The effect of different doses of lime on the potash state in sod-medium podzolic medium loamy soil

A N Isupov*, D V Belosludtsev, P A Ukhov and L A Lozhkina
FSBEI HE Izhevsk SAA, Studentskaya Str., 11, the Udmurt Republic, 426069 Izhevsk, Russia

* Email: isupov_l@mail.ru

Abstract. To study the transformation of soil potassium under the action of lime doses, long-term microfield experience was used. The one-factor experiment is laid in sixfold repetition. The location of plots is systematic with an offset. During three years of research, the following cultures of the crop rotation link were cultivated: annual grasses (vetch-oat mixture), winter triticale (variety - Izhevsk 2), spring wheat (variety - Yoldyz). In a long-term experiment on sod-medium podzolic medium loamy soil, it was found that the use of various doses of lime did not reduce the content of water-soluble and easily exchangeable potassium, but significantly increased the amount of mobile potassium to 8 mg/kg and non-exchangeable potassium to 13 mg/kg in the soil. In addition, liming affected the productivity of agricultural crops. Depending on the lime dose, it increased by 4 - 20%.

1. Introduction
According to the level of consumption of basic nutrients by most agricultural crops, potassium is on the first place. Nevertheless, little attention is paid to the study of the potash state in the profile of sod-podzolic soils, and the use of potash fertilizers is at a minimum level. This is justified by the fact that the main arable soils contain fairly high reserves of gross potassium, and its distribution over the soil profile, unlike nitrogen and phosphorus, is fairly uniform [15].

A number of studies have been devoted to the study of changes in the content of potassium forms in the soil profile during their agricultural use [7, 8]. The connection between the distribution of potassium fertilizers in the soil profile and the granulometric composition of soils is often noted. Thus, potassium migration is observed up to 100 cm on light soils, up to 60 cm - on medium loamy soils, up to 40 cm - on heavy loamy soils [9, 12, 13]. Nevertheless, the data on the liming effect on the content of various forms of potassium in the profile of sod-medium podzolic medium loamy soil is ambiguous.

Due to the reduction of liming areas and the complete rejection of potash fertilizers in the conditions of the Udmurt Republic, it is possible to predict a decrease in all forms of soil potassium and depletion of the non-exchange-fixed reserve, which will lead to a significant decrease in the optimization of potassium supply of agricultural crops due not only to the arable, but also to the sub-arable layers [2, 3, 10]. The study of this issue will help to more fully assess the effect of lime on the potash state of sod-medium podzolic medium loamy soil.

The analysis of materials on the potash state of soils showed that, despite a significant amount of scientific information on this issue, the main attention of research even in long-term experiments was paid to the final, less often – individual intermediate results of the experiments. At the same time, data on the dynamics of the content of various potassium forms in the soil are insufficiently generalized [1,
In this regard, it is of interest to study the dynamics of changes in the content of the potash state of soils in both fertilized and non-fertilized versions of long-term experiments, since in practice the content of mobile potassium still serves as the main agrochemical indicator determining the need for the use of potassium-containing fertilizers for agricultural crops [6, 9, 11, 14].

In this regard, the purpose of our research is to study the effect of lime doses on the potash state in sod-medium podzolic medium loamy soil.

2. Materials and methods

To study the transformation of soil potassium under the action of lime doses, long-term micro-field experience conducted at the experimental field of JSC "Uchkhoz Uyulskeoye of the Izhevsk SAA" of the Votkinsky district of the Udmurt Republic was used. The experiment was laid in the fall of 2016. The soil of the experimental site is sod-medium podzolic medium loam on red-brown heavy loam with the following characteristics: the average acid reaction of the soil medium (pH_KCl - 4.6); hydrolytic acidity - 4.38 mmol/100 g of soil, the amount of absorbed bases - 8.9 mmol/100 g of soil, the degree of soil saturation with bases - 69%. The content of mobile forms of phosphorus and potassium according to the Kirsanov's method is 64 and 71 mg/kg, respectively, which corresponds to an average content of mobile phosphorus and a low content of mobile potassium. The humus content was 2.0%, which corresponded to the average humus content of the soil.

The one-factor experiment is laid in sixfold repetition. The location of plots is systematic with an offset. The size of the experimental plot is 1.0 × 1.05 m. The plots were bounded along the perimeter by a film to the depth of the arable layer.

The scheme of the experiment included five options: 1. Without fertilizers (control); 2. Lime of 0.25 N_s; 3. Lime 0.5 N_s; 4. Lime of 1 N_s; 5. lime of 1.5 N_s. Lime doses are calculated based on the hydrolytic acidity of the soil.

In the autumn of 2017-2019, soil samples from various layers up to a depth of 80 cm (0-20, 20-40, 40-60, 60-80 cm) were taken from all experimental plots by a soil drill. In soil samples, the content of various forms of potassium was determined by the following methods: water-soluble potassium - according to the Alexandrova method; light-exchange potassium - in a slightly saline calcium chloride extract (0.005n CaCl2); mobile potassium - according to the Kirsanov method (GOST 26207-91), non-exchangeable absorbed potassium - according to the Pchelkin method (2n HCl).

During three years of research, the following cultures of the crop rotation link were cultivated: 1. in 2017, annual grasses (vetch-oat mixture). 2. in 2018, winter triticale (variety - Izhevsk 2). 3. in 2019, spring wheat (variety - Yoldyz).

Yield accounting was carried out by a continuous method manually, followed by threshing of ears on a grain thresher. Immediately after threshing the crop at the time of weighing, samples were taken from each plot to determine the moisture content of the grain. After determining the moisture content of the grain, the yield from each plot was brought to the standard 14% moisture. The hay harvest was brought to the standard 16% moisture.

Mathematical processing of the results was carried out on a PC using Microsoft Excel application programs. The significance of the difference in indications between the variants in the experiments was established by the analysis-of-variance method [5].

3. Results

Studies in the microfield experiment on the study of lime doses were carried out during three growing seasons in 2017, 2018 and 2019 (Table 1). Lime applied in different doses had almost the same effect on the forms of potassium in the soil. The results of the 2017 experiment showed that lime doses do not contribute to the accumulation of water-soluble and easily exchangeable potassium in the soil, their amount according to the studied variants was at the same level. In subsequent years (2018, 2019), the effect of lime was similar to 2017. This can be explained by the absorption capacity of the plant root system, which in turn did not allow the accumulation of water-soluble and easily exchangeable potassium in the soil.
Table 1. The effect of different lime doses on the content of various forms of potassium in sod-medium podzolic medium loamy soil, mg/kg (JSC "Uchkhoy Iyulskoye Izhevsk SAA", 2017-2019).

| Variant | Water-soluble potassium | Easily exchangeable potassium | Mobile potassium | Non-exchangeable potassium |
|---------|-------------------------|-------------------------------|-----------------|-----------------------------|
|         | average dev. | average dev. | average dev. | average dev. |
| 2017    |             |             |             |             |
| Control | 7           | 9             | 56           | 309           |
| 0.25 Ng | 8           | 1             | 8            | 52            |
| 0.5 Ng  | 9           | 1             | 8            | 57            |
| 1 Ng    | 7           | 0             | 8            | 56            |
| 1.5 Ng  | 8           | 1             | 7            | 51            |
| LSD05=  | F<sub>r</sub><F<sub>05</sub> | -           | F<sub>r</sub><F<sub>05</sub> | -             |
| 2018    |             |             |             |             |
| Control | 16          | -             | 45           | 280           |
| 0.25 Ng | 14          | -2            | 19           | 47            |
| 0.5 Ng  | 14          | -2            | 16           | 50            |
| 1 Ng    | 15          | -1            | 15           | 48            |
| 1.5 Ng  | 13          | -3            | 17           | 46            |
| LSD05=  | F<sub>r</sub><F<sub>05</sub> | -           | F<sub>r</sub><F<sub>05</sub> | -             |
| 2019    |             |             |             |             |
| Control | 9           | 10            | 70           | 275           |
| 0.25 Ng | 9           | 0             | 8            | 71            |
| 0.5 Ng  | 10          | 1             | 11           | 75            |
| 1 Ng    | 10          | 1             | 10           | 72            |
| 1.5 Ng  | 8           | -1            | 9            | 78            |
| LSD05=  | F<sub>r</sub><F<sub>05</sub> | -           | F<sub>r</sub><F<sub>05</sub> | -             |

The content of mobile potassium in the soil depended on the lime dose and the year of action. In 2017, when using quarter and one-and-a-half doses, its amount decreased slightly in relation to the control variant. In the following years (2018, 2019), in relation to the control variant, its content significantly increased by 2-8 mg/kg of soil. It should be noted that the lime introduced in various doses contributed to an increase in yield during the years of research. As a result, the intake of organic matter into the soil has increased. Under the influence of microbiological processes, the mineralization of organic matter took place, which caused an increase in the content of soil mobile potassium. Obviously, this is due to the absorption of potassium by the root system and its transfer in the process of agrochemical reactions into mobile forms. Therefore, in the third year of lime action, the amount of mobile potassium in the variants increased by 19-27 mg/kg of soil, and the content of non-exchangeable potassium decreases. Thus, the average content of non-exchangeable potassium for the studied variants in 2017 amounted to 301 mg/kg of soil, and in 2019 its amount decreased by five percent.

The most important indicator characterizing soil fertility is the productivity of agricultural crops (Table 2).

In the conditions of microfield experiment, the productivity of crops directly depended on the dose of lime. In 2017, annual grasses (vetch-oat mixture) were cultivated, the vegetation period of which was 58 days, which is less than that of grain crops. Therefore, the productivity of annual grasses was low, on average, according to the variants, it amounted to 125-152 g of g.u./m².
Table 2. Productivity of agricultural crops depending on the doses of lime application (JSC “Uchkhoo Uyulskiy Izhevsk SAA”, 2017-2019).

| Variant | Annual grasses, (2017) | Winter triticale, (2018) | Spring wheat, (2019) | Total productivity |
|---------|------------------------|--------------------------|---------------------|-------------------|
|         | g g.u./m² ± | g g.u./m² ± | g g.u./m² ± | g g.u./m² ± |
| Control | 125 - | 142 - | 140 - | 407 - |
| 0.25 Ng | 136 11 | 171 29 | 146 6 | 453 46 |
| 0.5 Ng  | 136 10 | 158 16 | 147 8 | 441 34 |
| 1 Ng    | 139 14 | 155 13 | 150 11 | 445 38 |
| 1.5 Ng  | 152 26 | 163 21 | 154 14 | 469 62 |
| LSD_{0.05} | 3 2 | 2 2 | 2 2 |

In the variants with quarter and half doses of lime, the increase in productivity of annual grasses was the same 10-11 g g.u./m². With an increase in the dose of lime, the productivity of annual grasses increases. At the same time, the highest yield was obtained from the action of a one-and-a-half dose of lime, the difference with the control was 26 g g.u./m². A similar effect of lime doses was in the cultivation of spring wheat. The variant with a quarter dose of lime gave an increase of 6 g g.u./m², and a one-and-a-half dose of lime increased it by 14 g g.u./m². In terms of effectiveness, the remaining doses of lime occupied an intermediate position. The highest yield of the main products among the studied crops was obtained during the cultivation of winter triticale, in the variant with a lime dose of 0.25 Ng, while the maximum increase in products to the control was 29 g g.u./m². The calculation of the total productivity over three years of research showed that the most effective dose of lime in the conditions of the microfield experiment was 1.5 Ng, the yield increase in relation to the control variant was 15%.

4. Discussion
The results of the research showed that in the second and third years of lime's action, non-exchangeable forms of potassium turn into mobile ones, resulting in increased productivity of agricultural crops.

5. Conclusions
1. The studied doses of lime do not increase the content of water-soluble and easily exchangeable potassium in the soil, since these are the most accessible forms for plants that absorb them in the first place.
2. In the first year of lime action, there is no accumulation of mobile potassium in the soil. Its increase in relation to the control variant occurs in the second and third years of lime action, especially in the variant with a half dose of lime up to 6 mg/kg of soil.
3. The content of non-exchangeable potassium in the soil decreased in relation to the control under the action of lime, but this happened regardless of the dose of lime. It is obvious that it has moved into a mobile form.
4. The productivity of agricultural crops directly depended on the doses of lime. The highest increase in the yield of annual grasses and spring wheat was from the action of a one-and-a-half dose of lime of 15, 10 g g.u./m², respectively. Winter triticale reacted well to a dose of lime introduced by 0.25 Ng, resulting in a 20% increase in yield.

References
[1] Afanasyev R A, Myorzlaya G E 2013 The content of mobile potassium in soils with prolonged use of fertilizers Agrochemistry 6 5-11
[2] Belosludtsev D V, Isupov A N, and Bashkov A S 2019 Studying the influence of the relationship between the potash state of sod-medium podzolic medium loamy soil and the yield of hay of
annual grasses during liming and the use of mineral fertilizers. *Agrarian science-agricultural production: materials of the International scientific and practical conference FSBEI HE Izhevsk SAA* (Izhevsk: Izhevsk SAA) pp 14-17

[3] Beznosov A I 2005 *Liming of Udmurtia soils: monograph* (Izhevsk: Izhevsk SAA) 68 p

[4] Belosludtsev D V, Isupov A N, and Bashkov A S 2021 Changes in the potash state of the soil with prolonged use of mineral fertilizers against the background of the aftereffect of liming. *Fertility* 1(118) 33-36

[5] Demin V A, Musa A 2002 Forms of potash compounds in sod-podzolic soil with prolonged use of fertilizers. *Bulletin of the TAA* 4 41-50

[6] Dospekhov B A 1985 *Methodology of field experience (with the basics of statistical processing of research results)* 5th ed., supplement and revision (M.: Agropromizdat) 351 p

[7] Isupov A N, Bashkov A S, and Belosludtsev D V 2021 Characteristics of lime properties of various deposits of the Udmurt Republic. *Technological trends of sustainable functioning and development of agro-industrial complex: materials of the International scientific and Practical conference dedicated to the Year of Science and Technology in Russia*, Izhevsk, February 24-26, 2021 (Izhevsk: Izhevsk State Agricultural Academy) pp 51-55

[8] Lukin S M 2012 Potash state of sod-podzolic sandy loam soil and potassium balance with prolonged use of fertilizers. *Agrochemistry* 12 5-14

[9] Nikitina L V 2012 The effect of long-term use of fertilizers in grain-tillage crop rotation on the potash regime of sod-podzolic heavy loamy soil. *Agrochemistry* 12 15-23

[10] Nosov V V 2002 The importance of potash fertilizers for the preservation of ecological balance. *Fertility* 2 28-30

[11] Prokoshev V V, Deryugin I P 2000 *Potassium and potash fertilizers* (M.: Ledum) 185 p

[12] Yakimenko V N 2007 Changes in the content of potassium forms according to the soil profile with different potassium balance in agrocenoses. *Agrochemistry* 3 pp 5-11

[13] Yakimenko V N 2005 Mobility of potassium forms in soils. *Agrochemistry* 9 5-12

[14] Marschner H 2011 *Mineral nutrition of higher plants* 3rd ed. (London) 672 p

[15] Goulding K W T 1996 *Potassium fixation and release* Methodology in Soil–K Research. *International Potash Institute* (Bern, Switzerland) pp 137–197