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The effect of spring wheat cultivation methods on some fertility indicators of Southern carbonate chernozem in Northern Kazakhstan

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ABSTRACT

The long-term stationary data about the reserves of humus and its group composition in the southern carbonate Haplic Chernozems Pachic (WRB, 2014) in Northern Kazakhstan have been presented. Southern carbonate chernozems are characterized by low humus reserves of 97 t/ha in their natural state. Turning virgin land to arable land has significantly reduced the reserves of organic matter (49.1 – 66.6 t/ha). It has been found that the type of humus in the topsoil of southern carbonate chernozems is fulvate-humate. A two or more times decrease has been found in the content of the labile part of organic matter and humic acids on arable land, compared to virgin land. Of the considered variants, the most optimal one for increasing the yields (0.158 t/ha) and preserving soil fertility (3.26 % of humus) is continuous wheat cultivation with the introduction of fertilizers and herbicides. The use of two-field grain-fallow crop rotation causes irreplaceable loss of organic matter (2.48 %).

Key words*: Southern carbonate chernozem, Spring wheat, Humus group composition.*

Introduction

The main reasons for the loss of humus during the development of arable land are changes in the composition of the source of humus and a decreased amount of plant residues that enter the soil when a natural biocenosis is turned to agrocenosis. The decrease in the content and the organic matter loss rate depend on the nature of agricultural use, and the physical, biological, and chemical properties of the soil (Titova, Kogut, 1991; Polupan, 1986).

The problem of maintaining soil fertility and productivity should be resolved by improving its agrophysical properties through increasing the intake of organic matter.

Despite numerous studies of organic matter in the soil of Kazakhstan, the issues of humus formation in the conditions of anthropogenesis where the agricultural use of soil is one of the main factors for soil formation remain insufficiently studied. It turned out that long-term soil cultivation in Northern Kazakhstan had resulted in a decrease in the content of humus in the arable layer by 20 – 27 %, i.e., by almost one third. This fact was especially evident in continuous fallow and the grain-fallow crop rotations.

Based on the foregoing, the study was aimed at assessing the effect of the used arable land cultiva-

tion methods on the yield of humus and crops.

Materials and Methods

The object of the study was southern low-humus carbonate chernozem with heavy particle size distribution — Haplic Chernozems Pachic (WRB, 2014).

The experiments involved the following variants. The virgin land plot (N 51° 34' 35.4" E 71° 15' 47.5") the soil samples were taken from was located in the steppe zone with the predominance of mixed herbs and gramineous vegetation. The experiment with continuous wheat sowing without chemicals was started in 1961 (N 52° 32' 53.65" E 71° 1' 38.26"); the experiment with the use of herbicides and nitrogen-phosphorus fertilizers (N 51° 32' 54.83" E 71° 4' 23.22") and that with the two-field grain-fallow crop rotation (N 51° 33' 51.40" E 71° 4' 38.63") were started in 1984.

Mineral fertilizers were annually introduced into the rows upon continuous sowing of wheat at a dosage of $N_{30}P_{20}$ kg of active substance per hectare. In the variant with sowing wheat after fallow, only phosphorus fertilizers were introduced at a dosage of P_{20} into the rows.

Results and Discussion

To determine the actual changes in the humus reserves, it was necessary to compare its content in the soil of virgin and long-used arable land (Table 1).

Table 1 shows that the long-term (from the beginning of the 20th century) agricultural use of southern carbonate chernozem has significantly changed its humus state.

The highest content of organic matter was observed in the variants with virgin land (4.91 %) since virgin land is a natural object not involved in agricultural crop rotations. The humus reserves were also relatively higher there (97.2 t/ha). The organic substances in virgin land had been preserved due to the constant intake of the vegetative mass. It should be noted that southern carbonate chernozem is low in the reserves of organic matter. In virgin land, the content of humus did not exceed 100 t/ha, which, according to the Orlov's classification, was considered low. According to the results of the study, very low reserves of humus (< 50 t/ha) were noted in the variant with wheat cultivated after fallow. It should be noted that fallow fields are often used in production, because fallow ensures efficient moisture accumulation, reduces weediness, and improves mineral nutrition of the crops. However, frequent tillage of fallow fields increases the mineralization of organic matter (Takata et al. 2007; 2008).

At the same time, humus content had also markedly decreased in the variants with continuous wheat cultivation, where its loss had exceeded 30 % in the 0 – 20 cm layer. In this case, the humus content and reserves had mainly decreased before 1984 due to the increased mineralization of organic compounds on the background of annual tillage in the autumn and the spring. In the subsequent period, the difference in humus content and reserves between the variants with continuous wheat cultivation remained unchanged, which may be explained by its stabilization due to the introduction of the compounds not amenable to mineralization. Similar results were obtained in studying the organic matter dynamics in the ordinary chernozem of Northern Kazakhstan. A sharp decrease in the content of humus had occurred during the first 10 years, and the humus state of the soil had been gradually stabilizing for the subsequent 10 years (Karbozova-Saljnikov et al. 2004; Pashkov, Baybusinova 2017). The absence of changes in the humus content in the variants with continuous wheat sowing may be explained by both insignificant difference in wheat productivity (Table 2) between the intensification variants, and a significant intake of weed organic matter in the variant without the use of herbicides and fertilizers, since this variant was close to the organic background, and the only method of weed control was tillage. The reduction of weediness sig-

Table 1. The content and reserves of humus in the 0 – 20 cm soil layer, % of the soil weight

Variant	Humus	The degree of humification	Humus reserves, t/ha
Virgin land	4.91	20.5	97.2
Continuous wheat cultivation without chemicals	3.38	12.0	66.9
Continuous wheat cultivation with fertilizers and herbicides	3.26	12.0	64.5
Wheat cultivation after fallow	2.48	13.0	49.1

nificantly increased the wheat yield.

The lowest humus content (2.48 %) was observed in the variant with wheat and pure fallow alternated. In this case, the intake of organic matter from the harvest to the soil was insufficient for balancing the processes of dehumification and reducing the mineralization of organic matter with intensive tillage during fallowing. In general, it should be noted that various crop cultivation technologies had a significant effect not only on the total content of humus but also on its qualitative composition.

After turning virgin land into arable land, a sharp decrease in the content of semi-decomposed organic matter occurs. Due to the changes in the agrophysical properties of the soil, the air and water conditions change, thus significantly activating mineralization of semi-decomposed residues of plant organic matter after harvesting. Besides, after prolonged use of arable land as an agrocenosis, a limited amount of plant debris enters the soil; they cannot compensate for the loss of the nutrients taken away with the harvest. All this is accompanied by a decrease in the main groups of humic substances (the labile part of humus, humic and fulvic acids). According to I. N. Sharkov (2010), a decrease in soil fertility is not so much a decrease in the total humus content, but rather the loss of the labile forms of organic matter in it. The high content of labile humus in virgin land indicates that some humic substances are involved in the biological processes (Table 3). According to the data of the authors, during the development of virgin land, the content of labile humic substances had decreased by 40 %. This was because in cultivating the crops, about 50 % of the organic matter in the soil had been removed with the grains and straw of the new harvests, while the total intake of plant residues by the soil had decreased 3 – 4 times. It should be noted that after the prolonged use of soil, the content of labile organic matter had decreased, compared to virgin land, but the qualitative composition of humus varied only slightly between the variants.

In almost all cases, the fulvate-humate type of soil prevailed, except for the variant with wheat sown after fallow, where the humate-fulvate type was observed due to the low content of humus and the prevalence of fulvic acids. In the fallow field, dehumification and sharp reduction of all groups of humic compounds were evident, due to the mineralization of organic matter. It should be noted that the humate-fulvate type is not characteristic of southern carbonate chernozem. This boundary state $C_{ha}:C_{fa} = 1$ is due to the low content of humic acids, as a result of organic matter mineralization.

Continuous wheat cultivation without fertilizers and the processes reducing the content of organic substances together had formed deficient mineral nutrition.

A different pattern was observed in wheat nutrition in the variants with the use of fertilizers. Permanent wheat cultivation with the use of ammophos had improved the reserves of nitrogen and phos-

Table 2. The yield of continuous wheat crops and the productivity of two-field grain-fallow crop rotations, kg/ha

Variants	Year			Average
	2012	2013	2014	
Continuous wheat cultivation without chemicals	380	1.190	520	700
Continuous wheat cultivation with herbicides	860	2.070	1.080	1.340
Continuous wheat with fertilizers and herbicides	920	2.360	1.460	1.580
Wheat cultivation after fallow	960	2.770	1.540	1.760
Grain yield from 1 ha with wheat sown after fallow	480	1.380	770	880
LSD_{05}	102	288	110	0

Table 3. Humus group composition in the 0 – 20 cm layer of virgin and arable land, %

Variant	C_{tot}	C_{lab}	C_{ha}	C_{fa}	$C_{ha}:C_{fa}$
Virgin land	2.87	0.91	0.59	0.32	1.84
Continuous wheat cultivation without chemicals	1.98	0.43	0.23	0.20	1.15
Continuous wheat cultivation with fertilizers and herbicides	1.91	0.42	0.23	0.19	1.21
Wheat cultivation after fallow	1.45	0.38	0.19	0.19	1.0
$LSD_{0.95}$	0.20	0.06	0.04	0.02	-

phorus two times and more. This had increased the reserves of organic matter and its ability to maintain the optimal water, physical, and technological properties of the soil and, consequently, to increase its fertility.

Long-term use of soil in two-field crop rotations is impossible, as it would lead to a complete loss of fertility or would require the use of agrotechnical measures for increasing the intake of organic matter. Therefore, any farming system and any agricultural techniques and crop rotations should ensure constant replenishment of organic matter in the soil, which is the main source of mobile forms of humic acids.

Conclusion

The studies have shown that wheat cultivation on southern carbonate chernozem with and without the use of intensification methods has changed the humus state of arable land: the content of C_{lab} has decreased from 0.91 (virgin land) to 0.38 – 0.43 %, the content of C_{ha} — from 0.59 to 0.19 – 0.23 %, and the content of C_{fa} — from 0.32 to 0.1 – 0.20 %.

Reduction of organic matter intake by the soil and removal of organic matter with wheat harvest have reduced the humus content from 4.91 to 2.48 %.

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