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LONG-TERM EFFECTS OF CROP RESIDUES AND FERTILIZATION ON PRODUCTION AND SOIL FERTILITY

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ABSTRACT – The investigations conducted during 1995-2010 at the Podu-Iloaiei Agricultural Research Station, Iași County, have studied the influence of different mineral fertilizers rates on wheat and maize yield and soil agrochemical characteristics. Soil erosion caused a reduction in the percentage of aggregate by 14.5% to slightly eroded soil and 37.7% in the strongly eroded soil. The percentage of water stable aggregates was comprised between 73.5% in non eroded soil, at the bottom of slope land and 45.7% at the highly eroded soil. On weakly and highly eroded lands the content of organic carbon from soil, after 44 years of experiences, has decreased by 16.8-24.9% (3.3-4.9 g/kg soil) at the unfertilized control and by 12.2-18.3% (2.4-3.6 g/kg soil) at the rate of $N_{120}P_{80}$. On weakly and highly eroded lands the mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 9.6 and 11.3 kg in wheat and between 11.9 and 13.06 kg in maize ($N_{80}P_{60}$-$N_{160}P_{100}$).

Key words: Fertilizers; Crop residue; Organic carbon; Wheat; Maize; Soil aggregate water stability.

REZUMAT - Efectele de lungă durată ale resturilor vegetale şi ale fertilizării asupra producției şi a fertilității solului. Cercetările efectuate în perioada 1995-2010, la Stațiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, juteţul Iași, au urmărit influența diferitelor doze de îngrăşăminte minerale asupra producției de grâu şi porumb şi a însuşirilor fizice şi chimice ale solului. Eroziunea solului a determinat reducerea procentului de macro agregate cu 14,5% la solul slab erodat şi cu 37,7% la solul puternic erodat. Procentul de agregate hidrostabile a fost cuprins între 73,5% la solul neerodat de la baza pantei terenului şi 45,7% la solul puternic erodat. Pe terenurile slab şi puternic erodate, conținutul de carbon organic din sol, după 44 de ani de experimentare, a scăzut cu 16.8 - 24.9% (3.3 - 4.9 g / kg sol), la martorul nefertilizat şi cu 12.2 - 18.3% (2.4 - 3.6 g / kg sol), la doza de $N_{120}P_{80}$. Pe terenurile slab şi puternic erodate, sporurile medii de

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productie obținute, pentru fiecare kg de îngrăşăminte aplicate, au fost cuprinse între 9.6 şi 11.3 kg la grâu şi între 11.9 si 13.06 kg la porumb ($N_{80}P_{60}$-$N_{160}P_{100}$).

Cuvinte cheie: fertilizare; resturi vegetale; organic carbon; grâu; porumb; stabilitatea hidrică a agregatelor.

INTRODUCTION

The total area affected by erosion in Europe, excluding Russia, is 147 million hectares of which 16% (105 million ha) affected by water erosion and 6.4% (42 million hectares) are affected by wind erosion. In Europe, some 45 % of soils have low or very low organic matter content (0–2 % organic carbon) and 45 % have a medium content (2–6 %) (Jones, 2010). EEA (1998) considered that tolerable limit varies from 1 t/ha/year on shallow sandy soils to 5 t /ha/ year on deeper well developed soil, the Department of Agriculture of the United States defined as tolerable erosion rates ranging 2-11 t /ha/year and Bazzoffi (2009) believe that values should not exceed 3 tonnes /hectare / year. Doran (1996) observed that the formation of soil is slow, averaging 100–400 years for a centimeter of topsoil.

From the investigations carried out on effective erosion, based on direct determinations, we found that the effective erosion in the Moldavian Plateau, in peas-wheat-maize rotation, had a mean value 4.507 t/ha/year (Ailincăi, 2011). These elements were necessary for establishing the crop structure and dimensioning the anti-erosion works, which determine the decrease in soil erosion and water runoff, soil and nutrient losses below the limit corresponding to the natural capacity of annual soil recovery, of 3-4 t/ha/year of eroded soil. From the results obtained on erosion in different crop rotations, we have found that in 16% slope fields from the Moldavian Plateau, soil losses by erosion 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.

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 soil erosion (Lal, 2004, Wright, 2007, Bazzoffi, 2009, Rusu, 2009).

Many studies show that, by removing crop residues, high amounts of nutrients are removed from agro-ecosystem. These studies show that establishing the amounts of crop residues, which must be applied for maintaining the content of organic carbon and for diminishing soil erosion and should have in view the interactions between crop rotation, soil tillage, fertilization and soil and climate conditions. The amounts of applied crop residues must contribute to diminishing soil erosion, maintaining the content of organic carbon from soil and determining yield increases.

The conversion of natural lands to croplands can result in a 60% decrease in the SOC pool in temperate ecosystems and a 75% decrease in the SOC pool in tropical ecosystems (Lal, 2004).

In many areas, applying crop residues, together with moderate nitrogen rates, have resulted in improving physical, chemical and biological soil characteristics (Adesodum, 2001, Acosta, 2004; Campbell, 2005, Wilhelm, 2004; Blair, 2006, Arwyn, 2009). The crop residues, which remain on soil surface or are incorporated into soil, protect soil against erosion, determine yield increases and improve soil physical and biological characteristics.

The results obtained of Cambic Chernozem from Fundulea show an increase of the organic matter in wheat monoculture, owing to vegetable remain, more abundant than in row crops. Under the mineral and organic manure, both humus content and total nitrogen in soil increase (Oprea, 2009).

The practice of reduced tillage is ideal for enhancing soil fertility, water holding capacity and reducing erosion. Soil texture and structure have a strong effect on the available water capacity. The results clearly demonstrate that minimum tillage systems promote increased humus content (0.8-22.1%) *(Table 2)* and increased water stabile aggregate content (1.3-13.6%) at the 0-30 cm depth compared to conventional tillage (Moraru and Rusu, 2010**)**.

The smaller input of C to the soil in croplands results from removal of biomass in the harvested products, and can be further aggravation by crop residue removal, and by tillage which increases SOC loss (Smith, 2008).

In Norway the overall potential of adoption of improved practices for SOC sequestration was, on an average, 0.8 million Mg/yr. Of the total potential, 59% can be contributed to adoption of erosion control measures, 6% to restoration of peat lands, 21% to adoption of conservation tillage and residue management, and 14% to adoption of improved cropping systems (Singh and Lal, 2005). The cool temperate climate, dominance of perennial land use, and relatively large proportion of peat and organically rich soils, make the northern European regions to have a large potential of soil organic carbon (SOC) sequestration (Singh B.R., 2008).

Application of organic fertilizers and the introduction of crop rotation with perennial grasses and legumes are the main ways to maintain a positive balance of humus, with predominance humificare processes compared to the mineralization of organic matter. The amount of humus, resulting from the biodegradation of organic materials depends on their content of organic nitrogen compounds, method of application and climatic conditions. Humified coefficient expressed by the ratio between the amount of humus form and amount of organic matter applied to soil is influenced by many factors, including the nature of organic material, soil moisture content, the physical, chemical and biological properties of soil are most important (Lixandru, 2006).

Soil supply with nitrogen is achieved by oxidation of atmospheric dinitrogen by electric discharges, reduction of atmospheric dinitrogen to ammonia by microflora, containing nitrogenase enzyme, *Azotobacter chroococcum, and* symbiotic fixation of atmospheric dinitrogen with the bacteria of the genera *Rhizobium* and *Bradyrhizobium,* which activate in the nodules of leguminous plants roots. Nitrogen from the nitrates, resulted, by nitrification processes from humus and unhumified remains, does not influence the sum of fixed nitrogen, what it changes is only the form in which the nitrogen is combined (Ştefanic and Oprea, 2010).

MATERIALS AND METHODS

The investigations conducted in stationary experiments, which were set up in 1967, under non-irrigated, have followed the influence of organic and mineral fertilization on wheat and maize yield and on the evolution of soil physical, chemical and biological characteristics. 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 has a loam-clayey texture (422 g clay, 318 g loam and 260 g sand), a neuter to weakly acid response and a mean nutrient supply. The investigations have followed the influence of different fertilization systems on yields, 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 $N_{160}P_{100}$, manure fertilization (20, 40 and 60 t/ha) with and without mineral fertilization and mineral fertilizers + hashed crop residue applied in autumn under the base plugging.

The soil on which physical and chemical analyses were carried out was sampled at the end of crop vegetation period. The content of organic carbon was determined by the Walkley-Black method; to convert soil organic matter into soil organic carbon, it was multiplied by 0.58. The content in mobile phosphorus from soil was determined by Egner-Riechm Domingo method, in solution of ammonium acetate-lactate (AL) and potassium was measured in the same extract of acetate-lactate (AL) at flame photometer. ANOVA was used to compare treatment effects. The experiments were located on the direction of contour lines and on the entire length of slope (at the bottom of slope with silted soil, at the lower third of weakly eroded slope, the mean third with moderate erosion, and at the upper third of highly eroded slope), in order to investigate the influence of erosion degree on soil fertility.

The analysis of distribution and water stability of structural macro-aggregates was done according to Tiulin-Erikson method. Experiments were conducted in randomized blocks with split plots in six replicates. In wheat, we have used Gabriela Variety, and in maize, Oana Hybrid.

RESULTS AND DISCUSSION

At the Agricultural Research and Development Station of Podu-Iloaiei, Iași County, since 1966, investigations were conducted on the influence of different crop structures and fertilization systems on yield and soil fertility. 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 climatic conditions in the Moldavian Plain were characterized by a mean multiannual temperature of 9.6 ^{o}C and a mean rainfall amount, on 82 years, of 548.3 mm, of which 157.3 mm, during September-December, and 391.0 mm, during January-August.

Average rainfall amounts, recorded during 1995-2010, from January to September, were higher with 41.0 mm, compared to the multiannual average on 50 years (495.9 mm) (*Table 1*). During 1995 - 2010, the climatic conditions were favorable to plant growing and development in 8 years in wheat and 9 years in maize.

Table 1 – Rainfall recorded at the Weather Station of Podu-Iloaiei, during 1995-2010

Years/ month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
1995	42.4	13.0	38.8	20.6	85.8	58.0	33.0	74.7	104.0	11.5	41.4	33.5	556.7
1996	32.1	35.7	34.8	49.8	24.2	81.6	69.0	66.1	208.2	28.9	62.0	66.7	759.1
1997	7.1	10.4	6.1	91.5	25.1	69.9	64.7	74.9	37.2	52.2	20.5	59.1	518.7
1998	29.4	6.8	38.7	55.7	61.7	92.9	102.8	33.4	60.6	124.6	65.8	13.1	685.5
1999	35.3	38.2	19.3	71.7	24.3	80.0	84.7	60.6	21.8	48.8	26.8	40.9	552.4
2000	24.3	27.4	26.7	62.8	10.6	43.3	77.5	39.5	136.9	9.7	26.0	16.3	501.0
2001	23.0	11.4	30.9	74.7	43.8	103.3	67.2	20.4	146.6	30.4	67.2	21.3	640.2
2002	6.9	6.6	56.6	18.9	29.4	57.4	120.2	107.6	38.3	53.1	60.2	4.6	559.8
2003	35.3	21.6	22.3	21.1	10.0	19.1	118.4	44.1	38.5	85.1	4.9	23.5	443.9
2004	67.9	31.3	18.5	16.8	19.8	20.7	125.3	99.1	61.6	25.2	42.1	11.1	539.4
2005	42.4	42.1	25.6	86.2	106.0	86.3	64.7	160.0	14.3	21.7	47.0	30.1	726.4
2006	29.3	7.8	97.3	98.0	57.0	93.7	163.0	121.5	18.9	18.1	6.3	2.6	713.5
2007	20.3	30.2	30.2	27.0	30.7	15.6	63.6	63.6	108.7	91.4	46.8	54.0	582.1
2008	10.9	2.6	25.2	127.3	43.2	65.2	145.1	48.0	52.0	53.1	13.4	39.9	625.9
2009	80.0	56.5	37.5	5.0	44.0	139.0	122.0	12.1	25.0	87.0	9.0	35.0	652.1
2010	61.0	17.2	20.2	24.3	82.0	173.0	73.0	7.3	59.0	7.3	10.8	27.0	562.1
Average	**34.2**	**22.4**	**33.0**	**53.2**	**43.6**	**74.9**	**93.4**	**64.6**	**70.7**	**46.8**	**34.4**	**29.9**	**601.2**
Average on 50 Years	**26.0**	**22.2**	**28.8**	**49.4**	**55.3**	**85.2**	**87.4**	**57.7**	**51.0**	**32.9**	**31.2**	**26.3**	**553.4**
Difference	**8.2**	**0.2**	**4.2**	**3.8**	**-11.7**	**-10.3**	**6.0**	**6.9**	**19.7**	**13.9**	**3.2**	**3.6**	**47.8**

The climatic conditions recorded during 1995-2010 resulted in a good uptake and use of mineral fertilizers and manure by the main crops. The mean annual rainfall amounts, registered in the last 16 years, were higher, with values comprised between 28.7 and 205.7 mm, compared to the multiannual mean on 50 years (553.4 mm).

The main consequence of long-term intensive cultivation is the degradation of soil structure which diminishes of the effect of chemical fertilizers. Improving soil structure helps reduce soil erosion and decrease production costs. Soil quality is strictly related to soil structure which is one of the most important properties affecting crop production and the amount of water that is stored in the soil.

Incorporation of residues in the soil change the dynamics of soil nitrogen content that is part of the amount involved in the processes of decomposition. In temperate zones, the amounts of nitrogen immobilized vary, depending on the residue, up to 33 g nitrogen per kg of C administered in corn stalks and 1 g / kg C for the leaves of rape. At the end of the incubation period (168 days) the highest amount of nitrogen mineralized was recorded at alfalfa shoots (50 g N per kg C applied) and the lowest (-28 g N/kg C) from corn straw (Trinsoutrot I., 2000).

Mechanical stability of the aggregates, determined by dry sieving the soil samples, was between 84.3% to non eroded soil, at the bottom of slope land and 60.5% in highly eroded soil, in area with maximum erosion *(Table 2)*.

The percentage of aggregate stability by water was between 73.4% to non eroded soil and 45.7% in highly eroded soil *(Table 3)*. Soil erosion caused a reduction in the percentage of aggregate by 14.5% to slightly eroded soil and 37.7% in the strongly eroded soil.

Wet aggregate stability show how well a soil can resist raindrop impact and water erosion, and size distribution of dry aggregates can be used to predict resistance to wind erosion. Conservation tillage systems, such as no-till with cover crops and residue increased of soil organic matter and improved aggregate stability.

The stability of aggregates is influenced by soil texture, the type of clay, extractable cat ions, the amount of organic matter and the biological activity in soil. Aggregation affects erosion, movement of water, and plant root growth. The percentage of aggregates with mechanical stability (0.25-10 mm) was of 84.3% in non eroded soil and 60.5 % on highly eroded soil *(Figure 1)*.

The percentage of water stable aggregates was comprised between 73.5% in non eroded soil, at the bottom of slope land and 45.7% at the highly eroded soil *(Figure 2)*. The data obtained show that in highly eroded soil under the influence of pea-wheat-corn rotation, the percentage of structural aggregates increased to aggregates with a diameter between 0.5 and 2 mm. The least water stability in the highly eroded soil was found in aggregates of > 3 mm.

Table 2 - Influence of soil erosion on mechanical stability of structural macro-aggregates

Soil erosion	Depth, cm	Percentage (%) of structural elements with diameter (mm):							
		>5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25	Sum 0.25-10
Non eroded soil	0-10	16.4	15.4	13.2	28.9	3.8	4.7	17.6	82.4
	10-20	17.8	17.4	14.3	26.3	3.4	5.1	15.7	84.3
	20-30	11.9	17.8	23.7	27.1	2.4	3.2	13.9	86.1
	Average	15.4	**16.9**	**17.1**	**27.4**	**3.2**	**4.3**	**15.7**	**84.3**
Weakly eroded soil	0-10	12.8	14.8	13.2	17.3	2.8	6.3	32.8	67.2
	10-20	14.8	15.2	14.7	18.2	3.1	5.7	28.3	71.7
	20-30	20.1	13.2	11.7	19.8	3.4	4.1	27.7	72.3
	Average	15.9	**14.4**	**13.2**	**18.4**	**3.1**	**5.4**	**29.6**	**70.4**
Moderately eroded soil	0-10	19.4	12.3	11.6	13.5	2.8	5.4	35.0	65.0
	10-20	22.0	11.4	12.7	13.2	2.1	4.9	33.7	66.3
	20-30	16.4	11.1	9.9	14.2	3.8	5.7	38.9	61.1
	Average	19.3	**11.6**	**11.4**	**13.6**	**2.9**	**5.3**	**35.8**	**64.2**
Highly eroded soil	0-10	19.0	9.5	9.2	11.2	4.2	5.2	41.7	58.3
	10-20	18.6	10.3	7.5	12.1	6.2	7.2	38.1	61.9
	20-30	17.4	11.7	6.4	11.7	5.8	8.3	38.7	61.3
	Average	18.3	**10.5**	**7.7**	**11.7**	**5.4**	**6.9**	**39.5**	**60.5**
	LSD 5%								3.1%
	LSD 1%								5.7%
	LSD 0.1%								8.9%

Table 3 - Influence of soil erosion on water stability of structural macro-aggregates

Soil erosion	Depth, cm	Percentage (%) of structural elements with diameter (mm):							
		>5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25	Sum 0.25-5
Non eroded soil	0-10	3.7	10.8	14.6	13.5	11.4	20.1	25.9	**74.1**
	10-20	2.4	11.6	15.1	12.9	10.2	19.8	28.0	**72.0**
	20-30	2.2	12.3	16.4	13.2	11.3	18.7	25.9	**74.1**
	Average	**2.8**	**11.6**	**15.4**	**13.2**	**11.0**	**19.5**	**26.6**	**73.4**
Weakly eroded soil	0-10	3.2	8.5	11.6	8.7	10.2	18.2	**39.6**	**60.4**
	10-20	4.1	7.6	14.2	10.2	9.5	18.7	**35.7**	**64.3**
	20-30	2.4	8.4	12.3	11.4	9.8	19.4	**36.3**	**63.7**
	Average	**3.2**	**8.2**	**12.7**	**10.1**	**9.8**	**18.8**	**37.2**	**62.8**
Moderately eroded soil	0-10	5.6	4.3	6.5	7.8	8.6	19.3	**47.9**	**52.1**
	10-20	4.7	5.2	7.6	7.5	9.2	18.3	**47.5**	**52.5**
	20-30	3.5	6.9	7.9	8.5	8.7	18.6	**45.9**	**54.1**
	Average	**4.6**	**5.5**	**7.3**	**7.9**	**8.8**	**18.7**	**47.1**	**52.9**
Highly eroded soil	0-10	2.1	3.5	6.2	5.8	7.4	19.2	**55.8**	**44.2**
	10-20	1.5	5.9	5.9	6.7	8.4	19.4	**52.2**	**47.8**
	20-30	1.9	6.7	6.9	7.4	5.9	16.2	**55.0**	**45.0**
	Average	**1.8**	**5.4**	**6.3**	**6.6**	**7.2**	**18.3**	**54.3**	**45.7**
LSD 5%									1.6%
LSD 1%									2.8%
LSD 0.1%									3.9%

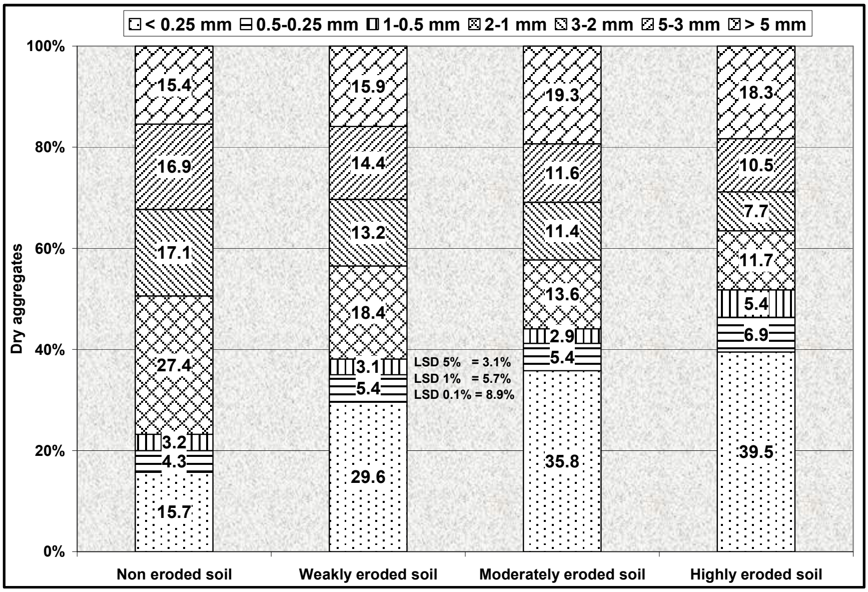

Figure 1 - Effects of soil erosion on dry aggregate size distribution, 0-30 cm

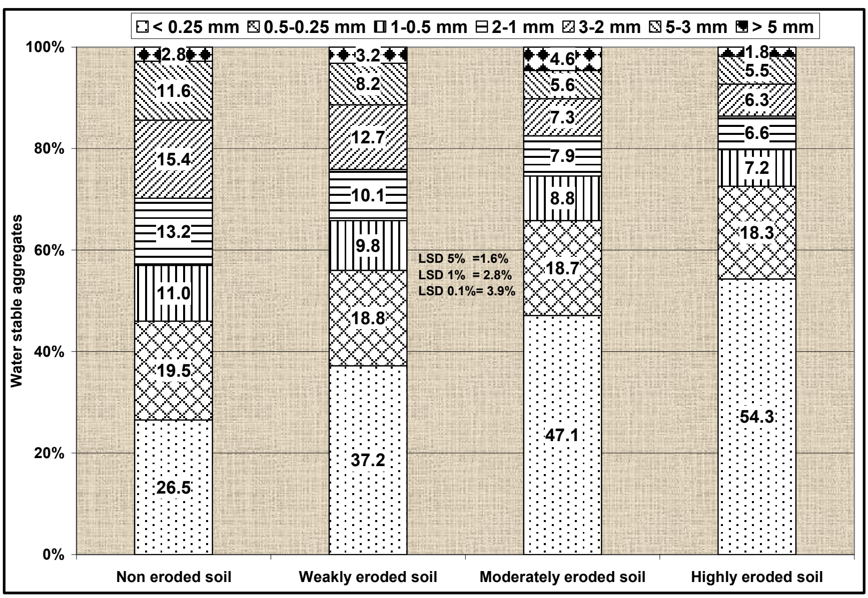

Figure 2 - Effects of soil erosion on size distribution of water stable aggregates, 0-30 cm

Determinations concerning the influence of chemical and organic fertilizers on eroded soil structure have shown that the rate of hydro stable aggregates on non-eroded land at the bottom of slope, after wheat harvesting, varied between 43.1 and 61.5%, according to applied fertilizers (*Table 4*). On weakly eroded soil, the rate of hydro stable aggregates was, according to rates and type of fertilizers, between 36.5 and 48.9%, and on highly eroded land, the rate of hydro stable aggregates increased from 33.8% in unfertilized control to 48.0 in the fertilized variant with 60 t/ha manure. Erosion has determined structure degradation, with negative impact on all the other physical, chemical and biological soil characteristics. In weakly and moderately eroded soils with the slope of 16%, the rate of hydro stable aggregates diminished by 16.0 and, respectively, 21.3%, compared to non-eroded soil at the bottom of slope (*Table 4*).

Table 4 - Influence of fertilization system and erosion on water stability of structural macro-aggregates (%: 0-30 cm)

Fertilizer rate	Depth, cm			Average
	0 - 10	10 - 20	20 - 30	0 - 30
Non-eroded soil at the bottom of slope				
Unfertilized control	41.2	43.2	44.8	**43.1**
$N_{120}P_{80}$	42.8	48.5	51.2	**47.5**
$N_{160}P_{100}$	40.1	47.3	49.5	**45.6**
$N_{80}P_{60}$ + 6 t/ha hashed of wheat	43.8	51.2	55.4	**50.1**
60 t/ha manure	56.8	61.3	62.7	**60.3**
$N_{80}P_{60}$ + 60 t/ha manure	57.9	62.4	64.1	**61.5**
Average	**47.1**	**52.3**	**54.6**	**51.3**
Weakly eroded soil				
Unfertilized control	36.2	37.4	35.8	**36.5**
$N_{120}P_{80}$	40.3	42.8	37.2	**40.1**
$N_{160}P_{100}$	38.2	43.6	41.5	**41.1**
$N_{80}P_{60}$ + 6 t/ha hashed of wheat	42.7	45.8	42.5	**43.7**
60 t/ha manure	45.3	54.3	44.8	**48.1**
$N_{80}P_{60}$ + 60 t/ha manure	48.5	51.2	46.9	**48.9**
Average	**41.9**	**45.9**	**41.5**	**43.1**
Moderately eroded soil				
Unfertilized control	31.4	35.2	34.7	**33.8**
$N_{120}P_{80}$	35.4	38.4	35.8	**36.5**
$N_{160}P_{100}$	33.7	38.2	38.6	**36.8**
$N_{80}P_{60}$ + 6 t/ha hashed of wheat	39.2	41.2	42.8	**41.1**
60 t/ha manure	45.3	48.9	49.8	**48.0**
$N_{80}P_{60}$ + 60 t/ha manure	44.8	46.8	47.8	**46.5**
Average	**38.3**	**41.5**	**41.6**	**40.4**

In maize crop placed on weakly eroded lands, the high rate mineral fertilization ($N_{160}P_{100}$) resulted in getting yield increases of 99%, compared to unfertilized variant (*Table 5*). In maize placed on weakly eroded lands, the mean yield increases obtained for each kg of a.i. of applied fertilizers have varied according to applied fertilizers rates, between 12.8 and 13.7 kg grains ($N_{80}P_{60}$-$N_{160}P_{100}$).

On highly eroded lands, the mean maize yield obtained under unfertilized was of 2534 kg/ha, and the mineral fertilizers ($N_{80}P_{60}$-$N_{160}P_{100}$) resulted in getting mean yield increases of 11.9- 12.8 kg grains/kg a.i. of applied fertilizer. Very close yield results were also obtained by applying, for 43 years, rates of 80 kg N + 60 kg P_2O_5/ha +6 t/ha hashed straw or stalks of maize, variants at which yield increases have varied, according to soil erosion, between 2555 and 2696 kg/ha (75-79%) on weakly eroded lands and between 2584 and 2590 kg/ha (102%) on highly eroded lands (*Table 5*).

Table 5 - Influence of mineral and organic fertilizers on maize yields, in weakly and highly eroded lands

Fertilizer rate	Weakly eroded soil				Highly eroded soil			
	Mean maize yields		Differ. kg/ha	Signif.	Mean maize yields		Differ. kg/ha	Signif.
	Kg/ha	%			kg/ha	%		
N_0P_0	3428	100			2534	100		
$N_{80}P_{60}$	5219	152	1791	***	4324	171	1790	***
$N_{120}P_{80}$	6172	180	2744	***	4965	196	2431	***
$N_{160}P_{100}$	6824	199	3396	***	5628	222	3094	***
$N_{80}P_{60}$+ 20 t/ha manure	6139	179	2711	***	5162	204	2628	***
$N_{80}P_{60}$+ 40 t/ha manure	6739	197	3311	***	5638	222	3104	***
$N_{80}P_{60}$+ 60 t/ha manure	7219	211	3791	***	5984	236	3450	***
$N_{80}P_{60}$+6 t/ha hashed straw	6124	179	2696	***	5124	202	2590	***
$N_{80}P_{60}$+6 t/ha stalks of maize	5983	175	2555	***	5118	202	2584	***
$N_{80}P_{60}$+3 t/ha stalks of pea	5892	172	2464	***	5067	200	2533	***
$N_{80}P_{60}$+3 t/ha stalks of soybean	5934	173	2506	***	5099	201	2565	***
Mean	**5970**	**100**			**4968**	**83**		
LSD 5%			345				335	
LSD 1%			460				440	
LSD 0.1%			590				550	

The fertilization of wheat crop with 40 t/ha manure + 80 kg N/ha + 60 kg P_2O_5/ha has determined yield increases of 153% (2877 kg/ha) on weakly eroded soils and 185% (2548 kg/ha) on highly eroded soils, compared to unfertilized variant (*Table 6*). 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.

Table 6 - Influence of mineral and organic fertilizers on wheat yields, in weakly and highly eroded lands

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	1875	100			1379	100		
$N_{80}P_{60}$	3459	184	1584	***	2719	197	1340	***
$N_{120}P_{80}$	4127	220	2252	***	3426	248	2047	***
$N_{160}P_{100}$	4679	250	2804	***	3972	288	2593	***
$N_{80}P_{60}$+ 20 t/ha manure	4236	226	2361	***	3468	251	2089	***
$N_{80}P_{60}$+ 40 t/ha manure	4752	253	2877	***	3927	285	2548	***
$N_{80}P_{60}$+ 60 t/ha manure	4996	266	3121	***	4382	318	3003	***
$N_{80}P_{60}$+6 t/ha hashed straw	3982	212	2107	***	3362	244	1983	***
$N_{80}P_{60}$+6 t/ha stalks of maize	3897	208	2022	***	3324	241	1945	***
$N_{80}P_{60}$+3 t/ha stalks of pea	3816	204	1941	***	3297	239	1918	***
$N_{80}P_{60}$+3 t/ha stalks of soybean	3729	199	1854	***	3266	237	1887	***
Mean	**3959**	**100**			**3320**	**83.8**		
LSD 5%			326				314	
LSD 1%			436				428	
LSD 0.1%			520				510	

The combined use of mean rates of mineral fertilizers ($N_{80}P_{60}$), 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 2022-2107 kg/ha (108-112%), on weakly eroded lands, and 1945-1983 kg/ha (141-144%) on highly eroded lands, compared to the unfertilized control.

The analysis of results obtained has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of the mean wheat yield, according to slope and erosion, from 3959 (100 %) to

3320 kg/ha (83.8 %). Mean annual losses of yields registered in wheat in the last 15 years, caused by erosion, were of 639 kg/ha (16.2 %).

On slope lands, poor in humus and mineral elements, the use of crop residues has a special importance for improving soil fertility indicators. The long-term use of crop residues determined a better soil conservation by increasing organic matter and mineral element stock from soil, resulting in a decrease with time in the necessary of nitrogen and phosphorus fertilizers for crops.

Because on slope lands, soil nutrient losses are very high, due to leaching, runoff and element fixing, establishing rates and time of fertilizer application must be done differentiate, according to soil characteristics, cultural practices and climatic conditions.

The analysis of agro-chemical data shows that nitrogen fertilizers (ammonium nitrate) have determined the pH decrease. A significant diminution was registered in the ploughed layer, at rates of 160 kg/ha N, where pH value has reached 5.6, after 44 years (*Table 7*).

Table 7 - Effect of soil erosion and fertilization system on the organic carbon and mineral element content in 16% slope fields

Fertilizer rate	Weakly eroded lands				Highly eroded lands			
	pH (H_2O)	Org. C g/kg	P-AL (ppm)	K-AL (ppm)	pH (H_2O)	Org. C (g/kg)	P-AL (ppm)	K-AL (ppm)
N_0P_0	7.0	16.4	14	198	6.9	14.8	10	179
$N_{120}P_{80}$	6.3	17.3	65	179	6.1	16.1	58	162
$N_{160}P_{100}$	5.7	18.6	69	164	5.6	16.5	65	153
60 t/ha manure	7.2	21.2	68	253	7.0	20.1	59	224
$N_{80}P_{60}$ + 60 t/ha manure	6.9	21.5	76	249	6.8	19.9	67	209
$N_{80}P_{60}$ + 6 t/ha hashed of wheat	6.8	19.2	66	239	6.8	18.7	58	197
$N_{80}P_{60}$+6 t/ha stalks of maize	6.8	19.1	62	234	6.7	18.4	54	189
Mean	**6.7**	**19.0**	**60**	**217**	**6.6**	**17.8**	**53**	**188**
LSD 5%	0.22	0.09	4.7	13	0.20	0.08	4.5	12
LSD 1%	0.34	0.12	7.1	21	0.31	0.11	6.3	19
LSD 0.1%	0.48	0.19	9.8	31	0.43	0.17	8.6	29

The analyses carried out on the evolution of soil response, after 44 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates than 120 kg N/ha.

The results of chemical analyses have shown that in the pea-wheat-maize rotation, by the annual rate application of $N_{120}P_{80}$, the decrease in the organic carbon content from soil could not be prevented, its level increasing only at variants where mineral fertilizers were applied with manure or crop residues. In this case, the values registered in macronutrients showed that soil supply was normal compared to crop demands. Maintaining under favorable limits for plant growing and development of main soil chemical characteristics was done only in case of organic and mineral fertilization.

Both on weakly and highly eroded lands, the mineral fertilization with lower rates than $N_{160}P_{100}$ kg/ha have determined the decrease of organic carbon content from soil until 16.1 - 17.3 g/kg soil. On highly eroded lands, the carbon content was kept at values of 19.9 - 20.1 g/kg soil only by the annual application of the rate of 60 t/ha manure or $N_{80}P_{60}$+ 60 t/ha manure. The analyses conducted on cambic chernozem soil, on which pea-wheat-maize rotations were used for 44 years, have shown that these crop structures were not sufficient for erosion control and maintaining soil fertility.

CONCLUSIONS

In peas-wheat-maize crop rotation, applying mineral fertilizers during 1995-2010 resulted in getting mean yield increases, which varied according to rates, between 84 and 218% (1584- 3003 kg/ha) in wheat and between 52 and 136% (1791-3450 kg/ha) in maize.

The mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 9.6 and 11.3 kg in wheat and between 11.9 and 13.06 kg in maize ($N_{80}P_{60}$-$N_{160}P_{100}$).

In peas-wheat-maize crop rotation, the content of organic carbon from soil, after 44 years of experiences, has decreased by 22.2% (4.4 g/kg soil) at the unfertilized control and by 13.6% (2.7 g/kg soil) at the rate of $N_{120}P_{80}$.

In the soils of the Moldavian Plain, situated on slope fields, poor in organic matter and nutrients, the proper use of different crops rotation and organic resources may replace a part of the rich technological consumption and determines the improvement in the content of organic matter from soil.

On weakly and highly eroded lands the content of organic carbon from soil, after 44 years of experiences, has decreased by 16.8-24.9% (3.3-4.9 g/kg soil) at the unfertilized control and by 12.2-18.3% (2.4-3.6 g/kg soil) at the rate of $N_{120}P_{80}$.

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