FERTILIZATION A WAY TO IMPROVE OF THE WATER USE EFFICIENCY IN MAIZE CROP FROM CRISURILOR PLAIN

Borza Ioana *

*University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048 Oradea; Romania, e-mail: borzaioanamaria@yahoo.com

Abstract

The paper studies the influence of organic and organic-mineral fertilization on water use efficiency and irrigation water consumption based on researches carried out in the experience field at Agricultural Research and Development Station Oradea. Following consumed a higher quantity of water from soil reserve and the values of total water consumption increased. Fertilization with manure determined the accumulation of a high quantity of water in the soil reserve. In average on the period 2013-2014 under unirrigation conditions the fertilization with manure 30 t/ha was obtained an yield gain of 29% in comparison with unfertilized variant; through organic-mineral fertilization the yield gain was higher (59%). Organic fertilization and especially organic-mineral fertilization determined increasing of water use efficiency.

Key words: maize, chemical fertilizers, organic fertilizers, water use efficiency

INTRODUCTION

The maize plant system is the most surprising that nature has for energy storage. From a seed weighs around a third frame, sprouts and grows into a tall plant about nine weeks to two to three meters, and around eight weeks following, it will produce 600-1000 grains. How realizes the maize plant this process is explained by the existence of a tremendous "laboratory" for conversion of solar energy into organic matter and secondly, by storing large amounts of energy in a product so focused that is maize grain (Cristea, 2004, Borza, 2006, Borza, Stanciu, 2010, Borza et al., 2011).

Maize grains are used in human nutrition, as a raw material and animal feed industry (Bîlteanu, Bîrnaure, 1991, Borcean, 2004, Muntean et al., 2011).

In the literature assessing of water efficiency is achieved by indicators that take into account all water consumption or only efficiency of irrigation water (Doorembos and Kasami, 1986 Grumeza et al., 1989; Doorembos and Pruitt 1992; Domuţa, 1995). Both indicators addresses the issue of water use efficiency from two perspectives: first comes to yield element, highlighting the quantity of yield (gain yield) obtained at 1 m^3 water consumed or used (Crăciun1990, Domuţa et al., 2000, Naescu, 2003) and the second factor highlights water consumption, showing the quantity of water used to obtain 1 kg main yield (gain yield) (Botzan, 1996 Grumeza et al., 1989, Domuţa, 1995, Tuşa, 1994, Petrescu, 1999).

Water use efficiency is influenced by pedoclimatic conditions, crop rotation used, plant density, weeds, diseases and pests, water reserve (Domuţa et al. 2000, Borza, 2006).

The paper studies the influence of organic and organo-mineral fertilization on water use efficiency and irrigation water consumption based on researches conducted by Domuta C. located in the experience field from Agricultural Research and Development Station Oradea in 1999.

MATERIAL AND METHOD

The research was made on preluvosoil conditions from Oradea. The soil is characterized by a very high hydrostability of soil aggregates more than 0.25 mm, 47.5% of layer by 0-20 cm.

Bulk density - 1.41 g/cm3 - characterizes a poorly compacted soil at depth 0-20 cm; on other depths studied the apparent weight highlights a moderately and strongly compacted soil. (Brejea, 2010, Brejea, Domuța, 2011). On watering depth (0-50 cm, 0-75 cm) and on 0-150 cm the soil is strongly compacted.

The soil had a total medium porosity at depth by 0-20 cm, 20-40 cm, 40-60 cm and less in depth by 6-80 cm, 80-100 cm and 100-150 cm. Total porosity values decrease on the soil profile from the surface to depth. Hydraulic conductivity is high on the depth 0-20 cm, medium on depth by 20-40 cm and 40 cm, low and very low on the following depths studied.

Field capacity had a middle value throughout the soil profile and wilting coefficient is also worth to middle depth of 80 cm and higher below this depth (Borza et.al., 2011) (Table 1).

Table 1

Physical and hydro physical properties of preluvosoil from research field of Oradea

Depth - cm -	Total aggregates %	Clay 0.002%	BD g/cm3	K mm/h	PT %	Field Capacity		Wilting Point coefficient		Easily available water content	
						%	m^3/ha	%	m^3/ha	%	m^3/ha
0-20	47.5	31.5	1.41	21.0	21	24.2	682	9.2	259	19.2	542
20-40	-	34.1	1.52	10.5	49	23.6	717	9.4	286	18.9	575
40-60	-	39.8	1.58	4.4	48	25.1	768	11.1	351	19.9	630
60-80	-	39.3	1.65	1.0	43	24.4	828	10.8	356	20.4	672
80-100	-	38.8	1.57	0.5	40	23.8	766	12.2	383	20.4	640
100-150	-	37.6	1.54	0.1	39	24.0	1833	14.2	1093	20.6	1586
0-50	-	-	1.49	-	-	24.0	1787	9.7	720	19.2	1431
0-75	-	-	1.53	-	-	24.2	2782	10.1	1158	19.5	2240
0-100	-	-	1.55	-	-	24.3	3769	10.5	1627	19.7	3055
0-150	-	-	1.55	-	-	24.1	5611	11.7	2720	20.0	4646

The chemical analyzes show that soil in the research field has a slightly acid reaction throughout the depth studied, with increasing values from surface to depth.

Humus supply is poor, and the total nitrogen, low – medium on the entire depth researched.

C/N ratio has a value higher on depth of 0-20 cm (8,01) and decreases with depth determination.

Mobile potassium content of soil is low - medium, with values increasing from the arable layer (124.5 ppm on the 0-20 cm) to depth (145.4 ppm in the 100-150 cm) .

The soil content in exchangeable magnesium on soil profile has a similar pattern with potassium content, the soil being middle supplied with this item's full profile.

Manganese characterize the soil from field research like a soil with medium content at depth 0-20 cm and 20-40 cm and low content at next depths.

The soil is moderately submezobazic on the entire deep studied (Table 2).

Table 2.

Chemical properties of preluvosoil from research field of Oradea

Depth - cm -	pH (H_2O)	Humus %	N_{total} %	C/N	P_{AL}	K_{AL}	Mg^{+2}	Mn^{+2}	V %
					ppm				
0-20	6.8	1.75	0.127	8.01	50.8	124.5	254	34	79.8
20-40	6.11	1.71	0.157	6.11	36.6	119.9	309	27	70.1
40-60	6.35	1.44	0.156	4.89	20.7	144.7	396	22	85.9
60-80	6.35	-	-	-	16.1	139.7	199	22	85.9
80-100	6.63	-	-	-	9.3	145.4	496	23	86.0

The irrigation equipment of the research field permitted to measure exactly and to distribute uniformelly the irrigation water.

The water sources for irrigation is water ground (15 m depth). The irrigation water has a low natrium content (12.9 %), the salinization potential is low (CSR = -1.7) and SAR index (0,52) is low too.

Laboratory analysis effectuated in 2012 and 2013 showed a pH (7.3) which, fit the water into the category of water suitable for irrigation. After the anions content irrigation water is bicarbonato- sulphate type and after the cations content is type of calc-magnesia. The content of sodium is low, 12.9%. Fixed mineral residue (0.5 g/l) is less than the allowable limit of 0.8-1 g/l (Table 3).

Table 3.

Average values of chemical indexes of irrigation water used in field research, Oradea 2013-2014

Ca^{2+}	Mg^{2+}	Na^{+}	K^{-}	CO^{2-}_{3}	HCO_3	CL^{-}	SO_4^{2-}
mg/liter							
49.1	44.0	20.8	2.7	-	266.8	35.4	80,3
pH	Na %	Fixed mineral residue g/l		SAR	CSR	N. Florea class	
mg/liter							
7.3	12.9	0.5		0.53	-1.8	II	

After CSR index (-1.8) irrigation water has a low alkalizing potential (class C.1) may be employed without restriction. Alkalizing potential (0.53) is also low (class S1), water can be used without restriction to irrigate land.

Classification of waters, after Florea N., depending on the absolute content and relative salts of Na shows that the irrigation water used in the research field within the group II, good water for irrigation

The experimental device was:

Factor A : fertilization

- a1 – unfertilized
- a2 – manure 30t/ha
- a3 – manure 30 t/ha + $N_{90}P_{45}$

Factor B: water regime

- b1 - unirrigated
- b2 – irrigated, maintaining the soil water reserve on irrigation depth (0-75 cm) between easily available water content and field capacity.

The water use efficiency and irrigation water use efficiency were calculated by specifical indicators (Domuța 2003, 2005, 2009, Domuța coord., 2009, 2012).

Water use efficiency (WUE) was calculated using the formula:

$$\text{WUE} = \frac{Y}{\sum(e+t)} \quad [\text{kg/m}^3]$$

In which:

Y = yield (kg/ha);

$\sum(e+t)$ = total water use (m^3/ha)

Irrigation water use efficiency (IWUE) was calculated using the formula :

$$IWUE = \frac{Y_i - Y_n}{\sum m} \qquad [\text{kg spor/m}^3]$$

where:

Y_i= irrigated yield (kg/ha);

Y_n = unirrigated yield (kg/ha);

$\sum m$ = irrigation rate (m^3/ha).

Maize water consumption was calculated based on the soil sample and soil water balance on 0-150 cm. Yields were calculated by variance analysis (Domuța, 2006).

RESULTS AND DISCUSSION

Influence of organic and organic-mineral fertilization, as well as of irrigation, on maize yields, average data for the 2013-2014 period

In the case of non-irrigated maize, organic fertilization caused an increase in yield of 12.96 q/ha (29%), which is very significant statistically; in the case of organic-mineral fertilization, the difference against control was higher, 25.9 q/ha (58.8%), which means a difference of 13.02 q/ha (22.8%) against the crop fertilized only with manure (Table 4).

When irrigation was applied, the differences between fertilized crops and the unfertilized control are higher than the differences registered in unirrigated conditions: 17.82 q/ha in the case of the organically fertilized crop and 36.23 q/ha in that of the organic -mineral one, which means a yield increase of 18.51 q/ha (23%) against the organically fertilized crop.

Irrigation caused statistically very significant yield increases for all backgrounds: 17.95 q/ha (40.6%) for the unfertilized variant, 22.81 q/ha (39.9%) for the organically fertilized crop and 28.3 q/ha (40.3%) for the organic-mineral fertilized one. Thus, the average on this two variants were registered an difference about 23.02 q/ha (40,3%), very significant statistically.(table 4).

Table 4.

Influence of organic and organic-mineral fertilization on the irrigated and non-irrigated maize crops, Oradea, 2013-2014

Water regime	Fertilization variant						Regime average	
	Control		Manure 30 t/ha		Manure 30 t/ha+$N_{90}P_{45}$			
	q/ha	%	q/ha	%	q/ha	%	q/ha	%
Unirrigated	44.21	100	57.17	129	70.19	159	57.16	100
Irrigated	62.16	100	79.98	129	98.49	158	80.17	140.2
Average	53.18	100	68.58	129	84.29	158	-	-

Water regime		Background	Background x Water regime	Water regime x Background
$LSD_{5\%}$	3.39	3.76	6.38	5.45
$LSD_{1\%}$	5.19	5.86	7.97	7.87
$LSD_{0.1\%}$	8.63	7.79	12.17	11.80

Influence of organic and organic-mineral fertilization on water use in unirrigated and irrigated maize crops, average data for the 2013-2014 period

Both in the case of non-irrigation and in that of irrigation, the organic and organic-mineral fertilization resulted in higher total water use than in the case of unfertilized control, with differences of 99 m^3/ha and 127 m^3/ha for the non-irrigated crop and 167 m^3/ha and 204 m^3/ha for the irrigated one. These differences were obtained in conditions of higher precipitation amounts stored in the cold season by the fertilized crops, which means that the maize could use a higher water quantity from the soil storage. The share of soil water storage in the water use was 28-30% for the non-irrigated crop and 15-18% for the irrigated one (Table 5).

The average of precipitation amount registered from sowing-harvesting period was 326.7 mm, which covered 70-72% of water consumption by the unirrigated maize crop and 54-56% of water consumption by the irrigated one.

Irrigation determined an increase about 29.4% of water consumption by the unfertilized variant and with 30.2% increase in the case of the other two variants. Irrigation covered 28-29% of the crop total water use (Table 5).

Table 5

Total water consumption and the covering sources in maize crop, Oradea 2013-2014

Variant	Water regime	Σ (e + t)		Covering sources of Σ (e+t)					
				R_i-R_f		P		Σm	
		m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha	%
Unfertilized variant	Unirrigated	4.508	100	1.241	28	3.267	72	-	-
	Irrigated	5.835	129.4	868	15	3.267	56	1.700	29
Manure 30 t/ha	Unirrigated	4.607	100	1.340	29	3.267	71	-	-
	Irrigated	6.002	130.2	1.037	17	3.267	54	1.700	29
Manure 30 t/ha +$N_{90}P_{45}$	Unirrigated	4.635	100	1.369	30	3.267	70	-	-
	Irrigated	6.039	130.2	1.072	18	3.267	54	1.700	28

Σ (e + t) = water consumption;

R_i-R_f = soil water reserve (initial reserve – final reserve);

P = precipitations in the growing season;

Σm = irrigation water

Correlation water consumption – yield in function of the fertilization. The water consumption - yield correlation is a direct one in all three variants of fertilization, statistically significant in the unfertilized variant and highly statistically significant in the organically and organic-mineral fertilized versions (Fig. 1).

Thus, it can be stated that by providing a better fertilization system, the water consumption - yield correlation obtained is better sustained statistically.

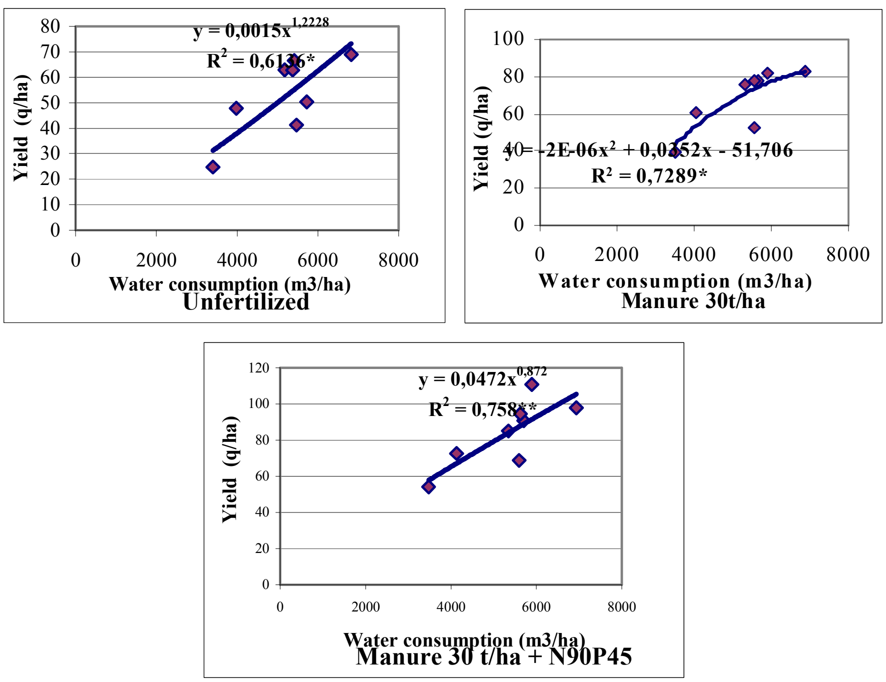

Fig. 1. The correlation between water consumption and yield under fertilization, Oradea, 2013-2014

The influence of organic and organic-mineral fertilization on water use efficiency, average data 2013-2014

In the unirrigated crop, organic fertilization caused an increase of 27.5% in the efficiency of water use against the unfertilized variant, and in the case of organic-mineral fertilization the increase was 57,1%. In the irrigated crop, the differences were 25.2% for the organic fertilization and 53.3% for the organic-mineral one (Table 6).

Table 6.
Influence of organic and organic-mineral fertilization on the unirrigated and irrigated maize on water use efficiency (WUE), Oradea, 2013-2014

Variant	Water regime	WUE		Difference
		Kg/m^3	%	%
1. Unfertilized variant	Unirrigated	0.98	100	-
	Irrigated	1.07	100	-
2. Manure 30t/ha	Unirrigated	1.25	127.5	27.5
	Irrigated	1.34	125.2	25.2
3.Manure 30 t/ha + $N_{90}P_{45}$	Unirrigated	1.54	157.1	57.1
	Irrigated	1.64	153.3	53.3

On average, in the period of research, in the case of unfertilized crop, with 1 m^3 irrigation (which maintained the water reserve on a depth of 0-75 cm between easily available water content and field capacity) the yield increase was 1.04 kg. In the fertilized crop, the efficiency of water consumption increased by 4%.

The highest water use efficiency was obtained in the organic-mineral fertilized crop, that is, 1.55 kg/m^3, which is higher than that of the unfertilized variant and of the crop fertilized with manure by 49% and respectively 30.2% (Table 7).

Table 7.
Influence of organic and organo-mineral fertilization on the maize crop irrigation water use efficiency (IWUE), Oradea, 2013-2014

Variant	IWUE		Difference	
	Increase in Kg/m^3	%	Increase in Kg/m^3	%
1. Unfertilized variant	1.04	100	-	-
2. Manure 30t/ha	1.19	114	0.15	14
3. Manure 30 t/ha+$N_{90}P_{45}$	1.55	149	0.51	49

CONCLUSIONS

The paper is based on research conducted at the Agricultural Research Development Station in Oradea located on a preluvosoil experience in 1999, and the conclusions are:

- On average over the period 2013-2014 under unirrigation conditions the fertilization with manure 30t / ha obtained a yield gain of 29% compared to unfertilized variant, through organic-mineral fertilization the yield gain was higher (59%) . Under irrigation conditions the yield gain values were similar (28% and 58%). Under irrigation conditions was obtained a yield gain of 40.2% compared to unirrigated variant.

- Fertilization with manure determined the accumulation of a high quantity of water from soil reserve. Following consumed a higher quantity of water from soil reserve and the values of total water consumption increased.
- The highest values of the regression coefficient for correlation water consumption - yield was obtained in variant fertilized organic-mineral.
- Fertilizarea organică si mai ales cea organo-minerală au determinat creșterea eficienței valorificării apei.
- Organic fertilization and especially organic-mineral fertilization determined increasing of water use efficiency.

Compared with the unfertilized variant (1.04 kg gain /m^3), using manure the water use efficiency of irrigation water increased by 14% and in variant with manure 30 t / ha + $N_{90}P_{45}$ value of water use efficiency increased by 49%.

REFERENCES

1. Bîlteanu Gh., Bîrnaure V., 1991, Fitotehnie. E.D.P., Bucureşti
2. Borcean I., Borcean A., 2004, Cultura şi protecţia integrată a cerealelor, leguminoaselor şi plantelor tehnice, Ed. de Vest Timişoara
3. Borza I., Stanciu A., 2010, Fitotehnie. Ed. Universităţii din Oradea
4. Borza I., 2006, Cercetări privind influenţa unor măsuri fitotehnice asupra eficienţei valorificării apei de către cultura porumbului în condiţiile Câmpiei Crişurilor.Teză de doctorat, USAMV Cluj-Napoca
5. Borza I., Domuţa C., Şandor M., Domuţa Cr., Brejea R., 2011, Research regarding the crop rotation and green manure influence on water use efficiency in wheat from north-western Romania. Analele Universitatii Oradea, Fascicula de Protectia Mediului, Vol. XVI, Anul 16 p. 47-54
6. Botzan M., 1966, Culturi irigate. Ed. Agro-Silvică, Bucureşti, p. 60-82
7. Brejea R., 2010 Știinţa solului – îndrumător de lucrări practice. Ed. Universităţii din Oradea, pp. 84-105.
8. Brejea R., Domuța C., 2011, Practicum de pedologie. Ed. Universităţii din Oradea
9. Canarache A., 1990, Fizica solurilor agricole. Ed. Ceres Bucureşti
10. Crăciun M., 1990, Cercetări privind raţionalizarea consumului de îngrăşăminte, apă, energie în funcţie de metodele de irigare. Teză de doctorat. ASAS Bucureşti.
11. Cristea M., 2004, Porumbul- studiu monografic, vol I (cap. 1,3,4,5,6,15), Ed. Academiei Române, Bucureşti
12. Domuţa C., 1995, Contribuţii la stabilirea consumului de apă al principalelor culturi din Câmpia Crişurilor. Teză de doctorat ASAS „Gheorghe Ionescu Siseşti, p. 112-126
13. Domuţa C. şi colab., 2000, Irigarea culturilor, Ed. Universităţii din Oradea.
14. Domuţa C., 2003, Oportunitatea irigaţiilor în Câmpia Crişurilor. Ed. Universităţii din Oradea
15. Domuţa C., 2005, Irigarea culturilor, Ed. Universităţii din Oradea.
16. Domuţa C., 2006, Tehnică experimentală, Ed. Universităţii din Oradea
17. Domuţa C., 2009, Irigarea culturilor. Ed. Universităţii din Oradea.

18. Domuta C, (coord.), si colab., 2009, Irigatiile in Campia Crisurilor 1967-2008, Ed. Universitatii Oradea
19. Domuta C, (coord.), si colab., 2012, 50 de ani de cercetări agricole în Oradea. Editura Universitatii Oradea
20. Domuţa Cr., 2010, Cercetări privind influenţa irigaţiei asupra culturilor de porumb, soia şi sfeclă de zahăr în condiţiile Câmpiei Crişurilor, Teză de doctorat Universitatea de Ştiinţe Agricole şi Medicină Veterinară Cluj-Napoca
21. Domuţa Cr. 2011, Subasigurarea cu apă a porumbului, soiei şi sfeclei de zahar din Câmpia Crişurilor Editura Universităţii din Oradea
22. Doorembos J. and Kassom A.M., 1986 Yield response to water, FAO Rome.
23. Doorembos J. and Pruitt W.O.,1992, Crop Water requirements FAO Rome.
24. Grumeza N, Popa V., 1988, Cercetări şi rezultate privind bilanţul apei în sol şi relaţia evapotranspiraţie-producţie în diferite zone pedoclimatice din România. Analele ICITID vol. V (XVI), p. 146-160
25. Grumeza N., Merculiev O., Klepş Cr., 1989, Prognoza şi programarea udărilor în sistemele de irigaţii Ed. Ceres Bucureşti, p. 162-164
26. Muntean L.S. şi colab., 2011, Fitotehnie. Ed. Risoprint Cluj-Napoca
27. Năescu V., 2003, Eficienţa irigării la principalii hibrizi de porumb în condiţiile de la Fundulea. Revista „Cereale şi plante tehnice" Nr. 9 p. 22-23
28. Petrescu E., 1999, Cercetări privind reducerea consumului de apă la cultura de sfeclă de zahăr irigată în condiţiile pedoclimatice ale Câmpiei Caracalului. Teză de doctorat. ASAS "Gheorghe Ionescu Şişeşti", Bucureşti
29. Tuşa C. 1992, Cercetări privind consumul de apă al culturilor de soia în condiţiile Câmpiei Burnasului, zona Băneasa-Giurgiu, Analele ICITID Băneasa-Giurgiu, p.42-60