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Original Research Article

Effect of pH and Forage Species on Mineral Concentrations in Cattle breeds in Major Grazing Areas of Uasin Gishu County, Kenya

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A B S T R A C T

Mineral content of grazing cattle is affected by soil pH and forage species within and between breeds. A three-year study was conducted at six major grazing areas located in Uasin Gishu County, Kenya for cattle grazing on Rhodes and Kikuyu pastures. Frieisian and Ayshire cattle breeds were assigned randomly to two different forage species treatments, Rhodes (*Chioris gayana)* and Kikuyu *(Pennisetum Clandestinum*). Kikuyu forage species recorded the highest mineral concentrations (P<0.05). Both Rhodes and Kikuyu forages had generally higher (P<0.05) mineral concentration. Acidity did not appear to be a problem in soil mineral availability since mean pH was 5.6 and higher. Consequently grazing cattle at these locations can be recommended for kikuyu grass as it has average mineral requirements to support optimum animal productivity.

K e y w o r d s

Grazing cattle; mineral imbalance; forage species; Soil pH; Blood serum

Introduction

The nutrition of grazing animals is a complicated interaction of soils, plants, and animals (Rocky, 2013). The performance and health of grazing livestock is dependent on the adequacy and availability of essential mineral elements from pastures. Grazing livestock requires an understanding of the dynamics of a broad range of forage nutrients (Provenza, 2003). This means that adequate intake of forages by grazing animals is essential in meeting mineral requirements. The ability of forage minerals to meet grazing livestock mineral requirements depends upon quantity (the concentration of minerals in the plant) and the bioavailability of those minerals (amount livestock can absorb from the digestive tract). Although mineral concentrations in the forage might be adequate, the percent that is available to the livestock might be much lower (Khan *et al.*, 2006).

Grazing livestock obtain part of their mineral supply from sources other than forages, particularly from water and soil. Plants, like animals, have nutrient requirements for growth and reproduction (McDowell and Valle, 2000). Plants react to inadequate minerals in the soil either by reducing plant growth or reducing concentration of the minerals in their tissue. Mineral concentration in plants can be affected by mineral concentration in the soil. This frequently exerts its importance through mineral impact on soil pH, which can enhance or restrict the ability of plants to incorporate minerals in their tissues (Khan *et al*., 2005).

Many naturally occurring deficiencies in grazing livestock can be related to soil characteristics (McDowell, 1992; McDowell and Valle, 2000). Mineral deficiencies may affect production of grazing livestock and pasture in most of the regions of the world, which include both the major elements Ca, P, Mg, Na, S, and the trace elements Co, Cu, I, Mn, Se, and Zn (Judson and McFarlane, 1998; Evitayani *et al*., 2004; Khan *et al*., 2005; Goswami *et al*., 2005). Excessive intakes of minerals can also commonly have an adverse effect on animal health, the more commonly encountered problems have been associated with excessive intake of the minerals such as Cu, Mo, Fe, S, Na, K, and F (Goswami *et al*., 2005).

Research in the area of mineral status of soil, forage and grazing ruminants is limited despite their importance in animal nutrition particularly in many developing African countries like Kenya (Goswami *et al*., 2005), which continually depend on the livestock as a livelihood resource. Hence, there is need to further investigate the status of minerals in soil, and forages in areas rearing ruminants. In order to have rapid and economic improvement in ruminant production in Kenya, as in other developing countries, factors influencing the mineral status of ruminants under grazing conditions must be determined.

The purpose of this study was to investigate and evaluate the minerals status of soil and forages in the ruminant producing regions of Uasin Gishu County, Kenya and investigate factors limiting livestock production as a basis for formulating mineral supplements. The present paper discusses the effect of soil pH and forage species on mineral concentrations in grazing cattle. This information would be used for different ruminant producing regions during wet and dry seasons in Kenya and other developing tropical countries with similar ecological conditions.

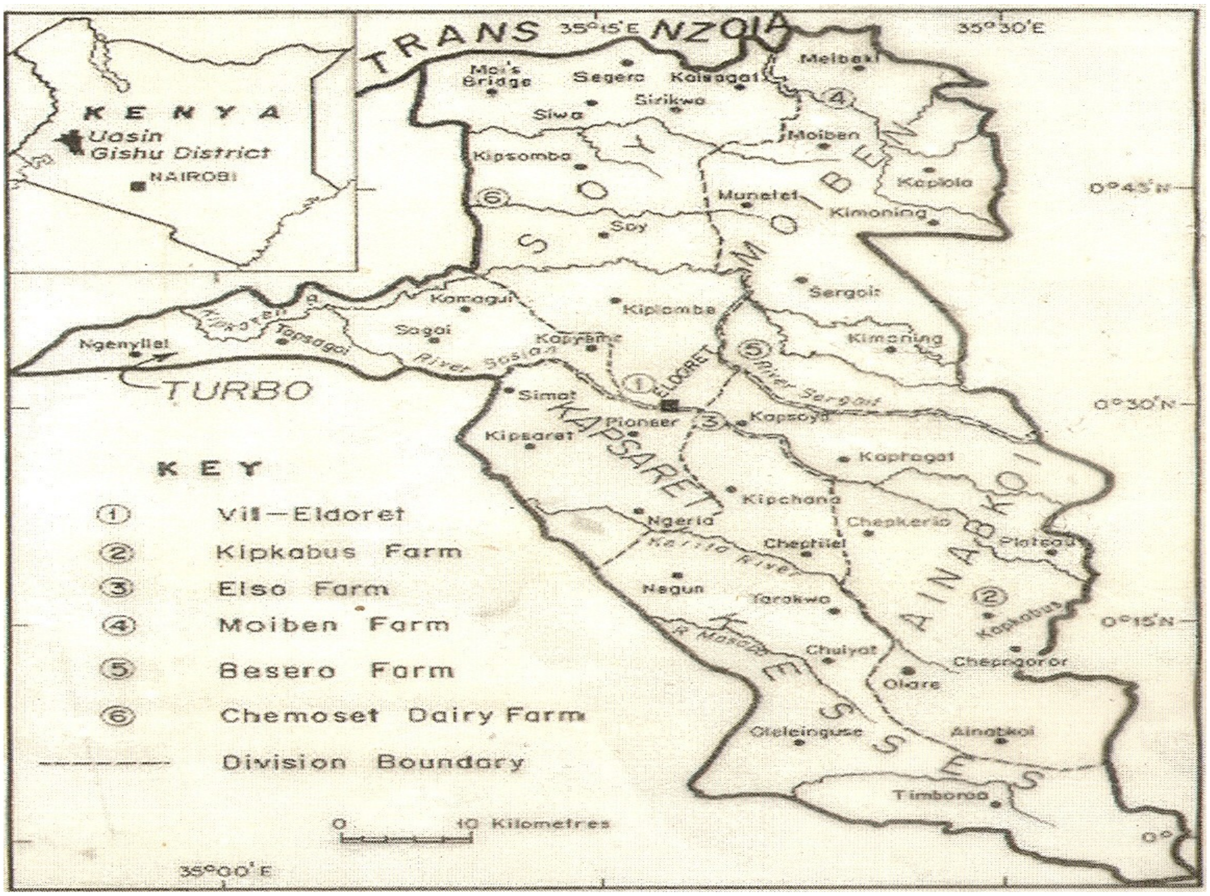
Materials and Methods

Samples of forage were collected from those species that were most frequently grazed by ruminants, based on cattle grazing patterns in order to obtain a representative sample (Fig 1).

The principal improved tropical forage species that was collected in all pastures were Rhodes (*Chioris gayana*) and Kikuyu grass (*Pennisetum Clandestinum*. Two herds of cattle breeds (Frieisian and Ayshire) were assigned randomly to two treatments of different forage species. Soil samples were analyzed for Ca, Mg, Fe, Mn, Cu, Zn and pH according to the procedure used of soil testing laboratory (Rhue and Kidder 1983). Soil and corresponding forage samples were collected at three different places with 5 replications from each place.

Each of soil and forage samples from each site of the pasture assigned to the experiment were collected after each

Figure. 1 Sampling sites in Uasin Gishu district



sampling period during each season. Each composite sample of soil or forage was derived from three sub-samples. Soil samples were obtained using a stainless steel sampling auger to a depth of 15 cm. The sub-samples of forages were collected from an area approximately 70 cm in diameter, and cut to a length of 3-6 cm to simulate grazing height. These samples were taken from the same area from which the soil samples were taken. Forage samples were cut using a stainless steel knife and placed in clean cloth bags on the site. Both the soil and forage samples were dried in an oven at 60°C for 48 h and subsequently ground, using a Wiley mill, with a 1-mm stainless steel sieve (forage) and 2-mm sieve for soil.

Ground samples were stored in plastic whirl pack sample bags until analysis. Soil minerals were extracted using Mehlich-1 method (0.05 M HCl+0.0125 M H_2SO_4) following Rhue and Kidder method, (1983). Forage samples were digested according to the procedures of Fick *et al*. (1979), and concentration of mineral elements determined by atomic absorption spectrophotometry (AAS) with graphite furnace and Zeeman background correction.

Soil samples were analyzed for Ca, Mg, Fe, Mn, Cu, Zn and pH according to the procedure used by soil testing laboratory while forage and blood serum samples were analyzed for only Ca, Mg, Fe, Mn, Cu, and Zn with Mo acting to check Cu availability in grazing cattle.

A total of 120 samples for both soil and forage were collected during the three years of the study (20 samples per season) while 20 blood samples each for Frieisian and Ayshire breeds each year were collected for the three years of study using a method by Espinoza *et al*, (1990). Data obtained in the present study were statistically analyzed using a 3 (years) by 2 (seasons) factorial design proposed by Snedecor and Cochran, 1984 using the GLM procedure of the SAS System

Result and Discussion

The results are presented below in tables showing mineral concentrations in soils and forages and subsequently in grazing ruminants. The soil pH and mineral concentrations for each forage species was also determined as part of the factors affecting livestock production. The results revealed that the sampled soils did not show severe deficiencies except that 14% and 4% of sampled soils had Cu and Zn deficiencies respectively (Table 1).

The forage samples were deficient in Ca, Mg, Cu and Zn with severe deficiencies in Cu (93%) and Mg (89%) as indicated in Table 2. The results in Table 3 show that grazing cattle were deficient mainly in Mn and Cu since 100% and 42% of the blood serum samples were deficient in these minerals.

Correlation between soil and forages mineral concentrations revealed a positive correlation except in only Ca (-0.002) and Cu (-0.257) as shown in Table 4. When the two forage species (Rhodes (*Chioris gayana*) and Kikuyu grass (*Pennisetum Clandestinum*)) were subjected to soils at different PH (Table 5), it was found that concentration of minerals in forages increased with increase in alkalinity of soils on which they grew.

There were no deficiencies of most minerals in soils (Table 1) because the mean soil pH of 5.6 was suitable for existence of minerals. Both macronutrient and micronutrient availability in the study was affected by soil pH (Sparks, *et al*; 2002; McDowell *et al*; 1993). Acidity can also induce deficiencies of micronutrients such as molybdenum, and copper. A soil pH of 6.5 is considered to be the optimum for a soil containing minerals in well-balanced amounts.

At soil pH values below 6.5 the availability is reduced and the availability of Fe, Mn, and Zn is increased; the opposite is true at soil pH values above 6.5 (Khan *et al*., 2005, Kehoe, 1981). Most nutrient deficiencies can be avoided between a pH range of 5.5 to 6.5, provided that soil minerals and organic matter contain the essential nutrients (Sparks *et al*.; 2002; Buol *et al*.; 2003).

Correlation analysis (Table 2) indicate that despite no deficiencies in soils, plant species had major deficiencies thus negative correlation in Ca (-0.002) and Cu (-0.257). The results presented in Table 3 indicate that the pasture species under study had major deficiencies with highest being recorded for Cu (93%) and Mg (89%).

Severe Zn deficiency results in poor pasture growth, which is due in part to the poor utilization of N within the plant when Zn is low (MacNaeidhe, 2001). Soil ingestion will increase with wet season conditions, high stocking rates, root intake, loose soils, and low amounts of forage available (Herlin and Andersson, 1996; Abrahams and Steigmajer, 2003) which results in less deficiencies in most minerals in soils.

Table.1 Soil macro and trace element concentrations (mg/kg DM) in relation to recommended levels.

Parameter	Mean ±SD	Range	Critical	% sample
	(n=120)	(n=120)	Levels	Deficient
Ca	720.00±33.30	280.00-184.00	71	0
Mg	330.00±11.90	161.30-627.70	30	0
Fe	551.00±22.80	228.30-1198.30	30	0
Mn	630.00±34.50	239.70-1583.50	10	0
Cu	3.30±0.90	1.60-5.13	2	14
Zn	6.70±0.40	1.97-22.06	2	4
CL - (NRC, 2001)				

Table.2 Correlation between soil and forage minerals

Parameter	Soil (mg/Kg)	Forage (mg/kg)	Correlation (r)
	n=28	**n=28**	
Ca	720.00± 33.30	570 ±19.00	-0.002
Mg	330.00± 11.90	1350.00± 71.00	0.005
Fe	551.00± 22.80	56.00 ±0.53	0.205
Mn	630.00± 34.50	105.00± 0.58	0.281
Cu	3.3±0 0.90	5.32 ±2.84	-0.257
Zn	6.70± 0.40	19.50± 8.20	0.078

Table.3 Forage macro (g/kg DM) and trace elements (mg/kg DM) in relation to the critical levels of cows needs

Parameter	Mean ±SD	Range	CL	% sample
	(n=120)	(n=120)	Cows	Deficient
Ca	0.57±0.19	0.15-1.17	0.80-15.00	86
Mg	1.35±0.71	0.10-3.13	2.10	89
Fe	56.00±0.53	10.25-231.00	<13.00	7
Mn	105.00±0.58	38.25-246.50	<13.00	0
Cu	5.32±2.84	2.00-15.50	<9.00	93
Zn	19.50±8.26	8.30-39.78	<18.00	39

CL-critical level based on cows needs (NRC, 2001)

Table.4 Mineral concentration in different forage species at pH 5.1 and 6.1

	Pasture species			
Element				
	pH=5.1		pH=6.1	
	Rhodes	Kikuyu	Rhodes	Kikuyu
	n=60	n=60	n=60	n=60
Ca	0.61	0.49	0.66	0.54
Mg	1.51	1.93	1.32	1.64
Fe	43.84	51.75	72.42	164.80
Mn	101.30	129.10	179.40	109.60
Cu	6.06	6.50	5.67	7.93
Zn	21.64	23.64	21.75	27.00

Table.5 The mean concentrations of macro (g/l) and trace elements (µg/l) in lactating cows in relation to their needs

	Mean ±S.D			%
Parameter			C L Cows	
	n=120			deficient
Ca	0.81 ±0.32		0.08	0
Mg	0.02±0.01		0.015	21
Fe	2.43±	1.53	<1.00	29
Mn	0.26±0.14		<1.00	100
Cu	0.60±0.17		<0.65	42
Mo	*0.36±0.35*		-	-
Zn	3.71 ±1.63		<0.70	4
CL - (NRC, 2001)				

The management of the pastures, as well as the physical attributes of the pasture is the key to animal production. Regardless of the species of grazing animal, graze management is a key point in the organic systems, and this should emphasize on maximizing dry matter intake from pasture (Sullivan, 2010). Efficient grazing practices can make the farm more profitable through reducing mechanical manure spreading costs and lower fertilizer costs as manure nutrients are returned to the soil. Pasture-based farm systems that provide fresh and conserved forages and occasional concentrate supplements lead to acceptable and sustainable productivity, as well as being a point of difference to concentrate-based production systems (Knowles *et al*., 2006). The higher an animal's requirements are, based on production level, the more important maximizing intake becomes. Thus, lactating dairy cows are the kind and class of livestock that are most sensitive to factors influencing intake. The copper status of cattle can be assessed from liver or serum copper concentrations. Liver concentrations <20 mg/kg dry tissue or serum concentrations <0.5 μg/mL indicate copper deficiency. Dietary manganese deficiencies in dairy cattle are less common than deficiencies of copper or selenium. Signs include poor growth and skeletal deformities in newborn calves and reproductive abnormalities, including anestrus, in adult cows. Recently recommended dietary manganese concentrations for cattle are 15–25 mg/kg; previous recommendations have been as high as 40 mg/kg dry matter. Recommended zinc concentrations in the diets of dairy cattle and calves are 23–63 mg/kg dry matter. Signs of zinc deficiency include reduced feed intake and general ill thrift. Parakeratosis, particularly around the nostrils and lower legs, and weakening of the hoof horn are signs of prolonged zinc deficiency. Normal concentrations of serum zinc are 0.7–1.3 μg/mL. Concentrations <0.4 μg/mL are considered deficient. Iron deficiency is extremely rare in adult cattle, because iron is ubiquitous in the environment and the endogenous concentrations of iron in most feedstuffs will more than meet requirements. Signs of iron deficiency are primarily anemia and low serum iron concentrations. Adequate serum iron concentrations are 110–150 μg/dL (Khan *et al*., 2005).

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