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INFLUENCE OF CROP ROTATION AND LONG-TERM FERTILIZATION ON WHEAT AND MAIZE YIELD AND SOIL FERTILITY IN THE MOLDAVIAN PLAIN

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ABSTRACT- Investigations, set up in 1968, were carried out on a Cambic Chernozem with a slope of 14%. They have shown the influence of different crop rotations and fertilization on soil erosion and fertility. The mean yield increases in wheat, during 1980-2007, were between 23 and 26 % (646 – 736 kg ha^{-1}), due to crop rotation and between 57 and 101 % (1099 – 1949 kg ha^{-1}), due to applied fertilizer rates. On slope lands from the Moldavian Plain, a good supply in mobile phosphorus for field crops (37-72 mg kg^{-1}) was kept in case of the annual application of a rate of $N_{100}P_{80}$, and a very good supply in mobile phosphorus (69-78 mg kg^{-1}) and mobile potassium (over 200 mg kg^{-1}) was found at a rate of $N_{60}P_{40}$+30 t ha^{-1} of organic manure, applied in 3 or 4 -year crop rotations with legumes and perennial grasses. The total carbon mass on Cambic Chernozem from the Moldavian Plain has registered significant increases at higher than $N_{140}P_{100}$ rates, at organo-mineral fertilization and in 4-year crop rotation + reserve field cultivated with perennial grasses and legumes. In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in organo-mineral fertilization, in 4-year crop rotation + reserve field cultivated with perennial grasses and legumes, and at $N_{140}P_{100}$ fertilization. The mean annual losses of nitrogen, phosphorus and potassium, once with water runoff and eroded soil on 14% slope fields were of 19.9 kg ha^{-1} in maize continuous cropping, 11.9 kg ha^{-1} in wheat-maize rotation and 8.1 kg ha^{-1} in rotation peas-wheat-maize-sunflower + two reserve fields cultivated with perennial grasses and legumes.

Key words: soil erosion, crop rotation, fertilization, wheat, organic matter, manure

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REZUMAT - Influenţa rotaţiei culturilor si a fertilizării de lungă durată asupra producţiei de grâu şi porumb şi a fertilităţii solului în Câmpia Moldovei. Experimentele au fost înfiinţate în 1968 pe un sol cernoziom cambic, având panta de 14%. Ele au urmărit influenţa diferitelor rotaţii şi a fertilizării asupra eroziunii solului şi a fertilităţii. In perioada 1980-2007, sporurile medii de producţie la grâu au fost cuprinse între 23 şi 26 % (646 – 736 kg ha^{-1}), datorită rotaţiei culturilor, şi între 57 şi 101 % (1099 – 1949 kg ha^{-1}), datorită dozelor de îngrăşăminte aplicate. Pe terenurile în pantă din Câmpia Moldovei, menţinerea unui nivel optim de aprovizionare cu fosfor mobil în sol, la culturile de câmp (37-72 mg kg^{-1}), s-a inregistrat în cazul aplicării anuale a dozei de $N_{100}P_{80}$; un nivel foarte bun de aprovizionare cu fosfor mobil (69-78 mg kg^{-1}) şi potasiu mobil (peste 200 mg kg^{-1}) s-a constatat la doza de $N_{60}P_{40}$+30 t ha^{-1} îngrăşământ organic, aplicat în cazul rotaţiilor de 3 sau 4 ani cu leguminoase şi ierburi perene. Conţinutul total de carbon la cernoziomul cambic din Câmpia Moldovei a înregistrat creşteri semnificative la doze mai mari de $N_{140}P_{100}$, în cazul fertilizării organo-minerale şi al rotaţiei de 4 ani + sola cultivată cu ierburi şi leguminoase perene. La monocultura de porumb şi la rotaţia grâu-porumb s-au înregistrat valori foarte semnificative ale conţinutului de carbon doar în cazul fertilizării organo-minerale, al rotaţiei de 4 ani + sola cultivată cu ierburi şi leguminoase perene şi al aplicării dozei de $N_{140}P_{100}$. Pierderile medii anuale de azot, fosfor şi potasiu, împreună cu scurgerile de apă şi pierderile de sol au fost de 19.9 kg ha^{-1} la monocultura de porumb, 11.9 kg ha^{-1} în cazul rotaţiei grâu-porumb şi 8.1 kg ha^{-1} la rotaţia mazăre-grâu-porumb-floarea soarelui + două sole cultivate cu ierburi şi leguminoase perene.

Cuvinte cheie: eroziunea solului, rotaţia culturilor, fertilizare, grâu, substanţă organică, îngrăşământ natural

INTRODUCTION

In many countries, the most recent research has investigated the diversification of cropping systems by increasing the rate of annual and perennial legumes within crop structure (Dalgliesh, 2007; Russell, 2006; Byrne et al., 2007).

The investigations conducted in long-term experiments at Rothamsted have shown that only at high fertilizer rates (>$N_{192}P_{35}K_{90}Mg_{35}$), a significant increase was found in the mass of total organic carbon and stable carbon from soil. The results have shown that all the nitrogen treatments (96, 144, 192, 240 and 288 kg ha^{-1}) determined the increase in the mass of instable carbon, compared to the unfertilized variant or to the one fertilized with $P_{35}K_{90}Mg_{35}$. Only at high nitrogen rates (192, 240, 288 kg ha^{-1}), significant increases of total carbon and stable carbon were registered (Blair et al., 2006). The diminution in the mass of organic carbon from soil, when lower rates than 180 kg N ha^{-1} were applied, was also noticed under long-term experiments carried out on sandy loam Mollisol from Nashua (set up in 1979) and on clayey-loam Mollisol from Kanawha (set up in 1954), in North Iowa, USA. In sandy loam Mollisol from Nashua, applying a rate of 270 kg N ha^{-1} has resulted in increasing the mass of organic carbon against the unfertilized control, from 18.3 to 20.0 g C kg^{-1} soil, in maize-soybean rotation and from 22.7 to 23.6 g C kg^{-1} soil in maize-maize-oats-alfalfa rotation.

In clayey-loam Mollisol from Kanawha, the value of the organic carbon mass has increased from 33.3 to 37.3 g carbon kg^{-1} soil, when using the rate of 270 kg ha^{-1} N against the unfertilized control, only in maize-oats-alfalfa-alfalfa rotation (Russell, 2006).

In the experiments set up in 1962 on fluvi-calcaric Cambisol from the University of Padova, with sandy-loam texture, the mineral fertilization with rates of 140, 140, 180 kg ha^{-1} N, P_2O_5, K_2O has determined the pH diminution from 7.84 to 7.74 as compared to the unfertilized control. Soil acidification caused by mineral fertilization was due to the absorption of the ammonium ion by plants or its nitrification. These processes are known to produce hydrogen ions (Morari et al., 2008). The 20 t ha^{-1} manure fertilization (mean composition 20% DM, 0.5% N, 0.25% P_2O_5, 0.7% K_2O) + mineral fertilizers (100 kg N ha^{-1} $year^{-1}$–50 P_2O_5–140 K_2O) have resulted in increasing the mobile phosphorus content until 61.7 mg P kg^{-1} against the unfertilized control (16.9 mg P kg^{-1}). Under these fertilization conditions, the content of mobile potassium from soil has increased from 119.0 mg K kg^{-1}, under unfertilized, to 286.3 mg K kg^{-1}. In the Big Creek hydrographical basin from Southern Illinois, with mean annual rainfall of 1220 mm, the mean content of organic carbon has decreased after 154 years, from 6.95 to 2.03 kg C m^{-2} in farming fields (during 1851 - 2005), and from 5.61 la 5.19 kg C m^{-2} in afforested areas. In the forested areas, until 1938, and used for cropping in the last 67 years (1938-2005), the content of organic carbon has decreased from 6.76 to 3.40 kg C m^{-2} (Yadav et al., 2008).

On sandy clayey fields from Foulum and Flakkebjerg in Denmark, where in the last 25 years they used mainly spiked cereals rotations, the content of organic carbon diminished by approximately 7% and 15% , respectively (Schjønning et. al., 2007). On clayey loam Cambisols from Texas, under conventional soil tillage, the content of organic carbon has decreased by 11.3 g C kg^{-1} at depth of 0-5 cm and by 2.3 g C kg^{-1} at depth of 30 -55 cm. At these two depths, the mean content of organic carbon diminished by 0.18, 0.24 and 0.23 g C kg^{-1} in continuous wheat, wheat–soybean, and sorghum-wheat–soybean rotation, respectively (Wright et al., 2007) .

MATERIALS AND METHODS

Since 1968, the investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei have followed the influence of different crop structures, rotations and fertilizers on crop yield and soil fertility. These experiments were carried out on a 14% slope field, on a Cambic Chernozem with clayey loam texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrient supply.

The soil on which physical and chemical analyses were done, was sampled at the end of plant growing. Soil response was determined in water suspension by potentiometrical means with glass electrode. The organic carbon content was determined by the Walkley-Black method, the mobile phosphorus content from soil was determined by the Egner-Riechm Domingo method, in solution of ammonium acetate-lactate (AL), and potassium was measured in the same extract of acetate-lactate (AL) at flame photometer. ANOVA was used to compare the effects of treatments.

The determination of water runoff, soil, humus and nutritive element losses by erosion in different crops was done by means of loss control plots, which are isolated from the rest of the area by metallic walls and have basins and devices for division. We took water and soil samples from plots, for determining the partial turbidity and for analyses on chemical elements.

The rainfall amounts registered during 1980-2007 (January-June) were greater, as compared to the average of the last 80 years (248.4 mm), with values between 20.4 and 140.2 mm in 16 years, and lower by 38.3-119.0 mm, in 12 years. The rainfall amounts registered in the last 28 years, during September-November, have determined normal conditions for wheat growing in 15 years, and were lower, compared to the multiannual mean (127.0 mm), in 13 years. During 1980-2007, the climatic conditions were favourable to plant growing and development, for 16 years in wheat and 18 years in maize. The mean annual rainfall amounts, registered in the last 28 years, were higher, with values comprised between 12.7 and 279.2 mm, compared to the multiannual mean on 80 years (544 mm) in 18 years, and lower by 25.3-236.7 mm in 10 years. Between January and September, the average rainfall amounts, registered in the last 80 years, were of 424.9 mm. During 1980-2007, drought has affected maize crop in 10 years, when differences were between 38.0 (1997) and 162.2 mm (1994), against the multiannual mean.

RESULTS AND DISCUSSION

The investigations carried out on eroded soil have tried to establish the crop rotations and fertilization systems, which contributed to maintain and restore soil fertility. Placing winter wheat in 3 and 4- year crop rotations with annual and perennial legumes has resulted in getting yield increases of 23 – 26% (646 – 736 kg ha^{-1}), as compared to continuous cropping. The mean yield increases in wheat, during 1980-2007, were between 23 and 26% (646 – 736 kg ha^{-1}), due to crop rotation and between 57 and 101% (1099 – 1949 kg ha^{-1}), due to applied fertilizer rates (*Table 1*).

Applying high fertilizer rates ($N_{140}P_{100}$) in maize has determined, in the last 28 years, an average yield increase of 86% (2837 kg ha^{-1}), while the use of low mineral fertilizer rates ($N_{60}P_{40}$), together with 30 t ha^{-1} of organic manure, resulted in getting an yield increase of 89% (2925 kg ha^{-1}) (*Table 2*). The mean yield increases, obtained in maize during 1980-2007, were between 13 and 31% (564 – 1364 kg ha^{-1}), due to crop rotation and between 35 and 89 % (1150 – 2925 kg ha^{-1}), due to applied fertilizer rates.

Table 1 - Influence of rotation on wheat and maize yield during 1980 – 2007

Crop rotation	Wheat yield		Dif.	Sign.	Maize Yield		Dif.	Sign.
	kg ha^{-1}	%	kg ha^{-1}		kg ha^{-1}	%	kg ha^{-1}	
Continuous cropping	2864	100	0		4398	100		
Wheat – maize	2898	101	34		4962	113	564	x
Peas –wheat-maize	3510	123	646	xxx	5380	122	982	xxx
Peas –wheat-maize– sunflower + reserve field cultivated with legumes and perennial grasses	3600	126	736	xxx	5762	131	1364	xxx
LSD 5%			194				459	kg ha^{1}
LSD 1%			365				622	kg ha^{1}
LSD 0.1%			577				834	kg ha^{1}

Table 2 - Influence of fertilizers on wheat and maize yield during 1980 – 2007

Crop rotation	Wheat yield		Dif.	Sign.	Maize Yield		Dif.	Sign.
	kg ha^{-1}	%	kg ha^{-1}		kg ha^{-1}	%	kg ha^{-1}	
N_0P_0	1936	100	0		3283	100	0	
$N_{60}P_{40}$	3035	157	1099	***	4433	135	1150	***
$N_{100}P_{80}$	3455	178	1519	***	5585	170	2302	***
$N_{140}P_{100}$	3780	195	1844	***	6120	186	2837	***
$N_{60}P_{40}$+30 t ha^{-1} manure	3885	201	1949	***	6208	189	2925	***
LSD 5%			224				532	kg ha^{-1}
LSD 1%			395				720	kg ha^{-1}
LSD 0.1%			607				955	kg ha^{-1}

Most of investigations have shown that on eroded slope lands, soil should be improved with organic and mineral fertilizers, which restored soil fertility, while crop fertilization assured the stability of yields in the planned crop rotation. Investigations conducted by Allmaras (2006) on loam-sandy soils from Rosemount, Minnesota, have shown that applying rates of 200 kg ha^{-1} nitrogen as ammonium sulphate has contributed to the increase in organic residues from soil. They found that at the conventional tillage system, the humification coefficient was of 0.11 and determined the increase in the organic carbon content by 20% as compared to unfertilized control. The use of wheat continuous cropping on slope Vertic Cambisols has diminished the content of organic carbon, at depth of 0-40 cm, in comparison with perennial grasses, from 15.0 g kg^{-1} to 8.3 g kg^{-1} in Southern Italy (Catanzaro, Calabria) and from 19.0 g kg^{-1} to 12.7 g kg^{-1} in the centre of Italy (Siena, Tuscany) (Papini, 2007). The diminution in the content of organic carbon has resulted in decreasing the capacity of cation exchange, in soil pH and supplying plants with mineral elements. The mass of total carbon from Cambic Chernozem in the Moldavian Plain has registered significant increases at higher than $N_{140}P_{100}$ rates, in organo-mineral fertilization and in 4-year crop rotation, which included breeder plants of perennial grasses and legumes (*Table 3*). In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in the organo-mineral fertilization, in 4-year crop rotations + reserve field cultivated with perennial legumes and under $N_{140}P_{100}$ fertilization. The analyses conducted on soil samples, taken from the field on which wheat-maize rotation had been used for 40 years, pointed out the worsening of some soil chemical characteristics. In comparison with 4-year crop rotations, in wheat-maize rotation with breeder plants (annual and perennial legumes and perennial grasses), the mean carbon content from soil has diminished from 18.6 to 16.4 C, g kg^{-1}, and the content in mobile phosphorus decreased from 51.6 to 36.8 P-AL, mg kg^{-1}.

Table 3 - Influence of long-term fertilization and crop rotation on carbon mass from soil (C, g/kg^{-1})

Treatment	Mcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Average	%	Dif.
N_0P_0	15.9	15.2	16.5	16.8	16.1	100	0
$N_{60}P_{40}$	15.7	14.8	16.9	17.1	16.1	100	0.0
$N_{100}P_{80}$	16.4	16.2	17.3	18.2^{x}	17.0	106	0.9
$N_{140}P_{100}$	17.2	17.0^{x}	18.5^{xx}	19.7^{xxx}	18.1	112	2.0^{x}
$N_{60}P_{40}$+30 t ha^{-1} manure	19.4^{xxx}	19.0^{xxx}	20.1^{xxx}	21.4^{xxx}	20.0	124	3.9^{xxx}
Mean	16.9	16.4	17.9	18.6			
Difference	0.0	-0.5	1.0	1.7^{xx}			
	Interaction	**Crop rotation**		**Soil background**			
LSD 5%	1.2	1.4		1.5			
LSD 1%	1.6	1.8		2.1			
LSD 0.1%	2.1	2.4		2.7			

Mcc – Maize continuous cropping; M-maize; W-wheat; P-pea; S- sunflower;
*GL- reserve field cultivated with perennial grasses and legumes

Applying a rate of $N_{140}P_{100}$ for 40 years has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) in wheat continuous cropping and wheat-maize rotation and was maintained within the weakly acid interval (5.9-6.8) in 3 and 4- year crop rotations with annual and perennial legumes (*Table 4*). The differences concerning the pH value at different crop rotations had no significant values, but in 3 and 4 –year crop rotations with perennial grasses and legumes, pH diminution, when applying high nitrogen rates, was limited to 6.1-6.2. The lowest pH values were registered in wheat-maize rotation, where long-term applying of $N_{100}P_{80}$ and $N_{140}P_{100}$ rates has diminished pH until 5.9 and 5.6, respectively.

Table 4 - Influence of long-term fertilization and crop rotation on soil response (pH-0-20 cm) in the Cambic Chernozem from the Moldavian Plain

Treatment	Wcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Mean background	Dif.	Signif.
N_0P_0	7.1	6.9	7.1	7.2	**7.1**	0.00	
$N_{60}P_{40}$	6.9	6.7	6.9	6.9	**6.9**	-0.25	
$N_{100}P_{80}$	6.5^{x}	5.9^{xx}	6.5^{x}	6.7	**6.4**	-0.70	x
$N_{140}P_{100}$	5.7^{xxx}	5.6^{xxx}	6.1^{xx}	6.2^{xx}	**5.9**	-1.20	xxx
$N_{60}P_{40}$+30 t ha^{-1} manure	7.0	6.9	7.0	7.0	**7.0**	-0.13	
Crop rotation Mean	**6.6**	**6.4**	**6.7**	**6.8**	**6.6**		
Difference	0	-0.2	0.12	0.2			
Significance							
	Interaction	**Crop rotation**	**Soil background**				
LSD 5%	0.32	0.43	0.52				
LSD 1%	0.55	0.69	0.82				
LSD 0.1%	0.84	1.02	1.19				

Wcc – Wheat continuous cropping; M-maize; W-wheat; P-peas; S- sunflower;
*GL- reserve field cultivated with perennial grasses and legumes

Table 5 - Influence of long-term fertilization and crop rotation on the content of mobile phosphorus from soil (P-AL, mg kg^{-1})

Treatment	Wcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Mean background	Dif.	Signif.
N_0P_0	13	10	14	15	**13.0**	0	
$N_{60}P_{40}$	29	26	35	40	**32.5**	19.5	xxx
$N_{100}P_{80}$	41	38	49	56	**46.0**	33.0	xxx
$N_{140}P_{100}$	58	52	63	69	**60.5**	47.5	xxx
$N_{60}P_{40}$+30 t ha^{-1} manure	67	58	69	78	**68.0**	55.0	xxx
Crop rotation Mean	**41.6**	**36.8**	**46.0**	**51.6**	**44.0**		
Difference	0	-4.8	4.4	10.0			
Significance		0	x	xxx			
	Interaction	**Crop rotation**	**Soil background**				
LSD 5%	3.3	3.8	4.3				
LSD 1%	4.4	5.1	5.7				
LSD 0.1%	5.8	6.7	7.5				

Wcc – Wheat continuous cropping; M-maize; W-wheat; P-peas; S- sunflower;
*GL- reserve field cultivated with perennial grasses and legumes

In Cambic Chernozem, on the slope lands from the Moldavian Plain, a good supply in mobile phosphorus of field crops (37-72 mg kg^{-1}) was maintained in annual application of a rate of $N_{100}P_{80}$ and a very good supply (69-78) at the rate of $N_{60}P_{40}$+30 t ha^{-1} of manure, applied in crops from 3 or 4 –year crop rotations with perennial grasses and legumes (*Table 5*). After 40 years of testing, the lowest rate of mobile phosphorus accumulation in soil was registered in wheat-maize rotation, and the highest one, in 3 and 4- year crop rotations, including annual and perennial legumes, which leave in soil easily degradable crop residues.

Johnston A.E., 2001 found out that barley cultivated on a soil with 300 mg kg^{-1} exchangeable K had a daily plant consumption of almost 6 kg K ha^{-1}, while barley cultivated on a weakly supplied soil in mobile potassium (50 mg kg^{-1}) has extracted the tenth part of the maximum rate proper to a good plant supply of potassium (0.5 kg K ha day^{-1}).

Table 6 - Influence of long-term fertilization and crop rotation on the content of mobile potassium from soil (K-AL, mg kg^{-1})

Treatment	Wcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Mean background	Dif.	Signif.
N_0P_0	210	189	226	200	206	0	
$N_{60}P_{40}$	176	164	192	188	180	-26	00
$N_{100}P_{80}$	189	173	190	183	184	-22	0
$N_{140}P_{100}$	204	182	210	189	196	-10	
$N_{60}P_{40}$+30 t ha^{-1} manure	286	267	294	298	286	80	xxx
Crop rotation Mean	**213**	**195**	**222**	**212**			
Difference	0	-18	9	-1			
Significance		0					
	Interaction	**Crop rotation**	**Soil background**				
LSD 5%	11	14	16				
LSD 1%	17	20	23				
LSD 0.1%	24	28	33				

Wcc – Wheat continuous cropping; M-maize; W-wheat; P-peas; S- sunflower;
*GL- reserve field cultivated with perennial grasses and legumes

The plant supply of mobile potassium from Cambic Chernozem, which is well supplied with mobile potassium, is done from soil stock, organic residues and, especially, from manure. The analyses on the mobile potassium content from soil have shown that in all the tested crop rotations, the supply condition was good (133-200 mg kg^{-1}) in case of mineral fertilization and very good (over 200 mg kg^{-1}) in case of fertilization with $N_{60}P_{40}$+30 t ha^{-1} of manure (*Table 6*). The mobile potassium supply in wheat-maize rotation was lower because of the high potassium consumption by these crops and of unfavourable conditions of soil structure, which influenced the mobile potassium supply from soil stock. In case of applying high rates of nitrogen and phosphorus fertilizers, a tendency of diminution in the content of mobile potassium from soil was found, which could be explained by the high potassium exportation from soil once with the harvest.

The investigations conducted on 14% slope fields, by means of control erosion plots, have shown that the mean annual nitrogen losses caused by erosion were between 16.3 and 16.6 kg ha^{-1} in row crops and between 1.48 and 3.43 kg ha $year^{-1}$ in peas and wheat crops. The use of 3 or 4- year crop rotations with perennial grasses and legumes, which leave in soil great amounts of roots and crop residues, also contributes to the diminution of soil, humus and mineral element losses; these are 2.5 times lower compared to the ones registered in maize and sunflower crops (*Table 7*).

Table 7 - Mean annual erosion losses of humus and mineral elements from different crop rotations in the Moldavian Plain, during 1980-2007

Crop rotation	Eroded soil (t ha^{-1})	Humus (kg ha^{-1})	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Total NPK
Maize continuous cropping	9.268	329	16.644	1.038	2.317	19.999
Wheat-maize	5.421	193	10.036	0.607	1.356	11.999
Peas –wheat-maize	3.703	132	7.183	0.415	0.926	8.524
*P-W-M-S+GL	4.317	154	7.8	0.489	1.069	9.358
*P-W-M-S+ 2 GL	3.517	132	6.758	0.421	0.919	8.098

*Wcc – Wheat continuous cropping; M-maize; W-wheat; P-pea; S- sunflower;
*GL- reserve field cultivated with perennial grasses and legumes.

CONCLUSIONS

On the Cambic Chernozem from the Moldavian Plain, placing winter wheat and maize in rotation peas-wheat-maize-sunflower + reserve field cultivated with perennial grasses and legumes, has resulted in getting yield increases of 26% (736 kg ha^{-1}) and 31% (1364 kg ha^{-1}), respectively, against continuous cropping.

Applying the rate of $N_{140}P_{100}$ for 40 years has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) in wheat continuous cropping and wheat-maize rotation, and was maintained within the weakly acid interval (5.9-6.8) in 3 and 4 –year crop rotations with annual and perennial legumes.

The total carbon mass on Cambic Chernozem from the Moldavian Plain has registered significant increases at higher than $N_{140}P_{100}$ rates, at organo-mineral fertilization and in 4-year crop rotation + reserve field cultivated with perennial grasses and legumes. In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in organo-mineral fertilization, in 4-year crop rotation + reserve field cultivated with perennial legumes, and at $N_{140}P_{100}$ fertilization.

The mean annual losses of nitrogen, phosphorus and potassium, once with water runoff and eroded soil on 14% slope fields, were of 19.9 kg ha^{-1} in maize continuous cropping, 11.9 kg ha^{-1} in wheat-maize rotation and 8.1 kg ha^{-1} in the rotation peas-wheat-maize-sunflower + two reserve fields cultivated with perennial grasses and legumes.

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