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Mineral concentrations of fresh herbage from mixed grassland as influenced by botanical composition, harvest time and growth stage

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Abbreviations:
DM, dry matter
CP, crude protein
ADF_{OM}, acid detergent fibre
$aNDF_{OM}$, neutral detergent fibre
Ca, calcium
P, phosphorus
Mg, magnesium
K, potassium
Na, sodium
Cl, chlorine
Cu, copper
Fe, iron
Mn, manganese
Zn, zinc
Co, cobalt
Se, selenium

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ABSTRACT

The mineral concentrations in herbage from mixed grassland are variable which lead to challenging situations for animal's mineral supplementation. The aim of this study consisted in assessing macro and micro mineral concentrations in fresh herbage from mixed grassland, according to a classification method used for nutrients and nutritive values. This classification consists of six classes of botanical composition, two classes of harvest time and seven classes of growth stage. Two hundred and thirty six samples of fresh herbage from mixed grassland were collected from one experimental site during five seasons. The analysed mineral concentrations were modelled using botanical composition and harvest time as fixed effects and growth stage as linear and quadratic effects. Whereas the repeatability of the models for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sulphur (S) and copper (Cu) were similar to the ones for crude protein and fibre, the repeatability for sodium (Na), chlorine (Cl), iron (Fe) and manganese (Mn) were low. Cobalt (Co, 0.113 ± 0.173 mg/kg DM) and selenium (Se, 0.020 ± 0.022 mg/kg DM) concentrations were hardly detected. Except Fe, mineral concentrations were influenced ($P < 0.05$) by class of botanical composition. Herbage with increasing presence of grasses and thus a reduced presence of legumes and other herbaceous plants, had lower ($P < 0.05$) Ca, P, K, Cu and zinc (Zn) concentrations. Herbage with ryegrass predominance had lower ($P < 0.01$) Mg, S and Mn concentrations. Mineral concentrations, except Fe, were lower ($P < 0.05$) in the first seasonal harvest than in subsequent harvests. With increasing growth stage, P ($P < 0.05$, linear), Mg ($P < 0.001$, linear and quadratic), K ($P < 0.001$, quadratic), S ($P < 0.001$, linear) and Cu, Mn and Zn ($P < 0.001$, linear and $P < 0.05$ quadratic) concentrations progressively decreased. Sodium and Cl concentrations responded quadratically ($P < 0.05$) to the developing growth stages and Ca concentrations remained stable ($P > 0.10$). The developed models may be considered to assess reference values in order to take into account the native mineral concentrations of fresh herbage from mixed grassland when optimizing herbivore diets. This, is a contribution for improving the sustainability of mineral supplementation.

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1. Introduction

Grassland supplies a major part of the feed used by herbivores in fresh or conserved form. In numerous countries, grazing pastures or feeding freshly cut herbage is of common practice during the vegetation period. Herbage contains minerals essential to livestock, but their concentrations are influenced by climatic, soil and agronomic factors leading to challenging situations for animal's mineral supplementation. Mineral supplementation consists in providing the necessary minerals not covered by native contents in herbage and other feeds. An excessive dietary mineral supply may lead to mineral accumulations in soils, when using manure fertilizers (Öborn et al., 2008; Flisch et al., 2009). For certain minerals, such as P, Cu or Zn such increased soil concentrations can affect important microbial processes (Giller et al., 1998, 2009) and increase the risk of environmental water pollution (Römkens et al., 2008). An excessive mineral supply also increases feed costs and may lead to metabolic deficiencies of other minerals by antagonistic effects (Suttle, 2010). An insufficient mineral supply may lead to physiological dysfunctions (Suttle, 2010). An efficient and sustainable mineral supplementation therefore requires a good knowledge of native mineral concentrations in herbage and their influencing factors within a given geographic area.

Analyzing fresh herbage for its mineral concentrations is not common in practice. Thus, there is a need for reference values for mineral concentrations, as they exist for other major nutrients such as absorbable protein or net energy. Reference values for nutrient concentrations in herbage from fresh mixed grassland can be organized according to botanical composition, harvest time (first seasonal harvest and subsequent harvests) and growth stage to cover the main influencing agronomic factors. Concentrations of several macro and micro minerals in forage species either grown alone or in mixed grassland were determined according to botanical composition (Hasler and Besson, 1972; Kessler and Jolidon, 1998; Stünzi, 1998; Daccord et al., 2001; Pirhofer-Walzl et al., 2011; Lindström et al., 2012, 2014), harvest time (Daccord et al., 2001; Wyss and Kessler 2002; Govasmark et al., 2005a,b; Pirhofer-Walzl et al., 2011) or growth stage (Kirchgessner et al., 1968; Stünzi, 1973; Casler et al., 1987; Brink et al., 2006; Nordheim-Viken et al., 2009). However, little is known regarding the importance of the combined effects of botanical composition, harvest time and growth stage in fresh mixed herbage, especially regarding micro mineral concentrations.

The aim of this study was to assess the concentrations of essential macro and micro minerals in fresh herbage from mixed grassland as influenced by botanical composition, harvest time and growth stage. This classification methodology for mixed grassland herbage described by Agroscope (2015a) was developed in the 1970's and is similar to the ones recommended in Germany (Jentsch et al., 2003) and France (Beaumont et al., 2011).

2. Material and methods

2.1. Experimental site, climate and soil characteristics

Fresh herbage samples were collected on the experimental farm of Agroscope in Posieux, Switzerland (46°46′N, 07°06′E, 650 m a. s. l.). The experimental farm is located on a cambisol soil type, known to be agriculturally highly productive and covering 12% of the European soils (EC, 2005). According to ten soil analyses from 2014, the sandy-loam soil contained 158 ± 12 g/kg clay, 293 ± 22 g/kg silt and 525 ± 35 g/kg sand and had a pH of 6.8 ± 0.3. Mean ammonium acetate EDTA extractable P, Mg and K in soils were 66 ± 21, 159 ± 68 and 139 ± 47 mg/kg, respectively. The herbage plots were fertilized over the vegetation period with up to 180 kg N, 44 kg P and 195 kg K per hectare and year according to their yield, mainly in the form of mixed liquid bovine and porcine manure and of ammonium nitrate. The swards originated from multi-species mixtures including seeds of *Lolium perenne, Poa pratensis, Dactylis glomerata, Phleum pratense, Festuca rubra, Trifolium repens* and *Trifolium pratense* and herbage growth was measured regularly (Agroscope, 2015b). Within the vegetation period (beginning of April–end-October), the mean temperature at 2 m above ground was 9.7, 13.4, 16.6, 18.0, 17.8, 14.1 and 11.9 °C during the respective months and the mean monthly rainfall was 89 ± 49 mm.

2.2. Sampling procedures and characterisation of herbage

Two hundred thirty six fresh herbage samples were collected in 2008–2011 and in 2014 on the experimental farm. A sample contained approx. 1 kg freshmatter and consisted in pooled subsamples systematically cut at a stubble height of 60–80 mm using a battery grass shearer (Gardena, Husqvarna Schweiz AG, Mägenwil, Switzerland). Subsamples were either collected at intervals of 20 m over the two diagonals of a selected plot (3.0 ha, two thirds of the samples) or collected within a fenced surface (10 × 5 m) inside a selected plot to follow the growth stages within the same harvest (one third of the samples). The class of botanical composition and growth stage were visually evaluated during the sampling procedure according to Agroscope (2015a). A second sample was taken in 72% of the sampling procedures to determine the proportional fresh weight of each botanical group (forage grass with distinction of ryegrass, legume, and other herbaceous plants). The classes of botanical composition depend on the presence of the botanical groups: grass rich (**G**, >70% grass; $\mathbf{G}_R$, >70% grass with more than half as ryegrass), equilibrated (**E**, 50–70% grass; $\mathbf{E}_R$, 50–70% grass with more than half as ryegrass) and rich in other herbaceous plants (**H**, >50% other herbaceous plants with thin leaves). The harvest time is distinguished between 1st seasonal harvest (**1st**) and subsequent harvests **(+2nd**). The classes of growth stage are the following: **1** (tillering), **2**