The impact of the cropping system management on soil erosion and fertility in Northeastern Romania

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ABSTRACT

The influence of different crop structures, rotations and fertilizers on crop yield and soil fertility has investigated at the Agricultural Research and Development Station of Podu-Iloaiei since 1968. These experiments were carried out on a 14 % slope field, on a Cambic Chernozem with clayey loam texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrient supply. The mean annual rainfall amounts, registered in the last 28 years, were higher, with values comprised between 12.7 and 279.2 mm, compared to the multiannual mean on 80 years (544 mm) in 18 years, and lower by 25.3 - 236.7 mm in 10 years. Placing winter wheat in 3 and 4- year crop rotations with annual and perennial legumes has resulted in getting yield increases of 23 - 26 % (646 - 736 kg·ha^{-1}), against continuous cropping. The average yield increases in wheat, during 1981-2008, were between 23 and 26 % (646 - 736 kg·ha^{-1}), due to crop rotation, and between 57 and 101 % (1099 - 1949 kg·ha^{-1}), due to applied fertilizer rates.
The mass of total carbon from Cambic Chernozem in the Moldavian Plain has recorded significant increases at higher than $N_{140}P_{100}$ rates, in organo-mineral fertilization and in 4-year crop rotation, which included melioration plants of perennial grasses and legumes. In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in the organo-mineral fertilization, in 4-year crop rotations + reserve field cultivated with perennial legumes and under $N_{140}P_{100}$ fertilization. In comparison with 4-year crop rotations, in wheat-maize rotation with melioration plants (annual and perennial legumes and perennial grasses), the mean carbon content from soil has diminished from 18.6 to 16.4 C, g·kg^{-1} and the content in mobile phosphorus decreased from 51.6 to 36.8 P-AL, mg·kg^{-1}.
The 40 year use of 3 and 4- year crop rotations has determined the increase in total carbon mass and mobile phosphorus from soil by 10% (1.7 C g·kg^{-1}) and 31%, respectively (11.8 P-AL mg·kg^{-1}), against maize continuous cropping.

Keywords: cropping systems, wheat, soil erosion, fertilizers, manure, organic carbon

INTRODUCTION

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 of soil erosion and the effect of greenhouse gases. (Ailincai C. et al. 2007; Francisco López-Bermúdez et al., 1998; Meijide Ana et al., 2009; Yadav Vineet et al., 2008). The investigations conducted in long-term experiments at Rothamsted have shown that only at high fertilizer rates (>$N_{192}P_{35}K_{90}Mg_{35}$), a significant increase was found in the mass of total organic carbon and stable carbon from soil (Blair et al., 2006). In clayey-loam Mollisol from Kanawha, the value of the organic carbon mass has increased from 33.3 to 37.3 g carbon kg^{-1} soil, when using the rate of 270 kg ha^{-1} N against the unfertilized control, only in maize-oats-alfalfa-alfalfa rotation (Russell, 2006**)**. In the Big Creek hydrographical basin from Southern Illinois, with mean annual rainfall of 1220 mm, the mean content of

organic carbon has decreased after 154 years, from 6.95 to 2.03 kg C m^{-2} in farming fields (during 1851 - 2005), and from 5.61 la 5.19 kg C m^{-2} in afforested areas. In the forested areas, until 1938, and used for cropping in the last 67 years (1938-2005), the content of organic carbon has decreased from 6.76 to 3.40 kg C m^{-2} (Yadav et al., 2008).

METHODS

Since 1968, the investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei have followed the influence of different crop structures, rotations and fertilizers on crop yield and soil fertility. These experiments were carried out on a 14% slope field, on a Cambic Chernozem with clayey loam texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrient supply. The soil on which physical and chemical analyses were done, was sampled at the end of plant growing. The organic carbon content was determined by the Walkley-Black method, the mobile phosphorus content 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 effects of treatments. The mean annual rainfall amounts, registered in the last 28 years, were higher, with values comprised between 12.7 and 279.2 mm, compared to the multiannual mean on 80 years (544 mm) in 18 years, and lower by 25.3-236.7 mm in 10 years.

RESULTS AND DISCUSSION

The investigations carried out on eroded soil have tried to establish the crop rotations and fertilization systems, which contributed to maintain and restore soil fertility. Placing winter wheat in 3 and 4- year crop rotations with annual and perennial legumes has resulted in getting yield increases of 23 - 26 % (646 - 736 kg ha^{-1}), as compared to continuous cropping. The mean yield increases in wheat, during 1981-2008, were between 23 and 26 % (646 - 736 kg ha^{-1}), due to crop rotation and between 57 and 101 % (1099 - 1949 kg ha^{-1}), due to applied fertilizer rates (Table 1; 2). Applying high fertilizer rates ($N_{140}P_{100}$) in maize has determined, in the last 28 years, an average yield increase of 86 % (2837 kg ha^{-1}), while the use of low mineral fertilizer rates ($N_{60}P_{40}$), together with 30 t ha^{-1} of organic manure, resulted in getting an yield increase of 89% (2925 kg ha^{-1}) (Table 2). The mean yield increases, obtained in maize during 1981-2008, were between 13 and 31 % (564 - 1364 kg ha^{-1}), due to crop rotation and between 35 and 89 % (1150 - 2925 kg ha^{-1}), due to applied fertilizer rates. The mass of total carbon from Cambic Chernozem in the Moldavian Plain has recorded significant increases at higher than $N_{140}P_{100}$ rates, in organo-mineral fertilization and in 4-year crop rotation, which included melioration plants of perennial grasses and legumes (Table 3). In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in the organo-mineral fertilization, in 4-year crop rotations + reserve field cultivated with perennial legumes and under $N_{140}P_{100}$ fertilization. The analyses conducted on soil samples, taken from the field on which wheat-maize rotation had been used for 40 years, pointed out the worsening of some soil chemical characteristics. In comparison with 4-year crop rotations, in wheat-maize rotation with melioration plants (annual and perennial legumes and perennial grasses), the mean carbon content from soil has diminished from 18.6 to 16.4 C**,** g kg^{-1}, and the content in mobile phosphorus decreased from 51.6 to 36.8 P-AL, mg kg^{-1} (Table 3; 4).
Applying a rate of $N_{140}P_{100}$ for 40 years has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) in wheat continuous cropping and wheat-maize rotation and was maintained within the weakly acid interval (5.9-6.8) in 3 and 4- year crop rotations with annual and perennial legumes. The differences concerning the pH value at different crop rotations had no significant values, but in 3 and 4 -year crop rotations with perennial grasses and legumes, the pH diminution, when applying high nitrogen rates, was limited to 6.1-6.2. The lowest pH values were registered in wheat-maize rotation, where long-term application of $N_{100}P_{80}$ and $N_{140}P_{100}$ rates has diminished pH until 5.9 and 5.6, respectively.

In Cambic Chernozem, on the slope lands from the Moldavian Plain, a good supply in mobile phosphorus of field crops (37-72 mg kg^{-1}) was maintained in annual application of a rate of $N_{100}P_{80}$ and a very good supply (69-78) at the rate of $N_{60}P_{40}$+30 t ha^{-1} of manure, applied in crops from 3 or 4 -year crop rotations with perennial grasses and legumes (Table 4). After 40 years of testing, the lowest rate of mobile phosphorus accumulation in soil was recorded in wheat-maize rotation, and the highest one, in 3 and 4- year crop rotations, including annual and perennial legumes, which leave in soil easily degradable crop residues.

Table 1. Influence of the rotation on wheat and maize yield during 1981 – 2008

Crop rotation	Wheat yield		Differ.	Sign.	Maize Yield		Differ.	Sign.
	kg ha^{1}	%	kg ha^{1}		kg ha^{1}	%	kg ha^{1}	
Continuous cropping	2864	100	0		4398	100		
Wheat - maize	2898	101	34		4962	113	564	x
Peas -wheat-maize	3510	123	646	xxx	5380	122	982	xxx
Peas -wheat-maize-sunflower + reserve field cultivated with legumes and perennial grasses	3600	126	736	xxx	5762	131	1364	xxx
LSD 5 %			194				459	
LSD 1 %			365				622	
LSD 0.1 %			577				834	

Table 2. Influence of fertilizers on wheat and maize yield during 1981 - 2008

Crop rotation	Wheat yield		Differ.	Sign.	Maize Yield		Differ.	Sign.
	kg ha^{-1}	%	kg ha^{-1}		kg ha^{-1}	%	kg ha^{-1}	
N_0P_0	1936	100	0		3283	100	0	
$N_{60}P_{40}$	3035	157	1099	***	4433	135	1150	***
$N_{100}P_{80}$	3455	178	1519	***	5585	170	2302	***
$N_{140}P_{100}$	3780	195	1844	***	6120	186	2837	***
$N_{60}P_{40}$+30 t ha^{-1} manure	3885	201	1949	***	6208	189	2925	***
LSD 5 %			224				532	kg ha^{-1}
LSD 1 %			395				720	kg ha^{-1}
LSD 0.1 %			607				955	kg ha^{-1}

Table 3. Influence of long-term fertilization on the content of carbon from soil (C, g/kg^{-1})

Treatment	*Mcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Average	%	Differ.
N_0P_0	15.9	15.2	16.5	16.8	16.1	100	0
$N_{60}P_{40}$	15.7	14.8	16.9	17.1	16.1	100	0.0
$N_{100}P_{80}$	16.4	16.2	17.3	18.2^{x}	17.0	106	0.9
$N_{140}P_{100}$	17.2	17.0^{x}	18.5^{xx}	19.7^{xxx}	18.1	112	2.0^{x}
$N_{60}P_{40}$+30 t ha^{-1} manure	19.4^{xxx}	19.0^{xxx}	20.1^{xxx}	21.4^{xxx}	20.0	124	3.9^{xxx}
Mean	16.9	16.4	17.9	18.6			
Difference	0.0	-0.5	1.0	1.7^{xx}			
	Interaction	Crop rotation		Soil background			
LSD 5%	1.2	1.4		1.5			
LSD 1%	1.6	1.8		2.1			
LSD 0.1%	2.1	2.4		2.7			

*Mcc - Maize continuous cropping; M - maize; W - wheat; P - pea; S - sunflower; *GL - reserve field cultivated with perennial grasses and legumes

Table 4. Influence of long-term fertilization and crop rotation on the content of mobile phosphorus from soil (P-AL, mg kg^{-1})

Treatment	* Wcc	W-M	P-W-M	P-W-M-S+GL	Mean	Differ.	Signif.
N_0P_0	13	10	14	15	13.0	0	
$N_{60}P_{40}$	29	26	35	40	32.5	19.5	xxx
$N_{100}P_{80}$	41	38	49	56	46.0	33.0	xxx
$N_{140}P_{100}$	58	52	63	69	60.5	47.5	xxx
$N_{60}P_{40}$+30 t ha^{-1} manure	67	58	69	78	68.0	55.0	xxx
Mean	41.6	36.8	46.0	51.6	44.0		
Difference	0	-4.8	4.4	10.0			
Significance		0	x	xxx			
	Interaction	Rotation	Fertilizer				
LSD 5%	3.3	3.8	4.3				
LSD 1%	4.4	5.1	5.7				
LSD 0.1%	5.8	6.7	7.5				

CONCLUSIONS

On the Cambic Chernozem from the Moldavian Plain, placing winter wheat and maize in rotation peas-wheat-maize-sunflower + reserve field cultivated with perennial grasses and legumes, has resulted in getting yield increases of 26% (736 kg ha^{-1}) and 31 % (1364 kg ha^{1}), respectively, against continuous cropping.

The total carbon mass on Cambic Chernozem from the Moldavian Plain has recorded significant increases at higher than $N_{140}P_{100}$ rates, at organo-mineral fertilization and in 4-year crop rotation + reserve field cultivated with perennial grasses and legumes. In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in organo-mineral fertilization, in 4-year crop rotation + reserve field cultivated with perennial legumes, and at $N_{140}P_{100}$ fertilization.

The mean annual losses of nitrogen, phosphorus and potassium, once with water runoff and eroded soil on 14% slope fields, were of 19.9 kg ha^{-1} in maize continuous cropping, 11.9 kg ha^{-1} in wheat-maize rotation and 8.1 kg ha^{-1} in the rotation peas-wheat-maize-sunflower +two reserve fields cultivated with perennial grasses and legumes.

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