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CHANGES IN THE HUMUS STATE OF CHERNOZEMS OF UKRAINE AND MOLDOVA UNDER IRRIGATION

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Abstract

The humus state of irrigated soils in Ukraine is determined mainly by the structure of sown areas, the specific growth of perennial legumes and the level of organic fertilizers application. A deficit-free humus balance is formed in crop rotations with perennial leguminous herbs (more 21-25%) and manure doses of 8-10 t ha^{-1}. When mineralized waters are used for irrigation, a deficit-free humus balance is achieved in crop rotations with alfalfa and organic fertilizers of 12-15 t ha^{-1}. In crop rotations without perennial leguminous grasses, there is a gradual decrease in the humus content from 3-5% in field crop rotations to 11-23% in vegetables. Research conducted in the conditions of the Republic of Moldova has shown that the use of weakly mineralized water, with a neutral reaction, has no negative consequences on the humus content of the soil. The humus state of soils is determined by the ratio of humic acid: fulvic acid. This integrated criterion, in the irrigation conditions of chernozems with Dniester water, also remains unchanged. Chernozem irrigated with alkaline mineralized water causes essential changes in the fractional composition of humus.

***Key words**: humus, crop rotation, irrigation, chernozem, Ukraine, Moldova.*

INTRODUCTION

The issue of humus state transformation in the soils under the irrigation influence was most actively studied at the first stages of the irrigation development. In many cases, a decrease in the content of humus was noted (Ковда, 1981; Крупенников et al., 1985). This was explained by the more activity of microflora on irrigated lands and increased mineralization of organic matter (Агроэкологическая, 1997). Loss of humus as a result of its migration with infiltration waters could also take place. Some studies noted both an increase in the content of humus (Позняк, 1989) and the absence of a change in its content (Приходько, 1988).

It was noted that with the beginning of irrigation, the humus content decreases, and with further irrigation, it increases. In the irrigation conditions of chernozems, the chemical composition of irrigation water and the irrigation regime must also be taken into account. If these factors contribute to the accumulation of calcium, then we can expect a decrease in the mobility of humus as a result of irrigation (Орлов et al., 1980). Long-term irrigation with waters, in which sodium cations predominate, cause the opposite effect, and in an alkaline environment, rapid decomposition of specific humus substances can be expected (…).

However, in the period of the modern development of land melioration, in conditions of changing methods, regimes of irrigation, land removal from irrigation, periodic irrigation at reduced rates, publication are few (Щедрин et al., 2017; Докучаева & Юркова, 2012). The published data are often contradictory, which is understandable, since the processes of organic matter humification and mineralization are closely related to the soil and climatic conditions of the irrigation region, the quality and quantity of irrigation water, the crop rotation system, doses of organic and mineral fertilizers and other measures applied to irrigated black soils (chernozems).

It is not possible to unambiguously assess the direction of the long-term dynamics of the humus content during the irrigation of chernozems on the basis of published data. This question is especially poorly studied for the chernozems of Ukraine and Moldova using for irrigation the water of different quality, in various reclamation conditions and crop rotation.

MATERIALS AND METHODS

The researches in Ukraine were conducted within the Experimental Stations (ES).

ES 1 - typical chernozem, low humiferous, clayey-loamy. Left-bank of Ukraine Forest-Steppe, Kharkov district of Kharkov region. Institute of Vegetable and Melon Growing, long-term experimental field of vegetable - fodder crop rotation. Irrigation water mineralization - 0.7-0.8 g dm^{-3}.

ES 2 - typical chernozem, moderately humiferous, clayey-loamy and light-clayey. Left-bank of Ukraine Forest-Steppe, Chuguevsky district of Kharkov region. National Scientific Center “Institute for Soil Science and Agrochemistry O.N. Sokolovsky”, long-term experimental field of grain-fodder crop rotation (the variants with perennial grasses and without them). Irrigation water mineralization - 0.4-0.6 g dm^{-3}.

ES 3 - ordinary chernozem, moderately humiferous, clayey-loamy. Ukraine Northern Steppe, Pervomaisky district of Kharkov region, monitoring site with a long term grain-fodder crop rotation. Mineralization of irrigation water - 1.1-1.2 g dm^{-3}.

ES 4 - ordinary chernozem, low humiferous, deep effervescence, light-clayey. Ukraine Northern Steppe, Slavyansk district of Donetsk region, monitoring site with long-term of grain crop rotation, mineralization of irrigation water - 0.6 g dm^{-3}.

ES 5 - ordinary chernozem, low humiferous, second weakly solonetzated, light-clayey. Ukraine Northern Steppe, Maryinsky district of Donetsk region, monitoring site with a long-term vegetable-fodder crop rotation, mineralization of irrigation water - 2.9 g dm^{-3}.

ES 6 - ordinary chernozem, low humiferous, second weakly solonetzated, light-clayey. Ukraine Northern Steppe, Yasinovatsky district of Donetsk region, monitoring site with a long-term vegetable-fodder crop rotation, mineralization of irrigation water - 2.3 g dm^{-3}.

Groundwater level at all Experimental Station is more than 5 m. The data are given for 0-30 cm soil layer. Field studies were carried out according to the methods of conducting stationary experiments (Доспехов, 1985) and route surveys - method of analog - keys.

The researches in Moldova were carried out in different agropedoclimatically zones on the experimental key polygons with drip irrigation. The main subtypes of chernozems that predominate in the composition of the irrigation fund of the republic were selected as a study objects. As sources of water for irrigation, the Dniester water, accumulation basins (ponds) and artesian water were chosen. These water sources are essentially different from the chemical composition and quality indices. Therefore, they have different effects on the improvement status of irrigated soils, properties, including humus.

The organic carbon content in soils of Ukraine was determinate by Tyurin method (ГОСТ 26213-84), in soils of Moldova - the same method with Nichitin modification (Практикум…, 1989).

RESULTS AND DISCUSSIONS

In the intensive vegetable crop rotation of ES 1, there is a constant, from rotation to rotation, decrease in the humus content in the unirrigated chernozems (Figure 1).

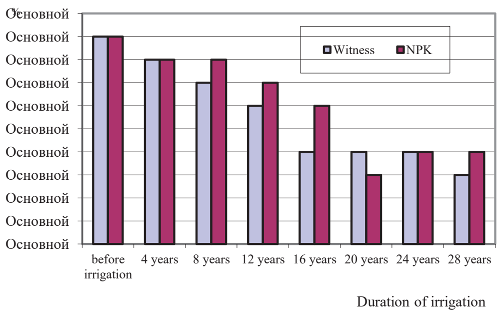

Figure 1. The dynamics of humus content (%) in the chernozems of ES 1 during irrigation

Reconstruction of the vegetable crop rotation of ES 1 after 20 years of irrigation and the introduction of perennial grasses (25%) into it led to a change in the balance of humus and the stopping the fall of its content. The noticeable loss of humus observed in intensive vegetable crop rotation is explained by increased mineralization of organic matter and weakened of humification process.

In the ES 2 - in the field crop rotation with perennial grasses (25-30%) without manure, is observed a tendency in the humus decrease content, the losses were 5-6% of the initial one (Figure 2).

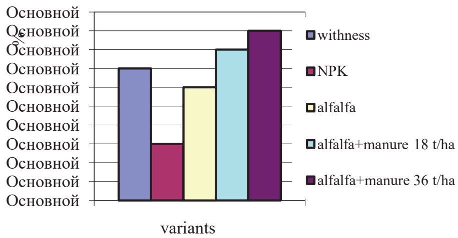

Figure 2. The changes in the humus content in the chernozems of the ES 2 during irrigation

The decrease in the humus content of the weakly humiferous typical chernozems does not occur in crop rotation with perennial grasses and manure. A tendency to increase the humus content in these soils takes place in crop rotation with perennial grasses (alfalfa) and manure in doses of 18 t ha^{-1}.

In a field crop rotation of the ES 3 without perennial grasses using NPK and manure of 9-10 t ha^{-1}, there is a tendency of decrease in the humus content in ordinary chernozem by 2-3% from the initial one (Figure 3). The tendency for an increase in the humus content in these soils is formed in crop rotation with alfalfa, NPK and manure in doses of 8-10 t ha^{-1}.

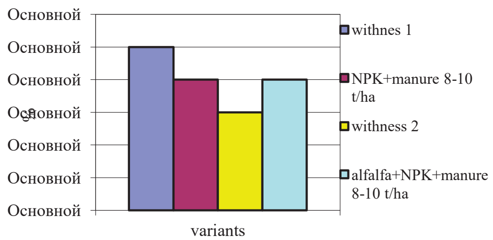

Figure 3. The changes in the humus content in the chernozems of ES 3 during irrigation

In the irrigated soils of ES 4 (Table 1), irrigated with fresh water, there was a slight decrease in the content of humus compared with the non-irrigated analogue (4.3% and 4.6%, respectively), which is associated with the agricultural system, the saturation of crop rotation with row crops, and the introduction of low doses of mineral and organic fertilizers.

Table 1. Humus content in ordinary chernozems of the Northern Steppe of Ukraine

ES No	Humus content, %	
	without irrigation	under irrigation
4	4.6	4.3
5	4.0	4.3
6	5.3	4.4
HCP_{05}	*0.1*	*0.1*

In ES 5 (Table 1), in conditions of equilibrated vegetable and fodder crop rotation, perennial grass cultivation, organic and mineral fertilizers during irrigation with reduced irrigation norms of mineralized waters show a significant increase in the humus content in irrigated soil compared to non-irrigated analogue (4.3% and 4.0%, respectively). In the irrigated soils of ES 6 (Table 1) during irrigation with fresh water, a decrease in the humus content was noted compared with the non-irrigated analogue, which is associated with a low level of agriculture, saturation of crop rotation with row crops, and the introduction of low doses of mineral and organic fertilizers (Щедрина et al., 2017; Докучаева & Юркова, 2012).

In the Republic of Moldova, the chernozems constitute about 74% of the soil's surface suitable for irrigation. Currently only 25-30 thousand ha of vineyards and orchards are irrigated. Changing the natural water regime of these soils through the irrigation one, even in the case of the use of good quality water, leads to degradation of the structure, compacting the surface layer, reducing the lacuna space and permeability for water. Negative effects are recorded in the adsorbent complex, expressed by decalcification and accumulation of sodium and magnesium cations (Крупеников & Подымов, 1978; Подымов, 1976; Орлов, 1980; Рекомендации…, 1991).

The research on the impact of drip irrigation on Moldavian soil regimes and properties has been carried out within systems equipped with sprinkler watering equipment. It was found that studies on the drip irrigation impact on the soil quality are very limited (Ursu, 2012; Andrieș & Filipciuc, 2015). The influence of irrigation on the organic matter content and composition is treated in the opposite way. The multiple researches carried out under different pedoclimatic conditions, including the Republic of Moldova, highlight the decrease of humus content in the irrigation process (Фильков & Попова, 1978; Filipciuc & Andrieș, 2015; Boaghe, 2015).

The impact of drip irrigation on the properties of cambic chernozem using the Dniester river water. The chernozem cambic (leached) was irrigated with Dniester river water - the mineralization: minim - 240 mg l^{-1} and maxim - 490 mg l^{-1}. Published data confirming the reduction of the humic acid content and increase the fulvic acid fraction content under the irrigation influence (Hera & Eliade, 1978; Щербаков & Рудай, 1983; Синкевич, 1989).

Research on the cambic chernozem does not show the decrease in humus content. At the same time, there was a tendency to increase the fraction of humic acids associated with R_2O_3 and to reduce the fraction related to Ca. It is important to emphasize that the solubility of soil organic matter increases considerably in irrigation. After 4 years of irrigation the soil carbon content in the water-soluble substance increased from 7 to 19 mg/100 g soil (Table 2).

Table 2. The humus composition of the cambic chernozem

Depth, cm	C total, %	C, %			$\frac{C_{AH}}{C_{AF}}$	C fraction of AH, %		C	
		extracted with $Na_4P_2O_7$+NaOH	AH	AF		unassociated and associated with R_2O_3	associ-ated with Ca	in the non-hydrolyzed residue, %	in the water-soluble substance, mg/100 g sol
Cambic chernozem - unirrigated									
0-5	1.97	0.96* / 48.7**	0,64 / 32.5	0.32 / 16.2	2.0	8.1	91.9	1.01 / 51.3	8
5-10	1.94	0.91 / 46.9	0.67 / 34.5	0.24 / 12.4	2.7	6.9	93.1	1.03 / 53.1	6
10-20	1.95	0.90 / 46.2	0.66 / 33.8	0.24 / 12.3	2.7	6.2	93.8	1.04 / 53.3	8
20-30	2.00	0.91 / 45.5	0.65 / 32.5	0.26 / 13.0	2.5	6.5	93.5	1.10 / 55.0	7
Cambic chernozem - irrigated 4 years									
0-5	1.97	0.96 / 48.7	0.66 / 33.5	0.30 / 15.2	2.2	9.5	90.5	1.01 / 51.3	16
5-10	1.95	0.97 / 49.7	0.66 / 33.8	0.31 / 15.9	2.1	9.8	90.2	0.99 / 50.8	19
10-20	1.98	0.99 / 50.0	0.67 / 33.8	0.32 / 16.2	2.1	10.0	90.0	0.99 / 50.0	21
20-30	1.97	0.99 / 50.2	0.67 / 34.0	0.32 / 16.2	2.1	9.4	90.6	0.98 / 49.7	21
*% from the soil mass; **% from the C total; AH - humic acid; AF - fulvic acid									

The impact of drip irrigation with water from local sources (ponds) on the properties of typical chernozem. Researches on typical chernozem confirm the evolution of negative changes in humus composition. The irrigation changes the humification process and the composition of the organic matter in the soils (Boaghe, 2015).

The water used for irrigation of the typical chernozem has a total soluble salt content of 605-676 mg l^{-1} and is characterized by weak and moderately alkaline reaction (pH = 8.05-8.40). The data from Table 3, shows that drip irrigation with water from local sources has a pronounced influence on the fraction of humic acids unassociated and coupled with iron and aluminum oxides, but also on the fraction of these calcium-related acids.

Thus, in the typical chernozem under irrigation regime the carbon content of free and bound with R_2O_3 - humic acids increased by 7.8% in the 0-30 cm layer and in the same proportion decreased the fraction coupled with Ca.

The impact of drip irrigation with groundwater on the properties of the ordinary chernozem. Research on ordinary chernozem irrigated with groundwater shows that humus content does not show appreciable changes (Table 4).

In both cases the total carbon has the average value of 2.09% in the 0-30 cm layer. In the soil under irrigation, the decrease in the amount of carbon extracted with the solution of sodium pyrophosphate mixed with sodium hydroxide is noted. The fraction of humic acids in irrigated soil is decreasing, which has changed the main evaluation indicator of the humic state of C_{AH}: C_{AF}. In the unirrigated soil this ratio has values between 2.0 and 2.2; therefore, the humus type is the humatic one. In the soil under irrigation, the ratio between humic and fulvic acids decreases to 1.7-1.9, the type of humus being appreciated as humato-fulvic (Table 4).

Table 3. The humus composition of the typical chernozem

Depth, cm	C total, %	*C, %			$\frac{C_{AH}}{C_{AF}}$	C fraction of AH, %		C_{RN}, %
		in the extract	AH	AF		unassociated and associated with R_2O_3	associated with Ca	
Typical chernozem - non-irrigated								
0-5	1.71	50.3	32.7	17.6	1.9	7.1	92.3	49.7
5-10	1.68	45.2	31.5	13.7	2.3	6.8	93.2	54.8
10-20	1.62	45.0	30.9	14.1	2.2	7.6	92.4	55.0
20-30	1.57	44.6	29.9	14.6	2.0	7.6	92.4	55.4
Typical chernozem - irrigated 7 years								
0-5	1.54	46.8	30.5	16.2	1.9	21.1	78.9	53.2
5-10	1.55	49.0	33,5	15.5	2.2	14.2	85.8	51.0
10-20	1.59	47.8	33,0	14.5	2.3	13.2	86.6	52.2
20-30	1.60	48.8	35,0	13.8	2.5	12.0	88.0	51.2
*% din C total; C_{RN} - carbon of the non-hydrolyzed residue								

Table 4. The humus composition of the ordinary chernozem

Depth, cm	C total, %	C, %			$\frac{CAH}{C_{AF}}$	C fraction of AH, %		C in the non-hydrolyzed residue, %	Gh, %
		in the extract	AH	AF		unassociated and associated with R_2O_3	associated with Ca		
Ordinary chernozem - non-irrigated									
0-5	2.10	0.96* 45.7**	0.64 30.5	0.32 15.2	2.0	6.2	93.4	1.14 54.3	30
5-10	2.12	0.94 44.3	0.65 30.7	0.29 13.6	2.2	7.4	92.3	1.18 55.7	31
10-20	2.06	0.95 46.1	0.64 31.1	0.31 15.2	2.1	4.7	95.3	1.11 53.9	31
20-30	2.08	0.91 43.6	0.61 29.3	0.30 14.4	2.0	3.3	96.7	1.17 56.2	29
Ordinary chernozem - irrigated - 3 years									
0-5	2.11	0.85 40.3	0.54 25.6	0.31 14.7	1.7	16.7	83.3	1.26 59.7	26
5-10	2.06	0.87 42.2	0.57 27.7	0.30 14.5	1.9	17.5	82.5	1.19 57.8	28
10-20	2.06	0.84 40.8	0.54 26.2	0.30 14.6	1.8	14.8	85.2	1.22 59.2	26
20-30	2.12	0.86 40.5	0.55 35.0	0.31 14.6	1.8	12.7	87.3	1.26 59.5	26
*% from the soil mass; **% from the C total; Gh - humification degree									

Significant changes record the fractions of free humic acid and associated with R_2O_3, but also its fraction related to Ca. On the whole 0-30 cm thickness of irrigated soil, the carbon content of humic acid coupled with R_2O_3 is on average 9.9% higher compared to the non-irrigated soil. It is noteworthy that the content of human acids coupled with Ca on average decreased from 94.5% in the non-irrigated soil to 84.6% in the irrigated one.

CONCLUSIONS

It was established that the humus state of irrigated chernozems of Ukraine is determined mainly by the structure of sown areas and the presence of perennial grasses in crop rotation, the application level of organic and mineral fertilizers, and, to a lesser extent, the quality of irrigation water, since reduced irrigation rates are used in Ukraine in modern conditions. To ensure a positive balance of organic matter, it is necessary to perform a high agricultural background, introduce organic and mineral fertilizers, and perennial and sidereal crops.

The water of the Dniester river corresponds to the quality requirements for irrigation of Moldovan soils, but it has an alkaline potential and causes the decalcification in the surface soil layer. Drip irrigation results in decreased the hydrostability of structure and secondary compaction of chernozems.

The application for soil irrigation the water from the accumulation lakes with poor quality indices has the following consequences: modification of the soluble salts composition with predominance of the toxic compounds of sodium and magnesium; changing the current reaction in the direction of alkalization; secondary salinization of the soil, including magnesium salinization; increasing the content of fine hydropeptized clay and increasing the dispersion factor; increasing the degree of compaction and worsening the potential ventilation conditions of soils; destructuring and reducing the hydrostability of the structure; increasing the degree of swelling and penetration resistance; decreasing the water permeability of the soils (Filipciuc & Boaghe, 2017; Filipciuc et al., 2016).

The groundwater is characterized by moderate to strong alkaline reaction and unfavorable chemical composition. Soluble salts include carbonate and sodium bicarbonate. The use of groundwater for irrigation of Moldavian soils has the effect of salinization in the first year of irrigation. Intensely degrades the physical, chemical, hydro- and physico-mechanical properties of the soils. Irrigation with groundwater has a negative impact on the organic matter composition of chernozems. In the irrigation regime the organic matter composition of the chernozems records unfavorable changes related to the reduction of the huminic acids content and the increase of the fraction of acids associated with R_2O_3.

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