Soil Microbial Activity under the Influence of Advanced Technologies for Minimum and Unconventional Tillage

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Abstract: *Cultivation of crops on sloping agricultural lands can cause occurring of water erosion and the related to it degradation process - loss of organic matter. The negative consequences of their development are deterioration of the physical, agrochemical and biological properties of the soil. To prevent degradation processes, a number of agro-technical measures, methods and technologies are applied. The activity and the composition of soil microflora are sensitive indicators of soil processes. The present study explores the impact of conventional and soil-protecting technologies on soil microbial activity.*

Keywords*: water erosion, minimum tillage, vertical mulching, surface mulching, soil microbial activity.*

INTRODUCTION

Water erosion causes significant changes in the physical and chemical properties of the soil, resulting in deterioration of biological ones. Research on lands with natural vegetation, soils of varying degrees of degradation as a result of water erosion, as well as eroded soil under the application of restoration measures, have shown that the microbiological activity of eroded soils is 8-10 times lower compared to lands with natural vegetation (Nunes et al., 2012). In soils under restoration, carbon and nitrogen in microbial biomass were increased 5 times and twice respectively compared to highly degraded soils (Nunes et al., 2012)

Except in biogeochemical cycles, plant nutrition, soil microflora has an important role in the formation of soil structure. Aggregation of soil particles is important for improving soil aeration, infiltration and erosion sustainability (A. Bot, 2005, Tisdall and Oades, 1982).

According to Pascual et al. (1999) soil chemical and physical parameters such as organic matter, nutrient concentration, flow measurement and soil structure are used as indicators of soil quality, taking into recording the degree of degradation. But these parameters change slowly and long periods of time are needed to record significant differences. Biological and biochemical indicators, on the other hand, are more sensitive to small changes occurring in the soil, thus providing rapid information on changes in soil. Microbiological activity changes rapidly due to rapid propagation, short life cycle, and sensitivity to changes in the environment. This leads to rapid changes in biological and biochemical soil indicators resulting from different processes (Pascual et al., 1999).

In all countries of the world and in Bulgaria, where exists the problem with water erosion and with the loss of organic matter in the soil, a systematic control is under way to limit these degradation processes, mainly using agro-technical erosion control measures, methods and technologies due to their advantages – their easy applying, rapid soil protection effect and their relatively low expensies. To limit the degradation processes water erosion and reduction of soil organic matter in cultivation of crops on slope terrains, advanced technologies for minimum and unconventional (surface and vertical mulch) soil tillage have been developed and applied. They have been developed by the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" - Sofia together with University of Ruse "Angel Kanchev".

The aim of the present work is to identify the changes occurring in some physical and chemical properties of the soil as well as its microbial activity under the application of conventional and advanced soil protection technologies for minimum and unconventional tillage of the soil for cultivation of maize on sloping agricultural lands.

MATERIALS AND METHODS

The field experiments were carried out in the period 2012-2017, in the field of the Experimental Station for Erosion Control - Ruse, to the ISSAPP "N. Pushkarov "- Sofia, on the territory of the village of Trastenik, Rousse, under non-irrigated conditions, on average eroded carbonate chernozem, with a slope of 50 (8.7%), in two stages. The experiments of 2012 - 2014 y. have been carried out using mulch material ready compost for vertical and surface mulching and those in the period 2015-2017y. were carried out with manure.

Experimental variants are:

1. maize plots, grown by using conventional technology, applied along the slope - control;
2. maize plots, grown by using conventional technology applied across the slope;
3. maize plots, grown by using erosion control technology, including surface mulching with ready compost or manure, all operations applied across the slope;
4. maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with ready compost or manure, making slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope.

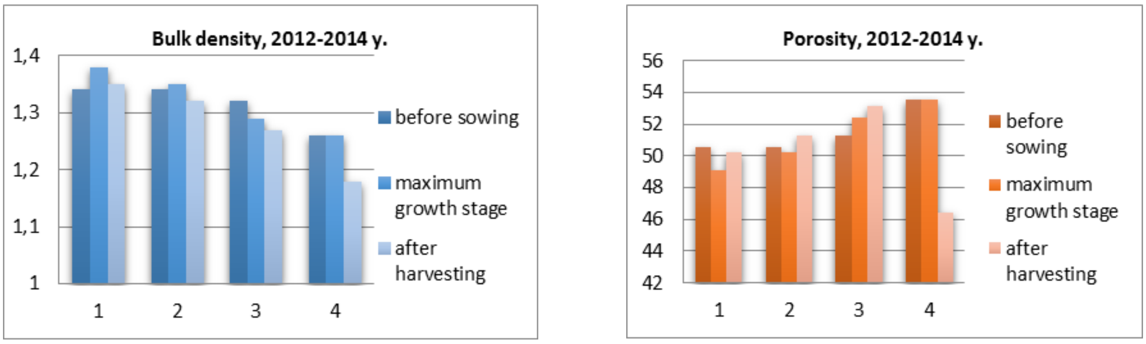
Annualy soil indicators (bulk density, total porosity, soil humidity in the 0-150 cm layer) were determined, and were carried out agrochemical and erosion studies, as well as microbiological analyzes in three phases of the crop development.

Isolated and quantified saprophytic soil microflora (total number and spore-forming bacteria) by the Koch method on peptone meat agar - for bacteria, starch ammonia agar - for actinomycetes, medium of Eshbie for nitrogen fixing bacteria, medium of Hutchinson to determine the amount of cellulose-decomposers.

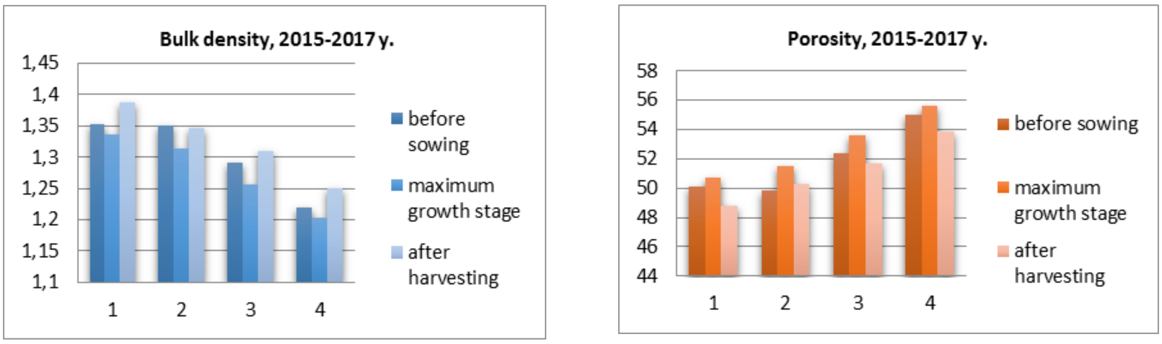
RESULTS AND DISCUSSION

The influence of applied technologies on some physical indicators of the soil is shown in Fig. 1. From the data submitted to it, it can be seen that the use of the advanced soil protection technology, including the erosion measures, vertical mulching, making slits with ducts, along with sowing and digging and furrowing along the hilling, contributes to the reduction of the bulk density and increase of its general porosity. This trend was observed both in the first survey period of 2012-2014 and in the second 2015-2017, with the use of various mulching materials.

Improving these soil indicators allows to increasing the water permeability and moisture content of the soil, positively influencing both the development of the cultivated crop and creating favorable conditions for the development of the soil microflora (tabl.1). The moisture content of 2, 3 and 4 (mulch with compost) variants is 0.09%, 0.97% and 1.44%, respectively higher than in control, for the initial phase of the study (pre-sowing). In the next two phases (maximum growth and harvest), the humidity in variant 2 was 0.36% and 0.32% higher than in control - variant 1, in variant 3 with 1.14% and 0.90%, at 4 - with 3.61% and 1.80%. When applying manure as a mulching material, a similar trend is observed. The moisture in variant 4 was 2.42%, 1.90% and 2.57% higher over the three observed phases compared to the control variant.



ANOVA: Bulk density 2012-2014; p= 0.000558; HSD[0.05]=0.08; HSD[0.01]=0.1; Porosity: P=0.0001 HSD[0.05]=2.49; HSD[0.01]=3.13;



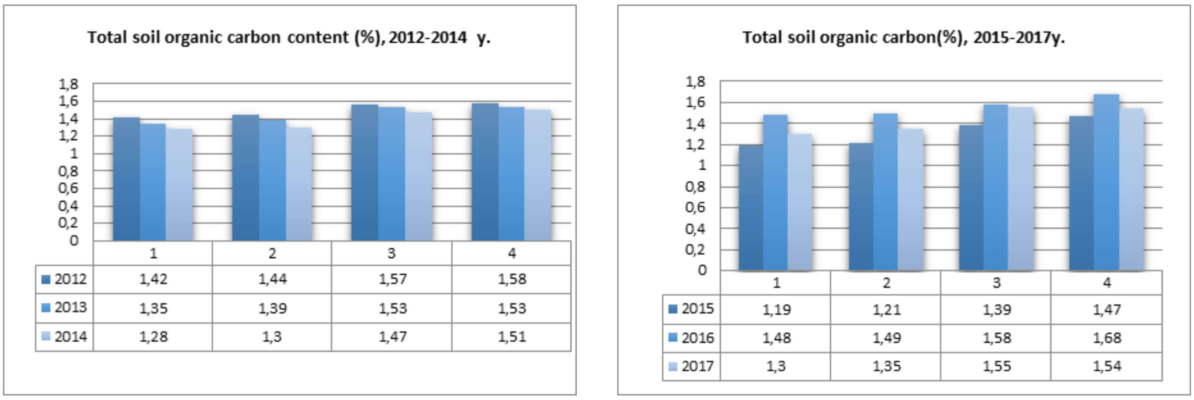
ANOVA: bulk density: p= 0.000700; HSD[.05]=0.07; HSD[.01]=0.09; 1 vs 2 nonsignificant; 1 vs 3 P<.05; 1 vs 4 P<.01; 2 vs 3 nonsignificant; 2 vs 4 P<.01; 3 vs 4 nonsignificant; total porosity p=0.000716; HSD[.05]=2.42; HSD[.01]=3.31

Fig. 1 Average bulk density and total porosity experience wheat for 2013-2015 observed in three phases

Table 1 Soil moisture 0-150cm, 2012-2014y.and 2015-2017y.

Year	***Phase***	**1**	**2**	**3**	**4**
2012 y.	***Sowing***	19.99	20.21	20.60	21.37
	Maximum growth stage	7.71	8.25	8.98	11.53
	After harvesting	8.72	9.05	9.06	9.39
2013 y.	***Sowing***	15.60	15.60	15.90	16.41
	Maximum growth stage	13.85	14.30	15.06	15.09
	After harvesting	9.32	9.86	10.62	11.11
2015y.	***Sowing***	17.90	17,95	19,90	20.03
	Maximum growth stage	14.17	14.25	15.15	19.95
	After harvesting	10.45	10.56	11.52	13,40
2012-2015 y.	***Sowing***	17,83	17.92	18,80	19,27
	Maximum growth stage	11,91	12,27	13,06	15,52
	After harvesting	9,50	9,82	10,40	11,30
2015 y.	***Sowing***	19.63	19.63	21.01	21.35
	Maximum growth stage	7.04	8.13	9.33	10.25
	After harvesting	22.60	23.45	24.10	25.85
2016 y.	***Sowing***	16.74	16.74	19.28	19.81
	Maximum growth stage	9.87	10.03	10.41	11.37
	After harvesting	9.18	10.44	10.68	12.05
2017y.	***Sowing***	17.71	17.71	18.36	20.20
	Maximum growth stage	12.85	13.30	13.44	13.85
	After harvesting	10.98	11.34	11.44	12.54
2015-2017 y.	***Sowing***	18,03	18,03	19,55	20,45
	Maximum growth stage	9,92	10,49	11,06	11,82
	After harvesting	14,25	15,08	15,41	16,81

The combination of minimum tillage with the importation of compost or manure as a mulching material into the improved erosion control tillage leads to preservation and improvement of the humus content of the soil as shown in Fig. 2. The importation of organic matter with surface mulching in the third variant also results in the storage and increase of the soil organic matter. All these effects have a positive impact on both the growth of the cultivated crop and the soil microflora, which has a major impact on soil and humus formation.



ANOVA: P<0.0001HSD[0.05]=0.05; HSD[0.01]=0.06 ; ANOVA p=<.0001; HSD[.05]=0.15; HSD[.01]=0.19

Fig. 2 Total soil organic carbon content (%)

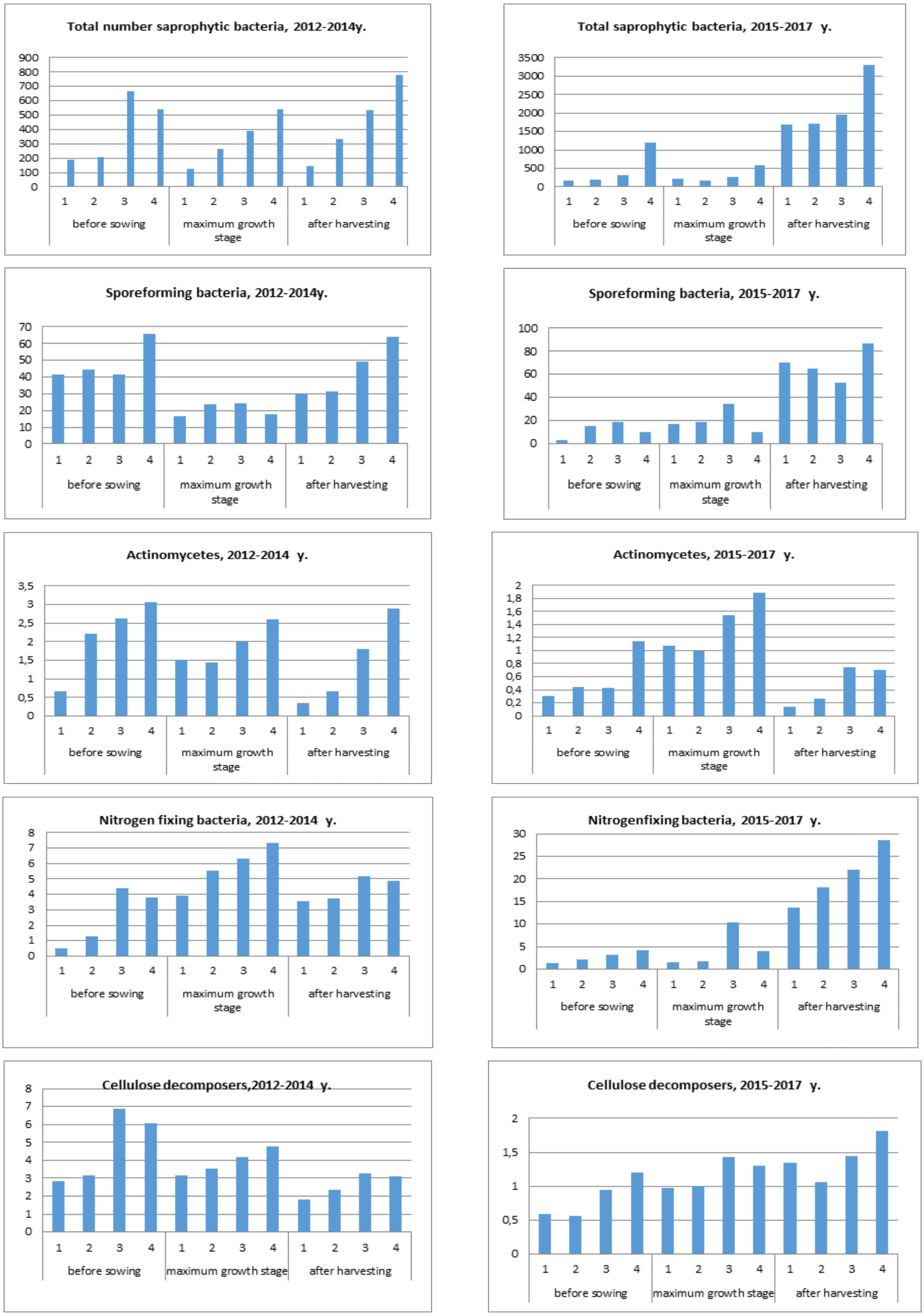
As a result of the improvement of the air and water regimes of the soil as well as the imported organic matter with a high content of nutrients, application of the applied soil protection technologies for minimum and unconventional tillage of the soil for growing maize on slope lands helps to enhance its microbiological activity (Figure 3).

Highest microbiological activity was observed in the variant 4 - using minimum tillage with vertical mulching, both with compost and manure (Figure 3). In this variant, the amount of heterotrophic bacteria was increased by an average of 4.09 times in the experiment with application of compost and 3.50 times by manure application compared to the control variants cultivated by conventional technology, applied along the slope. Higher porosity, soil humidity and lower bulk density, in variant 4, significantly influence the development of soil microflora.

The reported amount of actinomycetes in variant 4 is on average 3.40 times higher when mulching with compost and 2.47 times when manure is applied, compared to conventionally tilled areas.

Surface mulching with compost also has an increase in microbiological activity, with the total number of saprophytic bacteria being 3.50 and 1.23 times higher than the conventionally cultivated crops along the slope. The reported number of actinomycetes is 2.55 and 1.80 times higher on average for the three-year study with compost and manure respectively.

The increase of the nitrogen-fixing activity in variants 3 and 4 is also significant. In the experiment, using the advanced technology for minimal and unconventional tillage, during the two study periods it averaged 2.01 and 2.23 times higher compare to control variants. Upon application of surface mulching, the nitrogen fixation activity is increased on an average of 1.99 and 2.17 times (compost and manure as mulching material respectively) compared to the conventionally tilled plots, along the slope.



ANOVA (2012-2014 y.) Total number p=0.029954HSD[0.05]=451.65; HSD[0.01]=581.5;Spore - forming bacteria p=0.080692; Actinomycetes p=0.028579; HSD[0.05]=1.75; HSD[0.01]=2.25; Nitrogen fixing bacteria: p= 0.006229; HSD[0.05]=1.79; HSD[0.01]=2.30; Cellulose decomposers p=0.043562; HSD[0.05]=2.11; HSD[0.01]=2.63
ANOVA (2015-2017 y.) Total number p=0.621495; *Cellulose decomposers p= 0.1789*

Fig. 3 Soil microbiological activity in CFU (colony forming units)* 106/g dry sol, average for three years periods 2012-2014 y. and 2015-2017 y.

Cellulose degradation activity is also enhanced in variants 4 and 3 of both experiments. In variant 4, the increase by using compost, as mulching material, is 2.82 times, and when manure is applied - 3.18 times versus variant 1. With surface mulching this increase is 1.53 and 2.19 times in compared to the control conventionally grown along the slope.

CONCLUSION:

− Advanced soil protection technology that includes soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with compost or manure, making slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope has a proven erosion control effect.

− Application of erosion control operations such as surface mulching and minimum tillage with vertical mulching significantly improve the bulk density, total porosity and water retention capacity of the soil.

− The application of these two soil-protection technologies for maize grown on sloping terrains leads to the preservation of the soil organic matter.

− All these positive effects on the soil, as a result of the application of advanced technology for minimum and unconventional tillage, lead to increased microbial activity, which has a major role in the soil formation, humus formation, the aggregate stability of the soil particles, the release of nutrients.

REFERENCES

[1] Bot, A., (2005) The importance of soil organic matter key to drought-resistant soil and sustained food and production, Food and agriculture organization of the United nations, FAO bulletin 80.

[2] Dimitrov, P., Beloev, H., Trifonova, T., Russeva, S., Stoyanov, K., Ilieva, D., Kuncheva, G., (2016) Improved soil protection technologies for minimum and unconventional soil tillage on inclined terrains, Ruse University Publishing House "A. Kunchev ", Ruse, 62 pp.

[3] Kollarova K., Pogran, S., Kangalov, P., (2015) Precision Tillage: on the Way from Information to Decisions - Scientific Monograph. University of Ruse “Angel Kanchev”, 2015. ISBN 978-954-712-656-5.

[4] Norman and Newman. (1941) Some effects of sheet erosion on soil microbial activity. *Soil Science*. Volume 52 , Issue 1: 31-46.

[5] Nunes, J., S., Araujo, A., S., F., et al. (2012) Impact of Land Degradation on Soil Microbial Biomass and Activity in Northeast Brazil. Pedosphere, vol 22.

[6] Oades, J., M., (1993) The role of biology in formation, stabilization and degradation of soil structure, Geoderma, vol. 56.

[7] Pascual, J., A., García, C., Hernandez, T., (1999) Lasting microbiological and biochemical effects of the addition of municipal solid waste to an arid soil, Biol Fertil Soils, 30 :1–6.

[8] Pascual, J., A., García, C., Hernandez, T., Moreno, J., L., Ros, M., (2000) Soil microbial activity as a biomarker of degradation and remediation processes, pp.1877-1883, Soil Biology & Biochemistry 32 .

[9] Tisdall, J., M., Oades, J., M., (1982) Organic matter and water stable aggregates in soils. Journal of Soil Science 33: 141-163.

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