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ACCUMULATION OF ZN AND CU BY CEREAL AND LEGUMINOUS VEGETATION UNDER AGROCHEMICAL IMPROVEMENT OF NATURAL FODDER LANDS OF THE RIGHT BANK FOREST STEPPE OF UKRAINE

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ABSTRACT

The article is devoted to the study of the translocation of heavy metals-trace elements (Zn, Cu) in the cereal-legume vegetation of natural fodder lands during their surface improvement (milling with the introduction of sugar-juice defecation sludge, NPK fertilizers) and root improvement (plowing the soil with the introduction of sugar-juice defecation sludge and NPK fertilizers). Based on the analysis of literary sources, it was established that as a result of man-made activities, the condition of fodder lands is deteriorating due to the ingress of toxicants, in particular, heavy metals. The research was conducted in the conditions of natural fodder grounds of the Right Bank Forest Steppe of Ukraine during 2017-2019. The determination of heavy metals in soils and plant material was carried out in the laboratory by the atomic absorption method. The hazard ratio of heavy metals in soils and biodiversity and the accumulation ratio of heavy metals were determined. It was established that in cereal and leguminous vegetation during the three years of vegetation of natural fodder lands in the zone of their local pollution due to surface improvement, the concentration of Zn increased from 1.01 times to 1.07 times, Cu - from 1.01 times to 1.02 times, while with root improvement, the concentration decreased for Zn content from 1.1 times to 1.25 times, and for Cu content - from 1.02 times to 1.55 times. At the same time, a tendency towards a decrease in the hazard coefficients and the accumulation of Zn and Cu in cereal-legume vegetation was noted with the root improvement of natural fodder soils compared to surface ones.

Keywords: heavy metals, natural fodder grounds, danger factor, accumulation factor, concentration, vegetation.

INTRODUCTION

An important link in the production of livestock products is the vegetation of natural fodder lands, which is characterized by a low cost price compared to the vegetation of cultivated lands. However, natural fodder lands in the conditions of technogenesis are subjected to a strong anthropogenic load in some territories, which leads to soil and vegetation contamination with various toxicants, in particular, heavy metals such as Pb, Cd, Zn and Cu (Razanov et al., 2020). The use of natural fodder meadows under such vegetation conditions as fodder for both domestic and wild animals increases the risk of heavy metals entering their bodies, which endangers the production of safe and high-quality products. Practical experience shows that the ecological condition of natural fodder lands deteriorates from year to year, in particular, due to their contamination with toxicants as a result of man-made activities of the population (Razanov et al., 2018). A large amount of heavy metals also enters the environment during chemical production with wastewater, in which compounds of Cd, Pb and Zn have been detected. Rapidly growing sources of environmental pollution today are motor vehicles, agricultural production and industrial waste (Venkateswarlu et al, 2016). In agricultural production, especially in crop production, mineral fertilizers are a powerful source of heavy metals entering the environment (Razanov et al., 2021).

In Ukraine, natural fodder lands cover an area of about 6.7 million hectares, about 4.6 million hectares of which are pastures, and up to 2.1 million hectares are hayfields. In the forest-steppe zone, there is about 10% of natural fodder land from the total area of agricultural land. In the conditions of the Forest-Steppe of Ukraine, natural fodder lands cover an area of about 2.1 million hectares, which is 3.4% of the total area of this natural-climatic zone. The herbage of the natural fodder lands of the Forest Steppe includes a number of plant species for fodder, medicinal, decorative, honey-bearing, technical, medicinal-food, and ethereal use. Although natural plant communities are less nutritious compared to the vegetation of cultivated pastures, however, its use is low-cost, which plays an important role in providing the population of Ukraine with food. In addition, the vegetation of natural fodder lands sharply reduces soil erosion and is one of the factors of stabilization of disturbed agricultural landscapes. Analyzing the plant phytodiversity of the natural fodder lands of the forest-steppe zone, it should be noted that the largest share is occupied by cereal crops - *Dactylis glomerata*, *Timothy*, *Bromus inermis, Arrhenatherum elatius, Poa pratensis, Agrostis stolonifera*, *Phalaris arundinacea* and others (Mudrak et al, 2018). Natural fodder grounds as a component of the natural environment are subject to constant technogenic influence from modern sources of pollution, which increases the risk of their productive use. The concern today is the increase in the entry into the soil with the subsequent inclusion in the migration chains to plants of such toxicants as cadmium, Zn and Cu, which are able to accumulate several tens of times more in the plant phytomass compared to the soil (Kasowska et al, 2018; Makarenko et al, 2020; Dursun et al, 2020). One of the sources of pollution of natural fodder lands can be their chemical, in which heavy metals enter the soil with mineral fertilizers (Bondar et al, 2019). Therefore, there is a need for constant monitoring of the intensity of vegetation pollution of natural fodder lands by heavy metals in conditions of man-made load.

MATERIALS AND METHODS

The study of the effect of surface and root improvement of natural fodder meadows on the intensity of accumulation of heavy metals involved five research options according to the scheme (Table 1).

Table 1. Scheme of research

Variant	Measures to improve natural fodder meadows
I - control	Without improving natural forage meadows
II - experiment	Disking + sugar-juice defecation sludge. + NPK
III - experiment	Milling + conventional plowing + sugar-juice defecation sludge. + NPK
IV - experiment	Milling + deep plowing + sugar-juice defecation sludge. + NPK
V - experiment	Milling + sugar-juice defecation sludge. + NPK

For agrochemical improvement, sugar-juice defecation sludge - 5 t/ha, mineral fertilizers N_{60} (ammonium nitrate), P_{45} (simple superphosphate) and K_{45} (potassium chloride) were applied to the soil of natural fodder meadow.

Sampling of soil samples for analysis was carried out by the envelope method, namely: sampling with a soil auger at the depth of soil plowing (20-25 cm) of the soil at five points during surface and root improvement of natural fodder lands, on natural meadows - without applying these measures at depth 4-5 cm and preparation of soil samples.
The determination of heavy metals in soils and plant material was carried out by the atomic absorption method. Determination of the pH of the water extract of the soil was carried out by the potentiometric method. Sampling of vegetation was carried out by mowing it in different places on areas of 1 m² at the height of animal grazing (8-10 cm) in different places of natural meadows with an average weight of 2 kg. The coefficient of danger of heavy metals in soils and biodiversity was determined by the ratio of the amount of Zn and Cu in the vegetative mass of cereal-legume vegetation to the maximum permissible concentration (MPC). The coefficient of accumulation of heavy metals in the phytomass was determined by the ratio of the amount of Zn and Cu in the vegetative mass of cereal-legume vegetation to the content of these elements in the soil.

RESULTS AND DISCUSSION

The research results showed that with the use of disking and sugar-juice defecation sludge + NPK, the concentration of Zn in cereal and legume vegetation in the first, second and third year of vegetation increased from 1.01 times to 1.07 times, respectively, compared to similar raw materials without improvement of natural fodder meadows. The concentration of Cu in cereal and leguminous vegetation increased from 1.01 times to 1.02 times during the first, second and third year of growing season, respectively, due to surface improvement of natural fodder meadows. With milling + sugar-juice defecation sludge + NPK fertilizers, the concentration of Zn in the first, second and third year of vegetation of cereal-legume vegetation was practically at the same level as the similar vegetation obtained without the use of agrochemical measures. The concentration of Cu in cereal-legume vegetation decreased by 1.02 times in the first year of vegetation, by 1.12 times in the second year, and by 1.13 times in the third year. In cereal and leguminous vegetation, with the radical improvement of natural fodder meadows (milling + conventional plowing + sugar-juice defecation sludge + NPK), the concentration of Zn in plants of the first, second and third year of vegetation decreased by 1.19 times, 1.1 and 1.11 times, respectively, compared to similar raw materials obtained without the use of these agrochemical measures. The concentration of Cu in cereal and leguminous vegetation also decreased according to these agrochemical measures: in the first year of vegetation - by 1.28 times, in the second - by 1.27 times, and in the third - by 1.37 times. With the radical improvement of natural forage lands (milling + deep plowing + sugar-juice defecation sludge + NPK), the concentration of Zn in cereal and legume vegetation in the first, second and third year of vegetation decreased by 1.25 times, 1.18 times and 1.17 times, respectively, compared to the same raw materials without the use of agrochemical measures. The research results (Table 2) show that in cereal and leguminous vegetation, on average, over three years, the concentration of Zn decreased by 1.11 times during milling, plowing of the usual application of sugar-juice defecation sludge and NPK fertilizers to the soil of natural fodder lands, and during milling, plowing of deep and the use of sugar-juice defecation sludge and NPK fertilizers – 1.17 times.

Table 2. The content of heavy metals (trace elements) in cereal-legume vegetation of natural meadows, mg/kg, on average for 2017-2019 based on absolutely dry matter, (n=4, M±m)

Measures to improve natural fodder lands	Zn	Cu
	On average in the studied territories	On average in the studied territories
Without improving natural forage meadows	20±0.07	4.5±0.09
Disking + sugar-juice defecation sludge + NPK	21±0.038	4.5±0.05
Milling + conventional plowing + sugar-juice defecation sludge + NPK	18±0.077	3.5±0.06
Milling + deep plowing + sugar-juice defecation sludge + NPK	17±0.04	3.1±0.47
Milling + sugar-juice defecation sludge + NPK	20±0.03	4.2±0.036

The concentration of Cu in cereal and leguminous phytomass decreased on average over three years of vegetation when using: milling + sugar-juice defecation sludge + NPK fertilizers by 1.07 times; for milling + conventional plowing + sugar-juice defecation sludge + NPK fertilizers by 1.3 times and by milling + deep plowing + sugar-juice defecation sludge + NPK fertilizers by 1.4 times compared to the grass stand grown without surface and root

improvement of natural forage meadows. During disking and sugar-juice defecation sludge and NPK fertilizers, the concentration of Zn in cereal and leguminous vegetation in the zone of local pollution decreased in the second and third year of vegetation, respectively, by 1.04 times and 1.3 times compared to the first year, while the concentration of Cu in cereal leguminous vegetation decreased by 1.14 times in the second year of vegetation, and by 1.02 times in the third year. During milling and application of NPK fertilizers and sugar-juice defecation sludge to the soil in cereal and leguminous plants, the concentration of Zn in the second and third year of vegetation decreased by 1.05 times and 1.05 times, respectively, compared to the first year. The concentration of Cu in cereal and leguminous vegetation according to these agrochemical measures increased in the second year of vegetation by 1.12 times and in the third by 1.12 times compared to the first. During milling, conventional plowing, application of sugar-juice defecation sludge and NPK fertilizers, the concentration of Zn in cereal and leguminous vegetation in the second and third years of vegetation was practically the same compared to the first, and Cu decreased by 1.01 times, and by 1.07 times in the third compared to the first. During milling, deep plowing, application of sugar-juice defecation sludge and NPK fertilizers, an increase in Zn in cereal and legume vegetation was observed in the second year of vegetation by 1.01 times, and in the third – a decrease by 1.03 times compared to the first year. The analysis of the hazard ratio of heavy metals (trace elements) (Table 3) showed that the ratio of Zn in cereal and leguminous vegetation after disking and application of sugar-juice defecation sludge and NPK fertilizers to the soil was 1.02 times higher, while for milling with conventional plowing, milling with deep plowing and milling against the background of application of sugar-juice defecation sludge and NPK fertilizers in all options, on the contrary, this indicator was lower by 1.13 times, 1.2 times and 1.01 times, respectively, compared to the option without the application of surface and root improvement of natural fodder meadows .

Table 3. The coefficient of danger of heavy metals (trace elements) in cereal-legume vegetation, mg/kg

Measures to improve natural fodder lands	Zn			Cu		
	2017	2018	2019	2017	2018	2019
Without improving natural forage meadows	0.43	0.41	0.4	0.15	0.15	0.15
Disking + defecation + NPK	0.46	0.41	0.40	0.096	0.084	0.094
Milling + conventional plowing + defecation + NPK	0.36	0.37	0.36	0.12	0.12	0.11
Milling + deep plowing + manure + NPK	0.34	0.34	0.34	0.1	0.1	0.1
Milling + defecation + NPK	0.42	0.40	0.40	0.15	0.13	0.13

The hazard ratio of Cu in the cereal-legume mixture for discing with NPK fertilizers, milling and conventional plowing with sugar-juice defecation sludge and NPK fertilizers, milling and deep plowing with sugar-juice defecation sludge and milling with sugar-juice defecation sludge and NPK fertilizers was lower compared to the option without surface and root plowing improvement of natural fodder meadows.

Analyzing the coefficient of accumulation of Zn (Table 4) in the variant without the use of agrotechnical and agrochemical measures, it should be noted that it varied from 1.05 to 1.22, with the use of disking + sugar-juice defecation sludge + NPK fertilizer - from 1.03 to 1.24, for milling + sugar-juice defecation sludge + NPK fertilizer - from 1.0 to 1.13; for milling, conventional and deep plowing with sugar-juice defecation sludge and NPK fertilizer - from 1.12 to 1.18 and from 1.13 to 1.18, respectively. At the same time, it should be noted that the accumulation rate of Zn decreased with increasing years of vegetation. Certain differences in the coefficient of Zn accumulation in cereal and leguminous vegetation depending on agrochemical measures were also revealed. In particular, the coefficient of accumulation of Zn in cereal and leguminous vegetation of the first year of vegetation under the surface improvement of natural fodder lands in the zone of their local contamination compared to the similar vegetative mass obtained without agrochemical measures was slightly higher by 1.01 times, under the radical improvement of milling, conventional and deep plowing against the background of application of sugar-juice defecation sludge and NPK fertilizers, this indicator was lower by 1.08 times, 1.03 times, and 1.03 times, respectively. In the second year of vegetation, the coefficient of Zn accumulation in cereal and legume vegetation was 1.01 times lower under surface improvement, and 1.06 times lower under root improvement (milling, sugar-juice defecation sludge, and NPK fertilizers), while using conventional and deep plowing on the background of the introduction of sugar-juice defecation sludge, NPK fertilizers, on the contrary, are 1.07 times and 0.6 times higher, respectively, compared to the grass stand of natural fodder lands without the use of agrochemical measures.

A similar trend was observed in the third year of vegetation of cereal and leguminous vegetation, with disking and application of sugar-juice defecation sludge and NPK fertilizers and milling, sugar-juice defecation sludge and NPK fertilizers, the coefficient of Zn accumulation decreased, and when using milling, conventional and deep plowing against the background of introduction of sugar-juice defecation sludge, NPK into the soil of fertilizers increased.

Table 4. The coefficient of heavy metals accumulation (trace elements) in cereal-legume vegetation, mg/kg

Measures to improve natural fodder lands	Zn									Cu								
	2017			2018			2019			2017			2018			2019		
	Soil	Vegetative mass	C_{acc}	Soil	Vegetative mass	C_{acc}	Soil	Vegetative mass	C_{acc}	Soil	Vegetative mass	C_{acc}	Soil	Vegetative mass	C_{acc}	Soil	Vegetative mass	C_{acc}
Without surface and root improvement	17,5	21,5	1,22	18,7	20,5	1,09	19,0	20	1,05	0,65	4,7	7,2	0,65	4,6	7,0	0,7	4,57	6,5
Disking + sugar-juice defecation sludge + NPK	18,7	23,2	1,24	19,2	20,7	1,08	19,7	20,2	1,03	0,7	4,8	6,8	0,72	4,2	5,8	0,72	4,7	6,5
Milling + conventional plowing + sugar-juice defecation sludge + NPK	15,2	18,0	1,18	15,7	18,5	1,17	16,0	18	1,12	0,55	3,65	6,6	0,57	3,6	6,3	0,59	3,4	5,7
Milling + deep plowing + sugar-juice defecation sludge + NPK	14,5	17,2	1,18	14,8	17,3	1,16	15,0	17,0	1,13	0,51	3,2	6,2	0,55	3,0	5,4	0,57	3,0	5,2
Milling + sugar-juice defecation sludge + NPK	18,5	21	1,13	19,6	20	1,02	20	20	1,0	0,7	4,6	6,5	0,72	4,1	5,7	0,72	4,1	5,7

On average, over three years, the coefficient of Zn accumulation (Fig. 1) in cereal and leguminous vegetation without the use of agrochemical measures was 1.12; for disking, application of sugar-juice defecation sludge and NPK fertilizers - 1.05; for milling, ordinary and deep plowing against the background of application of sugar-juice defecation sludge and NPK fertilizers 1.14 and 1.15, respectively.

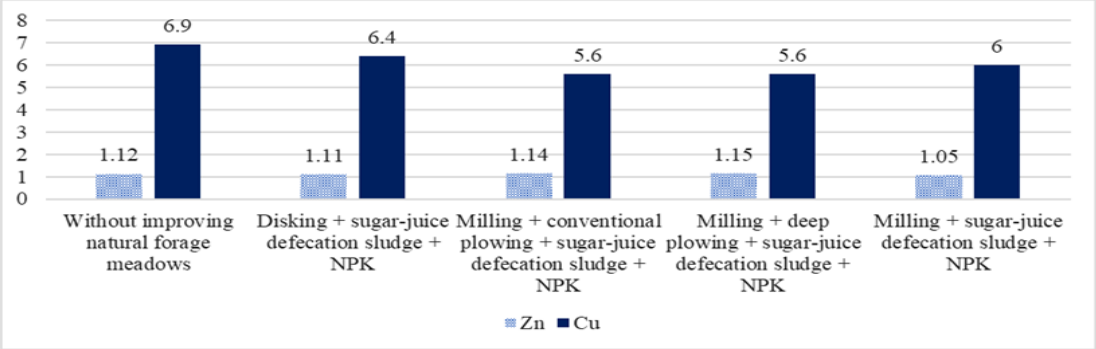

Figure 1. The coefficient of accumulation of heavy metals (trace elements) in cereal and leguminous vegetation.

Thus, the coefficient of accumulation of Cu in cereal and leguminous vegetation during the three years of research ranged from 5.7 to 6.5, respectively, for disking, application of sugar-juice defecation sludge and NPK fertilizers; for milling, conventional plowing against the background of application of sugar-juice defecation sludge and NPK fertilizers from 5.3 to 6.6; for milling, deep plowing against the background of application of sugar-juice defecation sludge and NPK fertilizers from 5.2 to 6.2; without the use of agrochemical measures from 6.5 to 7.5. At the same time, it was found that with increasing years of vegetation, the Cu accumulation coefficient in cereal and leguminous vegetation decreases. On average, over three years, the accumulation coefficient of Cu in cereal-legume vegetation without the use of agrochemical measures was 6.9; for disking, application of sugar-juice defecation sludge and NPK fertilizers - 6.4; for milling and introduction of sugar-juice defecation sludge and NPK fertilizers - 6.0; for milling, ordinary and deep plowing against the background of application of sugar-juice defecation sludge and NPK fertilizers – 5.6 and 5.6, respectively.

CONCLUSION

- In cereal and leguminous vegetation during the three years of vegetation of natural fodder lands in the zone of their local pollution under surface improvement, the concentration of Zn increased from 1.01 times to 1.07 times, Cu – from 1.01 times to 1.02 times, while under of radical improvement, the concentration decreased for Zn content from 1.1 times to 1.25 times, and for Cu content – from 1.02 times to 1.55 times.
- The hazard ratio of Zn and Cu in cereal and leguminous vegetation did not exceed the maximum allowable indicator (1), which indicates its safety when used as feed raw materials. At the same time, it is necessary to note the tendency to decrease the danger coefficient of both Zn and Cu in cereal and leguminous vegetation with radical improvement of natural fodder lands.
- The rate of accumulation of Zn and Cu in cereal and legume vegetation was also lower in root improvement of natural forage meadows compared to surface improvement.

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