INVESTIGATIONS ON THE INFLUENCE OF FERTILIZATION SYSTEM AND EROSION ON WHEAT YIELD AND ON SOME SOIL AGROCHEMICAL CHARACTERISTICS

C. AILINCĂI[1*], Despina AILINCĂI[1], Maria ZBANȚ[1], Ad. MERCUS[2], M. CARA[2]

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

ABSTRACT: *By diminishing soil fertility, the erosion process determined the differentiation of mean wheat yield according to slope and erosion, from 3905 (100%) to 3078 kg/ha (78.8%). The mean annual losses of yield registered in wheat in the last 10 years, caused by erosion, were of 827 kg/ha (21.2%). The humus and nutrient content from soil was maintained at a supply level proper to the requirements of plant nutrition, only under 3 or 4 year rotation, and in case of annual use of rates of at least 100 kg N + 100 kg P_2O_5 or mean rates of mineral elements with 60 t/ha manure. The use of mineral fertilizers with manure resulted in increasing mobile phosphorus content from soil until 94 ppm, achieving a good and very good supply in mobile phosphorus and increasing humus content from soil to 4.18%. On weakly and highly eroded soils, the application of moderate rates of mineral fertilizers with 3 t/ha pea stalks determined the improvement in soil ureasic and phosphatasic potential, ensuring a better plant supply with assimilate phosphorus. The use of manure or residues, which are easily degradable with mean rates of mineral elements, resulted in achieving soil nutrient supply and biological characteristics very close to those obtained by using high rates of mineral fertilizers. On slope lands, poor in organic matter and mineral elements, establishing the best fertilizer rates, which ensure crop consumption and maintain good soil supply in mineral elements, is more difficult, especially in crops requiring high amounts of mineral elements, as wheat and maize.*

Key words: fertilization, wheat, soil fertility

[*] E-mail: scdapoduail@zappmobile.ro

REZUMAT – Cercetări privind influenţa sistemului de fertilizare şi a eroziunii asupra producţiei de grâu şi a unor caracteristici agrochimice ale solului. *Procesul de eroziune, prin diminuarea fertilizării solului, a determinat diferenţierea producţiei medii de grâu, în funcţie de pantă şi eroziune, de la 3905 (100%) la 3078 kg/ha (78.8%). Pierderile medii anuale de producţie înregistrate la grâu în ultimii 10 ani, provocate de eroziune, au fost de 827 kg/ha (21.2%). Conţinutul de humus şi elemente nutritive din sol s-a menţinut la un nivel propriu cerinţelor de nutriţie a plantelor, doar în condiţiile rotaţiei de 3 sau 4 ani şi în cazul folosirii anuale a dozei de cel puţin 100 kg N + 100 kg P_2O_5 sau de doze medii de elemente minerale cu 60 t/ha gunoi de grajd. Folosirea îngrăşămintelor minerale împreună cu gunoiul de grajd a dus la creşterea conţinutului de fosfor mobil din sol până la 94 ppm, realizând o bună şi foarte bună alimentare cu fosfor mobil în sol şi crescând conţinutul de humus din sol până la 4.18%. Pe solurile slab şi puternic erodate, aplicarea de doze moderate de îngrăşăminte minerale cu 3 t/ha vreji de mazăre a îmbunătăţit potenţialul ureazic şi fosfatazic din sol, realizând o mai bună alimentare a plantei cu fosfor. Folosirea gunoiului de grajd sau a resturilor vegetale, care sunt uşor degradabile, cu doze medii de elemente minerale, a condus la realizarea unei alimentări a solului în elemente nutritive şi a unor caracteristici biologice apropiate de cele obţinute prin folosirea unor doze mari de îngrăşăminte minerale. Pe terenurile în pantă, sărace în substanţă organică şi elemente minerale, determinarea celor mai bune doze de îngrăşământ pentru menţinerea unei bune alimentări a solului în elemente minerale se face mai greu, mai ales la culturile ce necesită mari cantităţi de elemente minerale, ca grîul şi porumbul.*

Cuvinte cheie: fertilizare,eroziune, grâu, fertilitatea solului

INTRODUCTION

In the last period, the great decay of environment quality has determined profound investigations on cropping systems, where the whole complex of factors acts, influencing crop quality and quantity and parameters of soil fertility.

Many investigations carried out in long-term experiments, directed by FAO and other government or private institutions have shown that mineral fertilization was the main source contributing to yield increase with 35-50%. On the average, for each kg of applied mineral fertilizer, 10 kg yield increases were obtained (Ballayan, 2000; FAO, 2000; Ştefanic, 1994). Statistical data show that in 2002, EU countries applied between 157 kg NPK (Spain) and 367 kg NPK (Holland) on ha of arable land, and Bulgaria (49 kg/ha) and Romania (35 kg/ha) applied the lowest fertilizer rates (Ballayan, 2000; FAOSTAT, 2004).

Available arable land in the entire world is decreasing and it will be diminished from 0.24 ha/inhabitant, as nowadays, to 0.17 ha in 2020.

In the case that only 12% of the world area has no restraints for agriculture, 9% has a weak capacity of nutrient preservation, 23% of the area is affected by aluminum toxicity, 15% is weakly supplied with mobile phosphorus and 26% with low stocks of potassium (Hanson, 1992), yield will increase only by increasing soil fertility, based on sustainable technological systems or irrigation (FAO, 2000).

In 2020, the grains demand will reach 3.4 billion t, requiring an yield increase from 2.9 t/ha nowadays to 4.9 t/ha. At a global mean of 3 t/ha grains, 81 kg nitrogen, 15 kg phosphorus and 75 kg potassium are consumed from soil together with straw. These consumptions, to which leaching and erosion losses are added, must be given back to soil by fertilizers and other technological solutions (Hanson, 1992; Hera and Mihăilă, 1981; USDA-Foreign Agricultural Service (FAS), 2001a).

MATERIALS AND METHODS

Experiments for improving fertilization system in wheat, set up on cambic chernozem with different degrees of soil erosion had in view the influences of chemical, organic fertilizers and residues on yield and evolution of main agrochemical indices of soil.

Investigations conducted during 1997 - 2006 on a cambic chernozem at the Agricultural Research and Development Station of Podu - Iloaiei, Iasi County, have studied the influence of different fertilizer systems on yield in wheat and maize crops, placed in a three-year rotation (pea – wheat – maize). For each crop, three fertilization systems were experienced: mineral fertilization with nitrogen and phosphorus rates until $N_{140}P_{100}$, manure fertilization (20, 40, 60 t/ha), with and without mineral fertilization and mineral fertilizers + hashed residue, applied in autumn under the base ploughing.

The typical cambic chernozem from Podu - Iloaiei was formed on a loess loam, has a mean humus content (3.1 - 3.4%), is well supplied with mobile potassium (215 - 235 ppm) and moderately with phosphorus (24-38 ppm) and nitrogen (0.160 – 0.165%). In wheat, we have used Fundulea - 4 (1997 - 2001) and Gabriela (2002 - 2006) varieties. Investigations had as aim to improve the technology of fertilization according to the requirements of different genotypes from rotation and to physical, chemical and biological soil characteristics. Estimates of the effect of different chemical, organic fertilizer rates and residues on yield and soil fertility have been studied.

The biotic tests have investigated the knowledge of respiration and cellulosolitic soil potential, which was at the basis of calculating the Indicator of Vital Activity Potential (IVAP). Enzymatic tests had in view oxide-reduction processes (catalysis), sugar hydrolysis (saccharine), urea hydrolysis (urease) and phosphorus hydrolysis from organic combinations (total phosphatase). The

Indicator of Enzymatic Activity Potential (IEAP) was calculated on the basis of these processes, according to methods of Ştefanic and Irimescu (1984).

RESULTS AND DISCUSSION

The climatic conditions in the Moldavian Plain are characterized by a multiannual mean temperature of 9.6°C and a mean rainfall amount of 542 mm, on 79 years, of which 161.2 mm during September-December and 380.8 mm during January-August. Studying the amount of rainfall registered in the last 10 years, we found that in 4 years it was under the multiannual mean, the greatest deviation being registered in 2003, when the deficit was of 98.1 mm.

On weakly eroded lands, mean wheat yields obtained during 1997-2006 were comprised between 1806 kg/ha (100%) at the unfertilized control and 5284 kg/ha (293%) 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 2635 and respectively, 3116 kg/ha.

On highly eroded soil, the mean wheat yield obtained during 1997-2006 in wheat placed in pea-wheat-maize rotation, was of 1219 kg/ha under unfertilized and of 3890 kg/ha at high mineral fertilizer rates ($N_{140}P_{100}$). In wheat, application of mean rates of mineral fertilizers with 60 t/ha manure resulted in getting yield increases of 244% (2980 kg/ha), compared to unfertilized. Applying rates of 100 kg N + 100 kg P_2O_5 resulted in getting yield increases of 146% (2635 kg/ha) in wheat placed on weakly eroded lands and 184% (2240 kg/ha) in wheat placed on highly eroded soil, compared to unfertilized.

In wheat placed on weakly eroded lands, mean yield increases obtained for each kg of a. i. of applied fertilizers varied, according to applied fertilizers rates, between 10.5 and 13 kg grains ($N_{40}P_{40}$-$N_{100}P_{100}$). On highly eroded lands, mean wheat yields obtained under unfertilized were of 1219 kg/ha, the mean yield increases obtained by applying 40 or 60 t/ha manure were of 43-36.8 kg grains per t of manure and mineral fertilizers ($N_{40}P_{40}$-$N_{100}P_{100}$) resulted in obtaining mean yield increases of 8.6-11.1 kg grains/kg a. i. of applied fertilizer. 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 pea or soybean, variants at which yield increases varied according to soil erosion state, between 2454-2355 kg/ha (136-130%) on weakly eroded lands, and between 2171-2083 kg/ha (178-171%) on highly eroded lands (*Table 1*).

The analysis of results has shown that the erosion process, by diminishing soil fertility, determined the differentiation of mean wheat yield according to slope and erosion, from 3905 (100%) to 3078 kg/ha (78.8%). Mean annual losses of yield registered in wheat in the last 10 years, caused by erosion, were of 827 kg/ha (21.2%).

Table 1

Influence of mineral and organic fertilizers on wheat yields on weakly and highly eroded lands, after 42 years of experiments, (F-4 and Gabriela varieties)

Fertilizer rate	Weakly eroded soil				Highly eroded soil			
	Mean wheat yields		Difer. kg/ha	Signif	Mean wheat yields		Difer. kg/ha	Signif
	kg/ha	%			kg/ha	%		
N_0P_0	**1806**	100			**1219**	100		
$N_{40}P_{40}$	**2647**	147	841	***	**1910**	157	691	***
$N_{70}P_{70}$	**3492**	193	1686	***	**2650**	217	1431	***
$N_{100}P_{100}$	**4441**	246	2635	***	**3459**	284	2240	***
$N_{140}P_{100}$	**4922**	273	3116	***	**3890**	319	2671	***
$N_0P_{70}K_{70}$	**2116**	117	310	*	**1533**	126	314	*
$N_{40}P_{40}K_{40}$	**2790**	154	984	***	**2206**	181	987	***
$N_{70}P_{70}K_{70}$	**3707**	205	1901	***	**2877**	236	1658	***
$N_{100}P_{100}K_{100}$	**4776**	264	2970	***	**3774**	310	2555	***
$N_{140}P_{140}K_{140}$	**5209**	288	3403	***	**4138**	339	2919	***
20 t/ha manure	**2907**	161	1101	***	**2320**	190	1101	***
40 t/ha manure	**3671**	203	1865	***	**2937**	241	1718	***
60 t/ha manure	**4274**	237	2468	***	**3426**	281	2207	***
$N_{40}P_{40}$ +20 t/ha manure	**3779**	209	1973	***	**3044**	250	1825	***
$N_{40}P_{40}$+40 t/ha manure	**4302**	238	2496	***	**3525**	289	2306	***
$N_{40}P_{40}$+60 t/ha manure	**4610**	255	2804	***	**3799**	312	2580	***
$N_{70}P_{70}$+20 t/ha manure	**4391**	243	2585	***	**3464**	284	2245	***
$N_{70}P_{70}$+40 t/ha manure	**4956**	274	3150	***	**3848**	316	2629	***
$N_{70}P_{70}$+60 t/ha manure	**5284**	293	3478	***	**4199**	344	2980	***
$N_{70}P_{70}$+6 t/ha hashed straw	**4035**	223	2229	***	**3201**	263	1982	***
$N_{70}P_{70}$+6 t/ha stalks of maize	**3839**	213	2033	***	**3074**	252	1855	***
$N_{70}P_{70}$+3 t/ha stalks of pea	**4260**	236	2454	***	**3390**	278	2171	***
$N_{70}P_{70}$+3 t/ha stalks of soybean	**4161**	230	2355	***	**3302**	271	2083	***
$N_{70}P_0K_0$	**3356**	186	1550	***	**2689**	221	1470	***
Mean	**3905**	100	-		**3078**	**78.8**	**827**	
LSD 5%			310				300	
LSD 1%			420				410	
LSD 0.1%			550				560	

On slope lands, soil nutrient losses being very high, because of leaching, runoff and element fixing, establishing rates and time of fertilizer application must be differentiate according to soil characteristics and cultural practices. Annual application of residues in wheat crop, found in pea-wheat-maize rotation determined the increase in mineralizable organic nitrogen stock from soil, better water holding capacity of soil and limitation of water evaporation. The efficiency of residues depended on many factors, of which chemical composition

(carbon/nitrogen ratio), time and incorporation depth, residue breaking up degree had the highest influence on crop supply with nitrogen and soil fertility. Knowing the long-term influence of different technological elements on the evolution of soil chemical and biological characteristics allows the establishment of the most proper methods for the efficient use of all technological inputs.

The results of chemical analyses have shown that the decrease in humus content from soil in pea-wheat-maize rotation by annual application of rates of 100 kg N + 100 kg P_2O_5 could not be prevented, its level increasing only in variants where mineral fertilizers were applied together with manure or residues (*Figures 1, 2*).

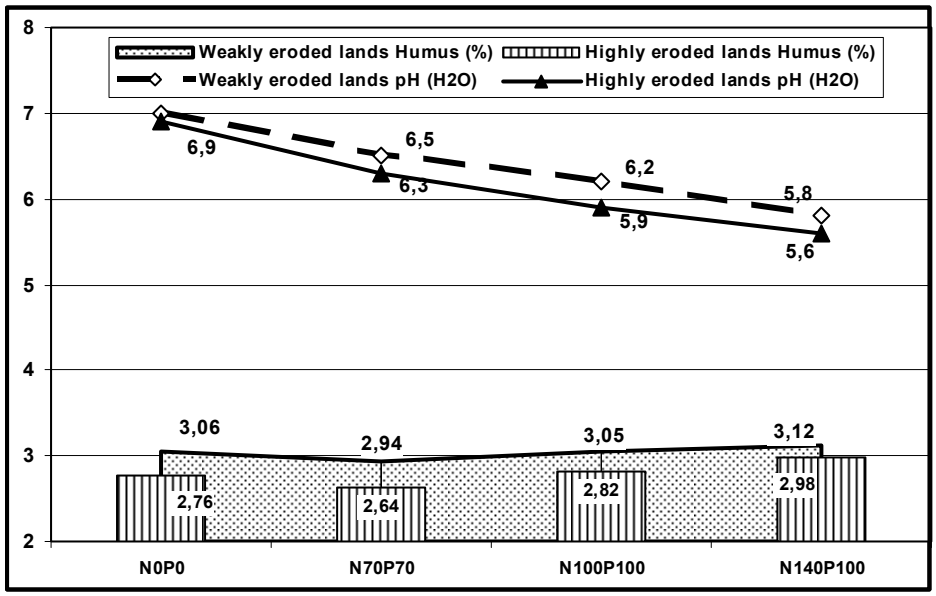

Figure 1. Variation of soil reaction and humus content as influenced by mineral fertilization on eroded lands

In this case, the values registered by other macronutrients (P, K, Ca, Mg) showed that soil supply was normal compared to crop demands (*Figure 3*). Maintaining the main soil chemical characteristics under favourable limits for plant growing and development was done only in case of organo-mineral fertilization (*Figure 2*). The use of mineral fertilizers with manure has resulted in increasing mobile phosphorus content from soil until 94 ppm, achieving a good and very good supply in mobile phosphorus and increasing humus content from soil to 4.18%.

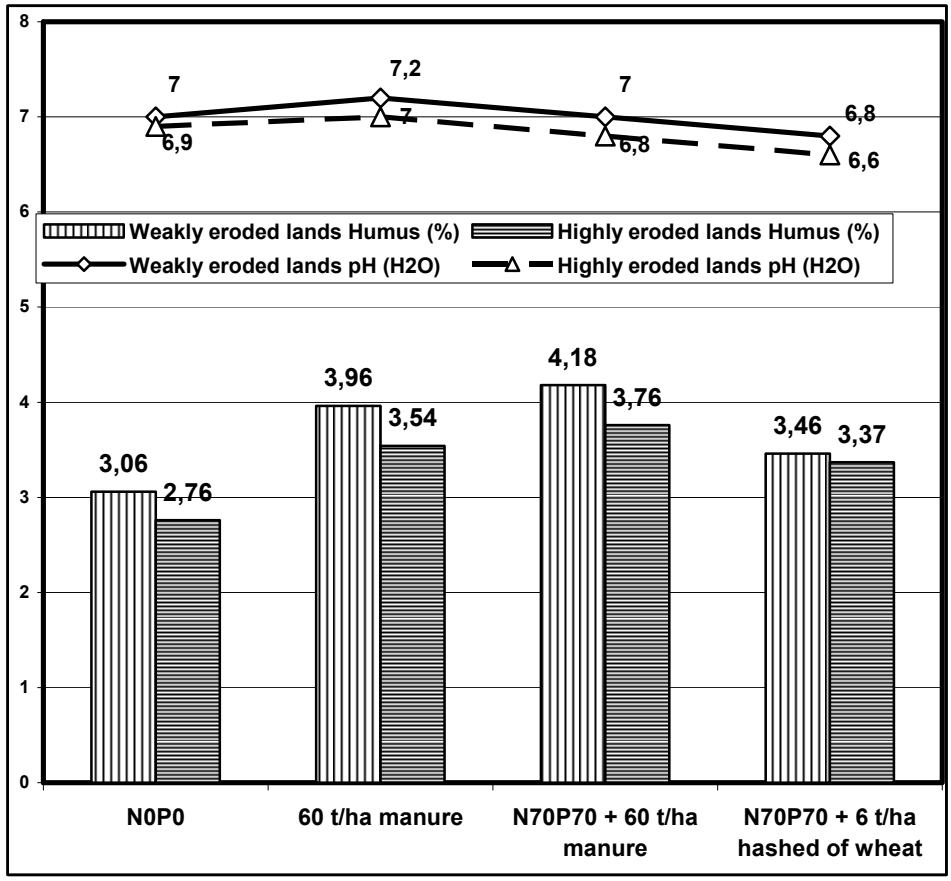

Figure 2. Variation of soil reaction and humus content, as influenced by organo-mineral fertilization on slope lands, with different erosion degrees

Even under conditions of intensive growing technologies and on slope lands, the humus content from soil could be maintained at a mean supply level (*Figure 3*).

The analyses carried out on the respiration and cellulosolitic potential of soil have shown that organic-mineral fertilization had a favourable influence on life level from soil and contributed to the stimulation of soil vital activity.

Manure application with 70 kg/ha nitrogen and 70 kg P_2O_5 determined the increase in respiration compared to unfertilized, from 38-43 mg CO_2/ 100 g soil DM to 48.1 at rates of $N_{70}P_{70}$ + 60 t/ha manure (*Table 2*). Under these conditions the degraded celluloses have increased from 74 g to 86 g on weakly eroded land and from 67 to 78 g on highly eroded land.

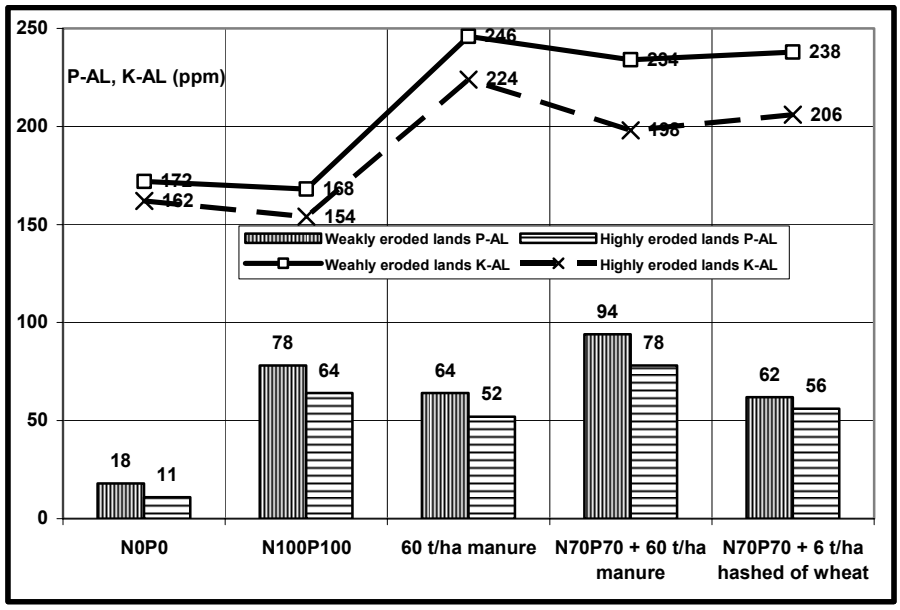

Figure 3. Variation of mobile phosphorus and potassium in cambic chernozem soil from Podu-Iloaiei, according to rates of applied fertilizer

The total phosphatase has increased, compared to unfertilized control, from 5.1 mg P/100 g soil DM to 14.6 mg P (at rate of $N_{70}P_{70}$ + 60 t/ha manure) on weakly eroded soil and from 6.9 to 11.2 on highly eroded soil.

The application of 6 t/ha hashed straw of wheat with $N_{70}P_{70}$ has determined, compared to unfertilized variant, the increase in ureasic and phosphatasic activity from soil, the amounts of NH_4 increasing from 51 to 93 mg/100 g soil and of phosphorus from 5.1 to 13.2 mg/100 g soil DM.

Organic-mineral fertilization had a good effect on both indicators, which was also transmitted to the level of the Biological Synthetic Indicator (BSI), representing the average between the Indicator of Biotic Activity Potential (IBAP) and Indicator of Enzymatic Activity Potential (IEAP). The estimate of soil fertility by means of these biological indicators allowed the knowledge of multiple biochemical changes which took place in soil, as influenced by climatic conditions and technological elements, resulting in opportunities for controlling growing technologies and the protection of water and soil resources.

Table 2

Influence of the mode of fertilization on some biological indicators of soil fertility in wheat placed on eroded lands in Moldavian Plain

Fertilizer rate	Potential ability of:		IVAP %	Potential ability of:				IEAP %	BSI %
	Respiration Co_2 mg	Cellulosolise g		Catalase O_2 cc	Invertase mg	Urease NH_4,mg	Phosphatase P, mg		
N0P0	53.7	74.7	89.7	697	1804	83.8	5.1	89.5	89.6
N100P100	38.2	83.2	91.5	698	1986	44.6	7.8	85.8	88.6
Manure 60 t/ha	41.2	51.8	96.36	823	2084	57.5	12.2	94.3	95.3
N70P70+ 60 t/ha manure	42.6	85.6	85.6	433	2095	89.9	14.6	85.8	85.7
N70P70 + 3 t/ha stalks of pea	37.8	83.1	91.2	771	2780	81.7	13.2	71.8	81.5
Mean weakly eroded soil	**42.7**	**75.7**	**90.9**	**684**	**2149**	**71.5**	**10.6**	**85.4**	**88.1**
N0P0	38.2	67.3	79.8	588	1657	51.8	6.9	53.4	66.6
N100P100	43.1	83.2	84.4	364	1062	33.7	6.3	48.6	66.5
Manure 60 t/ha	51.7	63.1	85.7	367	3328	90.5	10.9	84.1	84.9
N70P70+ 60 t/ha manure	48.1	77.6	90.7	494	2278	67	11.2	83.8	87.3
N70P70+ 3 t/ha stalks of pea	45.1	48.7	71.2	452	1498	93.4	9.4	70.6	70.9
Mean highly eroded soil	**45.24**	**67.98**	**82.36**	**453**	**1964.6**	**67.28**	**8.9**	**68.1**	**75.24**
LSD 5%			5.9					3.2	3.6
LSD 1%			8.4					4.5	5.2
LSD 0.1%			12.2					6.6	7.5

CONCLUSIONS

The erosion process, by diminishing soil fertility, has determined the differentiation of mean wheat yield according to slope and erosion, from 3905 (100%) to 3078 kg/ha (78.8%). Mean annual losses of yield registered in wheat in the last 10 years, caused by erosion, were of 827 kg/ha (21.2%).

The humus and nutrient content from soil was maintained at a supply level proper to the requirements of plant nutrition, only under 3 or 4 year rotation and in case of annual use of rates of at least 100 kg N + 100 kg P_2O_5 or of mean rates of mineral elements with 60 t/ha manure.

The use of mineral fertilizers with manure has resulted in increasing mobile phosphorus content from soil until 94 ppm, achieving a good and very good supply in mobile phosphorus from soil and increasing humus content from soil to 4.18%.

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On slope lands poor in organic matter and mineral elements, establishing the best fertilizer rates, which ensure crop consumption and maintain a good soil supply in mineral elements, is more difficult, especially in crops requiring high amounts of mineral elements, as wheat and maize.

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