Cercetări Agronomice în Moldova
Vol. XLV , No. 3 (151) / 2012

THE EVOLUTION OF SOIL FERTILITY UNDER LONG-TERM EXPERIMENTS IN THE MOLDAVIAN PLATEAU

Despina AILINCĂI [1], C. AILINCĂI[2*]

*E-mail: ailincai@uaiasi.ro

Received June 2, 2012

ABSTRACT. The paper presented the results of investigations concerning the influence of long-term fertilization (43 years) on some chemical characteristics of soil from the Moldavian Plateau, of wheat-maize rotation. The studies were performed on a typical cambic chernozem soil, prevailing in the Moldavian Plateau, and followed the dosing of fertilizers which ensures an efficient production increases and determines maintain or increase soil organic carbon content. Soil that has been placed experiences-clay loam, neutral to slightly acid reaction and a medium nutrient supply. On lands from the Moldavian Plateau, maintaining a good supply in mobile phosphorus for field crops (37-72 mg/kg) was done in case of the annual application of a rate of $N_{100}P_{100}$, and a very good supply in mobile phosphorus (69-78) and mobile potassium (over 200 mg/kg) was found at a rate of $N_{100}P_{100}$+60 t/ha manure. In wheat-maize rotation, applying a rate of $N_{100}P_{100}$, for 43 years, has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) and was maintained within the weakly acid interval (5.9-6.8) in case of the annual application of a rate of $N_{50}P_{50}$ + 60 t/ha manure. Soil organic carbon content, in wheat - maize rotation, decreased after 43 years of experiences from 19.8 to 16.3 g/kg in unfertilized variant and until 18.1 g/kg in case of the annual application of a rate of $N_{100}P_{100}$. In wheat - maize rotation, the significant increase in organic carbon content from soil has been registered at higher than $N_{50}P_{50}$ + 40 t/ha manure and at $N_{100}P_{100}$ + 60 t/ha manure. The determinations of mean annual amounts of nitrogen exported from soil by wheat (grains + straw) have shown that in wheat crop, its values varied according to fertilizers system, between 71.5 and 128.4 kg/ha. In maize crop, of the mean annual amounts of nitrogen exported from soil varied according to applied fertilizers, between 64.6 and 178.9 kg/ha.

Key words: Fertilization; Manure; Nitrogen; Phosphorus; Organic carbon; Wheat; Maize.

REZUMAT. Evoluția fertilității solului în experiențele de lungă durată din Podișul Moldovei. Lucrarea prezintă rezultatele cercetărilor privind influența fertilizării de

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

lungă durată (43 ani) asupra unor însuşiri chimice ale cernoziomului cambic din Podişul Moldovei, în rotaţia grâu-porumb. Studiile au fost efectuate pe un sol cernoziom cambic tipic, care predomină în Podişul Moldovei, şi au urmărit stabilirea dozelor de îngrăşăminte care asigură obţinerea unor sporuri eficiente de producţie şi care determină menţinerea sau creşterea conţinutului de carbon organic din sol. Solul pe care au fost amplasate experienţele are o textură luto-argiloasă, o reacţie neutră spre slab acidă şi o aprovizionare mijlocie în elemente nutritive. Pe terenurile în pantă din Câmpia Moldovei, menţinerea unei aprovizionari bune cu fosfor mobil pentru culturile de câmp (37-72 mg/kg) s-a realizat în cazul aplicării anuale a dozei de $N_{100}P_{100,}$ iar realizarea unei asigurari foarte bune cu fosfor mobil (69-78 mg/kg) şi potasiu mobil (peste 200 mg/kg) la doza de $N_{100}P_{100}$+60 t/ha gunoi. În rotaţia grâu-porumb, aplicarea unei doze de $N_{100}P_{100,}$ timp de 43 de ani, a determinat scăderea pH-ului până la limita intervalului acid moderat (5.1-5.8) şi s-a menţinut în intervalul slab acid (5.9-6.8), în cazul aplicarii anuale a dozei $N_{50}P_{50}$ + 60 t / ha gunoi de grajd. Conţinutul de carbon organic din sol, în rotaţia grâu - porumb, a scăzut, după 43 de ani de experienţă, de la 19.8 la 16.3 g / kg la varianta nefertilizată şi până la 18.1 g / kg în cazul aplicarii dozei de $N_{100}P_{100}$. În rotaţia grâu - porumb, creşterea semnificativă a conţinutului de carbon organic din sol a fost înregistrată la doze mai mari decât $N_{50}P_{50}$ + 40 t / ha gunoi de grajd şi la $N_{100}P_{100}$ + 60 t / ha gunoi de grajd. Determinările privind cantităţile medii anuale de azot exportate din sol la grâu (boabe + paie) arata că valorile au variat, în funcţie de sistemul de îngrăşăminte, între 71.5 şi 128.4 kg / ha. La cultura de porumb, cantităţile medii anuale de azot exportate din sol au variat, în funcţie de îngrăşămintele aplicate, între 64.6 şi 178.9 kg / ha.

Cuvinte cheie: fertilizare; gunoi de grajd; azot; fosfor; carbon organic; grâu; porumb.

INTRODUCTION

Knowing the long-term influences of different technological elements on the evolution of soil chemical characteristics allows us to establish the most proper methods for the efficient use of all technological inputs.

The results obtained in long-term experiments from different countries have shown that establishing methods for soil conservation were valuable only for soil and climatic conditions of the experiencing area. The results of investigations conducted under various soils and climatic conditions showed that the long-term practicing of wheat-maize rotation has resulted in high nutrient consumption from soil, while soil physico-chemical and biological characteristics worsened; therefore, improvement measures are required (Mihăilă and Hera, 1994; Alvares, 2005; Anderson *et al.,* 1997; McLauchlan, 2006; Rasmussen and Collins, 1991; Smith *et al.,* 2005, Ailincăi *et al.,* 2011).

Application of organic and inorganic fertilizers to crops in rotation results in increased plant biomass and hence greater return of organic material and increased soil organic carbon content. In addition to its nutritional value and enhancement of plant biomass, manure addition to crops in rotation is especially important in directly contributing to the organic matter of the soil by returning organic carbon. Different types of agricultural management practices lead to different outcomes

for soil organic carbon and nutrients, soil tillage tend to decrease concentrations of soil organic carbon and nutrients tends to increase these concentrations.

The positive effect of applying manure and crop residues, together with moderate nitrogen rates, on crop yield and soil physical, chemical and biological characteristics was found in many regions with different climatic and soils conditions (Blake *et al.,* 2003; Blair *et al.,* 2006; Franzluebbers, 2006; Russell *et al.,* 2006; Wright *et al.,* 2007; Morari *et al.,* 2008).

Results from the Rothamsted long-term experiment in Great Britain show that continuous application of manure almost tripled soil organic carbon content in 100 years. Soil organic carbon has decrease from 1.5% to 1.0% during the past century of cultivation at the site of the Woburn Experiment, where soils contain 10% clay; whereas soil organic carbon content has remained stable with similar management at Rothamsted, with 20–25% clay (Johnston, 1986). Manure addition to soils can therefore result in substantial carbon inputs and significant increases in organic carbon levels of soils. In the long-term experiment at Rothamsted, annual application of manure at a rate of 35 t/ha to continuous spring barley for over 140 years resulted in an increase in soil organic carbon levels of about three-fold over that in the unfertilized soil (Johnston, 1986). Other studies have shown that determining the rates of manure and crop residues, which had to be applied in order to improve soil characteristics and diminish erosion, must take into account the climatic conditions, soil type and cultural practices (Wright *et al*., 2007; Yadav and Malanson, 2008**).**

MATERIALS AND METHODS

The investigations conducted in stationary experiments, which were set up in 1968, 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. The experiments were conducted on a Cambic Chernozem, with loam-clayey texture, neuter reaction (pH 6.6-7.1) and 3.5% humus content. Applying organic fertilizers was done once in two years in maize, which has shown the direct effect of fertilization. The soil on which physical and chemical analyses were done was sampled at the end of plant growing. Soil pH was determined in water suspension by potentiometrical means with glass electrode. The content of organic carbon was determined by the Walkley-Black method, and multiplied by 1.724; the content in mobile phosphorus from soil was determined by the Egner-Riechm Domingo method, in solution of ammonium acetate-lactate (AL) and potassium was measured in the same extract of acetate-lactate (AL) at flame photometer. ANOVA was used to compare the treatment effects. In wheat, we have used the Gabriela variety and in maize, the Podu Iloaiei-110 hybrid.

RESULTS AND DISCUSSION

In the hilly areas of Moldavian Plateau cultivated intensively agricultural practices determine high loss of soil with consequent degradation of the soil resource. Predicting change in carbon content and soil nutrients under the influence of different culture systems in different climate and soil conditions is very difficult. Changes of organic carbon content and soil nutrients may be known by their analysis in long-term experiments where all the inputs and outputs of the soil system are well controlled. Investigations conducted in long-term (43 years) stationary experiments, under non-irrigated, followed the influence of different fertilizer rates on the evolution of soil agrochemical characteristics and yield obtained in main crops, placed in wheat-maize rotations. The soil thematic strategy of the European Commission (EC 2006) show that soil is a non-renewable resource which performs many functions and delivers services vital to human activities and ecosystems survival.

In the last period, the goal of many studies carried out in different countries was to improve the technological elements concerning soil fertilization, tillage and rotations with perennial grasses and legumes, which determine the increase in the content of organic carbon from soil and the diminution in the effect of greenhouse gases.

The organic fertilization has as goal to regenerate organic matters from soil and to improve soil physical, chemical and biological characteristics. From the analyses conducted at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, Romania, we found out that the mean supply with mineral substances per ton of applied manure was of 6.4 kg N, 2.6 kg P_2O_5, 8.9 kg K_2O, 0.6 kg Ca, 0.8 kg Mg and 320 kg organic matter. Therefore, the amounts of natural fertilizers, which must be applied, are determined according to the nitrogen consumption by crop, which capitalizes the direct effect of fertilization into the soil content in organic carbon, clay and nutrients and into the quality of used organic substances. The positive effect of applying manure and crop residues, together with moderate nitrogen rates, on crop yield and soil physical, chemical and biological characteristics was found in many regions with different climatic conditions and soils (Johnston and Poulton, 1992; Russell *et al.,* 2006; Morari *et al.,* 2008).

Increase in soil organic carbon levels due to long-term NPK applications have been observed in the Hoosfield continuous barley experiment, which was 15% higher than in the unfertilized treatment (Johnston, 1986). Similar increases in N, P and K contents were observed in long-term experiment at the Research Institute for Cereals and Industrial Crops Fundulea, Călăraşi County, Romania, where of annual application of 160 kg /ha N, total N was 13%

higher than in the unfertilized control (Mihăilă and Hera, 1994). The plots receiving 160 kg/ha P_2O_5 contained 126 mg/kg soluble P compared to 10 mg/kg P in unfertilized plots. Exchangeable K in the unfertilized plots decreasing from 234 to 218 mg/kg and it increased to 327 mg/kg in plots that had been receiving 120 kg K_2O annually. The long-term experiments at the Rothamsted have demonstrated that, up to 85% of the P and 40% of the K added as inorganic fertilizers over the last 100 years had been retained in the soil and were plant-available (Johnston and Poulton, 1992).

For protecting soils across the EU, the European Commission, by the Framework Directive for the protection of soil (COM 232, 2006), considers that the organic matter decline is one of the main threats affecting soil degradation. Utilization of manure in agriculture has a major interest, due to nitrogen, phosphorus and microelements supply (Zn, Cu). For slope lands degraded by erosion, manure and other organic resources can contribute to the improvement in soil characteristics.

The climatic conditions in the Moldavian Plain were characterized by a mean multiannual temperature of 9.6 ^oC and a mean rainfall amount, on 50 years, of 553.5 mm, of which 141.5 mm, during September-December, and 412.0 mm, during January-August. The climatic conditions during 1997-2011 were favorable to plant growing and development in 6 years, and unfavorable in the other 9 years, because of reduced rainfall. Average rainfall amounts, recorded during 1997-2011, from January to August, were higher with 6.8 mm, compared to the multiannual average on 50 years (412 mm) *(Table 1).* During 1997 - 2011, the climatic conditions were favorable to plant growing and development in 6 years in wheat and 7 years in maize. The climatic conditions recorded resulted in a good uptake and use of mineral fertilizers and manure by the main crops.

The mean content of nitrogen from grains of wheat has recorded values comprised between 1.79 and 2.28 %, according to the fertilization system (*Table 2*). In grains of maize, the content of nutrients has varied according to rates, between 1.22 and 1.65% at nitrogen, between 0.18 and 0.29% at phosphorus and between 0.43 and 0.54% at potassium (*Table 3*). From our studies, we found out that in wheat, placed in wheat-maize crop rotation, the mean annual amounts of nutrients extracted from soil (on the average of 1997-2011), together with the harvest, have varied according to rates, between 71.5 and 128.4 kg at nitrogen, between 13.1 and 26.4 kg at phosphorus and between 54.9 and 102.7 kg at potassium (*Table 4*). Of the total amounts of nutrients extracted from soil together with the harvest (grains + straw), 74-81% of nitrogen, 73-79% of phosphorus and 54-62% of potassium were found in grains and the difference, in by-products.

Table 1- Rainfall recorded at the Weather Station of Podu-Iloaiei, Iaşi County, during 1997 - 2011 (mm)

Years	Month												Total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
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	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	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	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**
2011	19.6	15.6	16.4	68.0	37.0	81.0	80.1	12.0	13.0	34.0	2.0	6.0	**384.7**
Average	**32.9**	**21.7**	**31.4**	**56.6**	**41.6**	**76.1**	**98.1**	**60.3**	**55.5**	**49.4**	**29.9**	**25.6**	**579.2**
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	**6.9**	**-0.5**	**2.6**	**7.2**	**-13.7**	**-9.1**	**10.7**	**2.6**	**4.5**	**16.5**	**-1.3**	**-0.7**	**25.8**

Table 2 - Content of nutrients from grains and straw (%) at different rates of mineral fertilizers and manure applied on the cambic chernozem at the Podu-Iloaiei Agricultural Research Station, Iaşi County

Fertilizer rate	Grains of wheat			Hashed of wheat		
	N	P	K	N	P	K
N_0P_0	1.79	0.34	1.10	0.39	0.08	0.61
40 t manure/ha	2.05	0.36	1.11	0.41	0.09	0.72
60 t manure/ha	2.08	0.38	1.14	0.45	0.10	0.83
$N_{50}P_{50}$	2.10	0.39	1.22	0.49	0.11	0.87
$N_{50}P_{50}$ + 40 t manure/ha	2.11	0.39	1.25	0.57	0.12	0.89
$N_{50}P_{50}$ + 60 t manure/ha	2.14	0.40	1.27	0.60	0.13	0.90
$N_{100}P_{100}$	2.22	0.42	1.28	0.62	0.12	0.90
$N_{100}P_{100}$ + 40 t manure/ha	2.25	0.43	1.34	0.67	0.13	0.92
$N_{100}P_{100}$ + 60 t manure/ha	2.28	0.46	1.40	0.69	0.15	0.92
Average	**2.11**	**0.40**	**1.23**	**0.54**	**0.11**	**0.84**
LSD 5%	**0.06**	**0.01**	**0.04**	**0.03**	**0.01**	**0.02**

Table 3 - Influence of mineral and organic fertilizers on the mineral element content in maize

Fertilizer rate	Grains of maize			Stalks of maize		
	N	P	K	N	P	K
N_0P_0	1.22	0.18	0.43	0.30	0.040	0.76
40 t manure/ha	1.24	0.22	0.43	0.35	0.050	0.81
60 t manure/ha	1.27	0.23	0.46	0.37	0.050	0.83
$N_{50}P_{50}$	1.37	0.26	0.48	0.45	0.060	0.87
$N_{50}P_{50}$ + 40 t manure/ha	1.42	0.28	0.50	0.47	0.063	0.95
$N_{50}P_{50}$ + 60 t manure/ha	1.45	0.29	0.51	0.51	0.066	0.97
$N_{100}P_{100}$	1.49	0.28	0.52	0.46	0.069	0.97
$N_{100}P_{100}$ + 40 t manure/ha	1.62	0.29	0.53	0.54	0.074	0.98
$N_{100}P_{100}$ + 60 t manure/ha	1.65	0.29	0.54	0.56	0.082	1.03
Average	**1.41**	**0.26**	**0.49**	**0.45**	**0.062**	**0.91**
LSD 5%	**0.05**	**0.01**	**0.02**	**0.03**	**0.04**	**0.04**

Table 4 - Mean annual amounts of nutrients exported from soil by wheat (grains + straw) and indices of their capitalization

Fertilizer rate	Grains+straw of wheat Kg/ha	Amounts of elements exported from soil, kg/ha			Capitalization indices		
		N	P	K	N	P	K
N_0P_0	3430	36.1	7.0	28.9	0.80	0.79	0.62
40 t manure/ha	6080	71.5	13.1	54.9	0.81	0.78	0.57
60 t manure/ha	6980	84.4	16.1	68.0	0.80	0.77	0.54
$N_{50}P_{50}$	5760	71.4	13.8	59.5	0.79	0.76	0.55
$N_{50}P_{50}$ + 40 t manure/ha	7650	98.4	18.8	80.9	0.76	0.74	0.55
$N_{50}P_{50}$ + 60 t manure/ha	8080	106.4	20.7	86.6	0.76	0.73	0.55
$N_{100}P_{100}$	7680	104.9	20.0	82.7	0.76	0.75	0.55
$N_{100}P_{100}$ + 40 t manure/ha	8350	117.4	22.5	93.2	0.75	0.74	0.56
$N_{100}P_{100}$ + 60 t manure/ha	8980	128.4	26.4	102.7	0.74	0.73	0.57

LSD 5%=220 kg/ha; LSD 1% =310 kg/ha; LSD 0.1%=430 kg/ha

In maize, the mean annual amounts of nutrients extracted from soil together with the harvest, have varied according to rates, between 44.6 and 178.9 kg at nitrogen, between 10.9 and 29.8 kg at phosphorus and between 55.2 and 143.9 kg at potassium. Among them, 68-77 % of nitrogen, 72-78% of phosphorus and 27-31% of potassium were used for the main production (*Table 5*). Both in wheat and maize, the organo-mineral fertilization has resulted in increasing the fertilizer capitalization indices, as compared to the application of only mineral or only organic fertilization, at which the use for the main production was lower, as compared to the one of total biomass. The combined use of moderate rates of mineral fertilizers ($N_{50}P_{50}$), together with 40 or 60 t/ha manure 40 t/ha from wheat and maize crops, has resulted in improving soil

physical and chemical characteristics and getting biomass increases in wheat of 123-136 % and in maize 103-116%, compared to the unfertilized control.

The applied fertilizer rates should complete the stock of mineral substances from soil until a good quality and economically efficient production is obtained, under conditions of improving water and soil quality.

Table 5 - Mean annual amounts of nutrients exported from soil by maize (grains +by-products) and indices of their capitalization

Fertilizer rate	Grains+stalks of maize Kg/ha	Amounts of elements exported from soil, kg/ha			Capitalization indices		
		N	P	K	N	P	K
N_0P_0	6210	44.6	6.3	38.1	0.77	0.78	0.31
40 t manure/ha	8628	64.6	10.9	55.2	0.74	0.78	0.30
60 t manure/ha	9390	72.2	12.2	62.5	0.73	0.79	0.31
$N_{50}P_{50}$	10266	87.0	15.0	72.0	0.70	0.77	0.30
$N_{50}P_{50}$ + 40 t manure/ha	12600	110.4	19.6	95.4	0.69	0.77	0.28
$N_{50}P_{50}$ + 60 t manure/ha	13390	122.1	21.7	103.6	0.68	0.77	0.28
$N_{100}P_{100}$	12743	114.3	20.2	99.3	0.70	0.75	0.28
$N_{100}P_{100}$ + 40 t manure/ha	16250	161.5	26.8	128.5	0.69	0.74	0.28
$N_{100}P_{100}$ + 60 t manure/ha	17560	178.9	29.8	143.9	0.68	0.72	0.27

LSD 5%=290 kg/ha; LSD 1% =400 kg/ha; LSD 0.1%=530 kg/ha

The analyses conducted on soil samples from the fields on which wheat-maize rotation was used for 43 years, resulted in worsening of soil chemical characteristics. Annual application of rates of 100 kg/ha P_2O_5 determined the accumulation of a reserve of mobile phosphates in soil, comprised, according to applied manure, between 72 and 89 mg/kg soil (*Figure 1*). The lowest value of phosphorus content was registered by the unfertilized control (8.0 mg/kg P_2O_5 at the depth of 0-20 cm and the highest value was registered at soil fertilizer with $N_{100}P_{100}$ + 60 t/ha manure (89.0 mg/kg).

The supply with mobile potassium in wheat-maize rotation was lower because of the high potassium consumption by these crops and of unfavorable conditions of soil structure, which influence the supply with mobile potassium from soil stock. In case of applying high rates of nitrogen and phosphorus fertilizers, a tendency of diminution in the content of mobile potassium from soil was found, which can be explained by the high potassium exportation from soil once with the harvest.

Applying for 43 years rates of $N_{50}P_{50}$ + 40 t/ha manure has increased from 224 to 276 mg/kg the content of mobile potassium from soil, compared to the untreated variant (*Figure 2*). The plant supply with mobile potassium from cambic chernozem,

which is well supplied with mobile potassium, is done from soil stock, organic residues and, especially, from manure. The analyses on the content in mobile potassium content from soil have shown that in all the tested, 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 $N_{100}P_{100}$+60 t/ha manure.

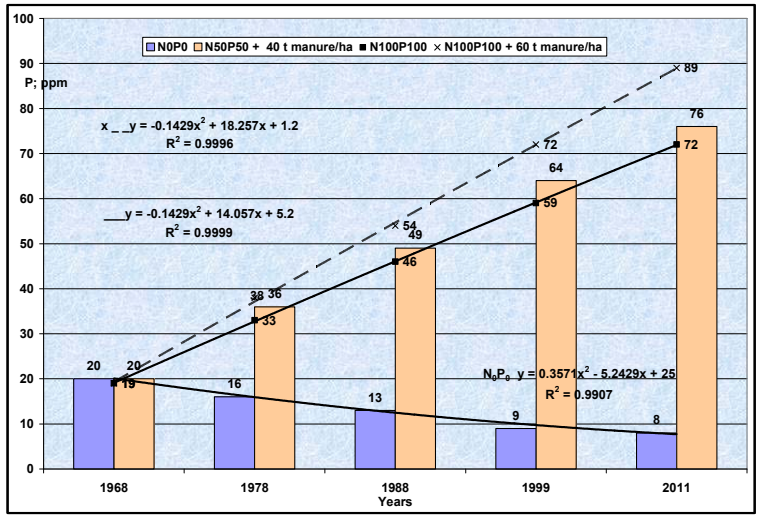

Figure 1 - Change of mobile phosphate content (P-AL) from soil as influenced by different fertilizer rates after 43 years of experiments

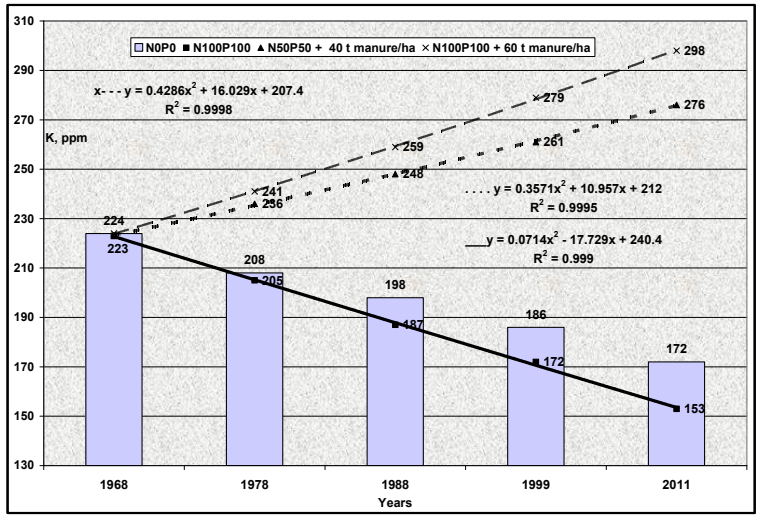

Figure 2 - Influences of fertilizers on potassium supply from soil, in wheat-maize rotation

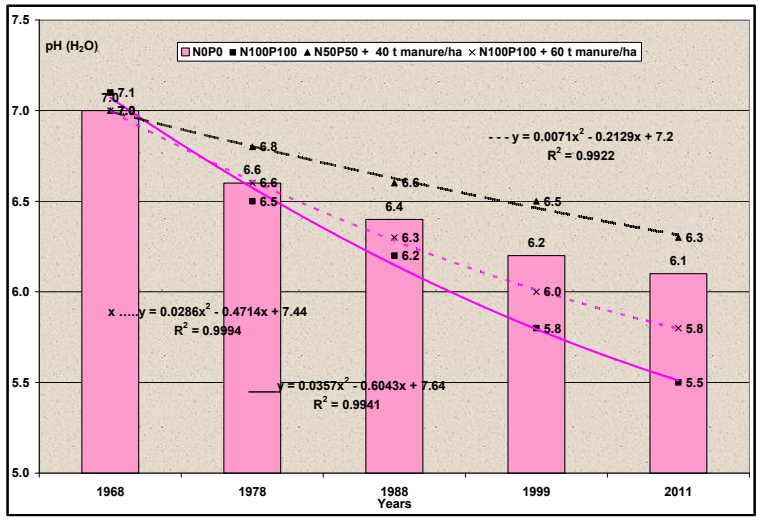

Figure 3 - Change of soil reaction, in wheat- maize rotation, at different fertilizer rates, after 43 years of experiments

The analyses carried out on the evolution of soil pH, after 43 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates (100 kg N/ha) (*Figure 3*). The lowest pH values were found in wheat-maize rotation, which can be explained by high nutrient uptake by these crop rotations.

Applying high nitrogen rates as ammonium nitrate (100) has determined pH diminution (0-20 cm) to 5.5 (soil moderate acid). In case of organic (40 t/ha manure) and mineral fertilization ($N_{50}P_{50}$), the pH diminution was less pronounced (6.1).

Analyzing the data concerning the humus balance from 2% humus content soil, Lixandru has found that the annual balance of humus content from soil was positive only in the case of the field cultivated with perennial grasses and of manure application, and for recovering annual humus losses by mineralization from unfertilized field, 12.7 t/ha manure should be applied every year (Lixandru, 2006). The diminution in the mass of organic carbon from soil, when lower rates than 180 kg N/ha were applied, was reported in long-term experiments carried out on sandy loam Mollisol from Nashua, USA (Russell *et al.,* 2006) and in long-term experiments at Rothamsted on loam sandy soil at rate lower than 192 kg/ha N and 35 kg/ha P_2O_5 (Blair *et al.,* 2006).

In soils from Moldavian Plateau applying moderate rates of mineral fertilizers ($N_{50}P_{50}$), together with 40 t/ha manure, has determined, after 43 years the increase in organic carbon content from soil by 2.8 and, respectively, 0.07 g/kg/year (*Figure 4*).

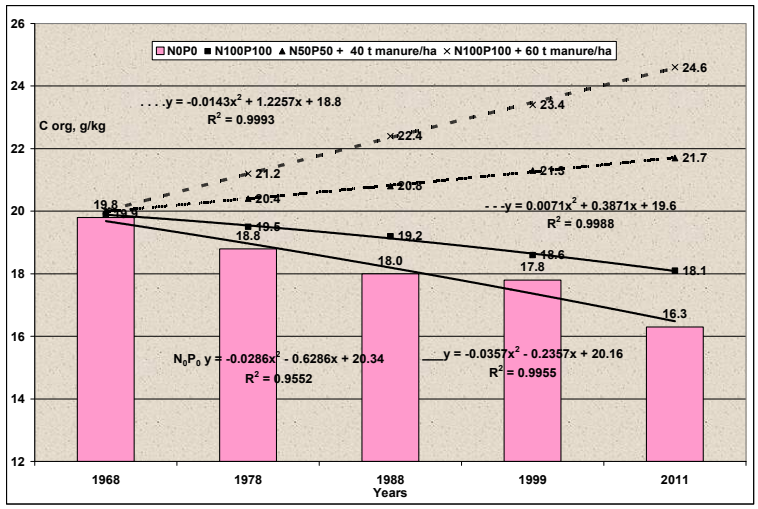

Figure 4 - Soil organic carbon content, in wheat-maize rotation, after 43 years of applying different fertilizer rates

CONCLUSIONS

In wheat-maize rotation, applying a rate of $N_{100}P_{100}$, for 43 years, has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) and was maintained within the weakly acid interval (5.9-6.8) in case of the annual application of a rate of $N_{50}P_{50}$ + 60 t/ha manure.

In the intensive rotations with high annual consumption of nutrients, maintaining a good soil supply with mineral elements is done only by organic fertilizers, applied together with mineral fertilization ($N_{100}P_{100}$ + 60 t manure/ha).

On the cambic chernozem from the Moldavian Plateau, a good supply with mobile phosphorus in wheat - maize rotation (72 mg/kg) was done in case of the annual application of a rate of $N_{100}P_{100}$, while a very good supply (89 mg/kg) was achieved at the rate of $N_{100}P_{100}$+60 t/ha manure.

The supply with mobile potassium, in wheat-maize rotation, was good (133-200 mg/kg) in case of mineral fertilization and very good (over 200 mg/kg) in case of fertilization with $N_{100}P_{100}$+60 t/ha manure.

Soil organic carbon content, in wheat - maize rotation, decreased after 43 years of experiences from 19.8 to 16.3 g/kg in unfertilized variant and until 18.1 g/kg in case of the annual application of a rate of $N_{100}P_{100}$.

In wheat - maize rotation, the significant increase in organic carbon content from soil has been registered at higher than $N_{50}P_{50}$ + 40 t/ha manure and at $N_{100}P_{100}$ + 60 t/ha manure.

REFERENCES

Ailincăi C., Jităreanu G., Bucur D., Mercuş Ad., 2011 - Protecting the soil from erosion by cropping systems and fertilization in

Moldavian Plateau. International Journal of Food, Agriculture & Environment – JFAE Vol. 9 (1): 570 - 574. January 2011, ISSN: 1459-0255.

Alvarez R., 2005 - A review of nitrogen fertilizer and conservation tillage effects on soil organic carbon storage. Soil Use Management, Vol. 21:38–52.

Anderson I.C., Buxton D.R., Karlen D.L., Cambardella C., 1997 - Cropping system effects on nitrogen removal, soil nitrogen, aggregate stability and subsequent maize grain yield. Agron J., 89:881-886.

Blair Nelly, Faulkner R.D., Till A.R., Poulton P.R., 2006 - Long-term management impacts on soil C, N and physical fertility. Soil & Tillage Research, 91 (2006) 30-38.

Blake L, Johnston A.E., Poulton P.R., Goulding K.W.T.,, 2003 - Changes in soil phosphorus fractions following positive and negative phosphorus balances for long periods. Plant Soil, 254:245–61.

Franzluebbers A.J., 2006 - Stratification of Soil Organic Matter and Potential Impact on Water Runoff Quality. International Soil Tillage Research Organization 17th Triennial Conference - Kiel, Germany 730-735.

Johnston A.E., 1986 - Soil organic matter, effects on soils and crops. Soil Use Management, 2:97–105.

Johnston A.E., Poulton P.R., 1992 - The role of phosphorus in crop production and soil fertility: 150 years of field experiments at Rothamsted, United Kingdom. In: J.J. Schultz (ed.), Phosphate fertilizers and the environment, pp. 45-64. Intl. Fertilizer Dev. Center, Muscle Shoals, USA.

Lixandru Gh., 2006 - Sisteme integrate de fertilizare în agricultură (Integrated fertilization systems in agriculture). Edit. Pim, Iaşi.

McLauchlan Kendra, 2006 - The Nature and Longevity of Agricultural Impacts on Soil Carbon and Nutrients: A Review, Ecosystems, 9: 1364–1382.

Mihăilă V., Hera Cr., 1994 - Long-term agricultural experiments in Eastern Europe. II. Some recent results from the long-term experiment at Fundulea, Romania. In: R.A. Leigh & A.E. Johnston (eds.), Long-term experiments in agricultural and ecological sciences, pp. 220-227. CAB Intl., Wallingford.

Morari F., Lugato E., Giardini L., 2008 - Olsen phosphorus, exchangeable cations and salinity in two long-term experiments of north-eastern Italy and assessment of soil quality evolution. Agriculture, Ecosystems & Environment, pp 85-96.

Rasmussen P.E., Collins H.P., 1991 - Long-term impacts of tillage, fertilizer and crop residue on soil organic matter in temperate semiarid regions. Adv. Agron., 45:93- 133.

Russell A.E., Laird D.A., Mallarino A.P., 2006 - Nitrogen Fertilization and Cropping System Impact on Quality in Midwestern Mollisols. Soil Sci. Soc. Am. J., 70:249-255.

Smith J., Smith P., Wattenbach M., Zaehle S., Hiederer R., Jones R.J.A., Montanarella L., Rounsevell M.D.A., Reginster I., Ewert F., 2005 - Projected changes in mineral soil carbon of European croplands and grasslands, 1990–2080. Global Change Biology, Vol. 11:2141–2152.

Wright A.L., Dou F., Hons F.M., 2007 - Soil organic C and N distribution for wheat cropping systems after 20 years of conservation tillage in central Texas. Agriculture, Ecosystems & Environment, Vol. 121, pp 376-382.

Yadav V., Malanson G., 2008 - Spatially explicit historical land use, land cover and soil organic carbon transformations in Southern Illinois. Agriculture, Ecosystems & Environment, Vol. 123, pp 280-292.