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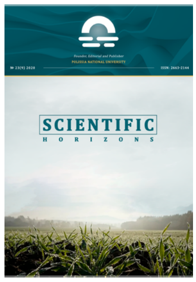


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# Mineral composition of alfalfa, alfalfa-cereal, and cereal feed agrophytocenoses biomass

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**Abstract**. The relevance of the results of these studies lies in the fact that until recently, changes in the mineral composition of different types of meadow agrophytocenoses under the influence of symbiotic alfalfa and mineral nitrogen in the content of macro- and microelements, heavy metals, and nitrates in feed biomass have not yet been sufficiently investigated, which hinders the development and implementation of feed production findings in agricultural production. The purpose of the study is to establish changes in the accumulation of various meadow agrophytocenoses in dry feed biomass on various agricultural zones of mineral elements during cultivation on dark grey soils of the Right-Bank Forest-Steppe. During this study, field and laboratory methods were used, and an analytical method was used to determine the mineral composition of dry feed biomass. The results of studies on the accumulation of alfalfa,



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alfalfa-cereals, and cereal stands in in dry feed mass on various backgrounds of fertilisation and liming of raw ash, macro- and microelements, heavy metals, and nitrate nitrogen are presented. It is shown that under the action of symbiotic nitrogen in alfalfa and alfalfa cereal stands, compared with cereals in the dry mass of feed, raw ash accumulates more macroelements, trace elements, and heavy metals by 0.6-0.8%, the ratio of calcium to phosphorus increases by 0.11-0.26, and potassium to the sum of calcium and magnesium decreases by 0.11-0.26. Under the action of mineral nitrogen in the case of the introduction of N90 in the cereal stand, the content of nitrates increases from 0.02 to 0.04%, zinc – from 9.1-9.2 to 12.4-12.6 or by 3.2-3.5 mg/kg, copper – from 3.4-3.7 to 5.3-5.5 mg/kg, as well as manganese, lead, nickel, cadmium in the dry mass of the feed of the cereal stand. It is proved that the content of macro- and microelements in the dry mass of feed corresponds to zootechnical standards for feeding cattle, and nitrates and heavy metals do not exceed the maximum permissible concentrations. The results of these studies can be used in the development of recommendations on technologies for growing perennial cereals for feed purposes and in the educational process

**Keywords**: heavy metals; zootechnical norm; macro- and microelements; nitrates; raw ash; dry mass; cereal feed

## INTRODUCTION

The effective functioning of animal husbandry largely depends on providing this branch of agriculture with cheap cereal feed. Hayfields, pastures, and crops of perennial cereals are their main source. One of the ways of environmentally safe intensification of feed production and meadow culture is the creation of feed agrophytocenoses with a high content of legumes. Due to symbiotic nitrogen fixation, they not only increase the productivity of forage lands but also improve the quality of feed, in particular, their mineral composition. Therefore, the results of researching the mineral composition of different types of meadow agrophytocenoses are certainly relevant.

Analysis of the studies (Dziubailo *et al.*, 2020; Kovtun *et al.*, 2020; Kamalongo & Cannon, 2020) shows that replacing mineral nitrogen in the cultivation of perennial cereals with symbiotically fixed nitrogen of perennial legumes for growing them in a single-species crop or mixed with cereals substantially reduces the energy costs of growing forage agrophytocenoses. Ultimately, the nitrogen of mineral fertilisers, used for the cultivation of highly productive cereal stands, can account for half or more of all total costs.

Due to the substantial increase in mineral nitrogen, increasing the use of perennial legumes as a source of symbiotic nitrogen in meadow culture and feed production is an important component of the programme for introducing energy-saving technologies abroad, including for organic agricultural production (Hannaway *et al.*, 2018; Kim *et al.*, 2019; Karbivska *et al.*, 2020).

The studies (Bo *et al.*, 2022; Odzijewicz *et al.*, 2023) identified that symbiotic nitrogen of perennial legumes both in legume-cereal mixtures and in single-species crops improves the chemical composition of feed. In particular, it helps to increase the content of crude protein, protein, macroelements of calcium and magnesium in the dry mass, improve the digestibility of feed, the nutritional content of feed units and energy intensity in the content of metabolic energy, and reduce the amount of nitrogen-free extractives, crude fibre, and potassium.

Authors (Bogovin & Ptashnyk, 2020; Tamahina & Turabov, 2021; Kurgak & Karbovskaya, 2020) also established that the quality of feed of cereal phytocenoses is positively affected by nitrogen mineral fertilisers. When it is applied, the content of crude protein and protein in herbs increases, the content of nitrogen-free extractive substances and, in particular, their component part – hydrocarbons, including water-soluble or sugars, decreases. However, it should be noted that the increase in the content of crude protein in herbs under the influence of nitrogen fertilisers in different conditions occurs at different rates.

It is known that the mineral composition of the feed, in particular, the content of macro- and microelements, is important in feeding animals. The content of mineral elements in the biomass of perennial phytocenoses depends on their species composition, fertiliser system, timing and frequency of harvesting, and other technological measures of cultivation (Nilsdotter-Linde *et al.*, 2016; Kurhak *et al.*, 2020; Martsinko *et al.*, 2021).

In the studies (Monti *et al.*, 2008; Demidas & Galushko, 2020) it is noted that a substantial danger to animals may arise from mineral fertilisers due to the introduction of increased doses of nitrogen and the accumulation of nitrate nitrogen ($N\text{-}NO_3$), which as part of crude protein accumulates in the biomass of herbs, in such cereal feed. It is also highlighted that in the early phases of vegetation (tillering of cereals and shoot formation of legumes), the nitrate content is substantially higher than in optimal periods of harvesting cereal stands (earing of cereals budding or flowering of legumes). It is also proved that the accumulation of $N\text{-}NO_3$ over 0.07% of the dry mass of feed is harmful, 0.07-0.2% can lead to poisoning, and over 0.25% can be fatal for cattle. According to DSTU 8528:2015 (2017), the maximum permissible concentration (MPC) of $N\text{-}NO_3$ which is safe for cattle is considered to be 500.0 mg/kg of dry weight or 0.05%.

All of the above indicates the need to apply such fertilisers and other agrotechnical measures that increase not only the productivity of forage lands but also contribute to obtaining high-quality feed in terms of mineral composition. Therefore, it is important to use such doses of nitrogen fertilisers that would not increase the accumulation of toxic elements (nitrates and heavy metals) in the feed over the maximum permissible concentration.

However, until recently, changes in the mineral composition of different types of meadow agrophytocenoses under the influence of symbiotic alfalfa and mineral nitrogen in terms of the content of macro- and microelements and heavy metals and nitrates in feed biomass have not yet been sufficiently examined and highlighted in open print, which hinders the introduction of feed production findings in agricultural production. The purpose of this study was to investigate these issues, the results of which are presented in the paper.

The purpose of the study is to establish changes in the accumulation of feed in the dry mass from various meadow agrophytocenoses macro-and microelements and heavy metals and nitrates on various agricultural backgrounds for growing on dark grey soils of the Right-Bank Forest-Steppe.

## MATERIALS AND METHODS

The study of the mineral composition of the dry mass of alfalfa, alfalfa-cereals, and cereals of perennial forage agrophytocenoses was conducted during 2019-2021. Plant samples for determining the mineral composition of feed were selected, according to research programmes, in the National Scientific Centre "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine" on dark grey podzolic large-dusty-light-loamy soil of the Forest-Steppe of Ukraine (Chabany village, Kyiv region) in a three-factor experiment, which was conducted according to the following scheme (Table 1):

***Table 1**. Scheme of the conducted experiment*

| Herbage factor (types of cereals, their mixtures, and seeding rates, kg/ha) | Liming factor (lime doses, t/ha) | Fertiliser factor (nutrients and doses, kg/ha) |
|---|---|---|
| Alfalfa, 18 | Without liming | Without fertilisers |
| Alfalfa, 10 + smooth brome, 15 | 1.5 t/ha | $P_{45}K_{90}$ |
| Alfalfa, 10 + smooth brome, 14 + eastern fescue, 8 | | |
| Smooth brome, 15 + eastern fescue, 14 | | |
| Smooth brome, 15 + eastern fescue, 14 + $N_{90\ (30+30+30)}$ | | |

***Source:** compiled by the authors*

In a 0-20 cm layer of soil, the humus content was at the level of 2.4%; pH (salt) – 5.2; the content of easily hydrolysed nitrogen – 13.1, mobile phosphorus – 17.1, and exchange potassium – 12.9 mg per 100 g of soil. Lime was applied once in pre-sowing tillage during alkalinisation in the spring of 2019. Mineral fertilisers, according to the scheme of the experiment, were applied annually. Phosphorous and potash fertilisers were applied in the spring, and nitrogen fertilisers in the cereal stand – in equal parts for each harvest.

The repetition rate of the experiment is fourfold with an area of the sown plot of 16 m$^2$, accounting – 10 m$^2$. Perennial herbs in the experiment were grown according to the generally accepted technology in the region, with the exception of the factors under study. Zoned varieties of perennial cereals were used in the experiment: alfalfa – the Narechena Pivnochi variety, smooth brome – Vizant, and eastern fescue – Domenika, mainly selected by the NSC of the Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine. Field studies were performed in accordance with generally accepted methods in feed production (Babich, 1994).

The content of crude ash and macroelements of phosphorus and potassium in dry plant samples was determined by infrared spectroscopy in accordance with DSTU 4117:2007 (2008). The content of macroelements (calcium and magnesium), trace elements (copper, zinc, manganese, iron), and heavy metals (lead, nickel, cadmium) was determined by atomic absorption spectrometry on the AAS-30 device. Nitrate nitrogen concentration (N-$NO_3$) calculated for the dry mass was determined by the ionometric method.

The analysis of the results was conducted by comparing changes in the mineral composition of the feed, which were obtained on different variants of the field experiment. Evaluation of the results was also conducted by comparing the content of macro- and microelements with zootechnical standards for feeding cattle, and safety indicators for the content of heavy metals and nitrates – with the maximum permissible concentrations (MPC). Zootechnical standards for the content of mineral elements according to citation (Demidas & Galushko, 2020) and the MPC according to DSTU 8528:2015 (2017) are shown in the tables of the following section, where the results are presented.

Agrochemical indicators of the soil were determined before laying a field experiment in a 0-20 cm layer of soil according to the following generally accepted methods: humus – according to Tyurin, easily hydrolysed nitrogen – according to Cornfield, mobile phosphorus and potassium – according to Chirikov, pH (salt) – potentiometrically.

Mathematical processing of the reliability of the obtained experimental data on the content of mineral elements and nitrate nitrogen in the dry mass of feed in the studies was conducted by the method of dispersion analysis according to the indicators of the smallest substantial difference ($HIP_{05}$) (Ermantraut, 2007).

## RESULTS AND DISCUSSION

The results of the study on average for 2019-2021 of the content of crude ash, macroelements, and their ratio in the biomass of alfalfa alfalfa-cereal, and cereal mixtures are shown in Table 2. These data indicate that on all fertiliser backgrounds, the highest content in the dry mass of raw ash (9.0-9.5%), calcium (0.56-0.63%), magnesium (0.13-0.18%), phosphorus (0.40-0.45%), and the lowest content of potassium (2.35-2.58%) was in the dry mass of alfalfa and its mixtures with cereals, respectively 0.6-0.8%, 0.13-0.16%, 0.07-0.08%, 0.03-0.04% more and 0.13-0.21% less than in dry feed biomass of cereal stand.

***Table 2**. The content of raw ash and macroelements and their ratio in the dry mass of alfalfa, alfalfa-cereals, and cereal stands in (average for 2019-2021), %*

| Herbage (types of cereals and seeding rate, kg/ha) | Liming* | Fertiliser | Raw ash | P | K | Ca | Mg | K:(Ca+Mg) | Ca:P |
|---|---|---|---|---|---|---|---|---|---|
| Alfalfa, 18 | – | Without fertilisers | 9.4 | 0.44 | 2.35 | 0.60 | 0.17 | 3.05 | 1.36 |
| | | $P_{45}K_{90}$ | 9.5 | 0.45 | 2.40 | 0.61 | 0.18 | 3.04 | 1.36 |
| | + | Without fertilisers | 9.4 | 0.41 | 2.45 | 0.62 | 0.17 | 3.10 | 1.51 |
| | | $P_{45}K_{90}$ | 9.5 | 0.43 | 2.53 | 0.63 | 0.18 | 3.12 | 1.47 |
| Alfalfa, 10 + smooth brome, 15 | – | Without fertilisers | 9.1 | 0.41 | 2.50 | 0.56 | 0.15 | 3.52 | 1.37 |
| | | $P_{45}K_{90}$ | 9.3 | 0.43 | 2.58 | 0.57 | 0.15 | 3.58 | 1.32 |
| | + | Without fertilisers | 9.0 | 0.41 | 2.40 | 0.58 | 0.14 | 3.33 | 1.41 |
| | | $P_{45}K_{90}$ | 9.2 | 0.43 | 2.48 | 0.59 | 0.13 | 3.44 | 1.37 |
| Alfalfa, 10 + smooth brome, 8 + eastern fescue, 6 | – | Without fertilisers | 9.0 | 0.41 | 2.50 | 0.56 | 0.15 | 3.52 | 1.37 |
| | | $P_{45}K_{90}$ | 9.2 | 0.43 | 2.58 | 0.57 | 0.15 | 3.58 | 1.33 |
| | + | Without fertilisers | 9.1 | 0.40 | 2.45 | 0.58 | 0.15 | 3.56 | 1.45 |
| | | $P_{45}K_{90}$ | 9.2 | 0.43 | 2.53 | 0.60 | 0.14 | 3.42 | 1.40 |
| Smooth brome, 15 + eastern fescue, 14 | – | Without fertilisers | 8.3 | 0.37 | 2.67 | 0.41 | 0.11 | 5.13 | 1.11 |
| | | $P_{45}K_{90}$ | 8.4 | 0.39 | 2.68 | 0.43 | 0.11 | 4.96 | 1.10 |
| | + | Without fertilisers | 8.3 | 0.41 | 2.60 | 0.48 | 0.11 | 4.41 | 1.17 |
| | | $P_{45}K_{90}$ | 8.4 | 0.43 | 2.58 | 0.47 | 0.11 | 4.45 | 1.09 |
| | – | $N_{90}$ | 8.7 | 0.36 | 2.60 | 0.45 | 0.10 | 4.73 | 1.25 |
| | | $N_{90}P_{45}K_{90}$ | 8.8 | 0.37 | 2.65 | 0.45 | 0.10 | 4.82 | 1.22 |
| | + | $N_{90}$ | 8.7 | 0.36 | 2.60 | 0.47 | 0.10 | 4.56 | 1.31 |
| | | $N_{90}P_{45}K_{90}$ | 8.8 | 0.37 | 2.65 | 0.48 | 0.10 | 4.57 | 1.30 |
| Zootechnical norm | | | | 0.2–0.35 | 1.0–3.0 | 0.3–0.6 | 0.12–0.26 | 2.5–5.5 | 0.7–2.5 |
| $HIP_{05}$, % | | | 0.4 | 0.02 | 0.12 | 0.03 | 0.01 | | |

***Source:** compiled by the authors*

In the dry mass of herbage with alfalfa in comparison with cereal herbage, the content of crude ash, calcium, and magnesium was correspondingly higher by 0.3-0.6%, 0.06-0.10%, 0.01-0.06%, and the content of potassium was less by 0.04-0.12%. Notably, the advantage of the alfalfa stands in comparison with the cereal stands in terms of the content of raw ash and the above-mentioned mineral elements was substantially greater than the advantage of alfalfa-cereal stands.

According to the data listed in Table 2 on the background of all fertilisers, a higher ratio of calcium to phosphorus Ca:P (in the range of 1.33-1.51) and a lower ratio of potassium to the sum of calcium and magnesium (K:(Ca+Mg)) (in the range of 3.04-3.58) were in the dry mass of alfalfa and alfalfa-cereal mixtures, which, respectively, is 0.11-0.26 units more and 0.83-2.08 units less than in dry feed biomass cereal stand. Similar patterns regarding the effect of nitrogen symbiotic fixation on changes in the ratio of these macroelements in the dry mass of feed were observed by other researchers (Karbivska 2019; Demidas & Galushko, 2020; Kurhak *et al.*, 2020).

Comparison of the content of macroelements indicated in Table 2 in the dry mass of feed from different types of herbage with zootechnical standards for feeding cattle showed that it mainly corresponded to them. However, in these studies the following deviations were noted: a slight excess of the zootechnical norm (0.2-0.35%) in the content of phosphorus in the dry mass of alfalfa feed and its mixtures with cereals, which is positive, and a decrease from the norm (0.12-0.26%) of magnesium, which is negative.

However, both the ratio of K:(Ca+Mg) and the ratio of Ca:P did not go beyond the limits of zootechnical standards for cattle. This indicates that the biomass for the production of cereal feed from the examined cereal stands is quite suitable for feeding cattle. Analysis of these studies showed that phosphorous and potash fertilisers had little effect on the mineral composition of the feed and on the ratio of mineral elements. However, under the influence of nitrogen application at a dose of N90 in the cereal stand, an increase in the content of crude ash, a decrease in the content of phosphorus and potassium, and an increase in the Ca:P ratio, were observed.

According to the data (Table 3), nitrate content ($N-NO_3$) in the dry mass of alfalfa, alfalfa-cereal mixtures, and cereal stand on different backgrounds, the average use of fertiliser for 2019-2021 ranged between 0.0-0.04% and did not go beyond the maximum permissible concentration (0.07%). Experimental data indicate that the content of nitrates ($N-NO_3$) in the dry mass of feed when eaten by animals is not harmful to animal health.

***Table 3**. Nitrate concentration (N-NO3) in the dry mass of alfalfa, alfalfa-cereals, and cereal stands in on different backgrounds of fertiliser and liming, % (2019-2020)*

| Herbage (types of cereals and seeding rate, kg/ha) | Liming* | Fertiliser | Years of life | | | Average for three years |
|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | |
| Alfalfa, 18 | – | Without fertilisers | 0.04 | 0.02 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.03 | 0.02 | 0.03 |
| | + | Without fertilisers | 0.04 | 0.03 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.03 | 0.02 | 0.03 |
| Alfalfa, 10 + smooth brome, 15 | – | Without fertilisers | 0.04 | 0.02 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.02 | 0.02 | 0.03 |
| | + | Without fertilisers | 0.04 | 0.02 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.03 | 0.02 | 0.03 |
| Alfalfa, 10 + smooth brome, 8 + eastern fescue, 6 | – | Without fertilisers | 0.04 | 0.02 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.02 | 0.02 | 0.03 |
| | + | Without fertilisers | 0.04 | 0.02 | 0.02 | 0.03 |
| | | $P_{45}K_{60}$ | 0.04 | 0.03 | 0.02 | 0.03 |
| Smooth brome, 15 + eastern fescue, 14 | – | Without fertilisers | 0.03 | 0.01 | 0.01 | 0.02 |
| | | $P_{45}K_{60}$ | 0.03 | 0.01 | 0.01 | 0.02 |
| | + | Without fertilisers | 0.03 | 0.02 | 0.01 | 0.02 |
| | | $P_{45}K_{60}$ | 0.03 | 0.02 | 0.01 | 0.02 |
| | – | $N_{90\ (30 + 30 + 30)}$ | 0.05 | 0.03 | 0.03 | 0.04 |
| | | $N_{90}P_{45}K_{60}$ | 0.05 | 0.03 | 0.03 | 0.04 |
| | + | $N_{90}$ | 0.05 | 0.04 | 0.03 | 0.04 |
| | | $N_{90}P_{45}K_{60}$ | 0.05 | 0.04 | 0.03 | 0.04 |
| | HIP$_{05}$, % | | 0.005 | 0.005 | 0.005 | 0.005 |
| | MPC, % | | | | 0.05 | |

***Source:** compiled by the authors*

In the dry mass of alfalfa and alfalfa-cereal stands in comparison with cereal ones on the same fertiliser backgrounds (options without fertilisers and application of $P_{45}K_{60}$) on average, 0.01% more nitrates accumulated over the years of research. When applying nitrogen fertilisers at a dose of $N_{90}$ (variants $N_{90}$ and $N_{90}P_{45}K_{90}$), the content of nitrates in the dry mass of cereal stands on average for 2019-2021 increased by 0.02%. Thus, introducing mineral nitrogen at a dose of N90 affects the accumulation of N-$NO_3$ more than the use of symbiotic nitrogen of alfalfa both in single-species sowing and alfalfa-cereal mixtures.

In the analysis of N-$NO_3$ accumulation over the years of use, it was identified that the nitrate content also changed noticeably. In the 1st year of life and use of herbage (2019), 0.01-0.02% more N-$NO_3$ was accumulated than in 2020 and 2021. However, patterns of changes in N-$NO_3$ accumulation under the influence of symbiotic nitrogen, alfalfa, and mineral nitrogen were preserved on the cereal stand for all years. In all years of research, the content of N-$NO_3$ did not exceed the maximum permissible concentration (0.05% in the dry mass of the feed).

It is known that both under the influence of mineral nitrogen in fertilisers and under the influence of nitrogen symbiotic fixation of perennial legumes, the microelement composition of feed biomass also changes substantially.

The studies (Table 4) also indicate that both when using nitrogen symbiotic fixation of alfalfa in feed agrophytocenoses with it, and mineral nitrogen fertilisers on perennial cereal stands substantially changed the microelement composition of cereal feed and the accumulation of heavy metals in it. Thus, in particular, in the dry mass of alfalfa and alfalfa-cereal stands with various cereal components, in comparison with cereal stands on nitrogen-free fertiliser backgrounds (variants without fertilisers and $P_{45}K_{90}$), zinc content increased from 9.0-9.2 to 12.3-14.8 mg/kg or by 3.3-5.6 mg, copper – from 3.3-3.7 to 4.4-4.7 or by 1.0-1.1 mg/kg, iron – from 54.6-62.7 to 58.3-72.1 or by 3.7-9.4 mg/kg, lead – from 1.4-1.5 to 2.0-2.2 mg or by 0.6-0.7 mg, nickel – from 1.-1.2 to 1.8 mg/kg, cadmium – from 0.1 to 0.2 mg/kg of dry mass.

***Table 4**. Content of trace elements and heavy metals in the dry mass of alfalfa, alfalfa-cereal, and cereal stands, depending on the fertiliser and liming systems (average for 2019-2021), mg/kg*

| Herbage (types of cereals and seeding rate, kg/ha) | Liming* | Fertiliser | Microelements | | | | Heavy metals | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zn | Cu | Mn | Fe | Pb | Ni | Cd |
| Alfalfa, 18 | – | Without fertilisers | 13.9 | 4.4 | 44.6 | 65.9 | 2.2 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 14.7 | 4.5 | 46.2 | 72.1 | 2.2 | 1.8 | 0.2 |
| | + | Without fertilisers | 14.3 | 4.6 | 44.8 | 65.9 | 2.2 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 14.8 | 4.7 | 46.4 | 72.1 | 2.2 | 1.8 | 0.2 |
| Alfalfa, 10 + smooth brome, 15 | – | Without fertilisers | 13.5 | 4.4 | 43.3 | 66.9 | 2.0 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 14.5 | 4.5 | 45.5 | 71.0 | 2.0 | 1.8 | 0.2 |
| | + | Without fertilisers | 13.8 | 4.5 | 43.5 | 66.9 | 2.0 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 14.7 | 4.6 | 45.8 | 71.0 | 2.0 | 1.8 | 0.2 |
| Alfalfa, 10 + smooth brome, 8 + eastern fescue, 6 | – | Without fertilisers | 12.3 | 4.4 | 38.9 | 59.0 | 2.0 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 12.9 | 4.5 | 43.9 | 58.3 | 2.0 | 1.8 | 0.2 |
| | + | Without fertilisers | 12.5 | 4.5 | 39.3 | 59.0 | 2.0 | 1.8 | 0.2 |
| | | $P_{45}K_{90}$ | 13.2 | 4.6 | 44.2 | 58.3 | 2.0 | 1.8 | 0.2 |
| Smooth brome, 15 + eastern fescue, 14 | – | Without fertilisers | 9.0 | 3.3 | 45.2 | 54.6 | 1.4 | 1.1 | 0.1 |
| | | $P_{45}K_{90}$ | 9.2 | 3.7 | 54.3 | 62.5 | 1.5 | 1.2 | 0.1 |
| | + | Without fertilisers | 9.0 | 3.4 | 45.4 | 54.6 | 1.5 | 1.1 | 0.1 |
| | | $P_{45}K_{90}$ | 9.1 | 3.7 | 54.3 | 62.7 | 1.5 | 1.2 | 0.1 |
| | – | $N_{90}$ | 12.4 | 5.3 | 65.9 | 58.2 | 1.7 | 1.3 | 0.2 |
| | | $N_{90}P_{45}K_{90}$ | 12.6 | 5.5 | 66.4 | 58.3 | 1.8 | 1.3 | 0.2 |
| | + | $N_{90}$ | 12.5 | 5.4 | 65.6 | 58.5 | 1.8 | 1.4 | 0.2 |
| | | $N_{90}P_{45}K_{90}$ | 12.6 | 5.5 | 66.2 | 58.7 | 1.8 | 1.4 | 0.2 |

*Table 4, Continued*

| Herbage (types of cereals and seeding rate, kg/ha) | Liming* | Fertiliser | Microelements | | | | Heavy metals | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zn | Cu | Mn | Fe | Pb | Ni | Cd |
| Zootechnical norm | | | 20–50 | 4–10 | 250 | 200 | – | – | – |
| MPC | | | 50.0 | 30.0 | – | – | 2–3 | 2.0 | 0.3 |
| $HIP_{05}$, % | | | 0.6 | 0.2 | 2.2 | 3.2 | 0.1 | 0.1 | 0.01 |

***Note:*** *trace elements in high concentrations exceeding MPC are also toxic elements, like heavy metals, and are harmful to animal health*
***Source:*** *compiled by the authors*

On the cereal stand under the influence of introducing $N_{90}$ on two backgrounds (without fertilisers and applying $P_{45}K_{90}$) in comparison with non-nitrogen backgrounds, the content of zinc in the dry mass increased from 9.1-9.2 to 12.4-12.6 mg/kg or by 3.2-3.5 mg, copper – from 3.4-3.7 to 5.3-5.5 or by 1.9 mg, manganese – from 45.2-54.3 to 65.6-66.4 mg, lead – from 1.4-1.5 to 1.7-1.8 mg, nickel – from 1.1-1.2 to 1.3-1.4 mg, and cadmium – from 0.1 to 0.2 mg/kg or by 0.1 mg/kg of dry mass.

The analysis of the studies showed that the content of zinc, copper, manganese, and iron in the dry mass of feed from alfalfa, alfalfa-cereals, and cereal perennial stands on various backgrounds of fertilisation and liming, with the exception of minor deviations, did not go beyond the zootechnical standards, which are given in Table 3. Indicators of the content of heavy metals (lead, nickel, cadmium) in the dry mass of feed of these cereal stands, as evidenced by these studies, did not exceed the maximum permissible concentrations (Table 4). This gives grounds to assert that such feed is quite safe for cattle.

The results of the studies on the mineral composition of feed obtained from the biomass of alfalfa, alfalfa-cereals, and cereal perennial stands, depending on fertiliser, are confirmed by experimental data from other researchers. In the studies (Kotyash *et al.*, 2019; Demidas & Galushko, 2020; Martsinko *et al.*, 2021), as in this one, it was shown that under the action of symbiotic nitrogen in alfalfa and alfalfa-cereal stands, compared with cereals among mineral elements, to the greatest extent increased the content of calcium and magnesium in the dry mass of feed (respectively, to 0.86-1.07% and to 0.21-0.35%), and the content of potassium decreased.

Kurhak *et al.* (2020) in their study identified that when applying high doses of nitrogen fertilisers to a perennial cereal stand, the nitrate content increases in the aboveground biomass of cereals in an amount that may exceed the maximum permissible concentration. When applying moderate doses of nitrogen fertilisers, as a rule, despite the fact that the accumulation of nitrates in the dry mass of feed increases, it does not exceed the MPC and is not harmful to animals, which confirms this and similar studies.

Most of the experimental data presented in the studies (Demidas & Galushko, 2020; Kurhak *et al.*, 2020) concerns changes in the microelement composition of feed from perennial cereals under the influence of nitrogen and mineral fertilisers. In particular, it was identified that under its influence, the copper content in the feed biomass of perennial cereals depends on its presence in the soil. On turf soils that are poor in copper, an increase in the dose of nitrogen, due to the formation of complex copper-ammonia compounds, reduces its content in cereals, while against the background of copper fertilisers and copper-rich soils, it increases.

The studies (Prorochenko, 2020) show that both under the influence of symbiotic nitrogen of perennial legumes, and under the influence of moderate doses of mineral nitrogen in the dry mass of feed, there is an increase in the content of trace elements (zinc, copper, iron) within zootechnical standards and without exceeding the maximum permissible concentrations of heavy metals (lead, nickel, cadmium)

Thus, the analysis of literature sources showed that both under the influence of nitrogen of mineral fertilisers and biological, in particular, symbiotic nitrogen, which is fixed by perennial legumes, the concentration of trace elements in the feed biomass of perennial cereals can also change substantially, with similar patterns obtained in this study.

## CONCLUSIONS

As a result of the study, it was established, that in the dry mass of feed obtained from alfalfa and alfalfa-cereal stands, there is a higher accumulation of raw ash by 0.6-0.8%, macroelements of calcium – 0.13-0.16%, magnesium – 0.07-0.08%, phosphorus – 0.03-0.04%, nitrate nitrogen – 0.01%, and 0.04-0.12% lower accumulation of potassium than in the feed of perennial cereal stands. The ratio of calcium to phosphorus is higher – by 0.11-0.26 and the ratio of potassium to the sum of calcium and magnesium is lower – by 0.11-0.26. Therewith, in the dry mass of feed made from cereal stands with alfalfa, the accumulation of the following elements is higher: zinc – by 3.3-5.6 mg/kg, copper – 1.0-1.1 mg/kg, iron – 3.7-9.4 mg/kg, and heavy metals of lead – 0.6-0.7 mg/kg, as well as nickel and cadmium, compared to cereal stands.

The chemical composition of cereal feed made from cereal stands is most affected by the mineral composition of the applied nitrogen fertilisers. In the dry mass of feed produced with the application of N90, the content of nitrate nitrogen increases from 0.02 to 0.04%, trace elements of zinc – from 9.1-9.2 to 12.4-12.6 mg/kg or by 3.2-3.5 mg/kg, copper – from 3.4-3.7 to 5.3-5.5 mg/kg, as well as manganese, heavy metals of lead, nickel, cadmium.

The content of these macro- and microelements in the dry mass of feed is within the limits of zootechnical standards for feeding cattle, and the content of feed safety indicators, in particular, nitrates and heavy metals, does not exceed the maximum permissible concentrations. The prospects for further research are to investigate the cultivation technologies and features of perennial cereals used for feed purposes.

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None.

## CONFLICT OF INTEREST

None.

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**Анотація**. Актуальність наведених результатів досліджень полягає в тому, що до останнього часу зміни мінерального складу різнотипних лучних агрофітоценозів під впливом симбіотичного люцерни посівної і мінерального азоту за вмістом у кормовій біомасі макро- і мікроелементів та важких металів і нітратів ще не достатньо вивчено, що стримує розроблення і впровадження розробок з кормовиробництва у сільськогосподарське виробництво. Мета досліджень полягає в установленні зміни з нагромадження в сухій кормовій біомасі різних лучних агрофітоценозів на різних агрофонах мінеральних елементів за вирощування на темно-сірих ґрунтах Правобережного Лісостепу. Для досліджень використано польовий і лабораторний методи, а для визначення мінерального складу сухої кормової біомаси – аналітичний. Наведено результати досліджень з накопичення у сухій кормовій масі люцернового, люцерно-злакових і злакового травостоїв на різних фонах удобрення і вапнування сирої золи, макро- та мікроелементів, важких металів і нітратного азоту. Показано, що під дією симбіотичного азоту в люцерновому та люцерно-злакових травостоях порівняно зі злаковим в сухій масі корму більше нагромаджується сирої золи на 0,6-0,8 %, макроелементів, мікроелементів та важких металів, відношення кальцію до фосфору збільшується на 0,11-0,26, а калію до суми кальцію і магнію зменшується – на 0,11-0,26. Під дією мінерального азоту за внесення $N_{90}$ на злаковий травостій в сухій масі корму злакового травостою збільшується вміст нітратів від 0,02 до 0,04 %, цинку – від 9,1-9,2 до 12,4-12,6 або на 3,2-3,5 мг/кг, міді – від 3,4-3,7 до 5,3-5,5 мг/кг, а також марганцю, свинцю, нікелю, кадмію. Доведено, що показники вмісту макро- та мікроелементів в сухій масі корму відповідають зоотехнічним нормам для годівлі великої рогатої худоби, а нітратів і важких металів – не виходять за межі гранично допустимих концентрацій. Результати цих досліджень можуть бути використані при розробленні рекомендацій щодо технологій вирощування багаторічних трав на кормові цілі та годівлі тварин, а також у навчальному процесі

**Ключові слова**: важкі метали; зоотехнічна норма; макро- та мікроелементи; нітрати; сира зола; суха маса; трав'яний корм