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THE INFLUENCE OF GREEN MANURE ON THE QUALITY STATE AND PRODUCTION CAPACITY OF THE CHERNOZEM CAMBIC FROM CENTRAL MOLDOVA

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Abstract

The paper presents research results regarding the influence of green manure on quality status of chernozem cambic from central Moldova and winter wheat harvest on this soil. Research has established that incorporation of two harvests of vetch green mass of 12.4 t/ha in the arable layer of chernozem cambic in the agricultural year 2015-2016 led to accumulation in the soil about 310 kg nitrogen; was synthesized about 3 t/ha of humus; was increased the labile organic matter content by 0.20% compared with witness variant; improved physical quality state of arable layer; formed a weak positive balance of organic matter and nitrogen in the soil. On the variant with application into the soil a harvest of green mass of vetch, the winter wheat harvest constituted 6.2 t/ha (growth rate 2.4 t/ha compared to control variant); on the plot with two harvests of green mass application - 7.0 t/ha (growth rate - 3.2 t/ha). Gluten content of wheat grains from variants with application of green fertilizers consists 28%, on the witness variant - 24%. Through the systematic use of green manure concomitantly with the phosphorus and potassium fertilizers in partial, the soil physical, chemical and biological quality state and agricultural productive capacity of soil can be restored gradually. In this content it is necessary to organize a system for green fertilizers use and create a seed basis of annual and perennial grasses for agricultural sector of Moldova.

***Key words**: chernozem cambic, green mass, humus, quality state, vetch, winter wheat.*

INTRODUCTION

Chernozem cambic from central zone of Moldova were formed under the influence of following pedogenesis phases: *under forest vegetation* (were formed Brown soils with illuvial-cambic argillizated and heavily compacted horizon) → *under plowing* (Brown soils arable) → *under steppe vegetation* (Brown soils were evolved in chernozem cambic) → *under agricultural tillage*, from 1800s (contemporary chernozem cambic).

Chernozem cambic arable from Central Moldova inherited from the pedogenesis phases of forest vegetation the textural differentiated profile, with high content of fine clay, dominated by colloidal fraction. In conditions of the agricultural existing system these soils have undergone the intensive organic matter losses and structure destruction of humus arable layer (Leah., 2016). High content of clay, dehumification and desstructured processes led to acceleration of secondary compaction of arable layer (Canarache, 1990). The main cause of compaction resistance decrease of arable layer of investigated chernozem cambic is the insufficiently flow of organic matter in soils.

Non application of organic fertilizers into the chernozem cambic, insufficiently and inadequate use of mineral fertilizers, strong secondary compaction of arable layer leads to decrease of their production capacity by 2 time (Leah and Cerbari, 2015).

The quantities of chemical fertilizers used to field crops are small and do not provide an equilibrated balance of nutrients in the soils. The secondary production from harvesting crops is not incorporated into the soils.

A long-term favorable state of the soil physical quality can be created by the existence of a permanent flow of organic matter in arable soil layer. This constant flow can be ensured by achieving in the farming the following systemic procedures (Cerbari and Leah, 2016).

Introducing into the soil about 10-15 t/ha/year of manure. Currently, in the agricultural soils are introduced about 50 kg/ha/year of manure and about 53 kg/ha/year chemical fertilizers in active substances, 70-75% of these are nitrogen fertilizers. This fertilization level cannot ensure a profitable agriculture that would lead to the reproduction of soil fertility.

Through the repeated fallow of arable land and restoring steppe vegetation that formed chernozems. This method is acceptable, but cannot be implemented in Moldova due to lack of free land (0.4 ha of arable land per capita). Along the 15 years the humus content in arable layer was increased by 0.8%; state structure was restored to 70-80% compared to standard fallow soil (Leah, 2016).

Using the land under alfalfa/sainfoin + ryegrass over a period of 10-15 years with utilization of production as feed for livestock. This method, unfortunately, cannot have a large implementation in the Republic of Moldova, because the livestock was reduced about 6 times at last 25 years. Restoring the livestock can be create a rational co-ratio between livestock and field crops sectors and restoration of leguminous grasses in crop rotations.

Using the vetch as green fertilizer (as intermediate crop or occupied field), incorporation into the soil two harvests of winter or spring vetch as organic fertilizer, in crop rotation with 5 fields, where one field is occupied by vetch (Wiesmeier et al., 2015).

In conditions of total exclusion of annual and perennial grasses from crop rotations, non-use of organic manure as fertilizer, the only possibility to restore the organic matter flow in the soils is utilization of green manure. Through the systematic use of green manure in couple with phosphorus and potassium fertilizers in part can be restored gradually the physical, chemical and biological quality state of soil and significant increase their agricultural production capacity.

MATERIALS AND METHODS

The research subject was the chernozem cambic (leachate) of Central Moldova (from Experiment Station, com. Ivancea, district Orhei). *Purpose of research:* testing procedures to increase the organic matter flux in the soil, restoration of quality state and production capacity of arable soil layer under the influence of phytotechnical measures.

Experience variants: Control (without green manure application); Variant with application into the soil - one harvest of vetch green mass; Variant with the application of two harvests of vetch green mass.

Soil research within each experimental variant was performed by placing in the field 3 soil semi-profile up to depth of 50 cm, their morphological description, collecting samples of soil from horizons (0-10 cm, 10-20 cm, 20-35 cm) for determination of bulk density and laboratory analyzes. In performing the researches were used traditional methods of conducting the field, laboratory and office works. The results will be used to create non-polluting system of sustainable agriculture of existing crop rotations using leguminous as green manure for soil fertilization.

RESULTS AND DISCUSSIONS

To study the characteristics of fallow chernozem cambic was placed a profile in the forest protection strip founded about 60 years ago. Research conducted on the chernozems from Bălți Steppe have shown that this period is sufficient to restore the initial values of soil characteristics under steppe vegetation in condition of non using the aerial mass of grasses vegetation (Cerbari, 2010a).

Initial state of fallow cambic chernozem characteristics. For foundation of forest protection belts the soil was slopped. The horizons Ahb1 and Ahb2 were formed from the soil material of former arable layer, buried at the 25-60 cm of depth. Soil evolved on the loess clayey loamy deposits located on the Pliocene-Pleistocene alluvial deposits in the deeper of 130 cm. Soil profile is leached of carbonates up to beginning of BCk horizon - the depth of 95 cm.

The fallow chernozem cambic is characterized with loamy-clay texture throughout the profile and pronunciation of cambic horizon in Bhw1 and Bhw2. The physical clay content in the soil profile ranges from 51% in fallow layer, up to 55% in the cambic horizons and clay content at the same time - from 35% to 38%. The fallow cambic chernozem characteristics were used as a baseline for comparing it with the arable cambic chernozem (Leah, 2016).

Initial state of arable cambic chernozem characteristics. The 0-35 cm layer of arable cambic chernozem on the same field is dehumificated and destructured, lost resistance to compaction as a result of its use in agriculture.

Chernozem cambic arable has clay-loamy texture. Physical clay content in humus profile is 60-61%, in the BC and C horizons - 56-58%. The content of clay in A and B horizons varies between 39-40%, and in the B, C and C horizons - within the limits of 56-57%. Argillic alteration of upper profile is due to change of hydrothermal regime after grubbing and use of these soils on the arable.

Chernozem cambic arable are a means of production in agriculture rather difficulties. They are characterized by large amounts of inaccessible water, mechanical and thermal favorable characteristics, soils are working hard, have great capacity for swelling and shrinkage, but have good chemical qualities (cation exchange and buffering capacity, high humus content). The characteristics of arable cambic chernozem served as a relative standard to assessing their changes under the influence of phytoameliorative procedures.

Changes of the quality status and production capacity of the soil under the influence of green manure. At the end of the agricultural year 2015, after incorporation into the soil of green mass of vetch and harvesting corn, on the witness plot was prepared seedbed by disking at depth by 10-12 cm and sown winter wheat. This work gave way to appreciate the size of winter wheat harvest after introduction into the soil as organic fertilizer one and two harvest of vetch green mass on the experimental variations. Winter wheat harvest was rated on the plots with an area of 1 m^2 in 5 repetitions. Simultaneously, by separate collection of wheat, was rated differently the total harvest on the plot where was introduced as organic fertilizer the green mass of vetch (2 ha) and on the witness plot (2 ha) where wheat was sown after maize.

Modification of the main characteristics of the soil layers on the experimental variant which was introduced one harvest and experimental variant with two harvests of vetch green mass was assessed by comparing the initial data (up to incorporation the vetch into the soil) with results obtained on the experimental variant in 2016. During the vegetation period the wheat plants on experimental plots sown after incorporation the vetch green mass phenological differed from wheat on the witness plot by following: dark green leaves; greater thickness of stalks; ear size greater by 20-30% etc. Changes of the status quality of soil top 0-10 cm of former arable layer under the influence of vetch green mass incorporation is shown in Table 1.

Positive changes in quality state of structure is observed for the soil layer 0-10 (12) cm, formed by disking and mixing of artificial structural elements of this layer with debris of two vetch harvests.

Integral characteristic of physical quality state of soil arable layer is bulk density value. The data confirm a favorable bulk density value for plants growing of 0-10 cm layer, formed by disking and incorporating in this layer two harvests of vetch green mass.

The resistance to penetration values correlates with bulk density values of these layers and are small for loose layer and large for compacted underlying horizons.

The layer 0-10 (12) cm, as a result of the incorporation into the soil of two harvests of vetch, was characterized by the increasing of labile organic matter content of about 0.20% compared to the control variant. The content of organic matter in soil layers where was introduced the vetch green mass - increased by about 0.20%. It should be noted that this organic mass is not yet humus and represent a labile organic matter, which is slightly mineralized in result of soil microbiological processes.

A trend of positive change was found for other indicators of the quality status of chernozem cambic under the influence of vetch green mass incorporated into soil. However some agrochemical soil characteristics practically have not changed.

Strategic issue remains the necessity to restore the phosphorus content in arable soils, which reserves in arable layer have been exhausted. Using the vetch green mass as fertilizer solve the nitrogen problem in soil, but not for phosphorus. Research data confirms that the vetch green manure, solving the problem of nitrogen in the soil, leading to a massive increase in nitrate nitrogen content, which is ecologically positive.

Table 2 presents data on soil moisture on the control and experimental variants, where into the soil was introduced two vetch harvest as green manure. The results demonstrate that 2016 was very favorable in terms of the rainfall amount for crops first category. The winter wheat harvest was formed mostly due to water precipitation fallen during the wheat growing period.

Table 1. Modification of chernozem cambic average values of physical and chemical properties in result of incorporation into the soil by disking one and two harvests of vetch green mass, 01.07.2016

Horizon and depth, cm	Witness variant (initial data)		Variant with 1 harvest of vetch		Variant with 2 harvests of vetch	
	Value	Assessment	Value	Assessment	Value	Assessment
1	2	3	4	5	6	7
Bulk density, g/cm^3						
Ahp1 0-10	1.24	small	1.21	Small	1.16	very small
Ahp1 10-20	1.42	great	1.42	Great	1.34	Moderate
Ahp2 20-35	1.53	extreme	1.52	Extreme	1.51	Extreme
Ah 35-50	1.43	great	1.42	Great	1.43	Great
Total porosity, % v/v						
Ahp1 0-10	52.3	great	53.5	Great	55.4	Extreme
Ahp1 10-20	45.6	moderate	45.6	Moderate	48.7	Moderate
Ahp2 20-35	41.8	small	42.2	Small	42.6	Small
Ah 35-50	46.0	moderate	46.4	Moderate	46.0	Moderate
Resistance to penetration, kgf/cm^2						
Ahp1 0-10	13	small	11	Small	9	very small
Ahp1 10-20	21	great	20	Great	15	Small
Ahp2 20-35	26	extreme	26	Extreme	24	Great
Ah 35-50	20	great	21	Great	21	Great
Organic matter content, % g/g						
Ahp1 0-10	3.47±0,13	moderate	3.59	Moderate	3.67	Moderate
Ahp1 10-20	3.33±0,10	moderate	3.30	Moderate	3.37	Moderate
Ahp2 20-35	3.07±0,09	moderate	3.08	Moderate	3.05	Moderate
Ah 35-50	2.75±0,12	submoderate	2.71	Submoderate	2.76	Submoderate
Mobile phosphorus content, mg/100 g soil						
Ahp1 0-10	1.9	moderate	2.0	Moderate	2.1	Moderate
Ahp1 10-20	1.4	low	1.4	Low	1.3	Low
Ahp2 20-35	0.8	very low	1.1	Low	1.0	very low
Ah 35-50	0.8	very low	0.8	very low	0.8	very low
Exchangeable potassium content, mg/100 g soil						
Ahp 1 0-10	31±2	high	33	High	33	High
Ahp1 10-20	26±2	optimal	23	Optimal	21	Optimal
Ahp2 20-35	22±2	optimal	19	Moderate	18	Moderate
Ah 35-50	22±2	optimal	18	Moderate	18	Moderate
Nitrates content ($N\text{-}NO_3$), mg/100 g soil						
Ahp1 0-10	0.3	extremely small	0.6	very small	0.4	extremely small
Ahp1 10-20	0.2	extremely small	0.2	extremely small	0.1	extremely small
Ahp2 20-35	0.1	extremely small	0.1	extremely small	0.1	extremely small
Ah 35-50	0.1	extremely small	0.1	extremely small	0.1	extremely small
Nitrites content ($N\text{-}NH_4$), mg/100 g soil						
Ahp1 0-10	3.9	great	4.8	Great	4.3	Great
Ahp1 10-20	3.6	great	2.8	Moderate	3.9	Great
Ahp2 20-35	3.2	great	2.4	Moderate	3.0	Great
Ah 35-50	2.3	moderate	2.5	Moderate	2.2	Moderate

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Table 2. Soil moisture on the variants, %

Depth, cm	*Witness variant* - Mini-till technology, without vetch incorporation		*Experimental variant* - winter wheat, after incorporated of two vetch harvests	
	22.03. 2016	*01.07. 2016*	*22.03. 2016*	*01.07. 2016*
0-10	23.3	25.9	23.9	25.9
10-20	23.5	23.8	25.2	23.9
20-30	24.3	23.9	26.7	25.1
30-40	25.1	23.5	26.3	24.1
40-60	24.4	23.9	26.2	23.3
60-80	24.0	20.5	24.4	19.7
80-100	23.6	20.0	23.5	19.3
0-100	**24.0**	**22.4**	**25.0**	**22.4**
Water total reserves (mm) in soil layer 0-100 cm in different period of winter wheat vegetation				
-	**358**	**334**	**368**	**329**
Estimation	great	moderate	great	moderate

Data regarding winter wheat harvest on the variants is shown in Figure 1 and Table 3.

Figure 1. Status of winter wheat in early July on experimental plots

Table 3. Winter wheat harvest (grain moisture – 8%) on the experimental variants, 2016

Variant	Winter wheat harvest, t/ha	Harvest growth rate, t/ha / %
Control (without vetch incorporation)	**3.8**	-
After incorporation into the soil - one vetch harvest	**6.2**	2.4 / 63
After incorporation into the soil - two vetch harvests	**7.0**	3.2 / 84

The average harvest of winter wheat on the witness plot was 3.8 t/ha.
On the parcel where into the soil by disking was introduced one harvest of vetch green mass, the wheat harvest increased with 2.4 t/ha, on the plot where into the soil was introduced two harvest of vetch green mass – 3.2 t/ha.
The method used on preventive recovery the quality state of soil arable layer has led to restoration of physical, chemical and biological quality of this layer, to increase production capacity of the soil and created prerequisites for successful implementation of the conservation system Mini-till in the agriculture of Moldova (Cerbari, 2010b; Cerbari, 2011).
Soil is an organic-mineral system that can provide high capacity agricultural production if there is a constant flow of fresh organic matter in the soils (Florea et al., 1987).
Creating a equilibrated or positive balance of organic matter in the soil is the main condition for the preservation of soil fertility in the long term period and avoid the degradation of arable layer by dehumification, destructuration and secondary compaction.
This principle can be achieved through regular application organic fertilizers or green manure.
Research conducted on the chernozem cambic have demonstrated the possibility of restoring the soil quality state by phytotechnical methods in combination with agrotechnical, forming a positive balance of carbon, nitrogen and humus in soil, halting degradation processes in arable layer and regulate CO_2 emissions in the soils.
Phytoameliorative researches revealed the following recommendation: in a crop rotation with five fields, one field must be introduced as "occupied field" with a sidereal leguminous crop - winter and spring vetch.
This gives the opportunity to apply 2-3 vetch harvest per year into the soil as green manure on each field of rotation (once in 5 years).
Crop rotation structure may be: field occupied with vetch → corn → winter wheat → winter barley → sunflower.
This method, used in the tillage systems of agricultural land will lead to the formation of a equilibrated balance of organic matter in soil, remediation of soil quality state, and increasing the soil production capacity.

CONCLUSIONS

Researches was established that incorporation of two harvests of vetch green mass of 12.4 t/ha in the arable layer of chernozem cambic in the agricultural year 2015-2016 led at following:

- in the soil was accumulated about 310 kg of nitrogen, of which 180 kg was fixed from the atmosphere; was synthesized about 3 t/ha of humus or 1.7 t/ha of carbon; was sequestrated about 6.3 t/ha of CO_2;
- in the soil layer 0-10 (12) cm was increased labile organic matter with 0.20% compared to control variant; improved physical quality of this layer; formed a weak positive balance of organic matter and nitrogen content in the soil.
- on the variant with application by disking into the soil a harvest of vetch green mass, wheat harvest constituted 6.2 t/ha (rate increase 2.4 t/ha); on the variant with two harvest incorporation - 7.0 t/ha (rate increase 3.2 t/ha).
- the gluten content in wheat grains from fertilized soils consists 28%, from witness soil - consists 24%.

By systematic utilization of green fertilizers concomitantly with phosphorus and potassium fertilizers, the quality state of soil and agricultural productive capacity can be restored gradually. In this context it is necessary to organize a system for use of green manure and create the seed bases of annual and perennial grasses in the agricultural sector.

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