INFLUENCE OF THE CROP ROTATION AND IRRIGATION ON YIELD, WATER CONSUMPTION AND WATER USE EFFICIENCY IN MAIZE FROM CRIȘURILOR PLAIN

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Abstract

The paper is based on the research carried out during 2014-2015 on the preluvosoil from Agricultural Research and Development Station Oradea. The years of experiment were very different climatical conditions point of view. In terms of 2014, the lowest yields were obtained in monoculture, yield gain due to application of irrigation were 41% in wheat-corn crop rotation and 85% at wheat-corn-soybeans crop rotation. The lower yields were obtained in monoculture. Differences in monoculture are smaller in rotation wheat-maize and higher in rotation wheat -maize-soybean. Both under irrigation and unirrigation conditions, initial water supply determined at the depth of 0-150 cm had a higher value in crop rotation wheat-maize-soybean-wheat in comparison with wheat-maize rotation and monoculture. The small amount of maize kernels obtained from 1 m^3 of water used was obtained in monoculture. In wheat-maize crop rotation and especially wheat-maize-soybean crop rotation the water used efficiency values are higher than in monoculture. Compared with monoculture in wheat-maize crop rotation irrigation water use efficiency by maize increased with 45% in 2014 and 47% in 2015; in crop rotation wheat-maize-soybean differences registered compared with monoculture were 94% in 2014 and 92% in 2015.

Key words: maize, crop rotation, irrigation, water use efficiency, yield

INTRODUCTION

Crop rotation is the central pivot of sustainable agriculture. Crop rotation is considered one of the most important agro-technical measures to maintain and enhance the soil fertility, control of diseases and pests, increase the effectiveness of other pedoameliorative and agrophytotechnical measures, of obtaining high yields and high quality in terms of profitability. In the same time crop rotation helps to reduce chemicals used in agriculture, with a particular ecological importance. Crop rotation is a basic measure in planning and organizing the work in farms (Budoi, Penescu, 2006; Domuța 2006, 2007, 2012).

In countries with advanced agriculture research about crop rotation performed in stationary experiments exceed 100 years. At Rothamstad, England, John Bennet Lawes in 1843 and Henry Gilbert established the Agricultural Experimental Station and famous experience with crop rotations and fertilizer (Budoi, Penescu, 1996; Guș et al. 2004; Vasiliu, 1959; Zăhan, Bandici, 1999). Other long-term experience of over 100 years there in Woburn (England), Halle (Germany), Askov in Denmark.

In Romania, the first experiences with crop rotations were made after the establishment of the Romanian Institute for Agronomic Research but for various reasons this researches did not have continuity (Bilteanu Gh., 2003; Borceanu I. et al. 2006). So, now lasting experiences are older than 50 years (Şimnic), 40 years, 30 years (Moara Domneasca), Oradea (Neamtu T., 1996).

Pintilie et al., 1985, quote on Wells and Bressman, great specialists in maize crop in the US, which showed that "the most important and most economical way to maintain the highest level of harvest at the maize is the application of good rotation" (Domuța, 2012).

MATERIAL AND METHOD

The research carried out in the Agricultural Research and Development Station Oradea on the preluvosoil with the following profile: Ap = 0-24 cm, El = 24-34 cm; BT_1 = 34-54 cm; Bt_2 = 54-78 cm; Bt / c = 78-95 cm, C = 95-145 cm. It is noted that migration of colloidal clay causes the apparition of horizon El with 31.6% colloidal clay and two horizons of colloidal clay accumulation with BT_1 and Bt_2 with 39,8% and 39,3% colloidal clay (Domuţa, 2008).

Preluvosoil is characterized by a very high hydro stability of soil aggregates more than 0.25 mm, 47.5% of layer by 0-20 cm. Bulk density (BD) - 1.41 g/cm^3 - 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, 2014). 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.

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. On watering depth (0-50 cm, 0-75 cm) and on 0-150 cm the soil is strongly compacted.

Depending on soil texture easily available water content was set at 2/3 IUA (Brejea, 2010, 2011, 2014; Brejea, Domuţa, 2011).

Active humidity interval (IUA) or useful water capacity had a high value in the depth 0-80 cm and the middle at depth 80-150 cm. On watering depth used on the research field the active humidity range had a great value (Domuţa, 2009, 2012). Depending on soil easily available water content was set at 2/3 IUA (Tab. 1).

Table 1

Physical and hydrophysical properties of luvosoil in the Oradea research field

Depth - cm -	Total agregate %	Clay 0,002%	TP %	K mm/h	BD g/cm^3	Field capacity		Wilting poin		Easily available water content		IUA	
						%	m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha
0-20	47.5	31.5	21	21.0	1.41	24.2	682	9.2	259	19.2	542	15.0	423
20-40	-	34.1	49	10.5	1.52	23.6	717	9.4	286	18.9	575	14.2	431
40-60	-	39.8	48	4.4	1.58	25.1	768	11.1	351	19.9	630	13.2	417
60-80	-	39.3	43	1.0	1.65	24.4	828	10.8	356	20.4	672	14.3	472
80-100	-	38.8	40	0.5	1.57	23.8	766	12.2	383	20.4	640	12.2	383
100-150	-	37.6	39	0.1	1.54	24,0	1833	14,2	1093	20.6	1586	9.6	740
0-50	-	-	-	-	1.49	24.0	1787	9.7	720	19,2	1431	14.3	1067
0-75	-	-	-	-	1.53	24.2	2782	10.1	1158	19.5	2240	14.1	1623
0-100	-	-	-	-	1.55	24.3	3769	10.5	1627	19.7	3055	13.8	2142
0-150	-	-	-	-	1.55	24.1	5611	11.7	2720	20.0	4646	13.4	2890

Chemical properties

The soil in the research field has a slightly acid reaction throughout the depth studied, with increasing values from surface to depth (Tab. 2).

Table 2

Chemical properties of preluvosoil from research field of Oradea (Domuta, 2012)

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

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) (Ciobanu, Domuta, 2003).

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.

Research method

The experiment was placed on in 1990 and had two factors as follows:

Factor A: Crop rotation

a_1: maize, monoculture;
a_2: wheat - maize;
a_3: wheat -maize-soybean.

Factor B: Water regime

b_1- unirrigated
b_2 – irrigated

Experimental plot area: 50 m^2.

Method of experience arrangement was after block method in four repetitions.

Maize crop technology comprised of three crop rotations was optimum one (Muntean et al., 2011).

- fertilization: $N_{120}P_{90}$. The entire dose of phosphorus was applied in the form of single superphosphate before making plowing. The dose of nitrogen was applied in fractions as follows 1/3 at sowing and 2/3 to in spring, ammonium nitrate fertilizer is used. Fertilization was done manually.
- hybrid used: Turda Super
- sowing regime: depending on seed quality indices
- weeds control: Sanolt combi SC 1,5 l/ha.
- irigarea: in irrigated variants was considered maintaining the water reserve between easily available water content and field capacity on the depth of 0-150 cm. Irrigation was carried out by sprinkling with a suitable device;
- harvesting was performed manually

Determinations:

1. **Soil moisture** was determined on the samples taken using agrochemical probe, in three repetitions, through the gravimetric method; Sample drying temperature was 105^o C for 8 hours.

2. **The total water consumption** was calculated using the equation of soil water balance in closed system (without the contribution of the ground water) (Grumeza et al., 1989):

$R_i + P_g + \sum m = R_f + \sum(e+t)$,

In which:

R_i = initial water reserve (at sowing, planting, when the culture restarts), m^3/ha;

P_g = precipitations during the growing season of the crop, m^3/ha;

$\sum m$ = irrigation water amount (m^3/ha);

R_f = final soil water reserve (at harvesting), m^3/ha;

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

Irrigation involves a set of technical and organisational measures so that a judicious irrigation scheme can be set up, which includes assessment of the water requirement, the amount of water applied, as well as the schedule of application, all this done in strong correlation with a thorough knowledge of the soil-water-plant relationship (Brejea, 2014).

3. Water use efficiency (WUE) was determined using the following formula:

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

in which:

P = yield (kg/ha);

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

Water use efficiency show the quantity of yield for 1m^3 water consumed (Domuţa, Domuţa, 2010). In 2014, the rainfall from maize vegetation was 367.8 mm and in 2015 of 340.0 mm. Multianual average of the rainfall form Oradea is 613.7 mm, 367.0 mm was registering during maize vegetation period (Pereş, 2012; Pereş, Koteles, 2015).

RESULTS AND DISCUSSION

The influence of crop rotation on maize yield, 2014

In terms of 2014, the lowest yields were obtained in monoculture, yield gain due to application of irrigation were 41% in wheat-maize crop rotation and 85% at wheat- maize -soybeans crop rotation (Tab. 3).

Table 3

The influence of crop rotation and irrigation regime on maize yield (kg/ha), Oradea 2014

Crop rotation	Water regime				Average on crop rotation	
	Unirrigated		Irrigated			
	kg/ha	%	kg/ha	%	kg/ha	%
1. Monoculture	3030	100	6360	100	4695	100
2. Wheat-Maize	4180	138	8990	141	6585	140
3. Wheat-Maize-Soybean	5360	177	11790	185	8575	183
Average	4190	100	9050	216	-	-

	Crop rotation	Water regime	Water regime x Crop rotation	Crop rotation x Water regime
$DL_{5\%}$	190	140	210	195
$DL_{1\%}$	280	270	420	340
$DL_{0,1\%}$	510	490	630	510

The influence of crop rotation on maize yield, 2014

The lower yields were obtained in monoculture. Differences in monoculture are smaller in rotation wheat-maize and higher in rotation wheat -maize-soybean (Tab. 4).

Table 4

The influence of crop rotation and irrigation regime on maize yield (kg/ha), Oradea 2015

Crop rotation	**Water regime**				**Water regime**	
	Unirrigated		**Unirrigated**			
	kg/ha	**%**	**kg/ha**	**%**	**kg/ha**	**%**
1. Monoculture	3620	100	7600	100	5610	100
2. Wheat-Maize	4880	135	10740	141	7810	139
3.Wheat-Maize-Soybean	5910	163	13590	179	9750	174
Average	4800	100	10640	222	-	-

	Crop rotation	Water regime	Water regime x Crop rotation	Crop rotation x Water regime
$DL_{5\%}$	210	170	240	210
$DL_{1\%}$	330	290	410	330
$DL_{0,1\%}$	610	510	670	560

The influence of crop rotation on total water consumption of maize in 2014

Table 5

Soil water balance on 0-150 cm at unirrigated and irrigated maize sowen in different crop rotations, Oradea 2014

Crop rotation	**Interval**		**No. days**	**Reserve initial**	**Rainfalls**	**Irrigations**	**Total in soil**	**Final reserve**	**Water consum-ption**
	From	**To**							
Unirrigated									
1. Monoculture	21.04.	1.10.	162	4710	2970	-	7680	2165	4515
2. Wheat-Maize	21.04.	1.10.	162	4750	2970	-	7720	2170	4550
3.Wheat-Maize-Soybean	21.04.	1.10.	162	4810	2970	-	7780	2210	4570
Irrigated									
1. Monoculture	21.04.	1.10.	162	4720	2970	3900	11590	4530	7060
2. Wheat-Maize	21.04.	1.10.	162	4760	2970	3900	11630	4610	7020
3.Wheat-Maize-Soybean	21.04.	1.10.	162	4820	2970	3900	11690	4720	6970

Table 6

Total water consumption and sources of coverage at maize crop in different crop rotation, Oradea 2014

Variant	**Water regime**	**Σ (e + t)**		**Sources of coverage**					
				R_i-R_f		**P_v**		**Σm**	
		m^3/ha	**%**	**m^3/ha**	**%**	**m^3/ha**	**%**	**m^3/ha**	**%**
Monoculture	Unirrigated	4515	100	1545	34	2970	66	-	-
	Irrigated	7060	156	190	3	2970	42	3900	55
Wheat-Maize	Unirrigated	4550	100	1580	35	2970	65	-	-
	Irrigated	7020	154	150	2	2970	42	3900	56
Wheat-Maize-Soybean	Unirrigated	4570	100	1600	35	2970	65	-	-
	Irrigated	6970	153	100	1	2970	43	3900	56

Both under irrigation and unirrigation conditions, initial water supply determined at the depth of 0-150 cm had a higher value in crop rotation wheat-maize-soybean-wheat in comparison with wheat-maize rotation and monoculture (Tab. 5).

Irrigation determined the increase of total water consumption by 53-56% (Table 6).

The influence of crop rotation on total water consumption of maize in 2015

Maize was sown on 13.04. and was harvested on a 1.10. Initial reserve had higher values in the cropping wheat - maize and wheat-maize-soybean compared to monoculture (Tab. 7).

Table 7

Soil water balance on 0-150 cm at unirrigated and irrigated maize sowen in different crop rotations, Oradea 2015

Crop rotation	**Interval**		**No. days**	**Reserve initial**	**Precipit ations**	**Irriga -tions**	**Total in soil**	**Final reserve**	**Water consum-ption**
	From	To							
Unirrigated									
Monoculture	13.04.	1.10.	170	4780	2985	-	7765	3410	4335
Wheat-Maize	13.04.	1.10.	170	4830	2985	-	7815	3430	4385
Wheat-Maize-Soybean	13.04.	1.10.	170	4910	2985	-	7895	3490	4405
Irrigated									
Monoculture	13.04.	1.10.	170	4790	2985	3350	11125	4610	6515
Wheat-Maize	13.04.	1.10.	170	4820	2985	3350	11155	4580	6575
Wheat-Maize-Soybean	13.04.	1.10.	170	4860	2985	3350	11195	4570	6625

Table 8

Total water consumption and sources of coverage at maize crop in different crop rotation, Oradea 2015

Variant	**Water regime**	**Σ (e + t)**		**Sources of coverage**					
				R_i-R_f		**P_v**		**Σm**	
		m^3/ha	**%**	**m^3/ha**	**%**	**m^3/ha**	**%**	**m^3/ha**	**%**
Monoculture	Unirrigated	4335	100	1350	31	2985	69	-	-
	Irrigated	6515	150	180	3	2985	46	3350	51
Wheat-Maize	Unirrigated	4385	100	1400	32	2985	68	-	-
	Irrigated	6575	149	240	4	2985	45	3350	51
Wheat-Maize-Soybean	Unirrigated	4405	100	1420	32	2985	68	-	-
	Irrigated	6625	150	290	4	2985	45	3350	51

The lowest values of water consumption were registered in monoculture both under irrigation and unirrigation conditions. By applying irrigation the water consumption increased with 50% in all three variants studied (Tab. 8).

The influence of crop rotation on water use efficiency (EVA) by maize in 2014

The efficiency of water used by irrigated maize had the highest value 1.17 kg / m^3 in crop rotation of 3 years, wheat-maize rotation registered a value of 0.92 kg / m^3 and 0.64 kg / m^3 in monoculture. Irrigation determined an improvement of water use efficiency, and the higher value of EVA registered in the wheat-maize-soybean crop rotation, 1.69 kg / m^3 (Tab. 9).

Table 9

The influence of crop rotation on water use efficiency (EVA) by irrigated and unirrigated maize in 2014

Crop rotation	**Water regime**	**EVA**		**Difference**
		Kg/m^3	**%**	**%**
Monoculture	Unirrigated	0.67	100	-
	Irrigated	0.90	135	35
Wheat-Maize	Unirrigated	0.92	100	-
	Irrigated	1.28	139	39
Wheat-Maize-Soybean	Unirrigated	1.17	100	-
	Irrigated	1.69	145	45

The influence of crop rotation on water use efficiency (EVA) by maize in 2015

In 2015, the lowest values of water use efficiency 0.84 kg / m^3 in conditions without irrigation and 1.17 kg / m^3 under irrigation conditions were registered in monoculture. In all three crop rotation, irrigation determined an improving of water use efficiency. Both under unirrigation (1.34 kg / m^3) and irrigation conditions (2.05 kg / m^3) the higher efficiency of water used was registered in wheat -maize-soybean crop rotation (Table 10).

Table 10

The influence of crop rotation on water use efficiency (EVA) by irrigated and unirrigated maize, Oradea 2015

Crop rotation	**Water regime**	**EVA**		**Difference**
		Kg/m^3	**%**	
Monoculture	Unirrigated	0.84	100	-
	Irrigated	1.17	138	38
Wheat-Maize	Unirrigated	1.11	100	-
	Irrigated	1.63	147	47
Wheat-Maize-Soybean	Unirrigated	1.34	100	-
	Irrigated	2.05	153	53

Influence of crop rotation on irrigation water used efficiency (EVAI) in 2014

Irrigation water used efficiency values were 1.65 kg gain / m^3 in wheat-mazie-soybean crop rotation, 1.23 kg gain / m^3 in wheat-maize rotation and 0.85 kg gain / m^3 in monoculture (Tab. 11).

Table 11

Influence of crop rotation on irrigation water used efficiency(EVAI) at maize crop, Oradea 2014

Crop rotation	**Water regime**	**EVAI**		**Differences**	
		Kg gain/m^3	**%**	**Kg gain/m^3**	**%**
Monoculture	**Irrigated**	0,85	100	-	-
Wheat-Maize	**Irrigated**	1,23	145	0,38	45
Wheat-Maize-Soybean	**Irrigated**	1,65	194	0,80	94

Influence of crop rotation on irrigation water used efficiency (EVAI) in 2015

Irrigation water used efficiency efficiency in 2015 had the lowest values in monoculture (1.19 kg gain / m^3) and were higher with 47% in wheat-maize crop rotation and with 92% in wheat-maize-soybeans crop rotation (Tab. 12).

Table 12

Influence of crop rotation on irrigation water used efficiency(EVAI) at maize crop, Oradea 2015

Crop rotation	**Water regime**	**EVAI**		**Differences**	
		Kg gain/m^3	**%**	**Kg gain/m^3**	**%**
Monoculture	Irrigated	1,19	100	-	-
Wheat-Maize	Irrigated	1,75	147	0,56	47
Wheat-Maize-Soybean	Irrigated	2,29	192	1,10	92

CONCLUSIONS

The paper is based on research conducted in the years 2014-2015 at the Agricultural Research and Development Station Oradea in an experiment founded in 1990. In the sustainable agriculture system, crop rotation is the backbone for its complex role. At the maize crop years was accepted as technological practice the monoculture, but the emergence of corn root worm western (*Diabrotica virgifera virgifera*) and evolution of soil characteristics experiences with long-term crop rotations, determined the reconsideration of maize monoculture opportunity. Both in conditions of irrigation and unirrigation the lower yields were obtained in monoculture of maize. In crop rotation wheat-maize yields obtained were very significantly higher than in monoculture. The highest yields were obtained in crop rotation wheat-maize-soybeans. The small amount of maize kernels obtained from 1 m^3 of water used was obtained in monoculture. In wheat-maize crop rotation and especially wheat-maize-soybean crop rotation the water used efficiency values are higher than in monoculture. Compared with monoculture in wheat-maize crop rotation irrigation water use efficiency by maize increased with 45% in 2014 and 47% in 2015; in crop rotation wheat-maize-soybean differences registered compared with monoculture were 94% in 2014 and 92% in 2015.

The ones above entitle us to affirm that monoculture is contraindicated in maize crop as in the practice of crop rotation wheat-maize and especially crop rotation wheat-maize-soybean were obtained higher yields and was found the improving of irrigation water used.

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