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MODIFICATION OF HUMUS CONTENT IN THE CHERNOZEMS OF MOLDOVA UNDER AGRICULTURE IMPACT

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ABSTRACT

The current state characteristic of the humus content in the chernozems of the Republic of Moldova is presented. Over a period of more than 140 years, the humus content in the arable layer of the chernozems, as a result of their use in agriculture, decreased by 2.47% or 43.2% from the content of the virgin (natural) chernozem, the rate of humus reduction of was 0.019% annually. Maintaining the annual reduction rate of humus content presents a significant ecological and economic danger for Republic of Moldova. The state quality of the investigated chernozems regarding the content of organic matter is satisfactory. The factors limiting the productivity of chernozems (and other soils) are: low humus and nutrient content, strong compaction and destruction of the arable and post-arable layer. The quality of the chernozem (and the soil resources in general) must be maintained by administering the organic-mineral fertilizers at optimum doses, incorporating plant residues and secondary production in soils, respecting crop rotation with the introduction of alfalfa into the soil, increasing the proportion of leguminous crops up to 20-25%.

Key words: agriculture, chernozem, degradation, fertilizer, humus.

Introduction

The content of organic matter in soils is a genetic and classification feature characteristic of each known types of soils. The change in the content of humus in soils occurs extremely slowly, being the result not of temporary circumstances, but of a complex and lengthy previous history of the soil-forming process and the interaction of the soil with the environment.

For each soil type, a certain stable humus content in the upper soil horizons and a stable type of distribution of its reserves along the profile have been established. At the same time, each type of soil is characterized by a certain qualitative composition of humus (4).

The humus content in the soil of each pedo-climatic region is a certain constant value, it varies within a certain limit and the increase in its amount is associated with a long cultivation period with the use of sufficiently high doses of organic fertilizers, the expansion of leguminous crops, and the reduction in the area of clean fallow. I.V. Tyurin pointed out that "under certain constant conditions regarding the intake and decomposition, the accumulation of organic matter in soils has a limit above which accumulation is impossible", quoted by Иванов et al. (13**).** The intensity of humus accumulation is largely determined by the properties of the soil itself.

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At present, everyone has a firm opinion about decrease in the content of humus in soils. Indeed, the loss of humus from arable soils is possible for various reasons (7):

- Increased mineralization of organic matter due to intensive machining, liming, predominant use of mineral fertilizers, consumption of organic matter in crop formation, which does not allow to compensate for the natural decrease in humus;

- Inadequate intake of organic residues due to low yields and lack of organic fertilizers. In a normally formed farming system, more than 50% of plant nutrients should be returned to the soil as part of organic matter (litter, stubble, root residues, organic fertilizers, etc.).

- Loss of humus during erosion and deflation. These losses will be even more significant from soils of light particle size distribution. “Not only that, and the humus that fell into the sandy soil has relatively few chances to remain there; firstly, there is nothing to connect humus with, secondly, due to the porosity of the sands it will most likely burn in the air and give the final products of decay”, noted Dokuchaev (6).

The research purpose - the comparative study of the humus content in the fallow (natural) chernozems and in the arable chernozems used in agriculture for a long time.

Material and method

The paper presents an analysis of the publications that reflect the problems regarding the humus content in the chernozems of the Republic of

Moldova, as well as the impact of the anthropogenic factors on the organic matter in soils. The humus content was determined by the I.V.Tyurin classical method.

Results and discussions

In the Republic of Moldova, chernozems of two facies groups are distributed approximately equally:

a) south-western or Danube - Pontic;

b) central or Eastern European.

Those and others are divided into several subtypes, forming genetical and geographical pairs:

1) for the south - surface carbonatic and high-carbonatic (carbonatic and ordinary);

2) for the north - typical and leached.

The remaining subtypes are less characteristic and occupy small areas. Existing genetic relationships between chernozems, on the one hand, forest and hydromorphic soils, on the other hand, are interesting, but not yet studied and explored enough. The total area of all chernozems is about 80% of the Moldova's territory and 86% of the territory of the plateaus. The moderately and highly eroded chernozems account about 20% of the area (1).

The plateaus and peripheral parts of the highlands of northern Moldova are covered with chernozems, which are divided into two subtypes - typical and leached, the first of which prevail at absolute heights of 160-210 m and the second - at 190-250 m. The parent rocks are eluvial - deluvial loamy - clays and clayey - loams, silty and moderately silty, rich in aluminium, iron, alkaline elements and metals. The climate of the northern regions is cooler and wetter than in the south of Moldova. The chernozems under consideration formed under the meadow-steppe vegetation characteristic for forest-steppe (1).

Chernozem typical. In this subtype, the progressive aspects of the chernozem soil formation process manifested themselves in the most striking in a harmonious form. Typical chernozems extend in a continuous strip from the eastern borders of Moldova to the Prut River and passes over to Romania. In the neighboring regions of Ukraine, they are known as powerful chernozems; they are humus-coloured up to 1.0-1.5 m (4).

Typical chernozems occupy an area of about 165 thousand ha and are characteristic of the northern forest-steppe part of Moldova, but are also found in the central part. They are formed most often on eluvial - diluvial rocks of a clayey-loamy composition with an average content of physical clay from 54 to 64% and silt from 30 to 38%; loess features are rather weak. Geomorphologically, these soils are confined to plain or slightly hilly watershed plateaus, ancient river terraces. The axis of the altitude zone is 200 m in the north with fluctuations of 180-200 m, in the areas of the center - 190 m with oscillations of 160-200 m (1).

The typical clayey-loamy chernozem from north-eastern of Moldova (com. Napadova, Floresti district). The investigated soil is characterized by the weakly acid reaction in the Ah horizon (pH = 6.5-6.7) and weakly alkaline in the underlying carbonatic horizons (pH=7.7-8.1). These pH values can be appreciated as optimal for growing and developing of crop plants. The distribution of carbonates on the investigated soil profile is typical for chernozem. Depth of occurrence of carbonates, depending on the soil moisture regime, can be within 50-70 cm from the soil's surface. The content of carbonates varies within 5-7% in the horizon Bh2, 13-20% in the BC and C (9, 10).

Typical Chernozems from Napadova are of interest because they were first studied by V.V. Dokuchaev in 1877 (6) and then by the scientists in pedology prof. I.A. Krupenicov (4), acad. A. Ursu (12). In 2010 in the framework of monitoring research was carried out by IPAPS N. Dimo scientists (14). Comparison of the humus content in the typical chernozem (fallow) in 1877 with the typical chernozems (arable) studied after Dokuchaev gives the possibility to assess the degree of soil degradation as a result of the long exploitation in agriculture (Table 1).

Table 1 - Morphological indices and humus content of the typical chernozem in the research years

Indices		1877 - steppe [6]	1960 - arable [4]		2003 - arable [12]	2010 - arable [10]
		-	p.42	p.43	-	p.22
The thickness of the genetic horizons, cm	A	0-61	0-43	0-44	0-50	0-48
	B	62-91	44-101	45-92	51-98	49-95
	C	92	102	93	99	96
	Effervescence		92	65	70	70
Humus content, %	cm	steppe	arable	arable	arable	arable
	0-20	5.718%	3.75	3.60	3.36	3.25
	30-40	-	3.65	3.30	3.15	2.97

	50-70	-	2.34	2.73	1.94	2.38
	70-90	-	1.59	1.57	1.68	1.35
	90-110	-	-	-	-	0.86

From 1877 to 1960 - the beginning of the intensive farming period, the humus content in arable 0-20 cm of chernozem typical decreased as a result of ploughing from 5.72% to 3.75%, i.e., by 1.97% or 0.024% annually. During the period of intensive agriculture from 1960 to 2010 - the initial period of the agrarian reform, the humus content in the arable 0-20 cm layer over the 50 years decreased from 3.75% to 3.25%, i.e., by 0.50% or 0.010% annually (Figure 1). Currently, due to the non-use of organic fertilizers and the lack of leguminous perennial and annual grasses in the crop rotation, the process of dehumification of chernozems is only intensifying (1, 7).

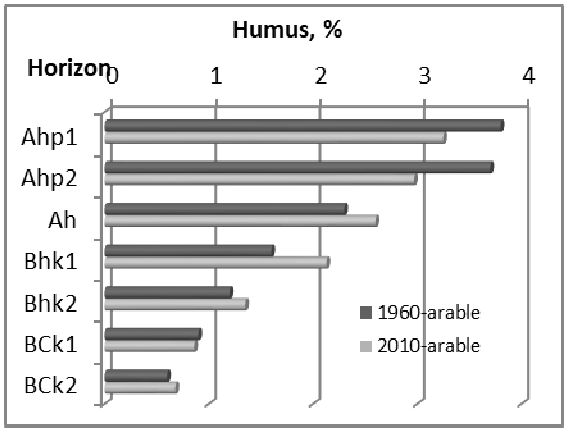

Fig. 1 - The humus content in the profile of arable typical chernozems, studied in 1960 and 2010.

The average statistical data of humus content in the humiferous layer of investigated soil in 2010 ranges from 3.25 ± 0.14% in the Ahp1 horizon to 1.35 ± 0.28% in the Bh2 horizon. The comparatively low humus content for typical chernozem in the Napadova commune is caused by the intensive use in agriculture and the sandy-dusty soil texture (9).

Comparison of the humus content in the typical loamy-clayey chernozem initially fallow near the commune of Napadova researched in 1877, 1960 and 2010 showed that the thickness of the humiferous horizon A was reduced in 133 years by 15 cm (from 61 cm - in 1877 to 46 cm - in 2010).

During the period of 1877-2010 the humus content in the arable layer of the typical chernozem as a result of its use in agriculture was reduced by 2.47% or 43,2% of the initial content of the soil (1877), the humus reduction rate was 0.019% annual (10).

During the period of 1960-2010, the humus content was reduced in these chernozems under the influence of intensive agriculture. The humus content in soil samples collected in 2003 and 2010 years is approximately the same, with some insignificant changes.

Comparison of the characteristics of the former fallow soil, studied in 1877, with the characteristics of the arable soil, studied on the same area in 1960, 2003, 2010 gives the possibility to appreciate the recent degradation of the typical chernozem as a result of long exploitation in agriculture. The characteristics of the typical chernozem are satisfactory. The limiting factors of the productivity of these chernozems are: strong compaction of the postarable layer, reduced humus content and nutrients. The change of the technological process of plant cultivation must be directed towards increasing the content of organic matter and nutrients in the soil and the implementation of a rational soil tillage system that would lead to the remediation of compacted postarable layer.

Typical loamy-clayey chernozem from northern of Moldova (Bălți Steppe). In the typical clay-loamy chernozem, the humus content was analyzed in the arable and fallow soils studied in 1960 by Krupenikov (4) and in the arable chernozems for monitoring researches of zonal soils in 2010. The humus content in the humiferous horizon (0-26 cm) of the typical arable chernozems constitutes 5.50% in 1960 and 4.03% in 2010. Their use in arable land has led to the decrease of humus in a period of 50 years - by 1.47% or 0.029% annually. Compared to the fallow chernozem the arable soils lost, respectively: 17.9% (until 1960) and 39.8% of the humus content of the natural soil. Up to a depth of 50 cm in the soil, an amount of 4.21% is maintained, which gradually decreases in the depth of the profile. In arable soils, humus content is maintained at only 3% at this depth (Figure 2).

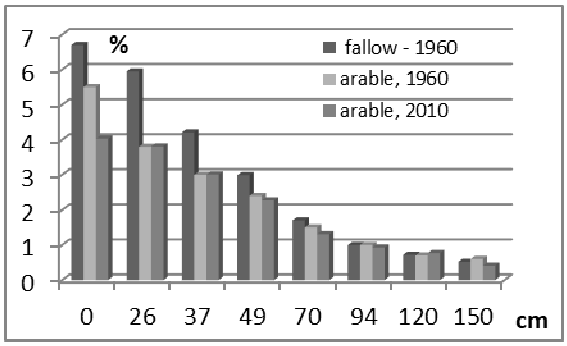

Fig. 2 - Humus content in the typical chernozems loamy-clayey from the warm semi-humid zone of northern Moldova (Bălți Steppe)

Chernozem leached occupy somewhat higher heights than typical chernozems, are formed on the same parent rocks, and are close to them in terms of humus content and its vertical distribution. The main external difference between the two subtypes of chernozems is that the leached effervescence from 10% - HCl 20-30 cm deeper and, therefore, there is a small humus-free and carbon-free layer in the profile. In addition, sometimes they have a weakly expressed of illuvial horizon, enriched with silty (4).

Leached chernozems occupy an area of about 315 thousand ha. Often meet together with typical on the same parent rocks and relief elements. In the north, the axis of their altitude zone is 210 m (180-240 m), which is only 10 m higher than typical (1).

In order to determine the changes in the humus content of the chernozem leached under the influence of mineral fertilizers, soil profiles were placed on the variants of the long-term experience with mineral fertilizers of the experimental stationary from Ivancea commune, Orhei district (used in 1964-1995). In 1996-2005, due to lack of fertilizers, soil fertilization on fertilizer variants was not performed. The research was limited to studying the post-action of soil fertilization for 30 years. Since 2006 the application of mineral fertilizers has started again (11).

The leached chernozem is characterized by the type profile: *Ahp1 - Ahp2 - Ah - Bhw1- Bhw2 - BCk1 - BCk2 - Ck*. The thickness of the humiferous profile - 90 cm. Effervescence from the depth of 90 cm. It is characterized by clayey-loamy texture and high fine clay content (35-36%), which favors the compaction of the degraded soils. The high clay content in horizons A and B is due to the more intensive process of "in situ" alteration of the mineral part of the soil in these horizons (8).

The humus content in the investigated chernozem profile decreases from 3.3% in the arable horizon to 1.5% in the Bhw2 horizon (71-90 cm). The total amount of nitrogen in the humiferous horizon Ah is in the range 0.192 - 0.151%. The values of the ratio C : N vary within the limits 10.1-9.2. Carbonates occur on the BCk1 horizon (90 - 120 cm) with increasing values from 12.9% on the BCk1 horizon to 18.8% on the Ck horizon (11).

According to the average statistical data (Table 2), the humus content in the 0-30 cm layer is 3.3% for the control variant and 3.4% for the fertilized variants.

The study of the modification in the humus content of the leached chernozem under influence of different doses of fertilizers in long-term field stationary showed that they did not increase the humus content in the fertilized variants.

Table 2 - Humus content in the chernozem leached under the influence of different fertilizer doses

Variant	Humus, %	Variant	Humus, %
Control	3,3	$N_{120}PK$	3,5
	3,3		3,3
	3,2		3,6
	3,3		3,4
	3,2		3,4
Average	*3,3±0,1*	*Average*	*3,4±0,1*
$N_{60}PK$	3,2	$N_{300}PK$	3,5
	3,6		3,4
	3,4		3,5
	3,4		3,2
	3,5		3,4
Average	*3,4±0,2*	*Average*	*3,4±0,1*

The humus reserves in the arable layer of the leached chernozem (control - unfertilized variant) constitute 154 t/ha, and in the 0-100 cm layer - 319 t/ha (Table 3).

Table 3 - Humus content of the chernozem leached on the control variant (unfertilized)

Genetic horizons	Depth, cm	Humus	
		%	t/ha
Ahp1	0-22	3,3	95,1
Ahp2	22-36	2,9	59,3
Ah	36-51	2,4	55,1
Bhw1	51-71	1,7	52,4
Bhw2	71-90	1,5	43,6
BCk1	90-120	0,9	41,0
BCk2	120-160	0,5	15,2
Ck	>160	0,4	11,3

The average statistical parameters of the humus content in the fertilized variants show that the

application of mineral fertilizers after a period of 10 years without fertilizer exploitation of the leached chernozem (1996-2005), did not lead to essential changes, the humus content was established at the level of 3.3-3.4% in the arable layer 0-22 cm.

As a result of the agricultural exploitation, the leached chernozem is affected by the dehumidification of the arable and subarable layer due to the insufficient flow of organic matter in the soil, the compaction of the arable and subarable layer as a result of the soil tillage. The influence of the application of mineral fertilizers $N_{60}PK$, $N_{120}PK$, $N_{300}PK$ after a period of 30 years of exploitation of the soil without fertilizers did not lead to a significant change in the humus content.

Chernozems carbonatic and ordinary. On the plateaus of the south of Moldova, the soil cover is represented by micellar - carbonatic chernozems, which are divided into:

1) surface-carbonatic (or simply carbonatic), characteristic of low altitude levels usually from 40 to 140 m (limiting fluctuations 10-180 m);

2) high-carbonatic (ordinary), occupying a high-altitude belt of 100-200 m with limit marks of 80-240 m (4).

Both subtypes of chernozems are formed on loess loams, less often on light clays. The climate in the south of Moldova is warm, rather dry, but with two maximums of atmospheric and soil moisture - winter-spring and summer. Vegetation in the past was a herbaceous and grassy degree with rich grass stand, a well-developed root system that penetrates deep into the soil.

Carbonatic and ordinary chernozems of the south of Moldova are described in the literature both as a whole and in certain regions (5).

Although these chernozems were analyzed together with southern or even chestnut soils, their dissimilarity was emphasized nevertheless in many important ways with the soils of the dry steppes of more south-eastern regions. In the north of Moldova and in Codri at low altitude levels, micellar-chernozems of both subtypes are also common.

Carbonate chernozems (low-humiferous) represent a link in the formation of chernozems under these conditions, although some of their properties are secondary characteristic (low humus content, high carbonate content) due to long-standing involvement in agricultural use.

By the amount of humus in them, three tiers are distinguished: uniform content (somewhat less than 3%), which coincides with horizon A; recession - up to 100-120 cm; almost humus less - deeper than 120 cm. Low-humiferous carbonatic chernozems, as a rule, occupy higher positions; they are more complex of profile structure, but at the same time they are quite similar to the previous ones. Formally, the humus content in the upper horizon, equal to 3%, serves as the boundary between these two varieties of chernozems.

The humus profile is divided into three tiers, the upper (up to 50 cm) is highly enriched in humus (4%), at a depth of 90-100 cm there is still 1.2% humus (1960 year), (2).

The most significant changes in humus content occurred in the humiferous horizon 0-40 cm (Figure 3). Fertilization of the carbonatic chernozem resulted in a non-essential increase of the humus content on the fertilized variants compared to the control variant (3.07%): $N_{120}P_{1,5}K_{60}$ - 3,17%, $N_{120}P_{2,5}K_{60}$ - 3,23, $N_{120}P_{3,5}K_{60}$ - 3,14%.

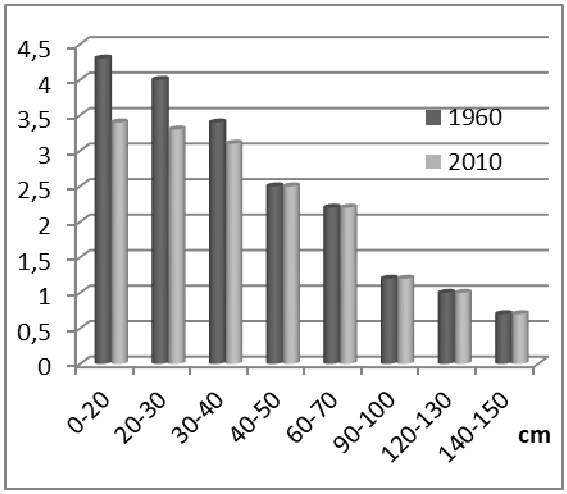

Fig. 3 - Content of humus in arable carbonatic chernozems, 1960 and 2010

The carbonatic chernozem from South-East of Moldova is characterized by satisfactory properties for growth and development of crop plants. As restrictive factors of quality status of these soils can be considered: dehumidification (over 50 years the humus content in these soils decreased by about 0.9-1.0% or 20-23% of the initial content); destruction and low resistance to secondary compaction. The systematic application of mineral fertilizers did not lead to essential changes in the humus content. The humus content in the fertilized variants compared to the control has changed non-essential.

In order to recover and conservation the properties of the carbonic chernozem, it is necessary that the share of legume crops and perennial herbs constitutes 25-30%; the crops rotation with a argued alteration of the tillage depth of soil and the lifting on the surface the compacted layers once in 3-4 years. For remediation the quality status of the

nutrients regimes its recommended to administrate organic fertilizers in optimum norms of 6-8 t/ha on average on soil and mineral fertilizers to obtain the discounted crops.

Chernozem ordinary. These chernozems prevail in the soil cover of the south of Moldova. They differ from carbonatic ones most noticeably in that they effervescence from 10% HCl not from the surface, but at a depth of usually 35-50 cm, rarely deeper (4); characterized by increased power, contain slightly more humus in the upper horizon (Figure 4).

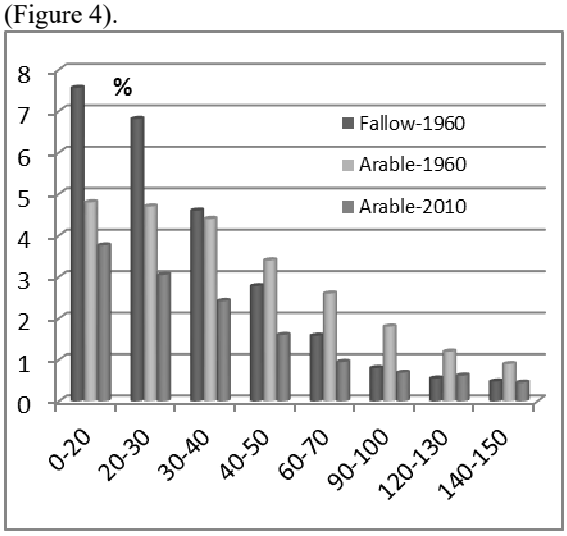

Fig.4 - Content of humus in arable and fallow ordinary chernozems, 1960 and 2010

According to the humus content, the studied ordinary chernozems falls into the submoderated humiferous soil class, which is not characteristic for the typical chernozem subtype with lute-clay texture and, therefore, represents a step towards southern (chestnut soils) chernozems (3). The average statistical data on micro-polygons confirm that after 10 years of cessation of fertilizer introduction their postaction on the humus content in the soil is not observed (Table 4).

Table 4 - Humus content in the ordinary chernozems on the fertilizers variants

Variant	Control	$N_{120}P_{120}K_{60}$	Manure 60 t/ha + $N_{90}P_{60}K_{60}$
0-22 cm	2,98±0,01	2,98±0,03	3,05±0,21
22-35 cm	2,87±0,02	2,83±0,05	2,89±0,19
35-50 cm	1,99±0,11	2,04±0,30	2,21±0,19

The determinations of humus index during the intensive agriculture period detected for the soil of the unfertilized variant a gradual decrease of the humus content in the years 1970-1990 (20 years) from 3.15% to 2.78% (with 0.37% in total or 0.018% on average annually). As a result of intensive use in agriculture for 36 years, the soil lost 0.3-0.4% humus from the upper layer. Since 1990, during extensive agriculture, the humus content in the researched soil has stabilized (3).

The ordinary chernozem in the south of Moldova is characterized by satisfactory properties (humus content) for growth and development the crop plants; as unfavorable factors can be considered: low content of humus content; low compaction resistance of the arable layer as a result of its dehumification and destruction; strong compaction of the postarable layer (20-35 cm).

The systematic administration of mineral fertilizers (1972-1996) did not lead to essential changes in the humus content. The application of organic fertilizers (60 t/ha of manure once in 5 years) stabilized the humus content at the level of 3.0-3.1% (Table 4).

For remediation of properties of the ordinary chernozem, it is necessary that the share of legume crops and perennial herbs in constitutes 20-25% rotation; to adhere at the advanced technologies of field crops cultivation and their rotation with an argued change of the depth of soil work and the surface lifting once in 3-4 years of the compacted soil layers.

For the improvement the nutrient regimes it is necessary to incorporate annually in the soil at least 30% of the secondary production of the cereal crops and 5-6 t/ha of manure (in average on the crop rotation).

The average statistics of the humus content (%) in the arable subtypes of chernozems of Moldova, studied in 1960 and 2010, show that losses of humus from the chernozem are higher, the less the chernozem is less fertile (they have a lower humus content).

Chernozems lost within the following 50 years from the arable humiferous layer (0-20 cm) the following content of humus (%): typical - 0.55; leached - 0.64; ordinary - 0.58; carbonatic - 0.47, and in total - 0.53%, or 0.011 annually (Table 5).

Table 5 - The average statistics of the humus content (%) in the arable subtypes of chernozems of Moldova

Dept, cm	Typical Chernozems	Leached Chernozems	Ordinary Chernozems	Carbonatic Chernozems	Chernozems in total

	1960	2010	Loss	1960	2010	Loss	1960	2010	Loss	1960	2010	Loss	1960	2010	Loss
0-20	4.67	4.12	0.55	4.46	3.82	0.64	3.47	3.01	0.58	3.54	3.07	0.47	4.04	3.51	0.53
20-40	3.98	3.71	0.27	3.37	291	0.46	3.10	2.78	0.52	2.90	2.53	0.37	3.38	3.00	0.38
40-50	3.20	-	-	2.81	-	-	2.71	-	-	2.70	-	-	2.71	-	-
60-70	2.44	-	-	2.12	-	-	2.02	-	-	1.80	-	-	2.11	-	-
90-100	1.46	-	-	1.43	-	-	1.20	-	-	0.90	-	-	1.29	-	-

Conclusions

The modern humus state of arable soils in Moldova is due to the length of their use. Studies conducted in Moldova more than 140 years ago by V.V. Dokuchaev, it was shown that chernozems contained 5-6% of humus. In subsequent years, the natural fertility of Moldavian soils has steadily declined, which has led to an average content of 3.1% humus in the upper layer of arable soils at present. The rhythms of these processes were different depending on the nature of the use of agricultural production. lands. The average loss of soil organic matter is 0.5 t/ha per year (1, 7).

The modern period is very important and can be called critical, bearing in mind the humus state of soils. If the degradation of natural fertility is not stopped by adequate measures, the level of humus content will reach values close to 2%, which corresponds to the lower threshold for chernozems. Humus stabilization at this level will limit grain yields by 1.5–2.0 t/ha. Fertility regeneration, starting from a critical level, will be very difficult to implement, it will take costs and efforts much longer and longer. Maintaining the speed of annual reduction of humus content presents a significant ecological and economic danger for the Republic of Moldova (7).

The quality status of the chernozems (and soils) must be maintained by administering the organo-mineral fertilizers at optimum doses, the cutting and incorporation in the soil of the vegetable residues and the secondary production, respecting crop rotation with introduction of the alfalfa and increasing the proportion of the legume crops up to 20-25%.

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