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Original Article

Soil Tillage for Sustainable Farming Systems

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Abstract

The article includes data from a long-term field polyfactorial experiment on typical cernozem from the Balti steppe, Republic of Moldova. The productivity of crop rotation with the mixture of perennial leguminous crop and grasses on different systems of soil tillage and fertilization was higher than of the crop rotation without perennial field crops. The share of soil tillage in yield formation is significantly lower than the share of fertilization and crop alternation. In crop rotation with perennial leguminous crops and grasses the efficiency of organo-mineral fertilization is decreasing relatively to crop rotation without mixture of leguminous crops and grasses. Crop rotation with perennial leguminous crops and grasses has a higher capacity to restore soil organic matter on all systems of fertilization and soil tillage for both soil layers 0-20 and 20-40 cm.

Keywords: soil tillage, crop rotation, sustainable farming.

1. Introduction

Soil tillage is a component and indispensable part of each farming system. The tentative to overestimate or to underestimate the importance of soil tillage in the farming system in different historical period of time has raised many contradictory opinions and discussions. The main issue was always – to plow or not to plow. In Basarabia this discussion began more than one century ago. Ivan Ovsinschi, the author of the book "New System of Agriculture", written in Polish language and later translated in Russian language who was working in Ocnita, Donduseni and Drochia districts of former Basarabia was in the favor of shallow soil tillage – no deeper than 5 cm [8].

In the same historical period of time researches from the Ploti Experimental Station in Ribnita district (Transnistria) have been convinced in the necessity to plow annually the soil at the depth of 20-22 cm [10]. To the supporters of annual plowing have belonged also Izmailski A.A, Wiliams V.R., Kosticev P.A. and others Russian scientists [4, 6, 9]. The discussions have been revitalized after the publication of the book "Fulish plower" by American farmer Folkner from Ohio State, USA [7].

In former USSR Terentii Malitev from Kurgan region (Ural mountains), Baraev in Kazahstan, Morgun in Poltava region (Ukraina) have promoted the nonreversible system of soil tillage made by blade working tools. Possibilities for extending minimum tillage have increased simultaneously with increased rates of mineral fertilizers and pesticides for weeds, pests and deseases control, which have replaced in great extent the positive role of moldboard plow.

The issue of positive and negative sides for different methods and systems of soil tillage requires a separate discussion. Some of them have been recently published [1].

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The conservative system of soil tillage became very popular on American continent being oriented mainly towards soil fertility conservation, water and wind erosion control [5].

Nevertheless, the issue of optimal system of soil tillage remain still very actual taking in consideration a large diversity of soil and climatic conditions together with nonconformance of the main components of zonal farming systems.

That's why we have initiated researches in a long-term field polyfactorial experiment on chernozem soils of the Balti steppe (northern part of Moldova).

2. Material and Method

There were studied a total of 4 species of the perennial leguminous pastures, namely: red clover cultivar Select 2, Satelit alfalfa variety, variety Vlamar sainfoin and trefoil variety Dacia1. For these species were discussed studies on how to prepare the seedbed at sowing by using the flat or annular roller. The first scythe was made for green mass and was harvested on buds and the second one for seed when 85 % of inflorescences were brown using the Wintersteiger combine. In the field the green mass weighed for the first scythe and average samples were taken for analysis in the laboratory. The results were calculated using modern methods.

The polyfactorial long-term field experiment includes: A - two crop rotations. I: 1. Alfalfa + grasses on the third year after first cutting, 2. Winter wheat, 3. Sugar beet, 4. Corn for grain, 5. Winter barley, 6.Corn for green mass + under sown mixture of alfalfa with grasses, 7. Alfalfa + grasses on the second year of life. II: 1. Corn for sillage, 2. Winter wheat, 3. Sugar beet, 4. Corn for grain, 5. Peas for grain, 6. Winter wheat, 7. Sunflower. B - two systems of soil tillage in crop rotation: 1. Combination of moldboard plow with nonreversible soil tillage. 2. Nonreversible system of soil tillage. C - three systems of soil fertilization: 1. Unfertilized, 2. Manure, 3. Manure + NPK.

Crop rotations are extended (unfolded) in space and in time, in three repetitions. The size of the experimental plot is 264 sq.m. The total area under the experiment is 8.7 ha. Simultaneously researches are conducted in permanent crops for the main crops on the same backgrounds of soil tillage and fertilization. No chemical control for pests, deseases and weeds in the experiment.

The soil on the experimental field is represented by typical chernozem with the content of soil organic matter for 0-20 cm soil layer 4.0-4.5%. The average amount of atmospheric precipitation consists 400-500 mm, with huge fluctuations for different years and different period of vegetation in each year. More details about this experiment can be found in our previous publications [2, 3].

3. Results and Discussions

Crop rotation with the mixture of perennial leguminous crops and grasses on unfertilized plots with combination of moldboard plow and nonreversible soil tillage was more productive than crop rotation without mixture of perennial leguminous crops and grasses on the same system of soil tillage without fertilization (table 1). In average for 1996-2012 years, the productivity of the first crop rotation has consisted 4.18 tonnes of cereal units per 1 ha relatively to 3.73 tonnes of cereal units per 1 ha for the second crop rotation.

Transition to nonreversible system of soil tillage on unfertilized plots has reduced the productivity of both crop rotation relatively to combination of moldboard plow with nonreversible system of soil tillage on 0.16 t.c.u./ha (3.8%) and 0.11 t.c.u/ha (2.9%), respectively.

Manure application have increased in equal extent the productivity of both crop rotations and on both systems of soil tillage. The productivity of the first crop rotation with the mixture of perennial leguminous crops and grasses has increased on 0.43 t.c.u./ha (10.3-10.7%) on both systems of soil tillage on 0.46 and 0.38 t.c.u./ha (12.3 and 10.5%) in the second crop rotation without mixture of perennial leguminous crops and grasses, respectively, for the combination of moldboard plow and nonreversible soil tillage and only nonreversible system of soil tillage.

The influence of nonreversible soil tillage relatively to combination of moldboard plow with nonreversible soil tillage on productivity of both crop rotations on manure plots was similar to one mentioned before for unfertilized plots. The reduction in the productivity of both crop rotations consisted 0.16 (3.5%) and 0.19 t.u.c./ha (4.5%), respectively for the first and second crop rotations. Adding mineral fertilizers to manure has increased in greater extent the productivity of crop rotation without mixture of perennial leguminous crops and grasses than of the crop rotation with mixture of perennial leguminous crops and grasses. The increase of productivity consisted on plots with combination of moldboard plow and nonreversible soil tillage 0.91 t.c.u./ha (24.4%) and 0.56 t.u./ha (13.4%), respectively. Nonreversible system of soil tillage didn't change significantly the above mentioned statement – 0.63 t.u./ha (15.7%) and 0.82 t.c.u./ha (22.6%), respectively.

Table 1. Productivity of crop rotations with different systems of fertilization and soil tillage in the polyfactorial experiment at the Research Institute of Field Crops "Selectia", average for 1996-2012, tons of cereal units/ha

Systems of fertilization	Crop rotation with perennial leguminous crops and grasses				Crop rotation without perennial leguminous crops and grasses			
	1*	2*	±	%	1*	2*	±	%
Unfertilized	4.18	4.02	-0.16	3.8	3.73	3.62	-0.11	2.9
Manure	4.61	4.45	-0.16	3.5	4.19	4.00	-0.19	4.5
±	+0.43	+0.43			+0.46	+0.38		
%	10.3	10.7			12.3	10.5		
Manure + NPK	4.74	4.65	-0.09	1.9	4.64	4.44	-0.20	4.3
±	+0.56	+0.63			+0.91	+0.82		
%	13.4	15.7			24.4	22.6		

*1 – combination of moldboard plow and nonreversible soil tillage; *2 – nonreversible soil tillage.

Similarly to previous systems of fertilization the nonreversible system of soil tillage has decreased the productivity of crop rotation with mixture of perennial leguminous crops and grasses on plots with manure + NPK on 0.09 t.c.u./ha (1.9%) and on 0.20 t.c.u./ha (4.3%) in crop rotation without perennial leguminous crops and grasses. It is evident the dominant influence of alternation of crops and soil fertilization on the productivity of crop rotations relatively to soil tillage.

The combination of moldboard plow and nonreversible soil tillage on crop rotation has advantages under the nonreversible system of soil tillage. We have evaluated also the share of crop rotation (relatively to permanent cropping), soil tillage and soil fertilization in yield formation for different crops in both experimental crop rotations – with and without perennial leguminous crops and grasses. Data for two full crop rotations are presented in table 2 and table 3. In crop rotation with the mixture of perennial leguminous crops and grasses the share of crop rotation and soil fertilization with manure and manure + NPK have consisted: on plots with combination of moldboard plow and nonreversible soil tillage: 2.14 t/ha (50.9%); 0 and 0.10 t/ha (2.3%), respectively; on plots with nonreversible system of soil tillage: 2.34 t/ha (55.6%); 0 and 0.12 t/ha (2.8%), respectively. For sugar beet: on plots with combination of moldboard plow and nonreversible soil tillage: 17.7 t/ha (50.3%); 3.8 t/ha (10.8%) and 5.2 t/ha (16.2%), respectively; on plots with nonreversible system of soil tillage: 16.5 t/ha (51.4%); 4.8 (13.6%) and 6.2 t/ha (19.3%), respectively.

For corn for grain: on plots with combination of moldboard plow and nonreversible system of soil tillage: 1.37 t/ha (26.6%); 0.09 t/ha (1.7%) and 0.22 t/ha (4.4%), respectively; on plots with nonreversible system of soil tillage: 1.30 t/ha (26.0%); 0.10 t/ha (1.9%) and 0.17 t/ha (3.4%). The share of soil tillage in yield formation is very low in crop rotation with the mixture of leguminous crops and grasses. The combination of moldboard more with nonreversible system of soil tillage has advantages under nonreversible system of soil tillage. It is practically negligible for winter wheat and corn for grain, being a little higher for sugar beet 5.2-8.8% on plots with combination of moldboard plow with nonreversible system of soil tillage. The situation is quite different in crop rotation without perennial leguminous crops and grasses (table 3).

The share of crop rotation and soil fertilization with manure and manure + NPK have consisted. For winter wheat: on plots with combination of soil tillage: 0.34 t/ha (14.2%); 0.40 t/ha (16.7%) and 1.31 t/ha (54.6%); on plots with nonreversible system of soil tillage: 0.45 t/ha (19.5%); 0.42 t/ha (18.2%) and 1.65 t/ha (62.3%). For sugar beet: on plots with combination of moldboard plow and nonreversible system of soil tillage: 11.4 t/ha (39.4%); 6.5 t/ha (22.5%) and 11.2 t/ha (38.1%); on plots with nonreversible system of soil tillage: 11.8 t/ha (43.1%); 5.8 t/ha (21.2%) and 8.9 t/ha (32.5%). For corn for grain: on plots with combination of moldboard plow and nonreversible soil tillage: 1.03 t/ha (21.4%); 0.25 t/ha (5.2%) and 0.32 t/ha (6.7%); on plots with nonreversible system of soil tillage: 1.03 t/ha (21.7%); 0.10 t/ha (2.1%) and 0.21 (4.4%).

The share of soil tillage in yield formation in crop rotation without mixture of perennial leguminous crops and grasses is also very low and practically negligible for winter wheat and corn for grain. The combination of moldboard plow and nonreversible system of soil tillage has advantages also under the nonreversible system of soil tillage.

Like in the previous crop rotation the share of soil tillage is higher in yield formation of sugar beet consisting on different systems of fertilization 1.5 t/ha (5.2%) – 3.8 t/ha (9.5%). By comparing experimental data from table 2 and table 3 it is possible to prove that the better is crop rotation the lower is the share of soil fertilization in yield formation and versa visa.

Changes in the content of soil organic matter during the last 10 years in the long-term field polyfactorial experiment are shown in table 4.

Table 2. The share of crop rotation with perennial leguminous crops and grasses, soil tillage and fertilization in yield formation for different crops in the long-term field polyfactorial experiment at the Research Institute of Field Crops "Selectia", average for two full rotations – 1996-2009, Balti, Republic of Moldova, t/ha and %

System of soil tillage	Yields on unfer-tilized plots	Yield increase from crop rotation		Yield increase from fertilization				Yield increase from soil tillage					
		±, t/ha	%	Manure		Manure + NPK		Unfertilized		Manure		Manure + NPK	
				±, t/ha	%	±, t/ha	%	±, t/ha	%	±, t/ha	%	±, t/ha	%
Winter wheat													
Combination of moldboard plow and nonreversible soil tillage	2.06	+2.14	50.9			+0.10	2.3	-0.01	0.2	+0.04	0.9	-0.04	0.9
Nonreversible soil tillage	1.86	+2.34	55.6	-0.05		+0.12	2.8						
Sugar beet													
Combination of moldboard plow and nonreversible soil tillage	17.5	+17.7	50.3	+3.8	10.8	+5.2	16.2	+3.1	8.8	+2.1	5.4	+2.1	5.2
Nonreversible soil tillage	15.6	+16.5	51.4	+4.8	13.6	+6.2	19.3						
Corn for grain													
Combination of moldboard plow and nonreversible soil tillage	3.78	+1.37	26.6	+0.09	1.7	+0.22	4.4	+0.14	2.7	+0.13	2.5	+0.19	3.5
Nonreversible soil tillage	3.71	+1.30	26.0	+0.10	1.9	+0.17	3.4						

Table 3. The share of crop rotation without perennial leguminous crops and grasses, soil tillage and fertilization in yield formation for different crops in the long-term field polyfactorial experiment at the Research Institute of Field Crops "Selectia", average for two full rotations – 1996-2009, Balti, Republic of Moldova, t/ha and %

System of soil tillage	Yields on unfer-tilized plots	Yield increase from crop rotation		Yield increase from fertilization				Yield increase from soil tillage					
		±, t/ha	%	Manure		Manure + NPK		Unfertilized		Manure		Manure + NPK	
				±, t/ha	%	±, t/ha	%	±, t/ha	%	±, t/ha	%	±, t/ha	%
Winter wheat													
Combination of moldboard plow and nonreversible soil tillage	2.06	+0.34	14.2	+0.40	16.7	+1.31	54.6	+0.09	3.7	+0.07	2.5	-0.25	
Nonreversible soil tillage	1.86	+0.45	19.5	+0.42	18.2	+1.65	62.3						
Sugar beet													
Combination of moldboard plow and nonreversible soil tillage	17.5	+11.4	39.4	+6.5	22.5	+11.2	38.1	+1.5	5.2	+2.2	6.2	+3.8	9.5
Nonreversible soil tillage	15.6	+11.8	43.1	+5.8	21.2	+8.9	32.5						
Corn for grain													
Combination of moldboard plow and nonreversible soil tillage	3.78	+1.03	21.4	+0.25	5.2	+0.32	6.7	+0.07	1.4	+0.22	4.3	+0.18	3.5
Nonreversible soil tillage	3.71	+1.03	21.7	+0.10	2.1	+0.21	4.4						

The highest ability to accumulate soil organic matter has crop rotation with the mixture of perennial leguminous crops and grasses on nonreversible system of soil tillage for all systems of fertilization, but especially for organic and organo-mineral systems of fertilization.

Combination of moldboard plow with nonreversible system of soil tillage in the same crop rotation contributes mainly to the accumulation of soil organic matter on plots with manure + NPK in both soil layers 0-20 and 20-40 cm.

The same tendency was established in crop rotation without mixture of perennial leguminous crops and grasses, but with a lower accumulation of soil organic matter in both soil layers.

Table 4. Soil organic matter content (%) in two crop rotations under the influence of different systems of fertilization and soil tillage, polyfactorial long-term field experiment at the Research Institute of Field Crops "Selectia", soil layers 0-20 and 20-40 cm, years 1999-2009, Balti, Republic of Moldova

Years	Soil layers, cm	Crop rotation with perennial leguminous crops and grasses						Crop rotation without perennial leguminous crops and grasses					
		Combination of moldboard plow and nonreversible soil tillage			Nonreversible soil tillage			Combination of moldboard plow and nonreversible soil tillage			Nonreversible soil tillage		
		Unferti-lized	Manure	Manure + NPK	Unferti-lized	Manure	Manure + NPK	Unferti-lized	Manure	Manure + NPK	Unferti-lized	Manure	Manure + NPK
1999	0-20	4.24	4.14	4.11	3.95	4.00	4.09	3.95	4.10	4.05	3.96	4.13	4.20
2009	0-20	3.97	4.18	4.51	4.13	4.32	4.41	3.94	4.12	4.19	4.07	4.23	4.38
±		-0.27	+0.04	+0.40	+0.18	+0.32	+0.32	-0.01	+0.02	+0.14	+0.11	+0.10	+0.18
1999	20-40	3.66	3.81	3.94	3.61	3.59	3.69	3.72	3.62	3.86	3.75	3.71	3.76
2009	20-40	3.22	3.82	4.36	3.82	3.94	4.04	3.51	3.73	3.98	3.51	3.90	3.82
±		-0.34	+0.01	+0.42	+0.21	+0.35	+0.35	-0.21	+0.11	+0.12	-0.24	+0.19	+0.06

4. Conclusions

Crop rotation with mixture of perennial leguminous crops and grasses are providing a higher level of productivity relatively to crop rotation without perennial field crops on all systems of soil tillage and fertilization in crop rotation. The combination of moldboard plow and nonreversible system of soil tillage has advantages under the nonreversible system of soil tillage in both crop rotations.

The share of soil tillage in yield formation is very low for winter wheat, sugar beet and corn for grain in both crop rotations, but the share of fertilization in yield formation for all crops is decreasing in crop rotation with the mixture of perennial leguminous crops and grasses.

The highest ability to accumulate soil organic matter in both soil layers 0-20 and 20-40 cm has crop rotation with the mixture of perennial leguminous crops and grasses on all systems of fertilization, especially by using the nonreversible system of soil tillage.

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