EVALUATION OF THE CONSERVATIVE AGRICULTURE BENEFITS ON SOIL PROPERTIES AND HARVESTS IN CROP ROTATION WITH LEGUMES

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Abstract

The experimental results regarding the changes in the properties of degraded arable ordinary chernozem from southern zone of Moldova and agricultural crops harvests in 5-field crop rotation with incorporation into the soil of one and two harvests of vetch green mass as organic fertilizer are presented. The results carried out in 2015-2019 showed that the introduction in the first agricultural year by disking into the soil of two green mass of vetch, led to restoration of the physico-chemical properties of the arable layer 0-20 cm and increased crop productions. The bulk density of 0-20 cm soil layer from unfavorable state became very favorable, the resistance to penetration from high and very high, became extremely low and low, which contributed to the easy penetration into soil of plant roots. The soil structure became agronomical favorable. The hydrostability of soil aggregates not soil layers 0-10 and 0–20 cm did not change, that is explained by the texture peculiarities of ordinary chernozem (loamy-dusty with high fine sand content). The porosity values correlate with the bulk density are favorable for a normal regime of soil aeration. The humus content increased by 0.16-0.26% in five years. The money value of the 4-year harvest increase was 18 080 MDL or 1090$. The results conducted in 2015-2019 confirmed that the preventive restoration of the quality state of the degraded arable soils is absolutely necessary to be carried out until the implementation or in the process of using the conservative agriculture system, based on No-till or Minimum-till technologies.

Key words: benefits, conservative agriculture, crop rotation, legumes, soil properties

Effective sustainable agriculture, based on the conservative technologies, can be designed in a system of long-term protection and preservation of soil quality and production capacity. The classic tillage system used in agriculture of the Republic of Moldova from 1950 to 1993, has led to the degradation of agricultural land, decreased fertility and soil production capacity: decreasing the organic matter and nutrients content in the soils, deteriorating the soil structure, increasing the compaction of the arable layer (Cerbari V., 2010**)**.

At the same time, the existence in the post-privatization period of an unbalanced correlation between the volume used of chemical and organic fertilizers did not ensure the increase of the soil production capacity. The chernozems of Moldova are characterized by fine textures and not always favorable correlation of the granulometric fractions. The high content of clay in the arable layer of soils without resistance to compaction, led to the strong compaction of the lower part of this layer in 1-2 years after the transition to the No-till or minimum-till. As result of compaction, when implementing conservative soil tillage systems, the lower part of the arable layer is not penetrated by plant roots, which leads to decrease in the volume of physiologically active soil and crop yields (Cerbari V., 2015; Leah T., 2018).

The reduction of the secondary compaction of the arable soil layer in the first 5-7 years of implementation of the conservative agriculture system, based on no-till or mini-till, can be performed by using phytoameliorative and agrotechnical procedures. These processes, by increasing the flow of organic matter and performing the subsoil periodically, can contribute to the restoration of the structure and the gradual loosening of the compacted postarable layer (Berca M., 2011; Canarache A., 1990).

At the moment, the restoration of the quality state of the arable layer is possible only by introducing in the soil the green fertilizers and the secondary production of the agricultural crops, simultaneously with the mechanical loosening of the former arable layer 0-35 cm once in 3 years by subsoiling with chisel (Wiesmeier M. *et al*, 2015.

The implementation in Moldova of various basic tillage systems that protect the soil depends on the initial properties of the soil, providing the

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territory with rainfall and the technical possibilities of farmers (Florea N *et al*, 1987; Cerbari V., 2011).

The research aimed was the preventive restoration of the degraded properties of the former arable soil layer 0-30 cm, recently compacted, through the systemic use of green manures and agrotechnical procedures of No-till.

MATERIAL AND METHOD

The researches were carried out on the agricultural lands of SRL Natcubii-Agro, Larga Nouă commune, Cahul District, South zone of Moldova. The land is a quasi-horizontal surface of the last (and highest) terrace of the Prut River. The absolute altitude of the soil profiles location is 120 m. The experimental soil was researched in order to assess the initial state of quality after its tillage two years according to No-till technology. The land is not affected by erosion processes.

The soil cover of the terrace is made up of ordinary chernozems with a moderately deep humiferous profile, clayey, post-excavated about 40 years ago and again used in arable land after the agrarian reform. The soils are typical for southern Moldova. The parental rock on the high terrace of the Prut River is composed by loessoid deposits of wind origin. Both the global subaeral process for the formation of loessoid deposits and the local process of accumulation of wind deposits from the primary bed of the Prut River participated in the formation of these deposits (Cerbari V., 2010). As a result of the combination of these two processes, the deposits of the Prut river terraces are characterized by a coarser texture than that of the analogy deposits on the surrounding plateaus

The assessment of the quality status and production capacity of degraded ordinary chernozems in Southern Moldova was made as a result of incorporation into the soil as organic fertilizer the green mass of two vetch crops in the 5-fields crop rotation. Alternation of crops in rotation in the 2015-2019 yrs: vetch (which was incorporated into the soil) → winter barley → rapeseed → winter wheat → sunflower.

RESULTS AND DISCUSSIONS

The initial assessment of the No-till work system on the quality status of ordinary chernozems in Southern Moldova was performed by comparison with soils worked according to conventional technology. It was established that the former arable layer of soil worked No-till two years was divided into three layers: 0-5 cm - very loose, consisting of mulch and soil aggregates as result of passing the No-till seed drill; 5-10 cm - with monolithic structure, weakly cracked; 10-30 cm - with massive structure. Thus, under the No-till system the strongly compacted post-arable layer (0-10 cm) was formed (Cerbari V., 2015; Cerbari V., Rusu A., 2019; Leah T., 2016a).

The texture is a virtually unchangeable feature of the soil, so agricultural technologies must be adapted to the structural specifics of each soil type. The soil properties depend on the content of different particle size fractions. The ordinary chernozems on the high terrace of the Prut River are characterized by a homogeneous clayey-dusty texture with a high content of fine sand (Leah T., 2016a). Regarding the soil tillage, the texture is one of the most favorable properties at the implementation of No-till technology. At the same time, being comparatively coarse (rough), the texture ensures a drier thermal regime in the soil, a greater possibility of mineralization of humus and organic residues, and water evaporation from soil.

Research has established that prolonged use in arable, the 0-30/35 cm soil layer of ordinary chernozems has dehumidified and the natural crumb-grained structure has deteriorated. Thus, the arable layer of the researched chernozems lost the resistance to secondary compaction (Leah T., 2018; Leah T., Cerbari V., 2015). The physical and chemical properties of conventionally and No-till soil worked are presented in *table 1.*

Table 1

The average values of the soil properties worked conventionally and No-till, 0-10 cm

Soil properties	Conventi-onal tillage	No-tillage 2 years
Hygroscopic water, %	4.1	4.3
Hygroscopic coefficient, %	6.0	6.2
Density, g/cm^3	2.65	2.60
Bulk density, g/cm^3	1.11	1.22
Total porosity, %	58.1	54.4
Penetration resistance, kgf/cm^2	7	14
Water field capacity, %	6.1	6.2
Wilting coefficient, %	9.0	9.1
$CaCO_3$, %	1.3	1.7
Humus, %	2.49	2.62
Mobile phosphorus, mg/100 g	1.46	1.75
Exchangeable potassium, mg/100 g soil	23	26
Nitrates (N-NO_3), mg/100 g	0.42	0.31

The hygroscopic water content, hygroscopic and wilting coefficients for soil layers 0-10, 10-30 cm are practically analogous. This is explained by texture homogeneity and poor differentiation in humus content of these layers. The wilting coefficient are medium, which indicates that the inaccessible water reserves for plants are comparatively small. At the time of research, the water field capacity of the conventionally cultivated soil was very low. A tendency to keep water reserves in No-till worked soils is due to the mulch layer. Bulk density is a main feature of the physical quality of the soil.

As result of the total loss of resistance to secondary compaction of the arable layer worked No-till two years, was strongly compacted starting with a depth of 5 cm from the soil's surface.

The ordinary chernozems on the high terrace of the Prut are weakly carbonate and are characterized by weakly alkaline reaction. These properties do not negatively affect the quality of chernozem. According to the humus content, the researched soils are moderately humiferous, which in the absence of organic fertilization, become destructured and loss the resistance to compaction of the arable layer. At the No-till, an increase of the organic matter content in the layer of 0-10 cm was obtained as a result of the humidification of the organic residues of secondary production left on the soil surface.

The experimental strip was organized at the end of September 2014 and was sown with a mixture of winter vetch (80 kg/ha) and winter wheat (50 kg/ha). The total area sown was 1.15 ha. One hectare of winter vetch was sown for seed production. The experimental strip occupied 0.15 ha. The winter vetch was incorporated into the soil in early of May by disking. On the same day, spring vetch was sown again. and incorporated into the soil as green manure in late of September.

Autumn vetch for seed was harvested in July. Vetch straw in the seed harvesting process was spread on the soil surface. The fallen vetch grains sprouted and formed a new green cover of vetch at the end of September, the average wet mass was about 8-10 t/ha.

Wheat straw and 8-10 t/ha of new green mass of vetch were incorporated into the soil by disking as organic fertilizer at the end of September. At the beginning of October 2015, winter wheat was sown as basic agricultural crop.

Data on the mass and composition of two autumn and spring vetch crops, sown on the experimental plot and incorporated into the soil as green manure are presented in *table 2*.

Table 2

Harvests of vetch on ordinary chernozem (vetch strip was founded on 30.09.2014)

Harvest	Green mass, t/ha	Humidity, % of wet mass	Dry mass, t/ha	Ash	N	P_2O_5	K_2O	C
				% of dry mass				
Green mass of autumn vetch, incorporated in the soil, 12.05.2015								
Main harvest	26.0	81.6	4.8	10.5	3.9	0.6	4.2	41.6
Roots, total mass in 0-30 cm			1.9	10.2	1.7	0.5	1.6	40.6
Total organic residues and roots			6.7	10.4	3.3	0.6	3.5	41.1
Green mass of spring vetch, incorporated in the soil, 30.09.2015								
Main harvest	17.0	67.9	5.5	10.9	3.1	0.7	1.5	41.2
Roots, total mass in 0-30 cm			2.1	10.6	1.6	0.5	1.3	41.6
Total organic residues and roots			7.6	10.7	2.7	0.6	1.4	41.4
Total organic residues and roots of two vetch crops incorporated in the soil			14.3	10.5	3.0	0.6	2.4	41.2

Note: *Humidity coefficient of vetch mass is 0.25. From 14.3 t/ha of absolutely dry aerial and underground vegetal mass of vetch, incorporated in the soil in April and August of 2015, about 3.6 t/ha of humus will be synthesized. 14.3 t/ha of dry organic vetch residues contain about 429 kg/ha of biological nitrogen, 60% of which (about 250 kg/ha) are of symbiotic origin (fixed from the atmosphere). The C: N ratio in the total aerial plant mass and pea roots is 41.2: 3 = 13.7.*

Data on the quantity of organic residues and green mass of vetch incorporated in the soil are presented in *table 3*. On average, the dry mass of organic vetch residue, consisting from the straw of the vetch sown for grain and the green mass of vetch shaken at the harvesting of the first crop, is practically equal to the mass of an average crop of vetch. At the end of September, the experimental strip was sown with winter barley.

Table 3

The quantity of organic residues (straw) and green mass of vetch incorporated in the soil

Harvest	Green mass, t/ha	Humidity, % of wet mass	Dry mass, t/ha	Ash	N	P_2O_5	K_2O	C
				% of dry mass				
Mass of straw and roots vetch, incorporated into the soil, 28.08.2015								
Vetch straw	6.0	45.6	2.9	10.2	2.1	0.6	2.6	41.8
Roots, total mass in 0-30 cm			1.9	10.2	1.7	0.5	1.6	40.6
Total organic residues and roots			4.8	10.2	1.9	0.6	2.2	41.3
Main harvest	8.0	77.9	1.7	10.9	4.1	0.6	1.5	41.2
Roots, total mass in 0-30 cm			0.7	10.6	1.6	0.5	1.3	41.6
Total organic residues and roots			2.4	10.7	3.4	0.6	1.4	41.3
Total organic residues and roots of two vetch crops incorporated in the soil			7.2	10.5	2.4	0.6	1.9	41.3

Note: *Humidity coefficient of vetch plant mass - 0.25. From 7.2 t/ha of absolutely dry aerial and underground vegetal mass of vetch, incorporated in the soil, about 1.8 - 2 t/ha of humus will be synthesized. In the 7.2 t/ha of dried organic vetch residues contain about 173 kg/ha of biological nitrogen, 60% of which (about 104 kg/ha) are fixed from the atmosphere. The C: N ratio in the total aerial plant mass and of vetch roots is 41.3: 2.4 = 17.2.*

Field research on changes in the quality status of the arable layer of soils under the action of green mass of peas, incorporated into the soil or started in mid-June, when the apparent density of the arable layer become balanced. The research was repeated every agricultural year - in 2016, 2017, 2018 and 2019.

In *table 4* are presented the data that characterize the values in dynamics for main properties of the researched soils for appreciation the changes in their quality state as a result of the incorporation in the soil as organic fertilizer the green mass of vetch.

The incorporation of the green mass of vetch led to the positive changes of some indicators of the physical quality of soil layer 0-10/12 cm and 10-20 cm. More significantly, the state of physical quality (apparent density, resistance to penetration) changes was in the 0-20 cm layer in result of the incorporation into the soil two vetch green mass.

The structure of the soil layers 0–10 cm, where one green mass of vetch was introduced and 0-20 cm, where two green mass of vetch was introduced, became agronomical favorable.

However, the hydrostability of the structure of these layers into which the green mass of vetch was introduced changed very little.

The insignificant change in hydrostability is due to the peculiarities of the texture of these soils. The ordinary chernozems investigated are characterized by a clayey-dusty texture with a high content of fine sand, coarse dust and comparatively low clay content, which ensures poor cohesion between the elementary soil particles within the existing structural aggregates (in wet conditions these structural aggregates are easily destroyed).

The content of organic matter in the soil layers where the vetch green mass was introduced increased by 0.16-0.26%. It is necessary to note that this organic mass with high nitrogen content, as a result of microbiological processes in the soil, partially turns into labile humus. Unstable humus is not closely related to the mineral part of the soil and is relatively easily mineralized as a result of microbiological processes. However, the process of mineralization of labile humus takes place slowly, over several years, which ensures a normal activity of microbiological processes in the soil over a period of 4-5 years (Cerbari V., Leah C., 2016; Leah T., Cerbari V., 2019).

Table 4

Modification of the average values of the physical and chemical properties of the soils on the experimental variants in the 2016-2019 years

Layer, cm	No-till	The application of one vetch harvest in the soil				The application of two vetch harvests in the soil			
	2015	2016	2017	2018	2019	2016	2017	2018	2019
Content of agronomically favorable structural aggregates 10-0,25 mm, dry sieving , %									
0-10	65.0	73.9	72.2	77.4	75.9	74.5	75.1	77.6	75.1
10-20	48.8	57.5	44.0	40.8	42.5	77.7	77.7	71.0	70.4
20-30	42.7	49.0	47.8	48.2	50.8	45.1	45.1	44.3	40.0
Content of favorable hydrostable agronomic structural aggregates, wet sieving, %									
0-10	24.3	31.6	21.6	23.2	25.6	31.4	27.3	29.8	29.2
10-20	14.7	23.9	19.4	26.4	26.2	23.6	25.5	28.0	24.2
20-30	13.3	14.1	18.2	19.4	17.0	13.4	14.6	15.0	14.4
The mean values of apparent density, g/cm^3									
0-10	1.24	1.12	1.21	1.22	1.24	1.18	1.24	1.22	1.23
10-20	1.48	1.44	1.48	1.46	1.47	1.21	1.26	1.28	1.37
20-30	1.49	1.49	1.49	1.45	1.48	1.50	1.44	1.45	1.47
The average values of total porosity , %									
0-10	52.9	56.9	54.0	55.1	53.2	54.6	52.9	53.2	53,6
10-20	44.5	45.7	44.6	44.9	45.4	54.3	52.8	51.7	48,7
20-30	44.4	44.2	44.4	45.7	44.8	43.8	46.3	45.3	45,2
Average values of resistance to penetration, kgf/cm^2									
0-10	13	7	8	6	6	6	11	6	5
10-20	20	17	19	19	19	7	12	15	10
20-30	20	20	20	23	22	21	16	22	21
Average of humus content, %									
0-10	2.63	2.79	2.85	2.78	2.82	2.89	2.85	2.85	2.86
10-20	2.52	2.67	2.71	2.65	2.69	2.84	2.83	2.81	2.82
20-30	2.45	2.47	2.49	2.47	2.47	2.49	2.52	2.50	2.51

This process can cause the appearance of "nitrogen hunger" which is influenced by the low nitrogen content of mineralized soil in the organic residues of previous crops. The negative action of vetch straw could have been avoided if 100-150 kg/ha of ammonium saltpetre or urea had been introduced on the control plot immediately after the rapeseed harvest, which would have intensified the process of mineralization of the organic remains of the rapeseed low nitrogen content.

Another strategic problem is the need to restore the mobile phosphorus content in agricultural soils; the decrease of phosphorus reserves in the arable layer becomes catastrophic.

The use of green mass of vetch as an organic fertilizer largely solves the problem of nitrogen in the soil, but not of phosphorus (Leah T., 2015, 2016b, 2016c).

The basic criteria on assessing the positive changes in the quality of the soil is the harvest of the crops sown after the application in the soil of the vetch green mass (*table 5*).

Table 5

The harvest of agricultural crops obtained on the variants of the experience located on the ordinary chernozem

2016 **Experimental Variant**	Average barley harvest, t/ha (humidity - 8%)	Harvest increase, t/ha / %
Control	4.9	-
After incorporation into the soil - one crop of vetch green mass	6.3	1.4 28.6
After incorporation into the soil - two crops of vetch green mass	7.1	2.2 44.9
2017 **Experimental Variant**	Average rapeseed harvest, t/ha (humidity - 8%)	Harvest increase, t / ha /%
Control	3.1	-
After incorporation into the soil - one crop of vetch green mass	3.6	0.5 16.1
After incorporation into the soil - two crops of vetch green mass	4.1	1.0 32.3
2018 **Experimental Variant**	Average wheat harvest, t/ha (humidity - 5%)	Harvest increase, t / ha /%
Control	3.8	-
After incorporation into the soil - one crop of vetch green mass	3.9	0.1 2.6
After incorporation into the soil - two crops of vetch green mass	4.6	0.8 21.0
2019 **Experimental Variant**	Average sunflower harvest, t/ha (humidity - 5%)	Harvest increase, t / ha /%
Control	2.8	-
After incorporation into the soil - one crop of vetch green mass	3.0	0.2 7.1
After incorporation into the soil - two crops of vetch green mass	3.3	0.5 17.8

In the second year (2016) of the 5-field crop rotation, the autumn barley was cultivated. The average harvest on the control plot was 4.9 t/ha of barley. On the plot where a green mass crop of vetch was incorporated into the soil by disking, the barley harvest increased by 1.4 t/ha and formed 6.3 t/ha, and on the plot where two crops of vetch green mass introduced into the soil, the barley harvest increase was 2.2 t/ha, the total harvest was 7.1 t/ha. Experience data confirm a 2-time increase in the barley harvest under the action of green manure (vetch green mass).

Research conducted in 2015-2019 yrs. showed that the introduction in the agricultural year 2014-2015 in the soil one and two crops of vetch green mass by disking, as an intermediate crop, led to the positive recovery of soil properties of layers 0-20 cm and increase crop production.

Crop yield after application of one vetch green mass was:

- 2016: the winter barley harvest - 6.3 t/ha, the increase - 1.4 t/ha/year, the monetary value of the harvest increase: 3080 lei or 229$.
- 2017: the rapeseed harvest - 3.6 t/ha, the increase - 0.5 t/ ha/year, the monetary value of the harvest increase: 3550 lei or 214$.
- 2018: the winter wheat harvest - 3.9 t/ha, the increase - 0.1 t/ha/year, the monetary value of the harvest increase: 330 lei or 20$.
- 2019: the sunflower harvest 3.0 t/ha, the increase - 0.2 t/ha/year, the monetary value of the harvest increase: 1400 lei or 84$.

Harvest of agricultural crops after the application of two green masses of vetch was:

- 2016: the winter barley - 7.1 t/ha, the increase - 2.2 t/ha/year, the monetary value of the harvest increase: 4840 lei or 292$.
- 2017: the rapeseed harvest - 4.1 t/ ha, the increase - 1.0 t/ha/year, the monetary value of the harvest increase: 7100 lei or 428$.
- 2018: the winter wheat harvest - 4.6 t/ha, the increase - 0.8 t/ha/year, the monetary value of the harvest increase: 2640 lei or 159$.
- 2019: the sunflower harvest - 3.3 t/ha, the increase 0.5 t/ha/year, the monetary value of the harvest increase: 3500 lei or 211$.

The recommended method of preventive restoration the quality status of the arable soil layer led to the remediation of soil properties, to the increase of crop production and created premises for successful implementation of the conservative agriculture system, based on No-till technologies.

Soil regeneration take place only if it is worked properly, it is not overexploited until depletion, the conditions of protection and conservation are respected and it is ensured in a permanent flow of qualitative organic matter in its arable layer. Restoring the destroyed soil cover is very difficult, requires a long time and high costs.

In this context, the permanent monitoring of changes in soil quality is necessary for the timely implementation the measures to combat or reduce the land degradation.

CONCLUSIONS

The implementation of the conservative agriculture system, based on the No-till technology increased crop yields in the first two years as a result of more efficient use of soil moisture due to the layer of mulch formed on its surface and balanced application of fertilizers. The physical quality of soils worked No-till two years has worsened, the soil become strongly compacted and with high resistance to penetration from depth of 5 cm from the soil's surface.

The researche confirmed that the preventive restoration of the quality status of the dehumificated, destructured and without resistance to compaction of arable layer is absolutely necessary to be carried out until the implementation of the conservative agriculture, based on No-till technology. The preventive restoration method of the arable soil layer state, based on the use of legume crops as green organic fertilizer, led to the remediation of the physical and chemical properties, increase soil production capacity, created premises for the successful implementation of No-till technology.

The implementation in the Republic of Moldova the conservative agriculture, based on the use of green fertilizers in combination with No-till or Mini-till tillage technologies will contribute to the establishment of a permanent of organic matter flow and the gradual restoration of soil quality, increasing the harvest of agricultural crops by 20-30%, reducing the need for nitrogen fertilizers by at least 50%. Currently it is necessary to organize the system of use of green fertilizers in the agricultural sector of the Republic of Moldova and to create the seed base of legumes.

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