Comparative Research on Advanced Technologies for Minimum and Unconventional Soil Tillage with Application of Different Mulching Materials for Growing Wheat on Sloping Agricultural Lands

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Abstract: *In the Republic of Bulgaria a significant part of the arable lands are on sloping terrains, which is a prerequisite for the influence of the degradation processes soil water erosion, compaction and loss of the soil organic matter. For their limitation, advanced soil protection technologies have been developed and studied, including technological processes surface and vertical (into the soil) mulching with the application of mulch materials compost and manure. The present research explores the results of long-term comparative studies with these technologies for growing wheat on slope areas in specific soil and climatic conditions and evaluates their agro technical and soil protection capabilities.*

Keywords: *soil water erosion, compaction, loss of soil organic matter, wheat, minimum and unconventional soil tillage, surface mulching, vertical mulching, compost, manure*

INTRODUCTION:

In the Republic of Bulgaria, wheat is the main bakery and cereal crop. It is the most widespread culture and 45.2% of the country's arable land and 51.7% of the cereal crop area are occupied with wheat (Dimitrov, 2008). Our research has found that between 1.0 and 1.3 million hectares of wheat, are sown every year, and bigger part of these sowings are (about 45-50%) spread over terrains with different slopes that are potentially threatened by impact of water erosion processes (Dimitrov, 2008, 2016). Moreover on these areas act and closely related to water erosion and dependent on it, degradation processes, soil compaction and loss of organic matter. The losses caused to the agriculture of Bulgaria by these three degradation processes are enormous and have serious consequences for both our agricultural production and of our national economy as a whole. They are a problem of general national importance, the solution of which, for cultivating agricultural crops on sloping terrains, can't be achieved with the established conventional technologies, and requires including of some soil protection measures with high runoff control and soil protection efficiency.

Minimum soil tillage is a measure that can be successfully applied to control water erosion as well as soil compaction and depletion of organic matter. The improvement of these technologies and their combination with the unconventional soil tillage surface and vertical mulching with organic materials of plant origin in order to further improve the humus content of the soil and counteract the loss of the organic matter is carried out by the Institute of soil science, agrotechnologies and plant protection "Nikola Pushkarov" - Sofia, together with University of Ruse "Angel Kanchev". These new advanced technologies for minimum and unconventional soil tillage are created in two variants, the first - using ready compost as mulching material and the second with application of cattle manure. With these two variants of technology, multi-year comparative studies have been conducted, with positive results.

The purpose of the present study is to identify and compare their agro-technical and soil protection capabilities on growing wheat on sloping agricultural lands, based on the results of these comparative studies between advanced soil protection technologies for minimum and unconventional soil tillage using ready compost or cattle manure.

MATERIAL AND METHODS

The assays were carried out in the experimental field of the Nikola Pushkarov Institute of Soil Science, Agrotechnologies and Plant Protection in the territory of the village of Trastenik in the Ruse region on non-irrigated areas, on a medium eroded calcareus chernozem, on a slope of 5º (8,7%). They were conducted during the period 2013-2017y., in two stages. The first stage of the experiment was carried out in 2013-2015y. Field experiment with wheat has been established and developed with soil protection technologies for minimum and unconventional soil tillage with the application of ready compost as mulching material. The second stage of the study was carried out in the period 2015-2017y., and during it were tested the agro technical and soil protection efficiency of the erosion control technologies for minimum and unconventional soil tillage with application of manure. To achieve the goal of the research, both experiments were conducted by block method with four variants and four replicates. The experiments are single factor, as the applied soil protection technologies (limiting water erosion, compaction and reduction of soil organic matter) are the factor.

The variants during the first stage of the experiments are:

1 st variant - wheat plots, grown by conventional technology, applied along the slope - control;

2 nd variant - wheat plots, grown by conventional technology, applied across the slope;

3 rd variant - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with ready compost, applied across the slope.

4 th variant - wheat plots, grown under advanced soil protection technology including erosion control measures vertically mulching with ready compost and direct sowing, as well as some plant protection operations for weed control, pests and plant diseases, all applied across the slope.

The variants of field experiment in the second stage of research are:

5 th variant - wheat plots, grown by conventional technology, applied along the slope - control;

6th crop - wheat plots, grown by conventional technology, applied across the slope;

7th - wheat plots, grown by soil protection technology including the erosion control measure - surface mulching with manure, applied across the slope

8th - wheat plots, grown under the advanced soil protection technology including erosion control measures vertically mulching with manure and direct sowing, as well as some plant protection operations to control weeds, pests and plant diseases, all operations applied across the slope.

During the research period, both control variants of the two experiments (variant 1 and variant 5) are common, conventional for this agricultural crop and are carried out along the slope. The same conventional technological operations were performed in variants 2 and 6, but with the difference that in them the direction of their application is across the slope. The erosion control agro-technical measures, in the other variants, were applied using the relevant methods in the following ways. Surface mulching, in variants 3 and 7, is performed across the slope with fertilizer spread trailer 1PTU – 6 (fig.1, at a rate of 4500-5000 kg/ha with mulch material - compost during the first stage 3) and manure in the second. Vertical mulching, in variants 4 and 8, was accomplished across the slope, pre-sowing at both stages of the experiment with the reconstructed machine cutter-dead furrower SHTN 2-140 with bunker for mulch (fig. 2) (with a distance between the pair of slits -1.4 m and a band intervals 3 m in the field) at a depth of 0.40 m, with compost in variant 4 for mulching material, and in case of variant 8 this material is manure. In both cases the norm is 4500-5000 kg/ha, and simultaneously with this technological operation was performed a single disking with heavy disc harrows for surface covering of slots and soil moisture conservation as well as fertilizer plowing.

Fig. 1 Fertilizer spread trailer 1PTU – 6

Fig. 2 Machine for vertical mulching SHTN 2- 140 with bunker for mulch

The direct sowing, which provides qualitative sowing of the wheat seeds without additional pre-sowing tillage of the terrain and which, according to Beloev (2008), safes the soil structure, slows the humus mineralization, improves the subsurface soil water permeability and reduces the erosion, is performed in both variants (4 and 8), with a seed drill cultivator SCS-2 (fig. 3). In the untilled field, this machine in a tractor unit with a tractor pulling capacity of 14 kN (fig. 4) performs four technological operations simultaneously: pre-sowing soil tillage, sowing, imports granulating fertilizers and rolling. Subsequent combating of weeds, pests and plant diseases, in these variants, is carried out exclusively by chemical methods, using pesticides.

Fig. 3 Seed drill cultivator SCS-2 “Belarus 952”

Fig. 4 General view of sowing aggregate and a seed drill cultivator SCS-2

During the two phases of the reported period, the experiments performed agrotechnical (soil and biometric) and erosion observations according to established methodology.

RESULTS AND DISCUSSION

The results obtained from the comparative studies carried out with the advanced soil protection technologies for minimum and unconventional soil tillage using compost or manure as mulching materials in wheat growing on sloping terrains show that their application has a positive impact on agro-technical and erosion indicators.

Table 1 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2013-2015 y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2013									
1	1.32	51.29	15.83	1.42	47.60	30.69	1.39	48.71	26.83
2	1.27	53.14	14.70	1.37	49.45	29.27	1.35	50.18	25.90
3	1.24	54.24	14.48	1.22	54.98	23.34	1.34	50.55	23.61
4	1.20	55.72	13.65	1.17	56.83	22.03	1.26	53.51	22.87
2014									
1	1.35	50.19	17.20	1.44	46.86	31.43	1.43	47.23	20.81
2	1.32	51.29	15.72	1.43	47.23	26.78	1.39	48.71	18.63
3	1.27	53.14	15.05	1.37	49.45	17.75	1.32	50.19	13.60
4	1.24	54.24	14.61	1.20	55.72	14.80	1.25	53.87	12.15
2015									
1	1.33	50.92	19.02	1.37	49.45	45.03	1.35	50.18	41.97
2	1.33	50.92	19.02	1.32	51.29	41.79	1.30	52.03	37.61
3	1.27	53.14	18.25	1.22	54.98	22.31	1.29	52.40	27.03
4	1.24	54.24	15.18	1.20	55.72	17.60	1.18	56.46	22.49
2013-2015									
1	1,33	50,80	17,35	1,41	47,97	35,72	1,39	48,71	29,87
2	1,31	51,78	16,48	1,37	49,32	32,61	1,35	50,31	27,38
3	1,26	53,51	15,93	1,27	53,14	21,13	1,32	51,05	21,41
4	1,23	54,73	14,48	1,19	56,09	18,14	1,23	54,61	19,17

Bulk density *p= 0.001485HSD[0.05]=0.09; HSD[0.01]=0.12 1 vs 2 NS; 1 vs 3 P<0.05; 1 vs 4 P< 0.01; 2 vs 3 NS; 2 vs 4 P<0.01 ; 3 vs 4 NS;* ***Hardiness*** *p=0.251675*

Table 2 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2015-2017y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2015									
5	1.33	50.92	19.02	1.37	49.45	45.03	1.35	50.18	41.97
6	1.33	50.92	19.02	1.32	51.29	41.79	1.30	52.03	37.61
7	1.27	53.14	18.25	1.22	54.98	22.31	1.29	52.40	27.03
8	1.24	54.24	15.18	1.20	55.72	17.60	1.18	56.46	22.49
2016									
5	1.32	51.29	23.08	1.41	47.97	37.72	1.38	49.08	35.32
6	1.32	51.29	19.84	1.40	48.34	35.11	1.37	49.45	31.84
7	1.30	52.03	18.31	1.35	50.18	32.40	1.33	50.92	23.78
8	1.21	55.35	15.37	1.28	52.77	21.13	1.27	53.14	16.68
2017									
5	1.29	52.40	17.61	1.31	51.66	24.51	1.30	52.03	27.25
6	1.29	52.40	17.61	1.24	54.24	21.34	1.27	53.14	24.33
7	1.27	53.14	16.10	1.17	56.83	18.26	1.25	53.88	21.14
8	1.23	54.73	14.52	1.16	57.20	17.42	1.22	54.98	19.71

ANOVA: Bulk density *p=0.000175; HSD[0.05]=0.05; HSD[0.01]=0.06; 5 vs 6 NS; 5 vs 7 P<0.01; 5 vs 8 P<0.01; 6 vs 7 NS; 6 vs 8 P<0.01; 7 vs 8 P<0.05;* ***Total porosity****: p=0.000175; HSD[0.05]=1.68; HSD[0.01]=2.29; 5 vs 6 NS; 5 vs7 P<0.01; 5 vs 8 P<0.01; 6 vs 7 NS; 6 vs8 P<0.01; 7 vs8 P<0.05; Hardiness; p= 0.127096*

The results in table 1 and table 2 show that the values of bulk density, hardness and total porosity of the soil using these technologies, including soil protection methods vertical mulching with compost or with manure and direct sowing in all three phases of observation and during both stages of the experiment are best compared to applied conventional technologies and are almost the same as in the use of compost, and when manure is incorporated as a mulching material. In these two cases soil parameters are in optimal range (for bulk density 1.2-1.3g/cm^3, for general porosity 50-55% and for soil hardness 15-19 kg/cm^2) for growing wheat on slopes (Todorov et al., 1982). This allows better development of the root system of this crop, to improve the moisture holding capacity, the nutritional and air regime of the soil.

Lower but relatively high are soil indicators with application of the second soil protection technology, which involves surface mulching at both stages of the study, the first using compost and the second with manure.

Similar are results of the observation of the height of the plants (table 3 and table 4) as well as the average yields of wheat straw and wheat grains (table 5, table 6, table 7 and table 8) .

Table 3 *Height of plants by phases of development (cm) wheat experiment 2013-2015y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	Flowe ring	stem elongation	heading	flowering
	2013			2014			2015			2013-2015		
1	32.50	45.10	60.30	48.92	57.80	66.67	41.00	52.15	72.20	40,81	51,68	66,39
2	33.60	46.50	66.10	57.34	76.00	76.00	44.10	60.30	85.30	45,01	60,93	75,80
3	38.50	50.40	69.50	67.20	77.60	92.67	48.30	67.50	92.50	51,33	65,17	84,89
4	40.10	52.30	72.50	73.72	88.00	100.67	51.60	75.20	97.70	55,14	71,83	90,29

ANOVA: ***For flowering phase;*** *p= 0.140272, 1 vs 3 p=0.093124; 1vs4 p= 0.067053*

Table 4 *Height of plants by phases of development (cm) wheat experiment 2015-2017 y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	flowering	stem elongation	heading	flower ing
	2015			2016			2017			2015-2017		
5	41,00	52,15	72,20	41,50	48,92	74,20	43.80	51.20	78.40	42.10	50.76	74.93
6	44,10	60,30	85,30	47,80	57,34	86,00	48.10	58.80	87.50	46.67	58.81	86.27
7	48,30	67,50	92,50	48,00	67,20	93,60	49.50	72.70	95.70	48.60	69.13	93.93
8	51,60	75.20	97,70	53,00	73,72	98,80	54.60	74.67	99.30	53.07	74.53	98.60

ANOVA: ***For flowering phase*** p<.0001; HSD[.05]=5.01; HSD[.01]=6.84; 5 vs 6 P<.01; 5 vs 7 P<.01; 6 vs 8 P<.01; 6 vs 7 P<.01; 6 vs 8 P<.01; 7 vs 8 nonsignificant

The height of plants, on average during the study period, is the highest, with the application of advanced soil protection technology for minimum and unconventional soil tillage (vertical mulching) and in the three phases of plant observation – stem elongation, heading and flowering. By comparing this indicator, the two stages of the experiment using compost or manure as mulching material (variant 4 and variant 8) show that the values in all three phases of development are close with a slight prevalence for those in which was applied manure as a mulch - variant 8. The same is also observed with the use of soil protection technology, including the erosion control method, surface mulching with manure (variant 7), although the plant heights are smaller compared to these with realization of the vertical mulching.

Table 5 *Grain yield at 14% humidity, 2013-2015y.*

	Yeild							
Year	**2013y.**		**2014y.**		**2015y.**		**2013-2015y.**	
Variant	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
1	3411	100,0	3871	100,0	3928	100.0	3736,67	100
2	3575	104,8	4042	104,4	4112	104.7	3910,67	104,6
3	3726	109,2	4203	108,6	4262	108.5	4063,67	107,8
4	4154	121,8	4649	120,1	4702	119.7	4501,67	120,5
GD5%	66.07	1.94	50.55	1.31	43.50	1.10		
GD1%	94.93	2.66	76.58	1.89	65.86	1.60		
GD0,1%	139.66	3.75	123.10	2.93	105.86	2.43		

Table 6 *Average yield of wheat straw 2013-2015 y.*

Year, Variant	Yeild							
	2013y.		**2014y.**		**2015y.**		**2013-2015y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
1	2707	100,0	3029	100,0	3103	100.0	2946,33	100,0
2	2813	103,9	3141	103,7	3226	104.0	3060,00	103,9
3	2987	110,9	3318	109,5	3378	108.9	3227,67	109,8
4	3245	119,9	3594	118,7	3654	117.8	3497,67	118,8
GD5%	56.69	2.09	95.85	3.16	26.64	0.86		
GD1%	81.44	2.90	145.19	4.62	40.36	1.25		
GD0,1%	119.81	4.01	233.40	7.03	64.88	1.92		

Table 7 *Grain yield at 14% humidity, 2015-2017 y.*

Year, Variant	Yield							
	2015y.		**2016y.**		**2017y.**		**2015-2017 y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
5	3928	100,0	4437	100,0	4827	100.0	4397.3	100.0
6	4112	104,7	4623	104,2	5059	104.8	4598.0	104.6
7	4262	108,5	4779	107,7	5165	107.0	4735.3	107.7
8	4702	119,7	5219	117,6	5622	116.5	5181.0	117.8
GD5%	39.24	11.50	25.26	0.57	6.06	1.78		
GD1%	56.38	15.77	38.26	0.83	8.71	2.43		
GD0,1%	82.94	22.263	61.50	1.29	12.82	3.44		

Table 8 *Average yield of wheat straw 2015-2017 y.*

Year, Variant	Yeild							
	2015y.		**2016y.**		**2017y.**		**2015-2017y.**	
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**	**kg/ha**	**%**
5	3103	100,0	3413	100,0	3730	100.0	3415.3	100.0
6	3226	104,0	3540	103,7	3881	104.1	3549.0	103.9
7	3378	108,9	3699	108,4	4024	107.9	3700.0	108.4
8	3654	117,8	3986	116,8	4317	115.7	3985.7	116.7
GD5%	42.45	3.01	20.55	0.60	6.04	0.16		
GD1%	64.31	4.33	31.13	0.88	9.14	0.24		
GD0,1%	103.38	6.70	50.04	1.35	14.70	0.37		

This gradation of the variants on their agro-technical efficiency, as shown in table 5 and table 6, table 7 and table 8 is also maintained taking into account the average yields of wheat and wheat straw. The highest average yields using the improved soil technology were in both stages of the experiment (variant 4 and variant 8). In the period 2013-2015y. the average grain yield in variant 4 using compost as mulching material is 765.0 kg/ha (with 20.5%) higher than variant conventionally grown along the slopes (control - variant 1), with 591.0 kg/ha (with 15.1%) higher than that of the variant conventionally tilled across the slope and 438.0 kg/ha (with 12.7%) higher than this of crop grown under soil protection technology, including surface mulching with ready compost. This tendency is also maintained in the results with the average annual yield of wheat straw at this stage. Here the increase of this indicator in variant 4, compared to the control - variant 1 is 551.34 kg/ha (with 18.8%) compared to variant 2 with 437.7 kg/ha (with 14.9%), and compared to variant 3 is 270.0 kg/ha (with 9.0%).

In the second stage of the survey (2015-2017y.), data for yields are similar to the average wheat grain in variant 8, using the vertical mulching method, with the mulch material manure was 783.7 kg/ha (with 17.8%) higher than that of the conventionally grown along the slope control - variant 5 with 583.0 kg/ha (with 12.7%) higher than conventionally grown across the slope - variant 6 and 445.7 kg/ha (with 9.4%) higher than that of variant 7, with application of the soil protection technology, including surface mulching with manure. At the average yield of wheat straw, at this stage, the yield increase in variant 8 compared to the control was 570.4 kg/ha (with16.7%) at variant 6, it was 436.7 kg/ha (12.3%) compared to variant 7, the increase was 285.7 kg/ha (7.7%).

Comparing all these results for the obtained yields, it can be seen that even with these indicators, their values are the highest and at the same time very close, in the variants using the advanced soil protection technologies for minimum and unconventional soil tillage, including vertical mulching with ready compost or bovine manure and direct sowing (variant 4 and variant 8), with slightly preponderance in the case of manure application as a mulching material.

These technologies, in both applications (with compost or manure, as mulch), wheat growing on sloping terrains have a higher erosion control effect compared to other examined technologies, both during the two experimental stages (table 9 and table 10). This, according to Dimitrov (2016), is due to the increased water permeability of the soil and the improved soil protection effect of vegetation and organic residues, reflecting both the volume of surface water runoff and the amount of eroded soil.

Table 9 *Total volume of surface water runoff and amount of eroded soil 2013-2015 y.*

Date	**Rain l/m²**	**Surface water runoff m³/ha**				**Eroded soil kg/ha**			
		Variant				**Variant**			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
14.04.13	17.5	112.071	75.306	63.434	39.231	1327.9	700.8	406.9	204.5
12.06.13	28.0	101.143	74.289	63.253	37.633	1151.2	626.9	366.9	182.7
13.06.13	12.0	89.143	64.082	53.494	31.953	948.1	592.9	301.1	149.0
For 2013 y.	57.5	302.357	213.674	180.181	108.817	3427.2	1920.6	1074.9	536.2
14.05.14	18.0	137.442	106.192	92.913	55.455	1658.1	971.6	552.6	267.1
31.05.14	54.0	115.814	76.603	64.702	38.485	1368.2	716.1	415.9	209.8
18.06.14	30.0	126.628	88.767	81.206	46.667	1572.9	869.1	504.2	249.3
For 2014 y.	102.0	379.884	271.562	238.821	140.607	4599.2	2556.8	1472.7	726.2
26.05.15	16,0	165,985	128,000	103,794	64,483	1983,2	1181,9	640,8	315,0
10.06.15	18,0	140,584	93,895	80,643	50,344	1663,9	884,0	510,9	258,3
02.07.15	14,5	118,467	78,947	66,945	41,552	1397,9	763,9	432,7	215,7
For 2015 y.	48,5	425,036	300,842	251,384	156,379	5045,0	2829,8	1584,4	789,0
Avarage for 2013-2015 y.	69,33	369,092	262,026	223,462	135,268	4357,1	2453,7	1377,3	683,8

*ANOVA: **Surface water runoff** , p<0.0001 HSD[0.05]=22.9; HSD[0.01]=28.49, 1 vs 2 P<0.01, 1 vs 3 P<0.01, 1 vs4 P<0.01, 2 vs 3 NS, 2 vs 4 P<.01, 3 vs 4 P<.01; **Eroded soil** , p< .0001; HSD[0.05]=241.15; HSD[0.01]=300; 1 vs 2 P<0.01, 1vs 3 P<0.01; 1 vs 4;P<0.01 ; 2 vs 3 P<0.01; 2 vs 4 P0<0.01; 3 vs 4 NS*

Table 10 *Total volume of surface water runoff and amount of eroded soil 2015-2017y.*

Date	**Rain l/m²**	**Surface water runoff m³/ha**				**Eroded soil kg/ha**			
		Variant				**Variant**			
		5	**6**	**7**	**8**	**5**	**6**	**7**	**8**
26.05.15	16.0	165.985	128.000	103.794	64.483	1983.2	1181.9	640.8	315.0
10.06.15	18.0	140.584	93.895	80.643	50.344	1663.9	884.0	510.9	258.3
02.07.15	14.5	118.467	78.947	66.945	41.552	1397.9	763.9	432.7	215.7
For 2015y.	48.5	425.036	300.842	251.384	156.379	5045.0	2829.8	1584.4	789.0
05.05.16	20.0	170.382	122.628	101.661	63.761	1925.1	1079.5	605.9	301.4
24.05.16	16.0	148.397	98.978	89.302	52.657	1598.2	926.0	491.3	247.5
06.06.16	12.0	109.924	73.577	62.193	37.687	1211.9	651.9	355.0	185.7
12.06.16	18.0	142.443	100.292	83.721	50.866	1567.1	888.2	471.7	243.6
For 2016 y.	66.0	571.146	395.475	336.877	204.971	6302.3	3545.6	1923.9	978.2
29.04.17	16.0	152.528	103.830	90.863	56.556	1578.8	878.9	495.2	246.3
06.05.17	20.2	165.626	123.319	99.604	62.284	1900.2	1062.3	598.9	300.4
27.05.17	13.0	105.934	71.915	59.808	36.979	1128.2	604.1	341.0	173.4
19.06.17	11.0	106.374	71.489	59.425	36.616	1136.1	602.9	337.3	175.2
02.07.17	32.0	169.231	128.511	103.898	65.619	2035.6	1206.2	654.2	324.3
For 2017 y.	92.2	699.693	499.064	413.398	258.54	7778.9	4354.4	2426.6	1219.6

ANOVA; *Surface water runoff*: p<.0001;HSD[.05]=21.62; HSD[.01]=26.67; 5 vs 6 P<.01;5 vs 7 P<.01; 5 vs 8 P<.01; 6 vs 7 nonsignificant; 6 vs 8 P<.01; 7 vs 8 P<.01; **Eroded soil** p<.0001; HSD[.05]=223.02; HSD[.01]=275.14; 5 vs 6 P<.01; 5vs7 P<.01; 5 vs 8 P<.01; 6 vs 7 P<.01; 6 vs 8 P<.01; 7 vs 8 P<.05

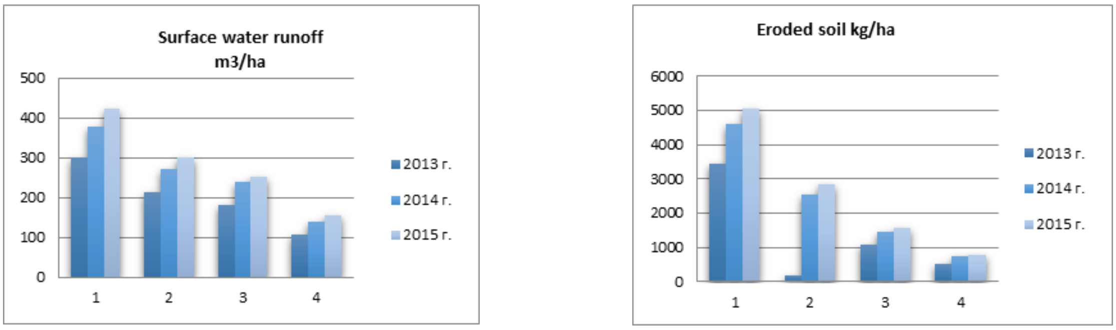

Fig. 5 Volume of surface water runoff (m3/ha) and amount of eroded soil (kg/ha) 2013-2015 y

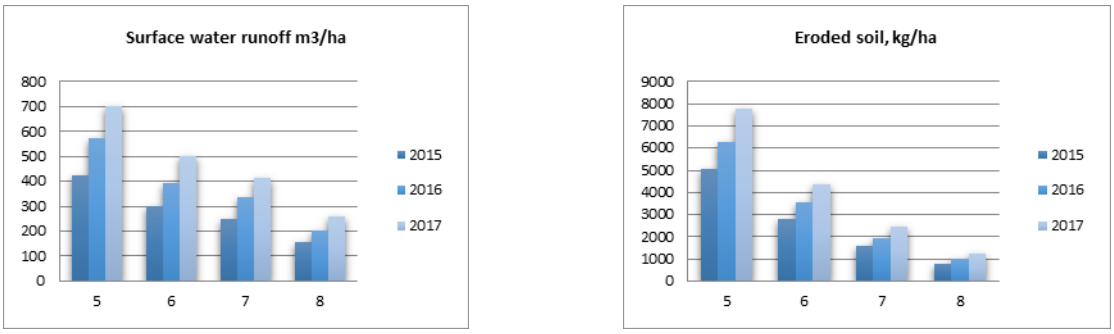

Fig. 6 Volume of surface water runoff (m3/ha) and amount of eroded soil (kg/ha) 2015-2017

Data on table 9 and fig. 5 show that in the first stage of the survey, in the period 2013-2015 y., the use of advanced soil protection technology including vertical mulching with compost and direct sowing, average annual water surface runoff values decreased from 2.5 to 3.0 times, and those of the eroded soil from 6.2 to 6.5 times, compared to conventional grown plots along the slope - control, variant1.

During the second stage of the experiment (2015-2017y.), in the variant with application of advanced soil protection technology including vertical mulching with manure and direct sowing, as shown in table 10 and fig. 6, this decrease in surface water runoff is almost the same as in the first stage, from 2.6 to 2.9 times, and in the quantity of eroded soil it is 6.3 to 6.5 times, compared to the control. A weaker erosion control effect was observed in variants 3 and 7 with the application of soil protection technology using the surface mulching method with manure. In the first stage of the experiment, when the mulching material is compost, the reduction of the surface water flow is 1.5 to 1.8 times, and for the eroded soil is 3.0 to 3.3 times, compared to control (fig. 5), this decrease in surface water runoff and soil loss relative to the control variant 5 during the second stage of the study, using this technology applying surface manure mulching, is 1.6 to 1.8 times, and in the water runoff from 3.1 to 3.4 times for the eroded soil (fig. 6).

CONCLUSION

Taking into consideration the results of the comparative study of the improved soil protection technologies for minimum and unconventional tillage of the soil by application of the erosion control method vertical mulching with different mulching materials, as well as soil protection technologies with the application of surface mulching with these materials for growing wheat on sloping agricultural lands, we can draw the following conclusions:

1. The two advanced soil protection technologies for minimum and unconventional soil tillage for wheat growing on inclined terrains, including vertical mulching with compost in first and manure in the other, as well as direct sowing in both on the calcareous chernozem, are applicable in the Republic of Bulgaria and are a reliable means of protecting the soil from the degradation processes - water erosion, compaction and loss of soil organic matter, on sloping agricultural lands with a slope of 5 ° (8.7%).

2. The application of advanced soil protection technologies for wheat growing on sloping terrains, in both variants, including erosion control methods vertical mulching with compost and direct sowing, in the first variant and vertical mulching with manure and direct sowing, in the second, help to obtain and maintain soil density, hardness and total porosity close to the most favorable for the cultivation and development of this crop, as evidenced by the high biometric values obtained, indicating higher average yields of grain and wheat straw. In the first variant, the use of compost as a mulching material was higher with 765.0 kg/ha (with 20.5%) for grain and 551.3 kg/ha (with 18.8%) at the straw compared to the conventional grown wheat plots along the slope, and in the second variant using for mulch manure, this increase is slightly higher by 783.7 kg/ha (with 17.8%) for the grain and 570.4 kg/ha (with 16.7%) for the straw compared to the control.

3. The runoff and erosion control efficiency of advanced soil protection technologies for wheat growing on sloping terrain in both variants of work using compost as mulching material and manure as a mulch are greater than those at conventionally used for growing this agricultural crop technology. In their application, in the first variant, the values of the surface water runoff decrease from 2.5 to 3.0 times, those of the eroded soil from 6.2 to 6.5 times compare to the conventionally grown sowings along the slope. In the second variant, this decrease is almost the same as for the surface water runoff of 2.6 to 2.9 times, and for the soil removed it is 6.3 to 6.5 times as compared to the control.

4. The application of the two soil protection technologies for growing wheat on slopes using the erosion control method of surface mulching with compost in the first and surface mulching with manure in the second, also has a relatively good soil protection role. Both types of mulching materials reduce surface water runoff to 1.8 times and for the eroded soil to 3.3-3.4 times compare to the control. In addition, they increased the average yield of grain by 327 kg/ha (with 8.8%) and wheat straw by 281.34 kg/ha (with 9.6%), compared to conventionally grown sowings along the slope in the first experiment, and in the second increase was 338.0 kg/ha (with 7.7%) for grain and 284.7 kg/ha (8.3%) for wheat straw.

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