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Influence of Organic Fertilizers and Soil Treatment on Agricultural and Environmental State of Soil

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Abstract

The paper presents the results of research involving a long-term stationary field experiment with chernozem typical of forest-steppe area of the region. The experiments were carried out in the Chechen Agricultural Research Institute from 2011 to2017 within the framework of state order, Russian Agricultural Academy topic no. 02.04.02.01, later substituted with the Russian Federal Agency for Scientific Organizations topic no. 0741-2014-0003: ``Development of resource-saving techniques for use of renewable bio-resources and organic fertilizers in growth practices of crops''. The research studied dependence of soil fertility on plowing with soil overturning, surface treatment with disk tiller and subsoiling with a chisel cultivator against the background of varying quantities of manure. At the beginning of the experiment, agro-environmental evaluation of soil revealed low content of humus, nitrogen, phosphorus, average content of potassium and low level of physical properties. The results of the experiment have demonstrated a positive influence the organic fertilizers and soil treatment had on the soil condition and physical state. The best indicators were obtained in the variant with disk harrowing combined with 30 t/ha of manure, where humus content increased by 8.7 %, availability of nitrogen and phosphorus increased to average level, availability of potassium reached above average level, physical properties of the soil improved as well. This research is a scientific lead to the topic no.0741-2019-0002 of the state order of the Ministry of Science and Higher Education of Russia: ``Development of scientifically-substantiated system of resource-saving soil treatment to actualize biological potential of highly productive agrophytocenozes and seed productivity of main fodder crops using organic fertilizers, green manure crops and biological preparations on typical chernozem soil''.

Keywords: Agro-environmental state of soil, soil treatment, soil fertility, organic fertilizers, nutrients, resource saving.

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1. Introduction

Modern requirements to a system of agriculture involve a necessity of its intensification with the aim of increasing production of environmentally-safe agricultural produce.

However, the intensification is often performed by extensive chemicalization, intensive soil treatment methods with high pesticide load that lead to decrease in fertility, worsening quality of produce, deficiency of organics and decrease of soil biodiversity. Such methods of intensification disrupt the natural balance of a biogeosystem, support of which in a relative equilibrium requires more and more effort, energy and labor, thus, leading to an environmental dead-end. This is supported by many researchers [9].

Another way to intensify agriculture is maximum application of primarily readily renewable bio-resources that provide environmental system stability, recovery and expanded reproduction of fertility, positive energy balance. This determines high economic return of anthropogenic expenses [9].

Preservation and improvement of soil fertility, improvement in providing plants with nutrients that are in the foundation of getting stable harvests are related to scientifically substantiated systems that regulate application of mineral and organic fertilizers, biological preparations [7].

The most energy intensive soil treatment operation is plowing, consuming more than 50 % of total fuel. Thus, its substitution with other types of soil treatment is a significant source of fuel saving. Due to this, development and practical implementation of energy-saving soil treatment systems with minimal consumption of combustibles and lubricants, facilitating reduction in amount of toxic substances released into the environment as a result of fuel combustion, is a quite timely topic of research [8].

Different soil treatment tools have different effect on soil. An example of this fact is that pre-sowing treatment of soil often breaks the whole surface of the soil, while cultivation breaks only the area between the rows. The production sequence as a whole may be seen as a series of soil treatment operations that variously change the soil surface [10].

2. Relevancy

Relevancy of this research is based upon the problem of low fertility of the majority of agricultural lands in the republic, leading to a significant drop in productivity of crops. It is largely caused by non-compliance with requirements of growth procedures in the agricultural production, including in use of organic and mineral fertilizers, soil treatment system and timing of the works.

3. Goals and Objectives

The goal of the research is to develop soil treatment techniques facilitating efficient use of renewable bio-resources and organic fertilizers in crop growth procedures.

The following tasks were involved in attaining the set goal:

- conduct a general analysis of soil cover and climatic conditions in the forest-steppe area within the borders of the Chechen Republic as agricultural-environmental resource;
- determine agrochemical and physical indicators of soil for evaluation of fertility level, physical state of the soil and identification of soil treatment techniques and amount of organic fertilizers serving to their improvement.

4. Scientific Novelty

Scientific novelty of the research lies in being the first study of soil treatment techniques facilitating efficient application of organic fertilizers within crop growth procedures in the Chechen Republic.

5. Location, Methods, Conditions, Materials

The research was conducted in the forest-steppe natural-climatic zone of the Chechen Republic (experimental fields of the Chechen Agricultural Research Institute) on typical chernozem without irrigation.

Laying out and conduction of the long-term field experiment was conducted according to guidelines and recommendations [1, 3].

Laboratory analysis for agrochemical indicators and physical state of the typical chernozem within the boundaries of the experimental field was conducted according to methods provided for a carbonate variety of chernozem [6]:

humus content was determined according to Tiurin;

- nitrate nitrogen content (NO_3) was determined by ionometric method;
- labile phosphorus (P_2O_5) was tested with the Machigin's method;
- labile potassium (P_2O5) was tested with the Machigin's method;
- bulk density was determined according to Kachinskii;

- determination of the number of structural aggregates (dry sieving) was performed according to Savvinov;
- determination of the water stability of structural aggregates (wet sieving) was performed according to Savvinov;
- Semi-decomposed manure in the amounts of 15, 30 and 45 t/ha was used as an organic fertilizer.

Soil treatment was performed in three variants:

1) plowing to a depth of 25--30 cm with a pickup plow PN-4-35;

2) disk harrowing to a depth of 10--15 cm with a disk harrow BDM-3×4;

3) subsoiling to a depth of 30--40 cm with a chisel-subsoiler D 380 NS.

Plowing with the PN-4-35 plow was taken as a control.

The area of the plot was 50 m^2. Repeatability -- 4-fold.

B is the soil of the experimental plot: typical average-thickness low-humus chernozem with gravel subsoil.

Soil solution reaction is pH 6.9, which is optimal for growth and development of crops.

6. Research

As it has been noted above, the research was conducted in the forest-steppe natural-climatic zone of the Chechen Republic (experimental fields of the Chechen Agricultural Research Institute) on typical chernozem without irrigation.

The climate of the zone is favorable to growing crops: warm and moderately wet. Winter is mild, with unstable snow cover. Summer is hot, average annual temperature reaches +9.6...+10.4 ˚C, the sum of active temperatures is 3200--3400 ˚C. Average humidity ratio is 0.60--0.85. During the period of active vegetation about 350...500 mm of precipitation occurs, while the annual value is 600 mm. Frost-free period lasts for 185. Despite moderate humidity, there are often droughts and dry hotwinds, accounting for 50...70 days in the period from April through October 50...70 [5].

Soil cover of the forest-steppe zone is characterized with a large variety due to a general non-uniformity of natural conditions and influence of various factors onto soil formation. The most widespread are chernozem soils. In mesohollows, where ground waters appear close to the surface there are meadow chernozem and meadow soils [4]. Alluvial meadow soils are common on flood lands, in river valleys and on terraces

above the flood plain. In the extreme south of the zone there are small contours of gray forest soil, as well as dark-gray forest soil [2].

Averaged data from the seven years of research are given below in three stages with a three-year interval (start, middle, final). After treatment with disk harrow BDM-3x4 with application of manure in the amount of 30 t/ha, a better moisture conservation was observed, at that, in the soil layers of 0-20 cm and 20-40 cm, soil moisture was on average by 1.5--2.0 % higher than in the soil treated with other machines; increasing amount of manure to 45 t/ha did not change the results significantly.

The same trend was seen in the soil's physical state. Analysis of the physical properties of the soil showed that by the seventh year of the experiment, in the variant with disk harrowing and the same amount of manure (30 t/ha), the bulk density of the soil reduced to 1.20, that is, by 8.8 %, the number of structural aggregates increased to 55.1 %, that is, by 10.4 %, while their water stability increased to 78.7 %, that is, by 8.2 %. Content of humus, nitrate nitrogen, labile phosphorus and potassium, just like in the case of physical properties, was better in the variant with disk harrowing and manure in the amount of 30 t/ha. By the seventh year of research, the humus content of soil in this variant increased to 3.86 %, that is by 8.7 %, nitrogen availability increased from 0.7 to 1.7 mg/100 g of soil (almost by a factor of 2.5), availability of phosphorus increased from 1.4 to 2.2 mg/100 g of soil (by 57 %), availability of potassium increased from 28 to 37 mg/100 g of soil (by 32 %). At that, the availability of nitrogen and phosphorus changed from low to average level, while that of potassium -- from average to above average (Table 1, 2).

7. Conclusions

The following conclusions have been made from the research results:

- organic fertilizers and conservative soil treatment have a positive influence on agricultural and environmental state of soil by means of increasing its fertility, and improving physical state of the soil;
- a significant improvement in practically all considered indicators of soil physical state, the highest values in content of humus, nitrogen, phosphorus and potassium, as well as better moisture conservation were observed in the variant that involved soil treatment with a BDM-3x4 disk harrower combined with application of manure in the amount of 30 t/ha; increasing the amount of manure to 45 t/ha did not have any significant effect.

TABLE 1: Dynamics of improvement in physical properties of topsoil depending on soil treatment and manure amount (with breakdown by years).

Variant		Bulk density, t/cm^3 (According to Kachinskii)	Number of structural aggregates, % (According to Savvinov)	Water stability of structural aggregates, % (According to Savvinov)
Aggregate	Amount of manure, t/ha			
2011 (initial values)				
--	--	1.35	49.6	52.3
2011 (after harvesting summer crops)				
PN-4-35 (control)	--	1.33	43.5	55.7
PN- 4-35	15	1.32	45.4	56.4
	30	1.32	46.5	57.2
	45	1.30	47.8	58.3
BDM-3x4	15	1.29	47.4	70.6
	30	1.28	49.9	72.5
	45	1.26	50.1	72.9
Chisel D 380 NS	15	1.31	46.8	65.4
	30	1.29	47.9	65.5
	45	1.29	49.3	66.1
LSD_{05}		0.11	3.74	5.14
2014				
PN-4-35 (control)	--	1.31	45.1	57.3
PN-4-35	15	1.29	48.6	60.8
	30	1.28	48.9	61.7
	45	1.25	49.3	62.0
BDM-3x4	15	1.25	50.2	74.1
	30	1.23	50.9	75.7
	45	1.22	51.8	75.9
Chisel D 380 NS	15	1.28	49.7	67.2
	30	1.28	50.2	67.8
	45	1.26	50.8	68.3
LSD_{05}		0.10	3.88	5.33
2017				
PN-4-35 (control)	--	1.30	46.3	59.2
PN-4-35	15	1.26	50.6	63.1
	30	1.26	51.8	63.9
	45	1.25	52.2	64.7
BDM-3x4	15	1.22	53.9	77.7
	30	1.20	55.1	78.5
	45	1.20	55.2	78.7
Chisel D 380 NS	15	1.24	52.5	68.4
	30	1.24	53.2	68.4
	45	1.22	53.7	70.3
LSD_{05}		0.10	4.06	5.51

In conclusion, it should be said that the research results form a foundation for development o resource and energy saving techniques in soil treatment that facilitate efficient

Table 2: Dynamics of humus and nutrient accumulation in topsoil depending on soil treatment and manure amount (with breakdown by years).

Variant		NO_3, mg/100g (By ionometric method)	P_2O_5, mg/100g (According to Machigin)	K_2O, mg/100g (According to Machigin)	Humus, % (According to Tiurin)
Aggregate	Amount of manure, t/ha				
2011 (initial values)					
--	--	0.7	1.3	23	3.54
2011 (after harvesting summer crops)					
PN-4-35 (control)	--	0.5	1.1	22	3.48
PN-4-35	15	0.5	1.2	24	3.50
	30	0.6	1.2	25	3.53
	45	0.6	1.3	26	3.53
BDM-3x4	15	0.7	1.3	27	3.52
	30	0.7	1.4	28	3.55
	45	0.8	1.5	28	3.56
Chisel D 380 NS	15	0.5	1.2	25	3.50
	30	0.6	1.3	25	3.54
	45	0.7	1.3	27	3.54
LSD_{05}		0.12	0.16	2.40	0.13
2014					
PN-4-35 (control)	--	0.6	1.2	22	3.53
PN-4-35	15	0.8	1.3	26	3.53
	30	0.9	1.6	28	3.55
	45	0.9	1.6	29	3.56
BDM-3x4	15	1.0	1.7	29	3.56
	30	1.1	2.0	30	3.60
	45	1.2	2.1	30	3.61
Chisel D 380 NS	15	0.9	1.6	29	3.55
	30	0.9	1.7	29	3.58
	45	1.0	1.8	30	3.59
LSD_{05}		0.24	0.36	3.20	0.13
2017					
PN-4-35 (control)	--	0.8	1.4	24	3.57
PN-4-35	15	1.0	1.7	29	3.59
	30	1.1	1.8	30	3.59
	45	1.1	1.9	32	3.63
BDM-3x4	15	1.4	2.0	35	3.78
	30	1.7	2.2	37	3.86
	45	1.7	2.2	38	3.86
Chisel D 380 NS	15	1.2	1.8	31	3.62
	30	1.4	2.0	32	3.68
	45	1.5	2.2	33	3.72
LSD_{05}		0.36	0.32	5.60	0.12

use of organic fertilizers and thus providing increased soil fertility and improvement of its physical properties, which in its own turn allows increasing productivity of crops.

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