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EVOLUTION OF SOME CHEMICAL PROPERTIES OF SOIL UNDER INFLUENCE OF SOIL EROSION AND DIFFERENT CROPPING SYSTEMS

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ABSTRACT - Since 1968, at the Agricultural Research Station of Podu-Iloaiei, Iași County (47°12′ N latitude, 27°16′ E longitude), investigations were conducted on the influence of different crop structures and fertilizers on yield, erosion and soil fertility. The paper presented the results of investigations concerning the influence of long-term fertilization (43 years) on some chemical characteristics of Cambic Chernozem from the Moldavian Plain and on the yield of wheat and maize, placed under different crop rotations with perennial grasses and legumes. The objectives of this study was, to monitor runoff, soil loss and soil chemical properties in monocultures of wheat and corn, compared with different rotations and fallow land. The climatic conditions in the Moldavian Plain were characterized by annual mean temperature of 9.6°C and a mean rainfall amount, on 50 years, of 553.5 mm, of which 141.5 mm during September-December and 412.0 mm during January-August. In the last 20 years, the mean annual recorded quantity of rainfall was of 588.7 mm (100%), of which 369.5 mm (62.8%) determined water runoff and soil losses by erosion. Mean annual losses of soil by erosion, recorded in the last 20 years, in the Moldavian Plain, were of 0.161 t/ha in perennial grasses in the second growth year, 3.883 t/ha in beans, 6.369 t/ha in maize and 6.733 t/ha in sunflower. The crop structure, which determined, during 1991-2010, the diminution in mean soil losses by erosion until 1.954 t/ha/year included 20 % straw cereals (wheat), 20% annual legumes (pea), 20% row crops (maize) and 40 % perennial grasses and legumes (Alfalfa + *Lolium perene)*. After 43 years of experience, in the pea - wheat - corn - sunflower rotation + reserve field, cultivated with legumes and perennial grasses, soil organic carbon content increased with 14.7% (2.8 C g / kg), in comparison with wheat - maize rotation.

Key words: Slope land; Cropping systems; Water erosion; Organic carbon; Nutrient losses.

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REZUMAT – Evoluția unor proprietăți chimice ale solului sub influența eroziunii şi a diferitelor sisteme de cultură. Începând cu anul 1968, la Stațiunea de Cercetări Agricole Podu-Iloaiei, județul Iaşi (47°12′ N latitude, 27°16′ E longitude), cercetările efectuate au urmărit influența diferitelor structuri de culturi şi a fertilizării asupra producției, eroziunii şi fertilității solului. Lucrarea prezintă rezultatele cercetărilor privind influența fertilizării de lungă durată (43 ani) asupra unor însuşiri chimice ale cernoziomului cambic din Câmpia Moldovei şi asupra producției la culturile de grâu și porumb, amplasate în diferite rotații cu plante de leguminoase şi graminee perene. Obiectivele acestui studiu au fost monitorizarea scurgerilor de apă, pierderile de sol și ale unor proprietăți chimice ale solului la monoculturile de grâu şi porumb, în comparație cu diferite rotații ale culturilor şi cu terenul necultivat. Condițiile climatice din Câmpia Moldovei se caracterizează prin temperaturii medii anuale de 9.6^{o}C şi o cantitate medie de precipitații, pe 50 de ani, de 553,5 mm, din care 141,5 mm în perioada septembrie-decembrie, şi 412 mm în perioada ianuarie-august. În ultimii 20 de ani, cantitatea medie anuală de precipitații înregistrată a fost de 588,7 mm (100%) , din care 369,5 mm (62,8%) a determinat scurgeri de apă şi sol prin eroziune. Pierderile medii anuale de sol prin eroziune, înregistrate în ultimii 20 de ani în Câmpia Moldovei, au fost de 0.161 t/ha la ierburile perene în anul doi de vegetație, 3.883 t/ha la fasole, 6.369 t/ha la porumb şi 6.733 t/ha la floarea-soarelui. Structura culturilor, care a determinat, în perioada 1991-2010, diminuarea pierderilor de sol prin eroziune sub 1,954 t/ha/an, a cuprins 20% cereale păioase (grâu de toamnă), 20% leguminoase anuale (mazăre), 20% culturi prăşitoare (porumb) şi 40% leguminoase şi graminee perene (lucernă şi *Lolium*). După 43 de ani de experimentare, în rotația mazăre – grâu – porumb - floarea-soarelui + o solă săritoare cu leguminoase şi graminee perene, conținutul de carbon organic din sol a crescut, în comparație cu rotația grâu porumb, cu 14.7% (2.8 C g/kg).

Cuvinte cheie: teren în pantă; sisteme de cultură; eroziunea produsă de apă; carbon organic; scurgeri de elemente nutritive.

INTRODUCTION

Intensive agriculture has resulted in the loss of fertility of soils, increased erosion and changes to the chemical composition of the soils because of changed vegetation and altered soil water conditions. One of the most important changes has reducing soil humus content, agricultural productivity and its resistance to erosion. Soil erosion is one of the most serious environmental problems, because it threatens agriculture and the natural environment. Research findings on the relationship between soil loss and productivity indicate that erosion causes considerable reduction of soil fertility by the physical, chemical and biological degradation (Lal and Singh, 1998; Alan *et al.,* 2007, Abid and Lal, 2008, Ailincăi *et al.,* 2011, Bucur *et al.,* 2011). The most dangerous erosion events are in May and June when the combined effects of high intensity rainfalls and poor vegetation cover on arable land occur. Soil losses due to water erosion are high in southern Europe and moderate in northern Europe. Soil loss rates in Europe, range between 10 and 20 t/ ha /yr, and in the United States 16 t/ha/year (Pimentel, 2009).

The main problems requiring agro-environment measures in Romania are the degradation degree of fields by erosion (6.3 million ha), deterioration of soil structure and compaction (44% of the total farming area). The north-eastern region has 15.45% (2.131.421 ha) of the farming area of Romania (14.836.585 ha) and includes very great areas with soils affected by erosion (over 60%), acidification, compaction, landslides and other degradation forms (Project of North-East Regional Development 2007-2013). The favorable influence of reduced tillage system and of crop residues on soil erosion was also signaled by Lal (2006). He showed that in no-tillage system, soil losses by erosion were close to the ones found in case of soil protection with 6 t/ha of mulch.

MATERIALS AND METHODS

Since 1968, at the Agricultural Research Station of Podu-Iloaiei, Iași County, investigations were conducted on the influence of different crop structures and fertilizers on yield, erosion and soil fertility *(Fig. 1)*. The experiments were carried out on slope land, with Cambic Chernozem soil-type, which has a loam-clayey texture (430 g clay, 315 g loam and 255 g sand), a neuter to weakly acid reaction and a mean nutrient supply. Investigations conducted on a Cambic Chernozem (SRTS - 2003) at the Agricultural Research and Development Station of Podu-Iloaiei, located in the East part of Romania (47°12′ N latitude, 27°16′ E longitude), and followed the influence of different crop rotations and fertilizers on water runoff and nutrient losses, due to soil erosion *(Fig. 1)*. Within the experiment, the following rotation scheme was followed: wheat and maize continuous cropping, 2-year crop rotation (wheat-maize), 3-year crop rotation (peas-wheat-maize) and 4-year crop rotation + outside field cultivated with legumes and perennial grasses (Alfalfa + *Lolium* or Sainfoin + *Bromus*). The soil has high clay content (39-43 %) and is difficult to till when soil moisture is close to the wilting point (12.2%). Composite soil samples from experimental site were collected from 0-20 cm depth before sowing or harvest. The samples were analyzed for organic matter by methods of soil analysis established from Nelson and Sommers (1982) and mineral nitrogen by semi-Kjeldahl digestion method (Jackson, 1982). The content of 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 solution 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 runoff control with the area of 100 m^2 and on the entire area of the watershed, where experiments were set up by means of a hydrological station. This station contains a triangular spillway, pluviometer, pluviograph, limnograph and devices for sampling soil and water during rainfall. When raining, samples are taken for the determination of the partial turbidity and of the content in humus and mineral elements lost by erosion. Experiments were conducted on the hydrographic basin of Scobâlțeni, Iași County, with a reception area of 159 ha and a mean altitude of 119.4 m. In wheat, we have used the Gabriela variety and in maize, the Podu Iloaiei - 110 and Oana hybrid. The content of total nitrogen, nitrates, phosphorus and potassium was determined on soil and water samples, lost by erosion, in different crops, thus establishing the losses of nutritive elements on the area of the watershed where experiments are placed.

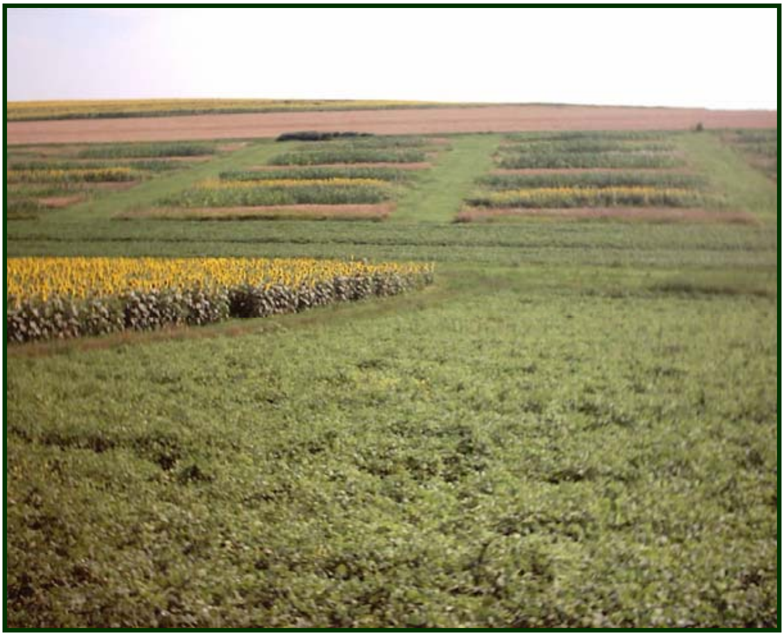

Figure 1- The experiences with different systems of fertilization and crops rotation on slope lands

RESULTS AND DISCUSSION

The climatic conditions in the Moldavian Plain were characterized by a multiannual mean temperature of 9.6^{o}C and a mean rainfall amount, on 50 years, of 553.5 mm, of which 141.5 mm during September-December and 412.0 mm during January-August. In the last 20 years, the mean annual recorded quantity of rainfall was of 588.7 mm (100%), of which 369.5 mm (62.8%) determined water runoff and soil losses by erosion. During 1991-2010, the climatic conditions were favorable to plant growing and development, during ten years in wheat and seven years in maize. The mean annual rainfall amounts, registered in the last 20 years, were higher, with values comprised between 22.2 and 269.7 mm, compared to the multiannual mean on 50 years (553.5 mm), in eleven years, and lower by 25.3-100.1 mm in nine years. Within the interval of January-September, the average amount of rainfall, registered in the last 50 years, was of 463.0 mm. During 1991-2010, the drought conditions have affected maize crop in nine years, when differences were between 21.1 (2002) and 200.3 mm (1994), compared to the multiannual mean.

Land use changes and soil management practices with potential for soil organic carbon sequestration include judicious use of fertilizers and manures, use of crop residues, diverse crop rotations, and erosion control measures. In all the countries, the investigations carried out in the last period have followed the establishment of some technological solutions that maintain the productivity of agro ecosystem and the protection of environment factors. The Soil Protection Framework Directive of EU includes the necessary legislative proposals, taken into account by all the Member States concerning the three main threats on the decline in organic matter, soil erosion and contamination and some additional aspects regarding compaction and diminution of biodiversity.

Land use and practices, through intensive cultivation and removal of plant biomass from the fields, may affect soil organic matter concentration, deteriorating implicit soil physical properties (Li *et al.*, 2007), and also a rapid oxidation of soil organic matter (Shang and Tiessen, 2003; Madari *et al.*, 2005; Mitra *et al.*, 2005). The conversion of natural lands to croplands can result in a 60% decrease in the soil organic matter (SOC) pool in temperate ecosystems and a 75% decrease in the SOC pool in tropical ecosystems (Lal, 2004). In the pedoclimatic conditions in Cluj-Napoca, chisel plow + rotary harrow determined, compared with the classic plowing, the increase in the content of humus in soil from 3.51% (100%) to 3.87% (110.2%) in Cambic Chernozem and from 2.48% (100%) to 3.02% (122.1%) to Haplic luvisols (Moraru and Rusu, 2010).

The introduction of reserve fields cultivated with perennial legumes into crop rotations has determined yield increases and improvement in soil physical and chemical characteristics. In maize cropping, the percentage of hydro stable aggregates was influenced both by rotation and by organic fertilization *(Table 1)*. The highest rate of hydro stable aggregates were found at the $N_{80}P_{80}$ + 30 t/ha manure fertilization and in case of placing maize in 4-year crop rotation+ reserve field cultivated with perennial grasses and legumes. At the mineral fertilization, significant differences of the rate of hydrostable aggregates were found when using high nitrogen and phosphorus fertilizer rates, which can be explained by the high amount of crop residues in maize continuous cropping and wheat-maize rotation. The fertilization with $N_{80}P_{80}$ +30 t/ha manure has increased by 33% the rate of hydrostable aggregates in maize continuous cropping and by 22-30% in 3 and 4-year crop rotations with ameliorative plants of perennial grasses and legumes, compared to the unfertilized control. The average rate of hydrostable aggregates > 0.25 mm (%) in maize, fertilized with $N_{80}P_{80}$ +30 t/ha manure, was higher by 28% (compared to unfertilized control) and by 16-25% higher in 3 and 4 year-crop rotations with ameliorative plants, compared to maize continuous cropping *(Table 2)*.

In many countries, the latest research has investigated the diversification of cropping systems by increasing the rate of annual and perennial legumes within crop structure (Shang and Tiessen, 2003; Mitra *et al.,* 2005; Jităreanu *et al.,* 2006; Lal, 2006; Li *et al.,* 2007; Ailincăi *et al.,* 2011; Bucur *et al.,* 2011). Crop rotation will continue to be one of the most important components of the farming technological system, which contributes to rationing the consumption of fuel, water, fertilizers and pesticides and biological preparations for plant protection. The analyses conducted on soil samples, taken from the field on which the wheat-maize rotation had been used for 43 years, pointed out the worsening of some soil chemical characteristics.

Table 1 - Influence of crop rotation and fertilization on soil degree of macro structural hydro stability

Fertilizer rate	Hydrostable aggregates >0.25 mm (%) at depth (cm)				%	Differ.
	0-10	10-20	20-30	Average		
Maize continous croping						
N_0P_0	44.3	45.2	46.1	45.2	100	0
$N_{120}P_{80}$	46.5	48.3	48.6	47.8	106	2.6
$N_{160}P_{80}$	48.6	49.4	51.2	49.7	110	4.5^{x}
$N_{80}P_{80}$+30 t/ha manure	58.2	60.2	61.8	60.1	133	14.9^{xxx}
Average	**49.4**	**50.775**	**51.925**	**50.7**		
Wheat-maize rotation						
N_0P_0	42.3	43.2	46.3	43.9	100	0
$N_{120}P_{80}$	43.5	45.7	48.6	45.9	105	2.0
$N_{160}P_{80}$	44.7	45.8	51.3	47.3	108	3.4
$N_{80}P_{80}$+30 t/ha manure	51.2	56.2	58.9	55.4	126	11.5^{xxx}
Average	**45.4**	**47.7**	**51.3**	**48.1**		
Peas- wheat-maize rotation						
N_0P_0	49.8	51.6	57.3	52.9	100	0
$N_{120}P_{80}$	53.7	57.8	62.7	58.1	110	5.2^{x}
$N_{160}P_{80}$	54.6	59.5	67.2	60.4	114	7.5^{xx}
$N_{80}P_{80}$+30 t/ha manure	59.6	64.2	69.6	64.5	122	11.6^{xxx}
Average	**54.4**	**58.3**	**64.2**	**59.0**		
Peas- wheat-maize-sunflower+reserve field cultivated with perennial grasses and legumes						
N_0P_0	51.2	56.9	59.4	55.8	100	0
$N_{120}P_{80}$	55.4	61.2	64.7	60.4	108	4.6^{x}
$N_{160}P_{80}$	57.9	64.9	68.9	63.9	115	8.1^{x}
$N_{80}P_{80}$+30 t/ha manure	68.9	74.3	75.2	72.8	130	17.0^{xxx}
Average	**58.4**	**64.3**	**67.1**	**63.2**		
LSD 5% = 4.1%; LSD 1% = 5.6%; LSD 0.1% = 8.7%						

Table 2 - The rate of hydrostable aggregates (> 0.25 mm; %) in different crop rotations and fertilization systems

Treatment	Mcc*	WM	PWM	PWMSf+G	Average	%	Differ.
N_0P_0	45.2	43.9	52.9	55.8	**49.5**	100	**0**
$N_{120}P_{80}$	47.8	45.9	58.1	60.4	**53.1**	107	**3.6^{x}**
$N_{160}P_{80}$	49.7	47.3	60.4	63.9	**55.3**	112	**5.8^{xx}**
$N_{80}P_{80}$+ 30 t/ha manure	60.1	55.4	64.5	72.8	**63.2**	128	**13.7^{xxx}**
Average rotation	**50.7**	**48.1**	**59.0**	**63.2**	**55.3**		
%	100	**95**	**116**	**125**			
Differ.	**0**	**-2.6**	**8.3^{xxx}**	**12.5^{xxx}**			
			Fertilizer	**Crop rotation**	**Interaction**		
LSD 5%			4.1	3.5	4.6	%	
LSD 1%			5.6	5.0	6.5	%	
LSD 0.1%			8.7	6.9	9.8	%	

[1]Mcc= Maize continuous cropping, BWSfMW = Beans-wheat-sunflower-maize-wheat rotation, WM = Wheat-maize rotation, PWM = Peas -wheat-maize, PWMSf + G = Peas-wheat-maize -sunflower + reserve field, cultivated with legumes and perennial grasses, BWM + 2G = Beans-wheat-maize + 2 reserve field, cultivated with legumes and perennial grasses, SWM = Soybean- wheat-maize + 2 reserve field, cultivated with legumes and perennial grasses

Table 3 - Influence of long-term fertilization and crop rotation on soil response (0-20 cm) at Cambic Chernozem from the Moldavian Plain

Treatment	*Mcc	Wcc	WM	PWM	PWMSf+G	Average	Difference
N_0P_0	6.4	6.5	6.5	6.6	6.8	**6.6**	0.00
$N_{80}P_{60}$	6.3	6.4	6.3	6.5	6.7	**6.4**	-0.13^{00}
$N_{120}P_{80}$	5.6	6.0	6.2	6.4	6.6	**6.2**	-0.38^{00}
$N_{160}P_{100}$	5.5	5.5	5.4	6.1	6.2	**5.8**	-0.81^{00}
$N_{80}P_{60}$+30 t/ha manure	6.5	6.5	6.4	7.0	7.0	**6.7**	0.12^{x}
Average	**6.0**	**6.2**	**6.2**	**6.5**	**6.7**	**6.3**	
Difference	0.0	0.15^{x}	0.13^{x}	0.46^{xxx}	0.63^{xxx}		
					Crop rotation	**Fertilizer**	**Interaction**
LSD 5%					0.13	0.12	0.33
LSD 1%					0.18	0.16	0.46
LSD 0.1%					0.24	0.21	0.63

*Mcc= Maize continuous cropping, Wcc= wheat continous cropping, WM= Wheat-maize rotation, PWM= Peas – wheat - maize, PWMSf + G = Peas-wheat-maize - sunflower + reserve field, cultivated with legumes and perennial grasses.

The analyses carried out on the evolution of soil response, after 43 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates than 120 kg N/ha *(Table 3)*. The results obtained have shown that the 5-year crop rotation with perennial grasses and legumes has limited the pH diminution (compared to the wheat-maize crop rotation), even under long-term use of high nitrogen fertilizer rates.

After 43 years of experiencing, in a 4-year crop rotation + reserve field cultivated with perennial grasses and legumes, soil response was found within the limit of weakly acid (6.2-6.6), even when using high fertilizer rates (120-160 kg/ha) with acidifying effect, as ammonium nitrate.

In maize continuous cropping and wheat-maize rotation, although a great amount of crop residues accumulated into soil, this supply of organic matter did not improve soil response. Applying high nitrogen rates as ammonium nitrate has determined pH diminution (0-20 cm) to 5.5-5.6 in maize continuous cropping and until 6.2-6.6 in peas-wheat-maize-sunflower + reserve field cultivated with perennial grasses and legumes. The lowest pH values were found in maize continuous cropping and wheat-maize rotation, which can be explained by high nutrient uptake by these crop rotations and unfavorable conditions in which the processes of nitrification and crop residue decay developed.

In Cambic Chernozem, on the slope lands from the Moldavian Plain, a good supply in mobile phosphorus of field crops (36-58 mg/kg) was maintained in annual application of a rate of $N_{120}P_{80}$ and a very good supply (63-73 mg/kg) 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 4).* After 43 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.

Table 4 - Influence of long-term fertilization and crop rotation on the content of mobile phosphorus from soil (P-AL, mg/kg)

Treatment	*Mcc	Wcc	WM	PWM	PWMSf+G	Average	Difference
N_0P_0	11	12	11	14	16	**13**	0.0
$N_{80}P_{60}$	31	36	35	39	50	**38**	25^{xxx}
$N_{120}P_{80}$	36	45	44	55	58	**47**	35^{xxx}
$N_{160}P_{100}$	49	56	52	65	65	**57**	44^{xxx}
$N_{80}P_{60}$+30 t/ha manure	64	68	63	72	73	**68**	55^{xxx}
Average	**38**	**44**	**41**	**49**	**2**	**45**	
Difference	0.0	5^{x}	3	11^{xxx}	14^{xxx}		
					Crop rotation	**Fertilizer**	**Interaction**
LSD 5%					3.3	4.7	8.1
LSD 1%					4.5	6.8	11.1
LSD 0.1%					5.8	10.2	15.3

The mobile potassium supply in wheat-maize rotation was lower because of the high potassium consumption by these crops and of unfavorable 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 *(Table 5)*. 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) in case of mineral fertilization and very good (over 200 mg/kg) in case of fertilization with $N_{80}P_{60}$ + 30 t/ha of manure.

Table 5 - Influence of long-term fertilization and crop rotation on the content of mobile potassium from soil (K-AL, mg/kg)

Treatment	*Mcc	Wcc	WM	PWM	PWMSf+G	Average	Difference
N_0P_0	197	206	187	218	207	**203**	0
$N_{80}P_{60}$	166	174	169	190	189	**178**	-25^{0}
$N_{120}P_{80}$	172	177	182	188	184	**181**	-22^{0}
$N_{160}P_{100}$	183	200	188	205	192	**194**	-9
$N_{80}P_{60}$+30 t/ha manure	271	276	274	280	274	**275**	72^{xxx}
Average	**198**	**206**	**200**	**216**	**209**	**206**	
Difference	0	8^{x}	2	18^{xxx}	11^{xx}		
					Crop rotation	**Fertilizer**	**Interaction**
LSD 5%					8	18	23
LSD 1%					10	26	31
LSD 0.1%					13	38	43

For comprising the cumulated effects and the interactions between all the factors (crop rotation, soil tillage, fertilization, soil characteristics, temperature and moisture, etc.), which are involved in the processes of accumulation and mineralization of the organic matter, the balance of humus reserve from soil should be controlled in all the crops from rotations and in more rotation cycles.

The organic carbon content from soil at the mineral fertilization has increased, in comparison with the control, by significant values only at high fertilizer rates ($N_{160}P_{100}$), in 3 and 4-year crop rotations with annual and perennial legumes *(Table 6)*.

In maize continuous cropping and wheat-maize rotation, applying mineral fertilizer at the rate of ($N_{160}P_{100}$), did not result in significant differences of the organic carbon content from soil, in comparison with unfertilized control, this demonstrated that within these crop rotations, maintaining a positive balance of the organic matter was done only by organic and mineral fertilization. The results obtained have shown that low rate mineral fertilization in intensive crop rotations could determine the diminution in the content of organic matter from soil, but under conditions of high rates, which covered the exportation of mineral elements through crop, according to soil characteristics, they determined the accumulation of high quantities of crop residues with positive effect on the organic carbon content from soil. The data obtained have shown that in cereals rotation and in the crop rotation with annual legumes + cereals, the organic matter balance was negative, and by the introduction of the reserve field cultivated with perennial grasses and legumes, a positive balance was reached. After 43 years of experience, in the pea - wheat - corn - sunflower rotation + reserve field, cultivated with legumes and perennial grasses, soil organic carbon content increased with 14.7% (2.8 C g / kg), in comparison with wheat - maize rotation.

Table 6 - **Influence of long-term fertilization and crop rotation on organic carbon from soil (C, g/kg)**

Treatment	*Mcc	Wcc	WM	PWM	PWMSf+G	Average	Difference
N_0P_0	15.0	15.1	14.7	16.8	17.9	**15.9**	0.0
$N_{80}P_{60}$	15.6	15.9	15.3	16.3	18.3	**16.3**	0.4
$N_{120}P_{80}$	15.7	16.2	15.5	16.8	18.6	**16.6**	0.7
$N_{160}P_{100}$	17.2	17.7	16.5	18.6	19.3	**17.9**	2.0^{xxx}
$N_{80}P_{60}$+30 t/ha manure	19.4	19.1	19.6	20.5	21.3	**20.0**	4.1^{xxx}
Average	**16.6**	**16.8**	**16.3**	**17.8**	**19.1**	**17.3**	
Difference	0	0.2	-0.3^{00}	1.2^{xxx}	2.5^{xxx}		
					Crop rotation	**Fertilizer**	**Interaction**
LSD 5%					0.3	0.9	1.0
LSD 1%					0.4	1.3	1.4
LSD 0.1%					0.5	1.9	2.0

The proven conservation technologies for different soils, slopes, crops, and rainfall conditions include the following: crop rotations, strip cropping, contour planting, mulches, organic fertilization, no-till planting, grass strips and various combinations of these conservation technologies. Studies in the Midwest of the USA indicate that the average annual soil loss on a 4° slope with a silt-loam soil over seven years was 7.0 t/ha for continuous maize and 6.5 t/ha for maize following soybeans. Under tropical and temperate agricultural conditions, at least 500 years are required for the formation of 2.5 cm of topsoil the best estimate of a renewal rate is about 11/ha/year (Pimentel, 2009). In the United States, on land with a slope of 12%, soil loss by erosion was 3.0 t/ha/ year in the corn-wheat-hay rotation and 44.0 t /ha /year in monoculture corn (Pimentel, 2009). In northern Pakistan, total runoff and soil losses from bare plots were 1.64 and 1.92 times higher than from intercropped plots. Inter-cropped plots reduced erosion by 48% whereas mono-cropping by 36% (Ali Ijaz *et al.* 2006).

Table 7 - Water, soil and organic carbon runoff by erosion in different crops

Crop	Rainfall that caused runoff, mm	Erosion t/ha	Water runoff, mm	Organic carbon, kg/ha
Field	384.0	14.491	83.2	296
Sunflower	384.0	6.733	65.6	137
I[st] year grasses	384.0	1.797	31.9	37
II[nd] year grasses	321.4	0.161	10.9	3
Maize	384.0	6.369	60.7	130
Pea	384.0	1.742	29.3	36
Wheat	341.2	0.519	16.0	11
Bean	384.0	3.883	53.4	79
Rape	341.2	1.364	24.8	28

In the last 20 years, from the Moldavian Plain, the mean annual recorded quantity of rainfall was of 588.7 mm, of which 369.5 mm (62.8%) determined water runoff and soil losses by erosion. The results on runoff and soil loss by erosion in different crops, which were determined by the help of plots for runoff control have shown that, during 1991-2010, of the total of 588.7 mm rainfall, 369.5 mm caused runoff between 10.9 mm in perennial grasses on the second growing season and 65.6 mm in sunflower *(Table 7)*. Annual soil losses by erosion registered at the same period were between 0.161 t/ha in perennial grasses on the second growing season and 6.733 t/ha in sunflower. Erosion affects soil fertility by removing together with eroded soil, significant organic matter and mineral element amounts which in maize and sunflower crops reach 17.6-18.4 kg/ha of nitrogen, 0.87-0.97 kg/ha of phosphorus and 1.5-1.7 kg/ha of potassium *(Table 8)*. In the Moldavian Plain at three and four year rotations, which include good and very good cover plants for protecting soil against erosion, the amount of eroded soil lost by erosion were very close to the limit allowable of 2 t/ha/year. During 1991-2010, the use of crop rotations with a percent until 20% of row plants, which also included outside fields cultivated with perennial grasses, has determined the diminution in soil and mineral element losses by 70.5 % (4.491 t/ha) and, respectively, 65.4% (13.1 kg/ha), as compared to maize continuous cropping *(Table 9)*. In the Moldavian Plain, on land with a slope of 16%, soil loss by erosion was 3.444 t/ha/year in the wheat-maize rotation and 6.369 t / ha / year in monoculture of corn. During 1991-2010, the use of winter rape - wheat - maize + two reserve field cultivated with perennial grasses, has determined soil loss by erosion of 1.878 t / ha / year. The crop structure, which determined, during 1991-2010, the diminution in mean soil losses by erosion until 1.954 t/ha/year included 20 % straw cereals (wheat), 20% annual legumes (pea), 20% row crops (maize) and 40 % perennial grasses and legumes (Alfalfa + *Lolium)*. According to these results concerning the contribution of melioration plants to the diminution of soil and mineral element losses due to erosion, were established the technical elements for anti-erosion works on slope lands.

Table 8 - Annual average losses of nutritive elements in different crops, kg/ha

Crop	N at water runoff	N at eroded soil	Total N	P-AL	K-AL	Total NPK
Field	7.421	20.722	28.143	1.666	3.478	33.287
Sunflower	8.725	9.628	18.353	0.970	1.683	21.006
Ist year grasses	3.605	2.660	6.265	0.207	0.447	6.919
IInd year grasses	1.232	0.237	1.469	0.018	0.040	1.527
Maize	8.559	9.044	17.603	0.873	1.535	20.011
Pea	3.663	2.596	6.259	0.190	0.348	6.797
Wheat	2.112	0.758	2.870	0.058	0.130	3.058
Bean	7.049	5.669	12.718	0.427	0.777	13.922
Rape	3.348	1.978	5.326	0.153	0.299	5.778

Table 9 - Average annual water, soil and nutritive elements runoff by erosion registered in different crops rotation

Crop rotation	Water Runoff, (mm)	Erosion, (t/ha)	Organic Carbon, (kg/ha)	NPK, kg/ha	Row plants, (%)
*Mcc	60.7	6.369	130	20.011	100
BWMSfW	42.3	3.605	74	12.211	60
WM	38.4	3.444	71	11.535	50
PWMSf+G	37.5	3.187	65	10.749	40
PWM	35.3	2.877	59	9.955	33
PWMSf+2G	34.0	2.751	57	9.437	33
BWM+ 2G	32.5	2.382	49	8.548	40
PWM +G	30.5	2.300	48	8.185	25
SWM+2G	26.7	2.225	46	7.540	40
PWM + 2G	27.6	1.954	40	7.123	20
RWM + 2G	26.7	1.878	39	6.919	20

*Mcc = Maize continuous cropping, BWSMW = Beans-wheat-maize sunflower-wheat rotation, WM = Wheat-maize rotation, PWM = Peas –wheat-maize, PWMSf+G = Peas–wheat-maize –sunflower + reserve field, cultivated with legumes and perennial grasses, BWM+ 2G = Beans-wheat-maize + 2 reserve field, SWM +2G = soybean- wheat-maize + two reserve field, RWM + 2G = winter rape-wheat-maize + two reserve field.

CONCLUSIONS

The 43-year use of 4- year crop rotations + reserve field, cultivated with perennial grasses and legumes, has determined the increase in the mass of total carbon from soil by 14.7% (2.8 C g/kg), in comparison with wheat - maize rotation.

Applying the rate of $N_{160}P_{100}$ for 43 years has determined the pH decrease until the limit of moderately acid interval (5.4-5.5) 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.

Mean annual losses of soil by erosion, recorded in the Moldavian Plain, were of 0.161 t/ha in perennial grasses in the second growth year, 3.883 t/ha in beans, 6.369 t/ha in maize and 6.733 t/ha in sunflower.

Mean annual losses of nitrogen caused by erosion, recorded during 1991-2010, were of 1.469 kg/ha in perennial grasses in the second vegetation year, 5.326 kg/ha in winter rape beans, 17.603 kg/ha in maize and 18.353 kg/ha in sunflower.

On 16% slope fields, the use of winter rape - wheat - maize rotation + two outside fields, cultivated with perennial grasses, determined the diminution by 70.5% (4.491 t/ha) in the mean annual losses of eroded soil and by 65.4% (13.092 kg/ha) in mineral elements (NPK) leakages, compared with maize continuous cropping.

From the results obtained on erosion in different crop rotations, we have found that in 16% slope fields from the Moldavian Plain, soil losses by erosion diminished below the allowable limit of 2.0 t/ha only in case of 3 or 4 year-crop rotations with two or three reserve fields, cultivated with legumes and perennial grasses, which protect soil.

The introduction of rotations peas - wheat - maize rotation + two outside fields cultivated with perennial grasses, which include in the crop structure 20% maize and plants for the protection against erosion, determined the diminution by 69.3% (4.415 t/ha) in mean annual losses of eroded soil and by 64.4% (12.888 kg/ha) in losses of mineral elements, in comparison with maize continuous cropping.

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