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Research Article

THE FERTILIZATION EFFECT OF PERMANENT MEADOWS WITH SPENT MUSHROM SUBSTRATE ON THE UPTAKING OF MANGANESE, COPPER AND ZINC BY THE MEADOW SWARD

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ABSTRACT

The study was conducted in the years 1999–2001 in a meadow with the following fertilizer combinations: control object (without fertilizer), NPK mineral fertilization, fertilizing with manure, manure with NPK fertilization, fertilizing with spent mushroom substrate; spent mushroom substrate with NPK fertilization. The aim of the study was to determine the effect of permanent grassland fertilization both with spent mushroom substrate and the one supplemented with NPK on the uptaking of manganese, copper and zinc by the meadow sward. After the cultivation of mushrooms, in comparison to the standard manure, the substrate used in the experiment was characterized by more than twice higher amount of manganese and zinc. However, the amount of copper in the organic materials was similar. In spite of having supplied lager amount of manganese, zinc and similar amount of copper to the mushrooms substrate, it caused the reduction of the uptake of the elements in the meadow sward. In spite of supplying larger amounts of manganese, zinc and copper the reduction of their uptaking by meadow sward was observed in comparison to manure mushroom substrate. This may be connected with a slightly alkaline reaction of the soil environment, thus limiting the uptake of the studied micronutrients.

Key words: spent mushroom substrate (SMS), farmyard manure (FYM), manganese, copper, zinc, uptaking, permanent meadow.

INTRODUCTION

With regard to large share of light soils in arable lands, conducting proper management of organic matter in soils is a major task in Poland. Organic fertilization of grasslands has always been used less frequently than mineral fertilization.

Because of the scarce natural fertilization resulting from limited production of manure, there is a strong need to look for new ways to increase the content of organic matter in soils. Improving the balance of organic matter in soils can be achieved through the use of waste organic materials, including the cultivation of mushroom substrate [Anon 2003; Kalembasa, Wiśniewska 2004, 2006; Jankowski et al. 2004, 2005; Ciepiela et al. 2007; Kolczarek et al. 2008].

According to the Decree of Minister of Environment as of 27 September 2001 the substrate from the production of mushroom is included in a group of wastes in agriculture, horticulture, aquaculture, forestry, hunting and food processing as “other unspecified wastes” [Regulation ... 2001]. The annual amount of this waste in Poland amounts to about 1500 tons. The waste caused some problems for mushroom producers because mushroom houses, usually act in isolation from agricultural lands and do not have the possibility of waste disposal on their own [Rutkowska 2009].

Jordan et al. [2008] reported that the used SMS was characterized by: a high content of organic matter, assimiliable forms of nutrients, neutral reaction, the preferred C : N ratio, and a low heavy metal content. The differentiation of the chemical composition of the spent mushroom substrate is determined by its manufacturing technology and the size of mushroom yield.

Maszkiewicz [2010], Briton [2001] and Hogg et al. [2002] reported that the content of trace elements in the SMS, including heavy metals, amounted to the following respectively ($g \cdot t^{-1}$): manganese – 118, copper – 15, zinc – 86. Kalembasa and Wiśniewska [2001], having examined the SMS, found out that it contains significant amounts of micronutrients, which predisposes this waste organic material for use in fertilization and recultivation, especially in case of light soils.

The amounts of heavy metals in the waste substrates usually do not exceed the amounts allowed for use in agricultural fertilization. Chemical properties of SMS allow for using this waste in agriculture to fertilize arable lands and permanent grasslands, in horticulture, and in the establishment and maintenance of green areas [Kalembasa, Wiśniewska 2004, 2006; Rak et. al. 2001; Jankowski et al. 2012a, 2012b, 2012c, 2012d].

The aim of this study was to evaluate the impact of a permanent grassland fertilization with mushroom compost and the one minerally supplemented on the uptake of manganese, copper and zinc by the meadow sward.

MATERIAL AND METHODS

The experiment was established in spring 1999 by randomized block design with four replications on a permanent meadow. Plots of 9 m^2 area (1.5×6 m) were separated by 1-meter wide paths. The paths and the edge of the experiment were mowed several times per year in order to maintain a low sward. The experiment was located on the ground soil-proper glial formed from loamy sand on the silty medium clay.

The humus level of the tested soil was slightly alkaline both in KCl and H_2O, and was characterized by a high content of nitrogen, manganese and iron, average content of magnesium and a very low content of phosphorus and potassium.

The object of the study was the organic fertilization of the meadow sward applied on the background of mineral fertilization. During the study the following fertilizing objects were highlighted: a control object (without fertilizer), NPK mineral fertilization, fertilizing with manure, manure with NPK fertilization, fertilizing with SMS; SMS with NPK fertilization. The fertilization with manure and with SMS was used once in early spring 1999 in the amount of 10 $t \cdot ha^{-1}$ of fresh weight. The mineral fertilizers were used in each year of the study, nitrogen at a dose of 180 $kg \cdot ha^{-1}$ (ammonium nitrate), phosphorus – 48 $kg \cdot ha^{-1}$ (TSP), potassium – 125 $kg \cdot ha^{-1}$ (potassium salt). The annual amount of nitrogen and potassium was divided into three equal parts for each regrowth, but phosphorus was used once in the spring.

In each growing season, three cuts were collected. Immediately after the cutting, the sward from each plot was weighed to determine the yield. 0.5 kg sample of green matter was collected to determine the dry coefficient and perform chemical analyzes on the contents of Mn, Cu and Zn by atomic absorption spectrometry.

On the basis of the collected yield, stated in earlier Jankowski's et al. publication (2004), and the content of Mn, Cu and Zn given by Jankowski et al. [2005] the uptaking of the elements was calculated. The obtained results were evaluated statistically using the analysis of variance. The calculations were performed using Statistica software and medium comparisons were made using Tukey's test at the significance level $\alpha \leq 0.05$.

According to the meteorological station in Zawady in the growing seasons (April – September) the average air temperatures amounted to 16.5 °C (average of long years 12.5 °C) and total precipitation amounted to 16.5 mm which was about 66.7 mm higher in comparison to long years.

RESULTS AND DISCUSSION

The study results show that the content of microelements in the organic materials varied (Table 1). The amount of manganese and zinc applied into the soil from the spent mushroom substrate (2.80 and 7.30 $kg \cdot ha^{-1}$ respectively) was twice as high in comparison to the manure (respectively 1.20 and 2.40 $kg \cdot ha^{-1}$), while the amount of copper introduced in both materials (0.50 and 0.40 $kg \cdot ha^{-1}$) was comparable.

Table 1. The quantity of Mn, Cu and Zn (kg) applied to the soil with a dose of 10 $t \cdot ha^{-1}$ of fresh matter

Organic material	Mn	Cu	Zn
	$kg \cdot 10\ t^{-1}$		
FYM	1.20	0.50	2.40
SMS	2.80	0.40	7.30

Jordan et al. [2008] reported that the SMS characterized by a high content of nutrients_belonging to the microelements and low heavy metal content. Due to the suitable chemical properties of the substrate Wuest et al. [1991] and Salomez et al. [2009] recommend the use of this material in the fertilization of cultivated plants.

Thanks to the positive effect of mushroom substrate on soil properties and plants, yielding as much as 72% of this waste (still practiced in Ireland) is used as natural manure [Maher et al. 2000].

The quantity of microelements in the soil introduced with SMS corresponds to the values estimated in this waste by Kalembasa and Wiśniewska [2001], Kalembasa and Wiśniewska [2008].

The statistical analysis showed significant differences in manganese uptaking (Table 2) depending on the fertilization. With regard to the kind of fertilization applied, it turned out that the uptaking of this micronutrient stated in the sward from the objects fertilized with manure (437.9 g $\cdot ha^{-1}$) was higher than the one with the SMS (389.2 g $\cdot ha^{-1}$). A similar dependence, but significantly higher values, was observed in the sward collected from the objects fertilized with the studied organic materials including NPK. The manganese uptake in the meadow sward from the object fertilized with manure and NPK was 686.1 g $\cdot ha^{-1}$, while in case of the object fertilized with SMS and NPK – 628.6 g $\cdot ha^{-1}$.

By comparing the amount of manganese in the obtained feed with the amount given by Falkowski, et al. [2000], we can consider the contents of the micronutrient in the obtained yield as optimum. The manganese uptake by the meadow sward from the objects fertilized with organic and with mineral fertilization NPK, was 3–4 times higher than the uptake of this microelement by the sward from the control object.

It has been reported more manganese uptake by the meadow sward from the object fertilized only with mineral, in comparison to uptake of this component by grasses from objects fertilized only with organic materials, like manure and waste after the mushrooms production. It was stated that larger manganese uptake by the meadow sward from the object fertilized with NPK, thought it did not introduce to soil any amount of this microelement in compare to organic fertilization. This can be probably explained by the pH reduction of the soil solution caused by the impact of mineral fertilizers, what consequently increased the uptake of tested micronutrient by the meadow sward.

Copper uptake by the meadow sward (Table 3) was significantly different depending on the fertilizer applied.

Table 2. Manganese uptaking (g $\cdot ha^{-1}$) by meadow sward organically and minerally fertilized in three-years experiment

Fertilization object	Study years			Mean for years
	I	II	III	
Control object	170.3	179.6	123.8	157.9
NPK	467.6	680.2	455.5	534.4
FYM	359.3	526.2	428.4	437.9
FYM + NPK	587.9	569.2	901.3	686.1
SMS	364.8	329.7	473.1	389.2
SMS + NPK	470.8	665.5	749.5	628.6
Mean	394.0	476.7	491.5	454.1

LSD $\alpha \leq 0.05$ for combination 369.2; for years n.s.

Table 3. Copper uptaking (g $\cdot ha^{-1}$) by meadow sward fertilized organically and minerally in three-year experiment

Fertilization object	Study years			Mean for years
	I	II	III	
Control object	47.7	36.0	30.6	38.1
NPK	86.2	81.7	87.6	85.2
FYM	73.9	83.0	67.7	74.9
FYM + NPK	120.1	92.2	113.1	108.4
SMS	76.9	68.4	72.5	72.6
SMS + NPK	118.9	87.1	110.2	105.4
Mean	86.3	74.8	79.7	80.3

LSD $\alpha \leq 0{,}05$ for combination 32,2; for years n.s.

Similar to manganese uptake, the larger copper uptake was observed in the meadow sward where only manure was used (74.9 g $\cdot$ ha^{-1}) and manure with NPK (108.4 g $\cdot$ ha^{-1}) than in the sward fertilized only with SMS (72.6 g $\cdot$ ha^{-1}) and supplemented with NPK (105.4 g $\cdot$ ha^{-1}).

The amounts of copper in the obtained feed are similar to the quantities reported by Falkowski, et al. [2000], who stated that 10 mg $\cdot$ kg^{-1} D.M. is a sufficient amount.

In case of copper uptake, the same dependence as in case of manganese was observed. In comparison to the control object, higher amount of manganese was taken up by the meadow sward from the object fertilized only with SMS, SMS additionally supplemented with NPK as well as manure with and without NPK. Mineral NPK fertilization resulted in higher copper uptake than fertilization with SMS alone or with manure.

Zinc uptake varied depending on the applied fertilizer (Table 4). In case of the objects fertilized only organically, higher amount of the studied microelement was taken up by the sward fertilized with manure (79.8 g $\cdot$ ha^{-1}) than in the object where SMS was used (60.9 g $\cdot$ ha^{-1}). A similar trend was observed on objects fertilized both organically and with mineral fertilization. The sward fertilized with manure and NPK (164.1 g $\cdot$ha^{-1}), has taken up more zinc than the sward fertilized with SMS with NPK (147.1 g $\cdot$ha^{-1}). Comparing the amount of zinc in the obtained feed with the amount given by Falkowski, et al. [2000] as well as Kruczyńska and Kujawa [1994], it is should be noticed that the content of this micronutrient in the obtained yield was extremely deficient.

The zinc uptake in the meadow sward from the objects fertilized with organic and mineral fertilizers NPK, was larger than the uptake of this microelement by the sward from the control object. Zinc uptake by meadow sward from object fertilized only with mineral in comparison to the uptake of this component by plants from the objects fertilized only with SMS or manure. The zinc uptake increased in the meadow sward fertilized with NPK in comparison to the organic fertilization of the sward.

According to Czuba [1996] improving the crop of the sward, achievable especially after intensive nitrogen fertilization accelerates the exhaust of micronutrients in soils. Except to the botanical composition of the sward, the biggest influence of this uptake vale has the type of organic material applied [Falkowski et al. 2000; Wyłupek 2003].

Jankowska-Huflejt's [2000], and Mazur's [2000] studies showed that the higher mineral content in different fertilizers applied to grassland the greater their accumulation in cultivated plants is.

The study results demonstrate that the use of manure both with and without NPK resulted in a greater uptake of the investigated microelements by the meadow sward in relation to the objects SMS only and minerally completed NPK were used. Although double amount of manganese and zinc with SMS was applied neither SMS waste nor mineral supplemented one influenced the uptake of the micronutrients. The results and the calculations indicate a decrease in the uptake of manganese, copper and zinc in the meadow sward on objects with SMS in relation to those with manure applied.

Despite having applied a double amount of microelements a smaller uptake of investigated microelements was noted. This can probably result from the soil reaction which was slightly alkaline, thus it did not favor the uptake of the microelements. A larger uptake of manganese in the

Table 4. Zinc uptake (g $\cdot$ ha^{-1}) by meadow sward fertilized organically and minerally in three-year experiment

Fertilization object	Study years			Mean for years
	I	II	III	
Control object	40.3	28.6	32.3	33.7
NPK	93.9	126.0	111.9	110.6
FYM	78.9	58.8	101.6	79.8
FYM+ NPK	210.5	84.6	197.2	164.1
SMS	64.9	52.5	65.4	60.9
SMS + NPK	113.3	130.2	198.7	147.4
Mean	94.3	77.6	109.9	93.9

LSD $\alpha \leq 0,05$ for combination 110,8; for years n.s.

meadow sward from the objects fertilized only with manure was due to the secretion of carbon dioxide during the mineralization of this fertilizer in the soil, what resulted in the soil acidification. Spent mushroom substrate did not cause soil acidification as its decompose is usually less intense due to the narrower C:N ratio, and a neutral or slightly alkaline nature of the waste.

According to Czuba [1996] and Domański [1999], conducting rational grassland one should not ignore the role of micronutrients, as the quality of forage depends on that as well. Trace elements are needed for plants in small amounts but are absolutely fundamental for their proper growth and development. They are also desperately needed for animal organisms [Kruczyńska, Kujawa 1994; Brzóska 2008].

The study shows that the amount of zinc taken up by the meadow sward fertilized only with organic and mineral were extremely scarce, and the amount of manganese and copper fluctuated in lower limits of the standards.

The study shows that regardless of the content of the microelements in the applied organic materials, there are sometimes situations justifying the use of micronutrient fertilizers. Neutral or alkaline pH of the soil environment as well as the use of organic materials may limit the uptake of most microelements by the meadow sward. The use of mineral fertilizers with microelement, especially the foliar one, guarantees the proper uptake of microelements needed for the meadow sward.

CONCLUSIONS

1. The spent mushroom substrate after the cultivation of mushrooms used in the experiment compared to the standard manure was characterized by more than twice abundance of manganese and zinc, however, the amount of copper in both organic materials was similar.
2. The obtained results clearly show that high amount of microelements introduced in organic materials may not be taken up by the meadow sward, what justifies the use of mineral micronutrient fertilizers. Although larger amounts of manganese and zinc were applied to the soil, the spend mushroom substrate resulted in a decrease of the uptake of microelements.

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