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Short Communication

Seasonal influence on mineral concentration of forages on flooded pastures in South Sumatra, Indonesia

Concentración de minerales en forrajes nativos en pastizales estacionalmente inundados en South Sumatra, Indonesia

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Abstract

This study was conducted to evaluate macro- and micro-mineral concentrations in forages growing on seasonally flooded native pastures in non-tidal swamps of South Sumatra, Indonesia and grazed by buffalo. The upper part of native forage plants from 5 species of Poaceae, 4 species of Leguminosae, 3 species of Cyperaceae and 1 species of Onagraceae were sampled by hand-plucking during flooded and dry seasons. The results showed that mineral concentrations of forages varied greatly between seasons. In general concentrations of most minerals were adequate to supply the dietary needs of grazing ruminants in both wet and dry seasons. Phosphorus (P) concentrations were low in all species in both wet and dry seasons but growing animals should select a diet adequate in P, while lactating females could benefit from P supplementation. In cut-and-carry situations, animals would probably respond to additional P in the diet. These hypotheses need testing in the field.

Keywords: Buffalo, mineral deficiency, mineral toxicity.

Resumen

En South Sumatra, Indonesia se realizó un estudio para evaluar las concentraciones de macro- y micro-minerales en plantas forrajeras nativas comunes en pastizales estacionalmente inundados y utilizadas con búfalos. Para el estudio see muestrearon por el método ´hand-plucking´ plantas de 5 especies de Poaceae, 4 especies de Leguminosae, 3 especies de Cyperaceae y 1 especie de Onagraceae durante las estaciones inundada y seca. Los resultados mostraron que las concentraciones minerales variaron considerablemente entre estaciones. No obstante, las concentraciones de la mayoría de los minerales fueron adecuadas para satisfacer los requerimientos nutricionales de rumiantes en pastoreo en ambas estaciones. Las concentraciones de fósforo (P) fueron bajas en todas las especies en ambas estaciones, pero se considera que bajo condiciones de pastoreo los animales en crecimiento seleccionan una dieta adecuada en P, mientras que hembras lactantes podrían beneficiarse de P suplementado. En situaciones de corte y acarreo, los animales probablemente responderían a P adicional en la dieta. Estas hipótesis necesitan ser probadas en el campo.

Palabras clave: Búfalos, deficiencia mineral, toxicidad mineral.

Introduction

The concentrations of individual minerals in forages vary greatly depending on the interactions of a range of factors including soil, plant species, stage of maturity, yield, management factors and climate. Forages represent an important source of minerals for grazing ruminants and play essential roles in preventing diseases and inhibiting or stimulating ruminal microbial activity (Spears 1994). Natural pasture species in non-tidal swamps have been traditionally the main source of feed for swamp buffalo in e.g. Brazil (Camarão et al. 2004) and South Sumatra (Ali et al. 2014). Forage nutritive values fluctuate with seasons and the dry season is the most limiting in terms of nutrient

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supply to grazing buffalo. As most grazing livestock in tropical countries including Indonesia are usually un-supplemented, they must fulfill their mineral requirements from forage. Camarão et al. (2004) failed to find evidence of mineral deficiencies in grazing buffalo. Data on mineral concentrations in forage species and their variability between seasons are essential for correct and cost-effective ration formulation and swamp buffalo nutrition.

However, mineral profiles of tropical forages in flooded pasture have received little attention and limited studies showed that forages can be deficient in one or more elements. In this study we aimed to estimate and compare the concentrations of mineral elements including calcium (Ca), phosphorus (P), magnesium (Mg), sulphur (S), copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn) in native flooded pasture species in non-tidal swamps of South Sumatra, Indonesia during the flooded and dry seasons.

Materials and Methods

Site description

Research was conducted during February–September 2014 on communal pastures in non-tidal swamps in Rambutan subdistrict, Banyuasin district and Pampangan subdistrict, OKI (Ogan Komering Ilir) district of South Sumatra Province (between 3°05' and 3°11' S, and 104°55' and 104°58' E). The study area was selected as representative of non-tidal swamps used for grazing buffalo where the highest populations of swamp buffalo were found. The study area (± 567 ha) is part of the Batang hari river watershed and is surrounded by settlements and plantations of oil palm and rubber. The soils are poorly drained, acid fluvisols with low availability of Ca, P and Mg and high solubility of Fe and Zn (Ali et al. 2014).

The dry season extends from April to September while the rainy season normally occurs from October to March with annual rainfall of 2,100–3,264 mm. The study area is regularly inundated for 3–8 months during rainy seasons. Minimum temperatures range from 22 to 25 °C (at 05.00–08.00 h) and maximum temperatures range from 30 to 34 °C (at 11.00–14.00 h). Farmers also use the communal pastures for paddy fields and vegetable production (± 304 ha) when the water level is low.

Forage sampling

In the representative areas forage plants were never fertilized nor had they any management intervention. Observations of forage consumed by grazing buffalo during 08.00–11.00 h and 14.00–17.00 h (Setianah et al. 2004; Hirata et al. 2008) and in our previous study (Ali et al. 2014) revealed that native vegetation species consumed by buffalo included: Poaceae [*Urochloa mutica* (syn. *Brachiaria mutica*), *Leersia hexandra*, *Hymenachne amplexicaulis*, *Ischaemum rugosum*, *Oryza rufipogon*]; Leguminosae (*Mimosa pigra*, *Sesbania exasperata*, *Neptunia oleracea*, *Aeschynomene sensitiva*); Cyperaceae (*Actinoscirpus grossus*, *Scleria gaertneri*, *Eleocharis dulcis*); and Onagraceae (*Ludwigia peploides*).

The study area on both left and right sides of the river was divided into 2 subareas based on land use. Samples of the forages eaten by buffalo were randomly collected by hand-plucking during flooding in the wet season (March 2014) and in the dry season (August and September 2014) from at least 2 different sites within each subarea. A mix of leaf and stem (± 250 g) was hand-plucked from the upper parts of herbaceous plants in the pre-flowering stage and from younger twigs of the shrubs, *M. pigra* and *S. exasperata*. Samples for each species were washed with distilled water, chopped and dried at 50 °C. The oven-dried samples were pooled within the subarea and then coarsely milled to pass 1 mm screen for mineral analyses.

Mineral analyses

Representative samples (in duplicate) were digested stepwise with nitric acid (HNO_3). Concentrations of minerals in the forage samples were analyzed by using inductively coupled plasma emission spectrophotometer (SPS7700, Seiko Instruments Inc., Chiba, Japan) in the Laboratory of Feed Technology and Dairy Nutrition, Faculty of Animal Husbandry, Bogor Agricultural University.

Statistical analyses

Data were analyzed using StatView SAS (1999). The differences in means between seasons were determined using an unpaired t-test and were considered significant if $P<0.05$.

Results

While season had a significant effect ($P<0.05$) on concentrations of Ca, P, Mg and S, the effects were inconsistent across species (Table 1). Calcium concentrations in most forages were higher in the flooded season than in the dry season except for *U. mutica*, *N. oleracea*, *S. gaertneri*, *E. dulcis* and *L. peploides*. With the excep-

Table 1. Concentrations of macro- and micro-minerals in forages in swamps in South Sumatra during flooded and dry seasons.

Species	Season	Macro-mineral (% DM)				Micro-mineral (ppm DM)			
		Ca	P	Mg	S	Cu	Fe	Zn	Mn
Poaceae									
Urochloa mutica	dry	0.62b[1]	0.10b	1.59b	0.50b	11.6b	105a	41.8a	366b
	flooded	0.11a	0.01a	0.86a	0.04a	9.6a	107a	60.2a	128a
Leersia hexandra	dry	0.08a	0.16b	1.01b	0.13a	15.3a	193a	128.0b	274a
	flooded	0.12b	0.09a	0.84a	0.14a	12.3a	806b	97.8a	283a
Hymenachne amplexicaulis	dry	0.07a	0.11b	1.02a	0.17a	15.5a	139a	40.9a	225a
	flooded	0.19b	0.08a	1.09b	0.09a	17.5a	208b	56.8b	252a
Ischaemum rugosum	dry	0.08a	0.04a	1.03a	0.06a	13.2a	184b	57.0a	125a
	flooded	0.14b	0.07b	1.11b	0.38b	12.2a	121a	78.1a	297b
Oryza rufipogon	dry	0.12a	0.05a	1.19b	0.03a	16.8a	499b	45.8b	906a
	flooded	0.16b	0.08a	0.95a	0.03a	13.6a	188a	26.1a	1,044b
Leguminosae									
Mimosa pigra	dry	0.32a	0.14b	1.68b	0.30b	22.1b	206a	76.9b	252a
	flooded	0.39b	0.10a	1.54a	0.14a	8.6a	317a	33.7a	342a
Sesbania exasperata	dry	0.42a	0.17b	1.41b	0.30b	23.4a	100a	76.4a	153a
	flooded	0.64b	0.15a	1.17a	0.23a	21.3a	181b	64.3a	128a
Neptunia oleracea	dry	0.66b	0.07a	1.80a	0.05a	43.3b	202a	176.0b	1,076b
	flooded	0.43a	0.14b	2.01b	0.18b	21.7a	358b	43.2a	402a
Aeschynomene sensitiva	dry	0.46a	0.12a	1.98a	0.43a	29.2a	129a	86.7a	407b
	flooded	0.48b	0.13a	2.35b	0.40a	42.1b	145a	94.4a	286a
Cyperaceae									
Actinoscirpus grossus	dry	0.08a	0.21b	0.65a	0.31a	14.3b	89a	49.6b	291a
	flooded	0.20b	0.11a	1.32b	0.33a	9.9a	318b	43.3a	568b
Scleria gaertneri	dry	0.25b	0.06a	0.89b	0.05a	14.7b	69a	48.1a	487b
	flooded	0.10a	0.08a	0.74a	0.08b	9.6a	151b	62.3a	210a
Eleocharis dulcis	dry	0.08b	0.14a	1.01b	0.29a	20.1a	936a	55.1b	231b
	flooded	0.03a	0.20a	0.17a	0.49b	19.1a	1,629b	28.0a	34a
Onagraceae									
Ludwigia peploides	dry	0.56b	0.16a	2.62b	0.16a	31.2a	728a	198.0a	969b
	flooded	0.33a	0.21b	2.06a	0.15a	244.0b	926b	207.0a	691a
Critical level[2]		0.30	0.25	0.20	0.26	11	50	33	40
Toxic level[3]						25	500	750	1,000

[1]Means followed by different letters within a species between seasons are significantly different (P<0.05).
[2]Levels for growth and production of ruminant animals (McDowell 1997).
[3]Levels suggested to produce toxic symptoms in ruminant animals (McDowell 1997).

tion of *U. mutica*, Ca concentrations in Poaceae and Cyperaceae were lower than those in Leguminosae. Concentrations of P in most forages also varied (P<0.05) between seasons with the exception of *O. rufipogon*, *A. sensitiva*, *S. gaertneri* and *E. dulcis*. Some species had higher P concentrations in the dry while others had higher concentrations during flooding. As opposed to Ca concentrations, Mg concentrations in most forages were higher during the dry than in the flooded season.

Concentrations of micro-minerals also varied (P<0.05) between seasons and among species (Table 1). In most Poaceae species, Cu concentrations did not differ significantly between seasons, while Fe concentrations were usually higher during flooding periods and Zn and Mn concentrations were usually higher in the dry season.

Discussion

Macro-minerals

The variation between species in occurrence of peak concentrations of nutrients could be due to a combination of main growth periods, time of maturity and genetic variation (Minson 1990; Underwood and Suttle 1999).

The higher Ca concentrations in Leguminosae and most Poaceae during the flooded season than in the dry season differ from results of earlier studies in tropical regions (Espinoza et al. 1991; Pastrana et al. 1991; Lundu et al. 2012). The higher concentrations in legumes than in grasses agree with the findings of Nasrullah et al. (2004) in dry land of South Sulawesi of 0.3 (*Cenchrus ciliaris*) to 4.0% (*Desmanthus virgatus*). Results of the current study showed that the range of Ca concentrations was similar to the range in the study of Pastrana et al. (1991) but lower than in other studies (Espinoza et al. 1991; Nasrullah et al. 2004; Lundu et al. 2012). Calcium concentration in the Leguminosae and Onagraceae species exceeded the 0.30% which meets the requirements of ruminants (McDowell 1997).

Phosphorus concentrations in all forages in this study were lower than the critical level for ruminants (0.25%; McDowell 1997) and fluctuated in both seasons. At the early heading stage, Nasrullah et al. (2004) reported that P concentration ranged from 0.20 [*Zea mays* subsp. *mexicana* (syn. *Euchlaena mexicana*)] to 1.80% (*Centrosema plumieri*) and was not significantly affected by season. A higher P concentration in rainy season than in dry season was found in highland forages on acid soils in Colombia (Pastrana et al. 1991) while Lundu et al. (2012) found in Zambia that P concentrations were higher in the hot dry season than in the wet season, ranging from 0.02 to 1.57%.

The low concentrations of Ca and P in forage in our study would be a function of acid soil conditions at this location with low availability of Ca and P for plants (Ali et al. 2014). Jumba et al. (1995) showed a significant positive correlation between soil P and herbage P, while Kanno et al. (2006) showed that soil pH related to not only grass growth and P uptake but also mycorrhizal dependency. Underwood and Suttle (1999) recommended that diets of livestock should have a Ca:P ratio in the range 1:1 to 2:1, and claimed this was more important than the absolute concentration for utilization by ruminants. In our study the Ca:P ratio for individual species ranged from 0.16:1 (*E. dulcis*) to 10:1 (*U. mutica*); thus grazing livestock would have a wide range from which to select an acceptable diet. Depending on the ability to select from available pasture, grazing buffalo, especially lactating females, could suffer from a P deficiency in the diet and would benefit from P supplementation. Studies by Jones (1990) and Miller et al. (1990) described some low-cost strategies on dryland pastures for overcoming P deficiency in grazing livestock. Direct P supplementation through the use of non-protein supplementation in urea-mineral blocks may serve as a more valuable alternative.

With the exception of *E. dulcis* in the flooded season, all forages had sufficient Mg concentration for requirements of ruminants (McDowell 1997); thus buffalo consuming forages in the area are unlikely to suffer Mg deficiency. The adequacy of Mg concentration in most forages has been reported in previous studies (Nasrullah et al. 2004; Lundu et al. 2012).

Sulphur is essential for microbial protein synthesis in the rumen and its concentration in ruminant diets is important. There was wide variation between seasons and species in S concentrations in the forages examined and some species contained sufficient S to satisfy ruminant requirements for effective rumen functioning. Availability of the various species and the opportunity to select by animals would determine the need for supplementation with sulphur. Similarly, S sufficiency was found in two legume trees consumed by goats in low land of Philippines (Uemura et al. 2014).

Micro-minerals

Based on mineral requirements (McDowell 1997) concentrations of Cu, Fe, Zn and Mn in most forages in flooded pasture exceeded the critical levels for grazing ruminants in tropical regions. Very high levels of Cu were found in *N. oleracea* in the dry season and in *A. sensitiva* and *L. peploides* throughout the year, the extremely high concentration in the flooded season in the latter species being particularly remarkable. If these species formed a significant portion of the diet, Cu toxicity could possibly occur in grazing animals. The range in Cu concentration in Poaceae and Leguminosae was higher than that reported by Fariani (2008) of 5.6–10.1 ppm and 3.8–16.6 ppm in 3 species of grasses and 4 species of legumes, respectively, in dry land of South Sumatra. Cu concentration ranges reported for forages in Pakistan were 10.9–25.7 ppm (Khan et al. 2006) and in West Sumatra, Indonesia 3.8–16.6 ppm (Evitayani and Warly 2010).

The generally higher Fe concentration in most Leguminosae, Cyperaceae and Onagraceae species during the flooded season than in the dry season was probably a function of a natural dilution process and translocation of minerals to the roots as plants mature. Khan et al. (2006) also reported that all forages had higher Fe concentrations in winter than in summer with a range from 93 to 202 ppm. As in our study, Khan et al. (2006) found that Zn and Mn concentrations in all forages were above critical levels and overall concentrations were higher in winter than in summer. Similar to Cu and Fe concentrations, ranges of Zn and Mn concentrations in our study were higher than studies in dry land (Khan et al. 2006; Fariani 2008).

Our findings could probably be explained by mineral level in soils (Minson 1990; Underwood and Suttle 1999). Soil condition in the study location was characterized by low pH, low availability of Ca and P, and excessive micro-mineral solubility for plants (Waluyo et al. 2012; Ali et al. 2014). High micro-mineral concentrations in aquatic plants could be associated with the ability to accumulate these minerals in their tissues (Asikin and Thamrin 2012; Veschasit et al. 2012) and with excessive micro-mineral concentrations in soils and water, possibly caused by intensive agricultural practices. Research by Jan et al. (2011) showed that there were higher concentrations of Cu, Zn, Cr, Ni, Pb and Mn in meat and milk in contaminated areas than in control areas and concluded that consumption of the foods had significantly increased the mineral concentrations in human blood. Similar results have been reported by Skalická et al. (2005), Blanco-Penedo et al. (2006) and Miranda et al. (2009). Therefore, high concentrations of Cu, Fe and Mn in *N. oleracea*, *A. sensitiva*, *E. dulcis* and *O. rufipogon* might not only raise toxicity risks for grazing buffalo, when consumed in large amounts, but also contaminate meat and milk of buffalo when milked or slaughtered for human consumption. Hence, there is a need to further investigate the status of trace and toxic minerals in blood, liver, kidney, meat and milk of buffalo in the region.

Conclusion

Mineral concentrations of forages varied greatly between seasons on flooded pastures in South Sumatra. Concentrations of most minerals appeared adequate for the dietary needs of grazing buffalo given that the samples we collected were not whole plant samples but attempted to be similar to forage that buffalo would select. However, all forages had low P concentrations and grazing animals, especially lactating females, might suffer P deficiency in the diet, while stalled animals fed on a cut-and-carry basis would certainly suffer a deficiency. Feeding studies would be warranted to test benefits from supplementing animals with P.

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