Variability for Ca, Mg, K, Cu, Zn, and K/(Ca + Mg) ratio among 3 wheatgrasses and sainfoin on the southern high plains

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Abstract

The objective of this study was to determine the variability of Ca, Mg, K, Cu, Zn, and K/(Ca+Mg) ratio in 'Jose' tall wheatgrass [*Thinopyrum ponticum* (Podp.) Barkw. & D.R. Dewey], 'Luna' pubescent wheatgrass [*T. intermedium* subsp. *barbulatum* (Schur.) Barkw. & D.R. Dewey], and 'Hycrest' crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. × *A. desertorum* (Fisch. ex Link.)]. Each grass was grown alone and in paired rows with 'Renumex' sainfoin (*Onobrychis viciifolia* Scop.) on a Pullman clay loam soil (a fine, mixed thermic Torrertic Paleustoll). Each species or mixture was evaluated under 3 cutting schedules in 1985 and 1986 and their mineral concentrations were compared to the recommended daily requirements of beef cattle. The concentration of minerals was similar in grasses grown as monocultures and in binary mixtures. The concentrations of all minerals and the ratio varied with harvest time, phenological stage, and year. Therefore, seasonal dynamics of mineral concentrations should be kept in mind when evaluating the mineral status of different forages. Among grasses, Hycrest had a better mineral profile for beef cattle than Luna or Jose. Sainfoin had higher concentrations of Ca, Mg, Cu, and Zn and much lower K/(Ca+Mg) ratio than the grasses. Hence, sainfoin-Hycrest mixtures may provide mineral concentrations more in balance with beef cattle requirements and help alleviate the problem of hypomagnesemia.

Key Words: ***Agropyron cristatum, Agropyron desertorum, Thinopyrum intermedium*** **subsp.** ***barbulatum, Thinopyrum ponticum, Onobrychis viciifolia,*** **cation ratio, grass tetany**

Forage and animal scientists are aware of the importance of the concentrations of Ca, Mg, K, Cu, and Zn, and the K/(Ca+Mg) ratio in diets for ruminants. Van Riper and Smith (1959) reported that the concentration of K was greater in bromegrass (*Bromus inermis* Leyss.)-clover (*Trifolium repens* L.) mixtures than in pure stands, while concentrations of Ca and Cu did not differ in monocultures vs. mixtures. With advancing maturity of bromegrass, K (MacLeod 1965), Cu, and Zn concentrations declined, while the K/(Ca+Mg) ratio increased (Harms et al. 1978). 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 (Ward 1966). Recent reviews concerning the biological significance of Cu (McMurray 1980) and Zn (Hidiroglou and Knipfel 1984) suggest that deficiencies of either may be related to infertility, anemia, or to suppressed immune response. Hidiroglou and Knipfel (1984) concluded that even though the concentration of Zn is generally high in semen and its constituents, the different roles of Zn in the male reproductive system are extremely complex and scarcely understood.

Wheatgrasses (tribe Triticeae) were used to reseed the range land in western North America, due to their (1) early growth in the spring, and (2) drought resistance (Rogler 1973). Thus, the wheatgrasses are components in range grazing systems. Since they provide pasture during the time of year when grass tetany may be a problem (Kemp and t'Hart 1957), it is important to consider the ratio of K/(Ca+Mg) in addition to mineral concentrations. Very few papers (Blincoe and Lambert 1972; Murray et al. 1978, 1979) have reported on the mineral concentrations of these grasses. Therefore, the major objective of this study was to determine the variability of the concentrations of Ca, Mg, K, Cu, and Zn and K/(Ca+Mg) ratio in 'Jose' tall [*Thinopyrum ponticum* (Podp.) Barkw. & D.R. Dewey; formerly *Agropyron elongatum* (Host) Beauv.] (Anon. 1966), 'Luna' pubescent [*T. intermedium* subsp. *barbulatum* (Schur.) Barkw. & D.R. Dewey; formerly *A. trichophorum* (Link) Richt.] (Niner 1967), and 'Hycrest' crested [*A. cristatum* (L.) Gaertn.) × (*A. desertorum* (Fisch. ex Link.) Schult.] (Asay et al. 1985) wheatgrass species and sainfoin (*Onobrychis viciifolia* Scop.) in grass monocultures and binary mixtures of wheatgrasses with 'Renumex' sainfoin (Melton 1978). Calcium, Mg, and K were chosen because of their role in causing grass tetany (Currier et al. 1986), while Cu and Zn were selected due to their part in reproduction. The ease of determining these minerals from

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Table 1. Sampling dates, phenologic stages[1], and rainfall[2] when Luna pubescent, Hycrest crested, and Jose tall wheatgrasses grown alone and in mixtures with sainfoin were harvested at 3 initial spring growth stages, 3 summer regrowth stages, and 1 winter residue stage in 1985 and 1986.

		Initial Spring Growth			Summer Regrowth			Winter residue	
Species	Harvests	Date of Sampling	Phenologic Stage	Rainfall[3]	Date of Sampling	Phenologic Stage	Rainfall[4]	Date of Sampling	Rainfall[4]
				cm			cm		cm
1985									
Luna	Early	April 24	1.8	5.2	July 11	2.0	25.8	Dec. 18	32.0
	Medium	May 16	3.0	9.0	July 23	1.2	22.0	Dec. 18	32.0
	Late	June 10	3.9	22.7	Aug. 23	1.4	13.7	Dec. 18	22.0
Hycrest	Early	May 03	3.2	8.5	July 15	1.4	22.5	Dec. 18	32.0
	Medium	May 24	3.7	15.7	July 29	1.8	22.8	Dec. 18	24.4
	Late	June 20	5.6	25.7	Aug. 30	1.2	17.8	Dec. 18	19.4
Jose	Early	May 09	2.0	8.7	July 19	2.8	22.3	Dec. 18	32.0
	Medium	May 30	2.1	15.7	Aug. 01	2.4	22.8	Dec. 18	24.4
	Late	June 25	3.0	26.7	Sept. 06	2.2	28.0	Dec. 18	19.4
1986									
Luna	Early	April 09	1.5	2.9	June 20	2.4	24.4	Dec. 16	43.1
	Medium	May 03	2.5	4.0	July 03	2.6	26.8	Dec. 16	40.0
	Late	May 28	3.3	6.8	July 16	1.2	16.8	Dec. 16	38.9
Hycrest	Early	April 15	1.6	3.1	June 25	2.3	26.3	Dec. 16	41.0
	Medium	May 08	2.9	4.0	July 07	2.5	27.5	Dec. 16	39.0
	Late	June 03	3.0	9.5	July 21	2.3	14.1	Dec. 16	38.9
Jose	Early	April 20	1.0	3.2	June 30	1.9	26.1	Dec. 16	41.0
	Medium	May 16	1.6	4.0	July 14	1.8	28.4	Dec. 16	38.9
	Late	June 12	1.8	11.0	July 28	1.2	12.7	Dec. 16	38.8

[1]Codes are (1) vegetative, (2) jointing, (3) boot, (4) heading, (5) anthesis, and (6) mature.
[2]Plots were irrigated on 6 Apr. 1986 and 26 May 1986 with 8.7 and 7.9 cm, respectively.
[3]Represents cumulative rainfall between 1 Jan. and the date of harvest.
[4]Represents cumulative rainfall between previous and current harvest dates.

a single digest also formed the criterion in selecting them for evaluation in these wheatgrasses.

Materials and Methods

The experiment was conducted at the Texas Tech University Agricultural Research Laboratory (34°N 102°W, 993 m elevation), near Lubbock, on a Pullman clay loam (a fine, mixed thermic Torrertic Paleustoll) during 1985 and 1986 growing seasons. Jose tall, Luna pubescent, and Hycrest crested wheatgrasses were planted alone and in mixture with sainfoin during September 1984, in rows 0.38 m apart. Spring growth of each forage species was initially harvested (I) at 3 stages: early (E, vegetative to boot); medium (M, jointing to heading); and late (L, jointing to mature). Regrowth of each species was harvested in mid- to late-summer (R), and residue harvest of all species was made in December (W). See Table 1 for dates and phenologic stages of growth at which the species were harvested. The experimental design was a randomized complete block with 3 replications. Grasses, alone and in mixture with sainfoin, were assigned to whole plots; initial dates of spring harvest were assigned to sub-plots, and successive harvests for both

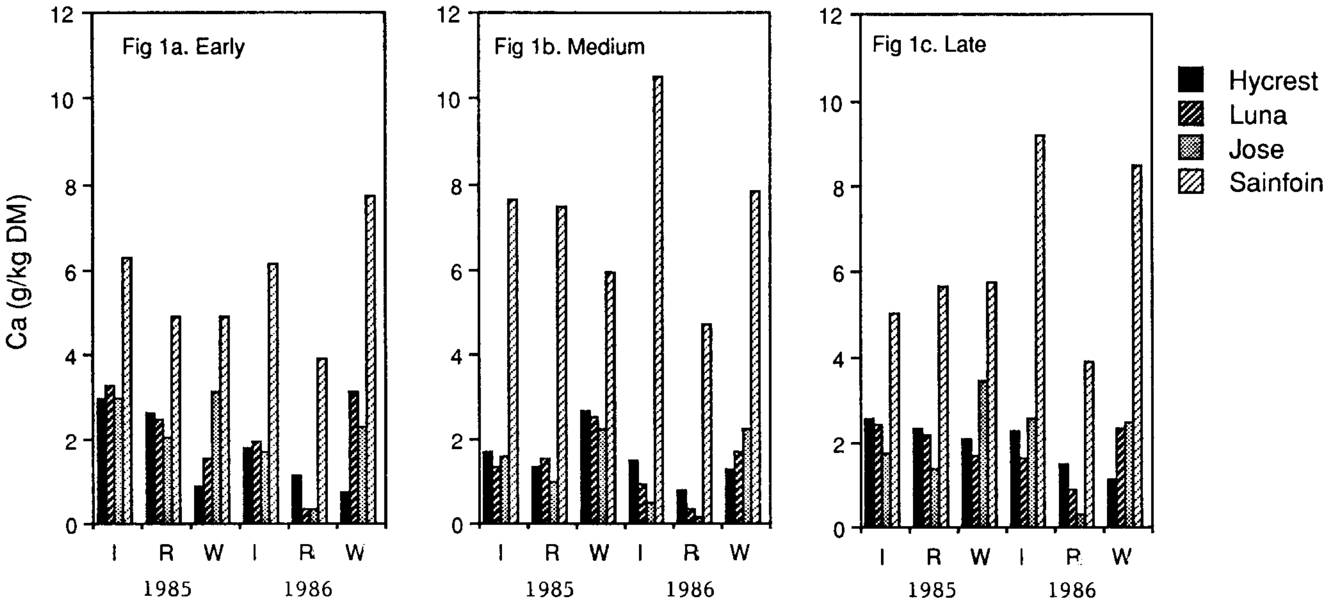

Fig. 1. *Calcium concentration in 3 wheatgrasses and sainfoin, measured under 3 cutting schedules, viz., early (Fig. 1a), medium (Fig. 1b), and late (Fig. 1c) with initial (I) spring growth, first regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

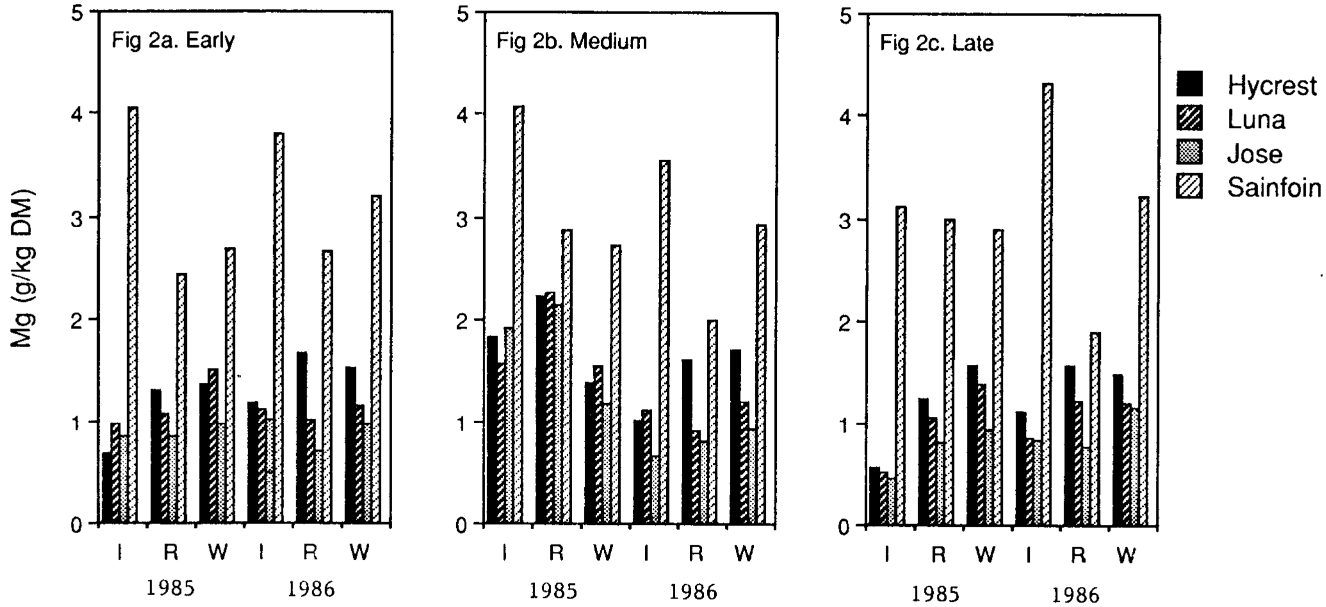

Fig. 2. *Magnesium concentration in 3 wheatgrasses and sainfoin, measured under 3 cutting schedules, viz., early (Fig. 2a), medium (Fig. 2b), and late (Fig. 2c) with initial (I) spring growth, first regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

years (i.e. initial, regrowth, and winter residue in 1985 and 1986) were assigned to sub-subplots (Steele and Torrie 1980). Plots were not irrigated during 1985, but due to a dry spring in 1986 (Table 1), they were irrigated on 6 April and 26 May with 8.7 and 7.9 cm, respectively. All plant nutrients, except N, were maintained throughout the study at soil levels recommended by the Texas Agricultural Experiment Station Soil Testing Laboratory, Lubbock, based on annual soil tests. No N was applied to any swards since N deficiency symptoms were not noticed and because an additional objective was to compare productivity of monocultures and mixtures without additional N. Weeds did not appear to compete significantly with the seeded species. Subplots were each 164 m^2 in size. Immediately following herbage sampling on 18 Dec. 1985, remaining plot areas were clipped to a 12-cm stubble height to remove fall growth.

At the time of the I and R harvests, phenological stages (PS) of grass species were evaluated on a scale of 1, 2, 3, 4, 5, and 6 indicating vegetative, jointing, boot, heading, anthesis, and mature stages, respectively. Since wheatgrasses were the main focus on this study, grasses in the monocultures and mixtures were coded. The PS of grasses in monocultures and mixtures were similar, therefore only the mean PS is shown in Table 1. Within each subplot in I and R harvests, herbage was clipped to a 1.5-cm stubble height within four 0.6 m^2 quadrats. Grass and legume components were separated in mixtures. In W harvests, grasses were sampled to a 10-cm stubble height by flail harvesting a 10.5-m long swath of paired rows in each subplot. Sainfoin was sampled to a 1.5-cm stubble height within two 0.3-m^2 quadrats per subplot in W harvests. The amount of dead tissue was negligible in all harvests. Plant material from all the 4 quadrats was bulked for each component in a subplot. Grab samples of approximately 0.25 kg fresh weight from each subplot were dried to constant weight at 60° C, ground in a shear mill to pass a 2-mm screen, reground in a cyclone mill to pass a 1-mm screen, and stored at 4° C in plastic bags. Forage samples were dry-ashed in porcelain crucibles at 600° C for 2 hr, then solubilized in hot 2N HCl. Final solutions contained 1% La, added as La_2O_3, to remove any anionic interferences.

Preliminary analysis showed no differences in the mineral concentrations of sainfoin among the 3 mixtures. Since Jose is increasingly being grown on the Southern High Plains, subsequent mineral analysis was done only on sainfoin grown with Jose.

Samples were analyzed for Ca, Mg, K, Cu, and Zn using an atomic absorption spectrophotometer (Perkin-Elmer, Model 560, Norwalk, CT)[1] using an air-acetylene flame. The 3 macronutrients (Ca, Mg, and K) were expressed as g/kg of dry matter (DM) and the cation ratio K/(Ca+Mg) was calculated on a milliequivalent basis. Micronutrients (Cu and Zn) were expressed as mg/kg of DM.

On the Southern High Plains, beef cattle are the ruminant livestock most commonly produced. Therefore, the concentrations observed in the wheatgrasses will be evaluated for beef cattle nutrition, assuming that daily feed intake is satisfactory.

Information on dates of herbage sampling, phenological stages of grasses in monocultures, cumulative rainfall (between 1 Jan. and the date of harvest for I, and between previous and current harvest dates for R and W) is provided in Table 1.

Results and Discussion

The concentrations of minerals and the cation ratio in the grasses grown alone and in mixture were not significantly ($P \leq 0.05$) different. Therefore, the average concentrations of each grass grown in monoculture and in mixture are presented.

The Ca content of 3 wheatgrass species and sainfoin are presented in Figure 1. All wheatgrasses exceeded the Ca concentration of 3.1 g/kg recommended for beef cattle (NRC 1984) only in I harvest at early date of initial harvest in 1985. Sainfoin had higher Ca concentration than the grasses at all times of initial spring harvest. The lower concentration of Ca in Hycrest relative to other grasses may have been due to its more advanced maturity (Table 1).

The concentration of Mg in sainfoin was higher than in the grasses in both years at all times of harvests (Fig. 2). The Mg level was higher than the recommended daily requirements of 1 g/kg for beef cattle (NRC 1984) in Hycrest and Luna wheatgrasses in all harvests, except in I of early and late initial spring harvests during 1985. Though Hycrest was more mature than Jose (Table 1) at all times of initial spring harvest during 1986, Hycrest had higher Mg

[1]Use of a company name is for production information only and does not imply approval or recommendation of the product to the exclusion of others.

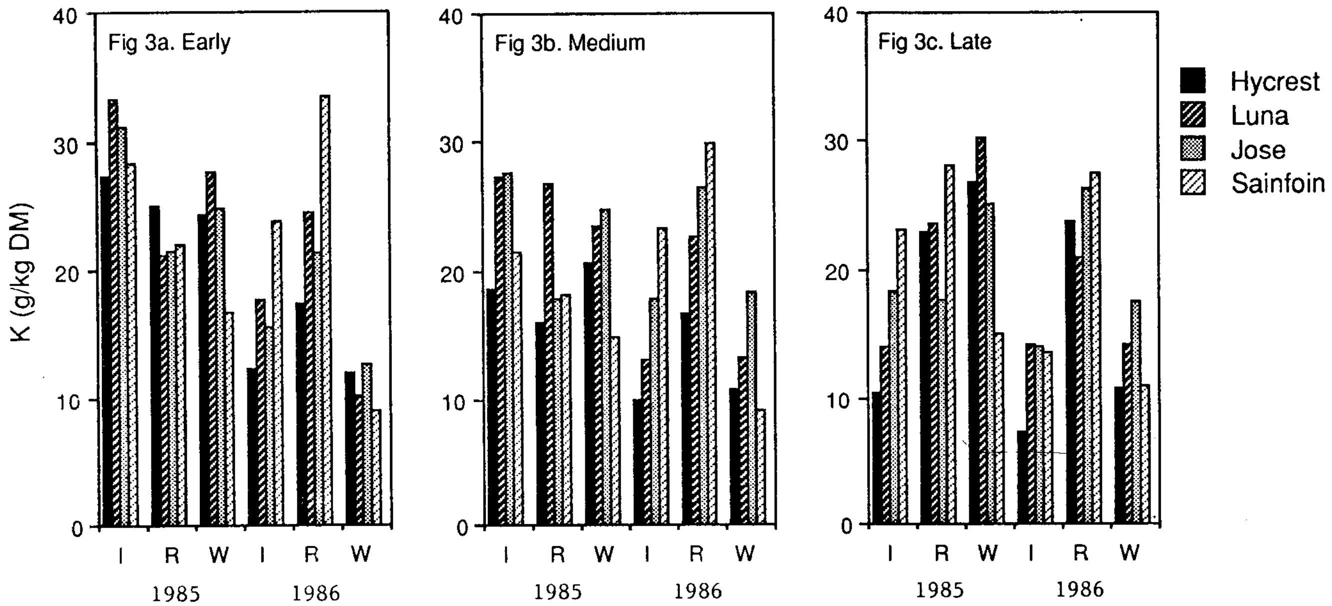

Fig. 3. *Potassium concentration in 3 wheatgrasses and sainfoin, measured under 3 cutting schedules, viz., early (Fig. 2a), medium (Fig. 2b), and late (Fig. 2c) with initial (I) spring growth, first regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

concentration than Jose. Luna exceeded Jose in all the harvests, except in I for the medium date of initial harvest during 1985.

All species had higher K concentration than the recommended daily requirement (6.5 g/kg) for beef cattle (NRC 1984). In both years, Hycrest had lower K concentration than Luna in 4 out of 6 harvests at early (Fig. 3a), all harvests at medium (Fig. 3b), and 5 out of 6 harvests at late (Fig. 3c) times of initial spring harvest. Jose had higher K concentration than sainfoin in I at early and medium times of initial spring harvest during 1985, and W at all times of initial spring harvest during both years. The herbage yields of Jose were higher than for other wheatgrasses, since it was harvested at a later date than other grass species (Table 1). However, Jose has a lower leaf:stem ratio than other grasses, leading to lower consumption of Jose, and therefore is less palatable to ruminant livestock.

Hycrest generally had higher Cu concentration than the other 2 grasses in each cutting at all times of initial spring harvest (Fig. 4). All 3 grasses exceeded the recommended daily requirement (8 mg/kg) of Cu for beef cattle (NRC 1984) only in I at the early time of initial spring harvest during 1985. Sainfoin had higher Cu concentration than grasses in R and W for early and I for medium in both years; and I and R for the late harvest in 1986. Jose had higher Cu concentration than Luna in I and W at all 3 times of initial spring harvest during 1986. The Cu concentrations found in this study were higher than those reported by Blincoe and Lambert (1972). The disparity between these 2 results may be due to differences in species used, cultural practices or nutrient status of the soils.

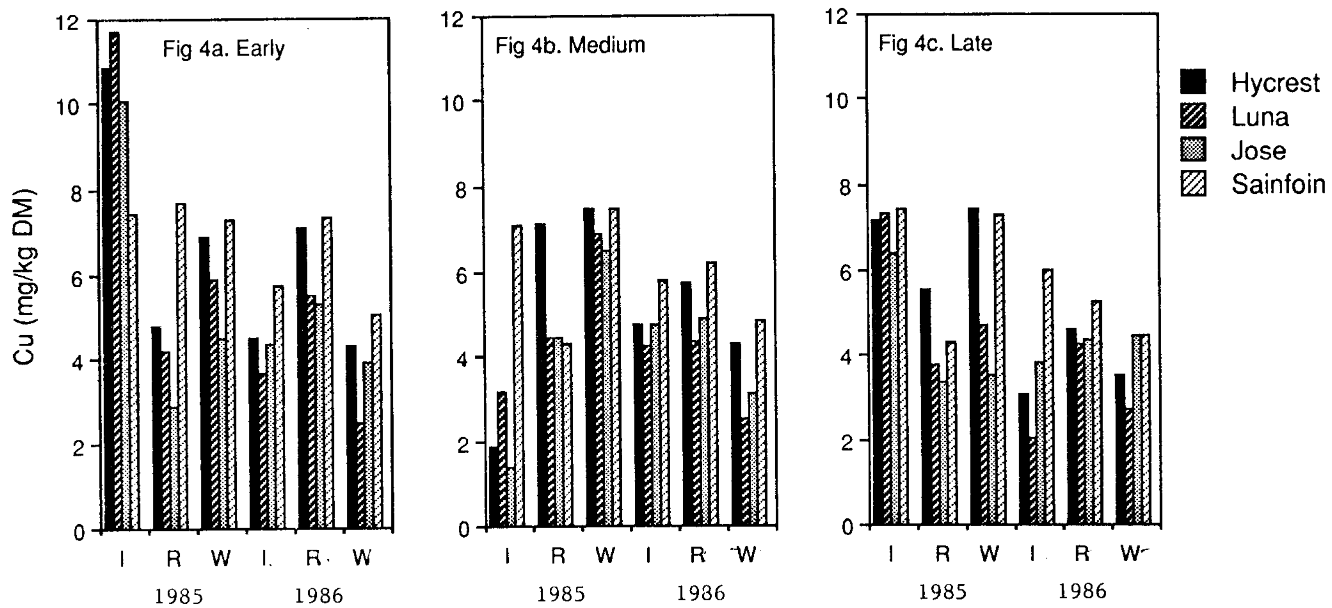

Fig. 4. *Copper concentrations in 3 wheatgrasses and sainfoin, measured under 3 cutting schedules, viz., early (Fig. 4a), medium (Fig. 4b), and late (Fig. 4c) with initial (I) spring growth, first regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

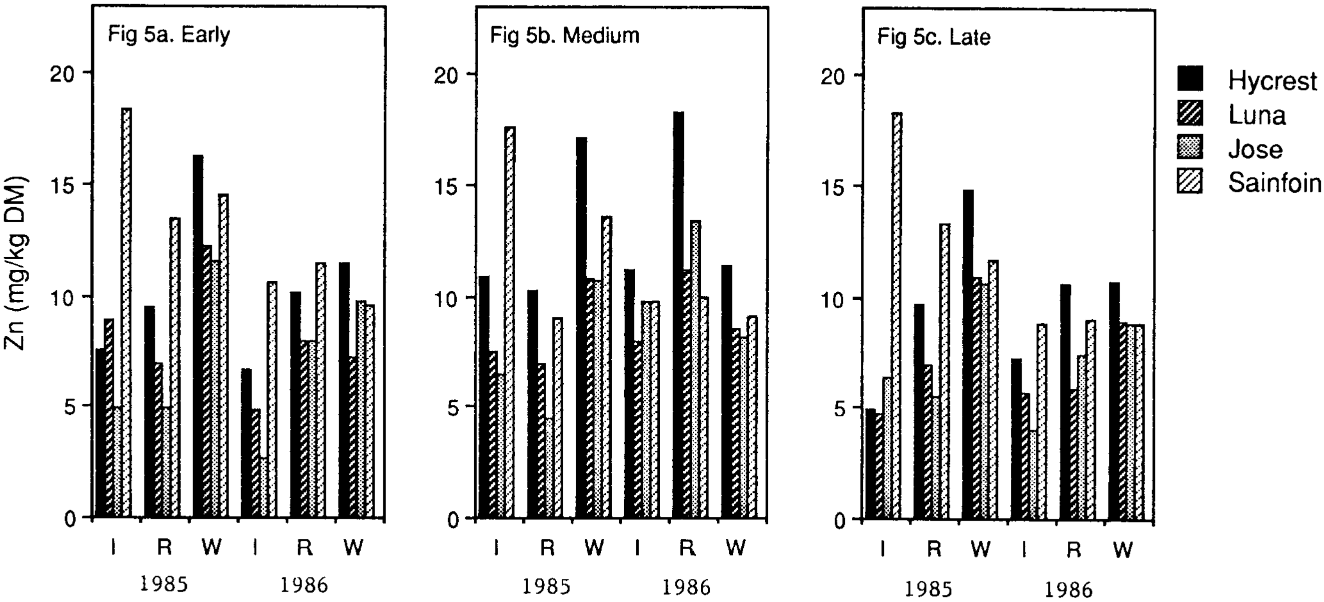

Fig. 5. *Zinc concentration in 3 wheatgrasses and sainfoin, measured under 3 cutting schedules, viz., early (Fig. 5a), medium (Fig. 5b), and late (Fig. 5c) with initial (I) spring growth, regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

All species had Zn concentrations below the recommended daily requirement of 30 mg/kg by the NRC (1984) for beef cattle (Fig. 5). Generally, Hycrest and sainfoin had higher Zn concentration than Luna or Jose wheatgrasses. In each year, Zn concentration reached a peak in all grasses in W, except for the medium time of initial spring harvest in 1986 (Fig. 5b). Earlier reports (Murray 1984, Murray et al. 1978) indicated a decreasing trend with advance in season. However, a significant regrowth noticed in W harvest during both years (not shown) may have resulted in increased accumulation of Zn. Compared to the grasses, sainfoin had more than twice the concentration of Zn in I of 1985 for each clipping date and differences were less in R and W harvests. In 1985, Luna had higher Zn concentration than Jose, while in 1986, the reverse was observed in W for early, I for medium, and R for late times of initial spring harvest.

Except for the W harvest in 1986, means of K/(Ca+Mg) ratio exceeded the critical 2.2 level (Kemp and t'Hart 1957) in Luna and Jose species at all times of initial spring harvest in both years (Fig. 6). However, the ratio was close to the critical level in Hycrest and sainfoin in I of each cutting within time. The ratio in all species in W at all 3 times of initial spring harvest during 1986 was less than the critical level. This finding is of interest because of earlier reports that indicate grass tetany may result from grazing forage in the cooler temperatures (Kemp and t'Hart 1957, Mayland and Grunes 1974). The R harvest of 1986 had higher ratio means than other harvests. This higher ratio may have been due to the irrigation

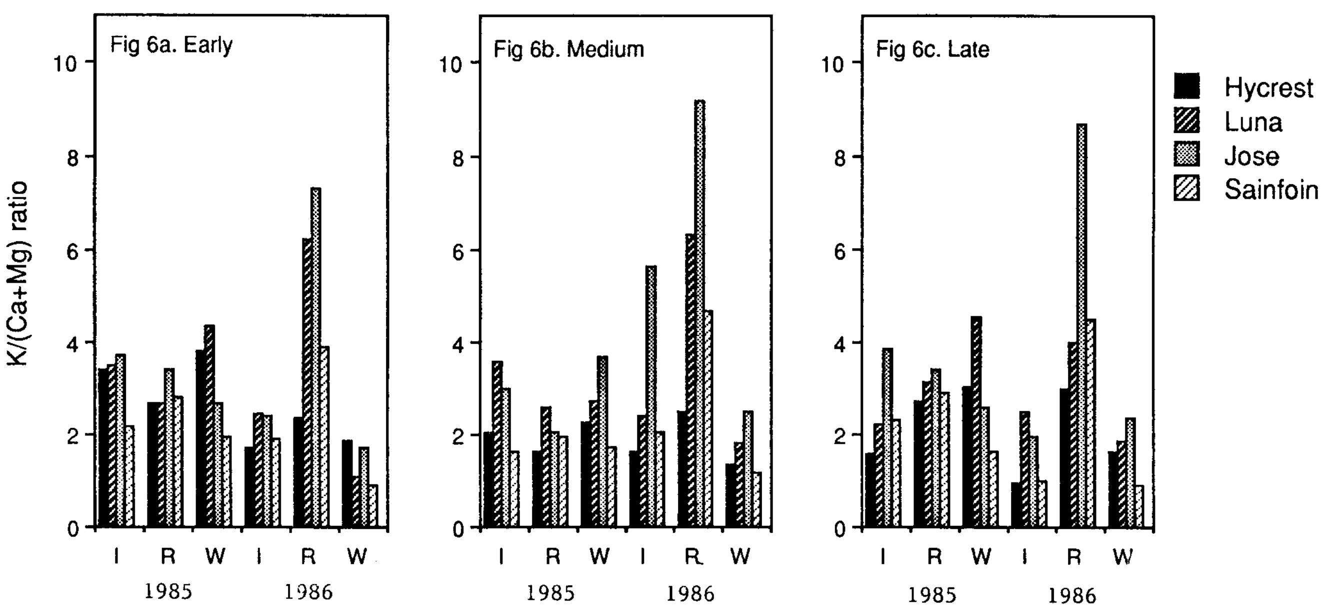

Fig. 6. *The K/(Ca+Mg) ratio (meq. basis) of 3 wheatgrasses and sainfoin, evaluated under 3 cutting schedules, viz., early (Fig. 6a), medium (Fig. 6b), and late (Fig. 6c) with initial (I) spring growth, first regrowth (R), and winter (W) residue harvests during 1985 and 1986.*

water applied (7.9 cm on 26 May 1986) leading to the higher uptake of K than Ca and/or Mg.

Species × initial spring harvest × subsequent harvests during the year interactions indicated that a particular species is not consistently superior or inferior to others in mineral concentrations. Since the species differed in time of growth and maturity (Table 1), it is not surprising that significant species interactions with times of initial spring harvest and subsequent harvests during the year were observed. The experimental site had been irrigated previous to this experiment, thus soil water content at the start of the growing season may have been higher in 1985 than in 1986. The significant ($P \leq 0.05$) interactions indicate that mineral concentrations in these species vary with stage of growth, date of sampling, and years. Therefore, more than one sampling per season is needed to adequately evaluate the mineral status of different forages.

Table 2. Average concentrations of Ca, Mg, K, Cu, Zn, and the K/(Ca+Mg) ratio in 3 wheatgrasses and sainfoin, and the minimum recommended values for beef cattle.

Species	Ca	Mg	K	Cu	Zn	K/(Ca+Mg)
	(g/kg DM)			(mg/kg DM)		(meq/meq)
Hycrest	1.80	1.40	19.1	5.59	11.11	2.49
Luna	1.80	1.20	21.6	4.80	8.40	3.17
Jose	1.70	1.10	21.6	4.69	7.94	3.97
L.S.D. (0.05)	0.03	0.01	0.16	0.24	0.90	0.25
Sainfoin	6.50	3.10	20.5	6.17	12.09	1.01
Recommended for beef cattel#	3.10	1.00	6.50	8.00	30.00	2.20

#NRC 1984

Knowing the variability in average concentration of minerals in these species over season may be helpful in management decisions. The means of grass species differed significantly ($P \leq 0.05$) for all the minerals and the cation ratio (Table 2) when pooled over all harvests. All 3 grasses had lower levels of Ca, Cu, and Zn, and much higher K levels and cation ratios than those recommended for a balanced beef cattle diet. Among grasses, Hycrest yielded 24% more Mg and 12% less K than Jose, resulting in a 37% lower cation ratio in Hycrest. Copper and Zn concentrations were also lower in Jose by 16 and 29% than Hycrest, respectively. The lower K and cation ratio in Hycrest indicates that Hycrest may be a better source of minerals for ruminant livestock than Jose. Compared to Jose, Luna had intermediate values of Mg and the cation ratio, and similar concentrations of Ca, K, Cu, and Zn. Since the K/(Ca+Mg) ratio was higher in Jose than either Hycrest or Luna, cattle consuming Jose herbage would have the greatest risk of contracting grass tetany. However, reduced availability of forage Mg to the grazing animal may be only 1 of the several factors (Mayland 1986) influencing the occurrence of grass tetany. Sainfoin had about 72, 54, 9, and 8% higher Ca, Mg, Cu, and Zn, respectively, and 5% lower K than Hycrest; consequently, sainfoin had 59% lower K/(Ca+Mg) ratio than Hycrest (Table 1). Furthermore, sainfoin had 2 times more Ca, and less than half the K/(Ca+Mg) ratio than the recommended values for beef cattle (NRC 1984). Sainfoin and Hycrest, when fed together, may improve the general health, fertility and reproduction of livestock, because of higher concentration of Cu and Zn in these 2 species than in Jose or Luna (McMurray 1980, Hidiroglou and Knipfel 1984).

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 sainfoin (Table 3). This indicates that breeding for higher Ca or Mg concentration may lead to lower concentration of K. In support of this conclusion, Currier et al. (1986) have reported that genotypes of 2 cool-season grasses, viz., tall fescue (*Festuca arundinacea* Schreb.) and orchardgrass (*Dactylis glomerata* L.), selected for high Ca and Mg produced progenies with high Ca and Mg concentrations and low K/(Ca+Mg) ratios. However, it is important to note that weather, soil, and water may influence chemical ratios which in turn may cause hypomagnesemia (Mayland 1986). Independent selection for Ca and Mg is suggested since the correlation between these elements was nonsignificant in grasses. However, the association between Ca and Mg was positive in sainfoin, indicating that the selection for either one of these elements may result in decreased K concentration. Because of the positive correlation between Mg and Zn, selection for increased Mg concentration in grasses may lead to higher Zn concentration. Breeding for Cu may lead to increased K concentration in grasses while it results in increased Zn concentra-

Table 3. Estimates of simple linear correlations among mineral concentrations and the K/(Ca+Mg) ratio of early, medium and late times of initial harvest for the 3 grasses grown in 2 years (n=108) above the diagonal and for sainfoin grown with Jose wheatgrass (n=24) below the diagonal.

Mineral	Time of initial spring harvest	Ca	Mg	K	Cu	Zn	K/(Ca+Mg)
		r					
Ca	Early		–0.15	0.26**	0.31**	–0.17	–0.55**
	Medium		0.25*	–0.04	–0.04	–0.15	–0.62**
	Late		0.02	–0.15	0.13	–0.07	–0.63**
Mg	Early	0.69**		–0.23*	–0.10	0.55**	–0.32**
	Medium	0.48*		–0.20*	–0.10	–0.33**	–0.55**
	Late	0.83**		–0.42**	–0.12	0.80**	–0.47**
K	Early	–0.27	0.23		0.69**	0.17	0.49**
	Medium	–0.28	–0.13		–0.03	–0.01	0.48**
	Late	–0.64*	–0.46*		0.24*	0.55**	0.66**
Cu	Early	–0.50*	–0.26	0.33		0.18	0.20*
	Medium	–0.24	0.20	0.16		0.34**	0.09
	Late	–0.22	0.12	–0.09		–0.07	0.09
Zn	Early	–0.46*	–0.07	0.26	0.66**		0.08
	Medium	–0.09	0.58*	0.05	0.71**		0.27*
	Late	–0.35	0.05	0.41	0.51*		0.16
K/(Ca+Mg)	Early	–0.81**	–0.44**	0.69**	0.46*	0.38	
	Medium	–0.65**	–0.54*	0.84**	0.16	–0.10	
	Late	–0.83**	–0.76**	0.88**	–0.13	0.17	

*,**Significantly different from zero at the 0.05 and 0.01 probability levels, respectively.

tion in sainfoin.

In conclusion, among the grass species studied, Hycrest generally had a mineral profile more in balance with beef cattle requirements than that for Jose or Luna. Since there is a potential for selecting increased concentrations of Ca and Mg to reduce the cation ratio (Currier et al. 1986), screening for higher concentrations of Ca and Mg in a large number of genotypes within a species is suggested. Significant species × initial spring harvest × subsequent harvests during the year interactions demonstrated that breeding for altered mineral concentrations will require evaluation in several environments. Sainfoin, when compared to Hycrest, had higher concentrations of Ca, Mg, Cu, and Zn and a much lower K/(Ca+Mg) ratio. The higher concentrations of Cu and Zn in sainfoin and Hycrest than in the other species suggests that sainfoin, fed alone or in combination with Hycrest, would provide a more desirable mineral balance for cattle than feeding any of the grasses alone. In addition to screening for higher or lower concentration of minerals and ratios, other characteristics such as leafiness (Kidambi et al. 1988, unpublished data) and early maturity should be considered for improving the nutritional status of forages.

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