INVESTIGATION ON THE INFLUENCE OF CROP ROTATION AND FERTILIZATION ON WHEAT YIELD, SOIL EROSION AND FERTILITY IN MOLDOVA PLAIN

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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.

Applying high mineral fertilizer rates (N_{140} P_{100}) has resulted, after 39 years of experiencing, in getting average yield increases (in comparison with unfertilized control) of 1657 kg/ha in wheat continuous cropping, 1736 kg/ha in wheat - maize rotation and 2085 kg/ha in peas - wheat - maize - sunflower + reserve field cultivated with legumes and perennial grasses. On slope lands from the Moldavian plain, maintaining a good supply in mobile phosphorus for field crops (37 - 72 mg/kg) was done in case of the annual application of a rate of $N_{100}P_{80}$, and a very good supply in mobile phosphorus (69 - 78) and mobile potassium (over 200 mg/kg) was found at a rate of N_{60} P_{40} + 30 t/ha manure, applied in 3 or 4 - year crop rotations with legumes and perennial grasses.

After 39 years of using different rotations, the humus content from soil, in case of high fertilizer rates (N_{140} P_{100}), was between 2.93 % in wheat-maize rotation and 3.38 % in peas - wheat - maize - sunflower + reserve field cultivated with legumes and perennial grasses.

The mean annual losses of nitrogen, phosphorus and potassium, once with runoff water and eroded soil on 14 % slope fields were of 19.9 kg/ha in maize continuous cropping, 11.9 kg/ha in wheat - maize rotation and 8.1 kg/ha in crop rotation peas - wheat - maize - sunflower + 2 reserve fields cultivated with perennial grasses and legumes.

***Keywords**: cropping system, fertilization, erosion, wheat, yield, soil fertility.*

The investigations carried out on eroded land have tried to establish crop rotations and fertilization systems, contributing to maintain and restore soil fertility. Most of investigations demonstrate that on eroded slope lands, they must achieve soil improvement fertilization with organic and mineral fertilizers, which restore soil fertility and crop fertilization which ensure the stability of yields of the planned crop rotation.

The organo-mineral fertilization of eroded luvisol and phaeosioms from the Transylvanian Plain has resulted in improving soil agro-physical and agro-chemical parameters, with positive effects on water runoff and soil losses, which diminished by 20-42% and 12.8-33%, respectively, and on humus content from soil, which has increased by 9-29% at depth of 0-30 cm [5]. Applying mineral fertilizers on eroded fields from the Transylvanian Plain ($N_{100}P_{100}K_{100}$) has determined, in comparison with the unfertilized variant, getting yield increases, comprised between 33.1 and 62.4% in maize and between 56.9 and 131.5% in wheat, according to soil type. Under the same conditions, the fertilization with only 20 t/ha manure has resulted in getting yield increases, comprised between 42.9 and 55.7% in maize and between 14.0 and 46.5 % in wheat, according to soil type. At the same time, on these fields, once with the growth of crop rotation duration, the yields obtained in 3 and 4 -year crop rotations were higher against the 2 -year crop rotation by 12-25% in wheat, by 27-29% in maize and by 11-26% in soybean.

The investigations conducted at Moara Domneasca on a reddish preluvosol have found that the average yield increases obtained under dry weather conditions, during 2005-2006, at 4-year crop rotation (sunflower-wheat-maize-maize) with alfalfa cultivated on reserve field, were of 6.2% in wheat and 13.2% in maize (in comparison with wheat-maize rotation) [14]. The 4- year crop rotation with reserve field has determined the increase in total soil porosity by 9.7% and in the rate of hydrostable aggregates by 33.9% (in comparison with wheat-maize rotation). The lowest values of the organic carbon content from soil were registered in maize continuous cropping (1.24%-1.26%), and the highest ones in 3 -year (soybean-wheat-maize) and 4 - year crop rotations (peas-wheat-beat-maize).

The positive effect of crop rotations which include legumes and perennial grasses, on physical characteristics and the content of organic matter from soil, was also signaled by [2, 4], who have found out the increase in the content of mobile carbon within these crop rotations and the diminution in the organic matter from soil in wheat continuous cropping. The crops with a less developed root system need a balanced fertilization with mineral elements, compared to the plants which root system explores a greater soil bulk.

The investigations carried out in long-term experiments situated under different climate and soil conditions, with different crop structures have tried to establish the fertilizer rates which ensure getting efficient yield increases from the economic point of view and determine the maintenance of increase in organic carbon content from soil.

Many investigations conducted in different countries have shown that applying low rates of mineral fertilizers with nitrogen, phosphorus and potassium in wheat and maize continuous cropping and wheat-maize rotation has determined the diminution in the content of organic matter from soil. The diminutions in the content of organic carbon from soil, due to mineral fertilization, was found in loam -sandy fields from Nashua, USA, where lower than 180 kg nitrogen/ha were applied in maize-soybean rotation [13] and in clayey loam soils from Rothamsted, England, where lower rates than $N_{192}P_{35}K_{90}Mg_{35}$ were applied [3].

Investigations conducted by Mikhailova E.A., 2000, on chernozems from Russia and Liu X.B., 2005, on chernozems from China, have shown that in wheat , maize and soybean continuous cropping, the carbon content decreased on the entire depth of soil profile. In maize and soybean continuous cropping, once with the diminution in C and N content, the biological activity from soil has also decreased. The total content of microbial carbon from the ploughed layer was of only 350 mg/kg at maize continuous cropping, 398 mg/kg at soybean continuous cropping, 533 mg/kg at wheat continuous cropping and 429 mg/kg in wheat-soybean rotation.

Loveland and Webb (2003) have shown that the threshold of 2% of organic carbon from soil, equivalent to 3.4% organic matter, represented in temperate areas the low threshold highly affecting the diminution in soil quality (2*1.724=3.448). After 16 year using of different fertilization systems in mollisol from China, Liu X.B., 2006, has found out that at depth of 0-15 cm, the content in organic carbon increased by 6.2, 7.7 and 9.3% in case of manure, mineral fertilization and manure + chemical fertilizers, against the unfertilized control. The results obtained have shown that in mollisol from China, at soil layer of 0-15 cm, without fertilization, the mean annual rate of diminution in total carbon content was lower than 0.58%/year, when a good crop rotation was planned.

Investigations conducted by Allmaras R. R., 2006 on loam-sandy soils from Rosemount, Minnesota, have shown that applying rates of 200 kg nitrogen as ammonium sulfate [$(NH_4)_2$ SO_4], contributed to the increase in the amount of organic residues from soil; by using ^{13}C he found out that at the conventional tillage system, they had a humification coefficient of 0.11 and determined the increase in the organic carbon content by 20% against the unfertilized control. In the long-term experiments from INCDA Fundulea, situated on cambic chernozem, the long-term application of a rate of 100 kg nitrogen has resulted in maintaining the humus stock from soil within wheat-maize rotation [6]. The use of wheat continuous cropping on slope lands, with vertic cambisol -type soils, has diminished the content of organic carbon, at depth of 0-40 cm, in comparison with perennial grasses, from 15.0 g/kg to 8.3 g/kg in Southern Italy (Calabria) and from 12.7 g/kg to 19.0 g/kg in the centre of Italy (Tuscany) [12]. The diminution in the content of organic carbon has resulted in decreasing the capacity of cationic exchange, in soil pH and supplying plants with mineral elements.

MATERIAL AND METHOD

Since 1968, the investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei has followed the influence of different crop structures and rotations and of fertilizers on yield and soil fertility. These experiments have been situated on a field with the slope of 14%, on a cambic chernozem with clayey loam texture (420 g clay, 315 g loam and 265 g sand), a neuter to weakly acid reaction and a mean supply in nutrients.

The soil on which physical and chemical analyses were done was sampled at the end of plant cropping period. Soil response was determined in watery suspension by potentiometrical means with glass electrode; the content of organic carbon was determined by the Walkley-Black method, modified by Gogoasa and multiplied by

1.724; the content in mobile phosphorus from soil was determined by 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.

The determination of water runoff, soil and nutrient losses by erosion was done by means of plots for loss control with the area of 100 m^2.

RESULTS AND DISCUSSIONS

The amounts of rainfall registered during 1997-2007 (January-June) were greater compared to the average of the latest 79 years, with values between 20.4 and 140.2 mm in five years, and lower by 38.3-119.0 mm, in six years (*tab. 1*). The amounts of rainfall registered in the last 11 years, during September-November, have created normal conditions for wheat cropping in six years, and were lower compared to the multiannual mean in five years. The stressed drought conditions of the latest 11 years were registered in November when the amount of rainfall was more reduced compared to the multiannual mean on ten years.

Table 1

Rainfall month deviations during 1996-2007, compared to multiannual mean registered during 1928-2007 at the Weather Station of Podu Iloaiei, Iasi

Year/ month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	± *
1996	4.5	11.8	10.3	8.0	-28.9	4.1	-4.0	4.7	166.1	-1.7	-5.2	45.4	9.8
1997	-20.5	-13.5	-18.4	49.7	-28	-7.6	-8.3	13.5	-4.9	21.6	-46.7	37.8	-38.3
1998	1.8	-17.1	14.2	13.9	8.6	15.4	29.8	-28	18.5	94.0	-1.4	-8.2	36.8
1999	7.7	14.3	-5.2	29.9	-28.8	2.5	11.7	-0.8	-20.3	18.2	-40.4	19.6	20.4
2000	-3.3	3.5	2.2	21.0	-42.5	-34.2	4.5	-21.9	94.8	-20.9	-41.2	-5.0	-53.3
2001	-4.6	-12.5	6.4	32.9	-9.3	25.8	-5.8	-41	104.5	-0.2	0.0	0.0	38.7
2002	-20.7	-17.3	32.1	-22.9	-23.7	-20.1	47.2	46.2	-3.8	22.5	-7.0	-16.7	-72.6
2003	7.7	-2.3	-2.2	-20.7	-43.1	-58.4	45.4	-17.3	-3.6	54.5	-62.3	2.2	-119.0
2004	40.3	7.4	-6.0	-25	-33.3	-56.8	52.3	37.7	19.5	-5.4	-25.1	-10.2	-73.4
2005	14.8	18.2	1.1	44.4	52.9	8.8	-8.3	98.6	-27.8	-8.9	-20.2	8.8	140.2
2006	1.7	-16.1	72.8	56.2	3.9	16.2	90	60.1	-23.2	-12.5	-60.9	-18.7	134.7
2007	-7.3	6.3	5.7	-14.8	-22.4	-61.9	-9.4						-94.4
Mean 1928-2007	27.6	23.9	24.5	41.8	53.1	77.5	73.0	61.4	42.1	30.6	67.2	21.3	248.4**

* Difference to the multiannual mean, January-June; ** Sum January-June

On the cambic chernozem from the Moldavian Plain, placing winter wheat in 3 and 4- year crop rotations with annual and perennial legumes has resulted in getting yield increases, in comparison with continuous cropping, of 34 - 39 % (832 - 963 kg/ha) (*tab. 2*). Placing wheat in a 4 -year crop rotation (peas-wheat-maize-sunflower) + ameliorating field cultivated with legumes and perennial grasses has resulted in getting yield increases of 37%, respectively 906 kg/ha, compared to wheat-maize rotation (which is the most commonly used by farmers).

Table 2

Influence of rotation and fertilizers on wheat yield, during 1997 - 2007

Crop rotation	Maize Yield		Dif kg/ha	Sign.	Fertilizer rate	Maize Yield		Dif. kg/ha	Sign.
	kg/ha	%				kg/ha	%		
Wheat continuous cropping	2454	100	0		N_0P_0	1662	100	0	
Wheat - maize	2511	102	57	*	$N_{60}P_{40}$	2492	150	830	***
Peas -wheat-maize	3286	134	832	***	$N_{100}P_{80}$	3110	187	1448	***
Peas -wheat-maize - sunflower+reserve field cultivated with legumes and perennial grasses	3417	139	963	***	$N_{140}P_{100}$	3536	213	1874	***
					$N_{60}P_{40}$+30 t/ha manure	3785	228	2123	***
LSD 5 %			204					265	
LSD 1 %			375					453	
LSD 0.1 %			587					689	

Applying high fertilizer rates ($N_{140}P_{100}$) in winter wheat has resulted in getting an average yield increase in the last 11 years of 113 % (1874 kg/ha), and using low mineral fertilizer rates ($N_{60}P_{40}$), with 30 t/ha manure, has determined getting an yield increase of 128% (2123 kg/ha).

The average wheat yield, obtained during 1997-2007, in wheat-maize rotation, under unfertilized, was of 1365 kg/ha, and in case of crop rotation with four annual crops and reserve field cultivated with perennial legumes, of 2030 kg/ha. Average yield increases in wheat, during 1997-2007, were between 34 and 39 % (832 - 963 kg/ha), due to crop rotation, and between 50 and 128 % (830 - 2123 kg/ha), due to applied fertilizer rates (*tab. 2*).

On the slope lands from the Moldavian Plain, applying high rates of mineral fertilizers ($N_{140}P_{100}$) has resulted in getting average yield increases, compared to unfertilized control, of 1657 kg/ha in wheat continuous cropping, 1736 kg/ha in wheat-maize rotation, and of 2085 kg/ha in peas-wheat-maize-sunflower+reserve field cultivated with legumes and perennial grasses (*tab. 3*).

Applying mean rates of mineral fertilizers ($N_{60}P_{40}$) with 30 t/ha manure has resulted in getting average yield increases, compared to unfertilized variant, comprised between 1958 kg/ha in wheat continuous cropping and 2285 kg/ha in peas-wheat-maize-sunflower+reserve field cultivated with perennial grasses and legumes.

Applying a rate of $N_{140}P_{100}$ for 39 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 (*tab. 4*).

The differences concerning the pH value at different crop rotations had no significant values, but in case of 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 $N_{100}P_{80}$ si $N_{140}P_{100}$ rates has diminished pH until 5.9 and 5.6, respectively.

Table 3

Mean wheat yields obtained, during 1997-2007, in Gabriela Variety, on 14% slope lands from the Moldavian Plain

Fertilizer rate	Wheat continuous cropping				Wheat-maize			
	Yield		Dif.	Signif.	Yield		Dif.	Signif.
	kg/ha	%	kg/ha		kg/ha	%	kg/ha	
N_0P_0	1318	100	0	-	1365	100	0	-
$N_{60}P_{40}$	2059	156	741	***	2038	149	673	**
$N_{100}P_{80}$	2644	201	1326	***	2694	197	1329	***
$N_{140}P_{100}$	2975	226	1657	***	3101	227	1736	***
$N_{60}P_{40}$+30 t/ha gunoi	3276	249	1958	***	3355	246	1990	***
Mean	2454	100	0		2511	102	57	
Crop rotation								
Fertilizer rate	Peas -wheat-maize				Peas-wheat-maize-sunflower+reserve field cultivated with legumes and perennial grasses			
	Yield		Dif.	Signif.	Yield		Dif.	Signif.
	kg/ha	%	kg/ha		kg/ha	%	kg/ha	
N_0P_0	1935	100	0	-	2030	100	0	-
$N_{60}P_{40}$	2875	149	940	***	2995	148	965	***
$N_{100}P_{80}$	3474	180	1539	***	3629	179	1599	***
$N_{140}P_{100}$	3953	204	2018	***	4115	203	2085	***
$N_{60}P_{40}$+30 t/ha manure	4194	217	2259	***	4315	213	2285	***
Mean	3286	134	832		3417	139	963	
LSD /year 5% = 138 kg/ha; LSD 1 % = 286 kg/ha; LSD 0.1 % = 470 kg/ha								

Table 4

Influence of long-term fertilization and crop rotation on soil response (0-20 cm) in the cambic chernozem from the Moldavian Plain

Treatment	Wheat continuous cropping	Wheat-maize	Peas-wheat-maize	Peas -wheat-maize - sunflower+reserve field cultivated with legumes and perennial grasses	Average 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 manure	7.0	6.9	7.0	7.0	7.0	-0.13	
Average crop rotation	6.6	6.4	6.7	6.8	6.6		
Difference	0	-0.2	0.12	0.2			
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				

On cambic chernozem of 12% slope lands from the Moldavian Plain, a significant increase of humus content was found at the rate of $N_{140}P_{100}$ in wheat-maize rotation and in case of organo-mineral fertilization ($N_{60}P_{40}$+30 t/ha manure), in all studied crop rotations (*tab. 5*).

Table 5

Influence of long-term fertilization and crop rotation on humus content from soil (%)

Treatment	Wheat continuous cropping	Wheat-maize	Peas-wheat-maize	Peas -wheat-maize - sunflower+reserve field cultivated with legumes and perennial grasses	Average background	Dif.	Signif.
N_0P_0	2.84	2.67	2.89	2.94	2.84	0	
$N_{60}P_{40}$	2.86	2.72	2.92	3.04	2.89	0.04	
$N_{100}P_{80}$	2.91	2.84	2.99	3.15^{x}	2.97	0.13	
$N_{140}P_{100}$	2.96	2.93^{x}	3.21^{x}	3.38^{xx}	3.12	0.28	x
$N_{60}P_{40}$+30 t/ha manure	3.36^{xx}	3.26^{xxx}	3.49^{xxx}	3.58^{xxx}	3.42	0.58	xxx
Average crop rotation	2.99	2.88	3.10	3.22	3.05		
Difference	0	-0.11	0.11	0.23			
LSD 5%	0.18	0.22	0.26				
LSD 1%	0.28	0.33	0.39				
LSD 0.1%	0.40	0.47	0.54				

Applying a rate of $N_{100}P_{80}$ in crops from the rotation peas-wheat-maize-sunflower+reserve field, cultivated with perennial grasses and legumes (excepting peas) has resulted, after 39 years of experiencing, in maintaining humus content from soil at 3.15%.

In wheat continuous cropping and wheat-maize and peas-wheat-maize rotations, applying a rate of $N_{100}P_{80}$ did not result in registering significant increases in humus content from soil.

In cambic chernozem, on the slope lands from the Moldova Plain, maintaining a good supply in mobile phosphorus for field crops (37-72 mg/kg) was done in case of 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 manure, applied in crops from 3 or 4 -year crop rotations with perennial grasses and legumes (*tab. 6*). After 39 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, which include annual and perennial legumes, leaving into soil easily degradable crop residues.

Wheat, barley and other grains have great requirements towards soil supply in nitrogen, phosphorus and mobile potassium.

From the research carried out by Subba Rao (2001), they found that 86% of potassium used by wheat came from potassium fixed in soil, but when potassium fertilizers were applied, the potassium usage by plants from soil stock was insignificant. Potassium nutrition depended on many factors, among which potassium rate from soil solution, soil structure and moisture content from soil had the main role in supplying proper plant nutrition.

Johnston A.E. (2001) has found out that barley cultivated on a soil with 300 mg/kg exhangeable K had a daily plant consumption of almost 6 kg K/ha, while barley cultivated on a weekly supplied soil in mobile potassium (50 mg/kg) has extracted the tenth part of the maximum rate proper to a good plant supply with potassium (0.5 kg K/ha/day). On weakly supplied fields in K, the yield of winter barley was of 3.08 t/ha grains and 1.12 t/ha straw, and on soils well supplied in potassium, 4.91 t/ha grains and 2.58 t/ha straw. He has also found out that a high K rate in soil was not sufficient for ensuring good plant nutrition in dry areas. The calculations done by Johnston A.E (1998), have shown that in wet soils, the K rate from soil solution which ensured a good consumption rate of 5 kg K/ha/day, was of 120 µM/l; in dry soils, for ensuring this consumption rate (5 kg K/ha/day), a four times higher K concentration was necessary in soil solution, respectively 490 µM/l [8].

Table 6

Influence of long-term fertilization and crop rotation on the content of mobile phosphorus from soil (P-AL, mg/kg)

Treatment	Wheat continuous cropping	Wheat-maize	Peas-wheat-maize	Peas -wheat-maize -sunflower+reserve field cultivated with legumes and perennial grasses	Average 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 manure	67	58	69	78	68.0	55.0	xxx
Average crop rotation	41.6	36.8	46.0	51.6	44.0		
Difference	0	-4.8	4.4	10.0			
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				

The plant supply with 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 content in mobile potassium content from soil have shown that in all the tested crop rotations, the supply condition was very good (133-200 mg/kg) in case of mineral fertilization and very good (over 200 mg/kg) in case of fertilization with $N_{60}P_{40}$+30 t/ha manure (*tab. 7*).

The supply with mobile potassium in wheat-maize rotation was lower because of the high potassium consumption by these crops and of unfavorable conditions of soil structure, which influence the supply with mobile potassium 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 can be explained by the high potassium exportation from soil once with the harvest.

When establishing a fertilization system, which ensures proper crop nutrition and maintains a positive humus balance, one must take into account both inputs in the soil system (crop residues, supply of nitrogen symbiotically fixed, etc.) and humus and mineral elements losses by erosion.

The mean annual rainfall amounts registered in the last 27 years were of 556.1 mm, of which 334.1 mm have determined water runoff of 17.1 mm in sunflower, 16.3 mm in maize, 7.1 mm in winter wheat and 5.3 mm in perennial grasses and legumes on the second growing year. Mean annual soil losses by erosion were of 9.794 t/ha in sunflower, 9.268 t/ha in maize, 1.574 t/ha in winter wheat and 0.286 t/ha in perennial grasses and legumes on the second growing year (*tab. 8*).

Table 7

Influence of long-term fertilization and crop rotation on the content of mobile potassium from soil (K-AL, mg/kg)

Treatment	Wheat continuous cropping	Wheat-maize	Peas-wheat-maize	Peas -wheat-maize -sunflower+reserve field cultivated with legumes and perennial grasses	Average 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 manure	286	267	294	298	286	80	xxx
Average crop rotation	213	195	222	212			
Difference	0	-18	9	-1			
LSD 5%	11	14	16				
LSD 1%	17	20	23				
LSD 0.1%	24	28	33				

Table 8

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

Crop	Runoffs (mm)	Eroded soil (kg/ha)	Humus and mineral elements losses by erosion, kg/ha					
			Humus (kg/ha)	N, (kg/ha) in:		Total N (kg/ha)	P-AL (kg/ha)	K-AL (kg/ha)
				runoffs	erodedsoil			
Field	20.1	13011	463	1.483	18.215	19.699	1.496	3.123
Sunflower	17.1	9794	349	1.438	14.887	16.325	1.126	2.400
Grasses I year	8.0	1864	66	0.709	2.610	2.532	0.214	0.464
Grasses II year	5.3	286	10	0.470	0.469	0.939	0.032	0.071
Maize	16.3	9268	329	1.444	15.200	16.644	1.038	2.317
Peas	8.7	268	10	1.037	0.440	1.477	0.030	0.067
Wheat	7.1	1574	56	0.846	2.581	3.428	0.176	0.394
Beans	10.7	4617	164	1.081	6.926	8.006	0.517	1.154

The investigations conducted on 14% slope fields, by means of erosion control plots, have shown that mean annual nitrogen losses by erosion were between 16.3 and 16.6 kg/ha in row crops and between 1.48 and 3.43 kg/ha/year in peas and wheat crops (*tab. 8*). If phosphorus and potassium losses are low (1.13-2.4 kg/ha/year), the humus and nitrogen ones must be diminished by establishing a crop structure which protects soil against erosion. 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 elements losses; these are 2.5 times lower compared to the ones registered in maize and sunflower (*tab. 9*).

Table 9

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)	Runoff water (mm)	Humus (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Total NPK (kg/ha)
Maize continuous cropping	9.268	16.3	329	16.644	1.038	2.317	19.999
Wheat-maize	5.421	11.7	193	10.036	0.607	1.356	11.999
Peas-wheat-maize	3.703	10.7	132	7.183	0.415	0.926	8.524
Peas-wheat-maize-sunflower+ reserve field cultivated with legumes and perennial grasses	4.317	11	154	7.8	0.489	1.069	9.358
Peas-wheat-maize-sunflower+2 reserve fields cultivated with legumes and perennial grasses	3.517	8.4	132	6.758	0.421	0.919	8.098

CONCLUSIONS

On the cambic chernozem from the Moldavian Plain, placing winter wheat in 3 and 4 -year crop rotations with annual and perennial legumes has resulted in getting yield increases of 34 - 39 % (832 - 963 kg/ha), compared to continuous cropping.

Applying the rate of $N_{140}P_{100}$ for 39 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 significant increase in humus content from soil in case of mineral fertilization has been registered at higher than $N_{140}P_{100}$ rates, in wheat-maize rotation, and at $N_{100}P_{80}$ rate in rotation peas-wheat-maize-sunflower+reserve field cultivated with perennial grasses and legumes.

The mean annual losses of nitrogen, phosphorus and potassium, once with runoff water and eroded soil on 14% slope fields were of 19.9 kg/ha in maize continuous cropping, 11.9 kg/ha in wheat-maize rotation and 8.1 kg/ha in crop rotation peas-wheat-maize-sunflower+2 reserve fields cultivated with perennial grasses and legumes.

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