Influence of different methods of soil treatment and fertilizer systems on the yield of winter barley in the central Ciscaucasia

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Influence of different methods of soil treatment and fertilizer systems on the yield of winter barley in the central Ciscaucasia

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Abstract. The data of five-year studies on the effect of fertilizer systems and soil tillage methods on the agrochemical indicators of leached chernozem and the yield of winter barley on the Stavropol Upland are presented. It is established that the methods of tillage did not have a significant impact on the response of the soil solution and the content of exchangeable potassium in the 0-20 cm soil layer. The calculated fertilizer system significantly exceeded not only the control, but also the yield indicators of the recommended and biologized systems.

1. Introduction

Winter barley is one of the grain-feeding crops, and 70–75% of the total grain harvest is used for feeding purposes to meet the needs of animal husbandry. Due to the important food value of the crop in the Stavropol Territory, the area under winter barley has tripled in five years, reaching 144 thousand hectares in 2018. [1,2,3,4,5,6].

However, the achieved level of crop yield does not correspond to the potential productivity of cultivated varieties. An important element of the grain crops technology, especially in regions with unstable moisture, is the main tillage system in combination with a scientifically based use of mineral fertilizers [7, 8, 9].

The productivity of agricultural crops, including valuable grain crops, depends on a rationally composed fertilizer system, taking into account the bioclimatic potential of the region (zone), plant characteristics and market conditions, which is also one of the most important agrotechnical methods for increasing soil fertility.

In this regard, the presented scientific work is devoted to optimizing the nutrition of winter barley against the background of various tillage methods on leached chernozem in the zone of unstable moistening of the Stavropol Territory.

2. The research purpose

to determine the effect of fertilizer systems and methods of tillage on agrochemical indicators of leached chernozem and winter barley yields.

Research conducted in 2005-2007 and 2016-2017 in an experimental crop rotation, which is located at the experimental station of the Stavropol State Agrarian University. The stationary department is a

long-term experience «Theoretical and technological bases of biogeochemical flows of substances in agrolandscapes», registered in the certificates list of long-term experiments of the GeoNetwork of All-Russian Research Institute of Agrochemistry of the Russian Academy of Sciences. In the experiment we studied the variety of winter barley Mikhailo.

According to the scheme of agroclimatic zoning of the Stavropol Territory, the land use of the agricultural experimental station of the SSAU, under the conditions of moisture supply, is located on the border of the moderate and unstable humidification zones. The soil of the experimental plot is leached chernozem, powerful, low-humus heavy loam, characterized by an average content of humus (5.2-5.9%), mobile phosphorus (22-28 mg / kg according to Machigin), and increased - exchangeable potassium (240-290 mg / kg). The reaction of the soil solution in the upper soil horizons is neutral, pH is in the range of 6.1-6.5, the nitrification capacity is 16-30 mg / kg.

The soil of the experimental plot is medium-grade manganese (18 mg / kg), has a low content of mobile zinc (0.7 mg / kg), and is highly provided with mobile boron (2.86 mg / kg) and sulfur (13.4 mg / kg of soil) .

The variants with the fertilizer systems studied according to the experimental scheme were superimposed on the variants with different ways of the main tillage:

- moldboard method (plowing with a mounted plough (PLN-4-35) to a depth of 20-22 cm);
- non-moldboard method (cultivator subsurface plough (KPG-250M) at 20-22 cm);

The type of crop rotation - grain-farming (pea-oat mixture (occupied steam), winter wheat, winter barley, maize for silage, winter wheat, pea, winter wheat, sunflower) is developed in space and time. Placement options for the method of split plots, triple repetition. Placing repetitions - continuous. The allocation of plots is two-tier. The total area of the plot is 108 м^2, and the declared area is 50 м^2, the width is 7.2 m, and the length is 15 m.

Regarding the control (without fertilizers) in the crop rotation, three systems of fertilizers were studied.

- Recommended fertilizer system is synthesized on the basis of materials obtained in the stationary departments in question with a saturation from the NPK crop rotation of 115 kg / ha + 5 t / ha of manure;
- Biological system of fertilizers - focused on maximum use of organic fertilizers with NPK crop rotation saturation of 63 kg / ha + 9 t / ha of organic matter, including bedding manure 5 t / ha);
- Computational fertilizer system - is planned to obtain the maximum possible yield of winter barley with saturation from the NPK crop rotation of 171 kg / ha + 5t / ha of manure.

The following doses of fertilizers was applied directly under the winter barley (table 1).

Table 1. Winter barley fertilizer system (average for 2005–2007, 2016–2017).

Fertilizer system	Fertilizer application methods		
	main	seedbed dressing	top-dressing
Control (without fertilizer)	0	0	0
Recommended	$N_{50}P_{70}K_{30}$	$N_{10}P_{10}$	N_{30}
Biologized	Straw 8,6 t/ha + N_{40}	$N_{10}P_{10}$	N_{30}
Computational	$N_{84}P_{79}K_{32}$	$N_{10}P_{10}$	N_{30}

As mineral fertilizers were used: ammophos, nitroammophos, ammonium nitrate, potassium chloride. As organic fertilizers: winter wheat straw.

3. Results

The reaction of the soil solution changed markedly during one vegetational season. The pH values on all variants of the experiment correspond to the neutral and weakly acid reaction of the soil solution, which is genetically inherent in the soil subtype in the arable layer (5.53–6.36 units). A more acidic reaction was observed in more humid years.

The studied fertilizer systems and methods of basic soil tillage had a different impact on the response of the soil solution. The recommended and computational fertilizer systems applied reliably (0.22-0.36 units) reduced the pH value compared to the natural agrochemical background, and the use of the biologized fertilizer system helped stabilize the pH of the soil solution during the growing season by culture, and amounted to 5.98 units when the difference with the control of 0.03.

On average, according to the experience on the variants using the moldboard soil tillage method, the reaction of the soil solution in the 0–20 cm layer was 5.84 units, which is insignificantly higher than the values on the variant with the non-moldboard tillage method by 0.04 units.

During the vegetation period of winter barley, a significant decrease in the soil reaction from crops to the earing phase is observed, the difference was 0.26-0.42 units, and increased to the phase of full ripeness to 5.84 units.

The maximum indicators of the soil solution reaction were noted on the variant with the use of a biologized fertilizer system before sowing winter barley 6.36 and 6.3 units. on moldboard and non-moldboard tillage methods, respectively.

Great importance for the growth and development of winter barley plants, as well as the formation of a high and stable yield, the quality of grain, soil fertility has a nitrogen content in the soil.

As a result of research, it was found that the highest nitrogen content in the nitrate form in the soil layer is 0–20 cm on all nutritional backgrounds observed in the tillering stage and reached its minimum value by the full ripeness phase. Compared with the natural agrochemical background, the studied fertilizer systems contributed to a significant increase in the nitrogen content in the nitrate form in the soil layer of 0-20 cm within 8.90-14.4 mg / kg.

The use of the moldboard soil tillage method reliably (+ 0.90 mg / kg) exceeded the content of nitrate nitrogen in the 0–20 cm soil layer as compared to the non-moldboard one.

The average content of nitrate nitrogen was, on average, experienced in the tillering stage of winter barley (23.5 mg / kg), its decrease was subsequently observed, and minimum values were obtained in the phase of full ripeness of the culture (9.2 mg / kg). The variants on which the culture nutrition system was superimposed differed from the control by an increase in the amount of nitrogen in the nitrate form in the soil layer of 0–20 cm by 5.6–15.6 mg / kg of soil in the tillering phase. The change in this indicator is due to the nitrogen fertilization of the culture in early spring, the increase in mineral nutrition elements in an accessible form, and also due to the aftereffect of previously applied organic and mineral fertilizers. In connection with the faster accumulation of vegetative mass of winter barley on variants with the use of fertilizers, an accelerated consumption of nitrate nitrogen was observed as compared with the control.

The dynamics of changes in the amount of mobile phosphorus in all variants of the experiment had one direction - this is a steady decline from the tillering stage and throughout the growing season with obtaining minimum values in the phase of full ripeness of winter barley.

All studied fertilizer systems contributed to a significant increase in the concentration of phosphorus in the mobile form in the soil layer 0-20 cm relative to the control by 2.1-7.4 mg / kg of soil.

The minimum amount of mobile phosphorus in winter barley crops was obtained when $N_{80}P_{10}$ + straw barley was added to 5.8 t / ha straw - 21.4 mg / kg, the indicator turned out to be more than control by 2.1 mg / kg and lower than when using $N_{90}P_{80}K_{60}$ and $N_{124}P_{89}K_{32}$ 2.5 and 5.3 mg / kg of soil, respectively.

On average, by experience, the use of the moldboard method of tillage reliably increased by 0.9 mg / kg the amount of mobile phosphorus as compared with the use of the non-moldboard tillage method.

On average, by experience, in the tillering phase of winter barley, the maximum phosphorus content (26.9 mg / kg) was observed on all nutritional backgrounds, which can be explained by an increase in biological processes with an increase in moisture provision and a temperature of 0–20 cm of soil layer.

Subsequently, the content of mobile phosphorus during the growing season of winter barley decreased, the minimum value reached full phase maturity in the phase and amounted to 18.4 mg / kg.

Agrometeorological conditions in the years of the experiments did not significantly affect the concentration of potassium in the exchange form in the arable layer of ordinary chernozem. In 2016-2017, the amount of exchangeable potassium was higher on all nutritional backgrounds and the difference compared to the rest of the studied years was: before sowing, from 22 to 49 mg / kg; in the tillering stage - from 22 to 49 mg / kg; in the stem-extension stage - from 24 to 49 mg / kg; in the earing phase, from 25 to 50 mg / kg, in the full ripeness phase, from 26 to 52 mg / kg, respectively.

On average, all the studied fertilizer systems increased the concentration of exchangeable potassium in the soil by 4–21 mg / kg of soil compared with the control variant. The largest amount of exchangeable potassium is fixed on the variants with the addition of $N_{124}P_{89}K_{32}$ - 272 mg / kg of soil, the indicator exceeding the control by 21 mg / kg of soil. When using fertilizer in a dose of $N_{80}P_{10}$ + straw 5.8 t / ha, the concentration of exchangeable potassium turned out to be 267 mg / kg of soil, which was significantly higher than the variant with the dose of $N_{90}P_{80}K_{60}$ and the control version by 12 and 16 mg / kg of soil, respectively, and insignificantly lower (5 mg / kg of soil) relative to the variant with a dose of $N_{124}P_{89}K_{32}$. The minimum content of exchangeable potassium was obtained when a dose of $N_{90}P_{80}K_{60}$ was applied under the culture, the indicator was 255 mg / kg of soil and exceeded the control variant by 4 mg / kg of soil, and was significantly less compared to the variants using the dose of $N_{80}P_{10}$ + straw 5.8 t / ha and $N_{124}P_{89}K_{32}$, respectively, 12 and 17 mg / kg of soil.

An analysis of the average data from experiment allowed to establish that the moldboard soil tillage method in winter barley crops did not significantly reduce the content of exchangeable potassium (–5 mg / kg soil) as compared to the application of the non-moldboard soil tillage method.

Yield is considered as a complex effect of many factors: variety biology, quality of seed, cultivation technology, climatic zone, and prevailing weather conditions.

Productivity is the end result of crop growing. Further growth in the production of all agricultural crops is possible only on the basis of measures set to increase the effective soil fertility and the introduction of resource-saving technologies for their cultivation (table 2).

Table 2. The impact of fertilizer systems and tillage methods on yield, (average for 2005-2007, 2016-2017), t / ha.

Fertilizer system, A	Soil tillage method, B		HCPB, t/ha =0,22
	moldboard	non-moldboard	
Control	3,61	3,28	3,45
Recommended	4,52	4,26	4,39
Biologized	4,70	4,34	4,52
Computational	5,51	5,21	5,36
HCPA, t/ha =0,2	4,59	4,27	HCP, t/ha = 0,45

4. Conclusion

Data analysis of table 2, allows to draw the following conclusions:

- The studied fertilizer systems provided a significant increase in the yield of winter barley compared with the natural agrochemical background;
- Regardless of the nutrient background, the moldboard method of tillage reliably increased the productivity of winter barley plants as compared to the non-moldboard method;
- The studied fertilizer systems for the analyzed period (2005–2007, 2016–2017) ensured an increase in the yield of winter barley compared to the natural agrochemical background, the difference with which amounted to 0.9 t / ha in the moldboard soil tillage method, on the non-moldboard method of tillage from 0.98 to 1.93 t / ha.
- The computational fertilizer system contributed to obtaining a substantial yield increase not only in comparison with the control, but also in comparison with the biologized and recommended

systems. The difference in the options with the moldboard tillage was 0.81-0.99 centners per hectare, on the non-moldboard 0.87 - 0.95 centners per hectare.

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