ALTERNATION OF CROPS, SOIL FERTILITY AND FERTILIZATION-CRUCIAL COMPONENTS FOR SUSTAINABLE DEVELOPMENT OF AGRICULTURE

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Abstract. *The article includes data from the long-term field experiments on chernozem soils from Balti steppe, Republic of Moldova regarding the efficiency of crop rotations and fertilization for different crops. It was established a lower efficiency of fertilization in crop rotation with higher diversity of crops. The share of soil fertilization in yield formation is increasing significantly in permanent crops. Higher yield potential for new, more intensive varieties of winter wheat can be achieved only in crop rotation with higher level of soil fertility. Respecting crop rotations and a proper management of soil fertility are the basis for transition to a more sustainable farming system in the Republic of Moldova.*

Key words: crop rotation, soil fertility, fertilization, sustainable agriculture, field crops.

1.Introduction

The industrialization of agriculture based on intensive use of inputs from nonrenewable sources of energy and their derivates have neglected the main agronomic laws (crop rotation; returning of nutrients and energy back in the soil; minimum, maximum and optimum etc). As a result many economic, ecologic and social consequences have appeared, which unfortunately are not evaluated properly or are externalized in the market economy, because of the dominated profit orientation.

Nevertheless, limited amount of nonrenewable sources of energy and increased prices for them, together with negative impact on the environment, including climate changes and health of people are reversing the industrial approach to agricultural intensification. This approach didn’t achieve a sustainable development of agriculture. That’s why many farmers and research organizations in all over the world are looking for alternatives to industrial model of agricultural intensification.

In this paper we present the results obtained in the long term field experiments with crop rotations and permanent crops, which are proving the significance of soil fertility and crop rotations for modern farming systems with less dependence from industrial inputs.

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2.Materials and Methods

Long-term field experiment with ten fields crop rotations was established in 1962 at the Research Institute of Field Crops "Selectia", Balti, Republic of Moldova. The experiment includes 8 crop rotations, in three repetitions, with different levels of saturation with raw crops – from 40 up to 70%. Simultaneously researches are conducted in permanent crops of winter wheat, corn for grain and black fallow on fertilized and unfertilized plots since 1965, without repetitions. The other permanent crops have been reestablished in 1984. Researches in a new long-term field experiment on ecological agriculture with seven fields began in 1989, which includes two crop rotations (with and without mixture of perennial leguminous crops and grasses) on four backgrounds of fertilization (without fertilization, manure, manure + PK and manure + NPK).

The size of the experimental plots in the long-term field experiment with different crop rotations consists 283 sq.m., in the experiment with permanent crops – 450 sq. m. and in the long-term field experiment on ecological agriculture - 220 sq.m.

More details regarding the design of the long-term field experiments can be found in our previous publications [1, 2].

The soils on the experimental field are represented by typical chernozem on heavy clay. The content of soil organic matter for 0-20 cm soil layer determined by Tiurin method consists – 4,8-5,0%; pH in water and salt extractions – 7,3 and 6,2 respectively; the total content of nitrogen, phosphorus and potassium – 0,21-0,25%, 0,09-0,11% and 1,22-1,28%, respectively; the content of mobile form phosphorus and potassium (by Ciricov method) – 130-150 and 160-180 mg/kg of soil, respectively.

The varieties and hybrids of cultivated crops are included in the Register of crops for the Republic of Moldova. The technologies of growing field crops are recommended for the Republic of Moldova.

3.Results and Discussions

Yields of field crops are higher in crop rotation with a larger diversity of crops, both on fertilized and unfertilized plots (tab.1). Unfortunately during the era of "green revolution" the number of fields in crop rotations and simultaneously the diversity of crops in crop rotations have been reduced up to monoculture. The expectations from narrow specialized crop rotations, with lower diversity of crops, have been related to higher rates of mineral fertilizers and pesticides for weed, pest and desease control.

Data from Table 1 A, B and C are proving the general tendency of higher relative yield increase under the influence of fertilization in permanent crops relatively to crop rotations with 7 and, especially, with 10 fields. So, yield increase from

organo-mineral fertilization in crop rotation relatively to permanent crops consisted, respectively:
-for winter wheat – 15.1-7.1% (0.67-0.27 t/ha) and 49.4% (0.89 t/ha)
-for sugar beet – 35.8-67.3% (10.58-14.24 t/ha) and 96.9% (7.64 t/ha)
-for corn for grain – 17.2-21.1% (0.84-0.91 t/ha) and 43.4% (1.49 t/ha)
-for sunflower – 80-23.6% (0.15-0.30 t/ha) and 13.9% (0.18 t/ha)
-for winter barley – 31.7-53.2% (0.92-1.17 t/ha) and 87.6% (1.48 t/ha)

Table 1A. The influence of fertilization in crop rotations and in permanent crops, average for 1994-2012, long-term field experiments at the Research Institute of Field Crops "Selectia", Balti, Republic of Moldova,
10 fields crop rotation

Crops	10 fields crop rotation			
	Unfert.	Fert	±, t/ha	%
Winter wheat	4.43	5.10	+0.67	15.1
Sugar beet	29.59	40.17	+10.58	35.8
Corn for grain	4.88	5.72	+0.84	17.2
Sunflower	1.87	2.02	+0.15	8.0
Winter barley	2.90	3.82	+0.92	31.7

Table 1B. The influence of fertilization in crop rotations and in permanent crops, average for 1994-2012, long-term field experiments at the Research Institute of Field Crops "Selectia", Balti, Republic of Moldova,
7 fields crop rotation

Crops	7 fields crop rotation			
	Unfert.	Fert	±, t/ha	%
Winter wheat	3.80	4.07	+0.27	7.1
Sugar beet	21.15	35.39	+14.24	67.3
Corn for grain	4.31	5.22	+0.91	21.1
Sunflower	1.24	1.57	+0.30	23.6
Winter barley	2.20	3.37	+1.17	53.2

Table 1C. The influence of fertilization in crop rotations and in permanent crops, average for 1994-2012, long-term field experiments at the Research Institute of Field Crops "Selectia", Balti, Republic of Moldova,
Permanent crops

Crops	Permanent crops			
	Unfert.	Fert	±, t/ha	%
Winter wheat	1.80	2.69	+0.89	49.4
Sugar beet	7.88	15.52	+7.64	96.9
Corn for grain	3.43	4.92	+1.49	43.4
Sunflower	1.30	1.48	+0.18	13.9
Winter barley	1.69	3.17	+1.48	87.6

The exception is sunflower, where the efficiency of fertilization is lower in permanent cropping than in crop rotations, which should serve as a subject for special studies.

We have determined also the effect of crop rotations on fertilized and unfertilized plots for different crops in the long-term field experiments with crop rotations and permanent crops at the Research Institute of Field Crops “Selectia” (Table 2 A and B).

Table .2 A. The effect of crop rotations for different crops on fertilized and unfertilized plots, average for 1994-2012, long-term field experiments at the Research Institute of Field Crops “Selectia”, Balti, Republic of Moldova

10 fields crop rotation

	10 fields crop rotation							
	Unfertilized				Fertilized			
	crop rotation, %	perma-nent crop-ping	±, t/ha	effect of crop rotation, %	crop rotation, %	perma-nent crop-ping	±, t/ha	effect of crop rotation, %
Winter wheat	4.43	1.80	+2.63	146.1	5.10	2.69	+2.41	89.6
Sugar beet	29.59	7.88	+21.71	275.5	40.17	15.52	+24.65	158.8
Corn for grain	4.88	3.43	+1.45	42.3	5.72	4.92	+0.80	16.3
Sunflower	1.87	1.30	+0.57	43.8	2.02	1.48	+0.54	36.5
Winter barley	2.90	1.69	+1.21	71.6	3.82	3.17	+0.65	20.5

Table .2 B. The effect of crop rotations for different crops on fertilized and unfertilized plots, average for 1994-2012, long-term field experiments at the Research Institute of Field Crops “Selectia”, Balti, Republic of Moldova

7 fields crop rotation

	7 fields crop rotation							
	Unfertilized				Fertilized			
	crop rotation, %	perma-nent crop-ping	±, t/ha	effect of crop rotation, %	crop rotation, %	perma-nent crop-ping	±, t/ha	effect of crop rotation, %
Winter wheat	3.80	1.80	+2.0	111.1	4.07	2.69	+1.38	51.3
Sugar beet	21.15	7.88	+13.27	168.4	35.39	15.52	+19.87	128.0
Corn for grain	4.31	3.43	+0.88	25.6	5.22	4.92	+0.30	6.1
Sunflower	1.27	1.30	-0.03	0	1.57	1.48	+0.09	6.1
Winter barley	2.20	1.69	+0.51	30.2	3.37	3.17	+0.20	6.3

The effect of crop rotation is the difference in yields between crop rotations and permanent crops for different crops both on fertilized and unfertilized plots.

The effect of crop rotation is significantly higher in crop rotation with 10 fields, than in crop rotation with 7 fields both on unfertilized and fertilized plots. So, the effect of crop rotation on unfertilized plots consisted for different crops in 10 and 7 fields crop rotations, respectively:

-for winter wheat – 2.63 t/ha (146.1%) and 2.0 t/ha (111.1%)
-for sugar beet – 21.71 t/ha (275.5%) and 13.27 t/ha (168.4%)
-for corn for grain – 1.45 t/ha (42.3%) and 0.88 t/ha (25.6%)
-for sunflower – 0.57 t/ha (43.8%) and -0.03 t/ha (0)
-for winter barley – 1.21 t/ha (71.6%) and 0.51 t/ha (30.2%)

The effect of crop rotation on fertilized plots in 10 and 7 fields crop rotations is lower than on unfertilized plots for different crops and consisted respectively:

-for winter wheat – 2.41 t/ha (89.6%) and 1.38 t/ha (51.3%)
-for sugar beet – 24.65 t/ha (158.8%) and 19.87 t/ha (128%)
-for corn for grain – 0.80 t/ha (16.3%) and 0.30 t/ha (6.1%)
-for sunflower – 0.54 t/ha (36.5%) and 0.09 t/ha (6.1%)
-for winter barley – 0.65 t/ha (20.5%) and 0.20 t/ha (6.3%).

Fertilizers are reducing the positive influence of crop rotation, but it stil remain high enough for winter wheat and sunflower, especially, in crop rotation with 10 fields. Less reactive to crop rotation are corn for grain and winter barley.

Crop rotation and soil fertilization are crucial in determining the share of soil fertility in yield formation (Table 3).

Table 3. The share of soil fertility in yield formation for different crops in the long-term field experiments at the Research Institute of Field Crops “Selectia”, average for 1994-2012, Balti, Republic of Moldova

Crops	10 fields crop rotation	7 fields crop rotation	Permanent cropping
Winter wheat	84.9	92.9	50.6
Sugar beet	64.2	32.7	3.1
Corn for grain	82.8	78.9	56.6
Sunflower	92.0	76.4	86.1
Winter barley	68.3	46.8	12.4

The higher is the diversity of crops in crop rotations, the higher is the share of soil fertility in yield formation for all crops, with the exception of sunflower. Permanent cropping is reducing soil functionality and as a results the share of soil fertility is decreasing, but the share of fertilization is increasing. It is cheaper from economic point of view to respect crop rotation with a higher diversity of crops than to compensate the lack of crop rotation by the excess of chemicals. By respecting crop rotation it is possible to prevent also degradation and pollution of soil and water resources.

As it was mentioned before, fertilization is less efficient in crop rotation with higher diversity of crops. Supplementary utilization of mineral fertilizers on plots with manure usually doesn’t provide an significant increase of yields for majority of crops (Table 4).

Table 4. Productivity of crops (t/ha) under the influence of different systems of fertilization in crop rotation on ecological agriculture, average for 1994-2012, Research Institute of Field Crops “Selectia”, Balti, Republic of Moldova

Crops	Unfert.	Manure			Manure + NPK		
		t/ha	±, t/ha	%	t/ha	±, t/ha	%
Winter wheat	3.71	4.12	+0.41	11.0	4.05	+0.34	9.2
Sugar beet	20.74	33.28	+12.54	60.5	34.95	+14.21	68.5
Corn for grain	4.59	5.09	+0.50	10.9	5.16	+0.57	12.4
Sunflower	2.36	3.05	+0.69	29.2	3.34	+0.98	41.5
Winter barley	1.27	1.45	+0.18	14.2	1.57	+0.30	23.6

So, respecting crop rotation and maintaining soil fertility by proper management of soil organic matter allow to cut the use of mineral fertilizers. This is true also for pesticides for weed, pest and desease control. Our recent researches have proved the negative influence of mineral fertilizers relatively to organic and organo-mineral fertilizers by a sharp reduction of the stocks of soil organic matter for the whole soil profile [3].

Transition to a more sustainable farming system can be achieved in a crop rotation with larger diversity of crops and proper management of soil organic matter in order to provide a good soil health (soil quality).

New varieties and hybrids of field crops are very important in increasing their productivity, but yields are determined mainly by the level of soil fertility. Experimental data obtained in the long-term field experiments for less intensive (Odesa 51) and more intensive (recently registered) varieties of winter wheat have demonstrated that new, more intensive varieties of winter wheat have provided an extra yield of 11.9 and 13.1% in crop rotation on unfertilized and fertilized plots, respectively (tab.5). In the same time the extra yield for new varieties of winter wheat in permanent crop have consisted only 5.9 and 2.3%, respectively on unfertilized and fertilized plots.

Table 5. The effect of new, more intensive varieties of winter wheat in crop rotation and in permanent crops, average for 1994-2012, long-term field experiments at the RIFC “Selectia”, Balti, Republic of Moldova

Crop rotations, permanent cropping	Unfertilized				Fertilized			
	New, more intensive varieties	Odesa 51	±, t/ha	%	New, more intensive varieties	Odesa 51	±, t/ha	%
Crop rotation	4.43	3.96	+0.47	11.9	5.10	4.51	+0.59	13.1
Permanent crop	1.80	1.70	+0.10	5.9	2.69	2.63	+0.06	2.3

It means that new, more intensive varieties of winter wheat with higher yield potential can achieve their potential only in good conditions of growing, where the requirements to the technology of growing are respected.

Conclusions

(1)The effect of fertilization is higher in permanent crops and lower in crop rotations with higher diversity of crops.
(2)The share of soil fertility in yield formation for majority of field crops is increasing in crop rotations with higher diversity of crops relatively to permanent crops. Crop rotations and manuring are reducing significantly the beneficial influence of mineral fertilizers on yields of field crops.
(3)In crop rotations with higher diversity of crops it is possible to reduce inputs of mineral fertilizers and pesticides for weeds, pests and deseases control, which makes agriculture more sustainable.
(4)Yield potential for new, more intensive varieties of winter wheat can be achieved only in crop rotations with higher diversity of crops and with proper management of soil fertility.

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