THE INFLUENCE OF THE CULTIVAR AND IRRIGATION ON WATER USE EFFICIENCY IN POTATO FROM CRISURILOR PLAIN

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Abstract

Potato is a crop with important water requirement and during 2010-2012 at Agricultural Research and Development Station Oradea an experiment regarding the influence of five cultivars (Ostara, Moldovița, Desireé, Sante and Star) and two water regime (unirrigated and irrigated) on water use efficiency were studied. The optimum water provisionment on watering depth (0-75 cm) determined the use of the irrigation: 400 m^3/ha in 2010, 3000 m^3/ha in 2011 and 1900 m^3/ha in 2012. The smallest values of the total water consumption were registered in the cultivar (Ostara) with the shortest vegetation period and the biggest values were registered in the cultivar (Star) with the longest vegetation period. The smallest yields were obtained in the cultivar with the shortest vegetation period (Ostara) and the biggest yields were obtained in the cultivar with the longest vegetation period (Star). The irrigation determined the yields gain between 15% an 21.9% in 2010, between 144% and 196% in 2011 and between 55% and 8% in 2012.

The smallest values of the water use efficiency were registered in the droughty year 2011 and the biggest values were registered in the rainy year, 2010, both in unirrigated cultivars and irrigated cultivars. Water use efficiency of the potato cultivars increased in the irrigated variants; the biggest differences in comparison with unirrigated variants were registered in the droughty year, 2011; all the potato cultivars had the biggest values of the irrigation water use efficiency in rainy year 2010.

The values of the irrigation water use efficiency increase together with the increase of the vegetation period duration. In average on the studied period, the smallest values of the irrigation water use efficiency (6.60 kg yield gain/m^3) was registered in the cultivar with the shortest vegetation period (Ostara) and the biggest value (10.34 kg yield gain/m^3) was registered in the cultivar with the longest vegetation period (Star).

Key words: cultivar, irrigation, water use efficiency, potato.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important plants for people food and for food industry. Consumed throughout the year, prepared in various forms, has easy digestibility, is pleasing and highly nutritious. The potato plant leave the field clean of weeds, and reacts to organic and mineral fertilization, positive feedback with large production increases by irrigating the crop. It can grow in various climatic and soil conditions. (Sandor, 2013).

The potato requirement for continously water provisionment is very big. Drought and water logging have a strong influence on plants growth and on level and quality of the yield. (Domuta et al., 2012)

About the favorability of the different areas on potato, Muntean et al. (2011) appreciated the potato requirement for wet and coolness area.

Water use efficiency can be calculated as a report between the quantity of the yield obtained for 1 m^3 (mm) water used or as the water quantity used for 1kg yield. Water use efficiency is different for every crop and is influenced by crop rotation, cultivar, plants tickness, soil tillage, fertilization, water regime, plants protection against the weeds, diseases and pests. (Domuța 2005, 2009, 2012)

Two factors with the influence on water use efficiency are studied in the paper: cultivars and water regime. The research were carried out in the Agricultural Research and Development Station Oradea.

The paper analyses the water use efficiency like quantity of yield obtained for 1 m^3 water and five representative potatoes cultivars were studied.

MATERIAL AND METHOD

Crisurilor Plain is situated in the middle of the Western Plain of Romania and the research was carried out at Agricultural Research and Development Station Oradea on preluvosoil. The main physical and chemical properetes of the soil from research field are: a great hydro stability (47.5%) of the aggregates (Φ 0.25 mm) on ploughed land; bulk density (1.41 g/cm^3) indicates a low settling and total porosity is median. All the soil profile are low acid (6.11 – 6.8), humus content (1.44 – 1.75 %) is small and total nitrogen is low median (0.127 – 0.157). After 35 years of good practices of soil management, the soil phosphorus content became very good (from 22.0 ppm to 150.8 ppm); on ploughing depth, potassium content (124.5 ppm) is median.

In the studied period, the following values were registered: rainfall of 869.0 mm in 2010, of 569.7 mm in 2011 and of 418.9 mm in 2012. The multiannual average (1931-2009) of the annual rainfall felt in Oradea is of 613.4 mm, average air temperature is of 10.2^{0}C and air humidity is of 78%.

In 2010, an experiment with two factors were placed. The following experimental device was studied: Factor A: cultivar (fig. 1) (a_1 Ostara; a_2 Moldovița; a_3 Desireé; a_4 Sante; a_5 Star); Factor B: water regime (b_1 unirrigated; b_2 irrigated).

In the irrigated variant, the soil water reserve on watering depth was maintained between easily available water content and field capacity. The watering depth (0-75 cm) was a fixed one and field capacity (FC = 24.2% = 2782 m^3/ha) and wilting point (WP = 10.1 = 1158 m^3/ha) have median values. Easily available water content (Wea) was established according to the texture: Wea = WP + 2/3 (FC – WP); their values for 0-75 cm depth are 19.5% (2240 m^3/ha). As a consequence, the soil samples for soil moisture determination were prelevated ten to ten days and the irrigation was used when the soil water reserve on 0-75 cm depth decreased at or bellow easily available water content. At the begining and at the end of every month, the soil water balance was made using the formula:

$$R_i + P + \Sigma m = \Sigma(e+t) + R_f$$ in wich:

R_i= initial water reserve, m^3/ha;

P = rainfall registered during the period post planting-harvesting;

Σm = irrigation rate, m^3/ha;

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

R_f= final water reserve, m^3/ha;

The yield, water use efficiency and irrigation water use efficiency data were calculated using the variance analysis (Domuta, 2006)

Fig. 1. An aspect with Desireé cultivar at harvesting

RESULTS AND DISCUSSIONS

Optimum irrigation regime

During the potato vegetation period in the studied period, the rainfall registered was of 345.0 mm in 2010, 244.9 mm in 2011 and of 270.6 mm in 2012. As a consequence, the irrigation rates used for maintaining the soil water reserve on 0-75 cm between easily available water content and field capacity were of 400 m^3/ha in 2010 (400 m^3/ha in July), of 3000 m^3/ha in 2011 (500 m^3/ha in July), of 1900 m^3/ha in 2012 (500 m^3/ha in May, 600 m^3/ha in June, 800 m^3/ha in July). (table 1)

Table 1

Irrigation regime used for maintaining the water reserve on 0-75 depth between easily available water content and field capacity in potato crop, Oradea 2010-2012

Year	April		May		June		July		August		April-August	
	∑m	n	∑m	n	∑m	n	∑m	n	∑m	n	∑m	n
2010	-	-	-	-	-	-	400	1	-	-	400	1
2011	500	1	800	2	1200	3	500	2	-	-	3000	9
2012	-	-	500	1	600	2	800	2	-	-	1900	4

∑m = irrigation rate
n = number of watering

Water consumption of the potato cultivars

Situation from 2010

In the unirrigated variants, the smallest value of the water consumption (3940 m^3/ha) was registered in Ostara, the cultivar with the shortest vegetation period; the greatest value of the plants water consumption (4160 m^3/ha) was determined in Star, the cultivar with the longest vegetation period. The greatest part of the water consumption was covered by the rainfall fallen during the planting-harvesting period; soil water reserve contributed with 13% in Ostara and Moldovița, 14% in Desireé, 15% in Sante and 17% in Star. The use of the irrigation determined the increase of the plants' water consumption with 8%, generally; the smallest value was of 4260 m^3/ha in Ostara and 4440 m^3/ha in Star. (table 2)

Situation from 2011

The year 2011 was the droughtest and the smallest values of the total water consumption were registered; the values were between 3219 m^3/ha in Ostara and 3359 m^3/ha in Star, in the unirrigated variant and between 5899 m^3/ha in Ostara and 6054 m^3/ha in Star. In the irrigated variant, the use of the irrigation determined the increase of the total water consumption with 82-84%.

Total water consumption of the unirrigatedd potato cultivars was covered by rainfall fallen during planting and harvesting in the highest percentage, 75%-84%. Soil water reserve contributed with 24-27% from total water consumption.

The main covering source of the water consumption of the irrigated variants was the irrigation with a contribution of the 50%. The rainfall registered during the planting and harvesting of the potato covered 41-42% from total water consumption; soil water reserve covered 8-9% from total water consumption.

Situation from 2012

In unirrigated conditions, the values of the total water consumption are a little higher than the values determined in 2011, but in the irrigated variant the values are lower.

In the unirrigated variants, the rainfall fallen during planting-harvesting of the potato was the main source for covering the total water consumption of the cultivars studied; the percentage of the covering was between 78% and 82%. In irrigated variants the same situation was registered but the covering percentage was smaller, 53%-54%.

Table 2

Total water consumption [∑(e+t)] of the potato cultivars and the covering sources, Oradea 2010-2012

Cultivar	Variant	∑(e+t)		Covering sources					
				Soil reserve		Rainfall		Irrigation	
		m^3/ha	%	m^3/ha	%	m^3/ha	%	m^3/ha	%
2010									
Ostara	Unirrigated	3940	100	490	13	3450	87	-	-
	Irrigated	4260	108	370	9	3450	81	400	10
Moldovița	Unirrigated	3960	100	510	13	3450	87	-	-
	Irrigated	4260	108	410	9	3450	81	400	10
Desireé	Unirrigated	4010	100	560	14	3450	86	-	-
	Irrigated	4370	118	520	12	3450	79	400	9
Sante	Unirrigated	4070	100	620	15	3450	85	-	-
	Irrigated	4390	108	540	12	3450	79	400	9
Star	Unirrigated	4160	100	710	17	3450	83	-	-
	Irrigated	4440	107	590	13	3450	78	400	9
2011									
Ostara	Unirrigated	3219	100	770	24	2449	76	-	-
	Irrigated	5899	183	450	8	2449	42	3000	50
Moldovița	Unirrigated	3229	100	780	24	2449	76	-	-
	Irrigated	5939	184	490	8	2449	42	3000	50
Desireé	Unirrigated	3250	100	801	25	2449	75	-	-
	Irrigated	5797	184	533	9	2449	41	3000	50
Sante	Unirrigated	3299	100	850	26	2449	84	-	-
	Irrigated	6009	182	560	9	2449	41	3000	50
Star	Unirrigated	3359	100	910	17	2449	83	-	-
	Irrigated	6054	180	605	10	2449	40	3000	50
2012									
Ostara	Unirrigated	3296	100	590	18	2706	82	-	-
	Irrigated	5016	152	410	8	2706	54	1900	38
Moldovița	Unirrigated	3354	100	648	19	2706	81	-	-
	Irrigated	5033	150	427	8	2706	54	1900	38
Desireé	Unirrigated	3396	100	690	20	2706	80	-	-
	Irrigated	5056	149	450	9	2706	54	1900	37
Sante	Unirrigated	3416	100	710	21	2706	79	-	-
	Irrigated	5066	148	460	9	2706	53	1900	38
Star	Unirrigated	3466	100	760	22	2706	78	-	-
	Irrigated	5086	147	480	9	2706	53	1900	38

Irrigation influence on the yields

In 2010, the irrigation determined a yield gain of 15% in Ostara, of 21.0% in Moldovita, of 21.9% in Desireé, of 21.6% in Sante and of 21.4% in Star. In the unirrigated conditions, the smallest yield (25300 kg/ha) was registered in Ostara and the biggest yield

(32290 kg/ha) was registered in Star. In irrigated variants, the smallest yield registered in the same cultivars: 29000 kg/ha in Ostara and 39200 kg/ha in Star. (table 3)

Both in unirrigated and irrigated variants, the smallest yields were registered in 2011. The yields were between 8700 kg/ha (Ostara) and 11640 kg/ha (in Star) in unirrigated conditions and between 25730 kg/ha (Ostara) and 29400 (Star) in irrigated conditions. The irrigation determined the increase of the yields with 190% in Ostara and Desireé, with 180% in Moldovița, with 53% in Star and with 44% in Sante.

In 2012, the yields were bigger than in 2011, but smaller than in 2010 in all studied cultivars. The yields were between 16870 kg/ha (Ostara) and 18200 kg/ha (Star) in unirrigated variants and between 26100 kg/ha (Ostara) and 33000 kg/ha (Star) in irrigated variants. The yields gains determined by irrigation were of 81% in Star, of 80% in Desireée, of 79% in Sante, of 71% in Moldoviâa and of 55% in Ostara. (table 3)

Table 3

Irrigation influence on potatoes yield cultivars, Oradea 2010-2012

Cultivar	Variant	Yield		Difference	
		Kg/ha	%	Kg/ha	%
2010					
Ostara	Unirrigated	25300	100	-	-
	Irrigated	29000	115	3700	15
Moldovița	Unirrigated	29100	100	-	-
	Irrigated	35060	121	5960	21
Desireé	Unirrigated	30100	100	-	-
	Irrigated	36700	121.9	6600	21.9
Sante	Unirrigated	31730	100	-	-
	Irrigated	38560	121.6	6830	21.6
Star	Unirrigated	32290	100	-	-
	Irrigated	39200	121.4	6910	21.4
2011					
Ostara	Unirrigated	8700	100	-	-
	Irrigated	25730	296	17030	96
Moldovița	Unirrigated	9360	100	-	-
	Irrigated	26200	280	16840	80
Desireé	Unirrigated	10100	100	-	-
	Irrigated	29300	290	19200	190
Sante	Unirrigated	11250	100	-	-
	Irrigated	27400	244	16150	144
Star	Unirrigated	11640	100	-	-
	Irrigated	29400	253	17760	153
2012					
Ostara	Unirrigated	16870	-	-	-
	Irrigated	26100	155	9230	55
Moldovița	Unirrigated	17100	-	-	-
	Irrigated	29300	171	12200	71
Desireé	Unirrigated	17350	100	-	-
	Irrigated	31280	180	13930	80
Sante	Unirrigated	17900	100	-	-
	Irrigated	32100	179	14200	79
Star	Unirrigated	18200	100	-	-
	Irrigated	33000	181	14800	81

In the average period, 2010-2012, in unirrigated and irrrigated variants, the biggest yield was obtained in the cultivar with the longest vegetation period (Star cultivar). The

differences between unirrigated and irrigated variant was between 59 % (Ostara) and 69% (Desireé), statistically provided. (table 4)

Table 4

The average of the potato yield obtained in different cultivars in the unirrigated and irrigated conditions, Oradea 2010-2012

Cultivar	Variant	Yield		Difference	
		Kg/ha	%	Kg/ha	%
Ostara	Unirrigated	16957	100	-	-
	Irrigated	26943	159	9986	59
	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime	
$LSD_{5\%}$	310	290	510	470	
$LSD_{1\%}$	570	510	820	730	
$LSD_{0.1\%}$	920	880	1270	910	
Moldovița	Unirrigated	18520	100	-	-
	Irrigated	30187	163	11667	63
	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime	
$LSD_{5\%}$	270	240	430	360	
$LSD_{1\%}$	460	410	670	510	
$LSD_{0.1\%}$	810	760	1010	830	
Desireé	Unirrigated	19183	100	-	-
	Irrigated	32427	169	13244	69
	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime	
$LSD_{5\%}$	310	260	470	390	
$LSD_{1\%}$	580	490	710	670	
$LSD_{0.1\%}$	760	630	1170	920	
Sante	Unirrigated	20293	100	-	-
	Irrigated	32687	161	12394	61
	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime	
$LSD_{5\%}$	280	196	420	305	
$LSD_{1\%}$	495	310	610	515	
$LSD_{0.1\%}$	630	520	985	796	
Star	Unirrigated	20710	100	-	-
	Irrigated	33867	164	13157	64
	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime	
$LSD_{5\%}$	325	224	446	360	
$LSD_{1\%}$	512	430	712	612	
$LSD_{0.1\%}$	650	596	1150	976	

There is a direct correlation between cultivars, water consumption and yield. Five functions (linear, logaritmic, polinomial, power and exponential) were tested and the polinomial was the best. The Desireé cultivar had the biggest correlation coefficient. (fig. 2)

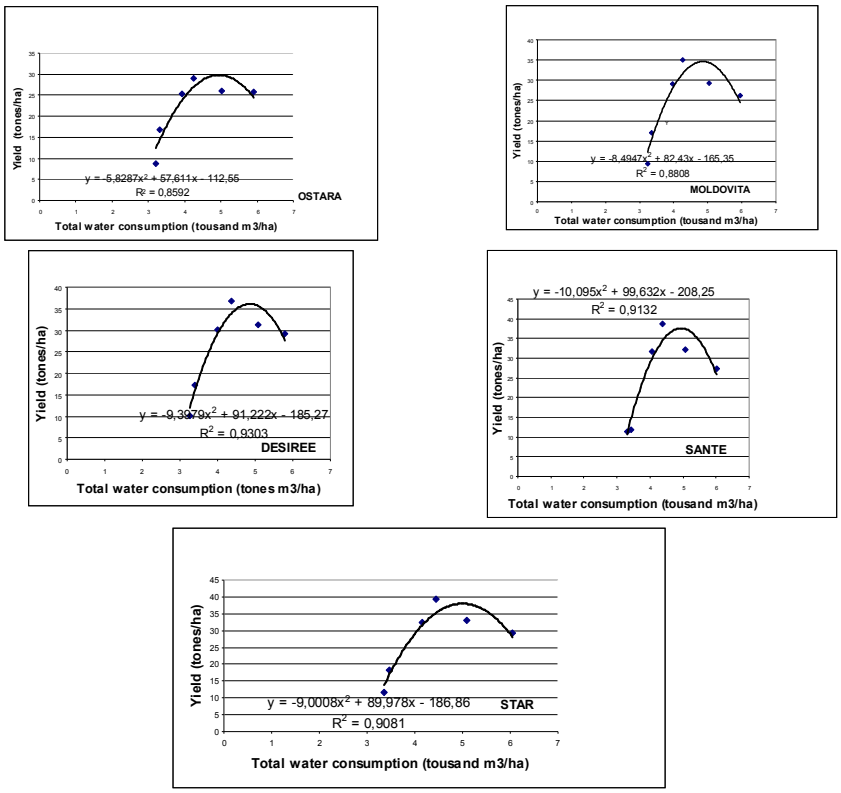

Fig. 2 Correlations between water consumption and yield in the studied potato cultivars, Oradea 2010-2012

Irrigation influence on water use efficiency

In 2010, the quantification of tuberous obtained for 1m^3 water used was between 6.42 kg/m^3 (Ostara) and 7.79 kg/m^3 (Sante) in unirrigated variants and between 6.80 kg/m^3 (Ostara) and 8.83 kg/m^3 (Star) in irrigated variants. The irrigation determined the increase of the water use efficiency with 6-14 %. (table 5)

The smallest values of the water use efficiency were registered in the droughty year 2011; the values were between 2.59 kg/m^3 (Moldovița) and 3.47 kg/m^3 (Star) in unirrigated variants and between 4.36 kg/m^3 (Ostara) and 4.90 kg/m^3 kg/m^3 (Desireé) in the irrigated variants. The irrigation determined the greatest difference in comparison with unirrigated variants: 70% in Moldovița, 62% in Ostara, 58% in Desireé, 40% in Star and 34% in Sante. (table 5)

The values of the water use efficiency obtained in 2012 are higher than the values obtained in 2011 but lower than the values obtained in 2010. The values were between 5.10 kg/m^3 (Moldovița) and 5.25 kg/m^3 (Star) in the unirrigated variants and between 5.20 kg/m^3 (Ostara) and 6.49 kg/m^3 (Star) in the irrigated variants. The irrigation determined the increase of the water use efficiency with values between 2% (Ostara) and 24% (Star).

In the average period, 2010-0-2012, the biggest water use efficiency was registered at the Star potato cultivar (5.49 kg/m^3 in unirrigated conditions and 6.73 kg/m^3 in irrigated conditions). (table 6)

Table 5

Irrigation influence on water use efficiency (WUE) from different potatoes cultivars, Oradea 2010-2012

Cultivar	Variant	WUE		Difference	
		Kg/m^3	%	Kg/m^3	%
2010					
Ostara	Unirrigated	6.42	100	-	-
	Irrigated	6.80	106	0.38	6
Moldovița	Unirrigated	7.34	100	-	-
	Irrigated	8.23	112	0.89	12
Desireé	Unirrigated	7.50	100	-	-
	Irrigated	8.40	112	0.90	12
Sante	Unirrigated	7.79	100	-	-
	Irrigated	8.78	113	0.99	13
Star	Unirrigated	7.76	100	-	-
	Irrigated	8.83	114	1.13	14
2011					
Ostara	Unirrigated	2.70	100	-	-
	Irrigated	4.36	162	1.66	62
Moldovița	Unirrigated	2.59	100	-	-
	Irrigated	4.41	170	1.82	70
Desireé	Unirrigated	3.11	100	-	-
	Irrigated	4.90	158	1.79	58
Sante	Unirrigated	3.41	100	-	-
	Irrigated	4.56	134	1.15	34
Star	Unirrigated	3.47	100	-	-
	Irrigated	4.86	140	1.39	40
2012					
Ostara	Unirrigated	5.12	100	-	-
	Irrigated	5.20	102	0.08	2
Moldovița	Unirrigated	5.10	100	-	-
	Irrigated	5.58	114	0.72	14
Desireé	Unirrigated	5.11	100	-	-
	Irrigated	6.19	121	1.08	21
Sante	Unirrigated	5.24	100	-	-
	Irrigated	5.41	103	0.17	3
Star	Unirrigated	5.25	100	-	-
	Irrigated	6.49	124	1.24	24

Table 6

The average of the water use efficiency (WUE) obtained in different cultivars in unirrigated and irrigated conditions, Oradea 2010-2012

Cultivar	Variant	WUE		Difference	
		Kg/m^3	%	Kg/m^3	%
Ostara	Unirrigated	4.75	100	-	-
	Irrigated	5.45	115	0.7	15
Moldovița	Unirrigated	5.01	100	-	-
	Irrigated	6.07	121	1.06	21
Desireé	Unirrigated	5.24	100	-	-
	Irrigated	6.50	124	1.26	24
Sante	Unirrigated	5.48	100	-	-
	Irrigated	6.25	114	0.77	14
Star	Unirrigated	5.49	100	-	-
	Irrigated	6.73	123	1.24	23

	Cultivar	Water regime	Water regime x cultivar	Cultivar x water regime
$LSD_{5\%}$	0.17	0.13	0.31	0.21
$LSD_{1\%}$	0.32	0.27	0.72	0.49
$LSD_{0.1\%}$	0.62	0.56	1.08	0.76

Irrigation water use efficiency

The analysis of the annual values of the irrigation water use efficiency shows the highest values in the rainy year 2010 and the lowest values in the droughty year. All the years, the lowest values of the irrigation water use efficiency was registered in the cultivar with the shortest vegetation period, Ostara, 6.60 kg yield gain/ 1 m^3 irrigation water. In comparison with the Ostara water use efficiency, a very statistically significant difference was registered: in average on the studied period, the differences in comparison with Ostara was of 36% in Moldovița, of 51% in Sante, of 53% in Desireé and of 57% in Star. (table 7)

Table 7

Irrigation water use efficiency from different potatoes cultivars (IWUE) from different potato cultivars, Oradea 2010-2012

Cultivar	Year	IWUE Kg/m^3 yield gain	Difference		Significal statistically
			Kg/m^3 yield gain	%	
Ostara	2010	9.25	-	-	
	2011	5.68	-	-	
	2012	4.86	-	-	
	Average 2010-2012	6.60	-	100	Control
Moldovița	2010	14.90	-		
	2011	5.61	-		
	2012	6.42	-		
	Average 2010-2012	9.00	3.40	136	***
Desireé	2010	16.5	-		
	2011	6.4	-		
	2012	7.3	-		
	Average 2010-2012	10.1	3.50	153	***
Sante	2010	17.1	-		
	2011	5.38	-		
	2012	7.47	-		
	Average 2010-2012	9.98	3.38	151	***
Star	2010	17.3	-		
	2011	5.92	-		
	2012	7.79	-		
	Average 2010-2012	10.34	3.74	157	***

$LSD_{5\%} = 0.35$
$LSD_{1\%} = 0.96$
$LSD_{0.\%} = 2.05$

CONCLUSIONS

The research carried out during 2010-2012 on the preluvosoil from Agricultural Research and Development Station Oradea determined the following conclusions:

- maintaining the soil watere reserve on 0-75 cm between easily available water content and field capacity in the 5 potatoes cultivars studied determined the use of the following irrigation rates: 400 m^3/ha in 2010, 3000 m^3/ha in 2011 and 1900 m^3/ha in 2012;
- the irrigation determined the increase of the total water consumption values. The irrigation participation in the covering sources of the total water consumption was of 9-10% in 2010, of 50% in 2011 and of 37-38% in 2012;
- the smallest values of the total water consumption were registered in the cultivar (Ostara) with the shortest vegetation period and the highest values were registered in the cultivar (Star) with the longest period;
- the smallest yields were obtained in the cultivar with the shortest vegetation period (Ostara) and the biggest yields were obtained in the cultivar with the longest vegetation period (Star);
- the irrigation determined the yields gain between 15% an 21.9% in 2010, between 144% and 196% in 2011 and between 55% and 8% in 2012;

- the lowest values of the water use efficiency were registered in the droughty year 2011 and the highest values were registered in the rainy year, 2010, both in unirrigated cultivars and irrigated cultivars;
- water use efficiency of the potato cultivars increased in the irrigated variant. The biggest differences in comparison with unirrigated variants were registered in the droughty year, 2011:
- all the potato cultivars had the biggest values of the irrigation water use efficiency in rainy year 2010.
- the values of the irrigation water use efficiency increase together with the increase of the vegetation period duration. In average on the studied period, the smallest values of the irrigation water use efficiency (6.60 kg yield gain/m^3) was registered in the cultivar with the shortest vegetation period (Ostara) and the biggest value (10.34 kg yield gain/m^3) was registered in the cultivar with the longest vegetation period (Star).

The paper demonstrates the need of the potato cultivars with longer vegetation period in the irrigation conditions and the need of the irrigation in potato because quantity of yield obtained for 1 m^3 water (rainfall, soil reserve, irrigation) is bigger than the quantity of the yield obtained for 1 m^3 water (rainfall, soil reserve) in unirrigated potato cultivars.

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