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The effect of organic extracts on the microelements content in selected species of forage grasses

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Highlights
- Interaction between organic extract type, harvest and year on microelement content.
- Changes in sum of microelements content depend on the grass species.
- Changes in sum of microelements content depend on the organic extract fertilisation.

Abstract: The aim of the study was to determine the effect of soil fertilising biopreparations, i.e. compost extract, vermicompost extract and humus extract, used against the background of NPK mineral fertilisation, on the content of manganese, iron, zinc and copper in the biomass of *Lolium perenne*, *Festulolium braunii*, and *Dactylis glomerata.* In the spring of 2019 and 2020, a single dose of the biological preparation was applied. During each vegetation period, the plants were mown three times. During mowing, fresh plant mass was taken from each plot, dried, ground and the content of Cu, Zc, Mn and Fe was determined using the ICP-AES method. The use of a biological preparation with the composition of an extract from compost significantly increased the content of Mn, Fe and Zn in the dry mass of the tested grass species. The grass species that accumulated the highest total content of microelements in its above-ground parts was *Lolium perenne*. The use of only biological preparations in the cultivation of the analysed grass species gave better production effects, for example in the form of a higher concentration of microelements in the dry mass of plants compared to objects fed only with minerals. This creates the possibility of using the tested biopreparations in organic farms. The Fe:Mn ionic ratio was too wide in relation to the standards on all experimental objects, which resulted from the excess of Fe in the plants. Only the combination of compost extract with mineral fertilisation narrowed the above relationship, but it was still too high.

Keywords: biopreparate, *Dactylis glomerata*, *Festulolium braunii*, *Lolium perenne*, soil conditioner

INTRODUCTION

Microelements perform functions in plants related to their metabolism. Microelement deficiency causes an imbalance in biochemical processes, but in too large amounts they become toxic (Hari Babu and Savithramma, 2014). What is important is the fact that some microelements, in the presence of certain fertiliser ingredients, transform into forms that are difficult to access for plants.

Manganese participates in many processes occurring in plants. It participates in respiration, photosynthesis and nitrogen metabolism (Radkowski and Nicia, 2009). The phytoavailability of manganese depends on the soil reaction; manganese is taken up from an alkaline soil solution in much smaller amounts than from an acidic soil solution (Spiak, 2000). Iron, like manganese, performs many important physiological functions in plants, it participates in photosynthesis, respiration, and additionally influences the development of chloroplasts and the process of cell division (Graziano and Lamattina, 2005). Copper is a unique microelement because it cannot be replaced by any other. This element is necessary for the growth and development of plants, it affects the chlorophyll content, the photosynthesis process and water relations in the plant (Olszewska *et al.*, 2008). According to Kuziemska *et al.* (2021) copper is an element necessary for the proper growth and development of plants, but when taken in excess it may be toxic. Its availability for plants can be reduced by using organic fertilisers or soil liming. Moreover, according to Ostrowska, Gawliński and Szczubiałka (1991), copper stimulates plant flowering, carbon and nitrogen metabolism, and leaf structure. Zinc, like other microelements, is an ingredient necessary for the growth and development of plants (Lombnaes and Singh, 2003). It is found in various enzymes. Its deficiency causes disruption of processes related to carbohydrate and protein metabolism. The content of available forms of zinc depends on the pH, sorption capacity of the soil and redox potential of the soil, as well as the content of organic carbon (Clark and Baligar, 2003; Murawska, Spychaj-Fabisiak and Długosz, 2006). Animal feed with the optimal content of nutrients such as iron, copper, zinc and manganese plays an important role for the living organisms fed on it, as it is responsible for metabolism at the cellular level (Jamroz, 2001).

There are many biological preparations on the market whose positive impact on the qualitative composition and quantity of feed from permanent grasslands has been proven in the literature (Truba *et al.*, 2018; Truba *et al.*, 2020; Sosnowski, Truba and Jarecka, 2022a). There are also reports that some preparations have biologically optimised the content of macro- and microelements in various plant species, and knowledge about their impact on plants is still being supplemented in the literature (Godlewska and Ciepiela, 2016; Sosnowski, Truba and Jarecka, 2022b). However, there is currently no information on the impact of substances such as compost extract, vermicompost extract and humus extract, which are the basis of many biological preparations, on the accumulation of microelements in valuable fodder grass species.

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There are many biological preparations on the market whose positive impact on the qualitative composition and quantity of feed from permanent grasslands has been proven in the literature (Truba *et al.*, 2018; Truba *et al.*, 2020; Sosnowski, Truba and Jarecka, 2022a). There are also reports that some preparations have biologically optimised the content of macro- and microelements in various plant species, and knowledge about their impact on plants is still being supplemented in the literature (Godlewska and Ciepiela, 2016; Sosnowski, Truba and Jarecka, 2022b). According to the literature, the use of humus extract and compost has a beneficial effect on the condition of grass (Espíndola-Gonzalez *et al.*, 2014; Deskoy, Merwad and Ibrahim, 2019). Compost extract supports the growth and development of grass (Mlalazi, Chimuka and Simatele, 2024). In addition, plants fertilised with compost and compost extract were rich in micro- and macroelements, in particular B, Fe, Cu, Zn, Ca, K, S (Michalak, Tuhy and Chojnacka, 2016). However, there is currently no information on the influence of substances such as compost extract, vermicompost extract and humus extract on the accumulation of microelements in valuable species of forage grasses in the temperate climate zone.

The aim of the study was to determine the effect of soil fertilising biopreparations, i.e. compost extract (trade name UGmax), vermicompost extract (trade name Eko-Użyźniacz) and humus extract (trade name Humus Active Papka), used against the background of NPK mineral fertilisation, on the content of Mn and Fe, Zn and Cu in the biomass of *Lolium perenne*, *Festulolium braunii*, and *Dactylis glomerata*. The research hypothesis is that the use of biopreparations will allow for the optimisation of the content of the tested microelements in plants, thus improving the quality of feed for ruminants. Such a solution could be one of the solutions for use in organic farming. Secondly, the use of biological preparations in combination with mineral fertilisation will bring better results than mineral fertilisation alone in terms of optimising microelements in the tested grasses. Such a solution would increase the potential of fertilisation used in integrated farming.

MATERIALS AND METHODS

STUDY SITE AND RESEARCH METHODS

The experiment was set up in the autumn of 2018 in the experimental field at the University in Siedlce. With a split-plot arrangement, the experimental units were plots of 4 m^2 and combination of factors in three replicates. The years of the study were the growing seasons of 2019 and 2020. In each year of the research, three harvests were made.

Before starting the experiment, soil samples were collected and analysed at the National Chemical-Agricultural Station (Pol.: Stacja Chemiczno-Rolnicza) in Warsaw. The tested soil is characterised by very high phosphorus – 0.79 $g \cdot kg^{-1}$ DM, potassium – 1.06 $g \cdot kg^{-1}$ DM and magnesium – 1.26 $g \cdot kg^{-1}$ DM. In addition, soil analysis showed high iron – 4,546.7 $mg \cdot kg^{-1}$ DM and copper – 5.8 $mg \cdot kg^{-1}$ DM content and average manganese 152.5 $mg \cdot kg^{-1}$ DM and zinc 14.3 $mg \cdot kg^{-1}$ DM content. The content of total N was determined by the Kiejdahl method and was 1.25 $g \cdot kg^{-1}$ DM. The C_{org} content by the oxidation-titration method was 12.3 $g \cdot kg^{-1}$ DM. The P content was determined by the colorimetric method. Total content of Ca, Na, K, Mg, Fe, Mn, Cu, Zn – were determined by the ASA method. According Polish soil classification (PTG, 2019), the soil used in the experiment was the Hortic Anthrosols, developed from sandy sediments, with pH 0.01M $CaCl_2$ of 6.60.

The following research factors were used in experiment. The first was a grass species: *Festulolium braunii* var. Sulino, *Datylis glomerata* var. Bora and *Lolium perenne* var. Info. The grasses were sown in single-species sowing. The second factor consisted of biopreparations with the following composition: compost extract (CE), vermicompost extract (VE) and humus extract (HE) with the composition presented in the study by Sosnowski *et al.* (2022a). Each of the biopreparations was used separately and in combination with mineral fertilisation (NPK). The biopreparations used in the experiment were approved for use by the Institute of Soil Science and Plant Cultivation (Pol.: Instytut

Uprawy Nawożenia i Gleboznawstwa – Państwowy Instytut Badawczy) in Puławy on organic farms. The obtained research results were compared for individual years and harvests.

In the autumn of 2018, grass species were sown according to the sowing norm. Then, in the spring of 2019 and 2020, a single dose of the biological preparation was applied in the amount of: compost extract (trade name UGmax) – 0.6 $dm^3 \cdot ha^{-1}$, vermicompost extract (trade name Eko-Użyźniacz – 15.0 $dm^3 \cdot ha^{-1}$, humus extract (trade name Humus Active Papka) – 5.0 $dm^3 \cdot ha^{-1}$. The biopreparations were dissolved in water according to the manufacturer's guidelines and, as a solution, were applied to the experimental plots by spraying both soil and grasses.

Mineral nitrogen, phosphorus, and potassium (NPK) fertilisers were used at the following doses: N – 150, P (P_2O_5) – 80, K (K_2O) – 120 $kg \cdot ha^{-1}$. Phosphorus mineral fertiliser was applied once in the spring, while nitrogen and potassium doses were split into three equal parts: the first before the growing season and second and third after the first and second harvests.

During each vegetation period, the plants were harvested three times, depending on the growth phase of the plants, these were similar dates, i.e. the second half of May, July and September. During mowing, fresh plant mass was taken from each plot and dried. Plant samples have been prepared and analysed in laboratory at University in Siedlce. The total content of Cu, Zn, Mn and Fe was determined by the ICP-AES method after dry mineralisation in a muffle furnace at a temperature of 450°C.

The climate of Siedlce and its surroundings is transitional and is shaped by the influence of continental (from the east) and oceanic (from the west) air masses. The lack of major orographic barriers facilitates their flow both in the meridional and latitudinal systems. The results of climate analyses (CLIMCITIES, 2017) indicate a systematic warming of the climate of the city and its surroundings, as indicated, among other things, by the increasing trend in the average annual air temperature. In Siedlce, the annual total rainfall and the number of days with moderate rainfall increased. Precipitation and temperature data (Fig. 1) were obtained from The meteorological station in Siedlce. Hydrothermal conditions during the experiment were variable. Very low precipitation in April and October 2019 and 2020

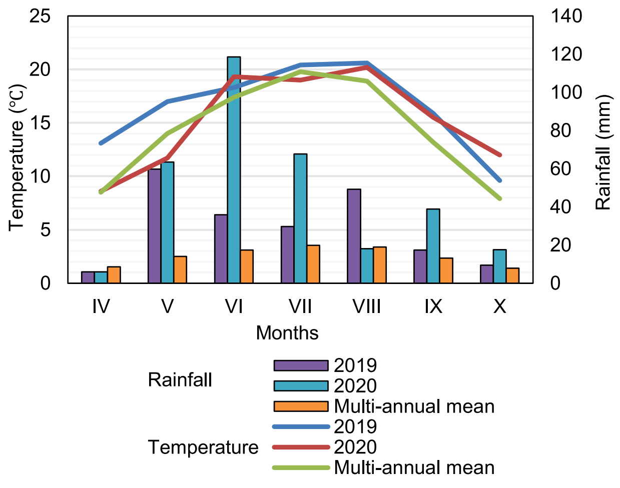

Fig. 1. Average monthly air temperature (°C) and monthly total precipitation (mm); source: own elaboration

could have delayed the start of the growing season and shortened the vegetation period of plants. Average monthly air temperatures in 2019 were higher than the multi-year average. In turn, 2020 was characterised by low temperatures in spring and high temperatures in the second half of the growing season.

STATISTICAL ANALYSES

The research results were statistically analysed using multivariate analysis of variance. The analysis of variance included two research factors: grass species and type of fertilisation. Verification of the significance of experimental factor impact on tested characteristics was done with the Fisher–Snedecor test, and the Tukey's test was used to evaluate differences between means. The data were analysed at the significance level of $p < 0.05$. The calculations were done with the Statistica 13.1 Program.

RESULTS AND DISCUSSION

In the experimental objects, content of manganese ranged from 14.3 to 18.7 $mg \cdot kg^{-1}$. The highest Mn content was found in the dry mass of *Dactylis glomerata* and *Lolium perenne*, while *Festulolium braunii* contained about 8% less of this element (Fig. 2a). Analysing individual objects in terms of Mn content, it was found that the plants in objects supplied with vermikompost extract had the most of this microelement, while the control objects had the least – the difference was about 24% (Tab. 1). Manganese appeared in the highest concentration in the dry mass of plants in the first year of the study. Then its content decreased by 17% in the following year. There was no difference in Mn content in individual sets, it ranged from 16.4 to 17.3 $mg \cdot kg^{-1}$. According to Hari Babu and Savithramma (2014), the sufficient concentration of Mn in the plant for its growth should be at least 50 $mg \cdot kg^{-1}$. According to the nutritional standard for ruminants (Strzetelski and Śliwiński, 2009), the minimum requirement for Mn is 45 $mg \cdot kg^{-1}$. Obtained results indicates significant deficiencies of this element in the dry mass of plants. Such a low Mn content does not cover the animals' demand for this element and during the summer feeding period may lead to deficiency symptoms in cattle. Manganese deficiency causes, among other things, weakened growth, changes in bones, reproductive disorders, lack of movement coordination (Patorczyk-Pytlik and Skoczyński 2004). Studies by Styrczula and Możdżer (2014) showed that the use of exogenous organic matter in the form of compost significantly increased the Mn content in the dry mass of *Lolium perenne*. This may be due to the acidic reaction (expressed as pH values) of exogenous organic matter, which lowered the soil pH and increased the amount and absorption of manganese ions by plants.

Analysing individual grass species, it was shown that the plant material from *Lolium perenne* was richest in iron, in the biomass of *Festulolium braunii* there was 19% less of this element and in *Lolium perenne* as much as 35% less (Fig. 2b). In the case of iron, the largest amount of this element was contained in the dry matter of plants from the site fertilised with vermicompost extract (258.82 $mg \cdot kg^{-1}$) and humus extract (203.98 $mg \cdot kg^{-1}$). In the remaining objects, its concentration in biomass was significantly lower (Tab. 1). Humus extract is the only one that contains iron (500 $mg \cdot kg^{-1}$), which may be the reason for the

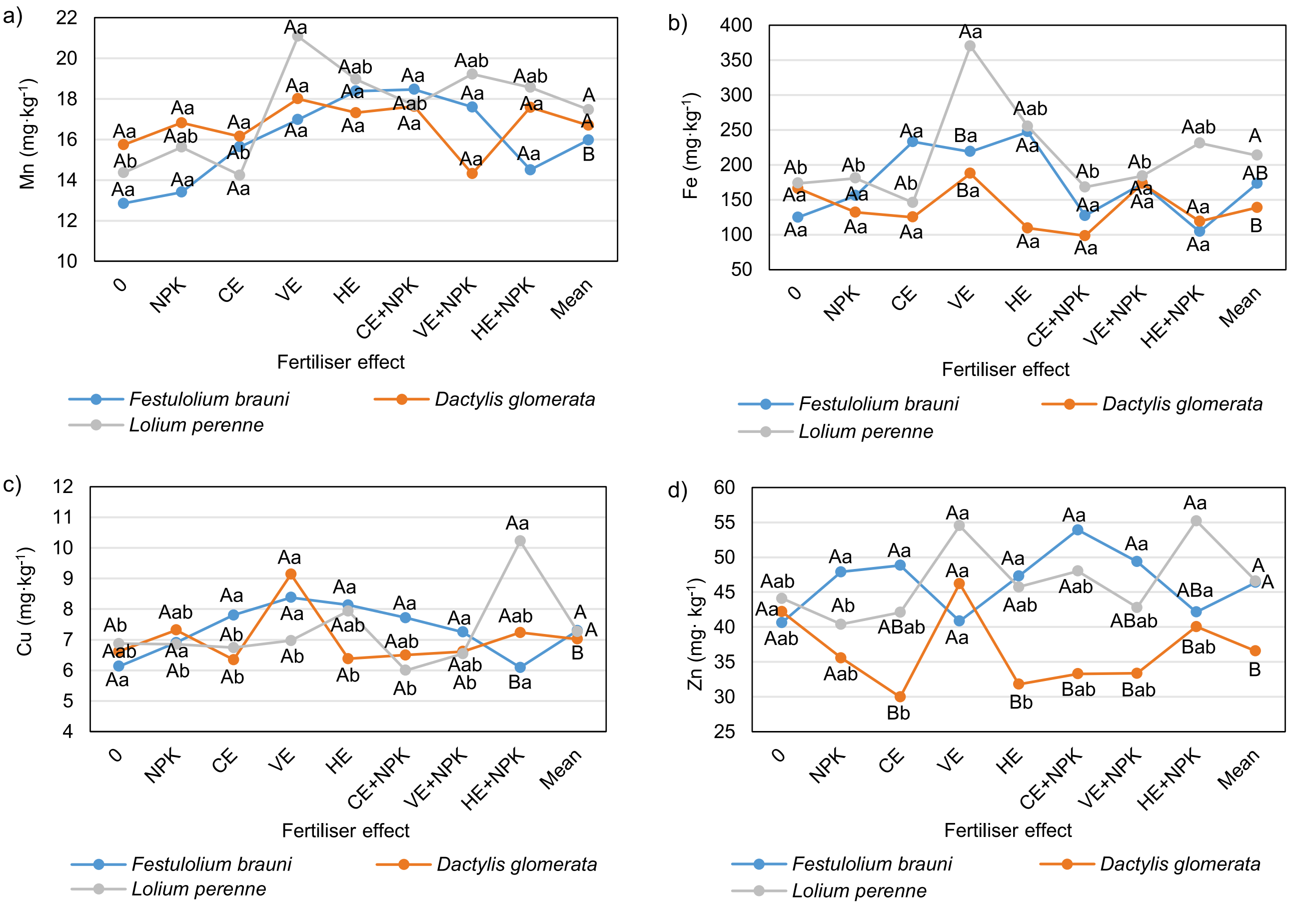

Fig. 2. Microelement content in the biomass of grass species due to different fertilisation for: a) manganese, b) iron, c) cooper, d) zinc; CE = compost extract, VE = vermicompost extract, HE = humus extract; means for grasses marked with the same small letters do not differ significantly; means for treatment marked with the same capital letters do not differ significantly; source: own study

high content of this microelement in the crops fertilised with it. In the case of vermicompost extract, where the preparation did not contain this microelement, the plants could be supported by the microorganisms contained in it, which made this element available to the plants during the mineralisation process. Plants contained the most Fe in the first growing season (2019), which was approximately 19% more than in the following year. Considering the Fe content of plants in individual cuts, it should be stated that the first and second cuts had this trace element more by approximately 10%, but this difference was not statistically significant.

According to Ostrowska, Gawliński and Szczubiałka (1991), *Dactylis glomerata* contains 29–54 mg·kg^{-1} of Fe in dry matter. The standard of cattle feeding states that the optimal Fe content

Table 1. Average content of Mn, Fe (mg·kg^{-1}) and Mn:Fe ratio in plant biomass for species in the years of study and individual cuts

Year/Cut	Fertiliser effect								Mean
	0	NPK	CE	VE	HE	CE + NPK	VE + NPK	HE + NPK	
Manganese									
2019	14.644^{Ab} ±3.733	16.211^{Ab} ±3.284	17.589^{Ab} ±2.540	22.322^{Aa} ±5.339	19.433^{Aab} ±6.225	19.933^{Aab} ±6.684	16.767^{Ab} ±5.506	19.200^{Aab} ±3.950	18.262^{A}
2020	13.987^{Aab} ±3.108	14.344^{Aab} ±3.228	13.092^{Bb} ±4.214	14.054^{Bab} ±4.687	17.011^{Aab} ±5.987	15.922^{Aab} ±3.749	17.322^{Aa} ±4.514	14.567^{Bab} ±2.963	15.163^{B}
I	16.200^{Aab} ±6.557	15.967^{Aab} ±6.116	14.925^{Ab} ±6.815	16.417^{Aab} ±7.598	20.033^{Aab} ±9.480	15.450^{Aab} ±6.352	20.900^{Aa} ±9.287	18.217^{Aab} ±7.838	17.264^{A}
II	13.030^{Ab} ±3.942	13.350^{Ab} ±4.009	13.693^{Ab} ±3.311	20.798^{Aa} ±8.329	19.733^{Aa} ±8.065	18.150^{Aab} ±4.106	16.333^{ABab} ±4.848	16.783^{Aab} ±5.414	16.484^{A}
III	13.717^{Ab} ±3.355	16.517^{Aab} ±3.875	17.403^{Aab} ±4.838	18.850^{Aab} ±5.354	14.900^{Aab} ±2.793	20.183^{Aa} ±8.566	13.900^{Bb} ±1.744	15.650^{Aab} ±3.156	16.390^{A}
Mean	14.316^{b}	15.278^{b}	15.341^{b}	18.688^{a}	18.222^{ab}	17.928^{ab}	17.044^{ab}	16.883^{ab}	

cont. Tab. 1

Year/Cut	Fertiliser effect								Mean
	0	NPK	CE	VE	HE	CE + NPK	VE + NPK	HE + NPK	
Iron									
2019	143.03 Ab ±67.946	145.21 Ab ±88.714	203.78 Aab ±104.552	313.89 Aa ±163.480	196.94 Aab ±194.531	139.10 Ab ±61.001	225.90 Aab ±157.953	179.80 Ab ±102.157	193.46 A
2020	166.57 Aa ±81.591	167.23 Aa ±87.889	132.11 Aa ±108.335	203.74 Aa ±193.924	211.02 Aa ±208.499	123.28 Aa ±82.390	127.51 Aa ±71.446	123.14 Aa ±69.188	156.83 B
I	182.93 Aab ±115.598	187.48 Aab ±112.784	139.60 Aab ±88.183	219.15 Aab ±114.263	263.15 Aa ±259.895	105.38 Ab ±61.204	213.08 Aab ±119.685	147.87 Aab ±83.112	182.33 A
II	131.02 Ab ±44.056	125.55 Ab ±36.173	138.13 Ab ±64.517	305.98 Aa ±215.301	220.37 Aab ±236.502	133.90 Ab ±62.473	209.93 Aab ±188.214	182.43 Aab ±131.971	180.91 A
III	150.45 Aa ±77.312	155.63 Aa ±118.674	226.10 Aa ±164.304	251.32 Aa ±250.914	128.43 Aa ±49.858	154.28 Aa ±102.253	107.10 Aa ±65.286	124.12 Aa ±64.668	162.18 A
Mean	154.80 b	156.22 b	167.94 b	258.82 a	203.98 ab	131.19 b	176.71 ab	151.47 b	
Iron to manganese ratio									
Mean	10.8	10.2	10.9	13.8	11.2	7.3	10.4	9.0	

Explanations: CE, VE, and HE as in Fig. 2; means in lines marked with the same small letters do not differ significantly, means in columns marked with the same capital letters do not differ significantly, 2019, 2020 = years of study, I, II, III = harvests, ± standard deviation.
Source: own study.

in feed is 50 mg·kg^{-1} (Chomyszyn, Strzetelski and Laszczka, 1998). However, this is a tolerated value in feed. In the case of feeding forage with Fe content slightly higher than the animal's needs, their excretion in faeces and urine increases. Excess iron in feed (over 800 mg·kg^{-1}) can inhibit the absorption of copper in animals and also make it difficult to absorb phosphorus (Falkowski, Kukiełka and Kozłowski, 2000). The studies carried out showed that the amount of Fe in the dry matter of plants is significantly exceeded, which may have a negative effect on the condition of plants and the content of other microelements – mainly Mn. According to Wang *et al.* (2021), Fe acted as a repressor of salt-induced leaf senescence in grasses, which is related to its antioxidant regulation abilities. According to Rios *et al.* (2023), high Fe content caused diffusion limitations in grass photosynthesis. In their studies, Godlewska and Ciepiela (2016) also noted that the Fe content in the grass species *Dactylis glomerata* and *Festulolium braunii* was at a similar level from 133.1 mg·kg^{-1} for the first species to 135.4 mg·kg^{-1} for the second species.

Iron and manganese are considered to be basic microelements necessary in animal nutrition. The obtained Fe to Mn ratios ranged from 7.3:1 to 13.8:1 (Tab. 1). The proper Fe:Mn in meadow plants is (1.5–2.5):1 (Kabata-Pendias and Pendias, 1999). All objects show too wide a ratio between these elements. The use of biological preparations most often expanded the Fe:Mn. In turn, the combination of mineral fertilisation with biopreparations narrowed this range below the value at the control site. A disturbed Fe and Mn relationship adversely affects the quality of feed. The content of Fe and Mn in plants depends on the soil's abundance of absorbable forms of these elements and is conditioned by the occurrence of antagonistic reactions between these components. The optimal supply of both Mn and Fe to plants is therefore related and takes place in similar oxidation-reduction and soil moisture conditions (Patorczyk-Pytlik and Skoczyliński, 2004). In the Fe:Mn above 2.5:1, both excess Fe and Mn deficiency symptoms are harmful (Kabata-Pendias and Pendias, 1999). Significant differences in copper content were observed between individual plant species (Fig. 2c). The greatest amount of this element was in the biomass of *Festulolium braunii*, and the least in *Dactylis glomerata* (difference of approx. 5%). The Cu content in plants at individual sites varied greatly. The plants fed with vermicompost extract contained the greatest amount of this element, and the control plant contained the least – a difference of 20% (Tab. 2). Over the years of research, it was observed that plants contained the most Cu in the first growing season (2019), in the following year they were 28% lower in this element. The variation in Cu content in phytomass is also visible at harvest dates during the growing season. The most Cu contained feed from the last harvest, and the least from the first – a difference of approximately 21%. In the research by Czyżyk (2009), higher doses of compost only increased the content of this element in the first cut, and then in the biomass from the second cut they were lower and amounted to 2–4 mg·kg^{-1}. Research results by Olszewska *et al.* (2008) indicate that Cu deficiency significantly reduced the rate of photosynthesis and transpiration, the concentration of chlorophyll in leaves and the yield of species such as *Dactylis glomerata* and *Lolium perenne*. According to Strzetelski and Śliwiński (2009), the Cu content in grasses intended for fodder purposes should be up to 10 mg·kg^{-1} DM. The obtained test results are within the upper limits of the values mentioned above. These values are characteristic of the natural environment and do not indicate contamination with this element. According to Kuziemska *et al.* (2021), increasing Cu doses increased its content and uptake by the tested plant, while decreasing the value of the bioaccumulation coefficient. In turn, organic soil amendments, i.e. cattle manure, limited the toxic effect of Cu in *Dactylis glomerata*.

The feed obtained from *Festulolium braunii* and *Lolium perenne* turned out to be the richest in zinc, while *Dactylis glomerata* contained approximately 22% less of this microelement (Fig. 2d). The obtained test results did not show significant differences between the fertilisation treatments, and the Zn

Table 2. Average content of Cu and Fe (mg·kg^{-1}) in plant biomass for species in the years of study and individual cuts

Year/Cut	Fertiliser effect								Mean
	0	NPK	CE	VE	HE	CE + NPK	VE + NPK	HE + NPK	
Cooper									
2019	6.983^{Ab} ±2.581	7.638^{Ab} ±2.177	8.049^{Ab} ±2.206	10.846^{Aa} ±3.376	8.018^{Ab} ±2.110	7.531^{Ab} ±2.152	8.281^{Ab} ±1.199	9.187^{Aab} ±3.111	8.317^{A}
2020	6.098^{Aa} ±1.277	6.407^{Aa} ±1.289	5.876^{Ba} ±1.493	5.482^{Ba} ±1.177	6.946^{Aa} ±1.363	5.948^{Aa} ±0.945	5.320^{Ba} ±0.656	6.516^{Ba} ±1.436	6.074^{B}
I	5.033^{Ba} ±2.012	5.325^{Ba} ±2.159	5.707^{Aa} ±2.483	7.047^{Ba} ±4.001	6.837^{Aa} ±3.127	5.737^{Aa} ±2.253	6.403^{Aa} ±2.873	7.273^{Aa} ±3.267	6.170^{B}
II	6.182^{ABb} ±1.847	7.403^{ABab} ±2.179	7.368^{Aab} ±3.198	9.802^{Aa} ±4.804	7.928^{Aab} ±2.242	6.635^{Ab} ±1.156	7.292^{Aab} ±2.054	8.585^{Aab} ±3.855	7.650^{AB}
III	8.407^{Aa} ±1.821	8.338^{Aa} ±0.863	7.812^{Aa} ±1.026	7.643^{Aba} ±2.793	7.680^{Aa} ±1.402	7.847^{Aa} ±2.607	6.707^{Aa} ±1.839	7.695^{Aa} ±2.437	7.766^{A}
Mean	6.541^{b}	7.022^{ab}	6.962^{ab}	8.164^{a}	7.482^{ab}	6.739^{b}	6.801^{ab}	7.851^{ab}	
Zinc									
2019	47.867^{Ab} ±16.406	45.211^{Ab} ±7.197	43.733^{Ab} ±11.083	58.811^{Aa} ±15.324	43.033^{Ab} ±12.314	51.644^{Aab} ±19.190	47.489^{Ab} ±12.548	54.356^{Aab} ±8.72	49.018^{A}
2020	36.756^{Ba} ±4.581	37.356^{Aa} ±8.257	36.867^{Aa} ±9.806	35.578^{Ba} ±9.055	40.167^{Aa} ±10.938	38.500^{Ba} ±8.053	36.189^{Aa} ±10.698	37.244^{Ba} ±8.542	37.332^{B}
I	38.650^{Aa} ±15.237	42.883^{Aa} ±17.608	39.333^{Aa} ±17.130	44.567^{Aa} ±19.853	41.633^{Aa} ±19.232	43.017^{Aa} ±18.130	49.967^{Aa} ±22.878	46.917^{Aa} ±21.534	43.371^{A}
II	38.450^{Aa} ±4.521	41.367^{Aa} ±8.318	40.800^{Aa} ±11.257	45.467^{Aa} ±12.810	44.783^{Aa} ±13.121	44.950^{Aa} ±10.579	42.700^{Aba} ±10.953	47.983^{Aa} ±10.863	43.313^{A}
III	49.833^{Aab} ±20.849	39.600^{Aab} ±11.344	40.767^{Aab} ±14.027	51.550^{Aa} ±26.037	38.383^{Aab} ±11.044	47.250^{Aab} ±25.720	32.850^{Bb} ±8.700	42.500^{Aab} ±13.769	42.842^{A}
Mean	42.311^{a}	41.283^{a}	40.300^{a}	47.194^{a}	41.600^{a}	45.072^{a}	41.839^{a}	45.800^{a}	

Explanations: CE, VE, and HE as in Fig. 2; means in lines marked with the same small letters do not differ significantly, means in columns marked with the same capital letters do not differ significantly, 2019, 2020 = years of study, I, II, III = harvests, ± standard deviation.
Source: own study.

content in the plant mass ranged from 40.3 to 47.2 mg·kg^{-1} (Tab. 2). The highest amount of Zn was recorded in the dry matter of plants collected in the first year of the study, in the second year its content decreased by 24%. In turn, the Zn content in individual cuts was similar and amounted to 43.0 mg·kg^{-1} dry matter. According to Hari Babu and Savithramma (2014), 6 mg·kg^{-1} of zinc in the plant is a sufficient amount to ensure growth. According to Strzetelski and Śliwiński (2009), the Zn content in cattle feed should be about 50 mg·kg^{-1}. The obtained test results show that the dry matter of grass from all fertilisation facilities had an optimal Zn content. It is an element that, if present in large amounts in the soil, is taken up in excess by the plant and accumulated in its biomass. According to Czyżyk (2009), the concentration of Zn in grass increased with each cutting and with an increasing dose of compost.

A summary of the tested microelements for individual objects fed with organic matter alone or in combination with mineral fertilisation allowed for the assessment of the content of plant dry matter in these elements (Fig. 3). The obtained results indicate that the dry plant matter from objects fertilised with vermicompost was the richest in microelements (330 mg·kg^{-1}). The least amount of tested microelements was recorded in the biomass in control plants fertilised with minerals and after combining compost extract with NPK.

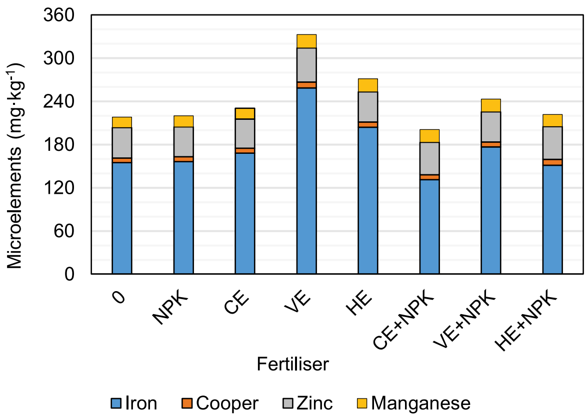

Fig. 3. Content of investigated microelements under the influence of various types of organic and mineral fertilisation; CE, VE, and HE as in Fig. 2; source: own study

The dry matter obtained from the cultivation of *Lolium perenne* (about 285 mg·kg^{-1}) turned out to be the richest in the analysed microelements, and the least – from *Dactylis glomerata* (200 mg·kg^{-1}) – Figure 4.

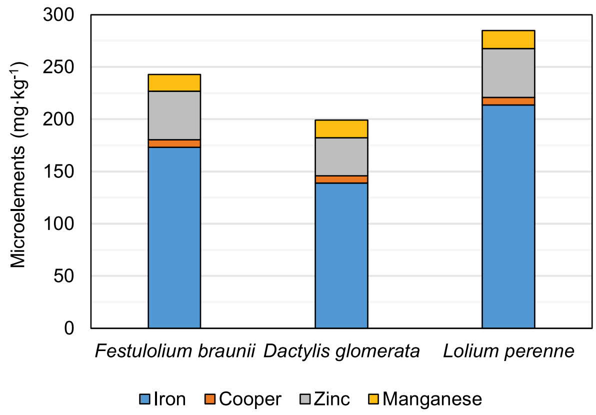

Fig. 4. The content of microelements in the dry matter of the tested grasses; source: own study

CONCLUSIONS

1. The use of vermicompost extract alone in the cultivation of the analysed grass species (*Lolium perenne*, *Festulolium braunii*, and *Dactylis glomerata*) optimised the content of manganese, copper and zinc in the dry mass of plants intended for ruminants. This creates the possibility of using the tested biopreparation on organic farms.
2. Mineral fertilisation used alone or in combination with biopreparations did not significantly contribute to improving the content of microelements in the tested grass species.
3. The grass species with the most favourable content of microelements in the biomass was *Dactylis glomerata*. This species accumulated the least iron and was characterised by the optimal content of other microelements for feed.
4. The Fe:Mn ionic ratio was too wide in relation to the standards on all experimental objects. This resulted from an excess of Fe in the soil and, consequently, also in the plants. Despite the high Fe content in the soil, the combined use of compost extract with mineral fertilisation narrowed the above relationship, but it was still too high.
5. The obtained research results indicate the possibility of using biological preparations in the cultivation of fodder grasses to improve the amount of microelements Mn, Fe, Cu and Zn, which creates scope for further scientific research.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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