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

Hristo Beloev, Petar Dimitrov, Gergana Kuncheva

Abstract: *Annually between 400,000 and 500,000 hectares of grain maize are grown in the Republic of Bulgaria, with about 50% of these areas being sown on sloping agricultural lands. On these terrains, the risk of soil degradation and in particular the risk of degradation processes, water erosion, compaction and loss of soil organic matter is significant. In order to reduce this danger or to prevent it, along with the many applied soil protection methods and technologies in our country, advanced technologies for minimum and unconventional soil tillage have been developed and studied. These include both combined reduced tillage system and the erosion control method of mulching (surface and vertically-into the soil), with ready compost or manure as a mulching material. The present research explores the results of long-term comparative studies with these technologies in the cultivation of grain maize on sloping agricultural lands in specific soil and climatic conditions, assessing their agro technical and soil protection capabilities.*

Keywords: *soil water erosion, compaction, soil organic matter reduction, grain maize, minimum soil tillage, surface mulch, vertical mulch, ready compost, manure.*

INTRODUCTION:

Annually about 400,000 hectares of grain maize are sown in the Republic of Bulgaria, which occupies 12.6% of the arable land (Dimitrov, 2008). An important requirement for growing this crop is to place it on plane terrains, free of water erosion, compaction and loss of soil organic matter. The erosion assessment of the relief of our country, made by Rousseva (2006) shows, that only 16% of our total territory has a slope of 0^0 to 3^0, and the rest is with bigger inclinations. This requires a large part, about 40-50% of the maize crops, to be located on terrains with different slopes, which are potentially at risk by the degradation processes of the soil (Dimitrov, 2008, 2016). In these areas, the implementation of established conventional technologies does not solve the problems of degradation, and even according to Dimitrov (2008), it can accelerate their development, especially if the operations are carried out along the slope. For this reason, on sloping agricultural lands sown with grain maize, it is necessary to use modern soil protection technologies aimed at limiting or completely preventing the degradation processes - water erosion, compaction and loss of organic matter. One of them is the advanced soil protection technology for minimum and unconventional soil tillage. It includes both combined systems for reduced tillage (loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling) and the erosion control method vertical (into the soil) mulching using compost or manure, in two mulch variants. At the Institute of Soil Science, Agrotechnology and Plant Protection "Nikola Pushkarov" – Sofia and University of Rousse "Angel Kanchev", joint research was carried out with these two variants of the advanced soil protection technology under particular soil and terrain conditions, from which positive results were obtained.

The aim of the present study is on the base of the results of comparative research, between the two variants of the work, the advanced soil protection technology for minimum and unconventional soil tillage using compost or manure as a mulching material, to compare their agrotechnical and soil protection capacities for growing maize for grain on sloping agricultural lands.

MATERIAL AND METHODS

The essays were conducted in the experimental field of the Nikola Pushkarov Institute of Soil Science, Agrotechnology and Protection of Plants 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 5^0 (8,7%). They were carried out in the period 2012-2017y., in two stages. During the first stage of the experiment, in 2012-2014y., a field experiment with grain maize with soil protection technology for minimum and unconventional soil tillage were performed applying ready compost as a mulching material. The second stage of the study was carried out between 2015y. 2017y. and during it, the soil protection technology for minimum and unconventional soil tillage for growing maize for grain was tested for agrotechnical and soil protection efficiency, using manure. To achieve the goal of the research, both stages and two field experiments were carried out by block method, in four variants with 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 tested variants during the first stage of the experiment are:

9 th – maize plots, grown by conventional technology, applied along the slope - control;

10^{th} - maize plots, grown by using conventional technology applied across the slope;

11^{th} – maize plots, grown by erosion control technology, including surface mulching with ready compost, all operations applied across the slope;

12^{th} - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with ready compost, forming slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum and unconventional soil tillage) applied across the slope.

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

13th - maize plots, grown by conventional technology, applied along the slope - control;

14 th - maize plots, grown by using conventional technology applied across the slope;

15 th - maize plots, grown by erosion control technology, including surface mulching with manure, all operations applied across the slope;

16 th - maize plots, grown by erosion control technology, including soil tillage without reversing the layer - loosening and soil protection operation vertical mulching with manure, forming slits with ducts, along with sowing and digging and furrowing along the hilling (advanced technology for minimum unconventional soil tillage) applied across the slope.

Throughout the research period, both the two control variants, in both experimental stages (variant 9 and variant 13), are common, traditional (conventional) for this crop, and are carried out along the slope. The same conventional technological operations were also carried out in variants 10 and 14, but with the difference that their application direction is across the slope. The erosion control agro-technical measures in the other variants were applied using the methods in the following ways: surface mulching, in variants 11 and 15, was carried out before sowing across the slope by means of a fertilizer trailer 1PTU-6 (Figure 1) at the rate of 4500-5000 kg/ ha with compost mulching material in the first stage (variant 11) and with bovine manure, in the second stage - variant 15.

Fig. 1 Fertilizer trailer

In variants 12 and 16, in both stages of the experiment, included erosion control methods - loosening, vertical mulching (with compost or manure), forming slits with ducts, along with sowing and digging, and furrowing along the hilling. Loosening in this case replaces the plowing with the reversal of the soil layer. It is carried out, across the slope, at a depth of 0.40 m, with cultivator CP - 9 (Figure 2), aggregated with tractors with a nominal power of 120 to 150 kW. Vertical mulching is also carried out across the slope, before sowing with a specialized device for incorporation of organic matter into the soil (Fig. 3), by a band scheme (with interval between the slits of 0.60 m and the interval between bands 3 m in the field), at a depth of 0.40 m. However, as a mulching material, variant 12 uses ready compost, and in variant 16 this material is bovine manure. In both cases, the norm is 4500 - 5000 kg/ha, and simultaneously with this technological operation, a single disking is performed with heavy disc harrows for surface covering of slots and for preservation of soil moisture. Forming slits with ducts is done annually, twice at different times of the technological process, with different technological devices. It was applied simultaneously with the maize sowing (fig. 4), across the slope in the formed row spacing, at a depth of 0.25 m, with a distance between the slits -1.4 m.

Fig. 2 Chisel cultivator CP - 9

Fig. 3 Device for vertical mulching

Fig. 4 Sowing maize with simultaneously forming slits with ducts in soil

Along with this, the cutting with walking is carried out simultaneously with the first hoeing, in the phase of plant growth, 3-5th leaf, across the slope, at a distance of 1.4 m and a depth of 0.25 m. In this case, an inter rows device KRN - 4,2 or KOB - 4,2 is used after the hoeing machine parts (fig. 5). The other erosion control method applied in these variants (variant 12 and variant 16) – furrowing with making slits and ducts is also performed transversely to the inclination of the slopes, and in this process slitting with hilling processes are performed sequentially and simultaneously with a combined device (fig. 6).

Fig. 5 General view of cultivator and ducts KRN-4,2 with device for slits with ducts

Fig. 6 General view of device for slits forming

During the two stages of the experimental period, agro technical (soil and biometric) and erosion observations were carried out according to established methodology.

RESULTS AND DISCUSSION

The results of the comparative studies carried out with the improved soil protection technologies for minimum and unconventional soil tillage using compost or manure as a mulching material in the cultivation of grain maize on sloping arable lands, show that their application has a positive impact on agronomic and erosion indicators.

Table 1 *Bulk density (g/cm^3), total porosity(%) soil hardiness (kg/m^2) in layer 0-40 cm, experiment 2012-2014 y.*

Year, variant	Before sowing			Maximum growth stage			Harvesting		
	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness	Bulk density	Total porosity	Hardiness
2012 y.									
9	1.26	53.51	13.34	1.30	52.03	32.82	1.32	51.29	27.41
10	1.26	53.51	13.34	1.26	53.51	31.12	1.27	53.14	24.52
11	1.26	53.51	13.34	1.24	54.24	29.57	1.24	54.24	22.34
12	1.15	57.57	10.57	1.21	55.35	25.60	1.20	55.72	21.25
2013 y.									
9	1.37	49.45	16.82	1.48	45.39	34.06	1.41	47.97	39.09
10	1.37	49.45	16.82	1.46	46.13	22.42	1.37	49.59	32.50
11	1.34	50.55	15.70	1.39	48.71	18.12	1.32	51.29	29.21
12	1.31	51.66	14.56	1.36	49.82	15.36	1.19	56.09	26.26
2014 y.									
9	1.40	48.34	14.78	1.35	50.19	18.69	1.33	50.92	25.91
10	1.40	48.34	14.78	1.34	50.55	16.21	1.32	51.29	21.89
11	1.35	50.19	11.20	1.25	53.87	11.27	1.25	53.87	19.02
12	1.32	51.29	10.10	1.20	55.72	10.45	1.14	57.93	15.18
2012-2014 y.									
9	1.34	50.55	14.98	1.38	49.08	28.52	1.*35*	50.19	30.80
10	1.34	50.55	14.98	1.35	50.19	23.25	*1.32*	51.29	26.30
11	1.32	51.29	13.41	1.29	52.40	19.65	*1.27*	53.14	23.52
12	1.26	53.51	11.74	1.26	53.51	17.14	*1.18*	56.46	20.90

__ANOVA: Bulk density__ p= <0.000558; HSD[0.05]=0.08; HSD[0.01]=0.1; 9vs 10 nonsignificant; 9vs 11 nonsignificant; 9vs 12 P<0.01; 10 vs 11 nonsignificant; 10 vs 12 P<0.01; 11 vs 12 nonsignificant; __Total porosity__: P=0.0001 HSD [0.05]=2.49; HSD[0.01]=3.13; 9vs 10 nonsignificant; 9vs 11 nonsignificant; 9vs 12 P<0.01; 10 vs 11 nonsignificant; 10 vs 12 P<0.01; 11 vs 12 nonsignificant; __Hardiness__ p<0.0001; HSD [0.05]=3.62; HSD[0.01]=4.56; 9vs 10 nonsignificant; 9 vs 11 P<0.01; 9 vs 12 P<0.01; 10 vs 11P<0.05; 10 vs 12 P<0.01; 11vs 12 nonsignificant

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									
13	1.38	49.08	16.22	1.33	50.92	34.06	1.33	50.92	23.08
14	1.38	48.08	16.22	1.30	52.03	31.21	1.31	51.66	20.84
15	1.31	51.66	10.06	1.28	52.77	26.84	1.29	52.40	18.31
16	1.21	55.35	7.76	1.17	56.83	22.20	1.25	53.87	15.37
2016									
13	1.35	50.18	16.75	1.30	52.03	17.37	1.37	49.45	44.68
14	1.35	50.18	16.75	1.28	52.77	15.62	1.30	52.03	33.63
15	1.29	52.40	15.02	1.20	55.72	13.19	1.25	53.87	28.36
16	1.23	54.61	14.40	1.18	56.46	11.20	1.18	56.46	21.49
2017									
13	1.33	50.92	14.85	1.38	49.08	25.42	1.46	46.13	34.10
14	1.32	51.29	14.41	1.36	49.82	23.20	1.43	47.23	30.25
15	1.27	53.14	13.30	1.29	52.40	19.15	1.39	48.71	27.50
16	1.22	54.98	12.80	1.26	53.51	17.21	1.32	51.29	24.33

__ANOVA: Bulk density__; HSD[0.05]=0.07; HSD[0.01]=0.09;13 vs 14 NS; 13 vs 15 P<0.05; 13 vs 16 P<0.01; 14 vs 15 NS; 14 vs 16 P<0.01; 15 vs 16 NS;__Total porosity__; p=0.000703; HSD[0.05]=2.42; HSD[0.01]=3.31; 13 vs14 NS; 13 vs 15 P<0.05; 13 vs16 P<0.01; 14vs15 NS; 14 vs 16 P<0.01; 15 vs16 NS; __Hardiness__: p= 0.429507

From table 1 and table 2, can be seen that values of the bulk density, total porosity and hardiness of the soil for these technologies, that include the soil protection methods, loosening, vertically mulching with ready compost or manure, making slits with ducts, along with sowing and digging and furrowing along the hilling and in the three phases of observation and the two stages of the experiment are the best (lowest density and hardness and highest total porosity) compared to those in conventional 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 density 1.2-1.3 g/cm^3, total porosity 50-55% and for soil hardness 15-19 kg/cm^3) for growing grain maize on slope lands (Todorov et al., 1982). This allows better development of the root system of this crop, to improve the moisture holding capacity, the nutrient and air regime of the soil.

Lower but relatively good soil indicators are also found in the application of the second soil protection technology, including the soil protection measure surface mulching at both stages of the study, the first one using compost and the second - with manure (variant 11 and variant 15).

Similar are the results from the observations of the height of the plants (table 3 and table 4), their leaf surface (table 5 and table 6), as well as the average yields of grain maize (table 7 and table 8).

Table 3 *Height of plants by phases of development (cm) maize experiment 2012-2014y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2012y.			2013y.			2014y.			2012-2014y.		
9	21,23	90,50	170,67	22,50	125,00	220,10	36,40	95,33	237,10	26,71	103,61	209,29
10	23,76	110,46	172,50	23,70	152,30	227,50	42,80	102,20	256,25	30,09	121,65	218,75
11	26,28	123,38	193,00	27,20	161,10	231,60	49,40	117,40	260,30	34,29	133,96	228,30
12	34,51	141,90	213,33	34,40	166,50	243,50	50,60	134,50	270,00	39,84	147,63	242,28

***ANOVA (tessel development)**: NS*

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

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2015y.			2016y.			2017y.			2015-2017 y.		
13	18,50	91,00	207,60	25,60	84,10	200,60	23.30	82.20	200.00	22.47	85.77	202.73
14	24,50	103,10	213,00	41,00	98,00	234,00	23.60	89.30	204.00	29.70	96.80	217.00
15	29,40	120,40	259,00	44,40	113,80	250,00	37.16	108.50	240.00	36.99	114.23	249.67
16	33,80	136,30	273,38	50,00	116,00	276,50	44.00	110.10	265.00	42.60	120.80	271.63

***ANOVA (tessel development)**: $p<0.0001$;HSD[0.05]=25.54; HSD[0.01]=34.92; 13 vs 14 NS; 13 vs 15 $P<0.01$; 13 vs16; $p<0.01$; 14 vs 15 $P<0.05$; 14 vs 16 $P<0.01$; 15 vs 16 NS*

Table 5 *Leaf area by phases of crop development (m^2/ha), experiment 2012-2014y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development	5th leaf	9th leaf	Tessel development
	2012y.			2013y.			2014y.			2012-2014y.		
9	239,85	831,55	16351,80	298,20	966,10	18660,50	294,85	1065,34	24999,10	277,63	954,33	19970,47
10	280,58	1341,20	17719,67	355,40	1291,40	19013,10	311,90	1315,83	24392,50	315,96	1316,14	20375,09
11	426,29	1714,40	21406,92	487,60	1813,30	23950,30	494,63	1667,17	25704,60	469,51	1731,62	23687,27
12	477,91	2011,39	23969,39	508,10	2140,10	26515,20	640,72	2205,94	29424,90	542,26	2119,21	26575,83

ANOVA: $p=0.123614$

***Table 6** Leaf area by phases of crop development (m^2/ha), experiment 2015-2017y.*

Variant	Phase of development			Phase of development			Phase of development			Phase of development		
	5th leaf	9th leaf	Tessel develop ment	5th leaf	9th leaf	Tessel develop ment	5th leaf	9th leaf	Tessel develop ment	5th leaf	9th leaf	Tessel develop ment
	2015y.			2016y.			2017y.			2015-2017 y.		
13	200,83	1172,20	14899,10	179,06	951,01	20709,94	170,16	935,10	20150,18	183,35	1019,37	18586,41
14	290,91	1506,60	16064,70	201,91	1243,02	22768,60	175,25	1072,20	21576,37	222,69	1273,94	20136,56
15	433,86	1792,40	24452,60	318,50	1808,68	24904,26	298,60	1719,32	23890,14	350,32	1773,47	24415,67
16	530,32	2344,40	25142,70	463,33	2166,02	29850,86	315,53	2080,25	28972,63	436,39	2196,89	27988,73

***ANOVA(tessel development**); p=0.010963; HSD[0.05]=7128.12; HSD[0.01]=9744.2; 13 vs 14 NS; 13 vs 15; NS; 13vs16 P<0.05; 14 vs 15 NS; 14 vs 16 P<0.05; 15 vs 16 NS*

The height of plants and their leaf area, on average over the period of the study, are again with the highest values, with the application of the advanced soil protection technology for minimum and unconventional soil tillage (vertical mulching) in the three phases of plant development - 5^{th}, 9^{th} leaf and forming a panicle. By comparing these indices, during the two stages of the experiment using compost or manure as a mulching material (variant 12 and variant 16) that the values of these two parameters in all three phases of development are similar to the slight prevalence of those in which manure is involved as mulch - variant 16. The same is also observed with the use of soil protection technology including the erosion control method with surface mulching with manure (variant 15), although at her application the plant heights and leaf surfaces are smaller than those of vertical mulching.

***Table 7** Grain yield at 14% humidity, 2012-2014y.*

Year, variant	Yield		Yield		Yield		Yield	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
	2012		2013		2014		2012-2014	
9	2885,0	100,0	6753,0	100,0	7067,0	100,0	5568,33	100,0
10	3182,0	110,3	7098,0	105,1	7421,0	105,0	5900,33	106,0
11	3274,0	113,5	7328,0	109,3	7648,0	108,2	6083,33	109,3
12	3443,0	119,3	7937,0	117,5	8264,0	116,9	6548,00	117,6
GD5%	114.0	3.10	203.0	3.01	33.47	0.47		
GD1%	158.0	4.30	307.0	4.30	50.71	0.68		
GD0,1%	216.0	5.80	494.0	6.70	81.52	1.07		

***Table 8** Grain yield at 14% humidity, 2015-2017 y.*

Year, variant	Yeild		Yeild		Yeild		Yeild	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
	2015y.		2016y.		2017y.		2015-2017 y.	
13	7158	100,0	6165	100,0	5723	100,0	6348,67	100,0
14	7513	104,9	6526	105,9	6041	105,6	6693,33	105,4
15	7840	109,5	6737	109,3	6326	110,5	6967,67	109,8
16	8387	117,2	7096	115,1	6677	116,7	7386,67	116,4
GD5%	18.96	5.56	27.14	7.96	3.83	1.12		
GD1%	27.23	7.62	39.00	10.91	4.50	1.54		
GD0,1%	40.06	10.75	57.37	15.40	8.09	2.17		

This gradation of variants in their agro-technical efficiency, as shown in table 7 and table 8, is also maintained taking into account the average yields of corn grain. The highest is the average yield of the variants using the advanced soil protection technology during both stages of the experiment (variant 12 and variant 16). In the period 2012-2014y., the average yield of grain in variant 12, with application of compost as mulching material was 979.7 kg/ha (with 17.6%) higher than that of conventionally grown crop, along the slope (the control variant 9) with 647.7 kg/ha (with 11.0%) higher than that of the variant conventionally grown across the the slope and with 464.7 kg/ha (with 7.6%) higher than that of plots grown with soil protection technology, including surface mulching with ready compost. In the second stage of the survey (2015-2017y.), these yield data are similar, with the average maize yield in variant 16 using the vertical mulching method with manure is with 1038 kg/ha (with 16.4%) higher than that of the conventionally grown control, variant 13, with 693.3 kg/ha (with 10.4%) higher than the crop grown across the slope - variant 14 and 419 kg/ha (6.0%) higher than that of variant 15 grown with soil protection technology including surface mulching with manure.

Comparison of these results for yields shows that in these indicators values are highest and at the same time very close, in variants using advanced technology for minimum unconventional soil tillage, including vertical mulching with ready compost or manure (variant 12 and variant 16) with slight preponderance, again with the application of manure as a mulching material.

These technologies in both variants (with the compost or manure, as a mulch), when growing corn for grain on slopes, have a higher erosion control effect as compared with other examined technologies, in both stages of the experiment (table 9 and table 10 as well as fig. 7 and 8). This, according to Dimitrov (2016), is due to increased water permeability of soil and improved soil protection effect of vegetation and organic residues, reflecting both the volume of runoff and the amount of the eroded soil.

Table 9 *Total volume of surface water runoff and amount of eroded soil 2012-2014 y.*

Date	Rain l/m^2	Surface water runoff m^3/ha				Eroded soil kg/ha			
		Variant				Variant			
		9	10	11	12	9	10	11	12
28.05.12	22.0	225.252	123.630	116.768	43.960	3622.0	1446.8	1378.0	168.5
06.08.12	15.5	141.907	73.913	70.909	26.733	1927.8	682.2	655.9	83.9
12.08.12	18.0	174.820	93.762	90.101	33.664	2598.6	981.4	939.0	116.5
27.08.12	12.5	128.957	65.217	62.828	23.960	1855.0	648.1	617.9	76.4
For 2012 y.	68.0	670.936	356.522	340.606	128.317	10003.4	3758.5	3590.8	445.3
12.06.13	28.0	182.113	105.763	95.932	35.140	2660.0	1014.9	937.1	117.2
13.06.13	12.0	157.183	89.492	79.661	29.533	2054.1	744.2	669.8	88.8
08.07.13	28.5	190.775	114.509	102.203	37.570	2899.1	1116.9	1044.1	128.6
For 2013 y.	68.5	530.071	309.764	277.796	102.243	7613.2	2876.0	2651.0	334.6
14.05.14	18.0	230.365	141.151	127.135	45.236	3260.2	1293.8	1185.6	145.3
31.05.14	54.0	165.547	93.237	83.027	31.099	2112.9	771.1	699.5	92.1
18.06.14	30.0	200.548	117.410	104.432	39.267	3102.5	1188.9	1104.2	136.2
For 2014y.	102.0	596.496	351.798	314.594	115.602	8475.6	3253.8	2989.3	373.6
Average 2012-2014 y.	79.50	642.153	370.615	310.999	115.387	8697.3	3296.1	3077.0	384.5

ANOVA Surface water runoff*; P<0.0001; HSD[0.05]=27.62; HSD[0.01]=34.26; 9 vs 10 P<.01;9 vs d11 P<.01;9 vs 12 P<.01;10vs 11 nonsignificant; 10 vs 12 P<.01;11 vs 12 P<.01;* ***Eroded soil****:P<0,0001; HSD[.05]=433.71; HSD[.01]=537.98; 9 vs 10 P<.01; 9 vs d11 P<.01;9 vs 12 P<.01;10vs 11 nonsignificant; 10 vs 12 P<.01;11 vs 12 P<.01*

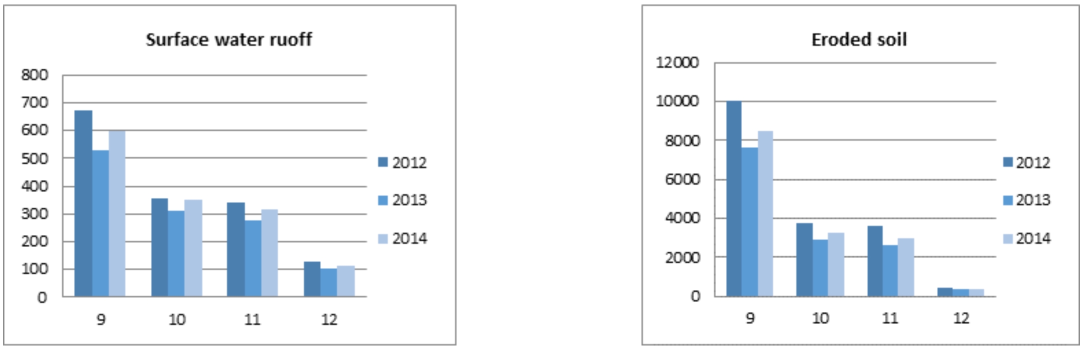

Fig. 7 Erosion control efficiency of the applied technologies for soil tillage, maize experiment, for the period 2012-2014y.

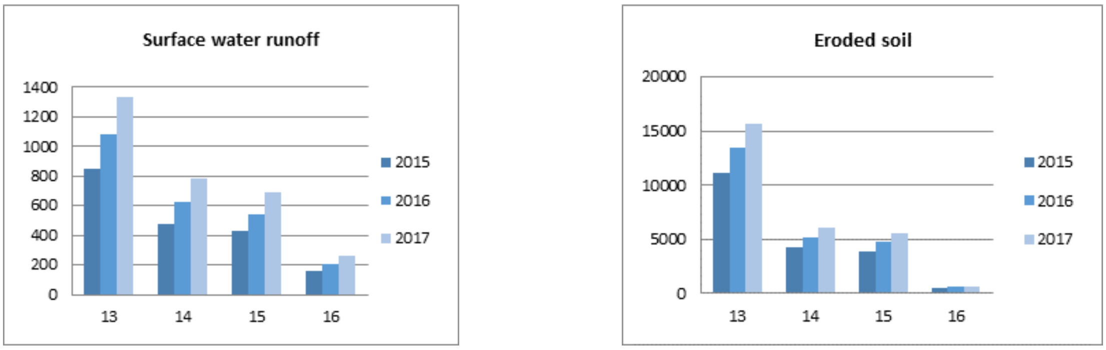

Fig. 8 Erosion control efficiency of the applied technologies for soil tillage, maize experiment, for the period 2015-2017 y.

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			
		13	14	15	16	13	14	15	16
26.05.15	16,0	266,426	154,983	142.614	51.378	3758.7	1501.6	1375.1	167.0
10.06.15	18,0	226,137	124,068	112.705	42.581	2879.9	1094.9	982.9	125.3
02.07.15	14,5	201,227	110,034	97.933	37.478	2517.8	939.5	843.6	109.3
21.08.15	51,0	154,224	83,797	74.407	28.856	1930.7	704.3	624.8	84.3
For 2015 y.	99,5	848,014	472,882	427.659	160.293	11087.1	4240.3	3826.4	485.9
05.05.16	20.0	265.263	159.468	140.964	52.023	3457.1	1375.7	1263.5	156.2
24.05.16	16.0	233.263	137.143	120.722	44.740	2920.0	1140.4	1050.0	129.7
06.06.16	12.0	174.737	98.073	84.217	32.601	2139.5	795.8	736.4	93.4
12.06.16	18.0	224.842	133.555	115.663	42.948	2802.0	1063.3	983.8	123.8
11.08.16	15.0	181.053	101.262	83.133	32.948	2192.2	812.8	727.1	95.4
For 2016 y.	81.0	1079.16	629.501	544.699	204.624	13510.8	5188.0	4760.8	598.5
06.05.17	20.2	255.582	149.591	133.060	50.269	3116.7	1240.6	1162.8	140.1
27.05.17	13.0	168.435	99.785	88.198	32.618	2017.7	748.2	697.6	89.0
19.06.17	11.0	170.149	95.054	85.230	31.812	2039.6	756.3	705.7	89.7
02.07.17	32.0	261.940	153.979	137.809	51.544	2960.6	1136.9	1059.6	133.4
13.08.17	18.0	220.299	129.462	114.912	41.477	2692.2	1036.7	925.9	119.2
03.09.17	42.0	256.567	153.979	134.841	50.336	2885.9	1118.3	1030.4	130.0
For 2017 y.	136.2	1332.97	781.850	694.050	258.056	15712.7	6037.0	5582.0	701.4

ANOVA Surface water runoff *HSD[0.05]=420.41; HSD[0.01]=574.7;13 vs 14 P<0.05; 13 vs 15 P<0.05; 13 vs 16 P<0.01; 14 vs 15 NS; 14vs16 P<0.05; 15 vs 16 NS;* ***ANOVA Eroded soil****: HSD[0.05]=3453.12; HSD[0.01]=4720.44; 13 vs 14 P<0.01; 13vs 15 P<0.01; 13 vs 16 P<0.01; 14 vs15 NS; 14 vs 16 P<0.05; 15 vs16 P<0.05*

The data on table 9 and figure 7 show that during the first stage of the study, in the period 2012-2014 y., the use of the advanced soil protection technology, with vertical mulching with manure, including the methods of loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling, the average of annual surface water runoff decreases from 5.2 to 5.4 times and those of the eroded soil from 21.5 times to 24.3

times compared to maize grown conventionally along the slope - control variant 9. During the second stage of the experiment (2015-2017y.), the use of advanced soil protection technology, including the methods of loosening, vertically mulching with manure, making slits with ducts, along with sowing and digging and furrowing along simultaneously the hilling of maize, as can be seen from the table 10 and fig. 8, this decrease in surface water runoff is almost the same as in the first stage of 5.1 to 5.5 times, and in the quantity of eroded soil is from 22.2 to 23.1 times, compared to the control – variant 13.

A lower erosion control effect was observed in variants 11 and 15 with the application of the soil-protection technology using the surface mulching method with compost or manure. Using this technology, during the first stage of the experiment, when the mulching material was compost, the reduction of the surface water runoff is 1.9 to 2.1 times, and the quantity of eroded soil is up to 3.0 times lower as compared to the control, variant 9 (fig. 7). This reduction in surface runoff and soil loss compared to the control variant 13 during the second stage of the research using surface mulching with manure is 1.9 to 2.2 times for water runoff and 2,7 to 3.1 times for the eroded soil (fig. 8).

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 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 advanced technology for minimum and unconventional soil tillage for growing grain maize on inclined terrains including the erosion control method vertical mulching with ready compost and vertical mulching with manure, as well as the loosening methods as main tillage, making slits with ducts, along with sowing and digging, and furrowing along the hilling in the maize, in the conditions of chernozem are applicable in the Republic of Bulgaria and reliable means to protect the soil from degradation processes - erosion, compaction and loss of soil organic matter on slope farmlands with inclination 5 ° (8.7%).

2. Application of advanced soil protection technologies for cultivation of grain maize on slope arable lands, in both variants including erosion control methods, vertical mulching with compost, loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling the first variant and the loosening, vertically mulching with manure, loosening, making slits with ducts, along with sowing and digging and furrowing along the hilling in the second, help obtaining and maintaining a soil density, hardness and total porosity close to the most favorable for the development and growth of that crop, as evidenced by the highest levels of the biometric indices and the higher average grain yield of maize. In the first variant using compost as a mulching material, it is 979.7 kg/ha (17.6%) higher compared to the conventional technology applied along the slope, and in the second variant using of manure for mulch, this increase is slightly higher with 1038 kg/ha (16.4%) compare to the control.

3. The runoff and erosion control efficiency of advanced soil protection technologies for growing corn on sloping terrains in both variants of work using compost and manure as a mulch material are higher than those of conventionally used technology in this agricultural crop cultivation. In their application, in the first variant of experiments, the values of the surface water runoff decrease from 5.2 to 5.4 times and those of the eroded soil from 21.5 to 24.3 times, compared to the conventionally grown plots along the slope. In the second variant, this reduction is almost the same as in the surface water runoff of 5.1 to 5.5 times, and in the eroded soil it is from 22.2 to 23.1 times, compared to the control.

4. The application of the two soil-protection technologies for growing maize for grain on sloping areas using the surface erosion control method of the first experiment with compost for surface mulching and with bovine manure in the second period of research, also have a relatively good soil protection role. Both mulching materials used, reduce surface water runoff to 2.1-2.2 times and eroded soil to 3.0-3.1 times the control. They also contribute to an increase in average maize grain yield of 515.0 kg/ha (9.3%), compared to conventionally grown crop along the slope, in the first soil protection technology, and in the second with 619.0 kg/ha (9.8%).

REFERENCES

[1] Beloev, H., (2008) Technology and system of machines for minimal soil tillage on inclined terrains in conditions of sustainable agriculture. Dissertation for acquisition of degree Doctor of Technical Science, Angel Kanchev University of Rousse, Rousse, 266 p.
[2] Dimitrov, P., (2008) Erosion control agrotechnical methods, technologies and systems for cultivation of wheat and grain maize on sloped terrains. Habilitation work for acquisition the title of "senior research fellow I degree", "Nikola Pushkarov" Institute, Sofia.
[3] Dimitrov, P., et al., (2016) Advanced Soil Protection Technologies for minimum and unconventional soil tillage in the Production of Maize on Sloping Terrains, "Nikola Poushkarov" ISSAPP - Sofia, Publishing Center of RU "A. Kunchev ", Rousse, 62 p.
[4] Dimitrov, P., (2016)Technology and System of Machines for Soil Protection. Dissertation for Acquisition of degree Doctor of Science", "Angel Kanchev" University of Rousse, Rousse, 375 p.
[5] Kollarova K., Pogran S., Kangalov, P., (2015) Precision Tillage: On the Way from Information to Decisions - Scientific Monograph. University of Ruse "Angel Kanchev", ISBN 978-954-712-656-5.
[6] Russeva, S., (2006) Degradation of Agricultural Land in Bulgaria. Discussion report, project: "Building capacity for sustainable land consolidation in Bulgaria", Sofia.
[7] Todorov, F., et al., (1982) Soil tillage. Zemizdat, Sofia.

CONTACTS

Hristo Beloev, Department of Agricultural Machinery, Agrarian and Industrial Faculty, University of Ruse "Angel Kanchev", 8 Studentska str., Bulgaria, e-mail: hbeloev@uni-ruse.bg

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