ASSESSMENT OF ACID STATE OF LOW-PRODUCTIVE IRRIGATED LANDS DEPENDING ON FERTILIZER SYSTEM AND PRECEDING CROPS

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Abstract. The mineral system of cultivating spring barley on degraded lands exacerbates the acidity of the soil solution, increasing it by an average of 0.2-0.3 pH for all preceding crops. To neutralize the acidity of physiologically acidic fertilizers, it is necessary to apply higher doses of lime, taking into account correction coefficients. The application of organic fertilizers in the form of manure extracted from the liquid effluents of animal husbandry complexes, combined with the use of spring rapeseed as a preceding crop, is essential in reducing soil acidity. In this case, over a seven-year research period, the acidity reduction of unproductive irrigated lands amounted to 0.42-0.48 pH at $LSD_{05} = 0.41\text{-}0.45$ pH. For other predecessors, there was only a positive trend of deoxidation of the soil, since the difference between the initial and final values was within the error of experience. The positive effect of liquid livestock runoff on soil deoxidation was noted, which provided a significant reduction in acidity when applying 100-120 $t \cdot ha^{-1}$ as the main fertilizer, equal to 0.40 pH units.

Keywords: low-productive land, acidity, fertilizers, predecessors, liquid effluents.

Introduction

One of the main limiting indicators of soil fertility, which have a direct effect both on the plant and on all physicochemical and biological processes in the soil, which ultimately determine the level of crop productivity, is the acidity of the soil solution. The acidity level also affects the mineral nutrition of plants and the biological activity of the soil; therefore, it requires a comprehensive study when developing a strategy for returning degraded and unproductive irrigated lands of the non-chernozem zone to agricultural circulation. The high acidity of the soil in this zone in the vast majority of cases acts as the main factor limiting the crop yield [1; 2].

The application of lime has a positive multilateral effect on fertility, since it eliminates soil acidity, increases the degree of soil saturation with bases to an optimal level. Liming improves the availability of nitrogen, phosphorus and molybdenum to plants, enriches the root zone with calcium and magnesium, reduces the mobility and negative effect of aluminum and manganese on the plant, increases the biological activity of the soil, improves its agrophysical, agrochemical and biological properties. Ultimately, it determines a high crop yield, better product quality, the effectiveness of mineral fertilizers, and also optimizes the ecological state of the agrolandscape [3].

Acidic soils have a number of unfavorable properties that should be taken into account for each soil zone, namely, the reaction of the soil solution in combination with a deficiency of mineral nutrition elements or their inaccessibility acts as the main factor limiting the crop yield level of agrocenosis [4].

For sod-podzolic soils, the high content of hydrogen and aluminum in the soil solution, which determine the level of acidity, is the most important reason for their liming.

An important factor determining the negative effect of acidity on the productivity of agricultural plants is the excessive accumulation in the soil of mobile forms of manganese and iron, the absorption of which by plants is especially enhanced with a deficiency of calcium and magnesium. With excessive moisture, the amount of highly available manganese and iron increases several times, which sharply affects the quality of these soils. The insufficient content of the exchangeable forms of calcium and magnesium is characteristic of strongly acidic soils of sandy loam texture, which should be limed foremost [5].

Along with acidity, the most important limiting factor of soil fertility is the content of humus. Humus substances have a major influence on the food regime, physical, mechanical and biological properties of the soil. The content of humus in the soil is mainly regulated by changes in the amount of incoming organic mass, so with the cultivation of crops that leave a lot of plant and root residues in the soil, the introduction of increased rates of organic fertilizers contribute to its accumulation.

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Currently, the problem of maintaining the humus state of soils in the non-chernozem zone of Russia at an optimal level is particularly important, since the humus content in the soil of this zone remains low. In the arable layer of light-loam podzolic soil, the humus content is 1.75-1.86 %, and in sod-podzolic medium-loam-1.90-2.13 %, which is significantly lower than the optimal values. In the current situation, for the reproduction of humus reserves in the soil, it is necessary to use straw, peat, green mass of sideral crops, as well as solid fraction and liquid effluents of large livestock complexes as organic fertilizers in the maximum possible volumes [6; 7].

The aim of our research was to study the dynamics of the acid state of sandy loam soils during the development of low-productive irrigated lands that were withdrawn from agricultural circulation, depending on the fertilizer system and preceding crops.

Materials and methods

The studies were carried out in Ruchevskoye LLC, Rzhevsky district, Tver region from 2012 until 2018. The soil of the experimental plot is sod-podzolic, sandy loamin terms of soil texture, the thickness of the arable layer is 16-18 cm, drained by open drainage. The initial content in the soil (2012): humus – 1.69-1.83 – very low; readily hydrolysable nitrogen – 74.8-77.2 mg·kg^{-1} – very low; P_2O_5 – 106-109 mg·kg^{-1} – high; K2O – 90-100 mg·kg^{-1} – average; pH_{KCl} – 4.78-4.83 units – the reaction of the soil solution is moderately acidic.

Meteorological conditions during the years of the experimental work varied significantly both in temperature and in the amount of precipitation and their distribution in decades and months. However, this was not a limiting reason for the cultivation of programmed grain yields of spring barley with a standard humidity of 40 c·ha^{-1} [3]. For sowing, we used a variety of German selection *Sunshine*, recommended for use in the non-chernozem zone of the Russian Federation.

The area of the test plot is 140 m^2; sown area – 280 m^2. Placement of variants – by the method of randomized repetitions, 4-fold repetition. Sowing was carried out in optimal time by seeds of the first class sowing standard; seed placement depth – 4-5 cm. Calculated rates of mineral and organic fertilizers were used as the main fertilizer and applied before sowing. The application of solid manure was carried out by spreaders of organic fertilizers. The liquid runoff of livestock complexes was evenly distributed over the field using the technology of flexible hose systems with their simultaneous incorporation into the soil, which eliminates the loss of gaseous forms of nitrogen. The solid manure contained: N – 0.63 %; P_2O_5 – 0.47 % and K_2O – 0.80 % with pH_{KCl}of7.9. The average humidity was 61 %. The dry matter content in liquid effluents averages 3 %. Whereinthey contain: N – 0.10 %, P_2O_5 – 0.03 % and K_2O – 0.13 %; pH_{KCl} of 7.3. Thus, both types of organic fertilizers have an alkaline reaction, and therefore it is advisable to apply them primarily in soils with an acidic reaction.

Studies on the dynamics of soil acidity were carried out by the generally accepted method (GOST 26483-85) in accordance with the Federal Law “On state regulation of ensuring the fertility of agricultural land” by the employees of the FGBU “Station of the Agrochemical Service Nelidovskaya”.

Results and discussion

It was established that various fertilizer systems during the cultivation of spring barley on redevelopedirrigated lands have an uneven effect on the dynamics of soil acidity. Thus, in the control group without fertilizing for a seven-year observation period, it decreased by 0.05 unitswith spring grains as a preceding crop, and by 0.08 units, when barley was sownafter winter grains. In the same variant the cultivation of barley after rapeseed provided an intermediate decrease in soil acidity by 0.06 units. In our opinion, the positive tendency towards a decrease in acidity in the control variant is ensured by the accumulation of crop-root residues as organic mass, which, with a barley grain yield of 10.4-12.2 c·ha^{-1}, were 15.7-16.6 c·ha^{-1}. After mineralization of the residues, their positive effect on the soil solution reaction was noted, which ensures stabilization of the acid state of the agrolandscape.

The cultivation of barley on the mineral fertilizer system for the planned yield of 40 kg·ha^{-1} of grain, on the contrary, provides for all preceding crops an increase in soil acidity by 0.3-0.6 units. Therefore, in order to obtain programmed crops, it is necessary to carry out soil liming. This is due to the fact that high crop yields against a balanced mineral system ensure a significant removal of calcium and magnesium with the crop.

It was found that when solid manure was introduced at a rateof 40 t·ha^{-1} for the main tillage, the acidity of the soil during the observation period decreased by 0.42 unitswith LSD_{05} = 0.29 pH. A further increase in the dosage of the solid fraction to 60 and 80 t·ha^{-1} provides an equal decrease in soil acidity by 0.48 pH. Thus, although increasing the dose of the solid fraction to 80 t·ha^{-1} reduces the acidity of low-productive lands, the decrease in pH with respect to the norm of 60 t·ha^{-1} is the same value (Table 1).

Table 1

Dynamics of acidity (pH_{kcl}) in barley planting, depending on the fertilizer system and preceding crops in the development of irrigated land removed from circulation

Variants (factor A)	**Preceding crops (factor B)**											
	Rapeseed				**Spring grains**				**Winter grains**			
	2012	2015	2018	Av.	2012	2015	2018	Av.	2012	2015	2018	Av.
Control group no fertilizer	4.91	4.94	4.97	4.94	4.91	4.93	4.96	4.93	5.02	5.06	5.10	5.06
Mineral system $N_{55}P_{30}K_{90}+P_{10}$ during planting, N_{30} – feeding	4.83	4.80	4.78	4.80	4.78	4.76	4.75	4.76	4.83	4.80	4.77	4.80
Manure 40 t·ha^{-1} + P_{10} during planting, N_{30} – feeding	4.76	4.82	5.18	4.92	4.80	4.88	4.97	4.88	4.97	5.09	5.18	5.08
Manure 60t·ha^{-1} + P_{10} during planting N_{30} – feeding	4.72	4.84	5.20	4.92	4.73	4.83	4.94	4.83	4.74	4.97	5.09	4.93
Manure 80t·ha^{-1} + P_{10} during planting, N_{30} – feeding	4.75	4.86	5.23	4.95	4.74	4.84	4.96	4.85	4.75	4.99	5.12	4.95
Liquid effluents 100 t·ha^{-1} + P_{10} during planting, N_{30} – feeding	4.77	4.89	5.15	4.94	4.76	4.86	4.91	4.84	4.79	5.00	5.07	4.99
Liquid effluents 120 t·ha^{-1} + P_{10} during planting, N_{30} – feeding	4.79	4.92	5.19	4.97	4.76	4.89	4.95	4.87	4.70	5.00	5.08	4.93
Average	4.79	4.87	5.10	4.92	4.78	4.86	4.92	4.85	4.83	4.99	5.06	4.96
LSD05 For A	0.29	0.30	0.31	0.29	-							
For B	0.30	0.29	0.30	0.28	-							
A & B	0.41	0.44	0.45	0.43	-							

We also noted the positive effect of liquid runoff on soil deacidification, which ensured the same significant decrease in acidity, equal to 0.40 pH, both when applying 100 t·ha^{-1}, and when applying 120 t·ha^{-1} before planting as the main fertilizer.

Preceding crops in the cultivation of barley affect the acid regime of the soil. Thus, when using spring rapeseed as a preceding crop, the concentration of hydrogen ions decreased by an average of 0.13 units; when sowing barley after spring crops (spring wheat, oats), the acidity decreased by 0.08 units, and after winter crops (winter wheat, winter rye) – by 0.14 units with $LSD_{05}$by factor B = 0.28pH.Therefore, of all the studied preceding crops the best in the cultivation of barley are winter grains and springrapeseed, which equally affect the decrease in soil acidity. However, it is preferable to choose spring rapeseed, as it simultaneously with deacidification improves the phytosanitary state of the agrolandscape. In addition, spring rapeseed does not have common diseases and pests with grain crops, which provides phytopathological and entomological improvement of irrigated land.

The mineral system of barley cultivation negatively affected the acidity level, increasing it by an average of 0.2-0.3 pH for all preceding crops. To neutralize the increase in acidity of irrigated land during fertilizer application, correction coefficients should be used when determining lime rates in the following proportions: 0.75 c $CaCO_3$ shouldbe added per 1 c ammonia nitrate; per 1 c of ammonium sulfate – 1.25 c $CaCO_3$; per 1 c of ammonia water – 0.5 c, and per 1 c of ammonium chloride – 1.4 c of $CaCO_3$. Mineral fertilizers themselves in the year of application are used less effectively on acidic soils than on weakly acidic and neutral soils, therefore they should be used at higher rates to obtain programmed crop yields. Correction coefficients when applying mineral fertilizers, depending on the acidity of the soil are: at pH up to 4.0 – 1.13; at pH 4.1-4.5 – 1.11; at pH 4.6-5.0 – 1.09: at pH 5.1-5.5 – 1.06; at a pH of 5.6 or more – 1.0.

In general, while assessing the complex effect of fertilizers and preceding crops on the acid regime of low-productive irrigated lands of the non-chernozem region, it should be noted that the maximum deacidification was observed when cultivating spring barley after rapeseed, which amounted to: when applying a solid manure – 0.42-0.48 pH; when using liquid effluents of livestock complexes – 0.38-0.40pH. The use of spring grain as preceding cropsalso provides positive dynamics of deacidification of land in the following intervals: for manure – by 0.17-0.22 pH; for liquid effluents – by 0.15-0.19 pH.

The cultivation of spring barley after winter grain crops determines the average value of indicators for improving the acid regime of the soil, which was: for manure – 0.21-0.37 pH, and for liquid effluents – 0.28-0.38 pH.

However, a significant decrease in acidity from the interaction of fertilizer systems and preceding crops is observed only when solid manure is added after spring rapeseed (the acidity was 0.42-0.48 pH at LSD_{05} = 0.41-0.45 pH).

Conclusions

1. For the low-productive irrigated lands of the non-chernozem zone reintroduced into the agricultural turnover the most important environmental factor limiting their direct use in the crop production system is the acidity of the soil solution, caused by the high concentration of hydrogen and aluminum ions, which determines the need for liming of the low-productive irrigated land.
2. The mineral system of cultivating spring barley on degraded lands exacerbates the acidity of the soil solution, increasing it by an average of 0.2-0.3 pH for all preceding crops. To neutralize the acidity of physiologically acidic fertilizers, it is necessary to introduce increased doses of lime taking into account correction coefficients.
3. The introduction of organic fertilizers in the form of manure extracted from the liquid effluents of animal husbandry complexes, combined with the use of spring rapeseed as preceding crops is essential in reducing acidity. In this case, over a seven-year research period, the acidity reduction of low-productive irrigated lands amounted to 0.42-0.48 pH. at LSD_{05} = 0.41-0.45 pH.
4. The use of spring grains as a precursor also provides a positive dynamics of soil deoxidation in the following intervals: for manure-by 0.17-0.22 units of pH; for liquid effluents – by 0.15-0.19 units of pH.

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