PEDOLOGICAL DROUGHT INFLUENCE ON WATER CONSUMPTION, YIELD AND WATER USE EFFICIENCY IN POTATO FROM CRIȘURILOR PLAIN

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Abstract

The paper is based on research carried out at the Agricultural Research and Development Station Oradea within a long term experiment which began in 1976 at a site with preluvosoil, in Oradea. The research was conducted between 2014 and 2016, in years very different climatically.

Determination of soil moisture every ten days within a depth of 0-75 cm shows that in the case of unirrigated potato the soil water reserve dropped below easily available water content 75 days in 2014, 58 days in 2015 and 27 days in 2016, water reserve dropped below the wilting point.

In order to maintain soil water reserve between easily available water content and field capacity within a depth of 0-75 cm, in 2014 the irrigation rate used was 3,700 m^3/ha, in 2015 it was 2,800 m^3/ha, and in 2016 the irrigation rate was 1,200 m^3/ha. As consequence the total water consumption was higher by 41% in 2014, by 43% in 2015 and by 18% in 2016.

The irrigation of potato determined a statistically very significant yield gains, with relative differences of 206% in 2014, of 119% in 2015 and of 40% in 2016.

The drop of soil water reserve below easily available water content within the watering depth, the influence of irrigation on water consumption and the yield gains obtained in each year of the research show the need of irrigation in potato in the Crişurilor Plain.

Key words: potato, pedological drought, water consumption, yield, water use efficiency

INTRODUCTION

Potato is one of the most important plants used as food. Prepared in various ways, it is consumed over the whole year, it is easy to digest, it has a pleasant taste and it is very nutritious.

In the food industry, potato is a valuable staple, its flour is an equivalent to, and can even replace, that made of cereals, being used for making starch, alcohol, dextrin, glucose, dry products such as flakes, chips, pommes frites etc. A tonne of potatoes will yield 95 l of 90% alcohol, or 100 kg of dextrin. As animal feed, both fresh tubers and pomace are used (Domuța, Domuța, 2010).

Potato is one of the most sensitive plants in respect of continuous water supply. Droughts, even short ones, as well as excessive water, even if it is only temporary, will effect the growth of the plant, its yield and quality (Domuța, 2003, 2005, 2009).

In the book by Munteanu et al., 2008, the authors state that there are areas which are more favourable for the cultivation of potato, that the plant prefers humid areas, with cool climate, and that it has particular needs in

respect of light, including its duration, intensity and quality. As a result, the Crişurilor Plain belongs to the area of early crop, as the total annual rainfall is 400-600 mm, and the average temperature of the hottest month is 20-22^{o}C (Pereș, 2012; Pereș, Koteles, 2015).

MATERIAL AND METHOD

Pedoclimatic conditions

In the years of the research, the climate conditions were different; from April to August the rainfall were of 235.2 mm in 2014, 281.6 mm in 2015 and 353.3 mm in 2016.

The research field is located at the Agricultural Research and Development Station Oradea, on the preluvosoil.

The total soil porosity is normal for the depths of 0 - 20cm, 20 - 40cm, 40 - 60cm and low for the depths of 60 - 80cm, 80 - 100cm and 100 - 150cm. Hydraulic conductivity is high for the depth of 0 - 20cm, average for the depth of 20 - 40cm and 40 - 60cm, low and very low for the following depths studied. The bulk density value – 1.41g/cm^3 – shows a poorly compacted soil for the depth of 0 - 20cm; for the other depths studied, the apparent weight shows soil compactions which are average and strong. For the watering depths (0 – 75 cm) and for 0 – 150cm the soil is strongly compacted. Field capacity has an average value for the entire soil profile, and the wilting point also has an average value up to the depth of 80 cm and high below that depth. Easily water content (Ewa), a high value for the 0 – 80 cm depth and average for the 80 – 150 cm one. Based on the soil texture, easily available water content was set to 2/3 Wea (Brejea, 2009, 2010; Brejea, Domuța, 2011).

The soil of the research field is mildly acidic for the entire depth studied, with values that increase when going down from the surface. Humus content is mild, and that of nitrogen is total, mild – average, for the entire depth studied. The C/N ratio has a higher value (8.01) for the 0 – 20 cm depth and it decreases with depth. Fertilization year after year with phosphorus doses specific to irrigated crops resulted in increased phosphorus level the amount of mobile phosphorus in the soil increased in the plowed layer from 22.0ppm (soil with average supply) to 150.8ppm (soil with a very good supply). The mobile potassium content of the soil is low - average, with values that increase when going down from the plowed layer (124.5ppm for 0 – 20cm), deeper layer (145.4ppm for 100 - 150cm).

The research was carried out from 2014 to 2016 into the soil water balance field placed in 1976 in the programme ”Exploitation of the irrigation and drainage system lead by Grumeza in the Research Institute for Irrigation and Drainage (ICID) Băneasa-Giurgiu. The water supply conditions were studied in two versions:

- unirrigated;
- irrigated, maintaining soil water reserve between easily available water content and field capacity within the depths of 0-75 cm.

Optimum potato cultivation technology was pursued. The potato variety chosen was Desiree (Fig. 1).

Soil moisture could be maintained between easily available water content and field capacity as a result of establishing the gravimetric soil moisture every 15 days.

Fig. 1. Desiree potato variety

Soil moisture was calculated using the well-known formula (Canarache, 1990).

Easily available water content (Wea) was calculated using the formula suggested by Canarache (1980), which takes into account soil texture and degree of compaction:

$$Wea = WP + f\,(FC + WP)$$

where:

Wea = easily available water content (% g/g);

f = fraction of the available water content for which the following values are used:

- 2/3 for sandy soils, strongly compacted sandy loam soils, clay loam soils with average and strong compaction, and loam soils

Soil water reserve was calculated using the well-known formula (Botzan, 1972).

Total water consumption was calculated using the equation of soil water balance in closed system (Grumeza et al., 1986; Ionescu Şişeşti, 1986).

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

$$WUE = \frac{\text{Yield}}{\text{Total water consumption}}$$

The indicator used shows the amount of tubers corresponding to $1m^3$ of water used.

Harvesting of the experiments and calculation of results were done observing the instructions provided by the experimental techniques. Interpretation of results was performed using variance analysis (Domuța, 2006).

RESULTS AND DISCUSSION

1. Pedological drought at potato crop

We speak of pedological drought when soil water reserve within the watering depth drops below the level of easily available water content, and of severe pedological drops when soil water reserve drops below the level of wilting point (Domuţa, 2009).

Pedological drought occurred in all years of the research, the number of days with soil water reserve below easily available water content within the depth of 0-75 cm being 75 days in 2014, 58 days in 2015 and 27 days in 2016 (Table 1).

Table 1

Number of days with pedological drought in unirrigated potato crop, Oradea 2014-2016

Year	Days with pedological drought					Total
	IV	V	VI	VII	VIII	
2014	-	6	18	31	20	75
2015	-	7	10	26	15	58
2016	-	7	-	-	20	27

Within the watering depth, soil water reserve also dropped below wilting point 9 days in 2014 and 5 days in 2015 (Table 2).

Table 2

Number of days with strong pedological drought in unirrigated potato crop, Oradea 2014-2016

Year	Days with strong pedological drought					Total
	IV	V	VI	VII	VIII	
2014	-	-	-	5	4	**9**
2015	-	-	-	3	2	**5**
2016	-	-	-	-	-	**0**

2. Potato crop optimum irrigation regime

In order to maintain soil water reserve within the 0-75cm depth between easily available water content and field capacity, the following irrigation rates were used: $3,700m^3$/ha in 2014, 2,800 m^3/ha 2015 and 1,200

m^3/ha in 2016. The number of rates 9 was in 2014, 7 in 2015 and 3 in 2016 (Table 3).

Table 3

Optimum irrigation regime in potato crop, Oradea, 2014 - 2016

Year	V		VI		VII		VIII		V-VIII	
	∑m	n	∑m	n	∑m	n	∑m	n	∑m	n
2014	1,000	2	700	2	1,400	3	-	-	3,700	9
2015	500	1	1,100	3	700	2	500	1	2,800	7
2016	500	1	700	2	-	-	-	-	1,200	3

∑m = irrigation rate; number of rates

3. Influence of irrigation on the total water consumption of potato

As a result of irrigation, the total water consumption of potato increased with 41% in 2014, with 43% in 2015 and with 18% in 2016 (Table 4).

Table 4

Total water consumption of the unirrigated and irrigated potato crop and the covering sources in Oradea, 2014-2016

Version	Total water consumption		Covering sources; m^3/ha		
	m^3/ha	%	S_i-S_f	Precipitations in the vegetation period	Irrigation
2014					
Unirrigated	4,237	100	1,194	3,044	-
Irrigated	5,975	141	131	3,044	2,800
2015					
Unirrigated	4,314	100	1,899	2,415	-
Irrigated	6,174	143	59	2,415	3,700
2016					
Unirrigated	4,710	100	1,180	3,530	-
Irrigated	5,580	118	870	3,530	1,200

S_i =Initial soil water reserve (at planting); S_f =Final storage (at harvesting)

The contribution of irrigation water to the optimum water consumption was 47% in 2014, 59% in 2015 and 22% in 2016.

Influence of irrigation on yield and water use efficiency (WUE) in 2014

In 2014, irrigation led to statistically very significant yield gain, of 21,060 kg/ha (Table 5).

Table 5

Influence of irrigation on potato yield, Oradea, 2014

Version	Yield		Difference		Statistical significance
	Kg/ha	%	Kg/ha	%	
Unirrigated	10,240	100	-		**Control**
Irrigated	31,300	306	21,060	206	***

$DL_{5\%}$ = 320;
$DL_{1\%}$ = 610;
$DL_{0.1\%}$ = 970.

Table 6

Influence of irrigation on water use efficiency in potato, Oradea, 2014

Version	WUE		Difference		Statistical significance
	Kg/m^3	%	Kg/m^3	%	
Unirrigated	2.42	100	-	-	**Control**
Irrigated	5.23	216	2.81	116	***

$DL_{5\%}$ = 0.35;
$DL_{1\%}$ = 0.82;
$DL_{0.1\%}$ = 1.14.

Influence of irrigation on yield and on water use efficiency (WUE) in potato, 2015

Maintaining soil water reserve between easily available water content and field capacity within the 0-75 cm depth using irrigation resulted in a yield gain of 18,500 kg/ha (119%), which is statistically very significant (Table 7).

Table 7

Influence of irrigation on potato yield, Oradea, 2015

Version	Yield		Difference		Statistical significance
	Kg/ha	%	Kg/ha	%	
Non-irrigated	15,500	100	-	-	**Control**
Irrigated	34,000	219	18,500	119	***

$DL_{5\%}$ = 1,310;
$DL_{1\%}$ = 2,180;
$DL_{0.1\%}$ = 4,110.

In 2015, as a result of irrigation, the amount of tubers corresponding to 1m^3 of water used was higher by 69%, which is a statistically very significant difference (Table 8).

Table 8

Influence of the irrigation on water use efficiency, Oradea, 2015

Version	WUE		Difference		Statistical significance
	Kg/m^3	%	Kg/m^3	%	
Unirrigated	3.59	100	-	-	**Control**
Irrigated	6.09	169	2.5	69	***

$DL_{5\%}$ = 0.43;
$DL_{1\%}$ = 0.89;
$DL_{0,1\%}$ = 1.65.

Influence of irrigation on yield and water use efficiency (WUE) in 2016

Irrigation provided to maintain soil water reserve between easily available water content and field capacity within a depth of 0-75cm resulted in a yield gain of 11.400 kg/ha (40%), which is statistically very significant (Table 9).

Table 9

Influence of irrigation on potato yield, Oradea, 2016

Version	Yield		Difference		Statistical significance
	Kg/ha	%	Kg/ha	%	
Unirrigated	28,300	100	-	-	**Control**
Irrigated	39,700	140	11,400	40	***

$DL_{5\%}$ = 1.500;
$DL_{1\%}$ = 2.700;
$DL_{0.1\%}$ = 4.650.

Irrigation led to an increase in the amount of tubers for $1m^3$ of water used, 7.12 kg/m^3 against 6.0 kg/m^3. The difference is statistically very significant (Table 10).

Table 10

Influence of irrigation on water use efficiency (WUE), Oradea, 2016

Version	WUE		Difference		Statistical significance
	Kg/m^3	%	Kg/m^3	%	
Unirrigated	6.0	100	-	-	**Control**
Irrigated	7.12	119	1.12	19	***

$DL_{5\%}$ = 0.30;
$DL_{1\%}$ = 0.51;
$DL_{0,1\%}$ = 1.94

On average, in the years included in the study, the yield in non-irrigated conditions was 18,000 kg/ha. When optimum water supply was provided, a yield gain of 17,000 kg/ha (94%) was reached, which is statistically very significant (Table 11).

Table 11

Influence of irrigation on yield and on potato crop water use efficiency (WUE), Oradea 2014-2016

Version	Yield		Statistical significance	WUE		Statistical significance
	Kg/ha	%		Kg/m^3	%	
Unirrigated	18,000	100	**Control**	4.00	100	**Control**
Irrigated	35,000	194	***	6.15	154	***

$DL_{5\%}$ = 1.000 0.36
$DL_{1\%}$ = 1.830 0.74
$DL_{0.1\%}$ = 3.243 1.20

Water use efficiency (WUE) increased using the irrigation with 54% the difference in comparison with unirrigated variant was statistically very signifiant.

CONCLUSIONS

The Crișurilor Plain belongs to an area with moderate sub-humid climate, which is favourable for potato crops. The research was conducted

in 2014, 2015 and 2016 into the field for soil water balance study from Oradea. The years of the research were different in respect of climate.

Determination of soil humidity every ten days within a depth of 0-75 cm shows that in the case of the unirrigated potato soil water reserve decreased below easily available water content 75 days in 2014, 58 days in 2015 and 27 days in 2016 soil, water reserve dropped below the wilting point.

In order to maintain soil water reserve between easily available water content and field capacity on 0-75 cm depth in 2014 the irrigation rate used was 3,700 m^3/ha, in 2015 it was 2,800 m^3/ha, and in 2016 the irrigation rate was 1,200 m^3/ha.

The daily water consumption of the irrigated potato increased and the total water consumption was higher with 41% in 2014, with 43% in 2015 and with 18% in 2016.

The irrigation of potato resulted in statistically very significant yield gains, with relative differences of 206% in 2014, of 119% in 2015 and of 40% in 2016.

The drop of soil water reserve below easily available water content on the watering depth, the influence of irrigation on water consumption and the yield gains obtained in each year of the research show the need of irrigating potato in the Crişurilor Plain.

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