INVESTIGATIONS ON THE CHANGE OF SOIL CHEMICAL AND BIOLOGICAL CHARACTERISTICS AS INFLUENCED BY CROP ROTATION AND LONG-TERM FERTILIZATION IN THE MOLDAVIAN PLAIN

***C. AILINCĂI*[1*], *Despina AILINCĂI*[1], *Maria ZBANȚ*[1], *Geanina BIREESCU*[1], *Ad. MERCUŞ*[2]**

[1]Agricultural Research and Development Station of Podu-Iloaiei-Iaşi
[2]Institute of Biological Research of Iaşi

ABSTRACT *- Investigations conducted in long-term (39 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 2, 3 and 4 year rotations. In maize crop, placed in 5 year rotations, the mean yield obtained during 1980-2005 was of 5920 kg /ha. Rates of $N_{100}P_{100}$ have determined yield increases by 94% (3030 kg/ha) and rates of $N_{40}P_{40}$ + 30 t/ha manure resulted in a double yield, in hybrid Oana (9 %; 3180 kg/ha) compared to unfertilized. The long-term use of 3 and 4 year rotation with ameliorative plants resulted in getting yield increases by 46 - 48% (1120-1150 kg/ha) in wheat and 27 - 35% (1180 – 1530) in maize, compared to continuous crop. Annual application of rates of 80 kg/ha P_2O_5 determined the accumulation of a reserve of mobile phosphates in soil, comprised, according to applied nitrogen, between 47 and 66 ppm. The humus and nutrient content from soil was maintained at a supply level proper to the requirements of plant nutrition, only under 3 or 4 year rotation and in case of annual use of rates of at least $N_{100}P_{100}$ or of mean rates of mineral elements with 30 t/ha manure.*

Key words: stationary experiments, non-irrigated, fertilization, crop rotation

INTRODUCTION

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

* E-mail: scdapoduail@zappmobile.ro

technological factors, fertilization and rotation influence the most crop yields and soil fertility and determine a better capitalization of the other costs (Ailincăi et al., 1998; Jităreanu et al., 2006). The control of soil fertility and estimate of economic impact on long-term farming activities could be done on the basis of results obtained in long-term stationary experiments with different graduations of technological factors, typical of the experiencing area. The results obtained in long-term experiments from different countries have shown that establishing some economic methods for soil conservation relied on these results and were valuable only for soil and climatic conditions of the experiencing area (Mihăilă et al., 1996; Heuman et al., 2006; Ştefanic et al.,1994).

MATERIALS AND METHODS

Investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei since 1968, have investigated the influence of different crop structures and sequences and fertilizers on yield and soil fertility. The experiments were placed on a 14 % slope field, a cambic chernozem-like soil with a clay-loam texture, a neuter to weakly acid reaction and a mean supply in nutrients.

The biotic tests have investigated the knowledge of respiration and cellulosolitic soil potential, which was found at the basis of computing the Indicator of Vital Activity Potential (IVAP).Enzymatic tests had in view: oxide-reduction processes (catalysis) sugar hydrolysis (saccharine), urea hydrolysis (urease) and phosphorus hydrolysis from organic combinations (total phosphatase) ; based on these processes, the Indicator of Enzymatic Activity Potential (IEAP) was calculated according to methods of Ştefanic and Irimescu (1984).

Average rainfall amounts registered in the last 79 years in the Moldavian Plain were of 548 mm. In the last 19 years, annual average amounts of registered rainfall were close to the multiannual mean in 8 years and lower by 39-206 mm in the other 9 years.

RESULTS AND DISCUSSION

The analyses conducted on soil samples from the fields on which wheat-maize rotation was used for 39 years, resulted in worsening of soil chemical characteristics. Under these conditions, compared to 3 and 4 year rotations with ameliorative plants (annual legumes for grains and perennial grasses), the humus content from soil decreased from 3.1 to 2.86%, mobile phosphorus content decreased from 57 to 37 ppm and soil pH from 7.0 to 6.6 (*Table 1*)

The introduction into rotation of annual or perennial ameliorative crops (pea, soybean, alfalfa) and the use of mineral fertilizers with manure have resulted

in increasing mobile phosphorus content from soil until 87 ppm and humus content from soil to 3.59%.

Main microelements content from soil differentiated according to nitrogen and phosphorus rates, between 3.5-4.9 ppm at copper, 0.45-0.72 ppm at boron, 1.1-1.6 ppm at zinc and 69-184 ppm at manganese.

Table 1

Evolution of main agrochemical indices of soil as influenced by rotation and fertilizers, after 39 years of experiments

Fertilizer rate	pH (H_2O)	Humus %	P-AL ppm	K-AL ppm	Boron ppm	Zinc ppm	Copper ppm	Manganese ppm
Rotation: Wheat-maize								
N_0P_0	7.1	2.58	12	178	0.41	1.3	3.4	142
$N_{70}P_{70}$	6.3	2.65	28	167	0.46	1.2	3.5	148
$N_{100}P_{80}$	5.8	2.98	47	158	0.48	1.1	4.0	184
$N_{70}P_{70}$ + 30 t/ha manure	7.1	3.24	61	261	0.55	1.4	4.3	126
Average	6.6	2.86	37	191	0.47	1.3	3.8	150
Rotation: Pea- wheat-maize								
N_0P_0	7.3	2.74	19	184	0.45	1.3	4.0	76
$N_{70}P_{70}$	6.8	2.84	31	176	0.58	1.2	4.2	89
$N_{100}P_{80}$	6.4	2.96	66	178	0.58	1.1	4.4	112
$N_{70}P_{70}$ + 30 t/ha manure	7.2	3.47	79	322	0.62	1.5	4.6	78
Average	6.9	3.00	49	215	0.56	1.3	4.3	89
Pea- wheat-maize-sunflower +perennial grasses								
N_0P_0	7.2	2.81	18	196	0.49	1.3	3.9	69
$N_{70}P_{70}$	6.9	2.96	51	254	0.58	1.1	4.4	78
$N_{100}P_{100}$	6.5	3.09	71	259	0.65	1.2	4.6	92
$N_{70}P_{70}$ + 30 t/ha manure	7.3	3.59	87	319	0.72	1.6	4.9	82
Average	7.0	3.1	57	257	0.61	1.3	4.5	80

Under 4 year rotation, an improvement was found in the potential of soil vital and enzymatic activities, due to soil inputs of greater amounts of organic matter, easily to decompose and carrying enzymes (*Table 2*).

Organic-mineral fertilization had a good effect on both indicators, which was also transmitted to the level of the Biological Synthetic Indicator (BSI), representing the average between the Indicator of Biotic Activity Potential (IBAP) and the Indicator of Enzymatic Activity Potential (IEAP). The contribution of easily decomposed organic matter from rotation crops resulted in increasing mobile phosphorus content by 31.1-32.5 mg P/ 100 g soil, compared to wheat-maize rotation.

The biotic potential (respiration, cellulosolis) and enzyme potential (catalase, sucrose, urease and total phosphatase) have higher values in spring, at the beginning of vegetation, compared to autumn, after harvesting (*Table 3, 4*).

Table 2

Influence of crop rotation and fertilization on some indicators of vital and enzyme of cambic chernozem at the Agricultural Research Station of Podu-Iloaiei

Fertilizer rate	Potential		IVAP %	Enzyme potential				IEAP %	BSI %
	of respiration (mg CO_2/100 g soil	Cellulosolisis (% degraded cellulose)		Catalase cm^3 O_2	Succrose mg glucose	Urease mg NH_4	Phosphatase mg P		
				la 100 g soil DM.					
Wheat-maize rotation									
N_0P_0	55.17	41.23	58.09	388	1361	42,18	3,84	51,73	54,9
$N_{100}P_{100}$	60.21	49.54	66.53	343	1227	47,31	18,41	46,63	56,6
$N_{40}P_{40}$+ 30 t/ha manure	66.36	53.73	72.36	307	1518	64,56	27,65	57,69	65,1
Average	60.58	48.17	65.66	346.00	1368.67	51,35	16,63	52,02	58,87
Pea-wheat-maize-sunflower + outside field with perennial grasses rotation									
N_0P_0	77.51	64.36	85.73	523	1664	70.47	39.51	63.24	74.5
$N_{100}P_{100}$	80.83	66.93	90.55	489	1910	85.94	49.12	72.59	75.6
$N_{40}P_{40}$+ 30 t/ha manure	84.14	69.51	95.37	455	2156	101.41	58.75	81.94	76.8
Average	80.83	66.93	90.55	489.00	1910.00	85.94	49.13	72.59	75.63
LSD 5% =			2.92					2.28	2.75
LSD 1% =			5.42					3.65	4.26
LSD 0.1% =			9.21					5.66	6.38

The lowest value of assimilable phosphorus content was registered by the unfertilized control (3.22 mg P at the depth of 0-20 cm, respectively, 2.05 mg P at the depth of 20-40 cm) and the highest value was registered at soil cultivated with legumes and perennial grasses (8.37 mg P at the depth of 0-20 cm, respectively, 20-40 cm (*Table 3*).

Table 3

Influence of fertilization on terraces on vital and enzyme potential of soil in the spring of 2005

Variants	Depth (cm)	Vital potential		Enzyme potential			
		Soil respiration (cm^3 CO_2)	Cellulolisis (% celluloses)	Catalase (cm^3 O_2)	Succrose (mg glucose)	Urease (mg NH_4)	Fosphatase (mg P)
Control	0-20	37.43	41.27	342	1517	50.83	7.08
	20-40	23.81	20.81	275	1303	25.16	3.17
$N_{100}P_{100}$	0-20	58.55	51.39	404	1664	68.53	8.07
	20-40	31.72	25.17	306	1405	31.08	4.22
$P_{70}K_{70}$	0-20	50.06	44.58	358	1584	55.17	7.75
	20-40	26.34	22.35	283	1388	28.31	4.01
$N_{140}P_{140}$	0-20	69.51	59.56	455	1708	72.75	8.23
	20-40	33.97	35.71	322	1427	34.81	4.31
Manure 40t/ha	0-20	60.18	48.23	361	1591	58.43	8.05
	20-40	24.58	24.19	294	1396	30.11	4.48
Manure 40t/ha+ $N_{70}P_{70}$	0-20	65.77	55.62	423	1663	59.26	8.25
	20-40	36.18	26.81	299	1417	30.44	4.88
$N_{70}P_{70}$+ 6 t/ha straw	0-20	54.23	46.23	361	1612	58.24	8.52
	20-40	27.04	23.51	296	1401	31.51	4.08
$N_{70}P_{70}$+ 6 t/ha stalk	0-20	55.36	47.81	375	1635	62.17	8.86
	20-40	28.18	24.08	299	1408	32.42	4.31
$N_{70}P_{70}$+ 6 t/ha pea stalk	0-20	57.11	49.86	383	1647	66.53	9.03
	20-40	29.21	26.07	301	1415	35.08	4.41
Perennial grasses	0-20	68.53	67.81	491	1775	77.86	9.31
	20-40	37.84	35.22	334	1453	36.53	4.88

The mineral fertilization resulted in an increase in total phosphatase level , according to the applied rate. 40 t/ha manure fertilization has determined the doubling of phosphatase level from soil , at the depth of 0-20 cm (7.01 mg P) and the depth of 20-40 cm (4.21 mg P). The energy contribution of manure and peas stalks was higher, compared to straw residues. According to used organic material, the total phosphatase level at the depth of 0-20 cm was between 5.94 mg P at the variant $N_{70}P_{70}$ + 6 t straws/ ha and 8.18 mg P at the variant with 40 t/ha manure + $N_{70}P_{70}$.

Table 4

Influence of fertilization on terraces on vital and enzyme potential of soil in the autumn of 2005

Variants	Depth (cm)	Vital potential		Enzime potential			
		Soil respiration (cm^3 CO_2)	Cellulolisis (% celluloses)	Catalase (cm^3 O_2)	Succrose (mg glucose)	Urease (mg NH_4)	Fosphatase (mg P)
Control	0-20	28.12	32.21	275	1268	31.41	3.22
	20-40	18.48	21.83	243	1157	20.73	2.05
$N_{100}P_{100}$	0-20	35.77	41.23	293	1487	38.23	6.68
	20-40	23.52	24.71	251	1248	25.16	4.51
$P_{70}K_{70}$	0-20	32.41	35.74	288	1408	36.82	5.71
	20-40	25.77	26.83	262	1275	25.83	4.92
$N_{140}P_{140}$	0-20	39.82	48.66	301	1521	40.28	7.62
	20-40	27.53	31.56	274	1308	28.51	5.13
Manure 40t/ha	0-20	36.51	37.28	299	1502	39.55	7.01
	20-40	18.34	21.51	211	1151	20.36	4.21
Manure 40 t/ha+$N_{70}P_{70}$	0-20	45.23	41.56	315	1589	44.17	8.18
	20-40	27.34	23.77	283	1307	28.31	5.03
$N_{70}P_{70}$+ 6 t/ha straw	0-20	33.75	37.48	306	1452	37.56	5.94
	20-40	26.01	27.15	271	1289	26.03	4.98
$N_{70}P_{70}$+ 6 t/ha cobs	0-20	34.56	38.83	311	1463	40.86	6.08
	20-40	28.71	28.43	278	1293	27.41	5.15
$N_{70}P_{70}$+ 6 t/ha pea stalks	0-20	36.72	39.41	318	1478	42.53	6.85
	20-40	29.66	29.01	281	1298	28.88	5.43
Perennial grasses	0-20	47.51	44.38	325	1593	45.18	8.37
	20-40	31.42	30.71	291	1344	30.01	5.78

The mean wheat yield obtained during 1980-2005 in wheat, placed in wheat-maize rotation, was of 1620 kg/ha under unfertilized and 3420 kg/ha at high mineral fertilizer rates (*Table 5*).

Wheat continuous crop used for 39 years has limited the mean wheat yield obtained in the last 29 years to 1510 kg/ha under unfertilized and to 2890 kg/ha at rate of $N_{100}P_{100}$. Wheat placed in 3 or 4 year rotation with ameliorative plants resulted in yield increases of 46 - 48% (1120 - 1150 kg/ha).

In maize, application of mean rates of mineral fertilizers with 30 t/ha manure resulted in getting yield increases of 99% (3180 kg/ha), compared to unfertilized variant. Applying rates of $N_{100}P_{100}$ has determined yield increases of 115% in wheat and 94% in maize, compared to unfertilized variant.

Table 5

Influence of rotation and fertilizers on wheat and maize yield, 1980-2005

Fertilizer rate	Wheat				Maize			
	Yield		Dif. kg/ha	Sig-nif.	Yield		Dif. kg/ha	Signif.
	kg/ha	%			kg/ha	%		
N_0P_0	1710	100	0	-	3210	100	0	-
$N_{40}P_{40}$	2680	157	970	xxx	4450	139	1240	xxx
$N_{70}P_{70}$	3470	203	1760	xxx	5720	178	2510	xxx
$N_{100}P_{100}$	3680	215	1970	xxx	6240	194	3030	xxx
$N_{40}P_{40}$+30 t/ha manure	3700	216	1990	xxx	6390	199	3180	
Rotation	LSD 5%= 290 kg/ha		LSD 0.1%= 490 kg/ha		LSD5%= 360 kg/ha		LSD 0.1%= 630 kg/ha	
Continuous crop	2410	100	0	-	4390	100	0	-
Wheat-maize	2690	112	280		4920	112	530	xx
Pea-wheat-maize	3530	146	1120	xxx	5570	127	1180	xxx
Pea-wheat-maize-sunflower+perennial grasses	3560	148	1150	xxx	5920	135	1530	xxx
	LSD 5%= 290 kg/ha		LSD 0.1%= 490 kg/ha		LSD 5%= 320 kg/ha		LSD 0.1%= 600 kg/ha	

CONCLUSIONS

The long-term use of 3 and 4 year rotation with ameliorative plants resulted in getting yield increases of 46 - 48% (1120-1150 kg/ha) in wheat and 27 - 35% (1180 – 1530) in maize, compared to continuous crop.

The humus and nutrient content from soil was maintained at a supply level proper to the requirements of plant nutrition only under 3 or 4 year rotation and annual use of rates of at least $N_{100}P_{100}$ or mean rates of mineral elements with 30 t/ha manure.

Annual application of rates of 80 kg/ha P_2O_5 resulted in the accumulation of mobile phosphates stock in soil, comprised between 47 and 66 ppm, according to applied nitrogen.

The 39 year use of the 4 year rotation with an outside field, grown with legumes and perennial grasses on slope lands poor in organic matter, determined, compared to wheat-maize rotation, the increase in soil vital potential by 25% and enzyme potential by 21%.

REFERENCES

Ailincăi C., Jităreanu G., Ailincăi Despina, 1998- *The evolution of main soil chemical and biological characteristics under the influence of crop rotation and fertilizers.* AKAPRINT, Gődőllő, Hungary;

Heuman Sabine, Bottcher J., 2004 - *Temperature function of the rate coefficients of net N mineralization in sandy arable soils.* Journal of Plant Nutrition and Soil Science, Vol. 167, pg. 390-396.

Jităreanu G., Ailincăi C., Bucur D., 2006 - *Influence of tillage systems on soil physical and chemical characteristics and yield in soybean and maize grown in the Moldavian Plain (North-Eastern Romania),* Advances in Geoecology, 38, CATENA Verlag, Reiskirchen, Germany.

Mihăilă V., Burlacu Gh., Hera Cr., 1996 –*Results obtained in long–term experiments with fertilizers on cambic chernozem of Fundulea,* Annals of the Institute for Technical Plant Growing Fundulea ,Vol. LXIII

Ştefanic Gh., 1994- *Biological definition, quantifying method and agricultural interpretation on the soil fertility.* Romanian Agricultural Research, 2, Bucharest.