Trace element imbalance in vegetation as a threat to free ranging cattle in the Gilgel Gibe valley, Ethiopia

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Abstract. As in many tropical countries, natural pastures are the main source of nutrients for cattle in Ethiopia. However, there is limited information available with regard to trace element concentrations in Ethiopian forages. In this study, 58 plants were sampled in the Gilgel Gibe valley based on the observed ingestion by zebu cattle (*Bos indicus*) herds, grazing at different elevation and soil types, and analysed for copper (Cu), cobalt (Co), iron (Fe), molybdenum (Mo), manganese (Mn), sulfur (S), selenium (Se) and zinc (Zn). The effect of elevation, soil type and plant type on the above trace element concentrations was investigated. Deficient Cu concentrations were present in 71% of samples. Plant samples contained at least marginally antagonistic concentrations of Mo, S and Fe towards Cu in 36, 48 and 88% of cases respectively, and deficient Se and Zn concentrations in 57 and 45% of cases respectively. For Mn and Zn, plant concentrations differed according to elevation region. Plants on Nitisol-Acrisol-Ferralsol associations contained higher amounts of Fe than on Planosol-Vertisol associations. Concentrations of Cu and S were higher in herbaceous and woody plants than in grasses and crop resides, whereas concentrations of Co were higher in herbaceous than in other plant types. Differences between plant types were also present for Fe. Overall, micro mineral deficiency is very likely to develop in cattle ranging at the studied area. Plant mineral concentrations were affected by a variety of factors, such as elevation, soil type and plant group, calling for a nuanced assessment of plant survey results.

Keywords: Trace elements, ruminants, humid tropics.

Introduction

In tropical areas, cattle are typically free ranging on natural pastures. Inadequate or imbalanced mineral supply in these pastures is frequently associated with a suboptimal status in cattle, inevitably leading to impaired health and production, are frequently observed (Dermauw *et al.* 2013). Targeted supplementation of ruminants in areas with potential mineral deficiencies or imbalances is considered the most efficient way to improve their mineral status (Suttle, 2010). However, accessibility and affordability of these solutions are rather limited for some farmers. Furthermore, supplementing these grazing cattle might pose some practical problems (McDowell 1996). Consequently, identifying plants rich in minerals as potential natural supplements as well as the role of associated factors, is warranted.

In this study, we evaluated mineral concentrations and the effect of elevation, soil and plant type in plants sampled around the Gilgel Gibe valley, Ethiopia.

Methods

Study area and sampling

In the Gilgel Gibe valley, South-West Ethiopia, 19 herds grazing at three different elevation regions (Elevation 1= 1700-1800 m above sea level (a.s.l.), 2= 1800-2000 m a.s.l. and 3= 2000-2200 m a.s.l.) within a radius of 35 km from the town of Jimma, were observed during one day (Fig. 1). Soil type was evaluated based on landscape position and visual inspection of the soil: dark reddish brown to yellowish red indicated Nitisol, Acrisol and Ferralsol (NAF) soil associations whereas dark grey, to light grey and bleached indicated Planosol, Vertisol (PV) soil associations (Van Ranst *et al.* 2011).

Plant species ingested by one animal per herd were recorded every 10 minutes. Mixture samples of dominant ingested plant species were sampled, oven dried at 65°C for 72 hours until constant weight and ground to pass a 2 mm screen.

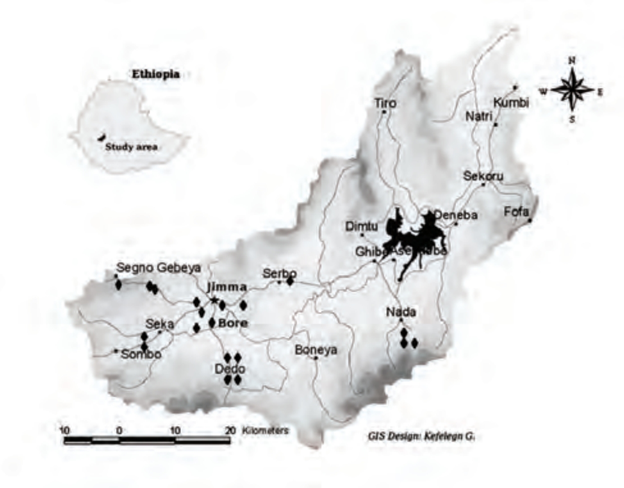

Figure 1. The Gilgel Gibe catchment in South-West Ethiopia (adapted with permission from Van Ranst *et al.* 2011). ♦= sampled herd.

Chemical analysis

Samples were ashed through microwave destruction with 10 ml HNO_3 in closed vessels followed by filtration. Afterwards, concentrations of Co, Cu, Fe, Mo, Mn and Zn were determined by means of inductively coupled plasma – optical emission spectrometry (ICP-OES) (Vista MPX radial, Varian, Palo Alto, USA) whereas concentrations of S and Se through inductively coupled plasma – mass spectrometry (ICP-MS) (Elan DRC-e, Perkin Elmer, Sunnyvale, CA, USA).

Data processing

Plant mineral concentrations were regarded deficient, adequate or above the maximum tolerable concentration (MTC) upon comparison with requirements for *Bos taurus* beef cattle established by NRC (2000, 2005 respectively), whereas concentrations of Mo, Fe and S were considered marginally or highly antagonistic for Cu according to criteria of Mortimer *et al.* (1999). Plants were classified as one of the following plant types: grasses, crop residues, herbaceous plants or woody plants. Grasses included the "true grasses" or *Poaceae* and the "sedges" or the *Cyperaceae*. Crop residues were defined as stovers from cultivated plant species offered by farmers to their cattle. Herbaceous plants contained sampled forbs while the group of woody plants contained leaf samples from trees and shrubs.

Statistical analyses

Statistical analysis was performed using SAS Version 9.3 (SAS Institute Inc., Cary, NC). Concentrations of trace elements were not normally distributed and therefore log transformed. A multivariable fixed effects model with elevation region, soil type and plant group as categorical fixed effect was fitted to the log of the different response variables. Pearson correlation coefficients were calculated to investigate associations between mineral concentrations in plant samples. Hypotheses were tested using the F-test at the 5% significance level.

Results

Sampled plant species (n = 58) on the two soil types are shown in Table 1. Only 29 % of plant samples contained adequate Cu concentrations whereas concentrations of Mo, S and Fe were above thresholds for antagonism against Cu in 36, 48 and 88% of samples respectively. Concentrations of Mo and S were usually within the

Table 1. Sampled plant species based upon observed ingestion by grazing cattle around the Gilgel Gibe catchment in South-West Ethiopia.

Soil	Plant type			
	Grasses	Crop residues	Herbaceous	Woody plants
NAF	*Andropogon abyssinicus*	*Ensete ventricosum*	*Aspilia africana*	*Coffea arabica*
	Brachiaria spp.	*Musa* spp.	*Aspilia* spp.	*Erythrina brucei*
	Cynodon spp.	*Pisum sativum*	*Bidens macroptera*	*Grewia ferruginea*
	Cyperus spp.	*Saccharum officinarum*	*Bidens pilosa*	*Maytenus obscura*
	Melinis spp.	*Sorghum bicolour*	*Centella asiatica*	*Persea americana*
	Panicium coloratum	*Zea mays*	*Desmodium uncinatum*	*Physalis peruviana*
	Pennisetum clandestinum		*Indigofera* spp.	*Premna schimperi*
	Pennisetum sphacelatum		*Ipomoea batatas*	*Rhus glutinosa*
	Pennisetum thunbergii		*Persicaria nepalensis*	*Sida rhombifolia*
			Satureja paradoxa	*Sida* spp.
			Satureja spp.	*Vernonia adoensis*
			Trifolium spp.	*Vernonia amygdalina*
PV	*Cynodon spp.*	*Sorghum halepense*	*Aspilia mossambicensis*	*Eucalyptus camaldulensis*
	Cyperus spp.		*Centella asiatica*	*Psidium guajava*
	Hyparrhenia hirta		*Hygrophila auriculata*	
			Senna didymobotrya	
			Sesbania sesbon	

NAF = Nitisol, Acrisol, Ferralsol associations, PV = Planosol, Vertisol assocations

Table 2. Trace element concentrations (GM) in different plant types sampled around the Gilgel Gibe catchment South-West Ethiopia.

Mineral	Plant group				GSEM	*P*
	Grasses (*n* = 20)	Crop residues (*n* = 7)	Herbaceous plants (*n* = 18)	Woody plants (*n* = 13)		
Co	0.48 a	0.25 a	0.92 b	0.35 a	1.128	0.005
Cu	5.4 a	4.2 a	8.4 b	10.9 b	1.072	<0.001
Fe	769 ab	312 ac	1276 b	286 c	1.151	<0.001
Mn	166	161	222	185	1.111	0.952
Mo	0.85	0.56	0.93	0.34	1.147	0.122
S	0.15 a	0.13 a	0.25 b	0.24 b	1.066	<0.001
Se	102	74	116	74	1.091	0.340
Zn	33	17	38	34.6	1.078	0.082

Different letters within a row differ significantly ($P < 0.05$), GM = geometric mean, GSEM = geometric standard of the mean.

Table 3. Pearson correlation coefficients between trace element concentrations in sampled plants around the Gilgel Gibe catchment, South-West Ethiopia.

	Cu	Mo	Fe	Zn	Co	Mn	S
Se	-.003	.217	.336**	.240	.350**	.243	.257
Cu		-.041	.044	.339**	.195	.068	.720**
Mo			.292*	.188	.224	.000	.066
Fe				.386**	.870**	.315*	.116
Zn					.518**	.291*	.438**
Co						.426**	.222
Mn							.260*

*$P < 0.05$, **$P < 0.01$

marginal antagonistic range (33 and 34% of samples respectively) but highly antagonistic or toxic S levels were also found in 14% of samples. Fe was highly antagonistic in 26% and above the MTC in 31% of samples. Furthermore, deficiencies of Se and Zn were found in 57% and 45% of samples. Co and Mn seemed to be adequate in sampled plants but toxic Mn concentrations were found in 1 sample.

Differences in mineral concentrations (shown as geometric means) according to plant type are presented in Table 2. Briefly, herbaceous and woody plants contained lower Cu and S concentrations than grasses and crop residues (P<0.001). Co concentrations were higher in herbaceous plants than in other types of plants (P = 0.005). For Fe, differences between plant types were not clear cut (P<0.001). Furthermore, higher Mn concentrations were present in plants sampled at lower elevation than at medium and very high elevation (366 versus 157 and 113 mg/kg DM (GM) ± 1.11 (GSEM), P = 0.011). Zinc concentrations were lower at medium elevation than at lowest elevation (23.5 versus 41.0 mg/kg DM ± 1.15, P = 0.020). Plant sampled on NAF soils contained slightly more Fe than on PV soils (597 vs. 586 mg/kg DM ± 1.15, P = 0.048). Overall plant samples, concentrations of Co and Fe, Cu and S as well as between Cu and Zn were well or highly correlated (r = 0.87; r = 0.77; r = 0.52; all P<0.01) (Table 3).

Conclusion

Unravelling associated factors and identifying affordable ways to increase micro mineral status in ranging cattle is imperative as it will lead to a better health and production of the animals, and hence to a better income for farmers. In our study, mineral analyses indicated that the available and ingested vegetation around the Gilgel Gibe valley in Ethiopia is most likely to induce mineral deficiencies in ranging cattle. Additionally, our data also point to the association of plant mineral concentrations with plant type, soil and elevation as well as to complex interrelationships between minerals.

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