Developing a tall fescue for reduced grass tetany risk

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ABSTRACT
Tall fescue (*Festuca arundinacea* Schreb.) is an important forage grass, and like other C_3 grasses, has the potential to cause grass tetany in grazing ruminants. Genetic variation in cation uptake by fescue was exploited by selecting for high Mg and Ca relative to K concentration in fescue. The grass tetany ratio, K/(Ca+Mg), was reduced about 18% after 2 selection cycles. The mean Mg and K/(Ca+Mg) values for 20 C_1 plants, grown at pH 6.4, were weakly related (r^2=0.42 and 0.48) to those of plants grown in calcareous soil pH 8.2. The P, Na, Mn, Fe, Cu, and Zn concentrations were not affected by the selection process.

KEYWORDS: cation uptake, *Festuca arundinacea*, forages, grass tetany, hypomagnesemia, magnesium

INTRODUCTION
Grass tetany (hypomagnesemia) occurs in ruminants throughout the temperate regions of the world. It occurs most commonly when animals graze rapidly growing C_3 grasses. Death losses are estimated at US$50 to $150 million annually in the USA alone. An estimated 30% of those losses are associated with the grazing of tall fescue (*Festuca arundinacea* Schreb.). Increasing the Mg and Ca relative to K concentrations in the herbage would greatly reduce these animal losses and contribute significantly to the value of this forage grass (Sleper et al. 1989).

Hides & Thomas (1981) increased the Mg concentration in Italian ryegrass (*Lolium multiflorum*). Others found that the Mg was readily available to sheep (Moseley & Griffiths 1984) and that it was very effective in reducing the incidence of grass tetany relative to the parent Italian ryegrass (Moseley & Baker 1991).

Reeder et al. (1986) showed that tall fescue had a 75-89% narrow sense heritability for Mg, Ca and K concentrations, and K/(Ca+Mg) values. This led us to believe that we could improve the elemental composition of tall fescue and lower the risk of tetany to animals grazing tall fescue. This paper reports the progress achieved during 2 cycles of selection for high Mg and low K/(Ca+Mg) values in tall fescue.

MATERIALS AND METHODS
Endophyte (*Acremonium coenophialum* Morgan-Jones and Gams)-free seed from a genetically broad-based tall fescue population was germinated in the greenhouse. Seedlings (C_0 population) of KENHY (950 plants), Kentucky 31 (831 KY-31) and Missouri-96 (688 MO-96) were transplanted to the field near Columbia, Missouri. The soil was a Mexico silt loam (fine, montmorillonitic, mesic Udollic Ochraqualf) of pH 6.4. Selection was applied against rust susceptibility, leaving 1011 plants from which shoots were harvested in autumn. Further selection was done upon elemental concentrations of Mg, Ca, K, and the tetany ratio (K/(Ca+Mg), computed as moles of charge). Primary selection was based on an index identified as "reduced tetany potential" (RTP) which was defined as the sum of the normalised values of Mg and the tetany ratio (Mayland & Asay 1989).

Sixty-five plants (11 KY-31, 54 MO-96) were selectively removed from the C_0 population and were cross-pollinated to serve as parents for the C_1 cycle. These 65 plants contained 5.0-7.0 mg Mg/g, 5.0-10.2 mg Ca/g and 20-33 mg K/g, and had K/(Ca+Mg) values of 0.61-0.99.

The process was continued through another cycle using the same selection criterion. Plant responses to climate conditions during the second year resulted in an overall greater tetany risk. This time 50 plants (15 from KY-31 and 35 from MO-96 maternal parentage) were selectively removed from the C_1 population (972 clones), and these contained 4.4-6.1 mg Mg/g, 5.5-8.1 mg Ca/g and 17.2-30.9 mg K/g, and had tetany ratios of 1.06-2.13. These plants served as the parents for the C_2 population which was planted in Kimberly, Idaho, for seed increase and further evaluation.

Selection effects on other elements were determined on 46 of the 50 highest rated and 10 (having no maternal parent in common) of the lowest-rated plants selected from the C_1 population. The data were subjected to a one-way analysis of variance.

The relative nutrient uptake by C_1 plants was determined by comparing the mean nutrient values of 20 groups of 10-20 half-sibs space planted in the Missouri nursery with values of the same groups planted in rows in a Portneuf silt loam (coarse-silty, mixed, mesic, Durixerollic Calciorthid). Values of Mg and K/(Ca+Mg) of the spaced plants in Missouri were regressed with data obtained for rowed plants in Idaho.

Elemental concentrations were determined by atomic absorption spectroscopy (Mg, Ca, Na, Cu, Zn, Mn and Fe), emission spectroscopy (K), or colorimetrically (P) after wet-ashing samples in nitric:perchloric (3:1) acid. Solutions containing 1 mg La/l as $LaCl_3$ were used for Mg, Ca and K determinations.

RESULTS AND DISCUSSION
Large numbers of plants from each of the three varieties were screened initially, but none of the KENHY plants were chosen. Yearly climatic differences changed the bioavailability and relative concentrations of Mg, Ca and K in plant tissue. Clonal controls were not harvested, precluding a direct check on selection progress. Relative comparisons were only available for KY-31, MO-96 and the 20 C_1 plants grown in Idaho. These comparisons indicated an 18% reduction in the grass tetany ratio of the 20 C_1 plants.

The Mg concentration and tetany ratio of plants grown on the slightly acid Missouri soil were weakly related to those same parameters (r^2=0.42 and 0.48, respectively) for plants grown on the calcareous Idaho soil. Additional comparisons will be sought for a range of edaphic and climatic conditions.

Correlation analysis of data for the C_0 population indicated that there was no relationship between K and Mg (r=0.0) and K and Ca (r=0.0), but the two divalent cations were correlated (r^2=0.4). This may be explained by the difference in ion mobility and sorption of the monovalent cation K and the two divalent cations. Solution K moves to roots mainly by diffusion, whereas Mg and Ca move to roots almost entirely by mass flow. Mass flow often results in excess divalent cation accumulating at the root surface (Wilkinson et al. 1990). Thus, differences in cation uptake, especially Mg uptake between control and high Mg selections, must be attributed to differences in membrane permeability and cation transport within the plant. Unfortunately, these mechanisms are not fully understood (Wilkinson et al. 1990).

Selection effects on elemental uptake were determined by comparing the concentrations of a nutrient in 46 of the 50 highest rated versus the 10 lowest rated plants selected from the C_1 population. Mean values for high/low plants were 5.3/2.8, 6.4/4.6, 26/24 and 2.35/2.26 in mg/g for Mg, Ca, K and P, respectively. The probability values for the F statistic were 0.0001, 0.0001, 0.069 and 0.25. Values were 0.89/1.34 and 322/123 for the grass tetany ratio and the RTP. Selected plants had different (P<0.0001) tetany ratio and RTP values than did non-selected plants. Values for Na, Mn, Fe, Cu and Zn were respectively 1180/1020, 92/95, 470/650, 5.4/5.0 and 19/18 μg/g. The probability values for the F statistic were 0.59, 0.76, 0.07, 0.10 and 0.39 for Na, Mn, Fe, Cu and Zn, respectively.

The selection process has increased the concentrations of Mg and Ca, and the values of the two indices. There was a small increase in K, but other elements tested were not changed by the selection process. The effects on other quality parameters are yet to be evaluated. Animal palatability of the fescue must also be measured. Experiences gained with the testing of the high-Mg Italian ryegrass indicate that sheep utilised the increased Mg, and since they ate more forage, the net Mg intake was greatly increased (Moseley & Griffiths 1984; Moseley & Baker 1991).

A tall fescue synthetic has been developed which, at least compositionally, possesses a reduced tetany risk. However, we still do not know the physiological or biochemical mechanisms which allow for the increased uptake of the two divalent cations (Mg and Ca). Also, and perhaps of greater practical information, we will need to determine palatability and performance of animals when grazing the new synthetic.

REFERENCES

Hides, D.H.; Thomas, T.A. 1981: Variation in the magnesium content of grasses and its improvement by selection. *Journal of the science of food and agriculture 32*: 990-991.

Mayland, H.F.; Asay, K.H. 1989: Genetic variability of Mg, Ca, and K in crested wheatgrass. *Journal of range management 42*: 109-113.

Moseley, G.; Baker, D.H. 1991: The efficacy of a high magnesium grass cultivar in controlling hypomagnesemia in grazing animals. *Grass and forage science 46*: 375-380.

Moseley, G.; Griffiths, D.W. 1984: The mineral metabolism of sheep fed high- and low-magnesium selections of Italian ryegrass. *Grass and forage science 39*: 195-199.

Reeder, L.R., Jr.; Nguyen, H.T.; Sleper, D.A.; Brown, J.R. 1986: Genetic variability of mineral concentrations in tall fescue grown under controlled conditions. *Crop science 26*: 514-518.

Sleper, D.A.; Vogel, K.P.; Asay, K.H.; Mayland, H.F. 1989: Using plant breeding and genetics to overcome the incidence of grass tetany. *Journal of animal science 67*: 3456-3462.

Wilkinson, S.R.; Welch, R.M.; Mayland, H.F.; Grunes, D.L. 1990: Magnesium in plants: uptake, distribution, function, and utilisation by man and animals. *Metal ions in biological systems 26*: 33-56.2.