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THE EVOLUTION OF CHEMICAL AND BIOLOGICAL CHARACTERISTICS IN CAMBIC CHERNOZEM, UNDER THE INFLUENCE OF CROP ROTATION, FERTILIZERS AND SOIL EROSION

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ABSTRACT - Investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, during 2004-2008, have followed the influence of different crop structures and different fertilization methods on crop yield, erosion and soil fertility. Within the experiment, the following rotation schemes have been followed: wheat and maize continuous cropping, 2-year rotation (wheat-maize), 3-year rotation (peas-wheat-maize) and 4-year rotation + reserve field cultivated with legumes and perennial grasses (alfalfa + *Lolium* or Sainfoin + *Bromus*). The use of 3 and 4 year- rotations with annual and perennial meliorate plants has resulted in yield increases of 25 – 30 % (632 – 768 kg/ha) in wheat and 24-28% (973-1161 kg/ha) in maize, as compared to continuous cropping. The fertilization of wheat and maize crops at the rate of $N_{60}P_{40}$+30 t/ha manure has determined the increase by 3.0 g/kg (17.9%) in the content of organic carbon from soil, as compared to the rate of $N_{100}P_{80}$. The use of peas-wheat-maize-sunflower rotation + reserve field grown with legumes and perennial grasses has contributed to the increase by 2.2 g/kg (13.4%) in the content of organic carbon. The use of 4-year rotation + reserve field cultivated with perennial grasses and legumes on slope lands, poor in organic matter has determined the increase by 47% in soil potential and by 34% in enzyme potential, as compared to wheat-maize rotation. On 11% slope lands, the use of soybean-wheat-maize rotation + two reserve fields cultivated with perennial grasses has determined the diminution of soil losses by erosion at 0.985 t/ha, and on 16% slope lands, peas-wheat-maize rotation + two reserve fields, cultivated with perennial grasses has

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determined the diminution in soil erosion at 1.371 t/ha. On 16% slope lands, the crop structure, which determined the diminution in mean soil losses by erosion until 1.371 t/ha/year included 20 % straw cereals, 20% annual legumes, 20% row crops and 40 % perennial grasses and legumes.

Key words: soil erosion, cropping systems, fertilization, organic matter, wheat, maize

REZUMAT – Evoluția caracteristicilor chimice şi biologice în solul cernoziom cambic, sub influența rotației, îngrăşămintelor şi a eroziunii solului. Cercetările, efectuate în perioada 2004-2008 la Stațiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, au urmărit influența diferitelor structuri ale culturilor şi a diferitelor metode de fertilizare asupra producției, eroziunii şi fertilității solului. În cadrul experimentului, s-au studiat următoarele scheme de rotație a culturilor: monocultura de grâu şi porumb, rotația de 2 ani (grâu-porumb), rotația de 3 ani (mazăre – grâu – porumb) şi rotația de 4 ani, cu o solă săritoare, cultivată cu leguminoase şi graminee perene (lucernă + *Lolium* sau sparcetă + *Bromus*). Folosirea asolamentelor de 3 şi 4 ani cu plante amelioratoare anuale şi perene a determinat obținerea unor sporuri de producție, în comparație cu monocultura, de 25 – 30 % (632 – 768 kg/ha) la grâu si 24-28% (973-1161 kg/ha) la porumb. Fertilizarea culturilor de grâu şi porumb cu doza de $N_{60}P_{40}$+30 t/ha gunoi de grajd a determinat creşterea conținutului de carbon organic din sol, comparativ cu doza de $N_{100}P_{80}$, cu 3.0 g/kg (17.9%), iar rotația mazăre–grâu-porumb–floarea-soarelui + o solă săritoare cultivată cu leguminoase şi graminee perene a contribuit, comparativ cu rotația grâu-porumb, la creşterea conținutului de carbon organic cu 2.2 g/kg (13.4%). Folosirea rotației de 4 ani cu o solă săritoare, cultivată cu leguminoase şi graminee perene pe terenurile în pantă, sărace în materie organică, a determinat, în comparație cu rotația grâu-porumb, creşterea potențialului vital al solului cu 47 % şi a potențialului enzimatic cu 34 %. Pe terenurile cu panta de 11%, folosirea rotației soia – grâu- porumb + două sole săritoare cultivate cu graminee perene, a determinat reducerea pierderilor de sol prin eroziune la 0.985 t/ha, iar pe terenurile cu panta de 16%, rotația mazăre – grâu – porumb + două sole săritoare cultivate cu ierburi perene a determinat reducerea eroziunii solului la 1.371 t/ha. Pe terenurile cu panta de 16%, structura culturilor, care a determinat reducerea pierderilor medii de sol prin eroziune până la 1.371 t/ha/an, a cuprins 20 % cereale păioase, 20 % leguminoase anuale, 20 % plante prăşitoare şi 40 % leguminoase şi graminee perene.

Cuvinte cheie: eroziunea solului, sisteme de cultură, fertilizare, substanță organică, grâu, porumb

INTRODUCTION

The environment deterioration is mainly caused by soil erosion, compaction, soil structure damages, caused by human activities and loss of organic matter, as well as by extreme climatic conditions, influenced by world changes. In the last period, the investigations conducted in different countries have followed the influence of improving technological elements on fertilization, soil tillage and crop rotations with legumes and perennial grasses, which determine the increase in the content of organic carbon from soil and the reduction of N_2O emissions. Investigations, carried out under different climatic conditions, have shown that the use of crop rotations with legumes and perennial grasses determined a very good capitalization of fertilizers and contributed to the improvement in physical, chemical and biological characteristics of soil (Bireescu, 2008; Gobin, 2003; Jităreanu, 2008; Klik, 2002; Russell, 2006, Tsadilas, 2002).

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 diminution in the content of organic carbon from soil, caused by mineral fertilization, was found in loam-sandy fields from Nashua, USA, where lower than 180 kg nitrogen/ha were applied in maize-soybean rotation and in clay loam soils from Rothamsted, England, where lower rates than $N_{192}P_{35}K_{90}Mg_{35}$ were applied (Blair et al., 2006; Russell, 2006).

Investigations conducted at the Agricultural Research and Development Station of Podu- Iloaiei, Iaşi County, since 1968 have followed the influence of different crop structures and different fertilization methods on crop yield, erosion and soil fertility. Within the experiment, the following rotation schemes have been followed: wheat and maize continuous cropping, 2-year rotation (wheat-maize), 3-year rotation (peas-wheat-maize) and 4-year rotation + reserve field cultivated with legumes and perennial grasses (Alfalfa + *Lolium* or Sainfoin + *Bromus*). In the experiments conducted in 1954, by Russell A. E., at Kanawha and at Nashua, in 1979, it was found that the high nitrogen rate mineral fertilization has diminished the cationic exchange capacity. At Nashuma, the content of exchangeable Mg diminished once with the increase in nitrogen rates (0, 90, 180 and 270 kg/ha) from 333 mg/kg soil to 325, 302, and 283 mg/kg. In the centre of Greece, on eroded slope lands with acid soils, which have a content of 15.2 % clay, a pH of 5.0 and 1.8 % organic matter, applying different organic materials have contributed to the growth of wheat yield, of the content of organic matter and the improvement of soil reaction, in comparison with mineral fertilization with 160 kg N/ha + 80 kg P_2O_5/ha (Tsadilas, 2002; Sgouras, Tsadilas, 2007).

MATERIALS AND METHODS

The investigations conducted during 2004-2008 on a Cambic Chernozem at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, have followed the influence of different crop rotations and fertilizers on yield, in wheat and maize crops, and of soil agrochemical and biological characteristics. The typical Cambic Chernozem from Podu-Iloaiei was formed on a loessy loam, has a mean humus content (3.1-3.4 %), is well supplied with mobile potassium (215-235 ppm) and moderately with phosphorus (28-35 ppm) and nitrogen (0.160-0.165 %). Experiments were conducted on the hydrographic basin of Scobâlțeni, with a reception area of 159 ha, a mean altitude of

119.4 m, a mean slope of 11 % and a mean slope length of 250 m. The area of the hydrographic basin has been anti-erosion arranged since 1983, being used combined cropping systems made of sod rewetting and strip cultivation. The width of cultivated strips is 200-250 m on 5-10% slopes, 100-150 m on 10-15% slopes and 50-100 m on 15-18 % slopes.

The experiments were set up in split-split plots with four replicates. Soil has a high clay content (39-41%), difficult to be treated when soil moisture is close to the wilting coefficient (12.2 %). In wheat, we have used Gabriela Variety, and in maize, Podu-Iloaiei 110 Hybrid. Soil on which physical and chemical analyses were done was sampled at the end of plant growing period. Soil response was determined in water suspension by potentiometrical means with glass electrode. The content of organic carbon was determined by the Walkley-Black method, the content in mobile phosphorus 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. The determination of soil respiration was made by means of the respirometer, which replaces the self-acting O_2 consumed in the process of soil respiration and collects the disengaged CO_2. The determination of the cellulosolythic potential was done according to the methodology used by Vostrov and Petrova (1961) with the contribution of Stefanic (1994).

The determination of water and soil losses by erosion was carried out by means of loss control plots with a collecting area of 100 m^2 (25x4 m) and by means of a hydrological section equipped with spillway and limnograph (an apparatuses for measuring in time the level of the runoff water from the outlet canal of the hydrographical basin) and devices for sampling water and soil lost by erosion. We took samples from drained water for determining runoff turbidity, leached soil amounts and for chemical analyses.

RESULTS AND DISCUSSION

Many investigations conducted in Romania and abroad paid a special attention to the technological elements and methods, which determined the recovery of soil physical, chemical and biological characteristics in a shorter time and with lower expenses. These are protection crop rotations with annual and perennial legumes, fertilization systems with various unpolluting biodegradable organic matters, conservation systems of minimum soil tillage, etc. In the organization of the arable field, crop rotation still represents a basic measure of the plant production. Its value cannot be replaced by any other measure, even if soil and growing conditions are optimum. Achieving mean or long-term projects for soil protection against erosion must have in view not only slope and valley arrangement works but also soil management works and protection crop rotations that do not require high expenses.

The mean yield increases, obtained in wheat during 2004-2008, were between 24.5 and 29.8% (632 – 768 kg/ha), due to crop rotation, and between 43 and 119% (755 – 2069 kg/ha), due to applied fertilizer rates (*Table 1*). The mean yield increases, obtained in maize during 2004-2008, were between 11 and 28%

(436 – 1161 kg/ha), due to crop rotation, and between 36 and 99% (1069 – 2015 kg/ha), due to applied fertilizer rates. Maize growing in 4-year rotation (peas-wheat-maize-sunflower) + ameliorative field, cultivated with perennial grasses and legumes, has determined yield increases of 15.9% and 725 kg/ha, respectively, as compared to wheat-maize rotation (which is the most commonly used rotation by farmers).

Table 1 - Influence of rotation on wheat and maize yield, on the slope lands from the Moldavian Plateau (Gabriela Variety created at the Agricultural Research and Development Station of Podu-Iloaiei and Podu-Iloaiei 110 Hybrid)

Crop rotation	Wheat yield		Dif.	Significance	Maize yield		Dif.	Significance
	kg/ha	%	kg/ha		kg/ha	%	kg/ha	
Continuous cropping	**2584**	100	0		**4123**	100	0	
Wheat – maize rotation	**2621**	101	37		**4559**	111	436	x
Peas –wheat-maize rotation	**3216**	125	632	**xxx**	**5096**	124	973	xxx
Peas –wheat-maize –sunflower + reserve field cultivated with legumes and perennial grasses	**3352**	130	768	**xxx**	**5284**	128	1161	xxx
LSD 5 %			**252**				**329**	
LSD 1 %			**368**				**465**	
LSD 0.1 %			**452**				**643**	

Applying the rate of $N_{140}P_{100}$ for 41 years has determined the pH decrease until the limit of moderately acid interval (5.3-5.7) in wheat continuous cropping and wheat-maize rotation, and was maintained within the weakly acid interval (6.2-6.9) in 3 and 4–year crop rotations with annual and perennial legumes (*Table 2*).

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 case of organo-mineral fertilization and in 4-year crop rotation, which included melioration plants made of perennial grasses and legumes.

In comparison with 4-year crop rotation, in the wheat-maize rotation with melioration plants (annual and perennial grasses and legumes), the mean carbon content from soil has diminished from 18.6 to 16.4 g/kg, and the content in mobile phosphorus decreased from 52 to 37 ppm. In maize continuous cropping and wheat-maize rotation, applying mineral fertilizers at the rate of $N_{140}P_{100}$ did not result in significant differences of the humus content from soil (in comparison with the unfertilized control); this demonstrated that within these crop rotations, maintaining a positive balance of the organic matter was done only by the organo-mineral fertilization.

Table 2 – Influence of fertilization and crop rotation on soil response and the content of organic carbon and mineral elements from soil

Fertilizer rate	pH, H_2O	Organic C, g/kg	P-AL, mg/kg	K-AL, mg/kg	Crop rotation	pH, H_2O	Organic C, g/kg	P-AL, mg/kg	K-AL, mg/kg
N_0P_0	7.1	15.8	13	206	Maize continuous growing	5.9	16.4	34	186
$N_{60}P_{40}$	6.9	16.1	33	180	Wheat continuous growing	6.6	16.9	42	213
$N_{100}P_{80}$	6.4	16.8	46	184	Wheat – maize rotation	6.2	16.4	37	195
$N_{140}P_{100}$	5.7	17.8	61	196	Peas–wheat-maize rotation	6.7	17.9	46	222
$N_{60}P_{40}$+30 t/ha manure	7.0	19.8	68	286	Peas–wheat-maize – sunflower rotation + reserve field cultivated with legumes and perennial grasses	6.9	18.6	52	212
LSD 5%	0.52	1.5	4.3	16		0.43	1.4	3.8	14
LSD 1%	0.82	2.1	5.7	23		0.69	1.8	5.1	20
LSD 0.1%	1.19	2.7	7.5	33		1.02	2.4	6.7	28

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 rotation + reserve field, cultivated with perennial legumes and in $N_{140}P_{100}$ fertilization. The 41-year use of 3 and 4-year crop rotations has determined the increase in the mass of total carbon and mobile phosphorus from soil by 13% (2.2 C g/kg) and, respectively, 40% (15 P-AL mg/kg), in comparison with maize continuous cropping.

The 3 and 4-year crop rotations with annual and perennial melioration plants have resulted in increasing the content of organic carbon from soil by 1.5-2.2 g/kg soil. At fertilization, significant increases in the content of organic carbon from soil were registered only at higher than $N_{140}P_{100}$ mineral rates (1.9 g/kg soil) and at organo-mineral fertilization with $N_{60}P_{40}$+30 t/ha manure (3.9 g/kg soil), as compared to the unfertilized control. In 3 and 4-year rotations, the annual application of rates of 80 kg/ha P_2O_5 has determined the accumulation of a reserve of mobile phosphates in soil, which was comprised between 49 and 56 ppm, according to applied nitrogen rates (*Table 2*).

The determination of biological indicators and estimate of soil fertility allow the knowledge of multiple soil biochemical changes under the influence of soil and climatic conditions and technological links and management of agricultural activities for soil protection and conservation. The studies concerning the soil respiration and ***cellulolysis*** potential pointed out that the organo-mineral fertilization had a positive influence on the life level from soil and contributed to the stimulation of soil vital activity (*Table 3*).

Table 3 - Influence of long-term fertilization and crop rotation on the potential ability of respiration and cellulolysis from soil

Fertilizer rate	Respiration (cm³ CO_2)			*Cellulolysis* (%, cellulose)		
	2007	2008	Average	2007	2008	Average
N_0P_0	9.08	9.42	9.25	12.67	12.38	12.52
$N_{100}P_{100}$	12.32	12.66	12.49	16.45	16.54	16.50
$N_{60}P_{40}$+30 t/ha manure	16.52	16.73	16.63	19.44	18.25	18.84
Average wheat continuous cropping	**12.64**	**12.94**	**12.79**	**16.18**	**15.72**	**15.95**
N_0P_0	26.92	28.04	27.48	35.02	33.91	34.46
$N_{100}P_{100}$	30.95	40.13	35.54	37.71	43.05	40.38
$N_{60}P_{40}$+30 t/ha manure	43.48	45.26	44.37	53.24	50.18	51.71
Average wheat – maize rotation	**33.78**	**37.81**	**35.80**	**41.99**	**42.38**	**42.18**
N_0P_0	33.21	33.34	33.28	41.96	41.23	41.59
$N_{100}P_{100}$	39.28	46.11	42.70	42.97	48.84	45.90
$N_{60}P_{40}$+30 t/ha manure	52.43	57.51	54.97	55.55	60.44	57.99
Average- peas - wheat – maize rotation	**41.64**	**45.65**	**43.65**	**46.82**	**50.17**	**48.50**
N_0P_0	42.51	38.64	40.58	50.19	51.32	50.76
$N_{100}P_{100}$	48.61	60.13	54.37	54.82	58.21	56.52
$N_{60}P_{40}$+30 t/ha manure	67.86	71.56	69.71	69.55	73.56	71.56
Average peas - wheat – maize rotation + an outside field grown with perennial grasses	**52.99**	**56.78**	**54.89**	**58.19**	**61.03**	**59.61**
LSD 5%			1.78			3.21
LSD 1%			3.04			4.86
LSD 0.1%			5.15			6.63

Following the influence of the fertilization and cropping system on some biological indicators of soil fertility, it was found out that the dynamics of enzyme accumulation in soil and their activity were very much influenced by the presence of organic and mineral substances, soil moisture and technological links. Enzyme processes from soil were developed in connection with the presence of the organic matter and mineral elements from soil. Applied at high rates, nitrogen and phosphorus fertilizers resulted in the diminution of the catalase and urease activity from soil, in comparison with the organo-mineral variant, this fact showing an intensification of burning processes of the organic matter and a low humus conservation in soil (*Table 4*).

Table 4 - Influence of long-term fertilization and crop rotation on enzyme activities from soil

Fertilizer rate	Catalase (O_2 cc)			Sucrose (mg glucose)			Urease (NH_4, mg)			Phosphatase (P, mg)		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
N_0P_0	128	134	131	634	655	645	10.91	12.08	11.50	5.74	5.88	5.81
$N_{100}P_{100}$	141	188	165	679	718	699	12.23	15.17	13.70	7.20	7.04	7.12
$N_{60}P_{40}$+30 t/ha manure	176	212	194	745	789	767	17.46	20.01	18.74	12.32	10.85	11.59
Average wheat continuous cropping	148	**178**	163	686	**721**	703	13.53	**15.75**	14.64	8.42	**7.92**	8.17
N_0P_0	256	256	256	1092	1114	1103	22.15	22.51	22.33	10.88	12.11	11.50
$N_{100}P_{100}$	250	288	269	1179	1201	1190	22.75	26.84	24.80	16.23	16.62	16.42
$N_{60}P_{40}$+30 t/ha manure	297	313	305	1234	1256	1245	32.05	34.08	33.07	22.56	24.81	23.69
Average wheat – maize rotation	268	**286**	277	1168	**1190**	1179	25.65	**27.81**	26.73	16.56	**17.85**	17.20
N_0P_0	323	321	322	1176	1288	1232	27.02	30.04	28.53	14.38	15.07	14.73
$N_{100}P_{100}$	340	358	349	1260	1384	1322	31.54	39.52	35.53	21.21	23.31	22.26
$N_{60}P_{40}$+30 t/ha manure	382	412	397	1437	1448	1442	43.18	44.83	44.01	24.64	27.81	26.22
Average peas - wheat – maize rotation	348	**364**	356	1291	**1373**	1332	33.91	**38.13**	36.02	20.08	**22.06**	21.07
N_0P_0	400	318	359	1312	1326	1319	32.26	34.52	33.39	18.76	19.81	19.28
$N_{100}P_{100}$	400	401	400	1351	1415	1383	32.77	38.61	35.69	23.54	28.02	25.78
$N_{60}P_{40}$+30 t/ha manure	451	495	473	1485	1524	1504	43.85	49.86	46.86	26.73	30.21	28.47
Average peas - wheat – maize rotation + an outside fields grown with perennial grasses	417	**405**	411	1383	**1422**	1402	36.29	**41.00**	38.65	23.01	**26.01**	24.51
LSD 5%			17			49			3.34			1.05
LSD 1%			24			64			5.06			1.75
LSD 0.1%			38			88			7.12			2.38

Table 5-Influence of the mode of fertilization and crop rotation on some biological indicators of soil fertility

Fertilizer rate	Indicator of Vital Activity Potential (IPAV, %)			Indicator of Enzyme Activity Potential (IPAE, %)			Biological Synthetic Indicator (ISB, %)		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
N_0P_0	10.9	9.3	10.1	11.5	9.8	10.6	11.2	9.6	10.4
$N_{100}P_{100}$	14.5	12.5	13.5	13.0	11.8	12.4	13.8	12.1	12.9
$N_{60}P_{40}$+30 t/ha manure	17.9	14.7	16.3	16.1	14.3	15.2	17.0	14.5	15.8
Average wheat continuous cropping	**14.4**	**12.2**	**13.3**	**13.5**	**12.0**	**12.8**	**14.0**	**12.1**	**13.0**
N_0P_0	30.7	25.7	28.2	21.8	17.9	19.8	26.2	21.8	24.0
$N_{100}P_{100}$	35.1	34.9	35.0	26.4	20.8	23.6	30.8	27.9	29.3
$N_{60}P_{40}$+30 t/ha manure	46.6	40.2	43.4	31.8	24.8	28.3	39.2	32.5	35.8
Average wheat – maize rotation	**37.5**	**33.6**	**35.5**	**26.7**	**21.2**	**23.9**	**32.1**	**27.4**	**29.7**
N_0P_0	35.7	31.7	33.7	26.0	22.0	24.0	30.8	26.9	28.8
$N_{100}P_{100}$	41.4	39.8	40.6	32.6	25.0	28.8	37.0	32.4	34.7
$N_{60}P_{40}$+30 t/ha manure	52.7	49.4	51.0	33.9	29.9	31.9	43.3	39.7	41.5
Average peas - wheat – maize rotation	**43.3**	**40.3**	**41.8**	**30.8**	**25.6**	**28.2**	**37.0**	**33.0**	**35.0**
N_0P_0	45.6	38.5	42.0	31.2	24.2	27.7	38.4	31.3	34.9
$N_{100}P_{100}$	52.0	49.2	50.6	34.9	28.6	31.7	43.5	38.9	41.2
$N_{60}P_{40}$+30 t/ha manure	67.6	60.6	64.1	40.5	32.9	36.7	54.1	46.8	50.4
Average peas - wheat – maize + an outside field grown with perennial grasses	**55.0**	**49.4**	**52.2**	**35.5**	**28.5**	**32.0**	**45.3**	**39.0**	**42.1**
LSD 5%			2.17			1.03			1.76
LSD 1%			3.48			2.85			2.54
LSD 0.1%			5.21			3.11			3.84

In 3 and 4-year rotations, the stimulating effect from energetic viewpoint of peas stalks and crop residues from legumes and perennial grasses has improved the biological activity from soil. In wheat-maize rotation, the great annual consumptions of mineral elements and the short period from maize harvesting until wheat sowing do not assure good conditions for crop residue decay. The long-term utilization of continuous cropping determines a severe limitation of the biotic and enzyme potential from soil, both in the control and in the fertilized variants. The organo-mineral fertilization has resulted in improving soil biological activity, by meliorating and stimulating contribution of manure,

The organo-mineral fertilization has stimulated very much the phosphate activity from soil, determining a better plant supply with mobile phosphorus. An improvement in enzyme potential (IPAE), due to a large amount of organic matter with enzymes, which entered the soil, was also transmitted to the level of the Biological Synthetic Indicator (ISB), which represents the average between Indicator of Vital Activity Potential (IPAV) and Indicator of Enzyme Activity Potential (IPAE) (*Table 5*).

The erosion process being unavoidable and the tolerance level of soil losses being of 2-4 t/ha/year, corresponding to the annual rate of soil renewal, the applied technologies must maintain these limits under control.

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 2005-2008, of the total of 625.5 mm rainfall, 396.3 mm (63.4 %) caused runoff between 9.0 mm in perennial grasses on the second growing season and 30.4 mm in sugar beet (*Table 6*). The annual soil losses caused by erosion registered at the same period on 11% slope lands were between 0.102 t/ha in perennial grasses on the second growing season and 2.544 t/ha in sugar beet. On 16% slope lands, the mean annual water runoff caused by erosion, registered during 2005-2008, was comprised between 9.8 mm on the plot cultivated with legumes and perennial grasses in the second year of vegetation and 36.6 mm in sunflower (*Table 7*). From the total of 396.3 mm of mean annual rainfall determining water runoff registered in the last 4 years in row crops, which protect weakly soil against erosion, the amounts of water runoff were of 30.2-30.4 mm (maize and sugar beet) on 11% slope lands and of 34.7-36.6 mm on 16% slope lands.

The mean annual amounts of eroded soil were comprised during 2005-2008 between 0.102 and 4.529 t/ha (IInd year grasses and field) on 11% slope lands and between 0.157 and 7.128 t/ha on 16% slope lands.

Table 6 - Mean annual water runoff and soil losses by erosion registered in different crops, during 2005-2008, on 11% slope lands from Scobâlțeni, Iaşi County

Years	2005		2006		2007		2008		Mean	
Rainfall (mm)	625		681.6		713.5		482.5		**625.5**	
Rainfall causing runoff (mm)	349.3		453.2		380		402.7		**396.3**	
Crop	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})
Field	11.3	2.314	80.7	6.617	25.9	3.102	40.9	6.083	39.7	4.529
Sugar beet	8.7	1.568	64.5	4.257	19.9	1.566	28.5	2.783	30.4	2.544
I^{st} year grasses	5.2	0.854	42.8	1.625	11.6	0.495	16.9	0.848	19.1	0.956
II^{nd} year grasses	1.7	0.079	26.8	0.241	2.7	0.021	4.6	0.067	9.0	0.102
Maize	9.1	1.219	62.1	3.788	20.2	1.683	29.3	3.050	30.2	2.435
Soybean	7.6	1.008	52.8	2.534	13.7	0.683	23.5	1.747	24.4	1.493
Wheat	3.4	0.213	31.2	0.468	4.4	0.099	6.2	0.163	11.3	0.236
Beans	7.9	1.043	56.5	3.277	14.7	0.807	24.3	2.114	25.9	1.810

Table 7 - Mean annual water runoff and soil erosion by erosion registered in different crops, during 2005-2008, on 16% slope lands from Scobâlțeni, Iaşi County

Years	2005		2006		2007		2008		Mean	
Rainfall (mm)	625		681.6		713.5		482.5		**625.5**	
Rainfall causing runoff (mm)	349.3		453.2		380		402.7		**396.3**	
Crop	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})	Water Runoff (mm)	Erosion (t ha^{-1})
Field	12.9	2.678	94.8	12.021	38.6	5.452	44.7	8.362	47.8	7.128
Sunflower	10.2	1.717	74.9	6.872	25.8	2.207	35.4	4.848	36.6	3.911
I^{st} year grasses	6.5	0.870	51.6	2.517	13.3	0.725	21.9	1.305	23.3	1.354
II^{nd} year grasses	2.9	0.087	27.4	0.418	3.3	0.029	5.7	0.093	9.8	0.157
Maize	9.2	1.453	70.2	5.708	25.4	2.199	34.1	4.392	34.7	3.438
Peas	8.1	1.036	60.7	3.405	18.2	0.915	14.3	0.885	25.3	1.560
Wheat	4.9	0.319	34.6	0.708	6.0	0.146	7.2	0.205	13.2	0.345
Beans	8.0	1.099	63.3	4.303	20.7	1.400	26.57	2.537	29.6	2.335

On 11% slope lands, the mean annual losses of nitrogen caused by erosion were comprised, during 2005-2008, between 5.5 and 7.7 kg/ha in maize and sugar beet crops and between 1.5 and 4.6 kg/ha/year in wheat and soybean crops (*Table 8*). If phosphorus and potassium losses are low (1.13-2.4 kg/ha/year), humus and nitrogen losses should be diminished by using rotations with crop structures that protect soil against erosion. On 16% slope lands, the mean annual nitrogen, phosphorus and potassium leaches, caused by erosion, registered during 2005-2008, were comprised between 7.4 and 10.9 kg/ha in row crops (beans and sunflower) and between 2 and 5 in wheat and peas crops (*Table 8*). Data are very important for establishing and regulating the fertilizer rates applied in crops and for controlling the environment pollution with nitrogen, phosphorus and potassium.

Table 8 – Mean annual losses of humus and nutritive elements in different crops

Crop	Eroded soil (t/ha)	Humus Kg/ha	Nitrogen from water runoff and eroded soil, kg ha^{-1}	Phosphorus kg ha^{-1}	Potassium kg ha^{-1}	Total NPK kg ha^{-1}
Cambic Chernozem with 11% slope						
Field	4.529	**152.2**	10.686	0.539	1.164	12.389
Sugar beet	2.544	**85.7**	7.723	0.315	0.633	8.672
Ist year grasses	0.956	**32.3**	3.243	0.112	0.238	3.593
IInd year grasses	0.102	**3.4**	0.970	0.012	0.026	1.007
Maize	2.435	**81.6**	7.089	0.273	0.609	7.970
Soybean	1.493	**50.3**	4.609	0.163	0.370	5.142
Wheat	0.236	**7.9**	1.537	0.026	0.059	1.622
Beans	1.810	**61.2**	5.501	0.208	0.458	6.168
Cambic Chernozem with 16% slope						
Field	7.128	240	13.863	0.820	1.711	16.394
Sunflower	3.911	132	9.356	0.450	0.958	10.764
Ist year grasses	1.354	46	4.237	0.156	0.337	4.730
IInd year grasses	0.157	5	1.126	0.018	0.039	1.182
Maize	3.438	115	9.195	0.385	0.860	10.440
Peas	1.560	53	4.657	0.148	0.387	5.192
Wheat	0.345	12	1.857	0.039	0.081	1.977
Beans	2.335	79	6.587	0.212	0.572	7.372

On 11% slope lands, the use of 3 and 4-year crop rotations with legumes and perennial grasses leaving in soil great amounts of roots and crop residues, which balanced the humus content, also contributes to the diminution in soil, humus and mineral element losses. These losses are by 2.5 lower than the ones registered in maize and sugar beet crops (*Table 9*).

The results concerning water runoff, soil and mineral element losses from crops placed in different rotations have shown that on 16% slope lands, the use of peas-wheat-maize rotation + 2 reserve fields cultivated with legumes and perennial grasses resulted in soil losses, which diminished by 25.1%, as compared to wheat-maize rotation (*Table 9*).

Table 9 - Mean annual losses of soil and nutritive elements in different crops rotations

Crops rotation	Eroded soil		Total NPK		Row plants, %
	t/ha	%	kg/ha	%	
Cambic Chernozem with 11% slope					
Beans - wheat –sugar beet-maize rotation	1.756	100	6.108	100	75
Soybean- wheat –sugar beet-maize rotation	1.677	96	5.852	96	75
Beans - wheat -maize rotation	1.494	85	5.253	86	66
Soybean- wheat-maize rotation	1.388	79	4.911	80	66
Wheat-maize rotation	1.336	76	4.796	79	50
Soybean- wheat-maize rotation + an outside field grown with perennial grasses	1.138	65	4.151	68	50
Beans - wheat -maize rotation + two fields grown with perennial grasses	1.051	60	3.900	64	40
Soybean - wheat -maize rotation + two fields grown with perennial grasses	0.988	56	3.694	60	40
Cambic Chernozem with 16% slope					
Beans - wheat – maize – sunflower - wheat rotation	2.075	100	6.506	100	60
Peas - wheat – maize – sunflower rotation + an outside field grown with perennial grasses	2.002	97	6.148	94	40
Wheat - maize rotation	1.892	91	6.209	95	50
Peas - wheat – maize – sunflower rotation + two fields grown with perennial grasses	1.794	87	5.517	85	33
Peas - wheat – maize rotation	1.781	86	5.870	90	33
Beans - wheat – maize rotation + two fields grown with perennial grasses	1.526	74	4.904	75	40
Peas - wheat – maize rotation + an outside field grown with perennial grasses	1.525	73	4.994	77	25
Peas - wheat – maize rotation + two fields grown with perennial grasses	1.371	66	4.468	69	20

During 2005-2008, the use of crop rotations with a percent until 20% of row plants, which also include reserve fields cultivated with perennial grasses has determined the diminution in soil and mineral element losses by 25% and, respectively, 26%, as compared to 2 year-rotation (wheat-maize) (*Table 9*). According to these results concerning the contribution of melioration plants to the diminution of soil and mineral element losses caused by erosion, the technical elements are established for the anti-erosion land arrangement, such as width of cultivated strips and of sod rewetting, crop structure, crop rotations and assortment of legumes and perennial grasses used for the slope lands.

CONCLUSIONS

The use of 3 and 4 year- crop rotations with annual and perennial meliorate plants has resulted, during 2004-2008, in yield increases of 25 – 30% (632 – 768 kg/ha) in wheat and 24-28% (973-1161 kg/ha) in maize, as compared to continuous cropping.

The fertilization of wheat and maize crops at the rate of $N_{60}P_{40}$+30 t/ha manure has determined the increase by 3.0 g/kg (17.9%) in the content of organic carbon from soil, as compared to the rate of $N_{100}P_{80}$. The use of peas-wheat-maize-sunflower rotation + reserve field grown with legumes and perennial grasses has contributed to the increase by 2.2 g/kg (13.4%) in the content of organic carbon.

The use of 4-year rotation + reserve field cultivated with perennial grasses and legumes on slope lands, poor in organic matter has determined the increase by 47% in vital soil potential and by 34% in enzyme potential, as compared to wheat-maize rotation.

On 11% slope lands, the use of the soybean-wheat-maize rotation + two reserve fields cultivated with perennial grasses has determined the diminution of soil losses by erosion at 0.985 t/ha, and on 16% slope lands, the peas-wheat-maize rotation + two reserve fields, cultivated with perennial grasses has determined the diminution in soil erosion at 1.371 t/ha.

On 16% slope lands, the crop structure, which determined, during 2004-2008, the diminution in mean soil losses by erosion until 1.371 t/ha/year included 20 % straw cereals, 20% annual legumes, 20% row crops and 40 % perennial grasses and legumes.

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