Effects of rotation and fertilization on Chernozem soils of Moldova

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Abstract
The dominant concept of technologic intensification of agriculture since the era of "green revolution" led to many negative consequences in economic, ecologic, energetic and social aspects. The results obtained in long-term experiments with different crop rotations and permanent crops at the Research Center "Selectia" Republic of Moldova have proved a high "effect of rotation" and the irreplaceable role of soil fertility on yield formation for the majority of crops. The importance of soil fertility on yield formation remains very high even for new varieties (hybrids) of crops and using optimal rates of mineral fertilizers and pesticides for weed, pest and disease control. Sustainable development of agriculture needs urgent structural changes in the existing farming systems on arable soils which in order to balance the processes of mineralization and humification of soil organic matter.

Key Words
Crop rotation, fertilization, soil fertility, soil organic matter.

Introduction
The technologic intensification of agriculture with increased rates of mineral fertilizers, new varieties (hybrids) of crops, new pesticides for weed, pest and disease control etc. led to the underestimation of crop rotations and organic fertilization, which are irreplaceable for restoring soil fertility. In other words, the main attention during technological intensification of agriculture was focused on increasing crop productivity without attention to soil fertility. Because of the non-observance of the principal laws of arable agriculture (crop rotation and returning energy, not only as NPK) agriculture is running into many ecological, energetical, economical and social problems, which do not allow achieve of sustainable development (Karlen *et al.* 1994; Lal 2001);. Agriculture needs both technological and structural changes in order to prevent the above mentioned problems (Herbert and Koepf 1992; Frederick and Kirschenman 2007). By respecting crop rotations, by integration of plant and animal husbandries, by ecological landscape management, etc. it would be possible to balance the mineralization and humification of soil organic matter as one of the most important particularities of arable farming.

Methods and results
Research have been conducted in long-term experiments with different crop rotations and permanent crops founded in 1962 in the northern part of Moldova (Balti steppe) on Chernozem soils. More details regarding methods and conditions of researches were described in our previous publications (Boincean 1999; Boincean 2009). Here we are presenting the results obtained during the last 15 years for both crop rotations and permanent crops, both on fertilized and unfertilized plots.

"The effect of rotation" means the difference between yields of crops in crop rotation and in permanent cropping expressed as percentages. The results obtained in our long-term experiments prove the importance of crop rotation even on fertilized plots, especially for winter wheat, sugar beets and sunflower (Table 1). All crops are receptive to crop rotation on unfertilized plots. It was supposed during the era of green revolution that chemicals (fertilizers, pesticides, new-more resistant crop varieties (hybrids)) would replace the agronomic significance of crop rotation. It was not the case. The effect of rotation remains very high even on fertilized plots. The other assumption during the era of total chemization of agriculture was that mineral fertilizers would certainly increase the level of yields, especially for the new varieties (hybrids) of crops. Data from Table 2 and 3 indicate on share of fertilization on yield formation for different crops in crop rotations with 10 and 7 fields and in permanent cropping. The higher the diversity of crops in crop rotation (10 fields comparatively with 7 fields crop rotations) the lower is the contribution of fertilization (organo-mineral fertilizers) to yield formation. The most receptive to fertilization are winter wheat, sugar beets and winter barley in both 10 and 7 fields crop rotations. For winter wheat we have determined the share of new varieties regularly registered in Moldova in yield formation comparatively with the variety Odesa 51, which was grown simultaneously in crop rotations after different predecessors and in permanent crop.

Table 1. Effect of rotation in the long-term experiment of the Research Center Selectia, Republic of Moldova, average for 1994-2008.

Crops	Unfertilized				Fertilized			
	Crop rotation (----------t/ha----------)	Permanent crop	±, t/ha	Effect of rotation, %	Crop rotation (----------t/ha----------)	Permanent crop	±, t/ha	Effect of rotation, %
Winter wheat	4,74	2,10	+2,64	125,7	5,10	2,99	+2,11	70,6
Sugar beets	34,07	9,56	+24,51	256,4	43,56	19,32	+24,24	125,5
Corn for grain	4,97	3,67	+1,3	35,4	5,36	5,13	+0,23	4,3
Winter barley	3,23	2,02	+1,21	59,9	3,93	3,69	+0,24	6,5
Sunflower	2,05	1,41	+0,64	45,4	2,16	1,51	+0,65	43,0

Table 2. Yields of different crops in 10 and 7 fields crop rotations on fertilized and unfertilized plots, Research Center "Selectia", average for 1994-2008, t/ha.

Crops	Crop rotations													
	10 field crop rotation										7 field crop rotation			
	Unfertilized			Fertilized			± from fertilizers		Share in the yield of		Un-ferti lized	Fer-tili-zed	± from ferti-lizers	Share of fertil.+ varie-ties
	Odesa 51	New varie-ties	±	Odesa 51	New varie-ties	±	Odesa 51	New variet	Varie-ties	Varie-ties+ fertil.				
Winter wheat (after vetch and oats for green mass)	4,18	4,74	+0,56	4,58	5,10	+0,52	+0,40	+0,36	13,4	22,0	3,98	A4,28	+0,30	7,5
Sugar beets		34,07			43,56			+9,49		27,8	24,76	38,95	+14,19	57,3
Corn for grain		4,97			5,36			+0,39		7,8	4,99	5,47	+0,48	9,6
Winter barley		3,23			3,93			+0,70		21,7	2,52	3,42	+0,90	35,7
Sunflower		2,05			2,16			+0,11		5,4	1,41	1,75	+0,34	24,1

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Table 3. Yields of permanent crops in the long-term experiment of the Research Center "Selectia", (Republic of Moldova) average for 1994-2008, t/ha.

Crops	Permanent crops									
	Unfertilized			Fertilized			± from fertilizers		Share in the yield of	
	Odesa 51	New varieties	±	Odesa 51	New varieties	±	Odesa 51	New varieties	varieties	varieties+ fertilizers
Inter wheat after vetch and oats for green mass	1,93	2,10	+0,18	2,94	2,99	+0,05	+1,01	+0,88	9,3%	54,9
Sugar beets		9,56			19,32			+9,76		102,1
Corn for grain		3,67			5,13			+14,6		39,8
Winter barley		2,02			3,69			+1,67		82,7
Sunflower		1,41			1,51			+0,10		7,1

The share of new varieties in yield formation of winter wheat is only 13,4% in 10 fields crop rotations and 9,3% in permanent cropping. New varieties of winter wheat react higher to the level of soil fertility than to increased rates of fertilizers. The share of fertilization in yield formation is significantly higher in permanent crop comparatively with both 10 and 7 fields crop rotations. The share of fertilization (together with the new varieties of winter wheat) in yield formation for different crops in crop rotation and permanent crop consists, accordingly:

Winter wheat – 7,5-22,0 and 54,9%
Sugar beets – 27,8-57,3 and 102,1%
Corn for grain – 7,8-9,6 and 39,8%
Winter barley – 21,7-35,7 and 82,7%
Sunflower – 5,4-24,1 and 7,1%

Therefore, the better is the crop rotation the lower is the share of fertilization in yield formation and vice versa. In other words, we have to compensate the lack of crop rotation by higher rates of mineral fertilizers and pesticides. This is problematic from economic and ecological points of view like also for people's and animal's health. The share of soil fertility in yield formation for different crops varieties in crop rotation and permanent cropping consists, accordingly:

Winter wheat – 92,5-78,0 and 45,1%
Sugar beets – 72,2-42,7 and 0%
Corn for grain – 92,2-90,4 and 60,2%
Winter barley – 78,3-64,3 and 17,3%
Sunflower – 94,6-75,9 and 92,9%

It is evident the predominance of soil fertility in yield formation in crop rotation. Data from our long-term experiments proves also the same level of yield for different crops under the influence of organic and organo-mineral fertilization, but organic fertilizers have indisputable advantages in restoring the stocks of soil organic matter in arable cernoziom soils.

Conclusions

1. "The effect of rotation" remain high enough even by extending new varieties of crops on fertilized plots.
2. The share of new varieties of winter wheat in yield formation is higher in crop rotation than in permanent crop and consists only 13,4 and 9,3%, accordingly. New varieties of winter wheat react more to the level of soil fertility than to the fertilization of crop.
3. The higher is the diversity of crops in crop rotation the lower is the share of fertilization in yield formation.
4. The share of fertilization in yield formation is significantly higher in permanent crop relatively to crop rotation for majority of crops. Accordingly, the share of soil fertility in yield formation is higher in crop rotation and lower in permanent crop. By respecting crop rotations it is possible to cut the dependence of farms from chemicals and to prevent simultaneously the pollution and degradation of the environment.
5. Agriculture needs both technologic and, especially, structural changes in order to increase the diversity of crops in crop rotations and integration of animal and crop husbandries for more efficient restoration of soil fertility.

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