THE IRRIGATION INFLUENCE UNDER THE SOIL, MICROCLIMATE AND PLANTS IN MAIZE FROM CRIŞURILOR PLAIN

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Summary

The paper is based on the researches carried out in the long term trial placed on the preluvosoil from Oradea in 1976, for establishing the soil water balance. In the irrigated variant the soil moisture was determined 10 to 10 days for maintaining the soil water reserve on irrigation depth (0 – 50 cm for wheat and bean, 0 – 75cm for maize, sunflower, soybean, sugarbeet, potato and alfalfa 1st year and 0 – 100 cm for alfalfa 2nd year) between easily available water content and field capacity. Thus, an average irrigation rate of 2560 m³/ha was used in the 9 experimental crops. The average of the annual rainfall for the 1976 – 2008 period was of 625.0 mm. The technologies used were correlated with the needes of the crops, such as melioration crop rotation, chemical fertilizers in accordance with the chemical export on the yield, manure (40 t/ha) was used in potato and sugarbeet. After 33 years of the irrigation use the soil structure degree (38.62%) did not decrease when compared to the unirrigated maize – wheat crop rotation (37.01%). Bulk density, total porosity, penetration resistance and hydraulic conductivity have worse values than the ones in the unirrigated variant. The humus content is very close to the humus content determined in 1976, the phosphorus and the potassium content increased very much in comparison with the initial content (117 ppm vs 22.0 ppm); (180.0 ppm vs 102 ppm). The use of the adequate fertilization system and of the irrigation water with a good qaulity did not determine a decrease of the pH value of the soil. The irrigation determined the improve of the microclimate conditions, the increase of the plant water consumption, yield gains very significant statistically and higher protein content of the maize grains.

INTRODUCTION

Drought and desertification are the major problems of the world in the context of the climate change (Doorembos, Pruitt, 1992, Kay, Angers,1999, Lado, Ben-Hur and Assouline, 2005, Page, Miller and Keeney,1982, Wakindiki, Ben-Hur, 2002) There are climatic changes in Romania, too (Canarache, 1990); Dobrogea and the South-Eastern part are considered the area with desertification; other areas are an important part of Moldavia and the Romanian Plain and a small part of the Western Plain (Domuta, 2005). The Crisurilor Plain is a part of the Western Plain and it was known for its large areas with water logging and drought and also for that the rainfall is not in accordance with the optimum water requirement of the crops. In 1968 the researches regarding the irrigation crop started in Girisu de Cris and in 1976 the researches regarding the crops' water consumption were carried out in Oradea (Domuta, 2003, Grumeza, Kleps, 2005)

The researches regarding the irrigation use in the Crisurilor Plain emphasized the irrigation opportunity in the sustainable agriculture system, the yield gains produced by irrigation were statistically significant every year, the maize, soybean and sugarbeet yields showed improvements in their stability and quality, and the water use efficiency improved, as well. The correlations quantified in the soil-water-plant-atmosphere system (soil moisture-yield, soil moisture – yield gains, water consumption – yield, climate indexes – yield) and economical efficiency sustain the irrigation opportunity in this area (Domuta, 2003, 2005, 2007, 2009, Borza, 2006, Grumeza, Kleps, 2005).

The paper presents the irrigation impact on the main physical and chemical properties of the soil based on a 33 years' study.

MATERIAL AND METHODS

The researches were carried out in the long term trial placed in 1976 on the preluvosoil from Oradea, in order to study the soil water balance and the crops water consumption. The research data was compared with the data determined in an experiment with whea-maize crop rotations near the research field for water balance study. The crop rotatation used in the research field for the soil water balance study was a melioration one: alfalfa 1st year – alfalfa 2nd year – maize – bean – wheat – soybean – sugarbeet – sunflower – potato.

In the ploughed land, the colloid clay content is of 31.5%.

The field capacity (FC) is a medium one on the soil profile and the wilting point (WP) has a medium value to 80 cm depth and a high value below this depth. The easily available water content (Wea) was established considering the soil's texture[6]. As a consequence, the following formula was used: Wea=WP+2/3(FC-WP).

During the research period (1976-2008), on the irrigation depth (0-50 cm for wheat and bean; 0-75 cm for maize, soybean, sunflower, sugarbeet, potato, alfalfa 1st year; 0-75 cm for alfalfa 2nd year) ten to ten days determinations of the soil moisture permitted to maintain the soil water reserve between the easily available water content and the field capacity. The accomplishment of this objective determined the use of 2.560 m^3/ha of irrigation water in the studied period and in the studied crops.

The water source for irrigation is ground water at a 15 m depth. The main chemical properties of the irrigation water used are presented in table 1. The natrium content (12.9%) is low and the salinization potential is low, too (CSR=-17; SAR=0.52) (table 1).

Table 1

Chemical parametes of the irrigation water used in the research field, Oradea

Ca^{2+}	Mg^{2+}	Na^{+}	K^{-}	CO^{2-}_3	HCO_3	CL^{-}	SO_4^{2-}	pH	Na %	Min. rezid.fix g/l	SAR	CSR	N. Florea Class
mg/litre													
49.1	44.0	20.8	2.7	-	266.8	35.4	80.3	7.3	12.9	0.5	0.53	-1.8	II

The crop technologies included the use of the chemical fertilizers according to the yield export for every crop and a medium rate on the melioration crop rotation: N 140 kg/ha s.a, P_2O_5 110 kg/ha s.a and K_2O 90 kg/ha s.a. In the sugarbeet and the potato crop a dose of 40 t/ha of manure was used.

The macrostructure's hydrostability (aggregates >0.25 mm) was determined using the Cseratzki method (Gh. Budoi, A. Penescu, 1996). The bulk density, hydraulic conductivity and the penetration resistance were determined using the same cylinders with a volume of 100 cm^3. The humus content, pH, the mobile phosphorus and mobile potassium content were determined using the common methods of the agrochemistry laboratories, in a laboratory of the Agricultural Research and Development Station Oradea.

De Martonne aridity index (IdM) was determined using the formula

$$\text{IdM} = \frac{12\text{p}}{t+10} \quad \text{in wich:}$$

p= monthly rainfall (mm); t= average temperature on the month (^oC)

Characterization class: < 15 arid; 15–24 demiarid; 24–30 moderate drought; 31–35 moderate wet I; 36–40 moderate wet II; 41–50 wet; 51–60 wet I; 61–80 wet II; 81–100 very wet; >100 excessive wet (Domuța, 2009)

Domuța climate index was determined using the formula:

$$\text{IcD} = \frac{100\text{W} + 12.9\text{A}}{\sum \text{t} + \text{Sb}} \quad \text{in wich:}$$

W= water (mm); A= air humidity (%); Σt = sum of the monthly average temperature (^oC); Sb= sun brilliance.

Characterization class: < 3 excessive drought; 3.1–5 very drought; 5.1–7 droughty; 7.1–9 median droughty; 9.1–12 median wet; 12.1–15 wet I; 51-60 wet I; 15.1–18 wet II; 18.1–25 wet II; >25 excessive wet (Domuța, 2009)

Both de Martonne aridity index and Domuța climate index for irrigated vriant included the irrigation rate in the calculation formula (Domuța C., 2009)

Water consumption was determined using the soil water balance method.

The research data was analysed using the variance analysis method (Domuta, 2009).

RESULTS AND DISCUSSION

The irrigation influence on the soil physical properties

The irrigation influence on the soil structure

The soil aggregates with a diameter bigger than 0.25 mm from the variant with irrigated melioration crop rotation had a value of 38.62%, higher than the value (37.01%) determined in the variant with unirrigated wheat-maize crop rotation but the difference (1.61%; 4%) is not statistically assured. In the variant with unirrigated melioration crop rotation, the macro aggregates' hydro stability increased statistically very significant in comparison with the unirrigated wheat-maize and an important difference (12.58%; 32.6%) was registered in comparison with the irrigated melioration crop rotation (table 2)

Table 2

Irrigation influence (1976-2009) on the macrostructue's hydrostability, in the conditions of the preluvosoil from Oradea

Crop rotation	Macrostructure hydrostability		Difference		Statistical significance
	%	%	%	%	
1.Unirrigated wheat–maize crop rotation	37.01	100	-	-	Control
2. Irrigated melioration crop rotation	38.62	104	1.61	4	-
3. Unirrigated melioration crop rotation	51.20	138	14.19	38	xxx
LSD 5%					2.01
LSD 1%					3.95
LSD 0.1%					6.03

Analyzing the situation of the macro aggregates for every determined diameter, a very different situation was registered regarding the macro aggregates with a diameter > 5.0 mm; in the variant with unirrigated melioration crop rotation a value (2.80%) with 618% higher than the value (0.39%) from the unirrigated wheat-maize crop rotation was determined; the value (0.62%) from the irrigated melioration crop rotation is with 39% higher than the value registered in the unirrigated wheat-maize crop rotation. There were differences regarding the macro aggregates' hydro stability in the 2.0 mm, 1.0 mm and 0.25 mm case, too (table 3).

Table 3

Macroaggregates diameter (mm) under the irrigation influence in the conditions of the preluvosoil from Oradea

Crop rotation	Macro aggregates diameter							
	>5 mm		2.1-5 mm		1.1-2.0 mm		0.25 – 1.0 mm	
	%	%	%	%	%	%	%	%
1.Unirrigated wheat–maize crop rotation	0.39	100	3.88	100	3.10	100	29.64	100
2. Irrigated melioration crop rotation	0.62	139	2.88	74	3.45	111	31.64	107
3. Unirrigated melioration crop rotation	2.80	718	3.90	101	3.76	121	40.74	137

The irrigation influence on the bulk density and on the total porosity

In the variant with unirrigated wheat-maize crop rotation, the value of the bulk density (1.34 g/cm^3) is high. In the variant with irrigated melioration crop rotation, the value of the bulk density (1.40 g/cm^3) increased statistically significant but is situated in the same characterization class. The value from unirrigated melioration crop rotation (1.20 g/cm^3) is statistically very significant lower than the value registered in the wheat-maize crop rotation emphasizing the importance of the melioration crop rotation in the evolution of the soil's physical properties (table 4).

Table 4

Irrigation influence (1976-2009) on the bulk density of the preluvosoil from Oradea

Crop rotation	Bulk density		Difference		Statistical significance
	g/cm^3	%	g/cm^3	%	
1.Unirrigated wheat–maize crop rotation	1.34	100	-	-	Control
2. Irrigated melioration crop rotation	1.40	104.5	0.06	4.5	x
3. Unirrigated melioration crop rotation	1.20	89.6	-0.14	-10.4	000
LSD 5%					0.05
LSD 1%					0.09
LSD 0.1%					0.13

As a consequence, in comparison with the total porosity (49.4 %) determine din the unirrigated wheat-maize crop rotation, in the irrigated melioration crop rotation a smaller value was determined (47.1%) but the values are situated in the same characterization class. The value of the total porosity (54.7%) in the unirrigated melioration crop rotation is statistically very significant, higher than the one registered in the unirrigated wheat-maize crop rotation (table 5).

Table 5

Irrigation influence (1976-2009) on the total porosity of the preluvosoil from Oradea

Crop rotation	Total porosity		Difference		Statistical significance
	%	%	%	%	
1.Unirrigated wheat–maize crop rotation	49.4	100	-	-	Control
2. Irrigated melioration crop rotation	47.1	95.4	-2.3	-4.6	0
3. Unirrigated melioration crop rotation	54.7	110.8	5.3	10.8	xxx
LSD 5%					0.9
LSD 1%					2.6
LSD 0.1%					4.9

The irrigation influence on the penetration resistance

In the irrigated melioration crop rotation the value of the penetration resistance (31.38 kg/cm^2) is statistically significant higher than the value (29.3 kg/cm^2) determined in the unirrigated wheat-maize crop rotation but the values are situated in the same characterization class, a median one. In unirrigated conditions, the melioration crop rotation determined a decrease of the penetration resistance with 32.7% statistically very significant. The characterization class changes to "small", in this case (table 6).

Table 6

Irrigation influence (1976-2009) on the penetration resistance of the preluvosoil from Oradea

Crop rotation	Penetration resistance		Difference		Statistical significance
	kg/cm^2	%	kg/cm^2	%	
1.Unirrigated wheat–maize crop rotation	29.3	100	-	-	Control
2. Irrigated melioration crop rotation	31.38	107.1	0.8	7.1	x
3. Unirrigated melioration crop rotation	19.71	67.3	-3.7	-32.7	000
LSD 5%					0.6
LSD 1%					1.4
LSD 0.1%					3.5

The irrigation influence on the hydraulic conductivity

Irrigation did not have a statistically significant influence, the value of the hydraulic conductivity registered in the melioration crop rotation, 13.5 mm/h, is very close to the value registered in the wheat-maize crop rotation (14.0 mm/h). In the unirrigated melioration crop rotation, the hydraulic conductivity (20.6 mm/h) is statistically very significant higher than the value determined in the unirrigated wheat-maize crop rotation (table 7).

Table 7

Irrigation influence (1976-2009) on the hydraulic conductivity of the preluvosoil from Oradea

Crop rotation	Hydraulic conductivity		Difference		Statistical significance
	mm/h	%	mm/h	%	
1.Unirrigated wheat–maize crop rotation	14.0	100	-	-	Control
2. Irrigated melioration crop rotation	13.5	96.5	-0.5	-3.5	-
3. Unirrigated melioration crop rotation	20.6	147.2	6.6	47.2	xxx
LSD 5%					1.7
LSD 1%					3.1
LSD 0.1%					5.6

The irrigation influence on the soil chemical properties

The irrigation influence on the humus content

In the melioration crop rotation conditions and good soil management practices in comparison with the humus content (1.7%) in the start year of the researches, a very close value (1.8%) was registered in the irrigated variant in 2008. In unirrigated conditions the melioration crop rotation and the applied soil management determined the increase of the humus content (1.9%) in comparison with the start year; the difference (11.8%) is distinctively significant (table 8).

Table 8

Irrigation influence (1976-2009) on the humus content of the preluvosoil from Oradea

Specification	Humus		Difference		Statistical significance
	%	%	%	%	
1. In 1976	1.70	100	-	-	Control
2. In 2008 (irrigated)	1.67	98.3	-0.03	-1.7	-
3. In 2008(unirrigated)	1.90	111.8	0.20	11.8	xx
LSD 5%					0.07
LSD 1%					0.12
LSD 0.1%					0.21

The irrigation influence on the pH value

In 2008, the soil reaction (pH=6.0) in the irrigated variant increased, distinctively significant, in comparison with the value of the soil reaction (pH=5.81) determined in the start year of the experiment. The explanation consists of the Ca^{2+} high content of the irrigation water used in the research field. In unirrigated variant the pH value (5.58) decreased, distinctively significant due to the chemical fertilizers use (table 9).

Table 9

Irrigation influence (1976-2009) on the pH values of the preluvosoil from Oradea

Specification	pH		Difference		Statistical significance
	Value	%	Value	%	
1. In 1976	5.81	100	-	-	Control
2. In 2008 (irrigated)	6.00	103.3	0.29	3.3	xx
3. In 2008(unirrigated)	5.58	96.1	-0.23	-3.9	00
LSD 5%					0.11
LSD 1%					0.17
LSD 0.1%					0.31

The irrigation influence on the mobile phosphorum and potassium

The mobile phosphorus content of the preluvosoil from the research field in the start year, 22.0 ppm was low, but after 33 years of good agriculture practices – melioration crop rotation with alfalfa, chemical fertilizers doses in accordance with the yield export – the mobile phosphorus content became very good, 117.0 ppm in unirrigated conditions and 109.0 ppm in irrigated conditions; the differences in comparison with the start year are statistically very significant both in unirrigated and irrigated conditions (table 10).

Table 10

Irrigation influence (1976-2009) on mobile phosphorus content of the preluvosoil from Oradea

Specification	P_{AL}		Difference		Statistical significance
	ppm	%	ppm	%	
1. In 1976	22.0	100	-	-	Control
2. In 2008 (irrigated)	109.0	495.5	87.0	395.5	xxx
3. In 2008(unirrigated)	117.0	531.9	95.0	431.9	xxx
LSD 5%					12
LSD 1%					21
LSD 0.1%					39

The mobile potassium content of the preluvosoil in the start year (183.0 ppm) was high and, after 33 years, the mobile potassium content was very high, 290.0 ppm in unirrigated conditions and 240.0 ppm in irrigated conditions; the differences in comparison with the start year are statistically very significant (table 11).

Table 11

Irrigation influence (1976-2009) on mobile potassium content of the preluvosoil from Oradea

Specification	K_{AL}		Difference		Statistical significance
	ppm	%	ppm	%	
1. In 1976	183.0	100	-	-	Control
2. In 2008 (irrigated)	240.0	131.2	57	31.2	xxx
3. In 2008(unirrigated)	290.0	158.5	107	58.5	xxx
LSD 5%					12
LSD 1%					19
LSD 0.1%					30

The irrigation influence on the microclimate conditions

The irrigation determined the improve of report between water and temperature quantified by de Martonne aridity index with 126%; the microclimate was characterized "wet" in comparison with "demiarid", the microclimate of the unirrigated maize. The use of the Domuța climate index show a "wet I" microclimate in comparison with "median drought" the microclimate of the unirrigated maize. (table 12)

Table 12

Irrigation influence on microclimate in maize, Oradea 2007-2009

Variant	Irrigation season (April-August)		
	Value	%	Microclimate characterisation
de Martonne aridity index (IdM)			
Unirrigated	21.7	100	demiarid
Irrigated	49.1	226	wet
Domuța climate index (IcD)			
Unirrigated	7.0	100	median drought
Irrigated	14.5	207	wet I

The irrigation influence on the plants water consumption

Total water consumption of the maize plants increased with 45.1% in irrigated conditions, variation interval 9-145%. The participation percentage of the irrigation in covering of the total water consumption across the yeas was between 7.4% and 61.2% (table 13).

Table 13

Irrigation influence on maize water consumption, Oradea 1976-2009

Variant	Total water consumption		Covering sources			
	m^3/ha	Variation interval %	Soil water reserve	Rainfall	Irrigation	
					m^3/ha	Variation interval %
Unirrigated	4343	100	1064	3279	-	-
Irrigated	6300	109 – 245	536	3279	2452	7.4 – 61.2

The irrigation influence on the maize yield quantity and quality

The irrigation determined an yield gains of 78%, variation interval 7-812%. The yield stability was improved, too; the standard deviation value decreased with 42.6% (table 14)

The protein content of the maize grains increased in the irrigated variant in comparison with unirrigated variant with 19.7%. As consequence, the relative difference between the protein production from irrigated varint and protein production from unirrigated variant (115%) is bigger than relative difference between grosss production (78%) (table 15).

Table 14

Irrigation influence on maize yield, Oradea 1976-2009

Variant	Yield				Standard deviation	
	Average		Variation interval			
	Kg/ha	%	Kg/ha	%	Kg/ha	%
Unirrigated	6870	100	1510 -11840	100	3271	100
Irrigated	12232	178	7850 - 16480	107 - 912	1879	57.4

LSD $_{5\%}$= 370; LSD $_{1\%}$= 490; LSD $_{0.1}$%= 720

Table 15

Irrigation influence on the grains protein content of the maize, Oradea 2007-2009

Variant	Protein content			
	%	%	Kg/ha	%
Unirrigated	8.88	100	605.0	100
Irrigated	10.63	119.7	1300.3	215

CONCLUSIONS

The researches that were carried out in the long term trial placed on the preluvosoil from Oradea, in 1976, in the Northern-Western part of Romania, led to the following conclusions:

- In the melioration crop rotation with alfalfa, after 33 years of a correct irrigation use, the macro aggregates' hydro stability degree (38.62%) did not decrease in comparison with the unirrigated wheat-maize crop rotation. In unirrigated conditions, the value (51.2%) determined in the melioration crop is very significant, higher than the value determined in the wheat-maize crop rotation; the highest differences were registered in the aggregates with a diameter bigger than 5 mm.
- In the irrigated melioration crop rotation, the bulk density, total porosity, penetration resistance and the hydraulic conductivity had worse values than the ones in the unirrigated wheat-maize crop rotation. In the unirrigated melioration crop rotation, the values were very significant better than the values from unirrigated wheat-maize.
- After 33 years of a correct irrigation use and in the conditions of the melioration crop rotation and organic and chemical fertilization in accordance with the yield export, the humus content did not decrease significant in comparison with the initial content 1.67% vs. 1.4%; in the unirrigated variant the difference is statistically very significant bigger than the initial content.
- The use of the irrigation water with a Ca^{2+} high content determined an increase of the pH value distinctively significant (6.0 vs. 5.81) in comparison with the initial pH. In the unirrigated variant, the chemical fertilizers use determined a decrease distinctively significant (5.5 vs. 5.81) of the pH in comparison with the initial value.
- The mobile phosphorus increased in comparison with the initial value (22.0 ppm) with 39.5% in the irrigated variant and with 431.9% in the unirrigated variant. The increase of the mobile potassium was of 31.2% and 58.5%. All the differences in comparison with the initial values are statistically very significant.

The irrigation determined the improve of the microclimate conditions, the increase of the plants water conditions, the yield gains very significant statistically and bigger protein content of the maize.

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