Long term researches regarding the irrigation influence on sugarbeet crop in the Crisurilor 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 Agricultural Research and Development Station Oradea, Crisurilor Plain in during 1976–2012.

The soil water reserve in 0–75 cm depth decreased bellow easily available water content every year and in 32% of years the soil water reserve decreased bellow wilting point. For optimum water supply an irrigation rate of 2665 m^3 ha^{-1} (variation interval 500–5090 m^3 ha^{-1}) was needed.

The irrigation determined improving of water/temperature + light report (Domuta climate index) with 47.4% in average in the period May–September. A statistically very significant connection was quantified between this indicator and the yield.

Daily water consumption increased in the irrigated variant, the biggest difference in comparison with unirrigated variant was registered in August, 86% in comparison with unirrigated variant. As consequence, the value of the total water consumption increased with 50%, variation interval was 11–154%. The irrigation covered 37.8% of total water consumption, the variation interval was 8.3%–67.9%.

The yield level of the sugarbeet increased in average with 61%, the variation interval was 9–227%. Standard deviation was lower in the irrigated variant and this emphasizes an improve of the yield stability with 25.1%. The sugar content of the sugarbeet roots from irrigated variant increased statistically very significantly in the droughty years and differs significantly in the rainy years.

Water use efficiency increased in the irrigated variant with 7% and irrigation water use efficiency was between 7.9 kg yield gain 1 m^{-3} irrigation water and 17.4 kg yield gain 1 m^{-3} irrigation water.

The positive influence of the irrigation on microclimate, water consumption, yield level, stability and quality and on water use efficiency sustain the need of the irrigation in sugarbeet from Crisurilor Plain.

Keywords: *sugarbeet, irrigation, Domuța climate index, yield, water use efficiency*

INTRODUCTION

The Crişurilor Plain was known for large surfaces with water logging but the land reclamation changed the area. (Domuţa, 200; Muntean et al., 2011) There was not a good correlation between plants water requirement and rainfall distribution. In this conditions the researches regarding the crops irrigation was started by Stepănescu E. in 1967 and the irrigation regime of sugarbeet (and other 4 crops) was established in the conditions of the chernozem from Girişu de Criş (Domuţa, 2009b, 2011, 2012). In 1973, Stepănescu E. placed the research field for study of the soil water balance in Girişu de Criş. Starting 1976 the researches regarding the study of the soil water balance were placed in Oradea (Domuţa, 2010, 2011), for obtaining the optimum water consumption, ten to ten days the soil moisture was determined and the soil water reserve was maintained between easily available water content and field capacity (Grumeza et al., 1989).

The paper presents the results researches during 1976–2012 regarding optimum irrigation regime in sugarbeet, the irrigation influence on microclimate, water consumption, yield quantity and quality and water use efficiency in optimum irrigated sugarbeet. In the same time, the determination of the optimum values for daily water consumption permits the calculation of the "crop coefficient , Kc" used in sugarbeet irrigation scheduling (Bazza and Tayaa, 1999).

MATERIAL AND METHODS

The paper presents the researches carried out during 1976–2012 in the long term trial for soil water balance study placed in Agricultural Research and Development Station Oradea, Western Romania in the conditions of a preluvosoil. All the preluvosoil profile are acidic (6.11–6.8), humus content (1.44–1.75%) is law and total nitrogen is low medium (0.127–0.157). After 37 years of good soil management, the soil phosphorus content became very good (from 22.0 ppm to 150.8 ppm) on ploughed depth, potassium content (124.5 ppm) is medium.

There are a high hydro stability (47.5%) of the aggregates (Φ = 0.25 mm) on ploughingland; the bulk density (1.41 g cm^{-3}) indicates a low settling soil, total porosity is medium. On the subjacent depth of the ploughed layer the bulk density characterizes the soil like moderate and very settled and total porosity is low and very low. Hydraulic conductivity is high (21.0 mm h^{-1}) on 0–20 cm; medium (10.5 mm h^{-1}; 4.4 mm h^{-1}) on 20–40 cm and 40–60 cm and very low (1.0 mm h^{-1}) on 60–80 cm depth (Domuţa et al., 2012).

The source of irrigation water was a drill of 15 m depth. Irrigation water quality was very good: pH = 7.2; Na^+= 12.9; mineral residue = 0.5 g l^{-1}; CSR = -1.7; SAR = 0.52.

In Romania, the watering depth for sugarbeet is fixed one, 0–75 cm for this area. Soil moisture on 0–75 cm depth was determined in ten days interval and monthly on 0–150 cm depth. In the irrigated variant, the moment of the irrigation use was applied when the soil water reserve on 0–75 cm depth decreased to easily available water content. On the 0–100 cm layer the value of the easily available water content (Wea) is of 19.7%. Easily available water content was established in function of clay content (Brejea, 2009, 2010, 2011) using the formula: Wea = WP+2/3 (FC-WP); in wich: FC = field capacity (24.3%) and WP = wilting point (10.5%).

The microclimate of the sugarbeet was characterizated by Domuţa climate index (ICD):

$$ICD = \frac{100W + 12.9A}{\sum t + Sb}$$

In which :

W = water (rainfall, irrigation, ground water) mm,

A = air humidity (%),

∑t = the sum of daily average temperature (ºC),

Sb = sunshine (hours).

The characterization class by ICD values are: <3 excessive drought; 3.1–5 very droughty; 5.1–7 drought; 7.1–9 medium drought; 9.1–12 medium wet; 12.1–15 wet I; 15.1–18 wet II; 18.1–25 wet III; >25 excessive wet.

The water consumption was determined by the soil water balance method. Water use efficiency was calculated like report between yield and water consumption. (Crăciun, 1990; Răcucu et al., 2012; Borza and Stanciu, 2010).

The experiment data were calculated using the variance analysis method (Domuţa, 2006).

RESULTS AND DISCUSSION

Optimum irrigation regime

Maintaining the soil water reserve on 0–75 cm depth between easily available water content and field capacity determined to use an average irrigation rate of 2665 m^3 ha^{-1}; the lowest irrigation rate, 500 m^3 ha^{-1}, was used in 1978 and 1997; the highest value of the irrigation rate was 5090 m^3 ha^{-1}, was used in 2000. In avarage, the irrigation was applied 6 times; variation interval of the number of irrigations was 1–11 *(table 1)*.

Table 1.

Optimum irrigation regime in sugarbeet (Oradea, 1976–2012)

Specification	Average	Minimum value	Maximum value
Irrigation rate (m^3 ha^{-1})	2665	500 (1978, 1997)	5090 (2000)
Number of irrigations	6	1	11

In average on the studied period the irrigation scheme used includes zero irrigation in April, 1/2 irrigation rate used in May and September, 1 irrigation rate used in June and 2 irrigation rates used in July and August *(table 2)*.

Table 2.

The average scheme of irrigation applied in sugarbeet (Oradea, 1976–2012)

Specification	April	May	June
Number of irrigations	0	½	1
Specification	July	August	September
Number of irrigations	2	2	½

Irrigation influence on microclimate

There are different possibilities for climate characterization. One of them consists of the climate indicators use. The main climate indicators used in Romania are: de Martonne aridity index, Seleaninov coefficient, Hellman criterium, Teaci index, Palfai aridity index, Domuta climate index (Petrescu, 1999).

The Martonne aridity index is the most known climate indicator. Ciobanu et al. (2003) used this climate indicator for quantification the relationships between the climate conditions and the wheat yields obtained in a long term trial with fertilizers; the climate indicator 'Domuta climate index' was used too. The correlation coefficients for relationships climate – yield were bigger using Domuta climate index: R^2 = 0.9895 vs R^2 = 0.6846 in the variant without manure and R^2 = 0.8802 vs R^2 = 0.8522. Palcut (2003) obtained better correlation coefficient using Domuta climate index in comparison with 'de Martonne aridity index' for quantification the relationship climate – yield of the maize hybrids. Domuta (2003) quantified the relationship climate-yield using 'de Martonne aridity index', 'Seleaninov coefficient', hydroheliotermic index and Domuta climate index; the following order of the correlation coefficient was registered for climate indicators used: R^2 = 0.9319 for Seleaninov coefficient, R^2 = 0.9225 for hydroheliotermic index, R^2 = 0.8662 for de Martonne aridity index (Domuţa, 2005).

As consequence for characterization of the microclimate created by the irrigation use, the climate indicator 'Domuta climate index' was used. In unirrigated condition, the sugarbeet microclimate was characterized "medium wet" in May, June, July and September and "medium drought" in August; in average on the May-September period the microclimate of the unirrigated sugarbeet was characterized like "medium wet". The irrigation use determined the increase of the "Domuta climate index" values with 12.2% in May, with 36,1% in June, with 76.2% in July, with 127.4% in August, with 12.4% in September and with 47.4% in average on the period May-September; in the month of the irrigation period, the microclimate characterization was "medium wet" in May and September, "wet" in June, July and August and "wet I" in average of the period May–September *(table 3)*.

There is a direct connection between microclimate conditions quantified by Domuta climate index and sugarbeet yields obtained in the unirrigated and irrigated variants. The best quantification was obtained using the exponential function: $y=21.492e^{0,0728}x$; $R^2=0.72^{xxx}$.

Table 3.

Irrigation influence on water/temperature + light raport (Domuta climate index (ICD) in sugarbeet (Oradea, 1976–2012)

Variant	Specification	May	June	July	August	September	May – September
Unirrigated	ICD value	9.8	11.9	9.7	7.3	10.5	9.8
	Characterization	Medium wet	Medium wet	Medium wet	Medium drowght	Medium wet	Medium wet
Irrigated	ICD value	11.0	16.2	17.1	16.6	11.8	14.5
	Characterization	Medium wet	Wet II	Wet II	Wet II	Medium wet	Wet I
Difference %		12.2	36.1	76.2	127.4	12.4	47.4

Irrigation influence on water consumption

In the months with irrigation, the values of the daily water consumption increased in comparison with the values were determined in unirrigated sugarbeet the relative differences were of 21.0% in April, of 17% in May of 31% in June, of 60% in July, of 86% in August and of 61% in September. The maximum daily water consumption for unirrigated sugarbeet (37.3 m^3 ha^{-1} day^{-1}) was registered a month (June) before than the maximum value from irrigated variant *(table 4)*.

The irrigation determined the increase of the total water consumption of the sugarbeet with 50%, variation interval 11–154%. The main covering source of the total water consumption was the rainfall registered during the vegetation period of the sugarbeet, 351.6 mm; this source covered a 74% from total water consumption of the unirrigated sugarbeet (variation interval 38–99%) and 49.8% from total water consumption of the irrigated sugarbeet (variation interval 15–89%). In average in the studied period, the water used from soil reserve presented 25.4% from total water consumption of the unirrigated sugarbeet and 12.4% from total water consumption of the irrigated sugarbeet. In average in the studied period, the irrigation covered 37.8% from total water consumption of the sugarbeet in the optimum water provisionement variation interval 8.3–67.9% *(table 5)*.

Direct link was quantified between the sugarbeet water consumption and yield obtained in unirrigated and irrigated variants. The mathematical expression of this link is: $y=4.02224x^{1.3731}$; $R^2=0.7706$.

Irrigation influence on yield level, stability and quality

In average on the period 1976–2012, the irrigation determined yield gain of 25 030 kg ha^{-1} (61%). Across the years, the yield gains, the relative differences in comparison with unirrigated variant were between 9% and 227%. The irrigation determined improving in yield stability because the standard deviation value decreased with 25.1% in comparison with unirrigated period, 6920 kg ha^{-1} vs 9240 kg ha^{-1} *(table 6)*.

Table 4.

Irrigation influence on daily water consumption in sugarbeet (Oradea, 1976–2012)

Variant	April		May		June		July		August		September	
	m^3 ha^{-1} day^{-1}	%	m^3 ha^{-1} day^{-1}	%	m^3 ha^{-1} day^{-1}	%	m^3 ha^{-1} day^{-1}	%	m^3 ha^{-1} day^{-1}	%	m^3 ha^{-1} day^{-1}	%
Unirrigated	20.1	100	27.8	100	37.3	100	35.6	100	25.2	100	18.4	100
Irrigated	24.1	121	32.6	117	48.9	131	56.6	160	46.8	186	29.7	161
Difference	4.0	21	4.8	17	11.6	31	21.0	60	21.6	86	11.3	61

Table 5.

Irrigation influence on total water consumption - Σ (e+t) in sugarbeet and the covering sources (Oradea, 1976–2012)

Variant	∑ (e+t)			Covering sources of the water consumption					
					Rainfall		Irrigation		
	Average		Variation interval (%)	Soil water reserve (m^3 ha^{-1})	(m^3 ha^{-1})	Variation interval (%)	(m^3 ha^{-1})	(%)	Variation interval (%)
Unirrigated	4714	100	100	1199	3516	38–99	-	-	-
Irrigated	7058	150	111–254	877	3516	15–89	2665	37.8	8.3–67.9

Table 6.

Irrigation influence on yield level and stability in sugarbeet (Oradea, 1976–2012)

Variant	Average yield		Variation interval of the yields		Standard deviation of the yields	
	(kg ha^{-1})	(%)	(kg ha^{-1})	(%)	(kg ha^{-1})	(%)
Unirrigated	41360	100	18960–80900	100	9240	100.0
Irrigated	66390	161	44850–87800	109–327	6920	74.9

$LSD_{5\%}$ = 53, $LSD_{1\%}$ = 970, $LSD_{0.1\%}$ =1520

There are different results regarding the irrigation influence on sugar content of the roots: Petrescu (1999) shows the positive influence of the water stress on sugar content; Bazza (1999) established the negative influence of the water stress on sugarbeet quality. Our researches were realized during 2009–2012 and show a higher sugar content in the irrigated variant. The differences are very significant statistically in the droughty years 2009, 2011 and 2012 and differ significant statistically in the rainy year 2010. The relative differences were of 16% in 2009, 7% in 2010, 25% in 2011 and 24% in 2012 *(table 7)*.

Irrigation influence on water use efficiency

Two types of the indicators are known for establishing the water use efficiency. First type emphasizes the yield quantity obtained for 1 m^3 water and the second type emphasizes the quantity of water used for 1 kilogram of main yield (Borza, 2006; Craciun, 1990; Domuta, 1995).

The paper presents the indicators 'water use efficiency' and 'irrigation water use efficiency'. They emphasize the quantity of yield obtain for 1 m^3 of water used and quantity of the yield gain obtained for every m^3 of irrigation water used. In average on the studied period, the irrigation determined the increase of the water use efficiency with 7%. The maximum difference between irrigated variant and unirrigated variant 52%, was registered in the very droughty year 2000. In the rainy year 1978, a negative difference of -1% was registered *(table 8)*.

In average on the studied period, the yield gain obtained for 1 m^3 irrigation water was of 9.5 kg m^{-3}. Variation interval was between 7.9 kg yield gain m^{-3} and 17.4 kg yield gain m^{-3} *(table 8)*.

Table 7.

The irrigation influence on sugar content of the sugarbeet roots (Oradea, 1976–2012)

Variant	Sugar content (%)		Difference (%)		Statistical significance (%)
2009 ($LSD_{5\%}$ 0.32, $LSD_{1\%}$ 0.65, $LSD_{0.1\%}$ 1.05)					
Unirrigated	14.5	100	-	-	Control
Irrigated	16.9	116	2.4	16	***
2010 ($LSD_{5\%}$ 0.39, $LSD_{1\%}$ 0.74, $LSD_{0.1\%}$ 1.20)					
Unirrigated	16.1	100	-	-	Control
Irrigated	17.2	107	1.1	7	**
2011 ($LSD_{5\%}$ 0.35, $LSD_{1\%}$ 0.64, $LSD_{0.1\%}$ 1.11)					
Unirrigated	14.7	100	-	-	Control
Irrigated	17.3	125	2.6	25	***
2012 ($LSD_{5\%}$ 0.29, $LSD_{1\%}$ 0.57, $LSD_{0.1\%}$ 0.98)					
Unirrigated	13.7	100	-	-	Control
Irrigated	17.0	124	3.3	24	***
Average ($LSD_{5\%}$ 0.34, $LSD_{1\%}$ 0.65, $LSD_{0.1\%}$ 1.09)					
Unirrigated	15.0	100	-	-	Control
Irrigated	17.1	114	2.1	14	***

Table 8.

Water use efficieny (WUE) and irrigation water use efficieny (IWUE) in sugarbeet (Oradea, 1976–2012)

Variant	WUE				IWUE	
	Average		Variation interval		Average	Variation interval
	(kg m^{-3})	(%)	(kg m^{-3})	(%)	(kg yield gain m^{-3})	
Unirrigated	8.77	100	5.47–10.73	100	-	-
Irrigated	9.40	107	8.31–11.63	99–152	9.5	7.9–17.4

CONCLUSIONS

The researches were carried out during 1976–2012 the soil moisture was determined in ten days interval, for maintaining the soil water reserve between easily available water content and field capacity and an irrigation rate of 2665 m^3 ha^{-1} was needed.

The irrigation determined the improving of water/temperature + light report (Domuta climate index) with 47.4% in average of the period May–September. Direct statistically very significant connection was quantified between this indicator and the yield.

Daily water consumption increased in the irrigated variant, the biggest difference in comparison with unirrigated variant was registered in August, 86%. As consequence, the value of the total water consumption increased with 50%, the variation interval with 11–154%. The irrigation covered 37.8% from total water consumption, variation interval was 8.3–67.9%.

The yield level of the sugarbeet yield increased in average with 61%, variation interval was 9–227%. There was lower standard deviation value in irrigated variant and this emphasizes improve in yield stability with 25.1%. The sugar content of the sugarbeet roots from irrigated variant increased very significantly statistically in the droughty years and differs significantly in the rainy years.

Water use efficiency increased in the irrigated variant with 7% and irrigation water use efficiency was between 7.9 kg yield gain 1 m^{-3} irrigation water and 17.4 kg yield gain 1 m^{-3} irrigation water. The positive influence of the irrigation on microclimate, water consumption, yield stability and quality and on water use efficiency sustain the need of the irrigation in sugarbeet from Crisurilor Plain.

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