4.33**	2.86	3.10*	2.83	2.86	3.60	4.90**	3.04	3.64**	2.80	3.26**
TWSC, %	9.0	7.4**	17.8	16.4	---	---	---	---	18.6	17.2**	---	---	---	---
HFA, meq/kg	88	97**	69	74	87	84	120	116	73	95**	85	92**	123	127
Aconitic acid, %	1.17	1.32**	1.58	1.96**	1.07	1.25**	1.24	1.24	1.47	1.75**	1.18	1.49**	1.17	1.22
Ash alkalinity, meq/kg	499	562**	596	753**	559	605**	545	556	600	756**	542	660**	527	560**
Dry matter, %	37.3	35.1**	---	---	35.5	34.3**	28.3	27.6	36.1	34.3**	35.5	33.9**	28.6	26.9**

*, ** Significant t-test at P=0.05 and 0.01, respectively. † Data are means for first seven sampling periods only, since later samples contained some reproductive material.
‡ For plots fertilized with N in 1968, the t-test for N effects on forage Mg has 11, 7, 13, and 5 df in 1968, 1969, 1970, and 1971, respectively; plots fertilized with N in 1969 have 13, 7, and 5 df in 1969, 1970, and 1971, respectively.

In February 1968, 0 and 150 kg/ha of NH_4NO_3-N were applied to experimental plots established at each site. Also, each plot was split and $MgSO_4 \cdot 7H_2O$ applied at rates of 0 and 90 kg Mg/ha. Additional plots were fertilized in February 1969 with 0 and 150 kg N/ha, and each plot was split and 0, 90, 200, and 600 kg M/ha were applied. No fertilizer was added in subsequent years.

During the potential tetany period, the plant samples were clipped at a 2-cm height above the stem base of randomly selected clones, immediately frozen in solid CO_2, and stored at −18 C until freeze dried, after which time samples were ground to pass a 40-mesh screen and stored at room temperature. The methods of chemical analyses have been described (8). The paired t-test was used to test the significance of seasonal differences in forage parameters resulting between treatments and controls (11). Data were pooled for the two sites and for the Mg treatments since Mg fertilization did not significantly affect values for forage parameters (7). Data points shown in Fig. 1 represent means of 4 and 8 samples for the 1968 and 1969 fertilized areas, respectively. Magnesium data points were not pooled and are means for the two sites, each having only one replication. The data represented in Table 1 are seasonal means for forage parameters and sampling dates indicated in Fig. 1.

RESULTS AND DISCUSSION

The effects of 150 kg N/ha on forage chemical composition are shown in Table 1 for four seasons after N application in February 1968, and for three seasons after N application in February 1969. Fertilizer N significantly changed the levels of most constituents when compared with the level in unfertilized forage. Droughty conditions during April 1968 probably accounted for the delay in response to N fertilization until mid-May (Fig. 1), when the soil moisture supply was then replenished (8). At that time, the plants in the N-fertilized plots became darker green, and the chemical composition was altered. The 1971 season was probably the most productive, and dry matter yields from the N-fertilized plots were estimated to be twice those from the unfertilized plots.

Nitrogen fertilization increased forage K in all years (Table 1 and Fig. 1). The increased K concentrations were anticipated (13) since exchangeable soil K supplies were high (1 to 2 meq K/100 g soil) (7). Forage K concentrations would have been reduced following N fertilization if soil K values were low (13). Thus the forage response to fertilizer N in this study might be similar to forage fertilized with fairly high rates of N and K in K-deficient areas. However, forage K concentrations were not unusually high.

Forage Mg concentrations were significantly increased by N fertilization (Table 1 and Fig. 1). The effects of N and Mg fertilizers were additive in increasing forage Mg concentrations (7). Fertilizing with 150 kg N/ha increased forage Mg more than fertilizing with 200 kg Mg/ha (7). It is possible that N fertilization could have increased root proliferation, Mg uptake per unit root weight, and/or the translocation of Mg to the aboveground portions of the plant.

The increase in forage K concentrations, after N fertilization would tend to produce a more tetany-prone forage (4). However, since N fertilization may increase forage Mg concentrations, the detrimental effects of K may be somewhat offset.

Hypothetical blood serum Mg values were calculated for this study using a nomograph of forage N, K, and Mg that is used for grazing dairy cows in the Netherlands (3, p. 15). Conditions of forage production and animal Mg requirements may be quite different between the Netherlands and the semiarid Nevada study. However, some lactating beef cattle grazing unfertilized crested wheatgrass pastures surrounding the study exclosures died from grass tetany during the May 1968 and May 1969 periods in which predicted serum Mg values were at very low levels (Fig. 2). In addition, the computed serum Mg values were generally decreased by N fertilization, thus illustrating the aggravating effect of N fertilization on the tetany proneness of forage. The potential tetany period suggested by the low serum Mg values between March 27 and Apr. 3, 1968 was not actually encountered because cattle did not begin grazing these pastures until April 15.

Nitrogen fertilization also significantly increased forage Ca (Table 1 and Fig. 1). The high Mg fertilizer rates tended to suppress these increases in forage Ca ($P = 0.10$, data not shown), suggesting some competition between these two divalent cations.

The K/(Ca + Mg) values, calculated on an equivalence basis, did not exceed 2.2 except on the last sampling date of 1971 (Fig. 1). Nitrogen fertilization depressed K/(Ca + Mg) values except in 1971. The Dutch indicated that when the forage K/(Ca + Mg) value was greater than 2.2, grass tetany incidence was much greater than when the value was less than 2.2 (6). In the Nevada study, N fertilization increased K, Mg, and Ca. However, the increase was greater in

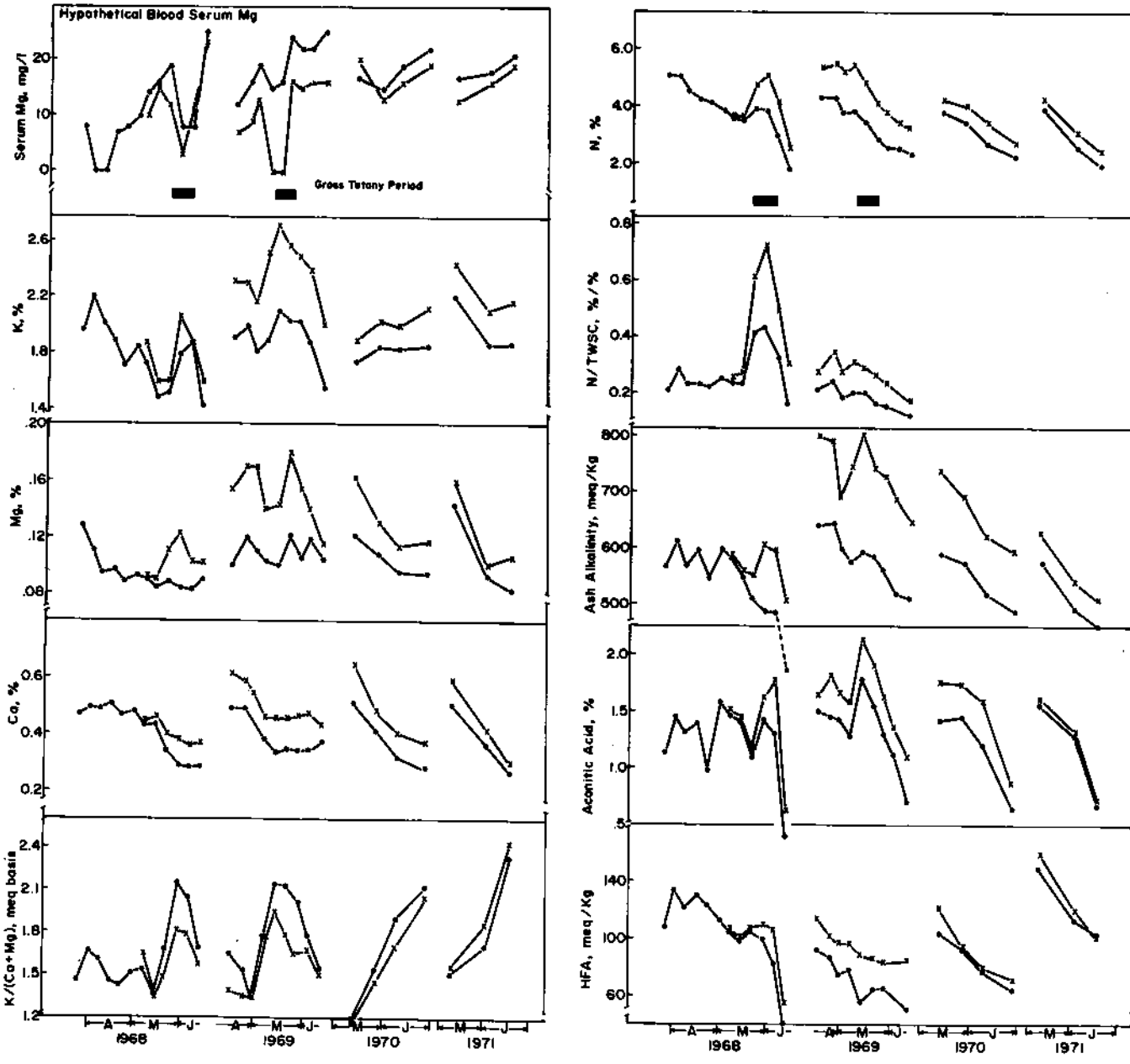

Fig. 1. Seasonal trends in the chemical composition of *Agropyron desertorum* as affected by 0 (O——O) or 150 (x——x) kg N/ha applied as NH_4NO_3. (Data for 1968 were from the 1968 fertilized plots, all other data were from the 1969 fertilized plots.) Also, hypothetical blood serum Mg values calculated from the Dutch nomograph (3, p. 15) using forage N, Mg, and K values for N-fertilized and unfertilized *Agropyron desertorum* in each of four grazing seasons. (The shaded blocks, upper left and right, indicate the time period when tetany was occurring on surrounding pastures.)

Ca and Mg than the increase in K concentrations, and thus the value of K/(Ca + Mg) was slightly depressed by N fertilization during the 1968-1970 period.

In general, the inorganic cations tended to decrease with time within each season because of dilution by products of photosynthesis. Magnitudes of N treatment effects on concentration of mineral elements generally decreased each successive year after fertilization, so that the differences resulting from N fertilization were not expected to be significant beyond the fourth season after application.

The effect of N fertilization on P and Cl levels was inconsistent (Table 1). As expected, nitrate-N was increased by N fertilization (Table 1), but these levels were not very high for N-fertilized forage. Seasonal NO_3-N values ranged from 100 to 950 ppm NO_3-N for the N-fertilized and 50 to 250 ppm NO_3-N for controls during the first season following the 1969 fertilization (data not shown). No relationship has been established between grass tetany and NO_3-N, P, or Cl.

A droughty March and April 1968 was ended when rain replenished the dry soil profile on May 9. This was followed by an increase in forage N and a decrease in total water-soluble carbohydrates (TWSC) as indicated by the large increase in N/TWSC values

(Fig. 1). These changes in N, TWSC, and the N/TWSC values were greater for the N-fertilized forage.

Grass tetany occurred outside the experimental exclosures simultaneously with the 1968 peak in N/TWSC values; In their report Mayland, Grunes, and Stewart (8) associated the intensity of grass tetany losses with the height of the N/TWSC peak. The peak values for N/TWSC were even higher for the N-fertilized plots, than for those not fertilized with N (Fig. 1). This may be one reason why fertilizer N increases the incidence of grass tetany. When the forage plant is suddenly confronted with adequate N, moisture, and optimum temperature, it begins to utilize its own readily soluble carbohydrates while taking up luxuriant amounts of N. The rapid increase in forage N/TWSC values may produce conditions in the rumen of the grazing animal which are favorable for Mg to complex with organic acids, HFA, and as magnesium ammonium phosphate (9). These metal-ligand complexes may reduce the Mg availability to the animal.

Aconitic acid was determined because it may influence the occurrence of tetany by reducing dietary Mg availability (2). Nitrogen fertilizer increased aconitic acid concentrations in forage (Table 1 and Fig. 1). Fertilizer N also increased total organic acids, as measured by ash alkalinity values. Aconitic acid accounted for about 40% of the ash alkalinity value regardless of N fertilization.

The cation minus anion (C — A) data from N-fertilized forage are not given because of incomplete SO_4-S data. However, the limited C — A data that were available were similar in magnitude to ash alkalinity values. Both parameters are indirect measurements of organic acid content. Ash alkalinity values gradually decreased as physiological age of forage increased (Fig. 1), as did aconitic acid and, presumably, total organic acids.

We believe that if organic acids are important in the grass tetany syndrome, they may be effective primarily when cattle first start grazing pastures high in organic acids. Later, rumen microflora populations probably adjust to the new diet and decompose the organic acids. An exception to this conditioning occurs in the presence of high K levels, which are known to decrease the rate at which rumen microorganisms can utilize citric acid (14).

Fertilizer N significantly decreased the percentage dry matter in most years. The lower forage dry matter would result in a shorter retention time of the ingesta in the animal, consequently reducing Mg absorption which is time-dependent (9).

A direct relationship has been found between higher fatty acids (HFA) and total N in forage samples representing a range of very immature to mature and cured samples (5, 10). This correlation is due partly to the fact that concentrations of both N and HFA decrease during the season because of physiological aging of plants (Fig. 1). In this study (Table 1), N fertilization often significantly increased the concentrations of HFA in forage of similar physiological age. To our knowledge, this is the first time that the effect of N on HFA has been published. Some HFA may have been autoxidized during storage of freeze-dried samples before analysis. However, we believe that the increases in HFA due to N fertilization, as shown in the present study, are valid. The influence of high N forage in helping to cause grass tetany may be at least partly due to an increase in the HFA content in the herbage (5). This could result in the formation of insoluble Mg soaps during digestion. When the diet of dairy cows is supplemented with peanut oil rich in HFA, dietary Mg availability decreased and insoluble fecal Mg soap increased (12).

Nitrogen fertilization of some semiarid grasslands may be considered to achieve maximum forage production. Such potential areas will likely have higher effective precipitation than the sites included in this study. However, the effects of N fertilization on forage quality noted in this study could be useful elsewhere in predicting changes in quality indices as related to grass tetany. Fertilizer N in this study increased forage Mg concentrations which would tend to reduce the incidence of grass tetany. The benefits from the increased forage Mg may be offset, however, by increased levels of K, N, HFA, and organic acids. Possibly of most significance is the large N effect on increasing forage N and on decreasing forage TWSC. This occurs when soil moisture and temperature are optimum for rapid growth. Thus, N fertilization could have its biggest effect, in relation to tetany, by widening this protein-to-energy ratio. Supplementing animal diets with Mg during tetany-prone seasons would be advisable.

LITERATURE CITED

1. Grunes, D. L. 1973. Grass tetany of cattle and sheep. p. 113-140. *In* A. G. Matches (ed.) Anti-quality components of forages. Special Publ. 4. Crop Sci. Soc. Am., Madison, Wis.
2. Grunes, D. L., P. R. Stout, and J. R. Brownell. 1970. Grass tetany in ruminants. Adv. Agron. 22:331-374.
3. Henkens, C. H., Chairman. 1973. Tracing and treating mineral disorders in dairy cattle. Centre for Agricultural Publishing and Documentation. Wageningen, The Netherlands.
4. Kemp, A. 1960. Hypomagnesaemia in milking cows: The response of serum magnesium to alterations in herbage composition resulting from potash and nitrogen dressing on pasture. Neth. J. Agric. Sci. 8:281-304.
5. ———, W. B. Deijs, and E. Kluvers. 1966. Influence of higher fatty acids on the availability of magnesium in milking cows. Neth. J. Agric. Sci. 14:290-205.
6. ———, and M. L. 't Hart. 1957. Grass tetany in grazing milking cows. Neth. J. Agric. Sci. 5:4-17.
7. Mayland, H. F., and D. L. Grunes. 1974. Magnesium concentration in *Agropyron desertorum* fertilized with Mg and N. Agron. J. 66:79-82.
8. ———, ———, and D. M. Stuart. 1974. Chemical composition of *Agropyron desertorum* as related to grass tetany. Agron. J. 66:441-446.
9. Molloy, L. F. 1971. Hypomagnesaemic tetany and the chemistry of dietary calcium and magnesium. N. Z. Soil Bur. Sci. Rep. 5. 21 p.
10. ———, A. J. Metson, and T. W. Collie. 1973. Grass tetany. IV. Relationships between higher fatty acids and nitrogen in some New Zealand herbages. N. Z. J. Agric. Res. 16:457-462.
11. Snedecor, G. W., and W. G. Cox. 1967. Statistical methods, 6th ed. Iowa State University Press, Ames.
12. Wilson, G. F., C. S. W. Reid, L. F. Molloy, A. J. Metson, and G. W. Butler. 1969. Grass tetany. I. Influence of starch and peanut oil supplement on plasma magnesium, calcium, and phosphorus levels in grazing dairy cows. N. Z. J. Agric. Res. 12:467-488.
13. Wolton, K. M. 1963. Fertilizers and hypomagnesaemia. NAAS Q. Rev. 14:123-130.
14. Wright, D. E. 1971. Citric acid metabolism in the bovine rumen. Appl. Microbiol. 21:165-168.