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ORIGINAL PAPER

## THE K:(Ca+Mg) RATIO IN MEADOW SWARD IRRIGATED WITH WASTEWATER\*

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### ABSTRACT

The aim of this study was to determine the content of potassium (K), calcium (Ca) and magnesium (Mg), and the K:(Ca+Mg) ratio in meadow sward irrigated with potato starch and brewery wastewater. The experiment was conducted in the center for wastewater treatment and use in Kupiski-Jednaczewo (approx. 600 ha), which has been equipped with facilities for sprinkler irrigation with wastewater since 1992. Samples of meadow sward were collected for chemical analyses in 1998, 2003, 2008 and 2013. Potato starch and brewery effluents were mixed in a storage reservoir at a ratio of 1:0.4. Meadow sward was irrigated with wastewater in autumn and after the first harvest, at an annual dose of 200-300 mm. On average, wastewater contained (mg dm<sup>-3</sup>): N – 223, P – 48, K – 285, Ca – 80, Mg – 46, Na – 68. The floristic classification based on the percentage of dominant species (more than 20% in the sward) revealed the following meadow communities: Fr+Ao – *Festuca rubra* + *Anthoxanthum odoratum*, Ap – *Alopecurus pratensis*, Ae – *Arrhenatherum elatius*, Pha+Gm – *Phalaris arundinacea* + *Glyceria maxima*, Dg+Fr – *Dactylis glomerata* + *Festuca rubra*, Pp+Dg – *Poa pratensis* + *Dactylis glomerata*. The Fr+Ao community developed in the control treatment without irrigation. Meadow sward irrigated with wastewater was characterized by high K content and Mg deficiency, whereas the K:(Ca+Mg) ratio exceeded the recommended upper limit for high-quality fodder. In general, the analyzed floristic types of meadow communities did not differ significantly in their chemical composition, with the exception of the Pha+Gm community, which was characterized by the significantly lowest Mg concentration. The average K content of meadow sward ranged from 18.1 (Fr+Ao) to 36.0 g kg<sup>-1</sup> (Ae); the average Ca content ranged from 4.68 (Pp+Dg) to 6.45 g kg<sup>-1</sup> (Fr+Ao); the average Mg content varied from 1.05 (Pha+Gm) to 1.50 g kg<sup>-1</sup> (Fr+Ao and Pp+Dg), and the K:(Ca+Mg) ratio ranged from 1.04 (Fr+Ao) to 2.64 (Ap).

**Keywords:** meadow irrigation with wastewater, potassium, calcium, magnesium, K:(Ca+Mg).

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## INTRODUCTION

Food processing and agricultural wastewater contains many valuable minerals, and therefore it can be used as fertilizer and soil amendment. Effluents from the potato starch (WANG et al. 2007, SINGH, SWAMI 2014) and brewing industries (NYILIMBABAZI et al. 2011, SENTHILRAJA et al. 2013) are also used for agricultural purposes, particularly in grasslands. The chemical composition of green forage has to be closely monitored since meadow sward is composed of numerous plant species with different nutrient content (ACAR et al. 2009, PIRHOFFER-WALZL et al. 2011, GRZEGORCZYK et al. 2013, YOSHIHARA et al. 2013). The concentrations and mutual proportions of minerals in feed are key factors in animal nutrition (ZHAO, MÜLLER 2015). The K:(Ca+Mg) ratio deserves special attention as it becomes imbalanced in response to Mg deficiency and K excess (CHERNEY et al. 2002, AYDIN, UZUN 2008, GAO et al. 2016, HEJCMAN et al. 2016). The aim of this study was to determine the content of potassium (K), calcium (Ca) and magnesium (Mg), and the K:(Ca+Mg) ratio in meadow sward irrigated with potato starch and brewery wastewater.

## MATERIALS AND METHODS

The experiment was conducted in the center for wastewater treatment and use in Kupiski-Jednaczewo (approx. 600 ha), which has been equipped with facilities for sprinkler irrigation with wastewater since 1992. Potato starch and brewery effluents were mixed in a storage reservoir at a ratio of 1:0.4. Meadow sward was irrigated with wastewater in autumn and after the first harvest, at an annual dose of 200-300 mm. On average, wastewater contained (mg dm<sup>-3</sup>): N – 223, P – 48, K – 285, Ca – 80, Mg – 46, Na – 68.

In 1998, 2003, 2008 and 2013, before the first harvest, samples of meadow sward were collected for chemical analyses from characteristic phytocenoses of different floristic types. The floristic classification based on the percentage of dominant species (more than 20% in the sward) revealed the following meadow communities:

- Fr+Ao – *Festuca rubra* + *Anthoxanthum odoratum*
- Ap – *Alopecurus pratensis*
- Ae – *Arrhenatherum elatius*
- Pha+Gm – *Phalaris arundinacea* + *Glyceria maxima*
- Dg+Fr – *Dactylis glomerata* + *Festuca rubra*
- Pp+Dg – *Poa pratensis* + *Dactylis glomerata*

The Fr+Ao community developed in the control treatment without irrigation, whereas the remaining communities developed in treatments irrigated with wastewater.

The chemical analyses of plant material were conducted by standard methods. The nutrient content of meadow sward was expressed on a dry matter basis. Statistical analyses were performed using Statistica 13 software.

## RESULTS AND DISCUSSION

The average K content of meadow sward ranged from 18.1 (Fr+Ao) to 36.0 g kg<sup>-1</sup> (Ae). In the control treatment (without irrigation), where the meadow community was dominated by *Festuca rubra* and *Anthoxanthum odoratum*, the K content was significantly lower than in irrigated treatments. Significant differences in the K content were also noted between communities that developed in response to irrigation with wastewater. The potassium content was lower in the Pp+Dg community than in Ap, Ae and Dg+Fr communities (Figure 1). The high K concentration in meadow

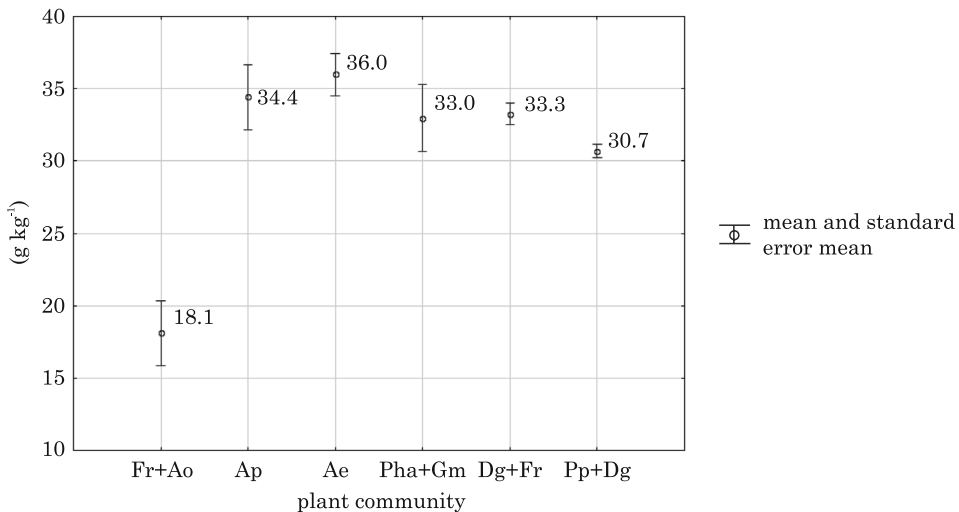


Fig. 1. Potassium content of meadow sward (means and 95.00 confidence interval)

sward resulted from K supply with wastewater and excessive K uptake by grasses (ACAR et al. 2009, KUMAR, SONI 2014). According to WILKINSON, MAYLAND (1997), a K concentration exceeding 30 g kg<sup>-1</sup> poses a threat to animal health. It should be noted that potato processing wastewater has a high K content (WANG et.al. 2007). In the present study, K deficiency in soil observed in the unfertilized control treatment without irrigation contributed to the development of a community of low-quality grasses dominated by *Festuca rubra* and *Anthoxanthum odoratum*. In this community, the K content was half the one noted in meadow sward irrigated with wastewater.

ACAR et al. (2009), who investigated various grass species, demonstrated that *Festuca rubra* was characterized by the lowest K content.

Significant differences were also found in the Ca content of meadow sward (Figure 2) between treatments. The highest average Ca content

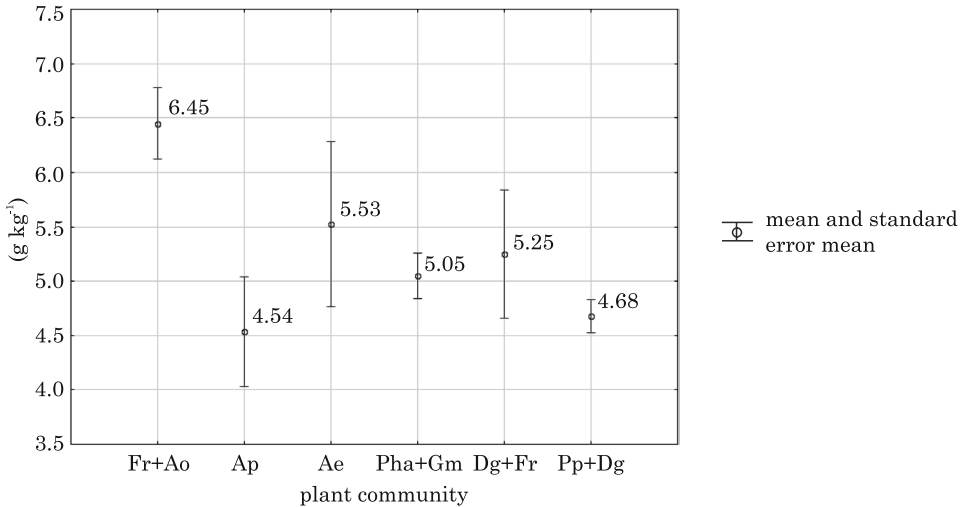


Fig. 2. Calcium content of meadow sward (means and 95.00 confidence interval)

(6.45 g kg<sup>-1</sup>) was noted in the Fr+Ao community (control treatment without irrigation). In general, plant communities irrigated with wastewater accumulated significantly lower amounts of Ca. In each case, average Ca content exceeded the lower threshold value of 2.8 g kg<sup>-1</sup> recommended for cattle feed, as well as the value of 4 g kg<sup>-1</sup> cited by WILKINSON AND MAYLAND (1997). Thus, the fodder made of the analyzed grasses contained adequate amounts of Ca to meet the requirements of cattle.

The lowest average Mg content (1.05 g kg<sup>-1</sup>) was observed in the meadow community dominated by *Phalaris arundinacea* and *Glyceria maxima* (Figure 3). In the remaining communities, the Mg concentration was significantly higher, and no significant differences were found between the treatments. In the analyzed plant communities, the average Mg content did not exceed 2 g kg<sup>-1</sup> which is typical of high-quality feed for livestock (GRUNES, WELCH 1989). A low Mg concentration in plant communities with *Glyceria maxima* as the dominant species was also reported by WESOŁOWSKI et al. (2016).

The K:(Ca+Mg) ratio in meadow sward varied widely (Figure 4). Its lowest value (1.04) was noted in the Fr+Ao community where wastewater irrigation was not applied. The K:(Ca+Mg) ratio was significantly higher in irrigated treatments, ranging from 2.20 (Pp+Dg) to 2.64 (Ap). The difference between the extreme values was statistically significant. In high-quality cattle feed, the K:(Ca+Mg) ratio should not be higher than 2.2 (ACAR et al. 2009, GRZEGORCZYK et al. 2013, GAO et al. 2016). In the present study, mead-

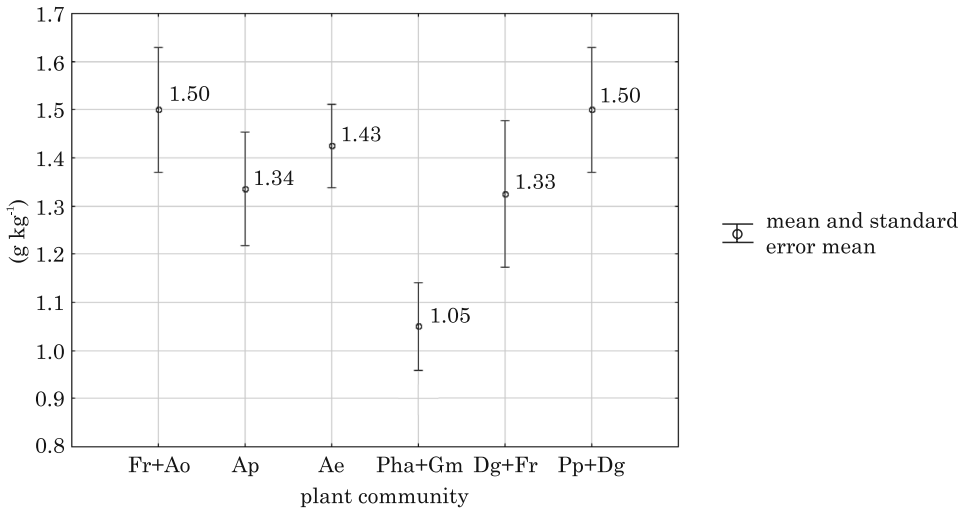


Fig. 3. Magnesium content of meadow sward (means and 95.00 confidence interval)

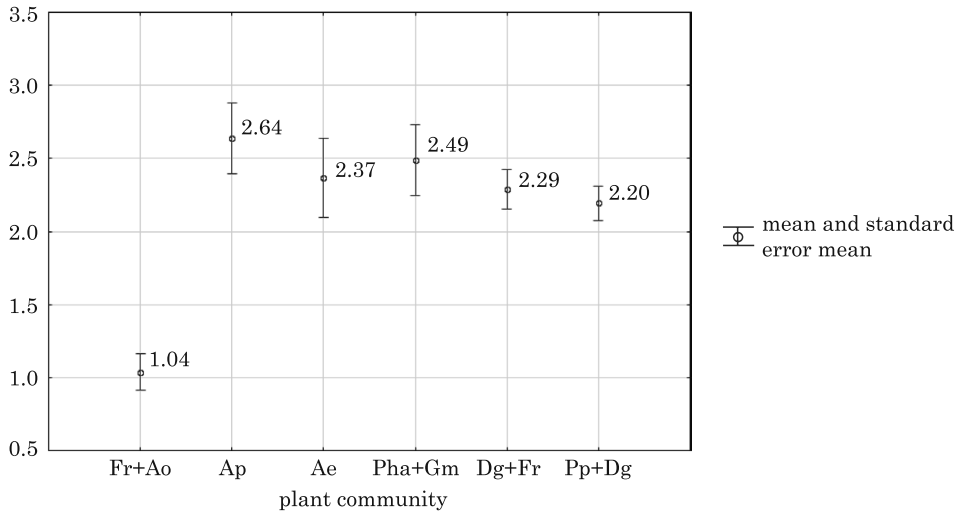


Fig. 4. K:(Ca+Mg) ratio in meadow sward (means and 95.00 confidence interval)

ow irrigation with wastewater contributed to exceeding the above threshold value, mostly due to the fact that wastewater supplied large amounts of K, which led to excessive K uptake by grasses (KUMAR, SONI 2014). An undesirable K:(Ca+Mg) ratio resulting from Mg deficiency and K excess in feed has been reported by numerous authors (CHERNEY et al. 2002, AYDIN, UZUN 2008, HEJCMAN et al. 2016).

## CONCLUSIONS

1. Meadow sward irrigated with wastewater was characterized by excessively high K content, high Ca content and Mg deficiency. As a result, the K:(Ca+Mg) ratio exceeded the recommended upper limit for high-quality fodder.

2. In general, the analyzed floristic types of meadow communities irrigated with wastewater did not differ significantly in their chemical composition, with the exception of the Pha+Gm community, which was characterized by the significantly lowest Mg concentration.

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