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# LONG-TERM EFFECTS OF CROPPING SYSTEM AND MINERAL FERTILIZATION ON PRODUCTION AND SOIL FERTILITY IN THE MOLDAVIAN PLAIN

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**ABSTRACT** – The investigations conducted during 2005-2010 at the Podu-Iloaiei Agricultural Research Station, Iaşi county, have studied the influence of different mineral fertilizers rates on wheat and sunflower yield and soil agrochemical characteristics. In bean-wheat-maize-sunflower-wheat crop rotation, applying mineral fertilizers resulted in getting mean yield increases, which varied according to rates, between 94 and 180% (1631- 3129 kg/ha) in wheat and between 38 and 101% (773-2063 kg/ha) in sunflower. The mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 11.2 and 13.6 kg grains ($N_{80}P_{40}$ - $N_{160}P_{80}$) in wheat and between 9.2 and 9.7 kg grains ($N_{40}P_{40}$ - $N_{120}P_{80}$) in sunflower. In the soils from the Moldavian Plateau, which are poor in organic matter and nutrients, the proper use of different rotations and fertilizer doses may replace a part of high technological consumption, determined the improvement in the content of organic matter from soil and ensured better conditions for the capitalization of nitrogen fertilizers. On the Cambic Chernozem from the Moldavian Plateau, a good supply with mobile phosphorus in wheat and sunflower crops (37-72 mg/kg) was done in case of the annual application of a rate of $N_{120}P_{80}$, while a very good supply (72-91 mg/kg) was achieved at the rate of $N_{140}P_{100}$. After 44 years of experiences, in five year crop rotation, fertilization of sunflower, wheat and maize crops with high rates of mineral fertilizers ($N_{160}P_{80}$), resulted increased soil organic carbon content by 22, 7% (3.5 g C / kg soil), compared to the unfertilized control.

**Key words:** Fertilization; Soil fertility; Nitrogen; Phosphorus; Wheat; Sunflower.

**REZUMAT – Efectele de lungă durată ale sistemului de cultură şi ale fertilizării minerale asupra producţiei şi a fertilităţii solului în Câmpia Moldovei.** Cercetările efectuate, în perioada 2005-2010, la Staţiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, jud. Iaşi, au urmărit influenţa diferitelor doze de îngrăşăminte minerale

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asupra producţiei de grâu şi floarea-soarelui şi a însuşirilor fizice şi chimice ale solului. În rotaţia fasole-grâu-porumb-floarea-soarelui-grâu, aplicarea îngrăşămintelor minerale a determinat obţinerea unor sporuri medii de producţie, care au variat în funcţie de dozele aplicate, între 94 si 180% (1631-3129 kg/ha) la grâu şi intre 38 şi 101% la (773-2063 kg/ha) floarea-soarelui. Sporurile medii de producţie, obţinute pentru fiecare kg s.a. de îngrăşământ aplicat, au fost cuprinse între 11,2 şi 13,6 kg boabe la grâu ($N_{80}P_{40}$ - $N_{160}P_{80}$) şi între 9,2 şi 9,7 kg la floarea-soarelui. Pe solurile din Podişul Moldovei, care sunt sărace în substanţă organică şi elemente nutritive, folosirea adecvată a diferitelor rotaţii si doze de îngrăşăminte poate înlocui o parte din consumul tehnologic ridicat, poate determina îmbunătăţirea conţinutului de substanţă organică din sol şi asigura condiţii mai bune de valorificare a îngrăşămintelor cu azot. Pe solul de tip cernoziom cambic din Podişul Moldovei, o asigurare bună cu fosfor mobil la culturile de grâu şi floarea-soarelui (37-72 mg/kg) a fost realizată prin aplicarea anuală a unei doze de $N_{120}P_{80}$, iar o asigurare foarte bună (72-91 mg/kg) a fost realizată la doza de $N_{140}P_{100}$. După 44 de ani de experimentare, în rotaţia de cinci ani, fertilizarea culturilor de floarea-soarelui, grâu şi porumb cu doze mari de ingraşăminte minerale ($N_{160}P_{80}$) a determinat, comparativ cu martorul nefertilizat, creşterea conţinutului de carbon organic din sol cu 22,7% (3.5 g C/kg sol).

**Cuvinte cheie:** fertilizare; fertilitatea solului; azot; fosfor; grâu; floarea-soarelui.

## INTRODUCTION

In the last period, the investigations conducted in different countries have followed the influence of improving technological elements on fertilization, soil tillage and crop rotations with legumes and perennial grasses, which determine the increase in the content of organic carbon from soil and the reduction of $N_2O$ emissions (Izaurralde *et al*., 2007; Wright *et al*., 2007; Farahbakhshazada *et al.,* 2008). The database importance of the experimental fields is widely known, having a duration of over 167 years and is functional even today (Rothamsted, 1843, England, Gottingen, 1873, Halle, 1878, Germany, Askov, 1894, Denmark, Morrow Plots in Illinois, 1876, USA etc), where the technological effects on environment, production quantity and quality, evolution of physical, chemical and biological soil condition are well controlled. The investigations conducted in long-term experiments at Rothamsted have shown that only at high fertilizer rates a significant increase was found in the mass of total organic carbon and stable carbon from soil (Blair *et al*., 2006). The diminution in the mass of organic carbon from soil, when lower rates than 180 kg N/ha were applied, was also noticed in long-term experiments carried out on sandy loam Mollisols from Nashua and on clayey-loam Mollisols from Kanawha at North of Iowa, USA (Russell *et al*., 2006).

In the pedoclimatic conditions in Cluj-Napoca, Chisel plow+ Rotary harrow determined, compared with the classic plowing, the increase in the content of humus in soil from 3.51% (100%) to 3.87% (110.2%) in Cambic Chernozem and from 2.48% (100%) to 3.02% (122.1%) to Haplic luvisols (Moraru and Rusu, 2010).

The North-Eastern region has 15.45% (2,131,421 ha) of the farming area of Romania (14,836, 585 ha) and includes very great areas with soils affected by erosion (over 60%), acidification, compaction, landslides and other degradation forms (Project of North-East Regional Development 2007-2013; Statistical Yearbook of Romania, 2003).

## 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 sunflower 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 (424 g clay, 316 g loam and 260 g sand), a neuter to weakly acid response and a mean nutrient supply. 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. Experiments were conducted in randomized blocks with split plots in six replicates. They followed the influence of long-term application of different fertilizer rates on wheat crop grown after bean and sunflower, in five year crop rotation (bean-wheat-maize sunflower-wheat). In wheat, we have used Gabriela Variety, and in sunflower, Performer Hybrid. The mean annual rainfall amounts, registered in the last six years, were higher, with values comprised between 33,8 and 178,1 mm, compared to the multiannual mean on 82 years (548,3 mm). The climatic conditions during 2005-2010 were favourable to plant growing and development in two years, and unfavourable in the other four years (2005, 2006, 2009, and 2010), because of reduced rainfall. 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.

## RESULTS AND DISCUSSION

Investigations conducted during 2005-2010 at the Podu-Iloaiei Agricultural Research Station have studied the influence of different mineral fertilizer rates on yield quality and quantity and soil agrochemical characteristics.

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. The climatic

conditions during 2005-2010 were favourable to plant growing and development in two years, and unfavourable in the other four years (2005, 2006, 2009, and 2010), because of reduced rainfall.The climatic conditions recorded during 2005-2010 resulted in a good uptake and use of mineral fertilizers and manure by the main crops. Average rainfall amounts, recorded during 2005-2010, from January to August, were higher with 106.3 mm, compared to the multiannual average on 82 years (391 mm) (*Table 1*).

**Table 1 - Rainfall recorded at the Weather Station of Podu-Iloaiei, during 2005-2010**

| Years | I | II | III | IV | V | VI | VII | VIII | Total |
|---|---|---|---|---|---|---|---|---|---|
| **2005** | 42.4 | 42.1 | 25.6 | 86.2 | 106.0 | 86.3 | 64.7 | 160.0 | 613.3 |
| **2006** | 29.3 | 7.8 | 97.3 | 98.0 | 57.0 | 93.7 | 163.0 | 121.5 | 667.6 |
| **2007** | 20.3 | 30.2 | 30.2 | 27.0 | 30.7 | 15.6 | 63.6 | 63.6 | 281.2 |
| **2008** | 10.9 | 2.6 | 25.2 | 127.3 | 43.2 | 65.2 | 145.1 | 48.0 | 467.5 |
| **2009** | 80.0 | 56.5 | 37.5 | 5.9 | 44.0 | 138.0 | 122.0 | 12.1 | 496.0 |
| **2010** | 61.0 | 17.2 | 20.2 | 24.3 | 82.0 | 173.0 | 73.0 | 7.3 | 458.0 |
| **Average** | **40.7** | **26.1** | **39.3** | **61.5** | **60.5** | **95.3** | **105.2** | **68.8** | **497.3** |
| **Average on 82 years** | **28.5** | **24.1** | **25.6** | **43.2** | **53.6** | **78.8** | **75.3** | **61.9** | **391.0** |
| **Difference** | **12.2** | **2.0** | **13.7** | **18.3** | **6.9** | **16.5** | **29.9** | **6.9** | **106.3** |

During 2005 – 2010, the climatic conditions were favorable to plant growing and development in 3 years in wheat and 4 years in sunflower. Since 1968, the investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei, have followed the influence of different crop structures, rotations and fertilizers on crop yield and soil fertility.

In wheat crop grown in five year crop rotation after sunflower, the mean obtained yields, during 2005-2010, were comprised between 1736 kg/ha (100%) at the unfertilized control and 4591 kg/ha (264%) at rates of 160 kg N +80 kg $P_2O_5$ +40 kg $K_2O$ (*Table 2*). The application of higher potassium rates than 40 kg/ha did not result in obtaining significant yield increases.

The unilateral fertilization of wheat crop grown after sunflower crop, only with potassium rates, resulted in limitation of yield increases of 305 kg/ha. The mean yield increases obtained in wheat for each kg of applied nitrogen, phosphorus and potassium, calculated with regression equation, were of 15.26, 3.92 and 3.0 kg. In wheat crop grown in 5-year rotation after sunflower, the mean yield increases obtained for each kg of a. i. of applied fertilizer were between 13.6 and 11.2 kg grains ($N_{80}P_{40}$ - $N_{160}P_{80}$).

**Table 2 - Mean yields obtained in wheat crop grown in five year crop rotation (bean-wheat-maize sunflower-wheat), after sunflower, during 2005 – 2010**

| No. | Fertilizer rate, kg/ha a.i. | | | Wheat yield | | Difference kg/ha | Significance |
|---|---|---|---|---|---|---|---|
| | Nitrogen | $P_2O_5$ | $K_2O$ | kg/ha | % | | |
| 1 | 0 | 0 | 0 | **1736** | 100 | | |
| 2 | 0 | 0 | 40 | **1862** | 107 | 126 | |
| 3 | 0 | 0 | 80 | **1944** | 112 | 208 | |
| 4 | 0 | 0 | 120 | **2041** | 118 | 305 | x |
| 5 | 80 | 40 | 0 | **3367** | 194 | 1631 | xxx |
| 6 | 80 | 40 | 40 | **3517** | 203 | 1781 | xxx |
| 7 | 80 | 40 | 80 | **3611** | 208 | 1875 | xxx |
| 8 | 80 | 40 | 120 | **3713** | 214 | 1977 | xxx |
| 9 | 120 | 80 | 0 | **3950** | 228 | 2214 | xxx |
| 10 | 120 | 80 | 40 | **4078** | 235 | 2342 | xxx |
| 11 | 120 | 80 | 80 | **4183** | 241 | 2447 | xxx |
| 12 | 120 | 80 | 120 | **4322** | 249 | 2586 | xxx |
| 13 | 160 | 80 | 0 | **4425** | 255 | 2689 | xxx |
| 14 | 160 | 80 | 40 | **4591** | 264 | 2855 | xxx |
| 15 | 160 | 80 | 80 | **4722** | 272 | 2986 | xxx |
| 16 | 160 | 80 | 120 | **4865** | 280 | 3129 | xxx |
| **Mean** | | | | **3558** | | | |
| LSD 5% = 223 kg/ha; LSD 1% = 304 kg/ha; LSD 0.1% = 403 kg/ha; | | | | | | | |
| $Y = 1808.63 + 15.26N + 3.92P + 3.00K$; $R^2 = 0.988$ | | | | | | | |

The mean yield increases obtained during 2005-2010 in wheat crop grown in five year crop rotation after bean, by the application of mineral fertilizers, were comprised between 69 and 121 % (1587-2765 kg/ha), according to applied rates ($N_{60}P_{40}$ - $N_{140}P_{80}$) (*Table 3*). In wheat crop grown in five year crop rotation after bean, the mean yield increases obtained for each kg a. i. of applied fertilizer were between 15.9 and 12.6 kg grains ($N_{60}P_{40}$ - $N_{140}P_{80}$). The mean yield increases, calculated by means of action coefficients for nitrogen, phosphorus and potassium in the regression equation, in wheat crop grown after bean (5051 kg/ha), compared to wheat crop grown after sunflower (4259 kg/ha), at the rate of $N_{140}P_{80}$, were of 792 kg/ha (18.6%). In soils from the Moldavian Plateau, most of them situated on slope fields, poor in organic matter and nutrients, the proper use of different crop rotation and organic resources may replace a part of rich technological consumption, determine the improvement in the content of organic matter from soil and ensure better conditions for the capitalization of nitrogen fertilizers.

The field experiments with fertilizers have the great advantage that they allow the study of the production potential and agrochemical indices in all the factors that condition crop yield formation and soil fertility.

**Table 3 - Mean yields obtained in wheat crop grown in 5-year rotation, after bean, during 2005 - 2010**

| No. | Fertilizer rate, kg/ha a.i. | | | Wheat yield | | Difference kg/ha | Significance |
|---|---|---|---|---|---|---|---|
| | Nitrogen | $P_2O_5$ | $K_2O$ | kg/ha | % | | |
| 1 | 0 | 0 | 0 | **2286** | 100 | | |
| 2 | 0 | 0 | 40 | **2499** | 109 | 213 | |
| 3 | 0 | 0 | 80 | **2597** | 114 | 311 | x |
| 4 | 0 | 0 | 120 | **3020** | 132 | 734 | xxx |
| 5 | 60 | 40 | 0 | **3873** | 169 | 1587 | xxx |
| 6 | 60 | 40 | 40 | **4085** | 179 | 1799 | xxx |
| 7 | 60 | 40 | 80 | **4184** | 183 | 1898 | xxx |
| 8 | 60 | 40 | 120 | **4308** | 188 | 2022 | xxx |
| 9 | 100 | 80 | 0 | **4530** | 198 | 2244 | xxx |
| 10 | 100 | 80 | 40 | **4652** | 204 | 2366 | xxx |
| 11 | 100 | 80 | 80 | **4781** | 209 | 2495 | xxx |
| 12 | 100 | 80 | 120 | **4972** | 218 | 2686 | xxx |
| 13 | 140 | 80 | 0 | **5051** | 221 | 2765 | xxx |
| 14 | 140 | 80 | 40 | **5261** | 230 | 2975 | xxx |
| 15 | 140 | 80 | 80 | **5382** | 235 | 3096 | xxx |
| 16 | 140 | 80 | 120 | **5466** | 239 | 3180 | xxx |
| **Mean** | | | | **4184** | | | |
| LSD 5% = 245 kg/ha; LSD 1% = 329 kg/ha; LSD 0.1% = 431 kg/ha; | | | | | | | |
| $Y = 2467.199 + 13.906N + 8.586 P + 4.078K$; $R^2 = 0.980$ | | | | | | | |

**Table 4 - Mean yields obtained in sunflower crop grown in five year crop rotation (bean-wheat-maize-sunflower-wheat)**

| No. | Fertilizer rate, kg/ha a.i. | | | Sunflower yield | | Difference kg/ha | Significance |
|---|---|---|---|---|---|---|---|
| | Nitrogen | $P_2O_5$ | $K_2O$ | kg/ha | % | | |
| 1 | 0 | 0 | 0 | 2038 | | | |
| 2 | 0 | 0 | 40 | 2203 | 108 | 165 | |
| 3 | 0 | 0 | 80 | 2307 | 113 | 269 | x |
| 4 | 0 | 0 | 120 | 2403 | 118 | 365 | xx |
| 5 | 40 | 40 | 0 | 2811 | 138 | 773 | xxx |
| 6 | 40 | 40 | 40 | 3026 | 148 | 988 | xxx |
| 7 | 40 | 40 | 80 | 3147 | 154 | 1109 | xxx |
| 8 | 40 | 40 | 120 | 3251 | 160 | 1213 | xxx |
| 9 | 80 | 80 | 0 | 3417 | 168 | 1379 | xxx |
| 10 | 80 | 80 | 40 | 3503 | 172 | 1465 | xxx |
| 11 | 80 | 80 | 80 | 3614 | 177 | 1576 | xxx |
| 12 | 80 | 80 | 120 | 3708 | 182 | 1670 | xxx |
| 13 | 120 | 80 | 0 | 3875 | 190 | 1837 | xxx |
| 14 | 120 | 80 | 40 | 4030 | 198 | 1992 | xxx |
| 15 | 120 | 80 | 80 | 4101 | 201 | 2063 | xxx |
| 16 | 120 | 80 | 120 | 4170 | 205 | 2132 | xxx |
| **Mean** | | | | **3225** | | | |
| LSD 5% = 232 kg/ha; LSD 1% = 305 kg/ha; LSD 0.1% = 482 kg/ha; | | | | | | | |
| $Y = 2119.21 + 10.757N + 5.78 P + 2.86K$; $R^2 = 0.989$ | | | | | | | |

The mean sunflower yields obtained in five year crop rotation, were comprised between 2038 kg/ha (100%) at the unfertilized control and 3875 kg/ha (190%) at a rate of 120 kg N + 80 kg $P_2O_5$ /ha (*Table 4*). The application of higher than 40 kg/ha potassium rates did not result in obtaining significant yield increases.

The mean yield increases obtained in sunflower crop grown in five year crop rotation after maize, by the application of mineral fertilizers, were comprised between 38 and 90 % (773-1837 kg/ha), according to applied rates ($N_{40}P_{40}$ - $N_{120}P_{80}$) (*Table 4*). The mean yield increases obtained in sunflower for each kg of applied nitrogen, phosphorus and potassium, calculated with regression equation, were of 10.76, 5.78 and 2.86 kg. In sunflower crop grown in five year crop rotation, after maize, the mean yield increases obtained for each kg a. i. of applied fertilizer were between 9.2 and 9.7 kg grains ($N_{40}P_{40}$ - $N_{120}P_{80}$).

Establishing fertilizer rates, under conditions of present costs, required the determination of agrochemical indices and the analysis of nutrient balance in the system soil-plant - air and establishing the necessary of nutrients with which one must interfere at a certain level of supply on consumption requirements of different crops and crop levels. The research concerning the influence of crop rotation and fertilizers on soil chemical characteristics pointed out the significant changes after 44 years of testing, the obtained data giving special information for following the survey of nutrients and diagnosing the evolution tendencies of soil fertility. The analyses concerning the evolution of soil response under the influence of crop rotation and fertilizers pointed out that pH lowest values were recorded in bean-wheat-maize-sunflower-wheat rotation and in case of a long-term use of rates of $N_{160}P_{80}$. After 44 year application of rates of 160 kg/ha nitrogen, as ammonium azotize, we determined the pH decrease from 7.0 to 5.3 (*Fig. 1*).

The annual application of rates of 80 kg/ha $P_2O_5$ has determined the accumulation of a reserve of mobile phosphates in soil, comprised, according to applied nitrogen, between 45 and 91 mg/kg. The mobile phosphorus content of soil, after 44 years of testing, was maintained at a good supply level, when the applied rates were of at least $N_{120}P_{80}$ (*Fig. 2*).

The analyses on the content of mobile potassium from soil have shown that in bean-wheat-maize sunflower-wheat rotations, the supply condition was good (133-200 mg/kg) in case of mineral fertilization and very good (over 200 mg/kg) in case of fertilization with $N_{120}P_{80}$ (*Fig. 3*). The supply with mobile potassium in this rotation was lower, because of the high potassium consumption by these crops and of the unfavorable conditions of soil structure, which influence the supply with mobile potassium from soil reserve.

Many investigations conducted in different countries have shown that applying low rates of mineral

fertilizers with nitrogen, phosphorus and potassium in wheat and maize continuous cropping and wheat-maize rotation has determined the diminution in the content of organic matter from soil (Hera *et al*., 1984; Mihăilă *et al*., 1996; Jităreanu *et al*., 2008; Ailincai *et al*., 2011). The diminution in the content of organic carbon from soil, due to mineral fertilization, was found in loam - sandy fields from Nashua, USA, where lower than 180 kg nitrogen/ha were applied in maize-soybean rotation (Russell, (2006) and in clay loam soils from Rothamsted, England, where lower rates than $N_{192}P_{35}K_{90}Mg_{35}$ were applied (Blair *et al*., 2006).

In the soils of the Moldavian Plain, the carbon organic content from soil, in five year crop rotation, under unfertilized, was of 15.4 g/kg and was kept at values close to the initial ones, in the balanced fertilization with high rates of phosphorus and nitrogen (160 kg N + 80 kg $P_2O_5$/ha) *(Fig. 4)*. During the long-term fertilization of sunflower, wheat and maize crops with high rates of mineral fertilizers ($N_{160}P_{80}$), the total content of carbon has increased by 22.7% (3.5 g organic C/kg soil), compared to the unfertilized control. In bean-wheat-maize-sunflower-wheat rotation, the mineral fertilization with 120 kg/ha nitrogen +80 kg/ha $P_2O_5$ has determined, after 44 years of testing, the diminution in the content of organic carbon from soil by 2.8 g/kg (14.1%). The content of organic carbon from soil, in five year crop rotation, has diminished by approximate 2.17 g/kg/year in unfertilized control, by 1.17 g/kg/year at the rate of $N_{80}P_{80}$ and by 0.17 g/kg/year at the rate of $N_{160}P_{80}$.

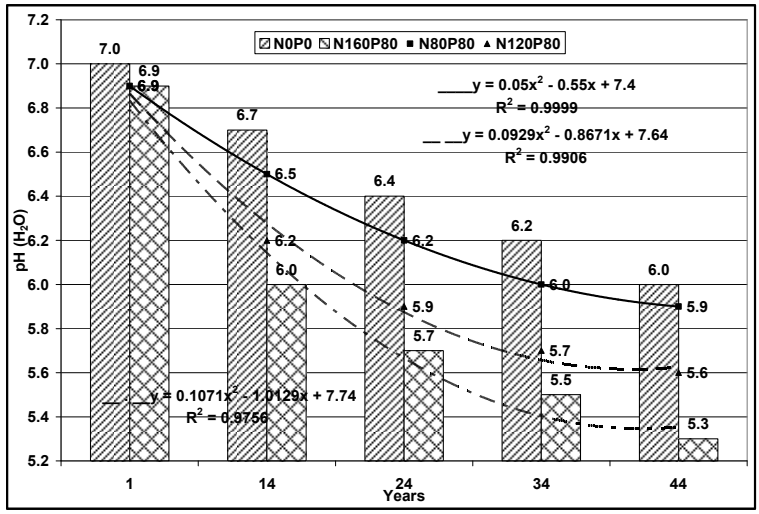


**Figure 1 - Change of soil reaction, in 5-year crop rotation, at different fertilizer rates**

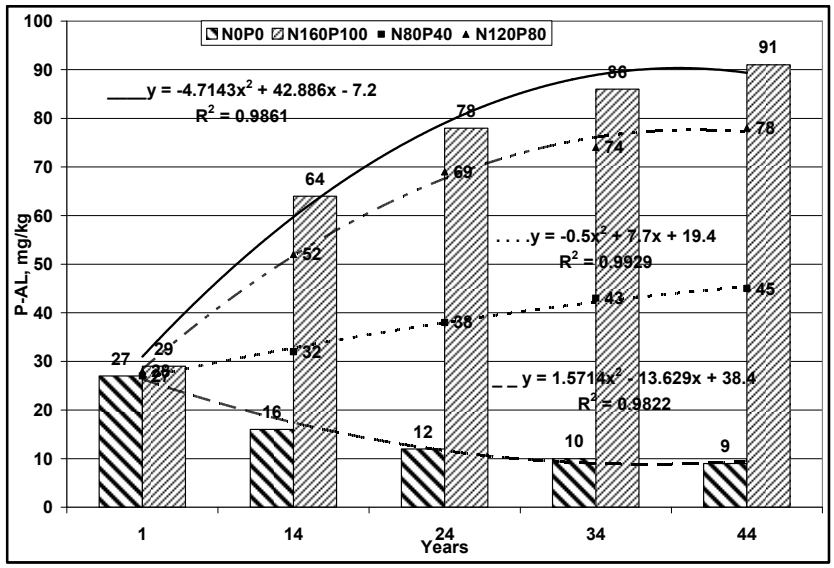


**Figure 2 - Change of mobile phosphate content (P-AL) from soil, as influenced by different fertilizer rates**

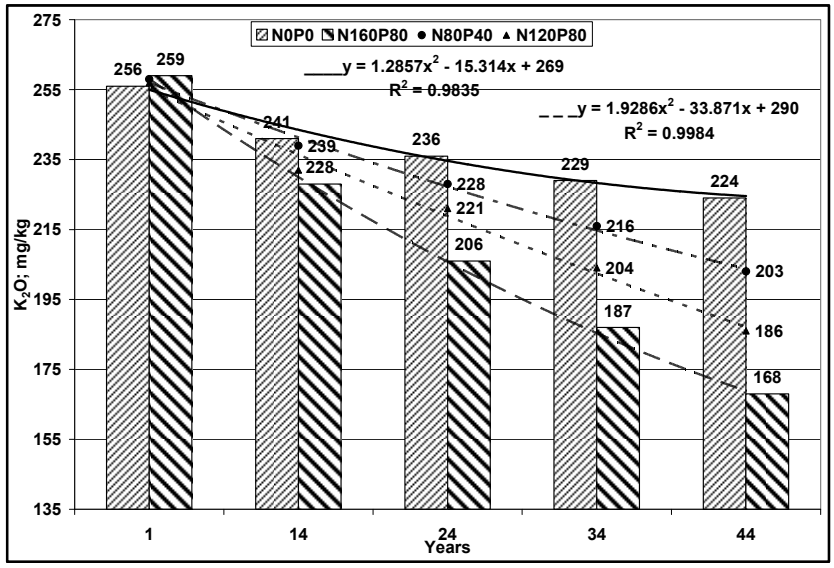


**Figure 3 - Change of mobile potassium content (K-AL) from soil, as influenced by different fertilizer rates**

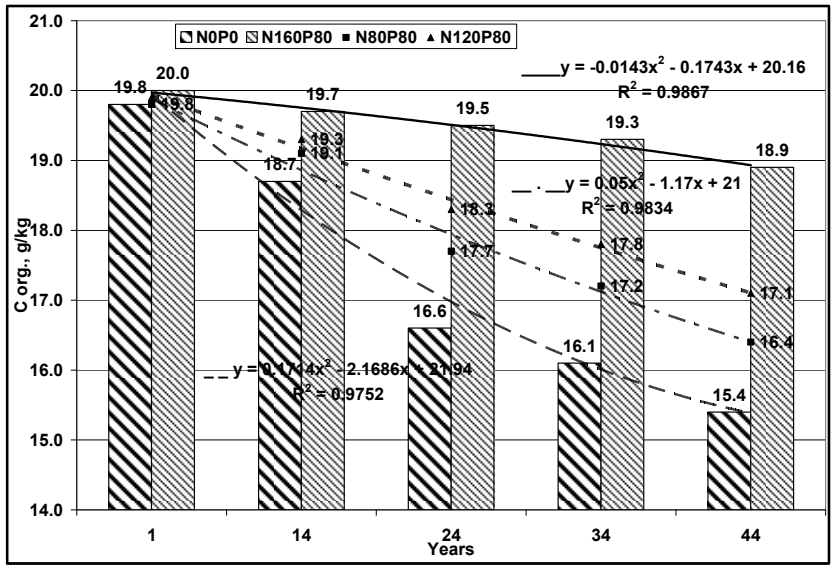


**Figure 4 - Influence of long-term fertilization on total organic carbon from soil (C, g/kg)**

## CONCLUSIONS

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.

Mean yield increases, obtained during 2005-2010, by applying the rate of 120 kg N + 80 kg $P_2O_5$/ha, were of 2214 (128%) in winter wheat crop, grown in five year crop rotation, after sunflower and of 1837 kg/ha (90%) in sunflower.

The mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 9.2 and 9.7 kg in sunflower ($N_{40}P4_0$-$N_{120}P_{80}$) and between 12.6 and 15.9 kg in wheat ($N_{60}P_{40}$-$N_{140}P_{80}$).

In bean-wheat-maize-sunflower-wheat crop rotation, applying mineral fertilizers during 2005 -2010 resulted in getting mean yield increases, which varied according to rates, between 94 and 180% (1631- 3129 kg/ha) in wheat and between 38 and 101% (773-2063 kg/ha) in sunflower.

After 44 years of experiences, in bean-wheat-maize-sunflower-wheat crop rotation, the content of organic carbon from soil 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 $N_{120}P_{80}$.

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