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# EFFECTS OF LONG-TERM FERTILIZATION ON THE FERTILITY OF EROSION-AFFECTED SOILS FROM THE MOLDAVIAN PLATEAU

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***ABSTRACT*** *– The paper presented the results of investigations concerning the influence of long-term fertilization (43 years) on some chemical characteristics of Cambic Chernozem from the Moldavian Plain and on the maize yield. On slope lands, the high rate fertilization of maize crop ($N_{140}P_{100}$) has determined, in the latest ten years, an average yield increase of 103% (3373 kg/ha), against the control, and applying a rate of $N_{70}P_{70}$+40 t/ha manure resulted in getting a very close yield increase (99%, 3258 kg/ha). The minimum supply level of mobile phosphorus in soil (37-72 ppm) in pea-wheat-maize rotation (37 ppm) was maintained in case of annual application of a rate of $N_{100}P_{80}$. The total carbon content in Cambic Chernozem from the Moldavian Plain has registered significant increases at higher rates than $N_{140}P_{100}$ and in case of organo-mineral fertilization. The annual fertilization of wheat and maize, at the rate of 70 kg N + 70 kg $P_2O_5$/ha + 6 t/ha stalks of wheat, has determined, compared to the unfertilized variant, the increase in the content of organic carbon from soil by 14.5% (2.4 g organic C/kg) on weakly eroded soils, and by 29.5% (4.2 g organic C/kg) on highly eroded soils. During the long-term fertilizing of wheat and maize with high rates of mineral fertilizers ($N_{140}P_{100}$), on highly eroded lands, the total content of carbon has increased by 16.9% (2.4 g organic C/kg soil), against the unfertilized control. Applying moderate rates of mineral fertilizers ($N_{70}P_{70}$), together with 60 t/ha manure, has determined, after 43 years of testing, the increase by 32% (5.3 g organic C/kg) in the content of organic carbon from soil, on weakly eroded soils, and by 42.3% (6.0 g organic C/kg soil) on highly eroded soils, compared to the unfertilized control. On 16% slope arable lands from the Moldavian Plateau, the mean annual soil losses by erosion, registered during 1986-2007, were of 1.640 t/ha in winter wheat, 4.618 t/ha in*

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*beans, 1.89 t/ha in the field cultivated with perennial grasses and legumes on the second year of vegetation, 9.176 t/ha in maize and 9.6 t/ha in sunflower.*

**Key words:** maize, long-term fertilization, soil erosion, crop residue, organic matter

***REZUMAT - Efectele fertilizării de lungă durată asupra fertilitații solurilor afectate de eroziune.*** *Lucrarea prezintă rezultatele cercetărilor privind influența fertilizării de lungă durată (43 ani) asupra unor însuşiri chimice ale cernoziomului cambic din Câmpia Moldovei şi asupra producției la cultura porumbului. Pe terenurile in pantă, fertilizarea culturii de porumb cu doze mari de îngrăşăminte ($N_{140}P_{100}$) a determinat obținerea, în ultimii zece ani, a unui spor mediu de producție, comparativ cu martorul nefertilizat, de 103% (3373 kg/ha), iar aplicarea dozei de $N_{70}P_{70}$+40 t/ha gunoi a determinat obținerea unui spor de producție foarte apropiat (99%, 3258 kg/ha). Menținerea unui nivel minim de aprovizionare cu fosfor mobil în sol (37-72 ppm), la rotația mazăre-grâu-porumb (37 ppm), s-a inregistrat în cazul aplicării anuale a dozei de $N_{100}P_{80}$. Conținutul total de carbon la cernoziomul cambic din Câmpia Moldovei a înregistrat creşteri semnificative la doze mai mari de $N_{140}P_{100}$ şi în cazul fertilizării organo-minerale. Fertilizarea anuală a culturilor de grâu si porumb cu doza de 70 kg N + 70 kg $P_2O_5$/ha + 6 t/ha tulpini de grâu a determinat, comparativ cu varianta nefertilizată, creşterea conținutului de carbon organic din sol cu 14.5% (2.4 g C organic/kg) pe solurile cu eroziune slabă şi cu 29.5% (4.2 g C organic/kg) pe solurile puternic erodate. În cazul fertilizării îndelungate cu doze mari de îngrăşăminte minerale ($N_{140}P_{100}$) a culturilor de grâu şi porumb, pe terenurile puternic erodate, conținutul total de carbon a crescut, față de martorul nefertilizat, cu 16.9% (2.4 g C organic/kg sol). Aplicarea unor doze moderate de ingraşăminte minerale ($N_{70}P_{70}$) împreună cu 60 t/ha gunoi a determinat, după 43 de ani de experimentare, comparativ cu martorul nefertilizat, creşterea conținutului de carbon organic din sol cu 32% (5.3 g C organic/kg) pe solurile slab erodate şi cu 42.3% (6.0 g C organic/kg sol) pe solurile puternic erodate. Pe terenurile arabile cu panta de 16% din Podişul Moldovei, pierderile medii anuale de sol prin eroziune, înregistrate in perioada 1986-2007, au fost de 1.640 t/ha la grâul de toamnă, 4.618 t/ha la fasole, 1.89 t/ha la sola cu leguminoase şi graminee perene în anul doi de vegetație, 9.176 t/ha la porumb şi 9.6 t/ha la floarea-soarelui.*

**Cuvinte cheie:** cultura porumbului, fertilizare de lungă durată, resturi vegetale, eroziunea solului

## INTRODUCTION

The investigations conducted on eroded soils have followed the establishment of crop rotations and fertilizing systems, which contribute to maintaining and recovery of soil fertility. The negative impact of continuous cropping on the content of organic carbon from soil was shown by Clapp et al., 2000; Mikhailova, 2000 and Liu, 2006. In many areas, applying crop residues, together with moderate nitrogen rates, have resulted in improving physical, chemical and biological soil characteristics (Clapp et al., 2000; Acosta, 2004; Wilhelm, 2004; Campbell, 2005; Andrews, 2006).

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. Power et al. (1986) and Linden et al.

(2000) have shown that applying maize and soybean residues in dry years has determined the increase in the average maize yield by 22%.

The crop residue incorporation into soil at rates of 4942 and 9884 kg/ha has resulted in diminishing eroded soil by 85 and 98%, respectively, as compared with the areas where no crop residues were applied. Applying 2471 and 4942 kg/ha crop residues, at soil surface, has determined the diminution by 90 and 100%, respectively, in eroded soil losses, as compared with areas without crop residues (McCool et al., 1995).

The investigations conducted on maize by Lindstrom, in Minnesota, USA, show that applying crop residues at rates of 927 and 3706 kg/ha has determined the decrease in soil erosion from 6.177 to 0.988 t/ha and in water runoff from 35.6 to 22.9 mm. The long-term investigations conducted by Dabney et al. (2004) and Wilson et al. (2004), showed that the removal of maize residues at different rates, has determined the increase in soil losses by 26-47%.

Many studies show that, by removing crop residues, high amounts of nutrients are also removed from agro-ecosystem, which are higher than those removed by grain production, because of erosion losses (Holt, 1979; Lindstrom, 1986).

Power and Doran (1988) show that applying high amounts of crop residues may determine the increase in the nitrogen uptake in soil and propose the increase in N fertilizer rate, in order to avoid soil depletion during crop residue decay. In other studies, Clapp et al. (2000) and Reicosky et al. (2002) show that applying crop residues, together with nitrogen fertilizers, under conventional soil tillage with ploughing, did not result in increasing the organic carbon content after 30 years of experiencing. 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, 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.

## MATERIALS AND METHODS

Since 1964, at the Agricultural Research and Development Station of Podu-Iloaiei, investigations were conducted on the influence of different crop structures and fertilizers on yield and soil fertility.

The investigations carried out during 1997 - 2006 on a Cambic Chernozem at the Agricultural Research and Development Station of Podu - Iloaiei, Iasi County, 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 $N_{140}$ $P_{100}$, 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 ploughing.

The typical Cambic Chernozem from Podu - Iloaiei was formed on a loessy loam, has mean humus content (2.56 - 3.48 %), is well supplied with mobile potassium (215 - 296 ppm) and moderately with phosphorus (24-69 ppm) and nitrogen (0.146 – 0.175 %). In maize, we have used Oana hybrid. The determination of water runoff, soil, humus and nutritive element losses by erosion in different crops was done by means of loss control plots, which are isolated from the rest of the area by metallic walls and have basins and devices for division; we sampled water and soil from plots, for determining the partial turbidity and for analyses on chemical elements. The total nitrogen, nitrate, phosphorus and potassium content were determined in soil and water samples, lost by erosion in different crops, thus establishing nutritive element losses. Chemical analyses were done according to the following methods: pH – potentiometrically, with combined electrode of glass and horn mercury, in watery suspension, at the ratio between soil and water of /2.5; humus – by wet oxidation, according to Walkely-Black Method, modified by Gogoaşă; carbonates – by gasovolumetric Scheibler Method; total nitrogen by Kjeldahl Method, with disintegration with $H_2SO_4$ at $350^0$ C, catalyst potassium sulphate and copper sulphate; mobile phosphorus – by extraction, in solution of ammonia lactate acetate (P-AL); mobile potassium – by extraction in solution of ammonia lactate acetate (P-AL), according to Egner-Riehm-Domingo Method and dosing by flame photometry.

## RESULTS AND DISCUSSION

The climatic conditions from the Moldavian Plain are characterized by a multiannual mean temperature of 9.6 $^oC$ and a mean rainfall amount on 80 years of 542.6 mm, of which 161.4 mm during September-December and 381.2 mm during January-August.

The climatic conditions during 1997-2007 were favourable to maize growing and development in seven years and unfavourable, because of low rainfall amount, in the other four years. In the last 11 years, the deficit of rainfall registered during January- August, as compared to the multiannual mean of the area, was between 42.3 and 96.8 mm in four years.

On weakly eroded lands, the mean maize yields obtained during 1997-2007, were comprised between 3287 kg/ha (100 %) at the unfertilized control and 7188 kg/ha (119 %) 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 2748 and 3373 kg/ha, respectively.

On highly eroded soil, the mean maize yield, obtained during 1997-2007, in maize placed in pea-wheat-maize rotation, was of 2452 kg/ha, under unfertilized, and of 5263 kg/ha at high mineral fertilizer rates ($N_{140}P_{100}$). In maize, the application of mean rates of mineral fertilizers (70 kg N + 70 kg $P_2O_5$) with 60 t/ha manure has resulted in getting yield increases of 134 % (3275 kg/ha), compared to the unfertilized variant. Applying rates of 100 kg N + 100 kg $P_2O_5$

resulted in getting yield increases of 84 % (2748 kg/ha) in maize, placed on weakly eroded lands, and 94 % (2306 kg/ha) in maize placed on highly eroded soil, compared to the unfertilized variant.

**Table 1 - Influence of mineral and organic fertilizers on maize yields, in weakly and highly eroded soils, after 43 years of experiments (Oana hybrid)**

| No. | 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 | % | | |
| 1 | $N_0P_0$ | 3287 | 100 | 0 | | 2452 | 100 | 0 | |
| 2 | $N_{40}P_{40}$ | 3865 | 118 | 578 | *** | 3124 | 127 | 672 | *** |
| 3 | $N_{70}P_{70}$ | 5159 | 157 | 1872 | *** | 4120 | 168 | 1668 | *** |
| 4 | $N_{100}P_{100}$ | 6035 | 184 | 2748 | *** | 4758 | 194 | 2306 | *** |
| 5 | $N_{140}P_{100}$ | 6660 | 203 | 3373 | *** | 5263 | 215 | 2811 | *** |
| 6 | $N_0P_{70}K_{70}$ | 3608 | 110 | 321 | * | 2792 | 114 | 340 | * |
| 7 | $N_{40}P_{40}K_{40}$ | 4107 | 125 | 820 | *** | 3273 | 133 | 821 | *** |
| 8 | $N_{70}P_{70}K_{70}$ | 5285 | 161 | 1998 | *** | 4251 | 173 | 1799 | *** |
| 9 | $N_{100}P_{100}K_{100}$ | 6324 | 192 | 3037 | *** | 5020 | 205 | 2568 | *** |
| 10 | $N_{140}P_{100}K_{100}$ | 6816 | 207 | 3529 | *** | 5475 | 223 | 3023 | *** |
| 11 | 20 t/ha manure | 4150 | 126 | 863 | *** | 3252 | 133 | 800 | *** |
| 12 | 40 t/ha manure | 5199 | 158 | 1912 | *** | 3909 | 159 | 1457 | *** |
| 13 | 60 t/ha manure | 5953 | 181 | 2666 | *** | 4505 | 184 | 2053 | *** |
| 14 | $N_{40}P_{40}$ +20 t/ha manure | 5362 | 163 | 2075 | *** | 3919 | 160 | 1467 | *** |
| 15 | $N_{40}P_{40}$+40 t/ha manure | 6136 | 187 | 2849 | *** | 4531 | 185 | 2079 | *** |
| 16 | $N_{40}P_{40}$+60 t/ha manure | 6541 | 199 | 3254 | *** | 5127 | 209 | 2675 | *** |
| 17 | $N_{70}P_{70}$+20 t/ha manure | 6119 | 186 | 2832 | *** | 4719 | 192 | 2267 | *** |
| 18 | $N_{70}P_{70}$+40 t/ha manure | 6545 | 199 | 3258 | *** | 5261 | 215 | 2809 | *** |
| 19 | $N_{70}P_{70}$+60 t/ha manure | 7188 | 219 | 3901 | *** | 5727 | 234 | 3275 | *** |
| 20 | $N_{70}P_{70}$+6 t/ha hashed straw | 5733 | 174 | 2446 | *** | 4646 | 189 | 2194 | *** |
| 21 | $N_{70}P_{70}$+6 t/ha stalks of maize | 5656 | 172 | 2369 | *** | 4500 | 184 | 2048 | *** |
| 22 | $N_{70}P_{70}$+3 t/ha stalks of pea | 5902 | 180 | 2615 | *** | 4675 | 191 | 2223 | *** |
| 23 | $N_{70}P_{70}$+3 t/ha stalks of soybean | 5837 | 178 | 2550 | *** | 4613 | 188 | 2161 | *** |
| 24 | $N_{70}P_0K_0$ | 4949 | 151 | 1662 | *** | 3788 | 154 | 1336 | *** |
| | **Mean** | **5498** | **100** | | | **4321** | **78.6** | | |
| | LSD 5% | | | 315 | | | | 336 | |
| | LSD 1% | | | 444 | | | | 450 | |
| | LSD 0.1% | | | 593 | | | | 605 | |

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 7.2 and 14.1 kg grains ($N_{40}P_{40}$-$N_{140}P_{100}$). On highly eroded lands, the mean maize yield obtained under unfertilized was of 2452 kg/ha, while the mean yield increases, obtained by applying 40 or 60 t/ha manure, were of 36.4-34.2 kg grains per ton of applied manure. The mineral fertilizers ($N_{40}P_{40}$-$N_{140}P_{100}$) resulted in getting mean yield increases of 8.4- 11.7 kg grains/kg a. i. of applied fertilizer. Very close yield results were also obtained by applying, for 43 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 have varied, according to soil erosion, between 2550 and 2615 kg/ha (78-80 %) on weakly eroded lands and between 2161 and 2223 kg/ha (88-91 %) on highly eroded lands (*Table 1*).

The analysis of results obtained has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of the mean maize yield, according to slope and erosion, from 5498 (100 %) to 4321 kg/ha (78.6 %). Mean annual losses of yields registered in maize in the last 11 years, caused by erosion, were of 1177 kg/ha (21.4 %).

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 140 kg/ha N, where pH value has reached 5.7, after 43 years (*Table 2*). The analyses carried out on the evolution of soil response, after 43 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates than 100 kg N/ha . The lowest pH values were found in maize at rates of $N_{140}P_{100}$ and 70 kg N + 70 kg $P_2O_5$/ha + 6 t/ha stalks of maize, which can be explained by the unfavourable conditions in which the processes of nitrification and crop residue decay developed.

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. 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.

The results of chemical analyses have shown that in the pea-wheat-maize rotation, by the annual rate application of $N_{100}P_{100,}$ the decrease in the organic matter 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 (N, P, K, Ca, Mg) 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 organo-mineral fertilization. On slightly eroded lands, keeping a good supply in soil nutritive elements was done by the annual use of fertilizer rates of at least $N_{100}P_{100}$ or $N_{70}P_{70}$+ 40 t/ha manure, applied once in two years or $N_{70}P_{70}$ + 6 t/ha straw and on highly eroded lands, keeping a good plant supply in mineral elements was done at rates of $N_{140}P_{100}K_{70}$ or $N_{70}P_{70}$ + 40 t/ha manure. Under these conditions, the organic carbon content from soil, after 43 years of experiencing, was maintained at the initial value and there were not found nutrition troubles with microelements in plants.

**Table 2 - 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) |
| $N_0P_0$ | 7.3 | 16.5 | 17 | 216 | 7.2 | 14.2 | 8 | 192 |
| $N_{70}P_{70}$ | 6.9 | 16.9 | 54 | 186 | 6.8 | 14.3 | 41 | 186 |
| $N_{100}P_{80}$ | 6.3 | 17.5 | 86 | 178 | 6.2 | 15.5 | 62 | 174 |
| $N_{140}P_{100}$ | 5.8 | 18.2 | 89 | 174 | 5.7 | 16.6 | 64 | 156 |
| 60 t/ha manure | 7.4 | 21.3 | 74 | 276 | 7.1 | 19.9 | 66 | 259 |
| $N_{70}P_{70}$ + 60 t/ha manure | 7.2 | 21.8 | 96 | 292 | 6.9 | 20.2 | 74 | 289 |
| $N_{70}P_{70}$ + 6 t/ha hashed of wheat | 7.0 | 18.9 | 64 | 234 | 6.8 | 18.4 | 57 | 216 |
| $N_{70}P_{70}$+6 t/ha stalks of maize | 6.6 | 18.8 | 58 | 239 | 6.6 | 18.1 | 52 | 196 |
| $N_{70}P_{70}$+3 t/ha stalks of pea | 6.9 | 18.5 | 47 | 228 | 6.8 | 18.0 | 48 | 184 |
| $N_{70}P_{70}$+3 t/ha stalks of soybean | 6.8 | 18.3 | 51 | 234 | 6.7 | 18.0 | 49 | 182 |
| **Mean** | **6.8** | **18.7** | **63.6** | **225.7** | **6.7** | **17.3** | **52** | **203** |
| LSD 5% | 0.27 | 0.07 | 5.9 | 16.1 | 0.24 | 0.10 | 4.8 | 15.7 |
| LSD 1% | 0.38 | 0.10 | 8.2 | 24.0 | 0.35 | 0.14 | 6.9 | 22.6 |
| LSD 0.1% | 0.55 | 0.15 | 11.5 | 36.2 | 0.56 | 0.20 | 9.9 | 33.4 |

Investigations on the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in NE Romania, the mean soil losses by erosion were of 18.6 t/ha/year. The studies carried out on the effective erosion, based on direct determinations and complex analyses, have shown that in the entire NE zone, the effective erosion had a mean value of 4.8 t/ha/year.

The results on runoff and soil losses by erosion in different crops, which were determined by means of runoff control plots, have shown that during 1986-2007, of the total of 559.2 mm rainfall, 392.4 mm (70.2%) caused runoff between 6.2 mm in perennial grasses, on the second growing season, and 29.7 mm in sunflower. The annual soil losses by erosion registered at the same period were between 0.298 t/ha in perennial grasses, on the second growing season, and 9.650 t/ha in sunflower (*Table 3*). In the last 21 years, erosion was within the “allowable limits" of 2 t/ha / year in perennial grasses, on the second growing season, and in wheat.

**Table 3 - Mean runoff, soil, humus and mineral element losses by erosion in the Moldavian Plateau**

| Crop | RunoffWater (mm) | ErodedSoil (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 | 51.2 | 18790 | 629.5 | 3.779 | 27.246 | 31.024 | 2.161 | 4.510 |
| Sunflower | 29.7 | 9650 | 323.3 | 2.768 | 14.668 | 17.436 | 1.110 | 2.364 |
| I$^{st}$ year perennial grasses | 9.8 | 1890 | 62.9 | 0.894 | 2.797 | 3.691 | 0.217 | 0.471 |
| II$^{nd}$ year perennial grasses | 6.2 | 298 | 9.9 | 0.549 | 0.489 | 1.038 | 0.033 | 0.074 |
| Maize | 28.4 | 9176 | 308.3 | 2.624 | 15.049 | 17.673 | 1.028 | 2.294 |
| Peas | 11.4 | 2690 | 90.4 | 1.051 | 4.008 | 5.059 | 0.245 | 0.538 |
| Wheat | 7.9 | 1640 | 55.1 | 0.773 | 2.690 | 3.462 | 0.184 | 0.410 |
| Beans | 16.2 | 4618 | 155.2 | 1.510 | 7.250 | 8.760 | 0.411 | 0.924 |

Taking into account that the erosion process cannot be avoided and that the tolerance level of soil annual losses is of 3-5 t/ha, which correspond to the annual rate of soil renewal, the mean annual losses of soil by erosion, registered during 1986-2007 in maize (9.176 t/ha) and sunflower (9.650 t/ha), may result in destructing fertile soil layer in a few decades. In the second growth year, in perennial grasses, the mean annual losses of soil by erosion were of 0.298 t/ha and on bare fallow plot, they were of 18.790 t/ha. At three and four year crop rotations, which include good and very good cover plants for protecting soil against erosion, the amount of eroded soil and nutritive elements lost by erosion were very close to the limit allowable for this area.

Erosion has affected soil fertility by removing once with eroded soil, high amounts of humus and mineral elements, which reached 17.4-17.7 kg/ha nitrogen, 1.1 kg/ha phosphorus and 2.3 kg/ha potassium, in maize and sunflower crops. These amounts have decreased very much at the same time with the increase in the structure of crops protecting soil against erosion, such as peas, wheat, alfalfa and perennial grasses. The results obtained on the potential erosion have shown that on the fields uncovered by vegetation from the Moldavian Plateau, the average soil losses by erosion were of 18.79 t/ha/year, values corresponding to a moderate erosion risk.

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 of 4.507 t/ha/year (*Table 4*). 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 3-5 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 3-5 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.

**Table 4 - Soil, humus and mineral element losses by erosion in different crop rotations**

| Crop rotation | Eroded Soil (t/ha) | Humus (kg/ha) | Nitrogen (kg/ha) | $P_2O_5$ (kg/ha) | $K_2O$ (kg/ha) | Total NPK |
|---|---|---|---|---|---|---|
| Maize continuous cropping | 9.176 | 308 | 17.673 | 1.028 | 2.294 | 20.995 |
| Wheat – maize rotation | 5.408 | 182 | 10.567 | 0.606 | 1.352 | 12.525 |
| Peas – wheat – maize rotation | 4.502 | 151 | 8.731 | 0.215 | 1.081 | 10.027 |
| Peas – wheat – maize – sunflower + reserve field cultivated with legumes and perennial grasses | 4.691 | 157 | 8.934 | 0.52 | 1.136 | 10.59 |
| Peas – wheat – maize – sunflower + 2 reserve fields cultivated with legumes and perennial grasses | 3.959 | 144 | 7.618 | 0.466 | 0.959 | 9.043 |
| Peas – wheat – maize + reserve field cultivated with legumes and perennial grasses | 3.451 | 116 | 6.808 | 0.486 | 0.829 | 8.123 |
| Beans- wheat – maize+ 2 reserve fields cultivated with legumes and perennial grasses | 3.206 | 108 | 6.394 | 0.338 | 0.755 | 7.487 |

## CONCLUSIONS

By decreasing soil fertility, the erosion process has determined the differentiation of the mean maize yield according to slope and erosion, from 5498 (100%) to 4321 kg/ha (78.6%). Mean annual losses of yield registered in maize in the last 11 years, caused by erosion, were of 1177 kg/ha (21.4%).

On weakly eroded lands, the mean maize yields obtained during 1997-2007, were comprised between 3287 kg/ha at the unfertilized control and 7188 kg/ha at rate of $N_{70}P_{70}$+ 60 t/ha manure.

On highly eroded lands, in maize after wheat, in a three year rotation, the mean yield obtained under unfertilized was of 2452 kg/ha, the mean yield increases obtained by applying 60 t/ha manure every two years, were of 34.2 kg grains per ton of manure applied and mineral fertilizers ($N_{140}P_{100}$) resulted in obtaining mean yield increases of 11.7 kg grains/kg a.i. of applied fertilizer.

On slightly eroded lands, keeping a good supply in soil nutritive elements was done by the annual use of some fertilizer rates of at least $N_{100}P_{100}$ or $N_{70}P_{70}$+ 40 t/ha manure applied once in two years or $N_{70}P_{70}$ + 6 t/ha straw; on highly eroded lands, keeping a good plant supply in mineral elements was done at rates of $N_{140}$ $P_{100}K_{70}$ or $N_{70}P_{70}$ + 40 t/ha manure.

Among all the processes of soil degradation in the Moldavian Plateau, erosion is the most damaging, causing the loss of mean annual soil amounts of 1.640 t/ha in wheat, 4.618 t/ha in beans, 1.89 t/ha in perennial grasses on the first growing year, 9.176 t/ha in maize and 9.6 t/ha in sunflower.

Erosion affects soil fertility by removing, together with eroded soil, significant humus and mineral element amounts, which reach 17.4-17.7 kg/ha of nitrogen, 1-2 kg/ha of phosphorus and 2-3 kg/ha of potassium in maize and sunflower crops, representing on the average between 10-15 % of the chemical fertilizers necessary for these crops.

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