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THE EFFECT OF DIFFERENT FERTILIZATION SYSTEMS ON WHEAT YIELD, EROSION AND FERTILITY OF ERODED SOILS FROM THE MOLDAVIAN PLATEAU

C. AILINCĂI[*1], Despina AILINCĂI[2], Maria ZBANȚ[2], Ad. MERCUŞ[2], D. ȚOPA[1] , M. CARA[1]

[1]*University of Agricultural Sciences and Veterinary Medicine of Iaşi*
[2]*Agricultural Research and Development Station of Podu-Iloaiei, Iaşi*

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ABSTRACT - *The long-term experiments carried out at the Agricultural Research Station of Podu-Iloaiei, Iaşi County, tried to establish some fertilization systems for getting efficient yield increases, which maintain or increase the content of organic carbon from soil. These trials were set up on a 16% slope field, with a cambic Chernozem soil, which has a clayey-loam texture, a neuter to weakly acid response and a mean supply in nutrients. The combined use of mean rates of mineral fertilizers ($N_{70}P_{70}$), together with 40 t/ha manure or 6 t/ha crop residues from wheat and maize crops, has resulted in improving soil physical and chemical characteristics and getting yield increases in wheat of 2313-2214 kg/ha (136-130%), on weakly eroded lands, and 2074-2001 kg/ha (178-172%) on highly eroded lands, compared to the unfertilized control. Both on weakly and highly eroded lands, the mineral fertilization with lower rates than $N_{140}P_{100}$ kg/ha has determined the decrease of humus content from soil. On highly eroded lands, the humus content was kept at values of 3.42-3.49% only by the annual application of the rate of 60 t/ha manure or $N_{70}P_{70}$+ 60 t/ha manure. Annual soil losses by erosion, registered during 1980-2007, in the Moldavian Plateau, were between 0.286 t/ha in perennial grasses, on the second year of vegetation, and 9.794 t/ha in sunflower. From the results obtained on erosion in different crop rotations, we have found out that in 16% slope fields from the Moldavian Plateau, soil losses by erosion were diminished below the allowable limit of 3-4 t/ha/year only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.*

Key Words: fertilization, wheat, soil fertility, soil erosion

[*] E-mail: ailincai@univagro-iasi.ro

REZUMAT - Efectul diferitelor sisteme de fertilizare asupra producţiei de grâu, a eroziunii şi a fertilităţii solurilor erodate din Podişul Moldovei. *Cercetările efectuate la S.C.D.A. Podu-Iloaiei, jud. Iaşi, au urmărit influenţa fertilizării cu ingrăşăminte minerale, gunoi şi resturi vegetale asupra producţiei, la culturile din asolamentul mazăre-grâu-porumb, şi asupra fertilităţii solului pe un teren cu panta de 16%. Studiile au fost efectuate pe un sol cernoziom cambic tipic, care predomină în Podişul Moldovei, şi au urmărit stabilirea dozelor de îngrăşăminte care asigură obţinerea unor sporuri eficiente de producţie şi care determină menţinerea sau creşterea conţinutului de carbon organic din sol. Solul pe care au fost amplasate experienţele are o textură luto-argiloasă, o reacţie neutră spre slab acidă şi o aprovizionare mijlocie în elemente nutritive. Folosirea combinată a unor doze mijlocii ($N_{70}P_{70}$) de îngrăşăminte minerale, împreună cu 40 t/ha gunoi sau 6 t/ha resturi vegetale, de la culturile de grâu şi porumb, a determinat îmbunătăţirea însuşirilor fizice şi chimice ale solului şi obţinerea unor sporuri de producţie la grâu, faţă de varianta nefertilizată, de 2313-2214 kg/ha (136-130%) pe terenurile slab erodate şi 2074-2001 kg/ha (178-172%) pe terenurile puternic erodate. Atat pe terenurile slab erodate, cât şi pe cele puternic erodate, fertilizarea minerală cu doze mai mici de $N_{140}P_{100}$ kg/ha a determinat scăderea conţinutului de humus din sol până la 2,49- 3,05%. Pe terenurile cu eroziune puternică, menţinerea conţinutului de humus la valori de 3,42-3,49% s-a realizat numai prin aplicarea anuală a dozei de 60 t/ha gunoi sau $N_{70}P_{70}$+ 60 t/ha gunoi. Pierderile anuale de sol prin eroziune, înregistrate în perioada 1980-2007, în Podişul Moldovei, au fost cuprinse între 0,286 t/ha la ierburile perene, în anul doi de vegetaţie, şi 9,794 t/ha la floarea-soarelui. Din rezultatele obţinute privind eroziunea la diferite asolamente s-a constatat că, în condiţiile terenurilor cu panta de 16% din Podişul Moldovei, reducerea pierderilor de sol prin eroziune sub limita „tolerabilă" de 3-4 t/ha/an se realizează numai în cazul asolamentelor de 4 ani, cu una sau două sole săritoare cu leguminoase şi graminee perene, care protejează mai bine solul.*

Cuvinte cheie: fertilizare, grâu, fertilitatea solului, eroziunea solului

INTRODUCTION

The main concerns on soil in the European Union are erosion, organic matter diminution, contamination, compaction, non-farming usage, biodiversity decrease, landslides and floods. Soil degradation has a direct impact on water and air quality, on biodiversity and climatic changes. The legislation proposed in September 2006 (Directive COM (2006) 232), by the amendment to the Directive 2004/35/EC, has as aim soil protection and conservation of soil capacity, in order to fulfill its economic, social, cultural and environment functions. The Directive COM (2006) 232 concerning soil protection in EU has identified the areas of erosion risk and organic matter decrease, as well as those affected by compaction, salinization and other degradation factors. The long-term experiments carried out at the Agricultural Research Station of Podu-Iloaiei, Iaşi County, have tried to establish some fertilization systems for getting efficient yield increases, which maintain or increase the content of organic carbon from soil. These trials were set up on a 16% slope field, with a cambic Chernozem soil, which has a clayey-loam texture (420 g clay, 315 g loam and 265 g sand), a neuter to weakly acid response and a mean supply in nutrients. For slope lands from dry areas with high rainfall

amount, a great importance must be paid to water preservation into soil, by means of nurse crops**,** of conservation works and crop residues, which restrain nitrate leaching, water runoff, soil and mineral element losses by erosion. The present concerns of scientists had in view the efficient use of nitrogen fertilizers, for not polluting the environment with nitrates and maintaining soil response, under the allowable limits. Data presented by the member states of the European Commission, during 2005-2006, on water quality and vulnerable zones to nitrate pollution, have shown that 17% of monitoring stations from EU had the mean values of nitrogen concentration over 50 mg NO_3/l; 7% of them had the mean values between 40 and 50 mg NO_3/l, 15%, between 25 and 40 mg NO_3/l, and 61%, a concentration below 25 mg NO_3/l. From data obtained by the European Agency on Environment, the raw balance of nitrogen in EU was of 55 kg/ha (the difference between the nitrogen supplies from mineral, organic fertilizers and symbiotic fixing, etc. and crop consumption/ ha of farming land used), with variations from 37 kg/ha (Italy) to 226 kg/ha (Holland). The nitrogen excess has decreased by 16% in all the member states of EU, excepting Ireland and Spain, comparatively to year 1990 (EEA, 2005 a). The impact of some elements of the Commune Agricultural Policy and environment policies on agriculture in EU has been studied by CAPRI (Commune Agricultural Policy Region Impact), which assesses within the environment protection, gas emissions and N,P,K balances at region level. The EU member countries must check and, if necessary, review the vulnerable areas, at least once in four years, based on the results of water management, according to Article 6 from the Directive on nitrates. The balanced fertilization, for limiting the total supply with nitrogen from fertilizers and diminishing the rate of nitrogen found in the roots area, has been insufficiently applied. The methods of calculating the nitrogen rates from crops, in correlation with soil and climate conditions, and establishing the standards concerning the total allowable nitrogen, as well as certain measures for restrictive fertilization periods (water-saturated, flooded and frozen soil), width of cover unfertilized strips, conditions of fertilizing slope fields, which prevent nitrogen losses by erosion, slides and subsoil drainage, are, in many cases, general and do not establish compulsory requirements for farmers.

MATERIALS AND METHODS

The experiments conducted at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, have studied the influence of mineral, manure and residues fertilization on production, in crops from peas-wheat-maize rotation, and on soil fertility, on 16% slope field. Investigations were carried out on a typical cambic Chernozem, which prevails in the Moldavian Plateau and have established the fertilizer rates ensuring efficient yield increases and increasing the content of organic carbon from soil. The soil on which experiments were set up have a loam-clayey texture (420 g clay, 315 g loam and 265 g sand), a neuter to weakly acid response and a mean nutrient supply. Soil on which

they did physical and chemical analyses was sampled at the end of crop vegetation period. Soil response was determined in aqueous suspension potentiometrically with glass electrode. The content of organic carbon was determined by the Walkley-Black method, while the content of 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 AL at flame photometer. The determination of water runoff, soil and nutrients 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 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. At raining, samples were taken for the determination of the partial turbidity and of the content in humus and mineral elements lost by erosion.

RESULTS AND DISCUSSION

The climatic conditions in the Moldavian Plain were characterized by a mean multiannual temperature of 9.6°C and a mean rainfall amount, on 79 years, of 542 mm, of which 161.2 mm, during September-December, and 380.8 mm, during January-August.

On weakly eroded lands, the mean wheat yields obtained during 1998-2007, were comprised between 1697 kg/ha (100 %) at the unfertilized control and 4894 kg/ha (188%) at rates of 70 kg N + 70 kg P_2O_5 + 60 t/ha manure (*Table 1*). Under these conditions, by applying rates of 100 kg N + 100 kg P_2O_5 or 140 kg N +100 kg P_2O_5/ha, the mean yield increases obtained were of 2381 and, respectively, 2826 kg/ha.

On highly eroded soil, the mean wheat yields obtained during 1998-2007, in wheat crop, placed in peas-wheat-maize rotation, were of 1163 kg/ha, under unfertilized, and of 3665 kg/ha at high mineral fertilizer rates ($N_{140}P_{100}$). In wheat, the application of mean rates of mineral fertilizers with 60 t/ha manure has resulted in getting yield increases of 183% (2131 kg/ha), compared to the unfertilized variant. Applying rates of 100 kg N + 100 kg P_2O_5 resulted in getting yield increases of 140% (2381 kg/ha) in wheat crop, placed on weakly eroded lands, and 179% (2085 kg/ha) in wheat, placed on highly eroded soil, compared to the unfertilized variant.

In wheat placed on weakly eroded lands, the mean yield increases obtained for each kg of a. i. of applied fertilizers varied, according to fertilizers rates applied, between 9.15 and 11.8 kg grains ($N_{40}P_{40}$-$N_{140}P_{100}$). On highly eroded lands, the mean wheat yields obtained under unfertilized were of 1163 kg/ha, the mean yield increases obtained by applying 40 or 60 t/ha manure, being of 41.3-35.5 kg grains per ton of manure applied. By applying mineral fertilizers ($N_{40}P_{40}$-$N_{140}P_{100}$), mean yield increases of 8.1- 10.4 kg grains/kg a. i. of applied fertilizer were obtained. Very close yield results were also obtained by applying, for 42 years, rates of 70 kg N + 70 kg P_2O_5/ha +3 t/ha stalks of peas or soybean, variants

at which yield increases obtained varied, according to soil erosion, between 2313 and 2214 kg/ha (136-130%) on weakly eroded lands, and between 2074 and 2001 kg/ha (178-172%) on highly eroded lands (*Table 1*).

Table 1

Influence of mineral and organic fertilizers on wheat yields, in weakly and highly eroded lands, (F-4 and Gabriela varieties)

Fertilizer rate	Weakly eroded soil				Highly eroded soil			
	Mean wheat yields		Differ. kg/ ha	Signif..	Mean wheat yields		Differ. kg/ha	Signif.
	Kg/ha	%			kg/ha	%		
N_0P_0	1697	100	0		1163	100	0	
$N_{40}P_{40}$	2429	143	732	***	1807	155	644	***
$N_{70}P_{70}$	3192	188	1495	***	2478	213	1315	***
$N_{100}P_{100}$	4078	240	2381	***	3248	279	2085	***
$N_{140}P_{100}$	4523	267	2826	***	3665	315	2502	***
$N_0P_{70}K_{70}$	1997	118	300	*	1470	126	307	*
$N_{40}P_{40}K_{40}$	2573	152	876	***	2068	178	905	***
$N_{70}P_{70}K_{70}$	3384	199	1687	***	2710	233	1547	***
$N_{100}P_{100}K_{100}$	4398	259	2701	***	3570	307	2407	***
$N_{140}P_{140}K_{140}$	4797	283	3100	***	3923	337	2760	***
20 t/ha manure	2761	163	1064	***	2165	186	1002	***
40 t/ha manure	3445	203	1748	***	2813	242	1650	***
60 t/ha manure	4018	237	2321	***	3294	283	2131	***
$N_{40}P_{40}$ +20 t/ha manure	3560	210	1863	***	2884	248	1721	***
$N_{40}P_{40}$+40 t/ha manure	4085	241	2388	***	3377	290	2214	***
$N_{40}P_{40}$+60 t/ha manure	4362	257	2665	***	3664	315	2501	***
$N_{70}P_{70}$+20 t/ha manure	4102	242	2405	***	3304	284	2141	***
$N_{70}P_{70}$+40 t/ha manure	4619	272	2922	***	3669	315	2506	***
$N_{70}P_{70}$+60 t/ha manure	4894	288	3197	***	4011	345	2848	***
$N_{70}P_{70}$+6 t/ha hashed straw	3770	222	2073	***	3041	261	1878	***
$N_{70}P_{70}$+6 t/ha stalks of maize	3578	211	1881	***	2929	252	1766	***
$N_{70}P_{70}$+3 t/ha stalks of pea	4010	236	2313	***	3237	278	2074	***
$N_{70}P_{70}$+3 t/ha stalks of soybean	3911	230	2214	***	3164	272	2001	***
$N_{70}P_0K_0$	2991	176	1294	***	2333	201	1170	***
Mean	**3632**	**100**			**2916**			
LSD 5%			340				310	
LSD 1%			450				430	
LSD 0.1%			580				570	

The analysis of results obtained has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of mean wheat yields, according to slope and erosion, from 3632 (100%) to 2916 kg/ha (80.3%). The mean annual yield losses, registered in wheat in the last 10 years, caused by erosion, were of 716 kg/ha (19.7%).

The positive effect of applying crop residues, together with moderate nitrogen rates, on crop yield and soil physical, chemical and biological characteristics was found in many regions with different climatic conditions and soils (Clapp et al., 2000; Nelson, 2004; Campbell, 2005; Liu, 2006; Russell, 2006). During 2004-2005, USDA (The US Department of Agriculture) has made seven projects on the development of technologies for converting celluloses materials (wood chips, crop residues and switch grass) into ethanol. In eight regions from USA, the quantity of crop residues from maize and wheat crops exceeded 500 million tons, which may support the biofuel production, at trade scale (Wilhelm et al., 2004).

The investigations conducted by Campbell (2005) on low slope fields, in the semi-arid zone from Saskatchewan, Canada, on a Chernozem with a pH of 6.5 and a mean texture, have shown that, during 36 years, wheat straws have supplied wheat crop with 37 kg nitrogen/ha.

Many research works have shown that the additional N application was necessary, when crop residues remained in soil, for avoiding the immobilization of N from soil and increasing the carbon content from soil (Clapp et al., 2000; Wilhelm et al., 2004). Other studies have shown that determining the rates of crop residues, which had to be applied in order to improve soil characteristics and diminish erosion, must consider the climatic conditions, soil type and cultural practices (McCool et al., 1995; Wilson et al. 2004).

On 16% slope fields from the Moldavian Plateau, the erosion process has resulted in decreasing the content of humus and nutrients from soil and the mean wheat yield by 19.7% (716 kg/ha), in 10 years. Both on weakly and highly eroded fields, the mineral fertilization with lower rates than $N_{140}P_{100}$ kg/ha has resulted in diminishing the humus content from soil until 2.49- 3.05 % (*Table 2*). On weakly eroded fields, keeping the humus content at over 3.2% was done by annual application of average mineral fertilizer rates ($N_{70}P_{70}$), together with 6 t/ha of wheat and maize residues, in annual legumes-wheat-maize rotation. On highly eroded fields, the humus content was kept at values of 3.42-3.49% only by the annual application of a rate of 60 t/ha manure or $N_{70}P_{70}$+ 60 t/ha manure. The annual application for 40 years, of 6 t/ha crop residues, together with 70 kg/ha nitrogen and 70 kg/ha P_2O_5, has kept the humus content from soil at values of 3.14-3.28% on weakly eroded fields and of 3.08-3.12% on highly eroded fields.

On weakly eroded cambic Chernozem from the Moldavian Plateau, a good supply with mobile phosphorus in wheat and maize crops (37-72 mg/kg) was done in case of the annual application of a rate of $N_{100}P_{80}$, while a very good supply (69-78) was achieved at the rate of $N_{70}P_{70}$+60 t/ha manure. On highly eroded fields, a very good supply with mobile phosphorus and potassium was done by applying manure at the amount of 60 t/ha or at the rate of $N_{70}P_{70}$ + 60 t/ha manure.

Table 2

Effect of soil erosion and fertilization system on the humus and mineral element content in 16% slope fields from the Moldavian Plateau

Fertilizer rate	Weakly eroded lands				Highly eroded lands			
	pH (H_2O)	Humus (%)	P-AL (ppm)	K-AL (ppm)	pH (H_2O)	Humus (%)	P-AL (ppm)	K-AL (ppm)
N_0P_0	7.2	2.86	18	206	7.1	2.46	9	189
$N_{70}P_{70}$	6.8	2.91	52	189	6.7	2.49	42	162
$N_{100}P_{80}$	6.3	3.05	87	186	6.1	2.66	61	154
$N_{140}P_{100}$	5.8	3.12	89	174	5.6	2.84	59	151
60 t/ha manure	7.3	3.72	79	287	7.1	3.42	62	254
$N_{70}P_{70}$ + 60 t/ha manure	7.1	3.79	94	314	6.9	3.49	79	286
$N_{70}P_{70}$ + 6 t/ha hashed of wheat	6.9	3.28	62	238	6.7	3.12	58	206
$N_{70}P_{70}$+6 t/ha stalks of maize	6.5	3.22	59	246	6.4	3.09	49	187
$N_{70}P_{70}$+3 t/ha stalks of peas	6.8	3.18	48	235	6.7	3.10	52	185
$N_{70}P_{70}$+3 t/ha stalks of soybean	6.8	3.14	49	232	6.7	3.08	49	179
Mean	**6.8**	**3.23**	**64**	**231**	**6.6**	**2.98**	**52**	**195**
LSD 5%	0.25	0.11	4.97	18.08	0.27	0.16	4.52	15.82
LSD 1%	0.36	0.16	7.15	26.00	0.39	0.23	6.50	22.75
LSD 0.1%	0.53	0.24	10.52	38.24	0.57	0.33	9.56	33.46

Incorporating into soil amounts of 2471, 4942 and 9884 kg/ha of crop residues has resulted in diminishing the eroded soil by 64, 85 and, respectively, 98%, comparatively to the areas where no crop residues were applied. The surface application of crop residues at amounts of 2471 and 4942 kg/ha has diminished eroded soil losses by 90 and, respectively, 100%, comparatively to the areas without crop residues (McCool et al., 1995). The investigations conducted by Lindstrom, in Minnesota, USA, have shown that the amounts of 927, 1853 and 3706 kg/ha of crop residues, applied in maize crops, have determined the decrease of soil erosion to 6.177, 1.730 and respectively, 0.988 t/ha and water runoff to 35.6, 25.4 and respectively, 22.9 mm. The long-term research works carried out by Dabney and Wilson, have shown that removing crop residues from maize crops, at different rates, has determined the increase by 26-47% of soil losses caused by erosion.

The results on runoff and soil losses by erosion in different crops from the Moldavian Plateau, determined by means of control plots, have shown that, during 1980-2007, of the total amount of 558.6 mm rainfall, 353.8 mm (63.3%) produced water runoff, which was between 5.3 mm in perennial grasses, on the second year of vegetation, and 16.3-17.1 mm in maize and sunflower crops

(*Table 3*). The annual soil losses by erosion, registered at the same period, were between 0.286 t/ha in perennial grasses, on the second year of vegetation, and 9.268 – 9.794 t/ha in maize and sunflower. Erosion has affected soil fertility by removing once with eroded soil, high amounts of humus and mineral elements, which reached 16-17 kg/ha nitrogen, 1-2 kg/ha phosphorus and 2-3 kg/ha potassium, in maize and sunflower crops.

Table 3

Mean water runoff, soil, humus and mineral elements losses by erosion in the Moldavian Plateau

Crop	Runoff Water (mm)	Eroded Soil (kg/ha)	Humus and mineral elements lost by erosion, kg/ha					
			Humus	N_t in runoff water	N_t in eroded soil	Total N	P-AL	K-AL
Field	43.8	18460	652	3.311	20.174	23.485	1.632	3.668
Sunflower	17.1	9794	349	1.438	14.887	16.325	1.126	2.400
Ist year perennial grasses	8.0	1864	66	0.709	2.610	2.532	0.214	0.464
IInd year perennial grasses	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	2680	95	1.037	3.216	4.253	0.244	0.536
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 results obtained on the potential erosion (conditioned by geo-morphological, soil and climate factors) have shown that on uncovered by vegetation fields from the Moldavian Plateau, the average soil losses by erosion were of 18.46 t/ha/year, values corresponding to a moderate erosion risk.

From the investigations carried out on effective erosion, based on direct determinations, we found out that the effective erosion in the Moldavian Plateau, in peas-wheat-maize rotation, had a mean value of 4.507 t/ha/year (*Table 4*). These elements were necessary for establishing the crop structure and dimensioning the antierosion works, which determine the decrease of soil erosion and water runoff, soil and nutrients losses below the limit corresponding to the natural capacity of annual soil recovering, of 3-4 t/ha/year of eroded soil.

Table 4

Soil, humus and mineral elements losses by erosion in different crop rotations from the Moldavian Plateau

Crop rotation	Eroded Soil (t/ha)	Humus (kg/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Total NPK
Maize continuous cropping	9.268	329	16.644	1.038	2.317	19.999
Wheat – maize rotation	5.421	193	10.036	0.607	1.356	11.999
Peas – wheat – maize rotation	4.507	160	8.108	0.486	1.082	9.676
Peas – wheat – maize – sunflower + field cultivated with legumes and perennial grasses	4.720	168	8.318	0.532	1.144	9.994
Peas – wheat – maize – sunflower + 2 fields cultivated with legumes and perennial grasses	3.984	142	7.088	0.441	0.965	8.494

CONCLUSIONS

In soils from the Moldavian Plateau, most of them situated on slope fields, poor in organic matter and nutrients, the proper use of different organic resources may replace a part of rich technological consumption (mineral nutrients), determine the improvement in the content of organic matter from soil and ensure better conditions for the capitalization of nitrogen fertilizers.

The combined use of mean rates of mineral fertilizers ($N_{70}P_{70}$), together with 40 t/ha manure or 6 t/ha crop residues from wheat and maize crops, has resulted in improving soil physical and chemical characteristics and getting yield increases in wheat of 2313-2214 kg/ha (136-130%), on weakly eroded lands, and 2074-2001 kg/ha (178-172%) on highly eroded lands, compared to the unfertilized control.

Both on weakly and highly eroded lands, the mineral fertilization with lower rates than $N_{140}P_{100}$ kg/ha has determined the decrease of humus content from soil until 2.49- 3.05%. On highly eroded lands, the humus content was kept at values of 3.42-3.49% only by the annual application of the rate of 60 t/ha manure or $N_{70}P_{70}$+ 60 t/ha manure.

Annual soil losses by erosion, registered during 1980-2007, in the Moldavian Plateau, were between 0.286 t/ha in perennial grasses on the second year of vegetation and 9.794 t/ha in sunflower.

From the results obtained on erosion in different crop rotations, we have found out that in 16% slope fields from the Moldavian Plateau, soil losses by erosion were diminished below the allowable limit of 3-4 t/ha/year only in case of

4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.

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