Cercetări Agronomice în Moldova
Vol. XLVI , No. 1 (153) / 2013

NITROGEN AND PHOSPHORUS MANAGEMENT UNDER LONG-TERM EXPERIMENTS

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Received January 4, 2012

ABSTRACT. The investigations conducted at the Podu-Iloaiei Agricultural Research Station, Iaşi County, Romania, have studied the influence of different mineral fertilizers rates on wheat and maize yield and soil agrochemical characteristics. In bean-wheat-maize-sunflower-wheat crop rotation, the mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 8.3 and 10.1 kg in wheat ($N_{120}P_{80}$-$N_{160}P_{80}$) and between 10.8 and 11.0 kg in maize ($N_{150}P_{80}$-$N_{200}P_{100}$). Generally, nitrogen use efficiency is low and, to achieve maximum yields, need for high doses of nitrogen which can increase the risk of environmental pollution. The N agronomic efficiencies and physiological efficiencies in wheat and maize declined with the increase of nitrogen rate. Wheat placed in rotation for five years, after sunflower at recommended dose ($N_{160}P_{80}$), physiological efficiency of nitrogen utilization was 43.4 kg grain per kilogram of nitrogen exported from soil, from fertilizer applied. Mean annual amounts of nutrients exported from soil by wheat in dry (14 yr.) and favourable (11 yr.) years in five year crop rotation have varied according to rates, between 34.5 and 100.7 kg at nitrogen and between 6.5 and 18.4 kg at phosphorus. The long-term use of bean - wheat - maize - sunflower - wheat rotation determined the diminution by 43.4% (2,772 t/ha) in the mean annual losses of eroded soil and by 38.5% (5.61 kg/ha) in nitrogen leakages by erosion, compared with maize continuous cropping.

Key words: Fertilization; Nitrogen; Phosphorus; Physiologic N efficiency; Nutrient losses; Wheat; Maize.

REZUMAT. **Gestionarea azotului şi a fosforului în experimentele de lungă durată.** Cercetările, efectuate la Staţiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, judeţul Iaşi, au urmărit influenţa diferitelor doze de îngrăşăminte minerale asupra producţiei de grâu şi porumb şi a însuşirilor chimice ale solului. În rotaţia fasole-grâu-porumb-floarea-soarelui-grâu, sporurile medii de producţie, obţinute pentru fiecare kg de îngrăşământ aplicat, au fost cuprinse între 8,3 şi 10,1 kg la grâu ($N_{120}P_{80}$-$N_{160}P_{80}$) şi între 10.8 şi 11.0 kg la porumb ($N_{150}P_{80}$-$N_{200}P_{100}$). În general,

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eficiența utilizării azotului este redusă şi, pentru a obține producții maxime, este nevoie de doze mari de azot, care pot creşte riscul de poluare a mediului. Eficiența agronomică şi fiziologică a azotului la culturile de grâu şi porumb a scăzut odată cu creşterea dozelor de azot. La cultura grâului, amplasată în rotația de cinci ani, după floarea-soarelui, la doza recomandată de $N_{160}P_{80}$, eficiența fiziologică de utilizare a azotului a fost de 43,4 kg boabe pe kilogramul de azot exportat din sol, din îngrăşământul aplicat. Cantitățile medii anuale de nutrienți exportați din sol, la cultura grâului, în anii secetoşi (14 ani) şi favorabili (11 ani), în rotația de cinci ani, au variat, în funcție de dozele aplicate, între 34.5 şi 100.7 kg la azot şi între 6,5 şi 18,4 kg la fosfor. Utilizarea îndelungată a rotației fasole - grâu - porumb - floarea soarelui - grâu a determinat, comparativ cu monocultura de porumb, diminuarea pierderilor medii anuale de sol erodat cu 43,4% (2772 t/ha) şi a scurgerilor de azot, prin eroziune, cu 38,5% (5.61 kg /ha).

Cuvinte cheie: fertilizare; azot; fosfor; eficiența fiziologică a azotului; nutrienți erodați; grâu; porumb.

INTRODUCTION

The most relevant EU environmental directives with respect to soil quality are the Nitrates Directive and the Water Framework Directive.

The main sources of nitrate pollution of EU waters are agriculture and the nutrients coming from untreated urban wastewaters. Because of the link between soil quality and water, measures taken under these directives may contribute to reducing soil contamination, with positive effects on soil biodiversity.

Member States must identify surface waters and groundwater affected or liable to be affected by pollution, in particular when nitrate concentrations exceed 50 mg/l and, vulnerable zones that contribute to pollution. More efficient use of nitrogen fertilizer is essential for improving the economic output of the farm and reducing the risk of environmental pollution. In 2000, around 20% of sites were protected from eutrophication. In 2020, under reductions in accordance with current legislation, about one third of the sites would be protected, and at best, half of the sites would be protected from eutrophication (Holmberg *et al.*, 2013). Of groundwater analyzes revealed that, in the EU, 17% of areas had nitrate concentrations above 50 mg /l (COM (2007) 120 final).

Member States must establish codes of good agricultural practice, as defined in Annex II to the Directive, that to contain provisions relating to the conditions for application of fertilizer. The Thematic Strategy show that in Europe, 115 million hectares or 12% of Europe's total land area, is affected by water erosion (COM (2006) 231) and besides soil loss, the cost of soil erosion for the EU-27 is EUR 0.7-14.0 billion.

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 (Rusu *et al.,* 2007; Jităreanu *et al.,* 2007; Izaurralde *et al.,* 2007; Abid and Lal, 2008; Alexander *et al.,* 2008; Yadav and Malanson, 2008; Zhang *et al.,* 2010; Săndoiu, 2011; Lal, 2011; Bucur *et al.,* 2011; Ailincăi *et al.,* 2011, 2012; Holmberg *et al.,* 2013).

MATERIALS AND METHODS

Investigations conducted on a Cambic Chernozem (SRTS - 2003) at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County (47°12′ N latitude, 27°16′ E longitude), since 1968, followed the influence of different crop rotations and fertilizers on water runoff and nutrient losses, due to soil erosion. The experiments were carried out on slope land, with Cambic Chernozem soil-type, which has a loam-clayey texture (418 g clay, 322 g loam and 260 g sand), a neuter to weakly acid reaction 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 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.

The content of total nitrogen, nitrates and phosphorus was determined on soil and water samples, lost by erosion, in different crops, thus establishing the losses of nutritive elements on the area of the watershed where experiments are placed.

In wheat, we have used varieties Fundulea 4 and Gabriela since 2005, and in maize, hybrids Podu - Iloaiei 110 and Oana, since 2003. After each cycle of crop rotation, physical and chemical tests of soil samples were carried out in tested variants according to the well-known methods.

In literature were used different definitions to describe the agronomic and physiological range of nitrogen efficiency, which referring to external and internal nitrogen control. Agronomic N-efficiency (Eq. 1) indicates effectiveness of fertilizer nitrogen recovery due to nitrogen uptake by the plant and physiological nitrogen efficiency (Eq. 2) takes into account dose of nitrogen fertilization (Craswell and Godwind, 1984).

$$\text{Agronomic N efficiency} = \frac{\text{Seed yield fertilized - Seed yield unfertiliz.}}{\text{N suply}} \quad \text{(kg/kg)} \qquad (1)$$

$$\text{Physiologic N efficiency} = \frac{\text{Seed yield fertilized - Seed yield unfertiliz.}}{\text{N uptake fertilized - N uptake unfertiliz.}} \quad \text{(kg/kg)} \qquad (2)$$

RESULTS AND DISCUSSION

To enhance the productivity of winter wheat cropping, integrated nitrogen management strategies are needed including optimized nitrogen supply due to varied crop rotations, fertilization and crop management practices. Nitrogen uptake depends mainly on spatial root development, capacity of the uptake system and demand of culture for nitrogen. To optimize nitrogen use on arable land in England and Wales, Dailey *et al.*, 2006, using Sundial modeling system and results obtained in different experiments to determine the amount of nitrogen lost through leaching and denitrification in different crops (*Table 1*).

During 1988-2012, the climatic conditions were favorable to plant growing and development, during 11 years in wheat and 10 years in maize (*Table 2*).

The research carried out at the Podu-Iloaiei Agricultural Research Station, Iaşi County, had in view the influence of different fertilizer rates on yield and soil fertility.

Table 1 - Mean amounts of nitrogen by soil and region applied as fertiliser, lost, or taken up by the several crop, kg/ha (Dailey, 2006)

Crop	Fertiliser applied	Potential yield Loam or clay	Denitrification	Leaching	Crop uptake
Winter wheat	172	9,0	8	17	200
Spring barley	68	6,0	7	19	133
Winter oilseed rape	169	3,5	6	8	197
Potatoes	88	42,5	8	19	178

The climatic conditions in the Moldavian Plain were characterized by a multiannual mean temperature of 9.6°C and a mean rainfall amount, on 51 years, of 547.4 mm, of which 139.1 mm during September-December and 408.4 mm during January-August. The mean annual rainfall amounts, registered in the last 25 years (*Table 2*), were of 566.0 mm, of which 158.4 mm during September-December and 401.3 mm during January-August.

From our studies, we found out that, in dry years, in wheat, placed in five year crop rotation (bean-wheat - maize - sunflower - wheat), after sunflower, the mean annual amounts of nutrients extracted from soil, together with the harvest, have varied according to rates, between 28.0 and 68.4 kg at nitrogen, between 5.3 and 12,2 kg at phosphorus (*Table 3*).

In favorable years, the mean annual amounts of nutrients extracted from soil, together with the harvest, have varied according to rates, between 42.8 and 99.0 kg at nitrogen and between 8.0 and 17.8 kg at phosphorus (*Table 4*).

Table 2 - Rainfall recorded at the Weather Station of Podu-Iloaiei, Iaşi County

Years	I	II	III	IV	V	VI	Total
A-1988	43.2	15.1	66.1	78.5	86.7	105.8	**395.4**
A-1989	6.9	5.5	18.0	40.6	65.9	98.8	**235.7**
A-1990	14.9	21.1	2.4	83.9	63.0	60.1	**245.4**
A-1991	9.2	22.0	12.3	35.4	154.7	95.5	**329.1**
A-1992	4.3	10.1	44.9	34.6	59.1	84.2	**237.2**
A-1993	9.0	21.8	90.7	70.6	68.4	67.3	**327.8**
A-1994	18.7	13.9	10.1	17.9	26.8	82.8	**170.2**
A-1995	42.4	13.0	38.8	20.6	85.8	58.0	**258.6**
A-1996	32.1	35.7	34.8	49.8	24.2	81.6	**258.2**
A-1997	7.1	10.4	6.1	91.5	25.1	69.9	**210.1**
A-1998	29.4	6.8	38.7	55.7	61.7	92.9	**285.2**
A-1999	35.3	38.2	19.3	71.7	24.3	80.0	**268.8**
A-2000	24.3	27.4	26.7	62.8	10.6	43.3	**195.1**
A-2001	23.0	11.4	30.9	74.7	43.8	103.3	**287.1**
A-2002	6.9	6.6	56.6	18.9	29.4	57.4	**175.8**
A-2003	35.3	21.6	22.3	21.1	10.0	19.1	**129.4**
A-2004	67.9	31.3	18.5	16.8	19.8	20.7	**175.0**
A-2005	42.4	42.1	25.6	86.2	106	86.3	**388.6**
A-2006	29.3	7.8	97.3	98.0	57.0	93.7	**383.1**
A-2007	20.3	30.2	30.2	27.0	30.7	15.6	**154.0**
A-2008	10.9	2.6	25.2	127.3	43.2	65.2	**274.4**
A-2009	80.0	56.5	37.5	5.0	44.0	139.0	**362.0**
A-2010	61.2	17.3	20.1	24.0	82.0	174.0	**378.6**
A-2011	19.6	15.6	16.4	68.0	37.0	81.0	**237.6**
A- 2012	31.0	38.4	39.0	67.0	77.4	22.4	**275.2**
Average	**28.2**	**20.9**	**33.1**	**53.9**	**53.5**	**75.9**	**265.5**
Average on 51 years	**26.5**	**22.6**	**28.5**	**50.9**	**56.3**	**84.4**	**269.2**
Difference	**1.7**	**-1.7**	**4.6**	**3.0**	**-2.8**	**-8.5**	**-3.7**

Table 3 - Mean annual amounts of nutrients exported from soil by wheat (grains + straw) in dry years, in five year crop rotation, after sunflower

Fertilizer rate	Grains + straw of wheat kg/ha	Amounts of elements exported from soil, kg/ha		Grain, kg/ha	Yield increases, kg/ha	Agronomic N+P efficienty
		N	P			
N_0P_0	2484	28.0	5.3	1080		
N_0P_{40}	2852	32.4	6.0	1240	160	4.0
$N_{40}P_{40}$	3784	44.2	7.9	1720	640	8.0
$N_{80}P_{40}$	4224	49.3	9.0	1920	840	7.0
$N_{120}P_{40}$	4851	58.3	10.6	2310	1230	7.7
$N_{160}P_{40}$	5095	64.0	12.1	2426	1346	6.7
N_0P_{80}	2961	32.1	6.6	1410	330	4.1
$N_{40}P_{80}$	4032	43.7	9.4	1920	840	7.0
$N_{80}P_{80}$	4515	54.3	10.1	2150	1070	6.7
$N_{120}P_{80}$	5145	64.5	11.2	2450	1370	6.9
$N_{160}P_{80}$	5229	68.4	12.2	2490	1410	5.9
LSD 5%		3,2	0,54		150 kg/ha	

Table 4 - Mean annual amounts of nutrients exported from soil by wheat (grains + straw) in favorable years, in five year crop rotation, after sunflower

Fertilizer rate	Grains + straw of wheat kg/ha	Amounts of elements exported from soil, kg/ha		Grain, kg/ha	Yield increases, kg/ha	Agronomic N+P efficienty
		N	P			
N_0P_0	3795	42.8	8.0	1650		
N_0P_{40}	4209	47.8	8.9	1830	180	4.5
$N_{40}P_{40}$	5522	64.5	11.6	2510	860	10.8
$N_{80}P_{40}$	6534	76.3	13.9	2970	1320	11.0
$N_{120}P_{40}$	7035	84.6	15.3	3350	1700	10.6
$N_{160}P_{40}$	7182	90.2	17.0	3420	1770	8.9
N_0P_{80}	4284	46.5	9.5	2040	390	4.9
$N_{40}P_{80}$	6552	71.1	15.3	3120	1470	12.3
$N_{80}P_{80}$	7182	86.4	16.0	3420	1770	11.1
$N_{120}P_{80}$	7392	99.0	16.1	3520	1870	9.4
$N_{160}P_{80}$	7644	97.7	17.8	3640	1990	8.3
LSD 5%		3,8	1,2		180 kg/ha	

In wheat, placed in five year crop rotation (bean - wheat - maize - sunflower - wheat), after bean, the mean annual amounts of nutrients extracted from soil, have varied according to rates, between 41.9 and 85.1 kg at nitrogen, between 7.8 and 16.1 kg at phosphorus, in dry years and between 66.0 and 131.0 kg at nitrogen, between 12.3 and 26.2 kg at phosphorus, in favorable years (*Tabs. 5 and 6*).

Generally, nitrogen use efficiency is low and, to achieve maximum yields, need for high doses of nitrogen which can increase the risk of environmental pollution.

In order to establish the technological elements for plant growing, fertilization, soil tillage, etc, we must know the soil characteristics.

In experiment conducted on a chernozem soil average nitrogen uptakes were 88–185 kg N/ha, when the average N contents in dry mater of silage maize were 0.8–1.25% and the average dry mater yields were 11.2–14.8 t/ha (Černýe *et al.,* 2012).

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.

Local variations of soil management methods have been studied by Craswell and Godwind (1984), Guş *et al.* (1998), Hera (1999), Aarts *et al.* (2000), Blair *et al.* (2006), Dailey *et al.* (2006), Alan *et al.* (2007) among many others.

Table 5 - Mean annual amounts of nutrients exported from soil by wheat (grains + straw) in dry years, in five year crop rotation, after bean

Fertilizer rate	Grains + straw of wheat kg/ha	Amounts of elements exported from soil, kg/ha		Grain, kg/ha	Yield increases, kg/ha	Agronomic N+P efficienty
		N	P			
N_0P_0	3638	41.9	7.8	1516	-	-
N_0P_{40}	4008	54.4	8.9	1670	154	3.9
$N_{40}P_{40}$	4730	67.1	10.4	2150	634	7.9
$N_{80}P_{40}$	5192	73.7	11.6	2360	844	7.0
$N_{120}P_{40}$	5796	84.3	13.3	2760	1244	7.8
$N_{160}P_{40}$	6006	78.1	15.2	2860	1344	6.7
N_0P_{80}	3885	45.5	9.3	1850	334	4.2
$N_{40}P_{80}$	4956	58.0	12.5	2360	844	7.0
$N_{80}P_{80}$	5502	80.0	13.1	2620	1104	6.9
$N_{120}P_{80}$	6069	85.1	13.9	2890	1374	6.9
$N_{160}P_{80}$	6237	72.6	16.1	2970	1454	6.1
LSD 5%		3,3	0,9		150 kg/ha	

Table 6 - Mean annual amounts of nutrients exported from soil by wheat (grains + straw) in favorable years, in five year crop rotation, after bean

Fertilizer rate	Grains + straw of wheat kg/ha	Amounts of elements exported from soil, kg/ha		Grain, kg/ha	Yield increases, kg/ha	Agronomic N+P efficienty
		N	P			
N_0P_0	5589	66.0	12.3	2430	-	-
N_0P_{40}	6348	88.1	14.4	2760	330	8.3
$N_{40}P_{40}$	6512	92.4	14.3	2960	530	6.6
$N_{80}P_{40}$	7590	107.7	17.0	3450	1020	8.5
$N_{120}P_{40}$	8358	121.5	19.1	3980	1550	9.7
$N_{160}P_{40}$	8946	116.3	22.6	4260	1830	9.2
N_0P_{80}	5964	69.8	14.2	2840	410	5.1
$N_{40}P_{80}$	7014	82.1	17.7	3340	910	7.6
$N_{80}P_{80}$	8358	121.5	19.9	3980	1550	9.7
$N_{120}P_{80}$	9345	131.0	21.4	4450	2020	10.1
$N_{160}P_{80}$	9933	115.6	26.2	4730	2300	9.6
LSD 5%		5,6	2,1		190 kg/ha	

Mean annual amounts of nutrients exported from soil by wheat in dry (14 yr.) and favorable (11 yr.) years in five year crop rotation, have varied according to rates, between 34.5 and 100.7 kg at nitrogen and between 6.5 and 18.4 kg at phosphorus (*Table 7*).

In maize, the mean annual amounts of nutrients extracted from soil together with the harvest, have varied according to rates, between 58.6 and 191.7 kg at nitrogen and between 9.0 and 26.7 kg at phosphorus (*Table 8*).

The prices for inputs used in agriculture have increased, resulting in the global deterioration of the agriculture worldwide. During the 2004-2010 period, the average level of world agricultural prices increased by 50% from its corresponding level in 1986-2003, by comparison, energy prices jumped by 220% and fertilizer prices by 150%. The rapidly growing demand for food, feed and fuel, over the next 20–30 years, will require further improvements of resource use efficiencies of nutrient and water, and phosphorus in especial, for who is a growing concern due of phosphorus crisis, which looming (Godfray *et al.* 2010).

Nitrogen and phosphorus are two elements that determine many environmental problems, such as eutrophication, global change and acidification. Mitigation of the negative environmental impacts caused by these nutrients requires understanding of their linkages through inputs and outputs from the agroecosystem.

Table 7 - Mean annual amounts of nutrients exported from soil by wheat in dry (14 yr.) and favorable (11 yr.) years in five year crop rotation

Fertilizer	In five year crop rotation, after sunflower		In five year crop rotation, after bean	
	N	P	N	P
N_0P_0	34.51	6.48	52.53	9.82
N_0P_{40}	39.19	7.26	69.22	11.35
$N_{40}P_{40}$	53.12	9.55	78.25	12.07
$N_{80}P_{40}$	61.20	11.14	88.65	13.97
$N_{120}P_{40}$	69.88	12.67	100.67	15.86
$N_{160}P_{40}$	75.49	14.25	94.89	18.42
N_0P_{80}	38.44	7.90	56.21	11.45
$N_{40}P_{80}$	55.77	11.97	68.65	14.82
$N_{80}P_{80}$	68.40	12.68	98.27	16.12
$N_{120}P_{80}$	79.71	13.37	105.27	17.20
$N_{160}P_{80}$	81.32	14.65	112.30	20.52
LSD %	3,5	0,9	3,6	2,1

Table 8 - Mean annual amounts of nutrients exported from soil by maize (grains +by-products)

Fertilizer rate	Grains + stalks of maize kg/ha	Amounts of elements exported from soil, kg/ha		Grain, kg/ha	Yield increases, kg/ha	Agronomic N+P efficienty
		N	P			
N_0P_0	7958	58.6	9.0	3460	-	
N_0P_{40}	8786	65.0	11.8	3820	360	9.0
$N_{50}P_0$	9430	79.3	10.8	4100	640	12.8
N_0P_{80}	8993	76.5	12.0	3910	450	5.6
$N_{120}P_0$	10695	91.0	15.7	4650	1190	9.9
$N_{50}P_{80}$	11293	100.9	18.3	4910	1450	11.2
$N_{100}P_{80}$	13156	133.5	18.2	5720	2260	12.6
$N_{150}P_{80}$	13731	153.7	21.5	5970	2510	10.9
$N_{200}P_{80}$	14283	170.6	23.3	6210	2750	9.8
$N_{50}P_{100}$	12029	108.1	18.8	5230	1770	11.8
$N_{100}P_{100}$	13754	161.9	22.5	5980	2520	12.6
$N_{150}P_{100}$	14352	169.8	24.2	6240	2780	11.1
$N_{200}P_{100}$	15433	191.7	26.7	6710	3250	10.8
LSD 5%		4,2	1,8		240 kg/ha	

Using N-efficient management strategies like choice of variety, form and timing of N application, adapted to land conditions, bring reduction in fertilizer N, thus minimizing environmental pollution.

In dry years, in wheat placed in five year crop rotation, the mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 4.0 and 8.0 kg. In favorable years, the mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 4.5 and 10.1 kg.

In wheat, the average N uptake of the control treatment was 45 kg N/ha and varied between 28 - 66 kg N/ha.

At recommended doses for maize in the Moldavian Plain, average quantities of nutrients consumed were of 171-192 kg nitrogen and 24-27 kg phosphorus (*Figs. 1 and 2*).

Nitrogen utilization efficiency shows the ability of plants to transform the nutrients from soil and fertilizers into the yield of the harvested product. The amount of nitrogen export from soil by the plants on the unfertilized control corresponds with the plant potential to use nitrogen from soil.

Establishing nitrogen use efficiency is needed for correlation dose of nitrogen with the absorption of crops during vegetative and reproductive growth. The N agronomic efficiencies and physiological efficiencies in wheat and maize declined with the increase of nitrogen rate (*Tabs. 9, 10 and 11*). Control of nitrogen efficiency is important to obtain maximum economic benefit, not polluting the environment load and reduce nitrogen losses.

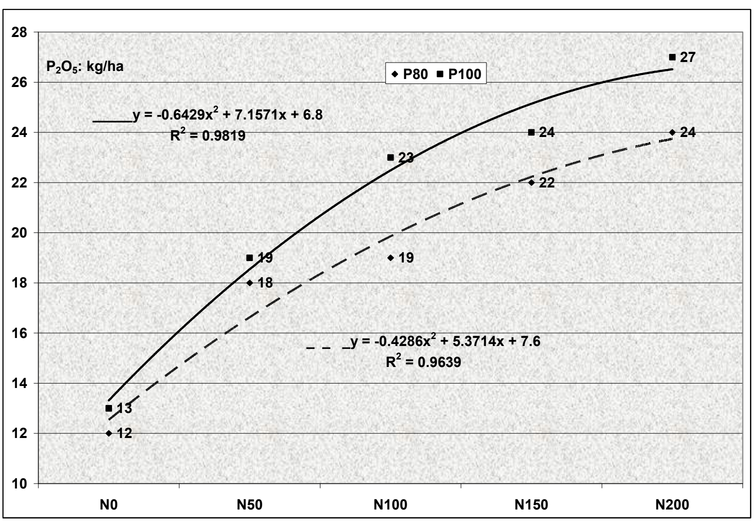

Figure 1- Effects of nitrogen on phosphorus absorption by plants

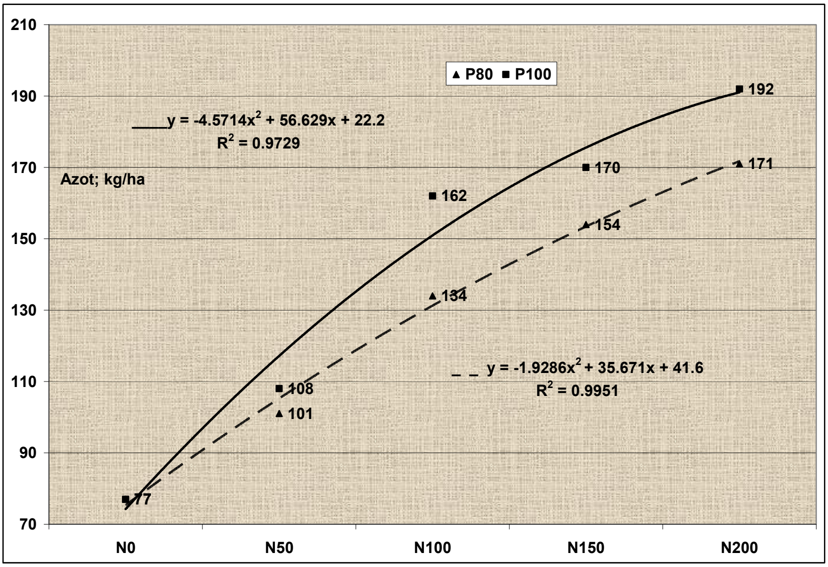

Figure 2 - Nitrogen export from soil at maize to phosphorus doses recommended

Table 9 - Physiological N use efficiency in wheat, placed in five year crop rotation (bean - wheat - maize - sunflower - wheat), after sunflower

Fertilizer rate	In dry years			In favorable years		
	N in grain yield, kg/ha	Yield increases, kg/ha	Physiologic N efficiency, kg/kg	N in grain yield, kg/ha	Yield increases, kg/ha	Physiologic N efficiency, kg/kg
N_0P_0	22.6			34.5		
$N_{40}P_{40}$	35.1	640	51.2	51.2	860	51.5
$N_{80}P_{40}$	39.2	840	50.6	60.6	1320	50.6
$N_{120}P_{40}$	47.1	1230	50.2	68.3	1700	50.3
$N_{160}P_{40}$	52.9	1346	44.4	74.6	1770	44.1
$N_{40}P_{80}$	33.8	840	75.0	54.9	1470	72.1
$N_{80}P_{80}$	43.9	1070	50.2	69.8	1770	50.1
$N_{120}P_{80}$	51.5	1370	47.4	73.9	1870	47.5
$N_{160}P_{80}$	55.0	1410	43.5	80.4	1990	43.4

Table 10 - Physiological N use efficiency in wheat, placed in five year crop rotation (bean - wheat - maize - sunflower - wheat), after bean

Fertilizer rate	In dry years			In favorable years		
	N in grain yield, kg/ha	Yield increases, kg/ha	Physiologic N efficiency, kg/kg	N in grain yield, kg/ha	Yield increases, kg/ha	Physiologic N efficiency, kg/kg
N_0P_0	32.1			51.5		
$N_{40}P_{40}$	49.5	634	36.4	68.1	530	31.9
$N_{80}P_{40}$	54.3	844	38.0	79.4	1020	36.6
$N_{120}P_{40}$	63.5	1244	39.6	91.5	1550	38.8
$N_{160}P_{40}$	62.3	1344	44.5	92.9	1830	44.2
$N_{40}P_{80}$	43.7	844	72.8	61.8	910	88.3
$N_{80}P_{80}$	60.3	1104	39.1	91.5	1550	38.8
$N_{120}P_{80}$	63.3	1374	44.0	97.5	2020	43.9
$N_{160}P_{80}$	56.4	1454	59.8	89.9	2300	59.9

Table 11 - Physiological N use efficiency in maize, placed in five year crop rotation

Fertilizer rate	Grain yield, kg/ha	Yield increases, kg/ha	N in grain yield, kg/ha	Physiologic N efficiency, kg/kg
N_0P_0	3460		42.9	39.8
$N_{50}P_0$	4100	640	59.0	48.6
$N_{12}0P_0$	4650	1190	67.4	46.5
$N_{50}P_{80}$	4910	1450	74.1	47.6
$N_{100}P_{80}$	5720	2260	90.4	50.0
$N_{150}P_{80}$	5970	2510	93.1	43.0
$N_{200}P_{80}$	6210	2750	106.8	48.4
$N_{50}P_{100}$	5230	1770	79.5	48.3
$N_{100}P_{100}$	5980	2520	95.1	49.4
$N_{150}P_{100}$	6240	2780	99.2	45.6
$N_{200}P_{100}$	6710	3250	114.1	39.8

The catchment is the basic territorial unit, where transport factors, for the loss of nutrients include erosion, leaching, runoff, vegetation and soil. Crop rotation helps to make a better use of natural resources and improve soil fertility, reduce erosion, pests and nutrients. To establish a crop rotation, good agronomical aspects, need to be taken into account prior to the economical ones.

Agri-environment measures with the explicit objective of soil conservation, particularly addressing erosion, are common the Member States under Regulations 1698/2005.

Monoculture and short crop rotations, increases the risk of depleting soil fertility, releasing greenhouse gases from lost soil carbon, and increasing inputs of fertilizers, which can pollute water and biodiversity. In the EU-27, among the arable crops, cereals and green fodder occupied the biggest area. Lithuania (79.0%), Poland (74.7%) and Romania (66.8%) had the highest share of cereals among the Member States and Latvia the highest share for green fodder (67.2%).

The analyses carried out on runoff water on slope lands showed that the total nitrogen content from runoff water varied between 7.3 and 17.9 mg/l, according to crop and applied fertilizers.

The results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that water runoff was between 13,10 mm in wheat and 32,7 - 34,5 mm in maize and sunflower crops (*Table 12*). Erosion has affected soil fertility by removing once with eroded soil, high amounts mineral elements, which reached 13.7 - 14.2 kg/ha nitrogen and 0.9 - 1.0 kg/ha phosphorus, in maize and sunflower crops (*Table 12*).

Table 12 - Mean water runoff, soil and mineral element losses, due to erosion, in the Moldavian Plateau

Crop	Runoff (mm)	Eroded soil (t/ha)	Nt at eroded soil	Nt at water (kg/ha)	Total N (kg/ha)	P-AL (kg/ha)	Total NP (kg/ha)
Bean	28.40	3.897	5.690	3.749	9.439	0.429	9.868
Wheat	13.10	0.548	0.800	1.729	2.529	0.061	2.590
Maize	32.70	6.392	9.077	4.611	13.688	0.876	14.564
Sunflower	34.50	6.717	9.605	4.589	14.194	0.967	15.161
Wheat	13.10	0.548	0.800	1.729	2.529	0.061	2.590
Average	24.36	3.620	5.194	3.281	8.476	0.479	8.955

CONCLUSIONS

After 45 years of experiences, in bean-wheat-maize-sunflower-wheat crop rotation, the mean annual amounts of nutrients exported from soil, on average for 25 years, by wheat in dry (14 yr.) and favorable (11 yr.) years have varied according to rates, between 34.5 and 100.7 kg at nitrogen and between 6.5 and 18.4 kg at phosphorus.

The N agronomic efficiencies and physiological efficiencies in wheat and maize declined with the increase of nitrogen rate. Wheat placed in rotation for five years, after sunflower at recommended dose ($N_{160}P_{80}$), physiological efficiency of nitrogen utilization was 43.4 kg grain per kilogram of nitrogen exported from soil.

The mean yield increases, obtained for each kg of a.i. of applied fertilizer, were comprised between 8.3 and 10.1 kg in wheat ($N_{120}P_{80}$-$N_{160}P_{80}$) and between 10.8 and 11.0 kg in maize ($N_{150}P_{80}$-$N_{200}P_{100}$).

Mean annual losses of nitrogen caused by erosion, were of 2,529 kg/ha in wheat, 13,688 kg/ha in maize and 14.149 kg/ha in sunflower.

The use of bean - wheat - maize - sunflower - wheat crop rotation determined the diminution by 43.4% (2,772 t/ha) in the mean annual losses of eroded soil and by 38.5% (5.61 kg/ha) in nitrogen leakages, compared with maize continuous cropping.

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