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LONG-TERM EFFECT OF FERTILIZER AND CROP RESIDUE ON SOIL FERTILITY IN THE MOLDAVIAN PLATEAU

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ABSTRACT. Since 1965, at the Agricultural Research Station of Podu-Iloaiei, Iaşi County, Romania (47°12´ N latitude, 27°16´ E longitude), investigations were conducted on the influence of different fertilizer systems on production and soil fertility. For wheat and maize crops, placed in a three-year rotation (pea - wheat - maize), three fertilization systems were experienced: (1) mineral fertilization with nitrogen and phosphorus rates until $N_{140}P_{100}$; (2) manure fertilization (20, 40, and 60 t/ha), with and without mineral fertilization and (3) mineral fertilizers + hashed residue applied in autumn under the base ploughing. The paper presented the results of investigations concerning the influence of long-term fertilization (46 years) on some chemical characteristics of Cambic Chernozem from the Moldavian Plateau. The climatic conditions in the Moldavian Plain were characterized by annual mean temperature of 9.6°C 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. After 46 years of experiences, in pea-wheat-maize crop rotation, the content of organic carbon from soil has decreased by 22.3% (4.2 g/kg soil) at the unfertilized control and by 14.4% (2.7 g/kg soil) at the rate of $N_{120}P_{80}$. In wheat and maize, nitrogen uptake by weeds was between 7 and 9.5 kg/ha from all the plots. Applying moderate rates of mineral fertilizers ($N_{80}P_{60}$), together with 6 t/ha wheat straw or 40 t/ha manure, has determined the increase in organic carbon content from soil by 0.5 and, respectively, 2.8 g/kg.

Key words: Slope land; N P K fertilizer; Crop residues; Organic carbon; Pea-wheat-maize rotation

REZUMAT. Efectul de lungă durată al îngrăşămintelor şi resturilor vegetale asupra fertilităţii solului în Podişul Moldovei. Începând cu anul 1965, la Staţiunea de Cercetări Agricole Podu-Iloaiei, judeţul Iaşi (47°12´ N latitude, 27°16´ E longitude), cercetarile efectuate au urmărit influenţa diferitelor sisteme de

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fertilizare asupra producției şi a fertilității solului. Pentru culturile de grâu şi de porumb, amplasate într-o rotație de trei ani (mazăre - grâu - porumb), au fost experimentate trei sisteme de fertilizare: (1) minerală cu azot şi fosfor, cu doze de până la $N_{140}P_{100}$; (2) fertilizarea cu gunoi de grajd (20, 40, şi 60 t / ha), cu şi fără fertilizare minerală şi (3) îngrăşăminte minerale + resturi vegetale, aplicate în toamnă, sub arătura de bază. Lucrarea prezintă rezultatele cercetărilor privind influența fertilizării de lungă durată asupra unor însuşiri chimice ale cernoziomului cambic din Podişul Moldovei. Condițiile climatice din Câmpia Moldovei se caracterizează prin temperaturii medii anuale de 9.6°C şi o cantitate medie de precipitații, pe 50 de ani, de 553,5 mm, din care 141,5 mm în perioada septembrie-decembrie şi 412 mm în perioada ianuarie-august. După 46 de ani de experimentare, în rotația culturilor mazăre-grâu-porumb, conținutul de carbon organic din sol a scăzut cu 22,3% (4,2 g/kg sol) la varianta martor nefertilizată şi cu 14,4% (2,7 g / kg sol) la doza de $N_{120}P_{80}$. La culturile de grâu şi porumb, cantitățile de azot consumate de buruieni au fost cuprinse între 7 şi 9,5 kg / ha la toate variantele. Aplicarea unor doze moderate de îngrăşăminte minerale ($N_{80}P_{60}$), împreună cu 6 t/ha paie de grâu sau cu 40 t/ha gunoi de grajd, a determinat creşterea conținutului de carbon organic din sol cu 0,5 şi, respectiv, 2,8 g / kg.

Cuvinte cheie: teren în pantă; fertilizare cu NPK; resturi vegetale; carbon organic; rotația mazăre-grâu-porumb.

INTRODUCTION

For controlling N_2O and nitrate emissions from farming, the experts propose the development of research by estimating the combined effect of fertilizers, derived from soil stock (P and K), and current fertilization, in order to increase the efficiency of using fertilizers and to study other nutrient sources. These sources are sewage sludge, manure, legumes, etc. (Norse, 2003). Nitrate losses from agricultural land were identified as a significant source of nitrate in drinking water supplies.

Soil nutrient losses were very high on slope lands, due to leaching, runoff, and element fixing. Establishing rates and time of fertilizer application must be done in a differentiate way, according to soil characteristics, cultural practices and climatic conditions. On slope lands, poor in humus and mineral elements, the use of residues had a special importance for improving soil fertility indicators. The EC set the maximum admissible concentration for nitrate in drinking water at 11.3 mg NO_3-N/l. FAO projects on the use of fertilizers show that in 2030, this increase will reach 37%, resulting in the augmentation of N_2O emissions by nitrogen fertilization.

In many areas, applying crop residues, together with moderate nitrogen rates, have resulted in improving physical, chemical and biological soil characteristics. 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. In many countries, the investigations conducted on eroded soils have followed the establishment of crop rotations and soil tillage and fertilizing systems, which contribute to maintaining and recovery of soil fertility.

Minimum quantity of plant residues needed to maintain soil organic carbon content determined by Johnson *et al.* (2005) systems with plow tillage and chisel plow or no tillage were 7.6 and of 5.3 t / ha in monoculture corn and 12.5 and 7.9 t/ha in soybean-corn rotation (Johnson *et al.,* 2005). The investigations conducted in Minnesota, USA, have shown that 927, 1853 and 3706 kg/ha/year of crop residues, applied in maize crops, have decreased soil erosion until 6.177, 1.730 and 0.988 t/ha respectively, and water runoff until 35.6, 25.4 and 22.9 mm, respectively (Lindstrom, 1986).

In all the countries, the investigations carried out in the last period have followed the establishment of some technological solutions that maintain the productivity of agro-ecosystem and the protection of environment factors (Aarts, 2000; Alvarez, 2004; Hera, 1981; Lixandru, 2006; Macdonald, 2005; Powlson *et al.,* 1992; Russell *et al.,* 2006; Wilhelm *et al.,* 2004). The Directive 2006/42/EC proposes the identification of zones with erosion-degraded soils and organic matter in decline, for meeting the requirements of the United Nations Convention to Combat Desertification (UNCCD) in Northern Mediterranean and Central and Eastern European Country Parties. In Romania, soil erosion is the most expensive degradation process, which affects almost 63% of the total area and 56% of the arable area from Romania. In Romania, total fertilizer consumption (N, P_2O_5, K_2O) has continuously decreased since 1986, from 1295 thousands t to 305 thousands t in 1999. Total fertilizer consumption has decreased in that period from 86 kg/ha to 21 kg/ha. This diminution is reflected by soil agrochemical parameters, by decreasing areas with very low contents of NPK. Data from the Ministry of Agriculture, Waters, and Forests show that at the end of 2000, 4.525 million ha of arable land had a low or extremely low humus stock, 1.867 million ha had a moderate and high acidity (pH under 5.6), 3.401 million ha, a low and very low supply in mobile phosphorus, 3.061 million ha were weakly supplied with nitrogen, 0.312 million ha were weakly and very weakly supplied with mobile potassium, and 1.5 million ha lacked microelements, especially zinc. The areas are also affected by other limitative factors of productive capacity, such as the deterioration of soil structure and compaction, caused by improper soil tillage (6.5 million ha), primary soil compaction (2.06 million ha) and tendency to crust formation (2.3 million ha).

MATERIALS AND METHODS

Investigations conducted on a cambic chernozem at the Agricultural Research and Development Station of Podu- Iloaiei, Iaşi County (47°12´ N latitude, 27°16´ E longitude) have studied the influence of different fertilizers systems on yield and soil fertility. For wheat and maize crops, placed in a three-year rotation (pea - wheat - maize), 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 residue applied in autumn under the base ploughing.

The typical cambic chernozem from Podu-Iloaiei was formed on a loess loam, has a mean humus content (3.1 - 3.4%), is well supplied with mobile potassium (215 - 235 ppm) and moderately with phosphorus (24-58 ppm) and nitrogen (0,160 - 0,185%) (*Fig. 1*). Experiments were situated on a 16% slope, according to the method of Latin rectangle, with split plots *(Fig. 2)*. They were carried out in two stages: 1965-1980 (Petrovici, 1971), when wheat-maize rotation was used. We have studied the influence of mineral fertilizers, manure and residues from these crops on yield and soil chemical characteristics. The second period was 1980 - 2011, when the great experiments from the first stage were split, in order to investigate the influence of rotation and other fertilizer categories and crop residues (pea and soybean stalks) on yield, soil erosion and fertility. 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. Trials were set up in a three year-crop rotation, pea-wheat-maize (*Fig. 2*).

Figure 1 - The typical cambic chernozem from Podu–Iloaiei, Iaşi county

Figure 2 - Experiences with different doses of fertilizers to pea-wheat-corn rotation on land with a slope of 16%

Soil samples were air dried, ground, and sieved with a 2 mm sieve prior to analysis. Available phosphorus and exchangeable potassium were determined after extraction with calcium lactate and ammonium acetate respectively. Soil samples from the tilled layer were taken in 2010, after 46 years, and analyzed for total nitrogen, by the Kjeldhal method and pH in water, soil: solution ratio 1:2.5. 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 (Nelson and Sommers, 1982). Weed dry weight and nitrogen content, phosphorus and potassium they were expressed from the oven dry at 80^{0}C. ANOVA was used to compare the effects of treatments.

RESULTS AND DISCUSSION

The results obtained in stationary experiments, which were set up in 1965, gave us the opportunity of carrying out analyses on the evolution tendencies of soil fertility, as influenced by climatic conditions and technological factors (soil tillage, fertilizers, pesticides, weed control, etc). The long-term use of residues determined a better soil conservation by increasing humus and mineral element stock from soil, resulting in a decrease with time, in the necessary of nitrogen and phosphorus fertilizers for crops.

The investigations have shown that crop rotation and fertilization resulted in the change of microbial associations from soil, which contributed to the mineralization of the organic matter and formation of organic carbon from soil.

The climatic conditions in the Moldavian Plain were characterized by annual mean temperature of 9.6^{o}C 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.

Changes in soil agrochemical indices, after 46 years of applying different amounts of nitrogen, phosphorus and potassium fertilizers are significant and there is a linear relationship between the agrochemical index and amount of nutrient applied.

The results on the evolution of organic carbon and mineral elements content from soil, after 46 years of using the rotation grain legumes-wheat-maize, have shown that a good supply in mineral elements was found only at the bottom of the slope. On 2/3 of slope length, erosion has caused the diminution in organic carbon content, from 17.3 to 10.1, according to soil erosion degree (*Table 1*). At the same time with the increase in erosion process, the content of mobile phosphorus and potassium from soil diminished from 49 to 12 mg/kg P and, respectively, from 287 to 145 mg/kg K. These data have shown that on 16% slope lands, the use of three-year rotation, with crop mineral fertilization was not enough to maintain soil fertility under favorable limits. In the critical erosion zone on valley side, once with the erosion of the horizon from soil surface, soil degradation processes intensified, even on chernozem, which were more resistant to erosion. Many investigations have shown that humus stock from soil diminished by 10%, when A horizon was half eroded, and by 30%, when the entire A horizon was eroded.

Crop residues are economical source of supply of soil with carbon and nutrients, protects soil against erosion and improves soil water capacity. Nutrient content of wheat and corn crop residues is greatly influenced by pre-plant (crop rotation) and fertilizer applied. Nutrient content of wheat straw used in experiments was between 0.460 and 0.665% for nitrogen, between 0.098 and 0130% for phosphorus and between 0.830 and 1.420% for potassium *(Table 2).*

Table 1 - Change of main soil chemical characteristics on a 16% slope, as influenced by soil erosion, fertilizer with $N_{70}P_{60}$ and pea-wheat-maize rotation

Depth (cm)	pH, (H_2O)	Org. C (g/kg)	N total (%)	P $_{-AL}$ mobile (mg/kg)	K $_{-AL}$ mobile (mg/kg)
0-30[a]	6.8	17.3	0.168	47	287
0-30[b]	6.2	12.6	0.139	25	186
0-30[c]	5.7	10.1	0.114	12	145
LSD 5%	0.21	0.09	0.03	3.6	13.6
LSD 1%	0.32	0.12	0.05	5.7	19.5
LSD 0.1%	0.49	0.15	0.09	7.8	29.4

[a]Weakly eroded soil situated at the lower third of slope

[b]Meanly eroded soil situated at the mean third of slope

[c]Highly eroded soil situated at the upper third of slope, in the critical erosion zone

Table 2 - The content of nitrogen, phosphorus and potassium in wheat and corn crop residues applied in experiments (%)

Crop residue	Fertilizer rate	N	P	K
Straw of wheat after pea	N0P0	0.460	0.098	0.830
	N80P60	0.495	0.099	0.920
	N120P100	0.635	0.110	0.950
	N140P100	0.685	0.120	0.950
Mean		**0.569**	**0.105**	**0.913**
Straw of wheat after maize	N0P0	0.387	0.085	1.290
	N80P60	0.441	0.094	1.310
	N120P100	0.471	0.099	1.320
	N140P100	0.665	0.130	1.420
Mean		**0.491**	**0.102**	**1.335**
Stalks of maize	N0P0	0.290	0.039	0.890
	N80P60	0.420	0.075	0.950
	N120P100	0.830	0.097	1.190
	N140P100	0.980	0.114	1.240
Mean		**0.630**	**0.081**	**1.068**

Generally, 168 days after incorporating the residues into the soil, the concentrations of mineral nitrogen present in the treated soils were less than those in the corresponding control soils; net mineralization was negative, when the initial residue C/N was between 24 and 150. When the initial residue C/N was between 10 and 24, the soil mineral nitrogen contents 168 days after adding residues were greater than those in the corresponding control soil, net mineralization was positive (Trinsoutrot *et al.,* 2000). From studies of Trinsoutrot *et al.,* (2000), found that during decomposition of plant residues in soil at 15 ^{0}C, after 168 days, only the crop residue with C / N <24 was achieved a surplus of mineral N compared with the control untreated.

The research concerning the influence of crop rotation and fertilizers on soil chemical characteristics pointed out the significant changes after 46 years of testing, the obtained data giving special information for following the survey of nutrients and diagnosing the evolution tendencies of soil fertility.

Analysis of agrochemical data has shown that nitrogen fertilizers (ammonium nitrate) had determined pH decrease. Soil pH has declined, depending on the amount of N applied. A significant diminution was registered in ploughed layer, at rates of 140 kg/ha N, where pH value has reached 5.5 after 46 years (*Fig. 3*).

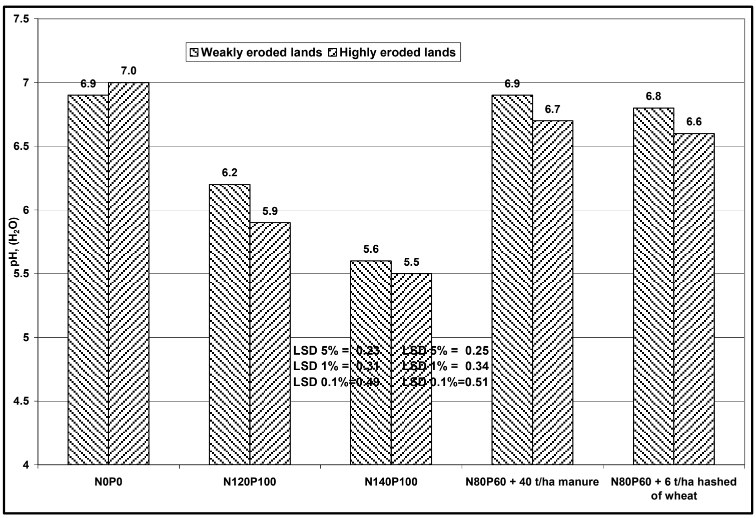

Figure 3 - Effect of soil erosion and fertilization system on pH in 16% slope fields

The analyses carried out on the evolution of soil response, after 46 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates than 120 kg N/ha . The lowest pH values were found in maize at rates of $N_{140}P_{100}$ and 80 kg N + 60 kg P_2O_5/ha + 6 t/ha stalks of maize, which can be explained by the unfavorable conditions in which the processes of nitrification and crop residue decay developed. In case of organo-mineral fertilization, the pH diminution was less pronounced.

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.

On slightly eroded lands, maintaining a good supply in soil nutritive elements was done by the annual use of fertilizer rates of at least $N_{120}P_{100}$ or $N_{80}P_{60}$+ 40 t/ha manure, applied once in two years, or $N_{80}P_{60}$ + 6 t/ha straw. On highly eroded lands, maintaining a good plant supply in mineral elements was done at rates of N_{140} $P_{100}K_{70}$ or $N_{80}P_{60}$ + 40 t manure (*Fig. 4*). From the analyses conducted, we found out that the mean supply with mineral substances per ton of applied manure was of 6.5 kg N, 2.9 kg P_2O_5, 9.5 kg K_2O, 0.5 kg Ca, 1.1 kg Mg, 5 g B, 16 g Zn, 9 g Cu and 262 kg humic matter. Under these conditions, the humus content from soil, after 46 years of experiencing, was maintained at the initial value. In that case, the values registered by other macronutrients (K, Ca, Mg) have shown that soil supply was normal, compared to crop demands. Maintaining main soil chemical characteristics under favourable limits for plant growing and development was done only in case of organo-mineral fertilization.

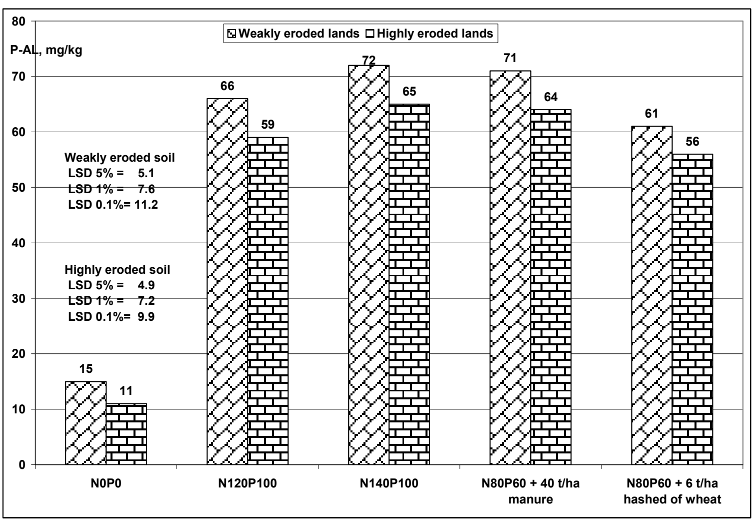

Figure 4 - Change of phosphorus content of soil as influenced by fertilizers, after 46 years of experiments

On weakly eroded soil potassium content was, according to rates and type of fertilizers, between 181 and 261 mg/kg, and on highly eroded land potassium content decreased from 186 mg/kg in unfertilized control to 152 mg/kg in the fertilized variant with $N_{140}P_{100}$ *(Fig. 5)*. In the intensive rotations with cereals, with high annual consumption of nutrients, maintaining a good soil supply with mineral elements is done only by organo-mineral fertilization ($N_{80}P_{60}$ + 40 t/ha manure).

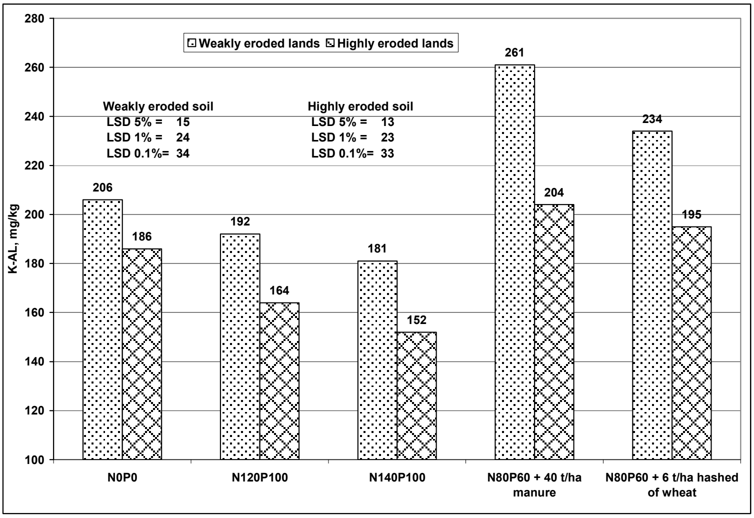

Figure 5 - Effect of soil erosion and fertilization system on potassium content in 16% slope fields

On weakly eroded soil, the mass of organic carbon in Cambic Chernozem from the Moldavian Plain has registered significant increases at higher than $N_{80}P_{60}$ rates + 6 t/ha straw of wheat or $N_{80}P_{60}$ + 40 t/ha manure (*Fig. 6*). On highly eroded lands, very significant values of the carbon content were found only at organo-mineral fertilization, with $N_{80}P_{60}$ + 40 t manure/ha (*Fig. 7*). The results of chemical analyses have shown that in pea-wheat-maize rotation, by annual application of rate of $N_{120}P_{100}$, the decrease in organic carbon content from soil could not be prevented, its level increasing only in variants where mineral fertilizers were applied with manure or crop residues.

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 quantity of nitrogen in the autumn grain fertilization must know the amount of nitrogen consumed by plants, which remain in the stubble and soil arable layer to the depth, and those lost to the atmosphere or in deep soil layers.

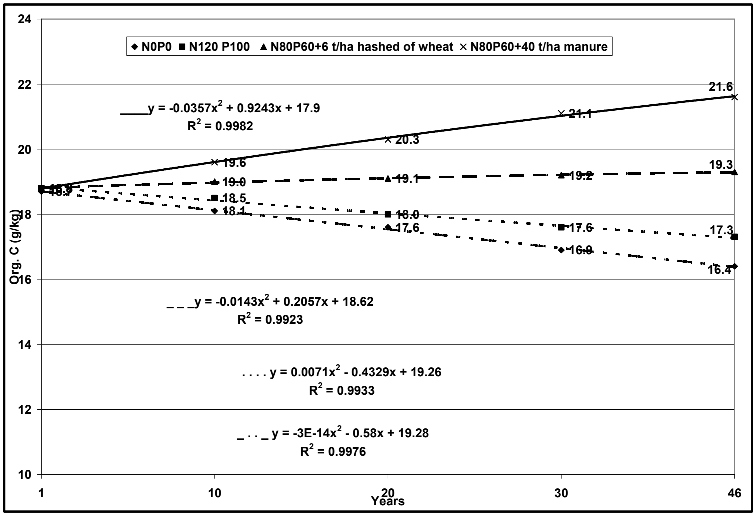

Figure 6 - Influence of mineral and organic fertilizers on organic carbon on weakly eroded lands

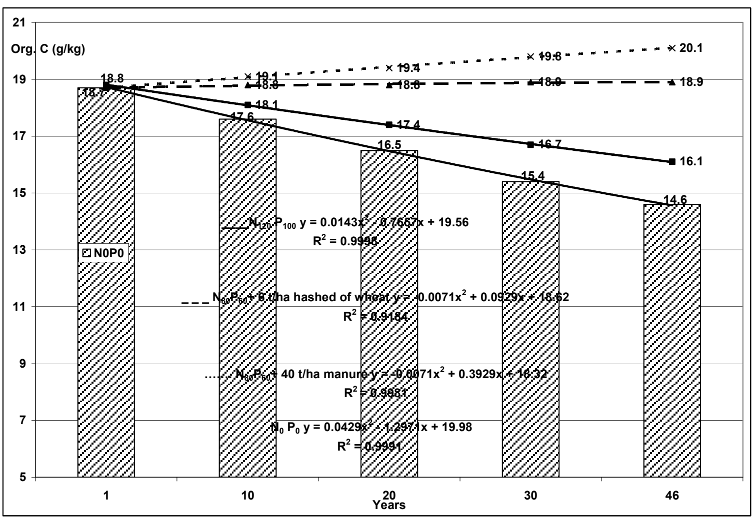

Figure 7 - Influence of mineral and organic fertilizers on organic carbon on highly eroded lands

In the autumn grain nitrogen losses to the atmosphere or the soil layer below 23 cm, recorded at the experimental field at Rothamsted, were 18.4% at a dose of 48 kg nitrogen/ha ($(NH_4)\ 2SO_4$) and 26.6% in dose of 144 kg / ha nitrogen (Glendining *et al.,* 2001). The total amount of nitrogen removed from the soil due to weeds was approximately 10 kg / ha with oscillations between 7 and 32 kg N/ha.

Weeds were present on most plots. Average nutrient content of weed plants were 2.06% nitrogen, 0.23% phosphorus and 2.97% in potassium (*Table 3*). The total amounts of nitrogen taken up by weeds were less than 10 kg N ha. In wheat and maize, nitrogen uptake by weeds was between 7 and 9.5 kg/ha from all the plots (*Table 4*).

Table 3 - Average nutrient content in different species of weeds in corn located in different conditions of fertilization (%)

Weeds	Fertilizer	Total N	P_2O_5	K_2O
Amaranthus retroflexus	N_0P_0	2.38	0.23	2.64
	$N_{140}P_{80}$	2.63	0.37	4.12
Chenopodium album	N_0P_0	1.92	0.16	3.18
	$N_{140}P_{80}$	2.14	0.25	4.25
Convolvului arvensis	N_0P_0	1.87	0.15	1.56
	$N_{140}P_{80}$	2.39	0.18	1.84
Echinochloa crus-galli	N_0P_0	0.89	0.15	2.98
	$N_{140}P_{80}$	1.92	0.17	3.41
Hibiscus trionum	N_0P_0	1.24	0.15	1.96
	$N_{140}P_{80}$	2.13	0.24	2.38
Solanum nigrum	N_0P_0	1.96	0.22	2.76
	$N_{140}P_{80}$	2.74	0.37	4.38
Sonchus arvensis	N_0P_0	1.99	0.21	2.48
	$N_{140}P_{80}$	2.57	0.32	3.65
Mean		2.06	0.23	2.97
LSD 5%		0.07	0.02	0.08
LSD 1%		0.09	0.05	0.12
LSD 0.1%		0.13	0.07	0.17

Table 4 - Dry weight of weeds and amounts of nutrients extracted and fixed by them in the soil, kg/ha

Crop	Dry weight	Fertilizer	Nitrogen	P_2O_5	K_2O	Total
Wheat	342	N_0P_0	7.045	0.787	10.157	17.989
	425	$N_{140}P_{80}$	8.755	0.978	12.623	22.356
Maize	389	N_0P_0	8.013	0.895	11.553	20.461
	462	$N_{140}P_{80}$	9.517	1.063	13.721	24.301
Average	405		8.333	0.931	12.014	21.277

CONCLUSIONS

In the soils from the Moldavian Plateau, which are poor in organic matter and nutrients, the proper use of different organic resources 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.

The organo-mineral fertilization has determined the pH maintenance in the field of weakly acid to neuter reaction, both on weakly eroded and highly eroded soils (6.6-6.9).

Soil supply with mineral elements on slope lands depended on organic carbon content from soil, which influenced soil structure and conditions of organic matter mineralization, as influenced by microorganisms, moisture, temperature and aeration.

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 $N_{140}P_{100}$ or $N_{80}6_{0}$ + 6 t/ha straw of wheat; on highly eroded lands, keeping a good plant supply in mineral elements was done at rates of $N_{80}P_{60}$ + 40 t/ha manure.

On the Cambic Chernozem from the Moldavian Plateau, a good supply with mobile phosphorus in wheat and maize crops (37-72 mg/kg) was done in case of the annual application of a rate of $N_{140}P_{100}$, while a very good supply (>72 mg/kg) was achieved at the rate of $N_{80}P_{60}$+40 t/ha manure.

The organic fertilizers, applied together with mineral ones ($N_{80}P_{60}$+40 t manure/ha), have improved soil chemical characteristics and determined mean nutrient content increases of 53 mg/kg in phosphorus and 55 mg/kg in potassium, compared with the control untreated.

Amounts of nutrients consumed by weeds were 0931 kg / ha P_2O_5, 8.333 kg/ha nitrogen and 12,014 kg/ha of K_2O.

After 46 years of experiences, in pea-wheat-maize crop rotation, the content of organic carbon from soil has decreased by 22.3% (4.2 g/kg soil) at the unfertilized control and by 14.4% (2.7 g/kg soil) at the rate of $N_{120}P_{80}$.

In wheat and maize, nitrogen uptake by weeds was between 7 and 9.5 kg/ha from all the plots.

Applying moderate rates of mineral fertilizers ($N_{80}P_{60}$), together with 6 t/ha wheat straw or 40 t/ha manure, has determined the increase in organic carbon content from soil by 0.5 and, respectively, 2.8 g/kg.

On highly eroded lands, after 46 years of experiences, in pea-wheat-maize crop rotation, with fertilizer rates ($N_{80}P_{60}$ + 6 t/ha straw of wheat), the content of organic carbon from soil had close values to the initial ones.

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