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Influence of species, cultivar and cut on the microelement content of grass forages

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ABSTRACT

A study was undertaken to determine the influence of species, cultivar, cut and year on the mineral content of forages as related to the requirements of lactating dairy cows. Four species of grass forages represented by nine cultivars were sown in a randomized block designed trial replicated four times. The test included: meadow fescue (MF) - Festuca pratensis (pratense), cultivars #920, #930 and Ensign; orchardgrass (cocksfoot) (OR) - Dactylis glomerata L., cultivars Arctic and Sumas; perennial ryegrass (PR) - Lolium perenne L. cultivar Norlea and tall fescue (TF) - Festuca arundinacea, cultivars Courteney, Barcel and Fawn. The plots were harvested four times in each of two years. Yields were measured for each plot and harvest time and samples were obtained for the determination of dry matter (DM), crude protein (CP) acid detergent fibre (ADF) and microelements: Fe, Mn, Zn and Cu. The TF cultivars tended to out yield the cultivars of other species with Courteney (TF) being higher in DM yield ($P \leq 0.05$) than Ensign (MF), Arctic (OG) and Norlea (PR). There were also differences in mineral content among individual cultivars. First cut forages had the lowest content ($P \leq 0.05$) of all microelements measured except Zn when compared to third and fourth cut forages. In terms of a lactating cow's requirements, the Zn and Cu content of these forages were consistently deficient. It was concluded from the results of this study that the species, cultivar, year and/or cut of forage can impact on microelement content sufficiently to warrant consideration when formulating diets for beef cattle and lactating cow.

Keywords: grass forage, microelements, iron, manganese, zinc, copper, grass species, cultivar

INTRODUCTION

Grass forages are an important source of minerals in the diet of ruminants. In the case of grazing ruminants they may be the only source of both macro and micro elements available to meet the animal's requirements. However, variability in the mineral content of forages has been shown to be high (Adams, 1975; Gralak et al., 1996; Thompson and Warren, 1995). Fisher and Bates (1993) have observed wide variations within the south coastal region of British Columbia in the content of specific minerals in a given class of forages. It, therefore, becomes impractical to use tabular values (NRC, 1989) to predict the mineral intake of ruminants on forage diets or to assist in formulating supplements for grazing ruminants.

The influence of soil and plant factors on the mineral content of forages has been reviewed, (Fleming, 1973; Ried and Horwath, 1980). Soil fertility and its physical characteristics have a major impact on the uptake of minerals by forage crops (Ried and Horvath, 1980). It has also been recognized that stage of maturity and growing conditions (Fleming and Murphy, 1968) influence the mineral content of grass forages. Evidence has also been presented (Tait et al., 1995) that there can be nutritionally significant differences in mineral content among species grown under the same conditions. Similarly, Gralak et al., (1996) observed that cultivars within a species had appreciably different contents of macroelements. However, the importance of species, cultivar and cut (season of growth) in determining the content of nutritionally important minerals in forages does not appear to have been studied extensively. The following study was undertaken with the objective of measuring the differences in mineral content of several species of forage crops grown under similar conditions of fertility and to evaluate these differences in terms of the specific mineral requirements for beef cattle as well as for lactating dairy cows.

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MATERIALS AND METHODS

The forage variety trial which consisted of an establishment year and two test years was located at the Agriculture and Agri-Food Canada's Pacific Agriculture Research Centre, Agassiz, B.C. Canada at 49°N lattitude and 122°W longitude. Four species of grass forages represented by nine cultivars were sown in a randomized block designed trial replicated four times. Individual plots were 1.2 m by 6.1 m and sited on a well drained sandy loam soil. The plot area was fertilized once and clipped twice during the year of establishement. The test included: meadow fescue (MF) - Festuca pratensis (pratense), cultivars #920, #930 and Ensign; orchardgrass (cocksfoot) (OR) - Dactylis glomerata L., cultivars Arctic and Sumas; perennial ryegrass (PR) - Lolium perenne L. cultivar Norlea and tall fescue (TF) - Festuca arundinacea, cultivars Courteney, Barcel and Fawn. The schedule of fertilizer and herbicide applications and harvest dates for the two test years are described in Table 1.

Table 1: Schedule of harvesting and fertiliser treatments for two test years

Date	Harvest/Treatment	Fertiliser application rate (kg.ha^{-1})		
		N	P	K
Year 1				
April 4		84	22	90
April 24	Herbicide 2, 4-D Mecoprop			
May 24	First cut			
May 28		84	56	56
July 9	Second cut			
July 11		84	56	56
Aug 21	Third cut			
Aug 22		84	56	56
Sept 27	Fourth cut			
Oct 18				
Year 2		-	-	168
Mar 13	Limestone 2.24 (t.ha^{-1})	84	21	45
April 15		84	56	56
April 30	Herbicide 2, 4-D Mecoprop			
May 16	First cut			
May 21		84	56	56
June 26	Second cut	84	56	56
Aug 14	Third cut			
Aug 15		84	56	56
Sept 22	Fourth cut			

At each harvest, yields from each plot were measured and a sample obtained for the estimation of DM determined using a forced air drying oven (Blue M, General Science 5501 4th Ave. S., Seattle WA, 98108) at 60°C for 48 h or until weight was constant. The dried samples were ground through a 1 mm screen using a Thomas Wiley Laboratory Mill (Authur H. Thomas & Co., Philadelphia, PA), the nitrogen content of the samples was determined by the Tecator Nitrogen Analyzer System (Tecator AB B0x 70 S-263-01 Hoganas, Sweden) and the acid detergent fibre (ADF) content estimated by the method of Van Soest et al. (1991). The mineral content of the samples was determined using inductively coupled plasma emission spectrometry (NIR ICP 3400).

Analyses of variance of nested effects (cultivar in species) using the GLM procedure (SAS, 1987) with the significant difference between means estimated by the PDIFF option was used. The mineral status of the forages was compared on the basis of concentration and yield of specific elements per ha. Variations in mineral content due to species, cultivar, cut and year were identified.

RESULTS

The total yield of forage DM averaged 1.8 kg*ha^{-1}, less in the second year due to lower precipitation. However, there was no effect of year on the crude protein (CP) or ADF content ($P > 0.05$) of the various forages therefore to compare relative yields and nutrient content among cultivars, data for the two years has been pooled and is presented in Table 2. The cultivars of TF tended to out yield the cultivars of other species in the test with Courteney (TF) being higher in yield than Ensign (MF), Arctic (OG) and Norlea (PR) ($P \leq 0.05$). In this test Norlea (PR) had a lower yield of DM than all other cultivars except Ensign (MF) and Arctic (OG) (Table 2). Moreover, Norlea (PR) had a lower ($P \leq 0.05$) ADF content and a higher CP content ($P \leq 0.05$) than all other cultivars except Ensign (MF) with respect to CP content. The three cultivars of TF were all lower in CP content ($P \leq 0.05$) than all other cultivars. Within the species Courtney (TF) was greater in CP ($P \leq 0.05$) than either Barcel or Fawn (TF) (Table 2).

The microelement content of the forage grasses grown in this trial is presented in Table 3. The Fe content was highest in perennial ryegrass (PR), followed by meadow fescue (MF) and tall fescue (TF) with orchardgrass (OG) being the lowest ($P \leq 0.05$) in Fe content (Table 3). The Zn content was greatest ($P \leq 0.05$) in PR, least in TF and intermediate in OG and MF. The level of Cu in the forages was not influenced by species ($P>0.05$) while Mn content was lower ($P \leq 0.05$) in MF than in the other three species.

Table 2: Effect of cultivar on yield, acid detergent fibre (ADF), and crude protein (CP) content of grass forages (average of both test years)

Species	Cultivar	n	Yield (tonne.ha-1)	ADF (% of DM)	CP (% of DM)
Meadow Fescue	#920	32	9.78ab	31.8b	16.6c
	#930	32	9.28ab	31.5b	16.6c
	Ensign	32	7.90bc	32.3ab	18.2ab
Orchard grass	Arctic	32	8.47bc	31.6b	17.8b
	Sumas	32	9.82ab	33.5a	16.5c
Perennial Ryegrass	Norlea	32	7.29c	29.3c	18.9a
Tall Fescue	Courtnenay	32	11.16a	31.7b	15.7d
	Barcel	32	10.96ab	32.0b	14.1e
	Fawn	32	10.12ab	31.9b	14.6e
SEM1		288	±0.78	±0.40	±0.26

[a-e] Means within columns with a different superscript differ significantly; at $P \leq 0.05$; [1] SEM - pooled standard error of the mean.

Table 3: Effect of species, cultivar, cut and year on microelement content in grass forage

Item	(mg.kg-1 DM) Fe	Mn	Zn	Cu
Species				
Meadow Fescue (MF)	132b	84b	15.5b	7.5
Orchard grass (OG)	104d	114a	16.7b	8.6
Perennial Ryegrass (PR)	151a	119a	19.9a	8.9
Tall Fescue (TF)	118c	115a	13.6c	6.9
SEM1	±6.1	±5.8	±0.58	±0.30
Cultivar				
(MF) #920	126abc	78c	14.8c	7.5ab
(MF) #930	140ab	85bc	15.0c	7.4ab
(MF) Ensign	130abc	90bc	16.6bc	7.6ab
(OG) Arctic	98cd	129a	18.1ab	9.0a
(OG) Sumas	110cd	99b	15.3c	8.1ab
(PR) Norlea	151a	119a	19.9a	8.9a
(TF) Courtenay	107cd	104ab	12.5d	6.9b
(TF) Barcel	121bcd	115ab	13.5cd	6.7b
(TF) Fawn	125abc	124a	14.5c	7.1ab
SEM1	±9	±8	±0.8	±0.4
Cut				
1st	93c	59d	13.3c	5.2d
2nd	121b	84c	12.6c	7.4c
3rd	155a	156a	17.5b	9.0b
4th	135b	133b	22.2a	10.2a
SEM1	±5.2	±2.4	±0.23	±0.12
Year				
Year One	112b	125a	15.0b	7.3a
Year Two	140a	91b	17.8a	8.6a
SEM1	±2.4	±2.4	±0.34	±0.22

[a-d] Species, cultivar, cut or year means within columns followed by the same superscript do not differ significantly at $P \leq 0.05$
[1] SEM - pooled standard error of the mean.

The trace mineral content of the cultivars (Table 3) in general reflected the differences that were observed for species. However, in the case of Mn, cultivar Arctic OG had a higher Mn content ($P \leq 0.05$) than Sumas OG. The Zn content of Fawn TF was higher ($P \leq 0.05$) than the Zn content of the cultivar Courtenay TF. The average Mn content was lower ($P \leq 0.05$) in the second year (Table 3). In contrast, Fe and Zn contents of the forages were higher ($P \leq 0.05$) in the second year. The first cut forage generally had the lowest ($P \leq 0.05$) content of minerals whereas third and fourth cut forages were higher ($P \leq 0.05$) in Fe, Mn, Zn and Cu content.

The relationship between the mineral content of the forage, the yield and quality factors are presented in Table 4. The CP% was negatively related to both yield of forage and the ADF% ($P \leq 0.01$). The contents of Zn and Cu were the most positively related to CP% ($P \leq 0.01$). The yields of all the minerals were negatively related to yield of forage ($P \leq 0.01$) (Table 4). The contents of Zn, Mn and Cu were positively related to each other ($P \leq 0.001$).

Table 4: Correlation coefficients between the microelement content, ADF, CP and TDN in grass forages

	ADF (%)	CP (%)	TDN (%)	YD ($t.ha^{-1}$)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
ADF (%)	-	-0.37***	-0.99***	0.47***	0.11	0.23**	-0.13	0.22**
CP (%)		-	0.36***	-0.77***	0.22***	0.14*	0.83***	0.67***
TDN (%)			-	-0.45***	-0.11	-0.23**	0.13	-0.22**
YD (t*ha-1)				-	-0.36***	-0.38***	-0.69***	-0.56***
Fe (ppm)					-	0.24***	0.28***	-0.07
Mn (ppm)						-	0.37***	0.48***
Zn (ppm)							-	0.71***
Cu (ppm)								-

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; ADF - acid detergent fibre; CP - crude protein; TDN - total digestible nutrients; YD - yield per year

DISCUSSION

The species and cultivars of forage grasses available to diary farmers are constantly changing with the primary justification being higher yields and greater persistency. The results of this study indicate that when new selections are made mineral content should be monitored to ensure that inadequacy of imbalances of minerals are not being introduced into the diet (Adams, 1975) by the planting of a new species or a new cultivar of the same species.

In this study there were differences between species in yield and standard quality factors. The PR cultivar Norlea had a lower yield but higher CP content than the three TF cultivars with the OG and MF cultivars being intermediate. Since increase in yield has been one of the factors influencing the wider use of TF cultivars by dairy farmers it is also of interest to determine if growing TF has a negative or positive influence on the amount of specific minerals provided.

Iron content of the forage was also influenced by species but not to the degree previously observed (Fisher and Bates, 1993). Even though iron was in excess, its level in grass forage would not likely have been to the degree that would approximate to maximum tolerance level (1000 ppm) estimated for cattle (NRC, 1980). Content of Cu was generally low in all the forages, relative to the needs of dairy cow (NRC, 1989). Moreover utilisation of copper is sensitive to inhibition by consumed iron and other antagonists reviewed by Lee et al. (1999). The Mn content of the MF cultivars was below that of the other cultivars tested but was still at a level sufficient to meet the requirements for a lactating dairy cow (NRC, 1989). However, Zn levels were low in all species particularly in the TF cultivars relative to requirements.

The only modification of the fertility program for the second year was the application of lime. This resulted in a decrease in the Mn content of the forages, an observation supported by previous studies (Hemingway, 1962).

Previous studies have observed seasonal variations for chemical composition of forage crops (Fleming and Murphy, 1968; Gralak et al., 1996) and in pasture (Metson and Saunders, 1978; Thompson and Warren, 1979; Popp et al., 1999). Seasonal differences in mineral content reflect different growing conditions associated with season such as changes in day length, heat stress or moisture stress. The levels of Mn and Cu also increased with cutting date which may have been partially attributable to the lower yields associated with the later cutting dates (Fleming and Murphy, 1968; Thompson and Warren, 1979). Iron content was lower in first cut forages possibly due to higher DM yields or less soil contamination (Metson and Saunders, 1978). In this study there were fairly strong negative correlation between yield and mineral content for all microelements. In previous study we have stated a strong negative correlation between yield and macroelement content for Ca, P, and K (Gralak et.al., 1996). The protein content of the forage was very positively related to Zn and Cu content like in previous studies (Fleming and Murphy, 1968; Fisher and Bates, 1986).

It may be concluded from the results of this study that differences in microelement content of practical nutritional significance can occur with the selection of different species or even a different cultivar within a species. There was also an influence of cut on the levels of Cu, Mn and Zn which were of nutritional significance. Major changes in the relationship between Fe and Cu intake may occur with subsequent impact on availability of Cu to the animal. Therefore, when analyzing forages for quality factors, analyses should also include micro minerals so that appropriate supplements may be formulated.

REFERENCES

ADAMS, R. S. 1975. Variability in mineral and trace mineral content of dairy feeds. In: *J. Dairy Sci.,* Vol. 58, 1975, p. 1538-1548.

FISHER, L. J. – BATES, D. L. 1986. The relationship between mineral elements and quality factors in forages. In: *Can. J. Anim. Sci.,* Vol. 66, 1986, p. 1198 (Abst.).

FISHER, L. J. – BATES, D. L. 1993. Thirteen years of forage - are we better? In: *Proc BCMAFF Dairy Short Course*, Abbotsford: B.C. Canada, 1993, p. 59-64.

FLEMING, G. A. 1973. Mineral composition of herbage. In: Butler, G.W. - Bailey, R.W. (Eds). *Chemistry and Biochemistry of Herbage.* New York: Academic Press, 1973, p. 529-566.

FLEMING, G. A. – MURPHY, W. E. 1968. The uptake of some major and trace elements by grasses as affected by season and stage of maturity. In: *J. Brit. Grassl. Soc.,* 23, 1968, p. 174-185.

GRALAK, M. A. – BATES, D. L. – KEYSERLINGK, M. A. G. von – FISHER L. J. – SHELFORD, J. A. 1996. Influence of species, cultivar and cut on the mineral content of grasses. In: *Proceedings of American forageand grassland council.* Vancouver: B.C., 1996, 155-159.

HEMINGWAY, R. G. 1962. Copper, molybdenum, manganese and iron contents of herbage as influenced by fertilizer treatments over a three-year period. In: *J. Brit. Grassl. Soc.*, Vol. 17, 1962, p. 182-187.

LEE, J. – MASTERS, D. G. – WHITE, C. L. – GRACE, N. D. – JUDSON, G. J. 1999. Current issues in trace element nutrition of grazing livestock in Australia and New Zealand. In: *Aust. J. Agric. Res*., Vol. 50, 1999, p. 1341-1364.

METSON, A. J. – SAUNDERS, W. M. H. 1978. Seasonal variations in chemical composition of pasture. I. Calcium, magnesium, potassium, sodium, and phosphorus. In: *J. Agricultural Research,* Vol. 21, 1978, p. 341-353.

NATIONAL RESEARCH COUNCIL 1980. Mineral tolerance of domestic animals. National Research Council. National Academy Press, Washington, DC., 1980.

NATIONAL RESEARCH COUNCIL 1989. Nutrient requirements of dairy cattle. 7th rev. ed. National Research Council. Washington, DC: National Academy Press, 1989.

POPP, J. D. – MCCOUGHEY, W. P. – THOMAS, L. R. – COHEN, R. D. H. 1999. Nutrient selection by cattle from grass and grass/legume pastures. In: *Can. J. Anim. Sci.,* Vol. 79, 1999, p. 391-395.

RIED, R. L. – HORWATH, D. J. 1980. Soil chemistry and mineral problems in farm livestock. A Review. In: *Anim Feed Sci. Tech.,* Vol. 5, 1980, p. 95-167.

SAS Institute, Inc. 1987. SAS/STAT Guide for Personal Computers. Version 6 Edition. SAS Institute Inc., Cary, NC, USA, 1987.

THOMPSON, J. K. – WARREN, R. W. 1979. Variations in composition of pastures herbage. In: *Grass Forage Sci.*, Vol. 34, 1979, p. 83-88.

TAIT, R. M. – HANSON, K. – FISHER, L. J. 1995. The response of perennial ryegrass, cocksfoot and tall fescue to sodium fertilization. In: *Proc. of Brit. Grassl. Soc.*, 1995, p. 284-285.

VAN SOEST, P. J. – ROBERTSON, J. B. – LEWIS, B. A. 1991. Methods for dietary fibre, NDF and nonstarch polysaccharides in relation to animal nutrition. In: *J. Dairy Sci*. Vol. 74, 1991, p. 3583-3597.

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