Changes in Physical, Chemical and Biological Properties of the Soil in the Application of Advanced Soil Protection Technology for Growing Wheat on Slope Lands

Petar Dimitrov, Gergana Kuncheva

Abstract: *This work examines the impact of advanced soil protection technology for unconventional minimum tillage for growing wheat on slopes on some physical, chemical and biological properties of the soil in conditions of carbonate chernozem.*

Keywords*: soil degradation, water erosion, soil humidity, soil bulk density, soil microbiology, minimum tillage.*

INTRODUCTION

Soil degradation, according to a report of UNEP (United Nations Environment Programme, 2007) causes disturbances that lead to long-term loss of ecosystem functions, from which they can't recover unaided. The direct effects of it are deterioration of soil structure and moisture retention capacity, reducing the content of humus and nutrients, loss of biodiversity. Indirect results are significant decline in the fertility of agricultural land and disruption of the natural environment. The deterioration of soil quality is a critical aspect of land degradation, particularly soil irreversible degradation, which leads to desertification.

Lal and Stewart (1990) distinguish three types of soil degradation, namely physical (soil erosion from wind and water), chemical (salinization, acidification) and biological (reduction of soil organic matter and microbiological activity).

The purpose of this paper is to establish the influence of improved soil conservation technologies and unconventional minimum tillage for growing wheat on slopes, on some physical, chemical and microbiological parameters of soil in conditions of carbonate chernozem.

MATERIALS AND METHODS

Studies have been conducted in the village of Trastenik, Ruse region, during 2012-2015 y., on the slope 5^0(8.7%) on carbonate chernozem. The experiment variants are:

e_0 - wheat plots, grown by using conventional technology along the slope - control;

e_1 - wheat plots, grown by using conventional technologies applied across the slope;

e_2 - wheat plots, grown by erosion control technology, including conventional tillage, applied across the slope and using surface mulching with compost;

e_3 - wheat plots, grown by minimum tillage (including operations vertical mulching with compost, direct sowing) applied across the slope.

Applied advanced soil protection technology and unconventional minimum tillage for growing wheat on slopes differs from conventionally applied in our country on the following:

- Includes erosion control method vertical mulching with ready compost.
- Includes direct sowing of the crop;
- carrying out all technological operations across the slope.

Each of these differences between conventional and unconventional technology, has certain soil protection effect. Vertical mulching is erosion control cultivation method used in soil conservation agriculture in many countries in the world to combat soil water erosion. Soil protection operation vertical mulching is performed by reconstructed soothers-forming machine H-2-140 depth of 0.40 m with compost in a band with a distance between the slots 1.4 m and an interval between bands 5 m. They are filled with plant residues like wheat straw, stalks of corn, sunflower and other organic materials and residues. In the case of advanced technologies and unconventional minimum tillage, such as mulch material is imported compost, waste product from mushroom production.

In Table 1 are represented contents of composts, applied as mulch material over the years of study.

Table 1. Chemical composition of the applied composts for mulching.

Parameters, units	**2013 y.**	**2014y.**	**2015y.**
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, %	0.428	0.215	0.391
Available K_2O, %	3.145	0.415	1.02

Through direct sowing it is ensured high quality sowing of the seeds of cereals (wheat) without additional pre sowing treatments on the field. In this way, by the opinion of Beloev H.I. (2008), application of direct sowing preserves soil structure, delays mineralization of humus, improves permeability of under surface soil layer and reduces erosion. For the realization of direct sowing in our case we used specialized cultivator drill SCS - 2 (Fig. 1) which makes both tillage and seeding the area.

In field, these machines simultaneously perform four technological operations: pre-tillage, sowing, introduction of granular fertilizers and rolling the planted rows.

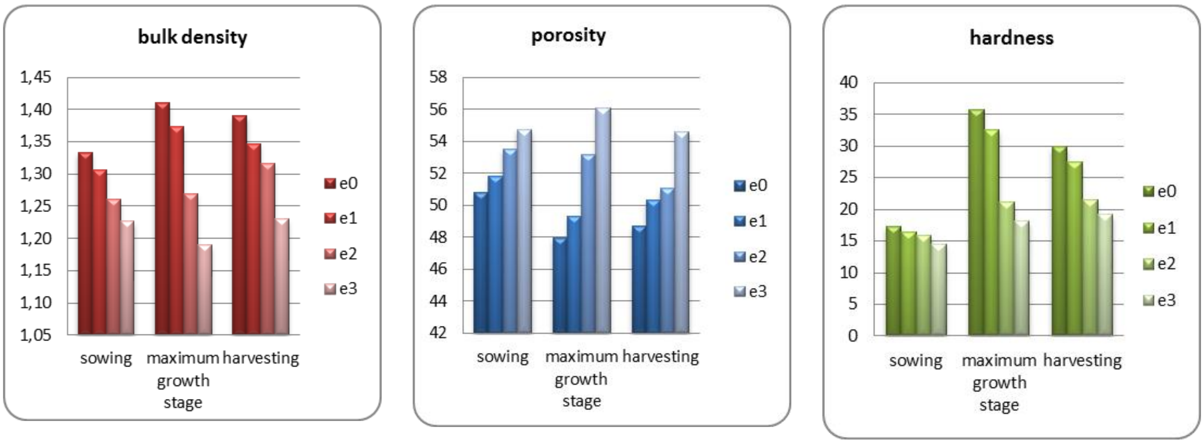
Fig. 1 Overview of sowing aggregate "Belarus 952" and cultivator drill SCS – 2

The performance of all technological operations across the slope is one of the important agronomic requirements to protect the soil from water erosion. Its implementation leads to the realization of additional conservation effect.

RESULTS AND DISCUSSION

The maximum average, for the period of study, is in the application of conventional technology for growing wheat along the slope, where the bulk density of soil is 1,41 g / cm^3, the total porosity is 47.97%, and the hardness is 35,97 kg / m^2, whereas in the application of soil protection technology for minimum tillage these values are 1.19 g / cm^3, 56.09% and

18.42 kg / m^2, and in the application of surface mulching the values of the same indices are 1,27 g / cm^3, 53,14%, 21,13 kg / m^2 (Figure 2).



Bulk density p= 0.001485HSD[.05]=0.09; HSD[.01]=0.12 e_0 vs e_1 NS; e_0 vs e_2 $P<.05$; e_0 vs e_3 $P<.01$; e_1 vs e_2 NS; e_1 vs e_3 $P<.01$; e_2 vs e_3 NS; Hardness : p=0.251675

Fig. 2 Average bulk density and total porosity experience wheat for 2013-2015 observed in three phases. Hardness of the soil layer 0-40 cm trying to wheat - average for the period 2013-2015.

The results for the average humidity of the soil in depth by 0-150cm are presented in Table 2. Soil moisture is highest at the implementation of minimum tillage and vertical mulching. It is lower in the variant e_2, using conventional technology for growing this crop, across the slope and with surface mulching with compost. The lowest value of this parameter is at the application of conventional technology, along the slope – e_0.

Table 2 Soil moisture 0-150cm, 2013-2015y.

Year	Phase	e_0	e_1	e_2	e_3
2013 y.	Sowing	8,72	9,05	9,06	9,39
	Maximum growth stage	7,58	7,71	10,49	11,55
	After harvesting	14,98	15,44	17,34	19,96
2014 y.	Sowing	15,09	15,09	15,09	15,09
	Maximum growth stage	14,08	14,70	15,20	16,88
	After harvesting	19,06	19,16	20,29	20,41
2015 y.	Sowing	11,52	11,52	11,52	11,52
	Maximum growth stage	8,69	9,42	12,20	14,56
	After harvesting	10,15	10,81	11,71	13,71
2013-2015y.	Sowing	11,78	11,89	11,89	12,00
	Maximum growth stage	10,12	11,61	12,63	14,33
	After harvesting	14,73	15,14	16,45	18,03

The applied erosion control tillage affects the content of humus and total nitrogen. The humus content is lowest at variants with conventional tillage applied along the slope (e_0) and it is the highest at $e_{3,}$ with the implementation of minimum tillage (Table. 2). An average of measurements over the three observed years, the amount of organic carbon in soil is 1.41%, 1.40%, 1.23% (2.43%, 2.41% and 2.12% humus), while at variant e_3, it is 1.79%, 1.59%, 1.49% (3.08%, 2.74%, 2.57%). It is high and the amount of organic carbon in variant with surface mulching - 1.72%, 1.62% and 1.45%, indicating that this method has a good effect on organic matter in the soil when growing wheat on slope arable lands.

Table 3.Humus content (%), total nitrogen (%), average for the year, 2013-2015 y.

Parameters	Year	e_o	e_1	e_2	e_3
Humus content %	2013 y.	2,43	2,44	2,96	3,08
	2014 y.	2,41	2,46	2,72	2,74
	2015 y.	2,12	2,13	2,50	2,57
	2013 y.- 2015 y.	2,32	2,34	2,73	2,80
Total nitrogen content %	2013 y.	0,127	0,128	0,150	0,157
	2014 y.	0,135	0,139	0,159	0,171
	2015 y.	0,134	0,140	0,180	0,186
	2013 y.- 2015 y.	0.132	0.136	0.163	0.171

Humus: p=0.050173; e0 vs e3 p= 0.057348;
Total nitrogen: p=0.006010 HSD[.05]=0.03; HSD[.01]=0.04; e0 vs e1 nonsignificant; e0 vs e2 P<.05; e0 vs e3 P<.05; e1 vs e2 nonsignificant; e1 vs e3 P<.05, e2 vs e3 nonsignificant

Total nitrogen levels are the highest in the three years at variant e_3 (table 3). The average, for the three monitored phases, content is 0.157%, 0.171%, 0.186%, while at the control variant with conventional tillage applied along the slope - 0.127%, 0.135%, 0.134%. The application of surface mulching with compost in variant e_2, also leads to an increase in the level of total nitrogen in the soil, the values for three years in these plots are 0.150%, 0.159% and 0.180%.

Table 4. Soil microbiological activity in CFU (colony forming units) 10^6*/g dry soil.*

Year	Phase	Variants	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)
2013	Sowing	e_0	114.14	17.83	178.336	0.89	0.0016	1.46	1.15
		e_1	160.90	27.52	1422.55	1.13	0.0014	1.46	1.10
		e_2	193.37	31.74	3765.33	3.47	0.0026	2.11	1.20
		e_3	347.55	85.82	1610.09	3.41	0.0038	1.60	1.50
	Maximum growth stage	e_0	638.99	45.80	468.48	1.18	0.0033	1.71	3.84
		e_1	663.66	37.81	420.58	1.16	0.0020	1.74	2.81
		e_2	1160.83	126.11	1357.52	1.74	0.0028	1.82	4.71
		e_3	1024.80	71.85	1346.23	5.14	0.0037	6.31	14.94
	After harvesting	e_0	226.50	69.88	130.68	2.11	0.0017	7.95	3.18
		e_1	656.69	75.70	211.78	3.28	0,0000	12.72	3.97
		e_2	1893.75	119.21	2640.78	4.40	0.0027	14.09	6.98
		e_3	1952.00	68.98	1895.69	7.74	0.0057	13.51	7.55
2014	Sowing	e_0	169.68	42.83	24.24	1.05	0.0002	4.44	1.41
		e_1	364.77	26.46	276.59	0.52	0.0007	1.44	1.77
		e_2	519.25	92.26	1055.67	3.86	0.0012	5.45	4.85
		e_3	945.36	91.30	335.32	2.99	0.0036	4.89	9.25
	Maximum growth stage	e_0	48.59	2.78	12.77	1.30	0.0012	0.54	2.62
		e_1	59.59	26.82	12.77	1.80	0.0015	1.07	2.64
		e_2	140.87	32.49	66.29	2.00	0.0020	1.88	2.92
		e_3	259.07	32.59	79.39	4.80	0.0074	2.72	4.85
	After harvesting	e_0	63.30	4.07	33.35	1.36	0.0028	3.96	0.79
		e_1	66.71	9.86	40.65	1.62	0.0030	5.45	0.79
		e_2	82.13	14.84	145.61	1.76	0.0030	6.78	1.07
		e_3	137.29	10.58	116.64	2.33	0.0046	7.00	1.90
2015	Sowing	e_0	82.88	3.31	26.04	0.39	0.0011	1.08	1.50
		e_1	88.16	10.17	77.23	0.51	0.0010	1.54	2.20
		e_2	305.15	27.88	497.29	0.41	0.0023	2.60	3.11
		e_3	271.25	23.35	478.45	0.64	0.0023	3.62	3.33
	Maximum growth stage	e_0	109.64	2.82	10.61	2.23	0.0042	0.74	1.70
		e_1	148.36	18.18	70.27	2.07	0.0044	1.82	1.72
		e_2	204.07	28.34	272.84	5.32	0.0059	1.43	2.50
		e_3	261.61	19.91	105.38	2.56	0.0061	2.39	2.70
	After harvesting	e_0	17.53	13.56	10.00	1.45	0.0039	2.83	2.30
		e_1	50.27	12.05	143.13	1.78	0.0037	4.52	3.81
		e_2	72.20	18.74	174.80	1.98	0.0044	7.37	5.41
		e_3	90.40	14.69	190.33	2.79	0.0059	13.53	6.00

(1) e_0 vs e_3, p=0.064570; (2) e_0 vs e_3 , p=0.095433
(4) p =0.004260 HSD[.05]=1.78; HSD[.01]=2.21; M1 vs M2 NS; M1 vs M3 NS; M1 vs M4 P<.01;M2 vs M3 NS; M2 vs M4 P<.05;M3 vs M4;
(6) e_0 vs e_3 , p=0.061895;
(7): p=0.012828 HSD[.05]=3.19; HSD[.01]=3.97; M1 vs M2 NS; M1 vs M3 NS; M1 vs M4 P<.05; M2 vs M3 NS; M2 vs M4 P<.05; M3 vs M4 NS

The highest microbiological activity was also observed at variants with minimum advanced tillage and vertical mulching with compost (Table. 4).

In this variant, the amount of heterotrophic bacteria is from 1.61 times to 8.61 times higher compared to the control variant grown by conventional technology applied along the slope. The higher porosity, soil moisture and low bulk density, in variant e_3, significantly affect the development of soil microflora.

Higher rates of microbiologic activity are observed in variants with surface application of compost - e_2. In both variants (e_2 and e_3), the introduction of organic matter (compost) in soil with high carbon and nitrogen content and a significant amount of macronutrients and microorganisms leads to an increase of microbial activity.

In variant e_3 compared to e_0, it is observed high amount of actinomycetes - 1.71 to 4.36 times, fungi - from 1.12 to 6.17 times, cellulose decomposers - from 1.61 to 8.61 times more, and 5.04 times higher amounts of nitrogen fixing bacteria. In the variant e_2 it is observed from 1.30 to 9.70 times higher amounts of saprophytic bacteria compared to the control e_0, and from 1.47 to 2.32 times higher amounts of actinomycetes, 2.60 times more nitrogen fixing bacteria and 2.19 times larger quantity of cellulose decomposers. The highest amount of spore-forming bacteria is in this variant (e_2), followed by variant e_3. The amount of oligotrophic bacteria is highest in the implementation of minimum tillage with vertical mulching as well as conventional tillage with surface mulching with compost.

Microbiological analysis show that implemented minimum and unconventional tillage has a positive impact on the microbiological properties of the soil at wheat cultivation on average eroded carbonate chernozem on slope lands. So this technology for minimum and unconventional tillage can be used to overcome the consequences of the biological degradation of the soil.

In addition, the analysis could lead to the conclusion that the microbial activity of the soil is very sensitive indicator which can be used to determine the ongoing processes in the soil as a consequence of erosion, soil tillage and more.

CONCLUSION

The application of advanced technology for unconventional minimum tillage, has not only proven soil conservation effect, but resulted on a significant improvement in both the physical and biological soil indicators and countered not only by water erosion degradation process, but also related with it processes of compaction and loss of organic matter.

The application of compost on an average eroded carbonate chernozem by vertical or surface mulching can counteract the loss of organic matter from water erosion and to increase microbial activity, which improves soil structure and plant nutrition.

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CONTACTS

Petar Dimitrov, Institute of Soil Science, Agricultural and plant protection “Nikola Poushkarov” Sofia, Experimental Station for Erosion Control, University of Ruse, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: pdimitrov@uni-ruse.bg,

Gergana Kuncheva, Institute of Soil Science, Agricultural and plant protection “Nikola Poushkarov” Sofia,, Laboratory of soil analysis and soil erosion research, University of Ruse, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: gkuncheva@uni-ruse.bg