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МИНЕРАЛЬНЫЕ УДОБРЕНИЯ, ИЗВЕСТЬ И СИДЕРАЦИЯ В ПЛОДОСМЕННОМ СЕВООБОРОТЕ В УСЛОВИЯХ ПРИБАЙКАЛЬЯ

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Представлены результаты исследований по влиянию длительного применения минеральных удобрений, извести и сидерации на кислотность почвы и продуктивность сельскохозяйственных культур. Эксперимент проведен в длительном (2017–2020 гг.) стационарном полевом опыте в пятой ротации четырехпольного плодосменного севооборота: кукуруза, ячмень + клевер, клевер, яровая пшеница. Почва опытного участка – серая лесная тяжелосуглинистая. Изучали следующие варианты: без удобрений, $N_{90}P_{60}$, $P_{60}K_{90}$, $N_{90}K_{90}$, $N_{90}P_{60}K_{90}$ на двух фонах – без известкования и с внесением извести по 0,5 Нг (5,7 т/га). Установлено, что пятикратное применение мелиоранта способствовало снижению кислотности серой лесной почвы: pH_{KCl} по сравнению с исходным показателем (4,5–4,9) увеличился на 0,9–1,5, гидролитическая кислотность снизилась на 6,1–8,3 мг-экв./100 г почвы, степень насыщенности основаниями увеличилась на 20,0–25,5%. За счет применения сидерации в севообороте pH_{KCl} возрос на 0,4–0,6, гидролитическая кислотность снизилась на 2,3–4,1 мг-экв./100 г почвы, степень насыщенности основаниями увеличилась на 9,2–13,3%. Минеральные удобрения в применяемых дозах не оказывали влияния на изменение кислотности почвы, как на непроизвесткованном, так и на произвесткованном фонах. Продуктивность севооборота по вариантам опыта увеличилась на 0,23–0,69 т зерновых единиц/га (т з. ед./га) (7–21%) и была наибольшей при совместном действии полного минерального удобрения ($N_{90}P_{60}K_{90}$) и извести. Окупаемость 1 кг д.в. минеральных удобрений сельскохозяйственной продукцией составила 6,1–11,5 кг зерна, 1 т извести – 2,5–3,2 ц зерна.

Ключевые слова: серая лесная почва, кислотность, плодосменный севооборот, известкование, минеральные удобрения, сидерация

MINERAL FERTILIZERS, LIME AND GREEN MANURING IN CROP ROTATION UNDER CONDITIONS OF THE BAIKAL REGION

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The results of research on the effect of long-term application of mineral fertilizers, lime and green manuring on soil acidity and crop productivity are presented. The experiment was conducted in a long-term (2017-2020) stationary field experiment in the fifth rotation of a four-field crop rotation: corn, barley + clover, clover, spring wheat. The soil of the experimental plot is gray forest heavy loam. The following variants were studied: without fertilizers, $N_{90}P_{60}$, $P_{60}K_{90}$, $N_{90}K_{90}$, $N_{90}P_{60}K_{90}$ on two backgrounds - without liming and with the introduction of 0.5 Ng of lime (5.7 t/ha). It was found that 5 times use of ameliorant helped to decrease acidity of gray forest soil: pH_{KCl} increased by 0,9-1,5 in comparison with the initial indicator (4,5-4,9), hydrolytic acidity decreased by 6,1-

8,3 mg-eq./100 g, the degree of base saturation increased by 20,0-25,5%. Due to the use of green manuring in the crop rotation, pH_{KCl} grew by 0.4-0.6; hydrolytic acidity fell by 2.3-4.1 mg-eq./100 g of soil, the degree of base saturation raised by 9.2-13.3%. The mineral fertilizers at the applied rates had no effect on changing the soil acidity, both on non-lime- and lime-fertilized backgrounds. The productivity of crop rotations by experiment variants increased by 0.23-0.69 tons of grain units per hectare (tgru/ha) (7-21%) and was the greatest with the combined effect of total mineral fertilizer ($N_{90}P_{60}K_{90}$) and lime. The recoupment of 1 kg rate of application of mineral fertilizers to agricultural products was 6.1-11.5 kg of grain, 1 ton of lime - 2.5-3.2 kg of grain.

Keywords: gray forest soil, acidity, crop rotation, liming, mineral fertilizers, green manuring

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INTRODUCTION

The degradation of soils and land resources is a global problem that has a negative impact on the income and food security of the population around the world [1, 2]. In the Russian Federation, a widespread decrease in the soil fertility of agricultural lands has been observed since the late 20th century, which is accompanied by a negative balance of nutrition elements [3] and a general deterioration of the agrochemical characteristics of all soil types and varieties [4, 5], including gray forest subtypes [6]. Strongly acidic and moderately acidic soils prevail among these soils, which are characterized by a low content of humus and mobile forms of nutrition elements.

After eliminating excessive acidity by applying lime and making up for the lack of nutrients with mineral and organic fertilizers, it is possible to improve the agrochemical properties of gray forest soil to create favorable conditions for the cultivation of crops [7, 8].

Liming and systematic use of mineral fertilizers contribute to their effective use and stable yields[1] [9-10]. The complex effect of the systematic use of mineral fertilizers, lime and sideration on the reduction of soil acidity is currently not enough studied. The results of the studies for four rotations of fruit and vegetable rotation showed a positive effect of liming on reducing the acidity of gray forest soils and crop productivity [11, 12].

The aim of the study was to study the change in the acidity of gray forest soils with long-term use of lime, mineral fertilizers and sideration at the end of five rotations of fruit-and-vegetable crop rotation.

MATERIAL AND METHODS

Field studies were conducted in 2020 on the experimental field of the Irkutsk Research Institute of Agriculture (NIISKh) in the Irkutsk district of the Irkutsk region at the end of the fifth rotation of the fruit and vegetable rotation,

[1]Gladysheva O.V., Svirina V.A., Artyukhova O.A. Changes in soil fertility and crop rotation productivity with long-term use of mineral fertilizers with liming. Plodorodie. 2021. № 1. pp. 27–29. DOI: 10.25680/S9948603.2021.118.08.

laid in 2001. Crop rotation included the following crops: corn (for silage) - barley + clover - clover (for green manure) - spring wheat. The experiment was conducted on two backgrounds - without lime and with lime applied at 0.5 Hr (5.7 t/ha). Soil of the experimental station was gray forest heavy loamy, humus content 4,5-4,8%, total nitrogen 0,17-0,21%, pH_{salt} 3,9-4,4; hydrolytic acidity (Hr) - 9,1-10,6 mg-eq./100 g, the degree of base saturation (V) - 68,4-72,1%, P_2O_5 - 100-120, K_2O - 80-100 mg/kg soil (by Kirsanov). The following fertilizer application systems were studied: 1) without fertilizer, 2) NP, 3) PK, 4) NK, 5) NPK. Mineral fertilizers (ammonium nitrate, double superphosphate, potassium chloride) were applied to corn (hybrid Katerina SV) in the first and second rotations at a dose of $N_{90}P_{40}K_{90}$, for barley (variety Biom) with undersowing clover (variety Rodnik Sibiri) - $N_{40}P_{40}K_{40}$. Given the positive effect of green-manuring on the yield of crops for two rotations of crop rotation, starting with the third rotation (2009), the doses of mineral fertilizers were reduced by 30%, they resulted in $N_{60}P_{30}K_{60}$ (for corn) and $N_{30}P_{30}K_{30}$ (for barley).

Limestone meal ($CaCO_3$ content - 85%) was applied in spring before sowing corn (seeding rate - 200 thousand grains/ha, or 60 kg/ha) on the surface with subsequent embedding with a disc harrow in two trails at a depth of 12-15 cm. Barley and clover were sown after early spring harrowing followed by rolling (sowing rate: barley - 6.5 million germinated grains/ha, clover - 4 million germinated grains/ha). In the second year of its life clover was used as a green manure. Spring wheat (Buryatskaya ostistaya variety) was sown as the closing crop in the rotation with a seeding rate of 7 million germinated grains/ha. The area of the cultivated plot was 122.5 m^2, the area of the record plot was 96.3 m^2. Repeatability is 4 times, arrangement of plots is single-row, consecutive.

Grain crops were counted on a plot by direct harvester "Sampo-500", fodder crops - manually. The research consisted of phenological observations, soil sampling, recording of crop yields, and agrochemical analyses in the laboratory. The samples were taken from 0-20 cm layer in the first field of the crop rotation to study the soil acidity dynamics in autumn, in which pHKCl was determined by the potentiometric method (GOST 26483-85)[2], the hydrolytic acidity - by the Kappen method, and the degree of base saturation - by the computational method[3]. Statistical processing of the results was performed using the application software package Snedecor[4].

RESULTS AND DISCUSSION

Prolonged use of lime in fruit and vegetable rotation had a significant impact on the reduction of acidity of gray forest soils. The pH_{KCl} of the fertilized varieties increased by 1,1-1,5 and the hydrolytic acidity decreased by 7,1-8,3 mg equivalent per 100 grams of soil in comparison with the initial value (4,5-4,9) by the end of the fifth rotation, the degree of base saturation increased by 22,8-25,5%. In the variant without fertilizers these indicators were 0,9 and 6,1 mg-eq./100 g of soil and 20% respectively (See Table 1).

There was a decrease in the soil acidity on the background without lime application. In the variant without fertilization pH_{KCl} increased by 0,4, the hydrolytic acidity decreased by 2,3 mg-eq./100 g of soil, the degree of base saturation increased by 9,2%. In the variants with the use of mineral fertilizers the value of pH_{KCl} increased in comparison with the initial one (3,8-3,9) by 0,4-0,6, the hydrolytic acidity decreased by 3,4-4,1, the degree of base saturation increased by 9,9-13,3%. We believe that the reduction of the soil acidity on the unlimed background was influenced by the use of green mass of clover for green manure. Similar results were obtained in the studies of other scientists [13]. The neutralizing effect of green legume crop on the soil acidity was established by V.N. Prokoshev [14]. L.P. Galeeva notes the reduction of

[2]GOST 26483–85. Preparation of salt extract and determination of its pH by the CINAO method. M., 1985. 7 p.
[3]Arinushkina E.V. Guidance on chemical analysis of soils. M.: Kolos, 1979. 416 p.
[4]Sorokin O.D. Applied Statistics on the Computer. 2nd ed. Novosibirsk, 2012. 282 p.

Табл. 1. Влияние извести и минеральных удобрений на показатели кислотности серой лесной почвы в слое 0–20 см

Table 1. The effect of lime and mineral fertilizers on acidity parameters of gray forest soil in a layer of 0-20 cm

Option	pH_{KCl}		Hg, mg-eq./100 g		V, %	
	2001	2020	2001	2020	2001	2020
Without fertilizers	4,0	4,4	10,1	7,8	68,7	77,9
$N_{90}P_{60}$	3,9	4,3	11,1	7,7	68,2	78,1
$P_{60}K_{90}$	3,8	4,4	11,4	7,6	65,7	78,6
$N_{90}K_{90}$	3,9	4,5	11,4	7,3	66,3	79,6
$N_{90}P_{60}K_{90}$	3,8	4,3	11,9	8,4	65,9	76,5
Without fertilizers + lime 0,5 Hg	4,8	5,7	8,8	2,7	73,2	93,2
$N_{90}P_{60}$ + lime 0,5 Hg	4,6	6,1	8,7	1,6	73,1	95,9
$P_{60}K_{90}$ + lime 0,5 Hg	4,9	6,0	9,8	1,5	70,5	96,0
$N_{90}K_{90}$ + lime 0,5 Hg	4,5	6,0	9,8	1,7	70,8	95,2
$N_{90}P_{60}K_{90}$ + lime 0,5 Hg	4,9	6,1	8,8	1,6	72,7	95,7
$LSD_{05\ total}$	0,2	0,2	0,5	0,4	0,7	1,1
$LSD_{05\ lime}$	0,3	0,3	0,9	0,8	1,2	2,0
$LSD_{05\ fertilizers}$	0,5	0,4	0,4	1,2	0,9	3,2

hydrolytic acidity of leached chernozems when green manure is used [15]. The studies of Sh.K. Khusnidinov in our region have established that the use of Eastern galega as a greenhouse crop reduces the value of hydrolytic acidity of the soil [16]. Studies have shown that the application of mineral fertilizers in the applied doses had no significant effect on the change in the soil acidity.

Agronomic efficiency of fertilizers and ameliorants is determined by yield increase, recoupment of fertilizers unit by grain or in grain units and the share of fertilizers in yield formation. In the fruitful crop rotation for the four years on average reliable yield increase was obtained in all variants of the experience in both backgrounds. The crop capacity of the crop rotation in the fifth rotation by the variants of the experiment was increased by 0,25 - 0,61 t grain units/ha (9-21%) for the unlimed background and by 0,23 - 0,69 t grain units/ha (7-21%) for the limed one (see table 2).

The most productive was the variant with the application of $N_{90}P_{60}K_{90}$. Yield increase on the unlimed background was 0,61 t grain units/ha, or 21%, on the calcified one - 0,69 t grain units/ha, or 21%, and was the highest in the experiment with the highest payback of 1 kg rate of fertilizer application - 10,2 and 11,5 kg grain units correspondingly. In the variant with a double combination of nitrogen and phosphorus on a limed background was the lowest increase in productivity, which was 0.23 t grain units/ha with the lowest payback of 1 kg rate of fertilizer application (6.1 kg grain units).

Application of lime allowed to increase productivity of crop rotation by 0.36-0.46 tons of grain units/ha (12-14%). Recoupment of 1 t of lime by agricultural production depending on the experiment variant was 2,5-3,2 centners and was the highest at joint application of complex mineral fertilizer and ameliorant. The results of analysis of variance showed a fairly high degree of influence of the studied factors in the formation of arable productivity. The influence of lime was 0.589, mineral fertilizers - 0.405.

CONCLUSION

On the basis of nineteen-year research in the fifth rotation of the fruit and vegetable rotation it was found that the use of lime at a dose of 0.5 Ng and clover fallow ensured the reduction

Табл. 2. Влияние удобрений и извести на продуктивность севооборота и их окупаемость сельскохозяйственной продукцией (в среднем за 2017–2020 гг.)

Table 2. The effect of fertilizers and lime on crop rotation productivity and their payback by agricultural products (averaged for 2017-2020)

Fertilizers applied per crop rotation, kg a.p./ha	Crop rotation productivity, t g.u./ha	Productivity increase, t g.u./ha		Product payback	
		fertilizers	lime	1 kg a.p. of fertilizers, kg of grain	1 t of lime, centners of grain
Without fertilizers	2,84	–	–	–	–
$N_{90}P_{60}$	3,09	0,25	–	6,6	–
$P_{60}K_{90}$	3,12	0,28	–	7,4	–
$N_{90}K_{90}$	3,27	0,43	–	9,5	–
$N_{90}P_{60}K_{90}$	3,45	0,61	–	10,2	–
Without fertilizers + lime 0,5 Hg	3,22	–	0,38	–	2,7
$N_{90}P_{60}$ + lime 0,5 Hg	3,45	0,23	0,36	6,1	2,5
$P_{60}K_{90}$ + lime 0,5 Hg	3,55	0,33	0,43	8,8	3,0
$N_{90}K_{90}$ + lime 0,5 Hg	3,71	0,49	0,44	10,9	3,1
$N_{90}P_{60}K_{90}$ + lime 0,5 Hg	3,91	0,69	0,46	11,5	3,2
$LSD_{05\ total}$	0,15				
$LSD_{05\ lime}$	0,07				
$LSD_{05\ fertilizers}$	0,11				

Note. Proportion of influence: lime - 0.589, fertilizers - 0.405.

of acidity in the gray forest soil. After five rotations of the fruit-planting crop rotation and fivefold addition of lime, the grey forest soil can be classified as close to the neutral and neutral (pH_{KCl} 5,7-6,1, Hr - 1,5- 2,7 mg-eq./100 g of soil, V - 93,2-96,0%). The use of mineral fertilizers contributed to an increase in the productivity of the crop rotation by 0.23-0.69 t grain unit / ha, lime - by 0.36-0.46 t grain unit / ha. Payback of 1 kg rate of fertilizer application for the rotation averaged 6.1-11.5 kg of grain, 1 ton of lime - 2.7-3.2 kg of grain.

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