Green forage in radioactive flood meadows

E V Smolskii, A L Silaev, V V Dyachenko, M M Nechaev and V E Mameeva

Bryansk State Agrarian University, 2a Sovetskaya Street, Kokino village, Vygonichsky district, Bryansk region, 243365, Russia

E-mail: sev_84@mail.ru

Abstract. The flood meadow was analyzed in the conditions of radioactive pollution of the territory to study the effect of mineral fertilizer on the efficiency of a meadow and $^{137}\text{Cs}$ content in green grass stand. The experiment was conducted in alluvial meadow sandy soil with $^{137}\text{Cs}$ pollution density of 559-867 kBq/m$^2$ in the subzone of sod-podzolic soil of southern taiga of the Belarusian province of sod-podzolic slightly humic soils and low-land swamps. The study revealed that the efficiency of natural grass stand is low, the introduction of mineral fertilizer increased the productivity of green grass stand of a meadow to 37 t/hectare with $^{137}\text{Cs}$ content in green forage in radioactive flood meadows is still not impossible for livestock production satisfying norms on $^{137}\text{Cs}$ content in milk and meat without the use of mineral fertilizers.

1. Introduction

The creation of stable food supply ensures effective and steady development of livestock production in particular and the entire agro-industrial complex. However, the use of flood meadows is complicated by the consequences of the Chernobyl accident when a considerable part of natural fodder grounds of the territory was polluted with artificial radionuclides, among which there was the main dose-forming radionuclide $^{137}\text{Cs}$ [1-3]. After a long time after the accident the radiation situation was improved due to some rehabilitation measures in the Chernobyl territories. Nevertheless, after 33 years the situation still remains unfortunate, especially on radioactive fodder grounds with the pollution density higher than 555 kBq/m$^2$, where there is still a risk for forage production not satisfying the existing standards [4-6].

Russia, the Republic of Belarus and Ukraine was able to accumulate a positive experience in studying $^{137}\text{Cs}$ migration in soil and its transformation within food chains, as well as protective measures reducing the accumulation of radionuclides in forage products. At the same time theoretical justification and development of any rehabilitation approaches, their practical improvement require further study in the conditions of a particular region. The optimization of the use of different types of mineral fertilizers in radioactive meadows is still not solved. Therefore, the development of theoretical bases of the rational use of agrochemical approaches to rehabilitation of radioactive flood meadows is one of the relevant and perspective directions concerning the problem of $^{137}\text{Cs}$ transition from soil to plants and covering the decrease of its transfer along food chains [7-9]. In this regard the purpose of the study is to analyze the role of mineral fertilizers in improving the efficiency of natural grass stand of radioactive flood meadows and decreasing $^{137}\text{Cs}$ transition from alluvial soils into green forages.
2. Materials and methods

The study is based on the system approach, which allowed estimating the efficiency of mineral fertilizers in flood meadows depending on conditions of the territory. The object of the study is located in the subzone of soddy-podzolic soil of southern taiga of the Belarusian province of sod-podzolic slightly humic soils and low-land swamps. None protective measures connected with the Chernobyl accident were held on the chosen site prior to the experiment.

The soil of the experimental site represents sandy alluvial meadow (according to 1977 Soil Classification [10], according to the World Reference Base (WRB) it corresponds to Fluvisols [11]) prevailing in flood plains of the rivers of the Bryansk region, occupying 133.1 thousand hectares or 55.1% with about 20% of meadows in the area. The $^{137}$Cs pollution density in the explored site of a floodplain made 559-867 kBq/m². Agrochemical parameters of alluvial meadow soil at the beginning of the study: humus content – 3.08-3.33%; pH$_{KCl}$ – 5.2-5.6; labile phosphorus and exchange potassium – 106-244 and 89-120 mg/kg respectively.

Ammonium nitrate, plain granulated superphosphate and potassium chloride in doses and ratios presented in Table 1 was used in the study. Nitrogen and potash fertilizers were introduced in two steps: half an estimated dose per 1st cut, the second half – per the 2nd cut, and phosphoric fertilizers – once per 1 cut.

The floristic composition of natural grass stand of a flood meadow is presented by the following grass species of the Pooidae: Festuca pratensis Huds., Alopecurus pratensis L., Phleum pratense L. Mixed herbs occupy about 10-15% of the total grass.

The productivity of green natural grass stand was defined through mowing of the natural grass stand from 1 m² with its subsequent weighing. Plant samples were collected in the middle of June – the first cut and at the end of August – the second cut.

The specific activity of $^{137}$Cs in the studied plant samples was defined via Gamma Plus spectrometer (Russia), the error of measurements did not exceed 10%, all measurements were made at the center of collective use of scientific equipment at Bryansk State Agrarian University.

The obtained data was subjected to dispersive and correlation analysis using Excel 7.0 and Statistica 7.0.

The specific activity of $^{137}$Cs in milk and meat was calculated as the product of daily consumption of 60 kg of a green forage, $^{137}$Cs specific activity of feed and the equilibrium coefficient of radionuclide transition to livestock products [12].

3. Results and discussion

The natural fodder lands in Russia are located on vast territories and play a significant role in feed production. Agroclimatic resources of the central meadow of a flood plain of the river Iput of Novozybkovsky district of Bryansk region and natural fertility of alluvial meadow soil ensure the productivity of the first and second cuts amounting to 4.4 and 2.2 t/hectare of green natural grass stand (Table 1). These are low indicators of meadow efficiency, the use of mineral fertilizers significantly increases the productivity of green natural grass stand.

Thus, the introduction of phosphorus-potassium and potash fertilizers respectively during the first and second cuts increases the productivity by 2.7 and 2.5 times in comparison with the flood meadow without the use of mineral fertilizers. The introduction of phosphorus-potassium and potash fertilizers, nitrogen fertilizer respectively during the first and second cuts significantly increases the productivity – 4.2 and 4.3 times – in comparison with the option without the use of mineral fertilizers and by 1.6 and 1.7 times in comparison with the option where phosphorus-potassium and potash fertilizers were applied.
Table 1. Change of productivity of green natural grass stand of a flood meadow depending on the use of mineral fertilizers

| Option       | Ratio K/N | Productivity, t/ha | $^{137}$Cs specific activity, B/kg (Bq/l) |
|--------------|-----------|-------------------|---------------------------------|
|              |           |                   | feed | milk | meat |
|              |           |                   | first cut |       |      |
| N0P0K0       | –         | 4.4               | 1137 | 682  | 2729 |
| N0P60K60     | –         | 12.0              | 109  | 65   | 262  |
| N45P60K60    | 1.3       | 18.6              | 135  | 81   | 324  |
| N60P60K60    | 1.0       | 21.8              | 152  | 91   | 365  |
| N60P60K90    | 1.5       | 24.5              | 70   | 42   | 168  |
| $HCP_{05}$   |           | 4.8               | 90   | –    | –    |
|              |           |                   | second cut |     |      |
| N0P0K0       | –         | 2.2               | 1201 | 721  | 2882 |
| N0K60        | –         | 5.5               | 113  | 68   | 271  |
| N45K60       | 1.3       | 9.5               | 164  | 98   | 394  |
| N60K60       | 1.0       | 11.6              | 181  | 109  | 434  |
| N60K90       | 1.5       | 13.3              | 78   | 47   | 187  |
| $HCP_{05}$   |           | 2.7               | 72   | –    | –    |

It was found that the main source for increasing the productivity of green natural grass stand during the first and second cuts were nitrogen fertilizers, which is confirmed by the correlation analysis (Figure 1).

The $^{137}$Cs pollution density of the territory, climatic resources of the central meadow of a flood plain of the river Iput of Novozybkovsky district of the Bryansk region and the natural fertility of alluvial meadow soil ensure the productivity of the green natural grass stand with $^{137}$Cs specific activity of 1137 and 1201 Bq/kg of the first and second cuts respectively (Table 1).

The surface application of phosphorus-potassium and potash fertilizers during the first and second cuts respectively reduces $^{137}$Cs specific activity of the green natural grass stand by 10.4 and 10.6 times in comparison with the option without the use of mineral fertilizers, at the same time in terms of the $^{137}$Cs content the green forage does not correspond to the existing standard (grass of natural meadows – at least 100 Bq/kg) [13].

The application of increasing doses of nitrogen fertilizer into phosphorus-potassium and potash fertilizers during the first and second cuts increases $^{137}$Cs specific activity of the green natural grass stand by 1.4 and 1.6 times in comparison with the option where phosphorus-potassium and potash fertilizers were applied, at the same time the green forage does not correspond to the existing standards for $^{137}$Cs content.

The use of mineral fertilizers with the K/N ratio of 1/1.5 leads to the production of green forage corresponding to the existing standard for $^{137}$Cs content.

It was found that the main source for decreasing the $^{137}$Cs specific activity of the green natural grass stand were potash fertilizers, while in turn, nitric fertilizers were increasing it, which is confirmed by the correlation analysis (Figure 1).
The use of a flood meadow with soil pollution density of over 555 Bq/m² as a pasture for green forages with their subsequent use for cattle feeding leads to livestock production not satisfying the standard (milk – at least 100 Bq/l, meat beef – at least 200 Bq/kg) [14] (Table 1).

The use of mineral fertilizers in radioactive flood meadows decreases $^{137}$Cs migration from the soil to plants, and hence reduces its contents in livestock products.

Data on the strength of relationship between variables, productivity of green grass stand and increasing doses of nutrients in mineral fertilizers confirm a significant role of nitrogen in improving the efficiency of a flood meadow during the first and second cuts. It was found that the use of nitrogen in doses from 0 to 60 kg against P60K60 and K60 increases the productivity of green grass stand during the first and second cuts, and the correlation dependence is quite strong and makes $r = 0.68$ and 0.74 respectively.

Data on the strength of relationship between variables, $^{137}$Cs specific activity of green grass stand and increasing doses of nutrients in mineral fertilizers confirm a significant role of potassium in decreasing $^{137}$Cs transition from soil to forage production of a flood meadow during the first and second cuts, as well as the average role of nitrogen in increasing transition $^{137}$Cs transition from soil to forage products.

It was found that the use of nitrogen in doses from 0 to 60 kg against P60K60 and K60 increases $^{137}$Cs specific activity of green grass stand during the first and second cuts, and the correlation dependence is quite strong and makes $r = 0.46$ and 0.61 respectively.
The correlation dependence between the decrease of $^{137}$Cs specific activity of green natural grass stand during the first and second cuts and increase of potassium against N60P60 and N60 is strong and makes $r = 0.88$ and 0.91 respectively. Thus, when utilizing radioactive flood meadows to receive green forages it is necessary to observe the ratios of nitric and potash fertilizers as part of mineral fertilizers. To increase the productivity of green grass stand it is recommended to use nitrogen fertilizers, which increase $^{137}$Cs content in feed, and potash fertilizers, which reduce $^{137}$Cs transition from soil to plants, but do not improve the efficiency.

4. Conclusion

To receive green forages from radioactive flood meadows with $^{137}$Cs pollution density of over 555 kBq/m$^2$ it is necessary to apply mineral fertilizers in a dose of N120P60K180 during two cuts, which increase the productivity of green grass stand to 37 t/ha, at the same time the forages correspond to the standard for $^{137}$Cs content. At the same time the leading role in increasing the efficiency of a meadow is assigned to nitrogen fertilizers and to potash fertilizers that decrease $^{137}$Cs content in feed.

The use of a flood meadow as a pasture at $^{137}$Cs pollution density of over 555 kBq/m$^2$ is impossible for livestock production satisfying norms on $^{137}$Cs content in milk and meat without the use of mineral fertilizers.

5. Acknowledgements

The work is performed under financial support of the Russian Foundation for Basic Research administration of Bryansk region within the research project No. 18-44-320001.

References

[1] Belous N M, Podolyak A G, Karpenko A F, Smolskii E V 2016 Efficiency of protective measures aimed at rehabilitation of forage lands polluted after the Chernobyl accident in Russia and Belarus. *Radiation Biology. Radio Ecology*. 56(4) 405–413

[2] Fesenko S, Jacob P, Alexakhin R, Sanzarova N I, Panov A, Fesenko G, Cecille L 2001 Important factors governing exposure of the population and countermeasure application in rural settlements of the Russian Federation in the long term after the Chernobyl accident. *J. Environ. Radioactivity*. 56 77–98

[3] Aleksakhin R M, Spirin E V, Savkin M N 1999 Radiation safety of the population and agro-industrial production (regulation of radionuclides in agricultural products). *Radiation Biology. Radio Ecology*. 39(4) 444–450

[4] Fesenko S V, Alexakhin R M, Balonov M I, Bogdevich I M, Howard B J, Kashparov V A, Sanzarova N I, Voigt C, Zhuchenko Yu 2006 Chernobyl consequences for agriculture. *Nuclear Eng. Int.* 51(620) 34–37

[5] Panov A V, Fesenko S V, Aleksakhin R M 2001 Efficiency of actions to decrease radiation doses of the rural population during a long-term period after the Chernobyl accident. Radiation biology. *Radio Ecology*. 41(6) 682–694

[6] Sanzarova N I, Fesenko S V, Romanovich I K, Marchenko T A, Razdayvodin A N, Panov A V, Choubina O A, Prudnikov P V, Isamov N N, Radin A I, Brook G Ya 2016 Radiological aspects of territories of the Russian Federation damaged during the Chernobyl accident towards normal conditions. *Radiation Biology. Radio Ecology*. 56(3) 322–335

[7] Podolyak A G 2007 Influence of vertical migration and forms of $^{137}$Cs and $^{90}$Sr in soils on their biological availability on the example of natural meadows of the Belarusian Polesye. *Agrochemistry*. 2 72–82

[8] Belous N M, Smolskii E V, Chesalin S F, Shapovalov V F 2016 Role of mineral potassium in the reduction of $^{137}$Cs in fodder grass and increase of their productivity on radioactive polluted lands. *Agricultural Biology*. 51(4) 543–552

[9] Prister B S, Omelyanenko N P, Perепятникова L V 1990 Migration of radionuclides in soil and their transition to plants in the accident zone of the ChNPP. *Soil Science*. 10 51–60
[10] Classification and diagnostics of soils of the USSR. (Moscow: Kolos) 1977 p. 223
[11] IUSS Working Group WRB. 2014. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.
[12] Fokin A D, Lurye A A, Troshin S P 2011 Agricultural radiology. (SPb.: Lan) p. 416
[13] Veterinary health requirements to radiation safety of forages, feed additives, raw materials fodder. Allowable levels of radionuclides $^{90}$Sr and $^{137}$Cs. Veterinary rules and regulations. VR 13.5.13/06-01. Veterinarian. Pathology. 2002 4 44–45
[14] Hygienic requirements to safety and nutrition value of food products: Sanitary and epidemiologic rules and regulations SanPiN 2.3.2.1078-01. (Moscow: Russian Ministry of Health) 2002 p. 164