Concentrations of micro-nutrients in forage legumes and grasses harvested at different sites

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Abstract

Forage is a major source of micronutrients for dairy cows. This study examined the concentrations of micronutrients in birdsfoot trefoil (Bf), red clover (Rc), timothy (Ti) and meadow fescue (Mf) at different sites, years and cutting dates. Mixtures of Bf+Ti, Rc+Ti and Rc+Mf were established at Skara (58°21'N; 13°08'E) and Umeå (63°45'N; 20°17'E) in Sweden. First-year leys (Umeå 2005, Skara 2005 and 2007) were cut on three occasions in spring relative to the maturity stage of timothy: one week before heading, at heading and one week after heading. Summer growth was cut six weeks after each of the three occasions in spring growth. The results show that there was a need for Cu supplementation in all treatments because of low Cu concentration. The relatively high Mo concentrations compared to the Cu concentration in both grasses at Skara, in Mf in second cut at Umeå, and in Bt in the second cut at Skara may further increase the demand for Cu supplementation in dairy cow rations because there is a risk that Cu can be bound to a sulphate-Mo-complex in the rumen. The Zn concentration was lower than required for dairy cows, except for the mixture with Ti and Rc in the second cut at Umeå. For Mn and Fe, concentration levels were appropriate for expected dairy cow requirements for all treatments.

Keywords: forages, grass, harvest time, legumes, micronutrients

Introduction

Micronutrients are important for health and production in dairy cattle systems (Suttle, 2010). Forage is a major source of micronutrients for dairy cows (Whitehead, 2000). The concentrations can be affected by different factors such as soil properties, especially pH (Lindström *et al.*, 2014), and harvest time and species (Høgh-Jensen and Søegaard, 2012). Despite the importance of micronutrients, it has not been common in practice to analyse their concentrations in forages. However, reduced costs for analysis and the objective of more sustainable production have increased interest in analysis, with the aim of reducing supplementation in cattle rations.

Materials and methods

Three field experiment was carried out at two sites in Sweden: (1) Lanna Research Station (58°21′N; 13°08′E; altitude 75 m.a.s.l.; silty clay loam; 3% organic matter (OM); pH: 7.2 (field for 2005) and 6.7 (field for 2007) at Skara and (2) Röbäcksdalen Research Centre (63°45'N; 20°17'E; altitude 5 m.a.s.l.; silty loam; 6% OM; pH: 6.4) at Umeå. Three mixtures: birdsfoot trefoil (*Lotus corniculatus* L.) + timothy (*Phleum pratense* L.) (Bt+Ti), red clover (*Trifolium pratense* L.) + timothy (Rc+Ti) and red clover + meadow fescue (*Festuca pratensis* Huds.) (Rc+Mf) were harvested as first-year leys (Umeå 2005, Skara 2005, Skara 2007). The cultivars were Bt (cv. Oberhaunstaedter), Ti (cv. Grindstad), Mf (cv. Kasper) and Rc (4n) (cv. Sara at Skara; cv. Betty at Umeå). The aim was to harvest at three different stages of maturity in the spring growth of timothy: one week before expected heading, at heading and one week after heading of timothy (Gustavsson, 2011). Samples from two blocks were sorted into sown legumes and grasses, dried and analysed for Fe, Zn, Cu, Mn and Mo with IPC-OES. A split-split-plot design was analysed using PROC MIXED (SAS, 2001). Grasses at spring growth, grasses in the second cut, legumes at spring growth and legumes in the second cut were analysed separately. The effects of site and year (named YS) (n=3) was treated as main plot, mixture (n=3) as sub-plot and cutting date (n=3) as sub-sub-plot. Pair-wise comparisons between LSMEANS were analysed with Tukey's test at $P<0.05$.

Results and discussion

Mixtures at Skara contained more legumes than mixtures at Umeå, and mixtures with Rc had higher legume proportions than mixtures with Bt at both sites. Forages at Skara 2005 yielded more than at Umeå 2005 and Skara 2007 when averaged over mixture and cut in spring growth (5.7 vs 4.4 and 5.0 Mg DM ha^{-1}, respectively; $P<0.01$). In the second cut, the experiment at Umeå 2005 yielded more than the two Skara experiments (3.2 vs 2.3 and 2.6 Mg DM ha^{-1}, respectively; $P<0.0001$). Mixtures with Rc yielded more than mixtures with Bt, when averaged over YS and cut both in spring growth and in second cut (5.3 vs 4.5 Mg DM ha^{-1}; $P<0.0001$ and 2.9 vs 2.4 Mg DM ha^{-1}, respectively; $P=0.0008$). Averaged over YS and mixture, DM yield increased with later cutting date in spring growth (3.8, 5.1 and 6.2 Mg DM ha^{-1} for early, mid and late cut, respectively; $P<0.0001$). Second cut after early first cut resulted in higher DM yield than after later first cuts (3.0 vs 2.6 and 2.5 Mg DM ha^{-1}; $P<0.0001$). Despite a very fast increase in DM yield in spring growth, the effects of harvest time on micronutrient concentrations were small. This indicates that the crop uptake of micronutrients was as fast as the growth and that the concentrations were not diluted. The numerical differences between harvest times were small also in second cut. Therefore, the micronutrient concentrations averaged over harvest time are presented in this paper (Table 1).

In first cut the Cu concentration in grass was lower at Umeå than at Skara. In both cuts the Cu concentration was higher in Rc than in Bt. There is a relationship between Mo concentration and utilization of Cu because Mo and sulphate interact in the rumen and can form an insoluble complex with high affinity to Cu (NRC, 2001). The requirements of Cu for dairy cows are 10-12 mg kg^{-1} DM when the concentration of Mo is below 2 mg kg^{-1} DM (NRC, 2001). If the Mo concentration is higher the Cu requirement can also be higher. In this experiment the Cu concentration was lower than 10 mg kg^{-1} DM for all species except in Rc where the concentrations were close to the requirement. The Mo concentration was high compared to the Cu concentration in both grasses at Skara, in Mf in second cut at Umeå, and in Bt in second cut at Skara. The Zn concentration was lower than the requirements for dairy cows (40-60 mg kg^{-1} DM; NRC, 2001) in all treatments, except in Ti + Rc in second cut at Umeå. In grasses, Umeå had higher Mn concentration than Skara, and it was higher in Mf than in Ti. There were no differences between Rc and Bt, but both had lower concentrations than the grasses. The Fe concentrations in grasses were higher at Skara than at Umeå in both cuts, but in Rc the concentrations at Umeå were higher than at Skara in first cut. Bt had higher concentration than Rc in spring growth, at summer growth the differences were small.

Conclusions

For Mn and Fe, concentration levels were appropriate for expected dairy cow requirements. Cu concentration was normally low in grasses and in Bt, but in Rc were at the levels required for dairy cows, and in Rc-grass mixtures were too low because of the low concentrations in the grass. The results show that there was a need for Cu supplementation in all treatments because of low Cu concentration. The relatively high Mo concentrations may further increase the demand for Cu supplementation in dairy cow rations because there is a risk of Mo-induced Cu deficiency. The Zn concentration was lower than required for dairy cows, except for the mixture with Ti and Rc in second cut at Umeå.

Acknowledgements

This study was financed by the Swedish Farmers Foundation for Agricultural Reseach (SLF), the Swedish Research Council for Environment, Agricultural Science and Spatial Planning (FORMAS) and by the Regional Farmers Foundation for Agricultural Research in Northern Sweden (RJN).

Table 1. Concentrations of Cu, Mn, Mo, Zn and Fe (mg kg^{-1} DM) in first-year leys of timothy (Ti), meadow fescue (Mf), red clover (Rc) and birdsfoot trefoil (Bt) in mixtures from different sites and years.[1]

Harvest	Nu[4]	Umeå 2005			Skara 2005			Skara 2007			*P*-value
		Ti+Rc	Mf+Rc	Ti+Bt	Ti+Rc	Mf+Rc	Ti+Bt	Ti+Rc	Mf+Rc	Ti+Bt	YS×S[5]
Grasses		Ti	Mf	Ti	Ti	Mf	Ti	Ti	Mf	Ti	
Spring growth[2]	Cu	2.67e	2.83e	2.33e	5.17b	7.17a	4.00cd	4.83bc	5.33b	4.00d	<0.0001
2nd cut[3]	Cu	6.00ab	5.00ab	4.83ab	5.33ab	7.00ab	5.00ab	7.11a	7.83a	4.67b	0.02
Spring growth	Mn	62.0ab	70.7a	56.3bc	36.7de	54.0bc	24.2e	42.9cd	56.8abc	27.5e	0.06
2nd cut	Mn	94.7b	133a	87.0b	24.8e	37.2de	29.2de	37.7d	52.3c	59.3c	<0.0001
Spring growth	Mo	0.45c	1.33c	0.55c	4.05b	4.32b	5.62a	3.23b	3.13b	3.47b	0.006
2nd cut	Mo	1.42d	4.10c	1.55d	3.78c	5.58b	8.13a	3.55c	5.70ab	6.60a	<0.0001
Spring growth	Zn	18.0c	17.5c	18.7c	23.9a	22.5ab	19.0c	23.1a	19.5bc	17.5c	0.002
2nd cut	Zn	39.3a	25.5cd	33.2bc	22.3d	20.8d	28.2cd	24.3cd	19.8d	21.7d	0.04
Spring growth	Fe	30.7c	26.0c	30.5c	75.6b	102a	73.3b	69.9b	78.9b	64.2b	0.008
2nd cut	Fe	49.7	48.7	46.8	82.3	148	95.2	97.8	136	93.8	0.26
Legumes		Rc	Rc	Bt	Rc	Rc	Bt	Rc	Rc	Bt	
Spring growth	Cu	9.67a	8.00b	-	9.33a	9.33a	6.83c	10.2a	9.17ab	6.50c	0.11
2nd cut	Cu	13.3a	12.3a	8.33b	13.0a	13.0a	8.00b	13.7a	13.2a	7.33b	0.63
Spring growth	Mn	24.5	22.2	-	18.5	17.7	14.0	18.6	18.4	19.7	0.23
2nd cut	Mn	24.8	23.7	25.7	21.3	19.8	18.2	19.3	20.5	22.2	0.30
Spring growth	Mo	1.79b	1.82b	-	3.53a	2.80ab	3.00ab	2.49ab	2.32ab	2.92ab	0.36
2nd cut	Mo	0.72d	1.13d	1.53d	4.18a	3.60a	5.52a	3.60a	3.65a	5.08a	0.18
Spring growth	Zn	34.6a	29.5a	-	19.3b	19.3b	19.3b	19.2b	19.3b	19.3b	0.06
2nd cut	Zn	47.2	39.8	39.5	22.5	23.0	20.0	21.8	21.3	17.5	0.33
Spring growth	Fe	97.7a	73.2bcd	-	55.5e	61.2de	85.5ab	66.2cde	66.7cde	83.3abc	0.001
2nd cut	Fe	49.0b	49.0b	75.5a	66.0ab	65.8ab	85.8a	59.5ab	57.3ab	74.5ab	0.67

[1] Values with different letters within a row are significantly different.

[2] Mean value of three harvest occasions in first cut (one week before heading; at heading; one week after heading).

[3] Mean value of 2nd cut harvested 6 weeks after each harvest occasion in spring growth.

[4] Nu = micronutrient.

[5] YS = year site; S = species.

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