Changes in Chemical and Biological Properties of the Soil at the Application of Advanced Technology for Minimum and Unconventional Tillage for Growing Wheat on Slopes

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***Abstract**: The need of development of sustainable agricultural systems requires soil protection from the effects of degradation processes and preservation of soil functions. The most significant degradation process is water erosion. Developed and tested are number of measures and technologies for protection of agricultural lands from water erosion. One of soil conservation technologies is unconventional minimum tillage, combining technological operations direct sowing and vertical mulching with organic wastes (straw and compost) that was created and tested in ISSAPP "N. Poushkarov "- Sofia. This paper presents some changes in chemical and biological indicators of soil at the application of advanced technology for minimum unconventional tillage for growing wheat on slope farmland.*

***Keywords:** water erosion, loss of soil organic matter, minimum tillage, vertical mulching, direct sowing, compost.*

INTRODUCTION:

Soil water erosion is soil degradation process that causes the most significant damages to agricultural land in the world and in Bulgaria. The consequences of the flow of water erosion are loss of soil and reduction of the soil root layer, deterioration of water holding capacity, disruption of soil structure, compaction, loss of macro- and micronutrients and soil organic matter, reduction of microbial activity and biodiversity. To prevent soil from these adverse effects of the flow of water erosion on slope lands, are developed a number of measures, methods and technologies. Such is a minimum tillage, which is applied more on slopes to protect the soil from the effects of water erosion. According Stoynev (1985) depending on soil, climate, technical and economic conditions of a particular area, minimum tillage is achieved by reducing the depth of tillage, number of treatments, replacing plowing with tillage without reversing the layers, usage of combined units that reduces the number of crossings of the machines, usage of herbicides for weed control, direct sowing.

In Bulgaria there were developed many technologies for minimum tillage (Stoichev, 1983, Stoynev, 1985, Bakalov, 1986, Stoynev, 2004, Beloev 2008). In their application in agricultural practice have established good agricultural and erosion control results, especially on carbonate and typical weak Haplustoll (Dimitrov, 2008). In recent years to improve soil protection efficiency of these tillage systems in ISSAPP "N. Pushkarov" - Sofia, were created and explored new improved erosion control technology for minimum and unconventional tillage at growing crops (wheat) on slope farming land, on soil carbonate chernozem, including vertical mulching with plant residues (straw and ready compost) and direct sowing.

Vertical mulching cultivation method is effective to protect the soil from water erosion. In this method mulch of straw, cornstalks and other organic materials of plant wastes imported into the soil in special slots with defined dimensions formed across the slope. For the implementation of vertical mulching in Bulgaria were created in Ruse University "Angel Kanchev" and the Institute of Soil Science Agrotechnologies and Plant Protection " N. Pushkarov" Sofia, two different specialized machinery - the reconstructed breaker-dead furrower ЩН 2-140 with hopper for mulch and device for depositing mulch or organic matter in the soil (Fig. 1 and Fig. 2)

From studies carried out with vertical mulching method with wheat straw, made with reconstructed ЩН 2-140 on land with a slope of 5 ° (8.7%) on the carbonate Chernozem before sowing of wheat is observed subsequently reduce surface runoff by 1.8 to 2.1 times, reduction of soil loss of 3.0 to 3.5 times and an increase in yield of wheat by 23.4% (at 730 kg / ha) as compared to crops grown by conventional tillage across the slope

(Dimitrov, 2008). Application of this method by using compost instead of straw, the results are even better in regard to erosion control. In this case, the values of surface runoff decreased from 2.5 to 3 times, while those of the eroded soil from 6.2 to 6.5 times, as compared to areas traditionally grown along the slope. Grain yield of wheat increasing by 20.9% (to 760,5 kg /ha) compared with the control (Dimitrov, Nikolova, 2014).

Fig.1 Reconstructed breaker-dead furrower ЩН 2-140 for making soil slots, with bunker for mulch

Fig. 2 Device for depositing mulch or organic matter in the soil

Implementation of organic matter in the soil affects microbial activity, agrochemical soil properties and these effects depend on the type and the quality of the used organic matter.

The purpose of this paper is to identify changes in microbial activity and agrochemical soil properties at adding organic material (straw and compost) in the implementation of anti-erosion method vertical mulching, together with minimum tillage.

MATERIALS AND METHODS

The study was conducted during the period 2013-2015 year, in the village of Trastenik, Ruse Region, in the experimental field of Institute of soil science, agricultural technology and plant protection "Pushkarov" Sofia, on medium eroded carbonate Chernozem, with a slope 5^0 (8.7%).

They are set and are drawn field trials with wheat cultivated by erosion control technology, combining minimum tillage method and vertical mulching. It is implemented by a special machine, which forms on the surface of the soil couple of slots with depth of 0.40 m, filled with organic residues (straw or compost) with a distance between slots 1.4 m in the pair and interval between the lines 5 m in the field. Sowing, soil tillage and harvesting are carried out in the direction perpendicular to the direction of the slope. Applied soil conservation methods have proven erosion control efficiency.

Soil samples for agrochemical and microbiological analyzes were taken from slots and at a distance 0.5 m from them in order to establish the influence of the imported organic substances on the microbiological and chemical processes in the soil.

Isolated and quantitatively are reported saprophytic soil microflora (bacteria total count and - spore-forming, actinomycetes, fungi, oligotrophic microflora, cellulose decomposers and nitrogen-fixators) by Koch method on MPA (meat peptone agar) - bacteria, SAA (starch ammonia agar) - for actinomycetes, medium of Chapek - for fungi, diluted soil agar - for oligotrophic soil microflora, medium of Hutchinson for cellulose-decomposers and medium of Eshbie for nitrogen-fixing bacteria.

Reported are mineral nitrogen, pH, and conductivity of the soil solution with pH-meter equipped with pH - and conductive electrodes. In determining pH in H_2O, soil solutions are used 1: 2.5, and for composts 1:10.

As mulching material were used straw and compost, waste product of mushroom production. Chemical composition of composts applied is given in the table 1.

Table 1 Chemical composition of used composts.

Parameters, units	2012 - mulch	2013 - mulch	2014 - mulch
NH_4^+, mg/kg	763.77	111.36	674.77
NO_3^-, mg/kg	286.77	1065.89	911.33
Total N, %	1.83	2.02	2.17
Total C, %	25.81	24.43	27.99
C/N	14.10	12.09	12.90
pH, H_2O	7.00	6.52	7.03
pH, KCl	6.82	6.22	6.82
EC, mS/cm	8.37	2.61	6.88
Available P_2O_5, %	0.43	0.22	0.39
Available K_2O, %	3.15	0.42	1.02

REZULTS AND DISCUSSION

The results of agrochemical studies are presented in table 2 and show that the concentration of nitrate and ammonium ions are highest in the slots, mulched with compost, and they are lower in the slots, mulch with straw.

Compost is an organic material with high nitrogen content, and the available forms of phosphorus and potassium, which is shown in table 1, and this leads to higher electrical conductivity and higher levels of nutrients in the soil. From the results obtained for the concentration of nitrate and ammonium ions in the slots, mulched with straw, are observed lower levels of available nitrogen (table 2). In the introduction of organic matter with high carbon and low nitrogen content, such as straw, soil microbiological processes are activated but lead to immobilization of available forms of nitrogen.

Table 2 Chemical soil parameters, pH (pH units), EC (µS/cm), NH_4^+ (mg/kg), NO_3^- (mg/kg), in two growth stages at two crops.

	pH, H_2O	EC	NH_4^+	NO_3^-	pH, H_2O	EC	NH_4^+	NO_3^-
In maximum growth stage, 2013					**After harvesting, 2013**			
Slot with straw, M1	8.41	219.00	20.42	36.14	8.33	181.65	17.05	18.56
0.5 m from slot with straw, M2	8.23	171.40	21.77	37.46	8.10	135.45	15.50	20.30
Slot with compost , M3	7.73	1845.00	17.09	67.03	7.58	2240.00	26.27	117.44
0.5 m from slot with compost, M4	8.06	240.00	13.75	31.38	8.08	211.00	14.13	45.53
In maximum growth stage, 2014					**After harvesting, 2014**			
Slot with straw	7.93	150.8	12.70	12.72	8.01	428.0	22.42	13.74
0.5 m from slot with straw	7.93	151.6	10.95	15.33	8.17	103.1	33.48	29.77
Slot with compost	7.74	506.0	61.42	52.23	7.23	1606.0	115.64	79.75
0.5 m from slot with compost	8.03	125.3	56.41	13.35	7.87	631.00	53.79	49.65
In maximum growth stage, 2015					**After harvesting, 2015**			
Slot with straw	8.16	114.4	12.85	13.33	7.96	137.2	12.10	23.69
0.5 m from slot with straw	8.11	112.3	14.08	12.20	7.91	117.9	13.45	24.51
Slot with compost	7.66	1284.0	60.40	32.22	7.61	1009.0	45.23	55.18
0.5 m from slot with compost	8.12	126.5	11.84	27.62	7.90	157.1	13.53	31.22

ANOVA: EC, p<0.0001; HSD[0.05]=533.32; HSD[0.01]=675.87; M1 vs M2 NS; M1 vs M3 P<0.01 ;M1 vs M4 NS; M2 vs M3 P<.01; M2 vs M4 NS; M3 vs M4 P<.01; [NH_4^+] p=0.019209; HSD[0.05]=34.15; HSD[0.01]=43.28; M1 vs M2 NS; M1 vs M3 P<0.05; M1 vs M4 NS; M2 vs M3 P<0.05; M2 vs M4 NS; M3 vs M4 NS; [NO_3^-], p=0.000421; HSD[0.05]=27.93; HSD[0.01]=35.4; M1 vs M2 NS; M1 vs M3 P<0.01; M1 vs M4 NS; M2 vs M3 P<0.01; M2 vs M4 NS; M3 vs M4 P<0.05

Table 3 Soil microbiological activity in CFU (colony forming units) 10^6/g dry soil.*

	Total number Saprophytic bacteria (1)	Spore-forming Bacteria (2)	Oligotrophic bacteria (3)	Actino Micetes (4)	Fungi (5)	Nitrogen-fixing bacteria (6)	Cellulose-decom-posers (7)
Maximum growth stage, 2013							
Slot with compost; M1	191.70	10.12	90.37	0.48	0.0015	0.16	0.90
0.5 m from slot with compost; M2	51.70	9.30	16.90	0.31	0.0022	0.17	0.47
Slot with straw; M3	78.35	17.51	182.45	0.36	0.0037	0.24	0.22
0.5 m from slot with straw; M4	55.00	8.90	13.00	0.12	0.0033	0.18	0.38
After harvesting, 2013							
Slot with compost	115.89	6.30	144.41	1.02	0.0019	0.97	0.66
0.5 m from slot with compost	45.67	6.70	134.60	0.33	0.0019	0.53	0.39
Slot with straw	65.67	19.79	270.01	0.54	0.0047	1.27	0.18
0.5 m from slot with straw	46.68	7.50	144.70	0.18	0.0043	0.45	0.32
Maximum growth stage, 2014							
Slot with compost	1105.93	7.87	29.88	0.67	0.0020	0.25	1.64
0.5 m from slot with compost	95.00	3.34	33.39	0.55	0.0015	0.36	0.55
Slot with straw	360.36	24.91	55.57	0.37	0.0027	1.05	0.57
0.5 m from slot with straw	83.35	1.49	19.17	0.27	0.0021	0.18	0.53
After harvesting, 2014							
Slot with compost	225.00	10.00	126.57	2.09	0.033	0.40	2.33
0.5 m from slot with compost	41.23	6.33	0	0.59	0.0040	0.23	0.56
Slot with straw	55.33	17.30	23.97	1.25	0.0053	0.43	0.64
0.5 m from slot with straw	39.65	7.11	11.86	0.48	0.0045	0.32	0.12
Maximum growth stage, 2015							
Slot with compost	286.66	4.00	183.33	0.37	0.0042	0.11	0.75
0.5 m from slot with compost	180.00	4.33	60.00	0.21	0.0047	0.20	0.21
Slot with straw	193.33	11.12	203.11	0.26	0.0048	0.33	0.23
0.5 m from slot with straw	186.67	4.13	53,66	0.18	0.0042	0.16	0.15
After harvesting, 2015							
Slot with compost	696.97	38.33	546.67	1.37	0.0054	0.45	0.34
0.5 m from slot with compost	202.0	34.00	334.13	0.73	0.0039	0.68	0.12
Slot with straw	235.66	152.32	1230.00	0.77	0.0058	1.69	0.26
0.5 m from slot with straw	195.14	32.56	298.00	0.29	0.0055	0.65	0.18

ANOVA: (1) P=0.033262; HSD[0.05]=337.15; HSD[0.01]=427.26; (2) M1 vs M3; p= 0.003010; (3) M1 vs M3; p= 0.039091; M1 vs M2 NS; M2 vs M3 p= 0.007795; M3 vs M4 p= 0.004537; (4) NS; (5) M1 vs M3 p <0.0001;(6) NS; (7) p = 0.019714 ; HSD[0.05]=0.72; HSD[0.01]=0.91

The results of analyzes of soil microbial activity are presented in table 3. There is a significantly higher amount of saprophytic microflora in the slots, as compared to samples taken at 0,5 m thereof. This is due to the introduction of organic matter in the soil and significantly higher moisture content in the slots, which leads to increased microbiological activity.

The total number of bacteria in the samples taken from the slots is greater than in the samples taken at a distance from them, and the highest amount of saprophytic bacteria is reported in plots mulched with compost. Spore-forming bacteria are in the largest quantities when straw is applied as mulch.

The larger amounts of actinomycetes are reported in compost mulched slots in comparison with those in which the straw is used.

Oligotrophic bacteria are more widely spread in slots mulch with straw.

Low levels of nitrogen compounds in the slots, mulched with straw, lead to higher activity of the nitrogen-fixing bacteria when compared to samples taken from the slots in which is compost introduced. That is occurring because high levels of nitrogen suppress the nitrogen-fixing activity.

Cellulose decomposers activity in samples taken from the slots with compost average for the three years period is 1.70 times higher than those of the slots with straw. This is the result of imported compost with cellulose decomposers and higher levels of available nitrogen forms.

CONCLUSION

From the results of conducted research and analyzes can be formulated following conclusions:

1. Agricultural soil conservation method vertical mulching with compost, included in the advanced technology and unconventional minimum tillage at growing wheat on slopes in conditions of carbonate Chernozem, except high erosion efficiency and significant positive effect on soil microbial activity and agrochemical properties.

2. The application of compost, instead of straw at erosion control method vertical mulching, helps more rapid decomposition of organic material, thus mulch of slots does not hinder subsequent tillage.

3. By substitution of the straw as mulch material with compost avoids immobilization of nitrogen which is obtained by adding organic substances in soil having a high C/N.

4. This research can serve to further development of vertical mulching method technologically, as well as specialized equipment.

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