

INFLUENCE OF PHYTO-AMELIORATION ON THE PRIMARY FACTOR OF PRODUCTION (SOIL) AS A METHOD OF AGRICULTURAL OUTPUT MANAGEMENT

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Abstract

Food security issue is one of the current major concerns in conditions of fast growing global population. In the Republic of Moldova about 73% of territory is arable land, but the amount of agricultural production is not enough to cover the necessities of population. Due to different types of soil degradation, which occurs on 56.4% of agricultural land, crop yields and profit from agricultural sector are relatively low. In the present research it was tested the influence of green manure on soil quality and crop yields. The experiment was conducted in the Central part of Moldova on greyzems. As green manure it was chosen *Vicia* which was tested in two trials: *Vicia villosa* Roth → *Vicia sativa* L. → wheat, and *Vicia villosa* Roth → sunflower → wheat. The results of the experiment showed that *Vicia* improved soil physical qualities, especially in the first trial where soil bulk density decreased from 1.36 g/cm³ to 1.22 g/cm³ in 0-12 cm layer and from 1.52 g/cm³ to 1.41 g/cm³ in 12-20 cm layer. Soil structure and hidrostability of soil aggregates were also improved. Besides, the amount of organic matter in soil increased from 2.41% before the experiment to 2.62% in the 0-12 cm layer in the first case and to 2.57% in the second case. The 2011 year was dry but the effect of *Vicia villosa* Roth on sunflower crop yield was registered, it increased on average by 0.4 t/ha. The largest harvest of wheat was obtained in the first variant - 4.1 t/ha, wheat after sunflower gave 3.2 t/ha while control plot only 2.4 t/ha. So, there is a good possibility to manage crop yields by use of *Vicia* as green manure even in dry years which occur once in four years in Moldova. That method will not only raise the harvest of crops but will improve significantly soil quality.

Key words: soil quality management, green manure, organic matter, soil structure, bulk density, crop productivity.

INTRODUCTION

In October 2011 Earth's population hit seven billion. Passing this milestone means that pressure on soil resources by humanity is growing daily. The situation in the Republic of Moldova is not an exception. According to the data of National Bureau of Statistics on 1 January 2011, about 59.4% of the country's territory is agricultural land (Anuarul Statistic, 2011), but still soil resources are not able to produce enough yields to cover the population necessities. At the same time the Republic of Moldova is known worldwide as a country of chernozems-reach soils with high natural fertility potential (Krupenikov, 2011). This paradox is explained by the fact that now different types of soil degradation persist on more than 56.4% of agricultural land (Andries, 2004). In these conditions it is necessary to find environmentally friendly methods to raise

crop productivity and at the same time to contribute to soil health remediation. The aim of the present research was to test the influence of *Vicia* as green manure on soil quality, especially on soil organic matter content and soil structure, and crop productivity. *Vicia* or vetch is used worldwide in agriculture as cover crop (Ramos, 2010; Norsworthy, 2010) or green manure (Fageria, 2007) but never in the Republic of Moldova.

MATERIALS AND METHODS

The study was conducted in the Central Moldova region at the experimental station of the Institute of “Nicolae Dimo” Pedology, Agrochemistry and Soil Protection nearby Ivancea village, Orhei district. The climate in the area is warm semi-humid, the mean annual temperature is 8.5-9.0°C, annual rainfall 550-600 mm/year, days of sunshine 290-300,

vegetation period – 178-182 days. Two trials were set up in 2010 on greyzems: 1) *Vicia villosa* Roth→*Vicia sativa* L.→ wheat; and 2) *Vicia villosa* Roth→ sunflower → wheat. In order to reduce nitrogen leaching after green manure incorporation into the soil a mix of *Vicia villosa* Roth and winter wheat with a ratio of 80:20 was used. The mix was sown early in September 2010 and late in April 2011, at the early flowering stage, the green mass was introduced into the soil with disk harrow. After that the first plot was sown with a mix of *Vicia Sativa* L. and rye with the ratio of 80:20 that was harvested in the middle of July for hay. Crop residues were incorporated in soil with a disk harrow, and the plot remained fallow until October. At that time the second plot was planted with sunflower which was harvested in September. Because of dry weather the two plots were sown with winter wheat only in October 2011 that was collected in June 2012.

The trials were set up on greyzems which had been in agricultural use more than 100 years, on a field with a slope less of 2% and elevation about 200 m. The soils characterized by the next profile type: Ahp1-Ahp2-Bhtw-Btw-BCTwk-BCK-Ck-2Ck; clay loam texture, thickness of humus profile (sum of horizons with humus content >1%) - 51 cm, average humus content 2.32%, moderate phosphorus and potassium content and pH = 6.3-6.5 in layer 0-35 cm. Carbonates are leached to 80-130 cm depth.

Soil samples were collected before the establishment of the experiment in autumn 2010 in order to determine the initial soil state; one month later after incorporation of *Vicia villosa* Roth in soil; after harvest of *Vicia Sativa* L. for hay and on the same plot three months later before winter wheat planting. Average crop yields of sunflower and winter wheat from the experimental and control plots were appreciated by manually harvesting five randomly selected squares of size 1x1 m. The approved laboratory and field research methods were used in the investigation. Soil bulk density was determined by core method, soil structure by dry sieving, aggregates hidrostability by wet sieving method of Savinov, total porosity by calculation (Vadiunina and Korceaghina, 1986). The degree

of compaction was calculated using a formula given by Canarache (Canarache, 1990). The organic matter content was determined by the Tiurin method, total nitrogen content by Kjeldahl method (Агрохимические методы исследования почв, 1975).

RESULTS AND DISCUSSIONS

In spring 2011 *Vicia villosa* Roth was incorporated into the soil as green manure. It's yield was 17 t/ha of green mass or 3.5 t/ha of dry mass. It was also determined in laboratory that in the soil remained on average 3.4 t/ha (dry mass) of root biomass in 0-30 cm layer (it is evident that *Vicia* root system is larger and the amount of residue is even greater).

The crop yield of *Vicia Sativa* L. was better – 20 t/ha but it was mowed for hay and in the soil remained only about 25% of above ground crop residues, that represents 5 t/ha of green mass or 1.5 t/ha of dry mass.

Root biomass in this case was 4.1 t/ha of dry mass. Thereby, according to the data, in the first trial in the soil was incorporated overall 12.5 t/ha of dry mass of organic matter. In the second trial the amount of organic matter was 6.9 t/ha of dry mass.

Previous researches showed that humus content decreased, and soil structure and aggregate stability degraded in cultivated soil in comparison with natural greyzems (Lungu, 2007).

Our investigation showed that the growing of *Vicia* and its incorporation as green manure led to an improvement of soil condition in both trials.

Laboratory analysis revealed that *Vicia* had a good influence on the physical soil state. This was expressed by an improvement of soil bulk density as values went down immediately after the *Vicia villosa* Roth growth and remained the same after *Vicia sativa* L. harvest (Figure 1).

Thus significant changes occurred in the 0-12 cm layer where bulk density values decreased from 1.36 g/cm³ to 1.17 g/cm³. In the 12-20 cm layer bulk density decreased from 1.52 g/cm³ to 1.45-1.46 g/cm³ and a slight change, from 1.56 g/cm³ to 1.50-1.52 g/cm³, was observed in 20-34 cm layer.

Bulk density of underlying 34-50 cm layer remained almost constant, probably due to

initial high values (1.61-1.62 g/cm³) which are reported to be critical for clay loam soils (Hazelton, 2007) and severely restrict root growth.

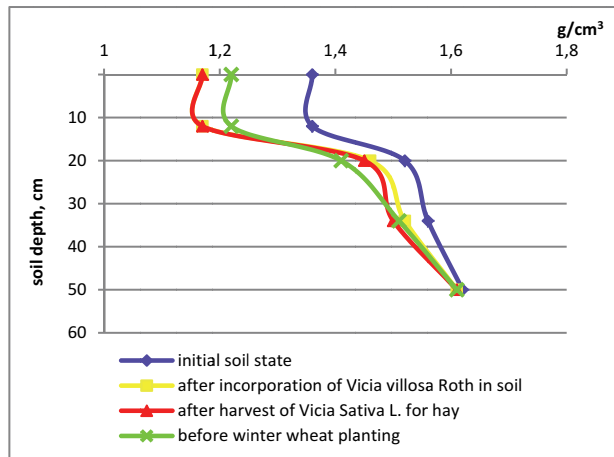


Figure 1. Greyzems bulk density

By the month of September when winter wheat was sown soil settled and its bulk density underwent small changes. The values of balanced bulk density slightly increased to the 1.22 g/cm³ in 0-12 cm layer and decreased to the 1.41 g/cm³ in 12-20 cm layer. The rest of the layers kept the same bulk density values.

There were similar changes in the degree of soil compaction (calculated using the formula of Canarache, 1990), which is directly related to soil bulk density. As can be seen in Figure 2, soil compaction decreased significantly and soil became loose in the first 12 cm. Some visible changes were produced in the 12-20 cm of soil profile, where moderately compacted soil became slightly compacted. The next soil layers were less affected by *Vicia* root action and their degree of compaction remained almost unchanged.

The effect of *Vicia* on total porosity has similar trends because it is directly related to soil bulk density and degree of compaction (Figure 3).

In general, soil porosity increased in the upper 0-12 cm layer from medium (48.2%) to high (55.5%), from very low (41.8%) to low (43.8-44.2%) in 12-20 cm layer, and remained in the same category of very low porosity in the next layers.

In literature *Vicia* is reported to work as soil conditioner by improving soil structure and aggregates stability (Clark, 2007). The results of our research confirmed the idea. In the field it was observed that soil structure enhanced

after *Vicia villosa* Roth and *Vicia sativa* L. cultivation (Figure 4).

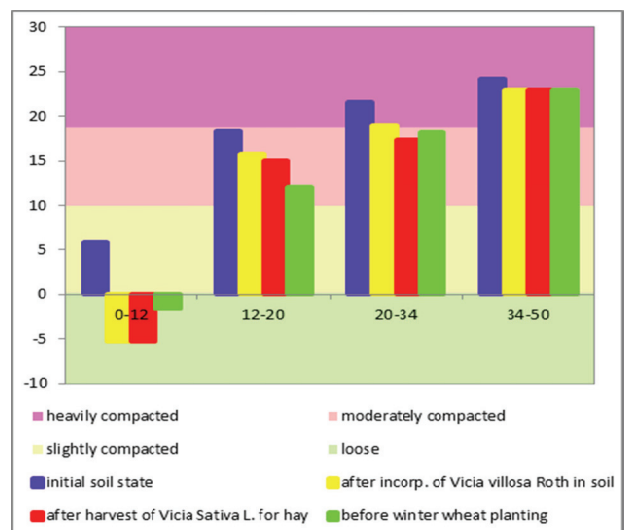


Figure 2. Greyzems degree of compaction

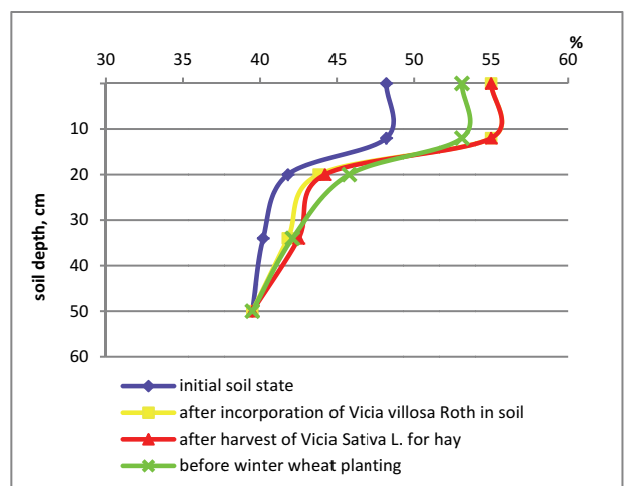


Figure 3. Greyzems total porosity

Initially poor soil structure improved significantly and became loose in the first 20 cm where the main root biomass of *Vicia* was located. The results of visual assessment were confirmed by laboratory analysis. The sum of favourable aggregates (10-0.25 mm) increased from 66.4% to 70.6-72.2% in the 0-12 cm layer and from 30.1% to 44.9-54.6% in the 12-30 cm layer (Figure 5).

Wet sieving analysis showed that *Vicia* contributed to soil aggregates hidrostability increase. Initially very low aggregate hidrostability of the first soil layer (48.5%) became good in both cases of *Vicia* (54-59.6%). Aggregates hidrostability of the next layer remained at the same level (Figure 6).

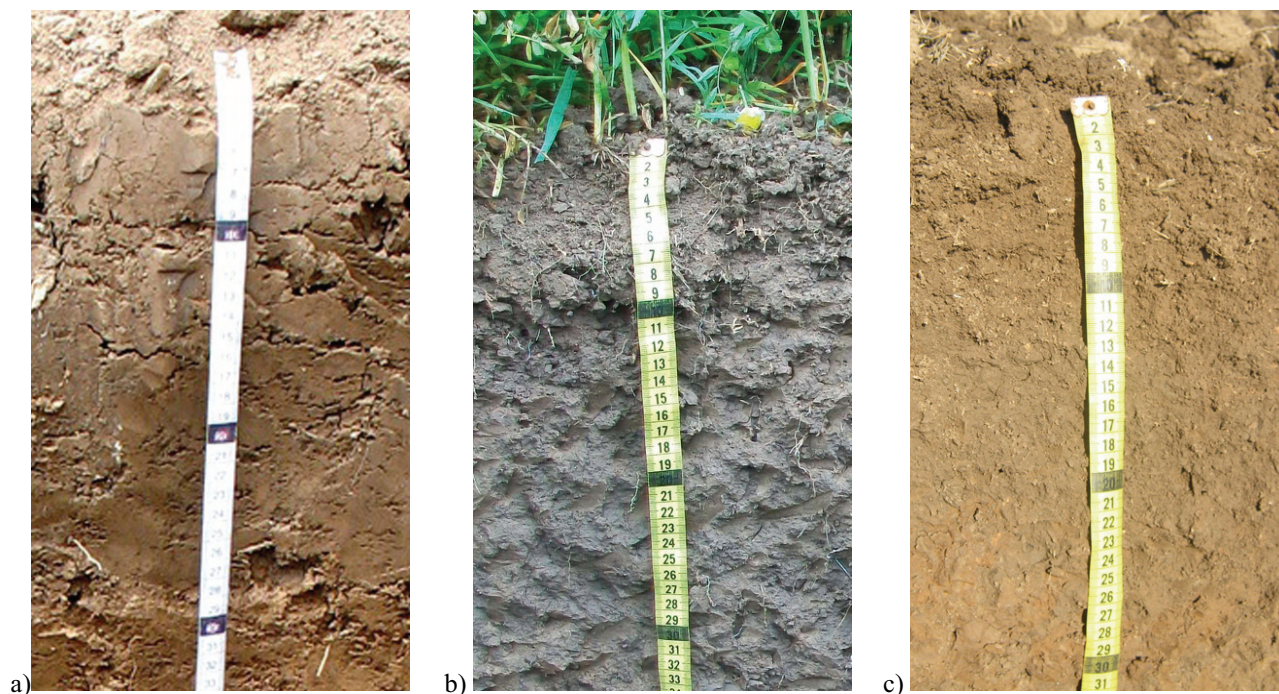


Figure 4. a) Initial state of arable greyzems; b) greyzems under *Vicia sativa* L.; c) greyzems before winter wheat

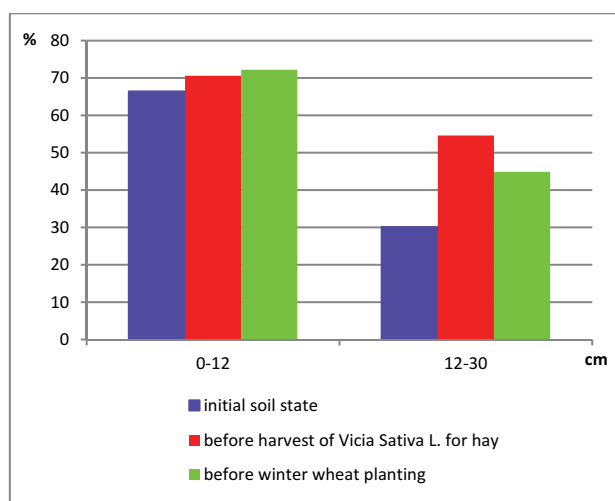


Figure 5. Sum of favorable aggregates 10-0.25 mm at dry sieving

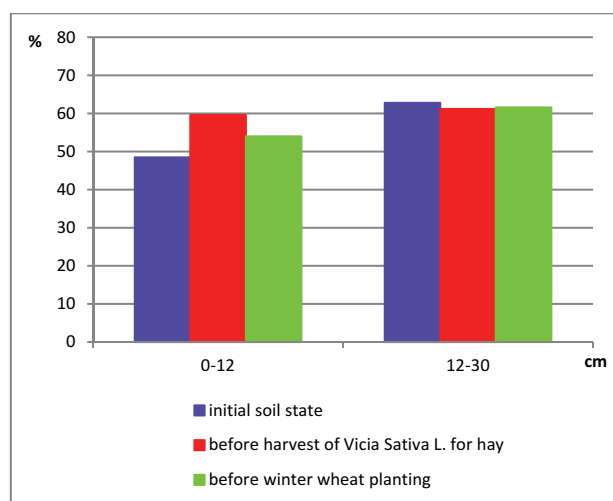


Figure 6. Sum of favorable aggregates 10-0.25 mm at wet sieving

The organic matter content in arable greyzems increased due to the use of green manure (Figure 7). Incorporation of 12.5 t/ha of *Vicia* biomass at a depth of 12 cm added an average 0.32% of organic matter to the soil (in the 0-12 cm layer). The next peak of organic matter accumulation is noticed in 20-34 cm layer probably due to *Vicia* roots residues. In the layer of 34-50 cm no difference occurred in the organic matter content.

In the second trial addition of the fresh biomass in the amount of 6.9 t/ha contributed to a growth of organic matter in the soil by 0.16% in the first 12 cm of soil. Similar to the first

case there is a growth of organic matter content by 0.27% in 20-34 cm of soil and only slight changes were noticed in the 34-50 cm of soil.

After three months the fresh organic matter had begun to decompose. As it can be seen in the Figure 7 its content slightly decreased from 2.73% to 2.62% in the first 12 cm of soil and from 1.92 to 1.72% in the 20-34 cm layer.

Due to the fact that *Vicia* has a relatively low carbon to nitrogen ratio that ranges from 8:1 to 15:1 (Clark, 2007), the amount of total nitrogen content increased respectively (Figure 8). Addition of *Vicia villosa* Roth as green fertilizer raised its values from low to medium:

from 0.14% to 0.20% in the first 12 cm and from 0.13% to 0.17% in 12-20 cm layer. The second addition of green manure increased the total nitrogen amount to 0.22% (0-12 cm) and 0.19% (12-20 cm).

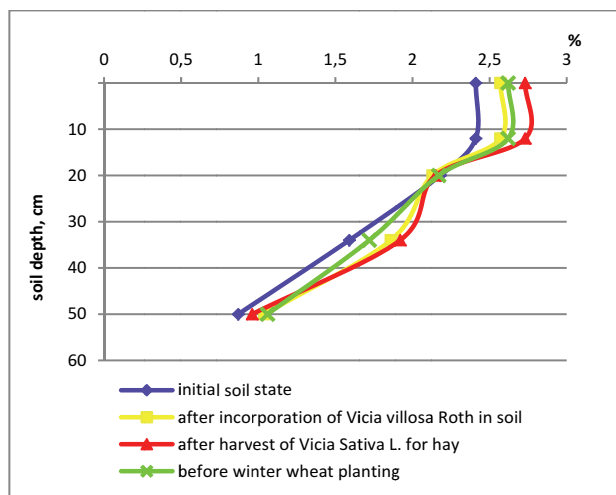


Figure 7. Organic matter content of greyzems

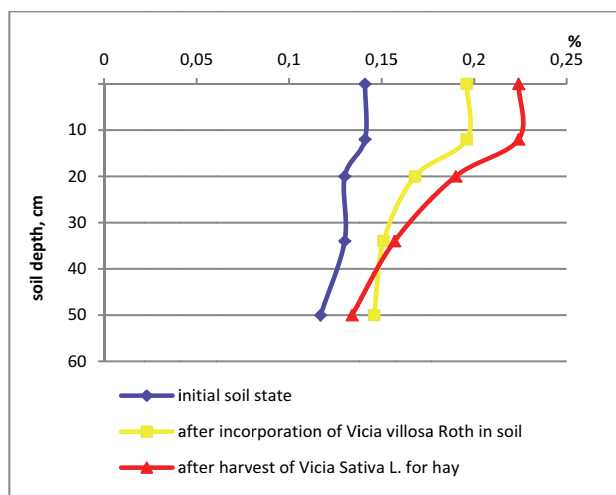


Figure 8. Total nitrogen content of greyzems

Multiannual experiments of “Nicolae Dimo” Institute of Pedology, Agrochemistry and Soil Protection showed that natural fertility of the greyzems from the above mentioned experimental station allow to obtain an average yield of 1.6 t of sunflower seeds or 2.4 t of winter wheat (Andries, 2007).

The assessment of the sunflower harvest sown after *Vicia villosa* Roth and from the control plot showed that the use of green manure yielded a 0.4 t/ha increase (Figure 9).

The yield from the control plot was 2 t/ha which is a bit more than the above mentioned average for that soil type.

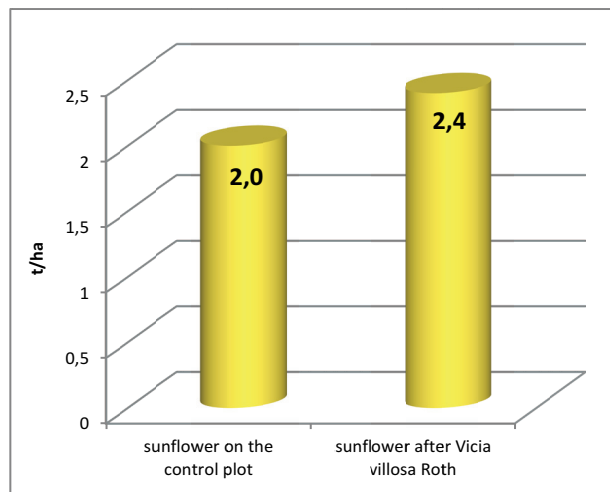


Figure 9. Yield of sunflower on greyzems

The evaluation of winter wheat yields also revealed a positive reaction of plants on *Vicia* as a predecessor (Figure 10).

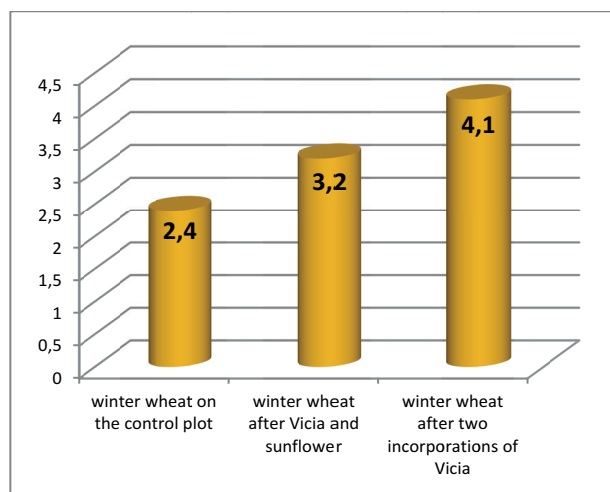


Figure 10. Yield of winter wheat on greyzems

In comparison with the control plot, the yield of winter wheat increased by 70% in the first trial: *Vicia villosa* Roth → *Vicia sativa* L. → wheat, where the yield was 4.1 t/ha. In the second trial: *Vicia villosa* Roth → sunflower → wheat, the yield increased by 33% and made 3.2 t/ha. Therefore two consecutive crops of *Vicia* had a significantly better effect on the crop of winter wheat.

CONCLUSIONS

Use of *Vicia* as green manure had a beneficial impact on greyzems physical state: soil bulk density and degree of compaction decreased, total porosity increased, soil structure and hidrostability of soil aggregates improved. Also

the incorporation of *Vicia* into the soil made some contribution to soil organic matter content – one of the main indicators of soil fertility.

The economic benefit from the use of green manure was represented by a significant growth of cash crops yields sown after it due to addition of fresh and readily decomposable organic matter to the soil and an improved soil physical state.

We consider that the use of *Vicia* as green manure is a good possibility to manage crop yields. That method will not only raise the harvest of crops but also will significantly improve soil quality.

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