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ORIGINAL ARTICLE

Effect of sewage water on mineral nutritive potential of six fodder species grown under semiarid conditions

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Abstract Investigation was performed to assess the effect of different sewage water treatments on the metal status of different fodder species consumed by ruminants under semi-arid conditions. Five samples each of six fodder species viz., *Trifolium alexandrinum*, *Cichorium intybus*, *Avena sativa*, *Medicago polymorpha*, *Brassica campestris* and *Medicago sativa* were collected from three fields irrigated with canal water, mix water (canal water and sewage water) and sewage water, respectively. Fodder samples were analyzed to determine the Mg, Co and Zn concentrations in shoots. Higher values of these metals were found in fodder species irrigated with sewage water relatively. Mg and

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Zn concentrations in all the fodder species were found to be below the critical level among all treatments. Whereas, concentrations of Co in the different fodder species were significantly different (*$p < 0.05$*) and above the critical level. Consequently, ruminants feeding on these fodder species need continued mineral supplementation of Zn and Mg elements to prevent diseases caused by the deficiency of these elements, and to support optimum animal productivity.

1. Introduction

The increasing demand for water in the arid and semi-arid areas of the world has resulted in the emergence of sewage water application for agriculture and landscape. Although treated sewage water in agricultural irrigation can provide more adequate supply of minerals to the plants, but the heavy metal present in sewage water must be regulated to ensure no physiological problems for both the plant and its consumer. Despite of the importance of sewage water for agricultural production due to nutrient recycling, it also contains varying amount of potentially harmful substances that may cause diseases (Al-Yemeni et al., 2011a). There are many diseases and abnormalities that are associated either with mineral deficiencies or with heavy metal toxicity. Due to industrial revolution heavy metal pollution has been increased many folds (McGrath et al., 1997; Ahmad et al., 2008; Al-Yemeni et al., 2011a). Hydrological properties of the soil are especially sensitive to wastewater compounds, elements concentration in the soils is reflected to some extent on the dry matter of the associated plants (Baker and Brooks, 1989; Al-Yemeni et al., 2011a,b).

Mineral concentrations among fodder species vary widely and are also affected by soil, climatic factors, water treatment, fertilizer application, plant growth stage and plant parts (Alyemeni and Alhelal, 2003). The variable metal binding capacity of the soil and immobilization of the metallic ions in the soil are responsible for uneven distribution of the metals in the soil (Usman et al., 2005). Plants take up only soluble and potentially exchangeable mineral fractions from the soil (Adriano, 1986). One of the important reasons for low livestock production and reproduction is mineral deficiencies or imbalances in soils and forages (McDowell, 1985). Animals take major proportion of minerals from plants that are important for their growth, reproduction, health and proper functioning of the body (McDowell, 1992).

Sargodha is an agricultural and industrial district of Pakistan. The vast fields in the district have allowed the farmers to develop a range of crops and animal breeding programs. The main livestock of this district include goats, sheep, buffaloes, and cattle and livestock depends on the fodders grown in fields although irrigated with sewage water. Little is known about the effect of sewage water on the mineral nutritive potential of fodder in this region of Pakistan despite its importance in livestock production and very little has been done to establish levels of minerals of these feed resources (Khan et al., 2006).

Keeping in view of the importance of elements like Mg, Zn and Co obtained from various forages and fodders by grazing livestock and the effect of sewage water on these mineral concentrations in fodder species, the present study was initiated to assess the critical values below which deficiency or above which toxicity of the elements take place. The information gathered could be useful for successful management of grazing livestock and fodder cultivation with similar ecological conditions where fodders are the main source of mineral nutrition for animals.

2. Materials and methods

2.1. Description of experimental site

The district Sargodha lies between longitudes 71° 37′ and 73° 18′ E and latitudes of 31° 32′ and 32°′ 44′ N. It is the 10th largest city of Pakistan and an important agricultural trade center. The district receives on the average 180 mm to 200 mm rainfall and classified under semi-arid region. The city has extremely hot and cold climate. Experimental site was representative of the natural agricultural fields of district Sargodha near Tehsil Municipal Administration sewage water disposal pump. The fields are located 13 km from the center of the Sargodha city and these fields were irrigated with water discharge from disposal pump.

2.2. Samples collection

Six different fodder species: *Trifolium alexandrinum* (F1), *Cichorium intybus* (F2), *Avena sativa* (F3), *Medicago polymorpha* (F4), *Brassica campestris* (F5), and *Medicago sativa* (F6) were collected from three different fields irrigated with water differing in canal, viz; (T0) canal water, (T1) sewage water and (T2) mix water (canal and sewage water), respectively. Five samples of each fodder species were collected randomly from five different places in the field as described by Fick et al. (1979).

2.3. Pre treatment

The shoot samples were washed under running tap water using sieve. The fresh samples were then weighed and kept in labeled sealed paper bags and placed for drying in an oven at 80 °C for 3 days. Dried samples of shoot of different fodder species were ground into a fine powder using a commercial blender (TSK-West point, France) and stored in polyethylene bags, until used for acid digestion.

2.4. Digestion of the samples

The samples were than digested by the ‘‘wet digestion method’’. One gram fodder sample was taken in a flask and digested with 2 ml of H_2SO_4 and 4 ml of H_2O_2 and placed in digestion block for 30 min. The samples were removed from the digestion block when the fumes stopped evaporating from the flask. Then 2 ml of H_2O_2 was added and heated again by placing it in digestion block. The process was repeated till the sample became colorless. This digested material was removed from the digestion block and diluted with double distilled water to make its volume 50 ml, and stored in labeled polyethylene bottles. An atomic absorption spectrophotometer (put the name of AAS) was used to determine the Mg, Co and Zn concentrations in fodders.

2.5. Statistical analysis

The obtained data were statistically analyzed and presented as mean ± SE. Split plot arrangement under randomized block design was employed for statistical analysis. The irrigation treatments were kept in main plot and fodder species were kept in sub-plot. One way analysis of variance (ANOVA) was used to determine significant difference between groups using the software SPSS ver. 18 and statistical significance was tested at 0.05 level as described by Steel et al. (1997).

3. Results

3.1. Magnesium level in fodders

The summary statistics show non-significant variation for interactive effect of irrigation and fodder species (Table 1). The Mg concentration in shoot dry weight of the fodders species ranged between 959.48 and 1027.834 mg kg^{-1} dry wt. in different treatments (T0, T1 and T2). The highest value for Mg concentration (Fig. 1) was found in fodder F5 (*B. campestris*) in sewage water of treatment (T1), while fodder F3 (*A. sativa*) possessed the lower value for Mg concentration in case of sewage water treatment (T1). Fodders F1 (*T. alexandrinum*), F2 (*C. intybus*) and F4 (*M. polymorpha*) showed gradual decrease in Mg concentration with respect to all treatments (Fig. 1).

3.2. Cobalt level in fodders

Significant variations ($p < 0.05$) exist for different fodder species grown under three irrigation treatments (Table 1). The concentration of Co in dry shoot of different fodder species ranged between 0.252 and 1.5 mg kg^{-1} dry wt. The highest values of Co concentration was observed in fodder F4 (*M. polymorpha)* irrigated with canal water (T0) irrigation and fodder F5 (*B. campestris*) recorded the least Co concentration in treatment T2 (canal and sewage water) as presented in Fig. 2.

3.3. Zinc level in fodders

The zinc concentrations in dry shoots of different fodders ranged between 10.884 and 31.702 mg kg^{-1} dry wt. Different fodder species were found to be statistically different ($p < 0.05$) for their shoot Zn concentrations (Table 1). The highest value of zinc concentration (991.47 mg kg^{-1} dry wt.) was in fodder F1 (*T. alexandrinum*) and the least value was observed in fodder F6 (*M. sativa*) when irrigated with canal water (T0) and canal + sewage water (T2) as presented (Fig. 3). In treatment T0 (canal water), zinc concentrations in shoot dry weight of all fodder species was observed to be the maximum and then decreased in case of treatments T1 and T2. Fodders F4 (*M. polymorpha*), F5 (*B. campestris*) and F6 (*M. sativa*) also showed gradual decrease in zinc concentration in addition to fodder F1 (*T. alexandrinum*) with respect to the three treatments (Fig. 3).

4. Discussion

Values of Mg concentration in this study were lower than the Mg values reported by Bukhsh et al. (2007). The Mg concentrations in shoot of the fodder species observed were lower than the values reported by Khan et al. (2008) in Pakistan. Mg concentrations in shoot found in our study were below the critical values reported by NRC (1984). So, Mg-fertilizers must be used to meet the requirements of grazing livestock in the studied fields as Mg is an important constituent of chlorophyll (Ahmad et al., 2010). One of the reasons for low concentration of Mg in fodder species found in our study was that the magnesium level in the fodders available to ruminants is significantly affected by other minerals, especially K. High K and N concentration in soil will inhibit magnesium absorption from the soil (Dua and Care, 1995). As the studied fodders were collected during the winter season (low temperature) and magnesium uptake from the soil is affected by low temperature therefore the fodder magnesium concentration will be low causing deficiency. Calcium, magnesium, soil cations concentrations and soil pH affect their uptake by plants (Skerman and Riveros, 1990).

Fodders *T. alexandrinum* (F1), *C. intybus* (F2), and *M. polymorpha* (F4), showed gradual decrease in Co concentration in the three treatments (T0, T1 and T2) as shown (Fig. 2). Khan et al. (2009) reported higher values of Co concentration in fodders in Pakistan than the values observed in the present investigation. Co concentration in the present study was higher than the critical values reported by NRC (2000). So there is no need of Co supplementation to the soil. Under grazing conditions lambs are the most sensitive to Co deficiency, followed by mature sheep, calves, and mature cattle (McDowell, 2003; McDowell and Arthington, 2005), but as the Co level in our study is below the toxic level suggested by NRC (1980), there is no potential threat for the grazing livestock feeding on these fodders. The Co concentration in the present study was lower than the findings of the Kubota (1964). Co level in present investigation was higher than the level of Co found by Rahim et al. (2008).

The observed values of Zn concentration in shoot dry weight of the fodder species were lower than the values of Zn reported by Chaney (1990). Fodders Zn concentrations

Table 1 Summary statistics of Mg, Co and Zn concentrations of six fodder species grown under different irrigation treatments.

SOV	df	Mg			Co			Zn		
		MS	*F*-ratio	*P*-value	MS	*F*-ratio	*P*-value	MS	*F*-ratio	*P*-value
Irrigation (I)	2	292.150	1.99	0.1991	1.17561	4.27	0.0547	103.67	0.23	0.7981
Fodder (F)	5	223.607	1.32	0.2682	0.83500	5.09	0.0006	5765.82	16.85	0.0000
I × F	10	109.488	0.65	0.7686	0.30861	1.88	0.0658	249.60	0.73	0.6938

SOV = Source of variation; df = Degree of freedom; MS = Mean sum of square.

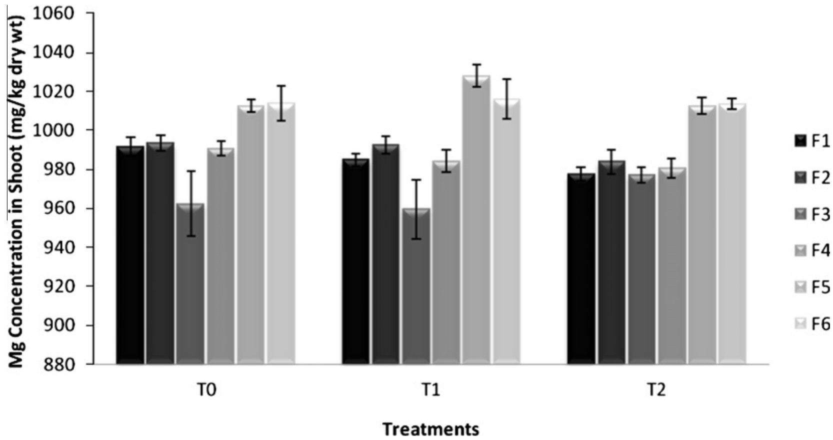

Figure 1 Magnesium concentrations in different fodder grown at different treatments [Note: The bars represent the standard error (±SE)]. T0 = Canal water; T1 = Sewage water; T2 = Mix (canal + sewage) F1 = *Trifolium alexandrinum*; F2 = *Cichorium intybus*; F3 = *Avena sativa*; F4 = *Medicago polymorpha*; F5 = *Brassica campestris* and F6 = *Medicago sativa*.

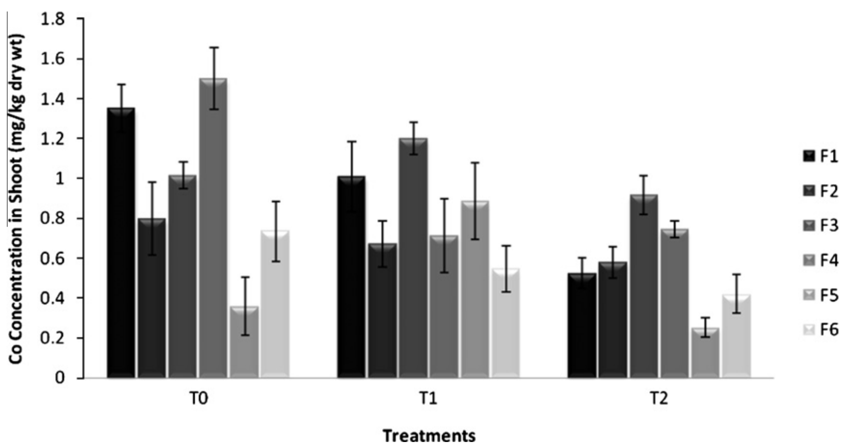

Figure 2 Cobalt concentrations in different fodder grown at different treatments [Note: The bars represent the standard error (±SE)]. T0 = Canal water; T1 = Sewage water; T2 = Mix (canal + sewage) F1 = *Trifolium alexandrinum*; F2 = *Cichorium intybus*; F3 = *Avena sativa*; F4 = *Medicago polymorpha*; F5 = *Brassica campestris* and F6 = *Medicago sativa*.

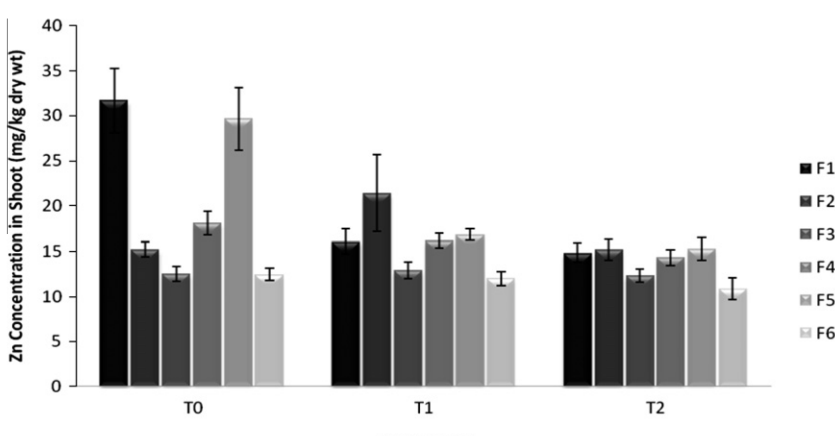

Figure 3 Zinc concentrations in different fodder grown at different treatments [Note: The bars represent the standard error (±SE)]. T0 = Canal water; T1 = Sewage water; T2 = Mix (canal + sewage) F1 = *Trifolium alexandrinum*; F2 = *Cichorium intybus*; F3 = *Avena sativa*; F4 = *Medicago polymorpha*; F5 = *Brassica campestris* and F6 = *Medicago sativa*.

during present investigation were found to be similar with the findings of Sultan et al. (2008) in Pakistan. High level of Zn was found in our investigation from the Zn level already reported by Rahim et al. (2008). Fodders *C. intybus*, *A. sativa*, *M. polymorpha*, *B. campestris*, and *M. sativa* exhibited deficiency in Zn concentration based on dietary requirement of

30 mg kg^{-1} suggested by McDowell et al. (1982). So, there is a need of proper supplementation to meet the requirements of Zn. As Zn concentrations were below the toxic level suggested by Kubota (1964), so there was no potential threat for Zn toxicity in the ruminants consuming these fodders (Farmer and Farmer, 2000).

5. Conclusions

Based on fodder analyses for the reported minerals, the supplementation may be needed for grazing ruminants under semi-arid conditions. The present findings may serve the guidelines for other Asian countries or of similar ecological conditions in the world. The levels of Mg and Zn in all fodders species and treatments were below the critical levels. Whereas, Co levels in different fodder species were above the critical level. The mineral supplementation (Zn and Mg elements) may be given to prevent diseases caused by the deficiency of these elements, and to support optimum animal productivity. Similar information may be very fruitful for understanding the physiology and metabolism of different elements.

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