IRRIGATION SCHEDULING FOR SUGARBEETS GROWN ON A LOAMY SOIL UNDER VARIABLE CLIMATIC CONDITIONS

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Abstract

Irrigation schedule for sugarbeets grown in an experiment organized on a loamy soil in the continental part of Serbia, which is characterized by variable climatic conditions, has been determined on the basis of soil moisture readings obtained by the gravimetric method.
The experiment was conducted in the period 2002-2005, in which 2002 and 2003 were very dry and 2004 and 2005 were moderately dry. Irrigation was scheduled on the basis of two pre-irrigation soil moisture levels: A – 60-65% of FWC and B – 75-80% of FWC. The nonirrigated variant C served as control. The rainfall levels during the 2002-2005 growing seasons (April - September) were 274, 236, 442 and 530 mm, respectively. The rainfall distribution varied from year to year and between months in a single year. In variant A, 360 and 330 mm of irrigation water were applied in the two very dry years and 120 mm in each of the two moderately dry years. In variant B, 300 and 270 mm were applied in the very dry years and 150 mm in the moderately dry years.
The average yields of sugarbeet roots in variants A, B and C were 89.86, 94.44 and 75.36 t/ha, respectively. The respective average sugar contents were 14.62, 14.91 and 14.81%.

Key words: irrigation, climatic conditions, irrigation scheduling, yield, sugar content

Introduction

In the agricultural regions of Serbia, where the rainfall sum and distribution are highly variable from year to year and within a single year, irrigation is a supplementary practice. The average annual rainfall is about 600 mm, with variations from 360 to 940 mm. Variations are also large during the growing season, especially in July and August, from 0-160 mm. In 70-80% of the years the rainfall in July and August does not meet sugarbeet plant requirements and irrigation becomes necessary (Dragović *et al*., 2004).

Insufficient rainfall is particularly detrimental for sugarbeet, which is presently grown in Serbia at about 80-90,000 ha for the country's 11 sugarbeet refineries. The sugarbeet has a high water requirement because of its high production of organic matter per unit area. At the same time, it is a thrifty consumer of water. The well-developed root system takes up water from the depth of two meters. Under conditions of favorable soil moisture and fertility, it develops large leaf mass and a large storage root with a high percentage of sugar.

In climatic conditions where the amounts and distribution of rainfall are variable, as is the case with the agricultural regions of Serbia, sugarbeet yield performance is directly dependent on weather conditions and irrigation. Sugarbeet yields vary in conditions without irrigation not only from one year to another but also from one region to another within the single growing season. About 10-20% of the total sugarbeet requirement for water is supplied from reserve soil water, while the rest is provided by rainfall and irrigation (Maksimović and Dragović, 2004).

Depending on the conditions of growing, cultural practices applied, genotype properties and yield performance, sugarbeet water requirement ranges in Serbia from 500 to 700 mm, or 550-600 mm on the average. The most critical period for water supply are the months of July and August because that period accounts for 40 to 50% of the total sugarbeet requirement for water. As the amount of rainfall during growing season is from 350 to 450 mm, there is regularly a water deficit of 100-200 mm, which reaches 300 mm in some years (Dragović *et al*., 2003).

Material and Method

The trails were conducted from 2002 to 2005 at the experiment field of Institute of Field and Vegetable Crops in Novi Sad (northern Serbia), on a loamy chernozem soil with favorable chemical and physical properties. The experimental object was the sugarbeet variety Lara (NS-H-8R) developed at the Novi Sad Institute.

The experiment included the two irrigation variants, scheduled on the basis of pre-irrigation soil moisture level determined by a gravimetric method:

A – 60-65% of field water capacity (FWC)

B – 75-80% of FWC

C – nonirrigated-control

Sprinkling irrigation was used in the experiment.

Phosphorus and potassium were each applied in the amount of 90 kg/ha in the fall during primary tillage. Total nitrogen (140 kg/ha) was applied in 3 turns: during primary tillage, before planting and for top dressing.

The other cultural practices used in the experiment followed the recommendation for intensive sugarbeet production: plowing to the depth of 30 cm, seedbed preparation, herbicide application, crop protection against diseases and insects and between-row cultivation.

Results

Weather conditions and irrigation scheduling. The annual sums and distribution of rainfall varied considerably in the experiment years. The 4-year average rainfall during growing season was 370 mm, but the actual rainfalls differed from 236 mm in 2003 to 530 mm in 2005. The first two years (2002 and 2003) were very dry from the point of crop production, 274 and 236 mm, respectively (Table 1). Furthermore, the monthly distribution of rainfall was quite unfavorable in these years, so it was necessary to irrigate sugarbeets throughout the growing season. In 2002, the rainfalls in June and July were significantly below the long-term average. In 2003, below-average rainfall persisted in all months except in the second half of July when 54 mm of rain were received.

Table 1 - Total monthly and 10-day rainfall sums (mm) at the experiment field

Month	10-day period	Year				Long-term 1923-2003
		2002	2003	2004	2005	
Outside of the growing season		194	226	298	376	263
April	I	2	1	36	0	
	II	11	3	61	11	
	III	13	4	15	22	
	Sum	26	8	112	33	50
May	I	7	0	23	22	
	II	21	4	22	15	
	III	59	19	44	1	
	Sum	87	23	89	38	60
June	I	5	0	55	122	
	II	12	12	17	8	
	III	10	19	25	5	
	Sum	27	31	97	135	77
July	I	9	6	2	74	
	II	21	34	2	45	
	III	3	20	59	4	
	Sum	33	60	63	123	60
August	I	49	18	4	59	
	II	6	12	3	56	
	III	0	0	32	19	
	Sum	55	30	39	134	56
September	I	3	18	7	0	
	II	2	63	6	45	
	III	41	3	29	22	
	Sum	46	84	42	67	44
Growing season		274	236	442	530	348
Hydrologic year		468	462	740	906	611

The years of 2004 and 2005 had much higher rainfall sums, 442 and 530 mm, respectively, and much better distribution of rainfall during growing season. These sums were above the long-term average (Table 1). Precipitation was particularly abundant in 2005, both in the winter period (376 mm) and during the growing season (530 mm). The total precipitation of 906 mm for the hydrological year is near the absolute maximum ever registered in this region. Still, significant differences in monthly rainfall occurred in these years too (Figure 1).

Insufficient rainfall was supplemented by irrigation so that sugarbeets grow under optimum soil moisture throughout the growing season. Variant A (60-65% FWC) received 360 and 330 mm of irrigation water in 2002 and 2003, respectively. Six irrigations were performed in both years. Variant B (75.80% FWC) received 300 and 270 mm in 2002 and 2003, respectively, in nine irrigations each year. In 2004 and 2005, which had more favorable distributions of rainfall, 120 mm of water were added each year, in two irrigations, to variant A, and 150 mm, in five irrigations, to variant B (Table 2).

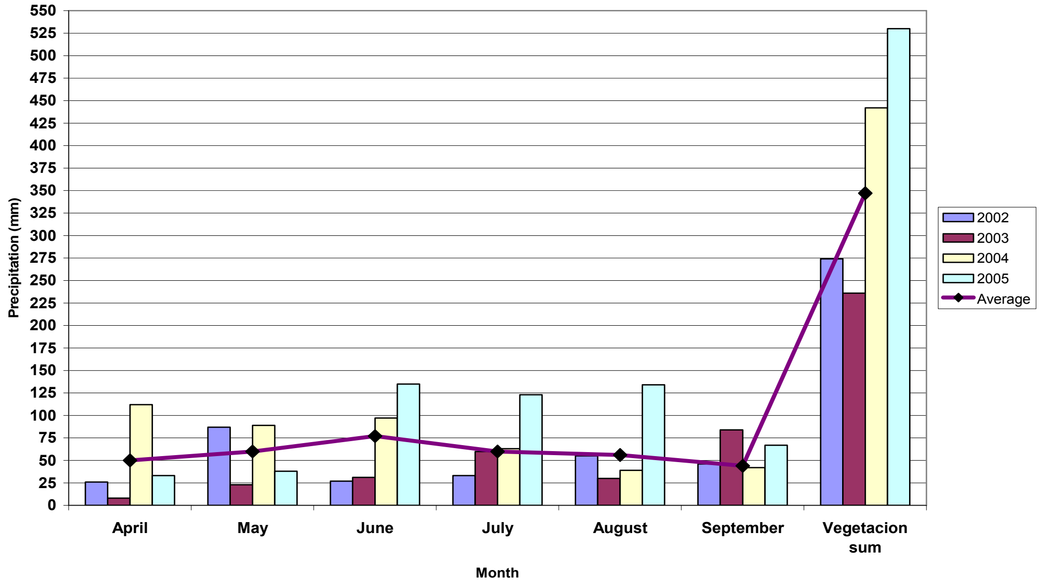


Figure 1 –Monthly and long-term average rainfall sums in the growing seasons

Table 2 – Irrigation schedule and rates (mm)

Year	Date of irrigation	Variant		Year	Date of irrigation	Variant	
		A: 60-65% FWC	B: 75-80% FWC			A: 60-65% FWC	B: 75-80% FWC
2002	19.06.	60	60	2004	30.06	-	30
	26.06.	-	30		08.07.	60	30
	28.06.	60	-		20.07.	60	30
	05.07.	-	30		24.07.	-	30
	13.07.	60	30		10.08.	-	30
	20.07.	-	30				
	30.07.	60	30				
	23.08.	-	30				
	28.08.	60	30				
	06.09.	60	30				
	Total	360	300		Total	120	150
2003	10.05.	30	30	2005	03.06.	60	30
	21.05.	-	30		21.06.	-	30
	03.06.	60	30		24.06.	60	-
	10.06.	-	30		30.06.	-	30
	13.06.	60	-		22.07.	-	30
	17.06.	-	30		29.07.	-	30
	30.06.	-	30				
	02.07.	60	-				
	08.07.	-	30				
	05.08.	60	30				
	15.08.	60	30				
	Total	330	270		Total	120	150

Air temperature had a significant effect on the intensity of evapotranspiration, therefore, on sugarbeet irrigation regimen. Average temperatures per 10-day period and per month are presented in Table 3.The average air temperature for the growing seasons of 2002-2005 was 18.7°C, the actual figures betwen years varying from 16.3 to 17.2°C. The long-term average for the growing season in this region is 16.8°C. In July and August, however, maximum daily temperatures typically exceed 30°C, frequently going above 35°C.

Table 3 – Mean daily air temperatures at the experiment field

Year	10-day period	Mean daily air temperature, ºC						
		April	May	June	July	August	Septem ber	Average
2002	I	8.3	18.3	18.8	23.8	23.2	21.3	
	II	12.6	19.6	22.9	24.8	21.0	15.8	
	III	14.2	19.4	23.7	22.2	22.3	14.1	
	Average	11.7	19.1	21.8	23.6	22.2	17.0	19.2
2003	I	5.9	22.3	24.7	22.1	24.4	17.1	
	II	12.1	19.5	24.2	21.9	24.8	16.9	
	III	14.8	20.1	23.1	23.6	24.7	17.9	
	Average	10.9	20.6	24.0	22.6	24.6	17.2	20.0
2004	I	11.4	15.8	18.5	23.0	22.3	18.1	
	II	11.2	14.3	20.3	21.1	22.5	16.8	
	III	14.8	15.5	20.7	21.9	20.4	13.9	
	Average	12.4	15.2	19.8	21.9	21.7	16.3	17.9
2005	I	10.8	14.3	15.2	19.8	18.9	19.5	
	II	12.3	14.9	20.0	21.1	19.1	17.1	
	III	12.4	21.2	22.8	22.2	20.2	15.2	
	Average	11.7	17.0	19.3	21.1	19.4	17.2	17.6
Mounthly average		11.7	18.1	21.2	22.3	22.0	16.9	18.7
Long-term average		11.3	16.7	19.7	21.3	20.8	16.8	17.8

Sugarbeet evapotranspiration. Sugarbeet evapotranspiration (ET) per test year and experiment variant was analyzed on the basis of water amounts received from soil reserve to the depth of 2 m, determined at the beginning of growing season, effective rainfall and irrigation.

The average ET in the variant of irrigation at 60-65% FWC (A) was 617 mm, 52 mm being supplied from soil reserve, 333 mm from effective rainfall and 232 mm from irrigation. The annual variation went from 552 mm in 2004 to 664 mm in 2003. Regarding water source, the variations were from 0 to 122 mm for soil reserve, from 212 to 477 mm for effective rainfall and from 120 do 360 mm for irrigation water. ET was similar in the variant of irrigation at 75-80% FWC (B). The average was 613 mm, with variations from 576 to 629 mm (Table 4). Regarding water source, the average values for soil reserve, effective rainfall and irrigation water were 63, 333 and 218 mm, respectively. The average ET in the nonirrigated variant (C) was 467 mm, with annual differences from 384 mm in 2003 to 565 mm in 2005. The high ET value in the nonirrigated variant was primarily due to water uptake from soil reserve (134 mm on the average), with annual variations from 76 mm in 2004 to 202 mm in 2002. Also, the abundant rainfalls in the 2004 and 2005 growing seasons contributed to the high ET values in the nonirrigated variant (Table 4).

Table 4 – Evapotranspiration of sugar beet including reserve of winter soil water to 2 m depth (mm)

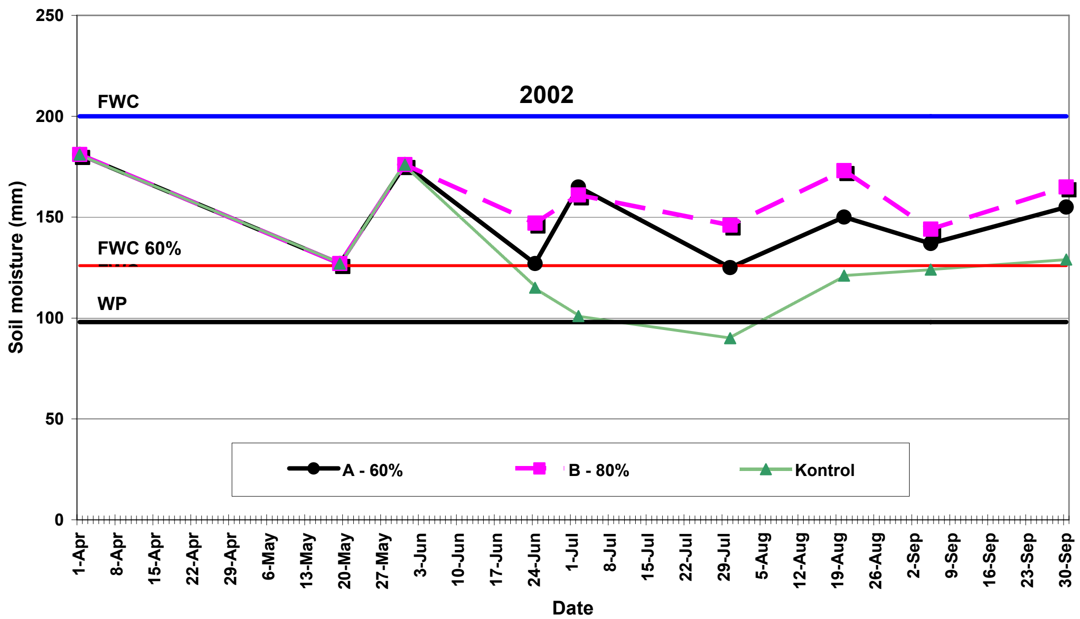
Year	Variant	Reserve of winter soil moisture	Sum of effective rainfall	Irrigation	Total
2002	A	51	245	360	656
	B	84	245	300	629
	C	202	245	0	447
2003	A	122	212	330	664
	B	142	212	270	624
	C	172	212	0	384
2004	A	34	398	120	552
	B	28	398	150	576
	C	76	398	0	474
2005	A	0	477	120	597
	B	0	477	150	627
	C	88	477	0	565
Average	A	52	333	232	617
	B	63	333	218	613
	C	134	333	0	467

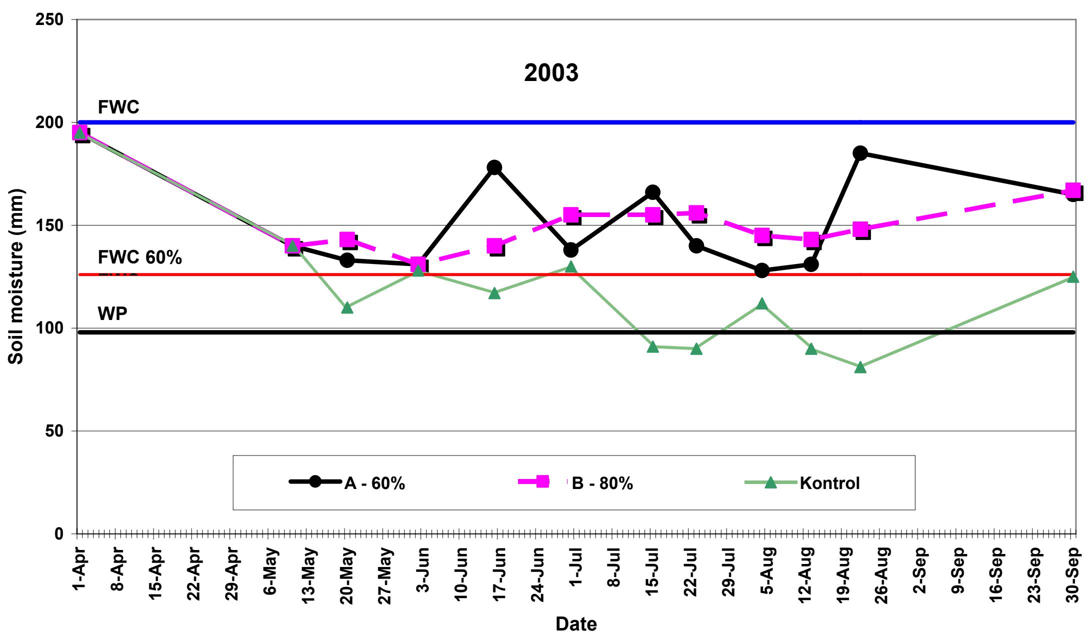
As the sugarbeets in the irrigated variants were provided with available water throughout the growing season, the average ET value for these two variants may be considered as the value of potential evapotranspiration of sugarbeet for the agroclimatic conditions of the region under study, which amounted to 615 mm.

Long-term studies (over 20 years) conducted in the same agroclimatic conditions indicated that the average sugarbeet requirement for water was 579 mm, with the annual variations from 530 to 625 mm depending on weather conditions during growing season. On the other hand, the actual evapotranspiration was considerably lower and it fluctuated significantly from one to another year. In warmer regions, such as Texas, USA, the requirement of sugarbeet is 1185 mm (Hilli *et al*., 1990). Ehling and LeMart (1979) report the requirement of 900 to 1195 mm for California.

Soil moisture determination. The irrigation schedule was made on the basis of soil moisture analyses. Soil moisture had been monitored throughout the growing season, at intervals of 10 or more days, depending on rainfall and air temperature. During the period of intensive growth of sugarbeet roots and high ET, soil moisture was monitored at 7-day or shorter intervals.

Before the beginning of irrigation, soil moisture values were similar in all variants so they were averaged across the variants. After the beginning of irrigation, soil moisture values were presented separately for each variant. At the beginning of the growing season, the average soil moisture in soil layer 0 - 60 cm ranged between 85 and 95% FWC. In the course of the season, the values changed in dependence of rainfall and irrigation schedule (Figure 2).


2002
FWC
FWC 60%
WP
Soil moisture (mm)
Date
A - 60%
B - 80%
Kontrol


2003
FWC
FWC 60%
WP
Soil moisture (mm)
Date
A - 60%
B - 80%
Kontrol

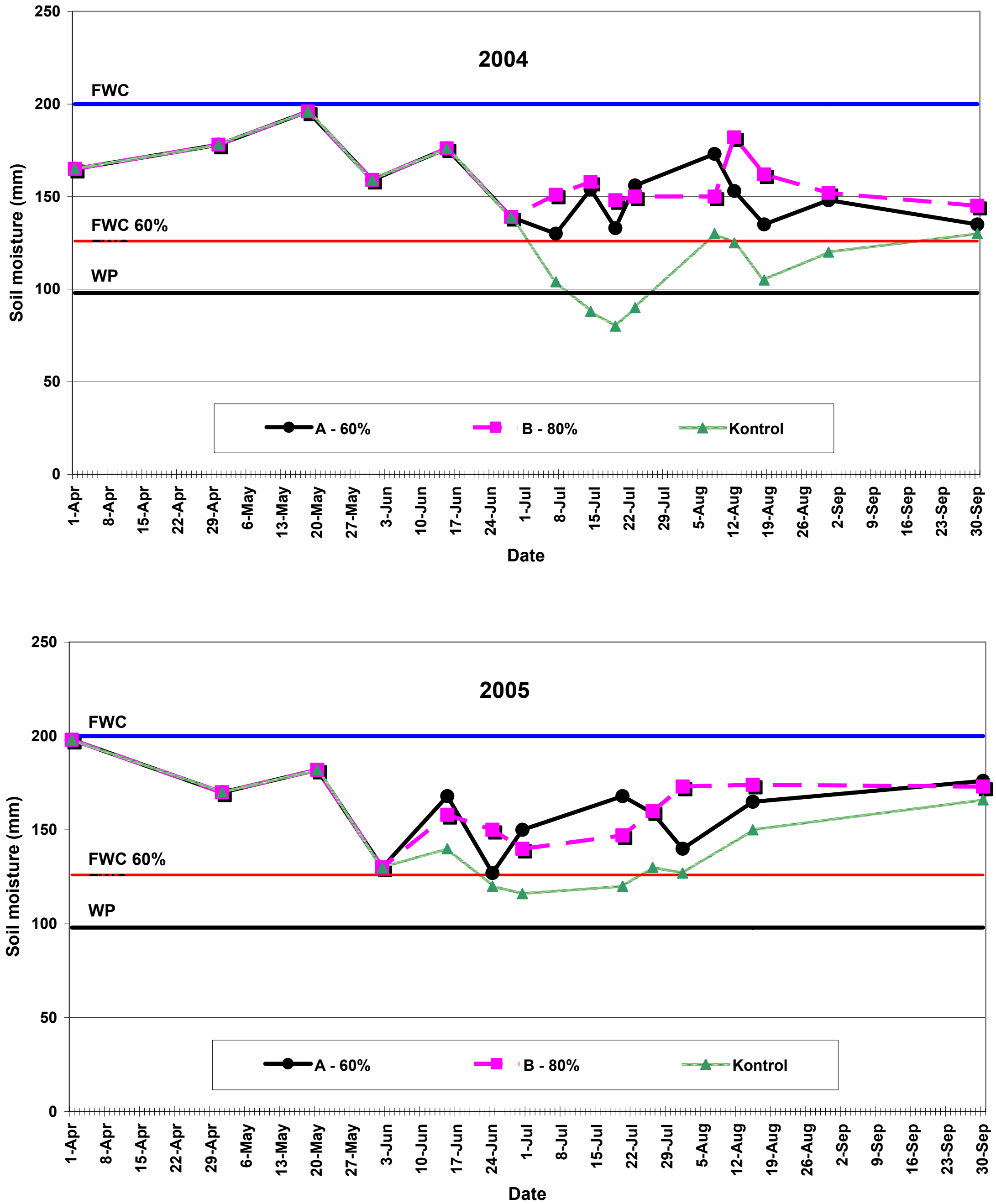


Figure 2 – Dynamics of soil moisture in the soil layer 0-60 cm in experimental years

In the nonirrigated control variant (C), soil moisture depended on rainfall and intensity of ET. In the very dry years (2002 and 2003), long dry spells brought the level of soil moisture to the wilting point or below it (Figure 2). During these periods, sugarbeet plants survived by taking up water from deep soil layers, 2 m or more.

Root yield. Effect of water scheduling on yield of sugarbeet differed in independence of rainfall and its distribution during growing season. Based on the calculated average values, the highest yield was in the variant of irrigation scheduling at 75-80% FWC (B) was 94.44

t/ha. The average yield in the variant of irrigation scheduling at 60-65% FWC (A) was 89.86 t/ha. The difference, 4.58 t/ha or 5.1%, was not statistically significant. But, in the very dry years of 2002, the differences in yield between these two variants were highly significant, 13.93 t/ha or 16.1%.

In 2004 and 2005, the effective rainfalls were 398 i 477 mm, respectively. These rainfalls were 110 mm higher than those registered in the previous two years. In 2004 and 2005, the average yields of sugarbeet in the two variants of irrigation scheduling were similar (Table 5).

Table 5 - Root yields depending on irrigation scheduling

Irrigation Sheduling A	Years B				
	2002	2003	2004	2005	*Average*
A-60-65% FWC	86.41	89.02	99.94	84.08	89.86
B-75-80% FWC	100.34	92.68	98.36	86.38	94.44
C-Control	64.36	63.56	87.12	86.38	75.36
Average	83.70	81.75	95.14	85.61	86.55
	A	**B**	**AxB**	**BxA**	
LSD 0.05	4.78	4.77	8.70	8.25	
0.01	7.24	6.44	12.26	11.15	

The average yield in the control variant was 75.36 t/ha. That was 16.79 t/ha or 22.3% lower than the average yield of the irrigated variants. However, differences were much larger in the very dry years of 2002 and 2003. Particularly high differences in these years were obtained in variant B, 35.98 and 29.12 t/ha or 56 and 46%, respectively. In the moderately dry year of 2004, the difference between variants B and C was mush lower, 11.24 t/ha or 13%. In 2005, which was favorable with respect to rainfall amount and distribution, especially in June, July and August, there was no significant difference in yield between the irrigated variants and the nonirrigated control. In 2005, variant A received 120 mm of water in 2 irrigation and variant B received 150 mm of water in 5 irrigations. Still, the irrigation practice showed no effect on sugarbeet yield.

The average yield of all variants in all years was 86.55 t/ha. The annual yields were similar, with the exception of 2004 which exceeded the average yields for the other three years by 11.63 t/ha or 13% (Table 5). This difference was high significant. Significant differences between years for sugarbeet yield without irrigation were also found. Berić (2000), reported that in the period 1990-1999 differences in the average yield of this crop ranged from 22.7 t/ha in a very dry year of 1993 to 46.62 t/ha in a rainy year of 1999.

In a previous study of the effect of soil water regimen on sugarbeet in reduced irrigation under variable climatic conditions, Dragović *et al*. (2003) found that irrigation increased sugarbeet yields from 4 to 90%. But in the years with moderate sums and relatively favorable distribution of rainfall, yields were 25% higher in irrigation than in the nonirrigated control (Dragović *et al*., 1999).

Analyzing data gathered over a 20-year period, Maksimović and Dragović (2000) found that the average yields of sugarbeet root in experiments without and with irrigation were 64.3 t/ha and 85.6 t/ha, respectively, the effect of irrigation being 33%. The annual yield variations were 40 to 94 t/ha and 64 to 124 t/ha, respectively. In very dry years, the average effect of irrigation was 190%, ranging in dependence of hybrid from 98 to 276% (Dragović *et al*., 1998).

Sugar content. Sugar contents in the root were similar in all variants. The average content was 14.78%. Some differences were observed among the test years, from 13.14% in 2002 to 16.96% in 2005 (Table 6). Long-term studies of the effect of irrigation on sugarbeet yield and sugar content in the root showed that in years with increased rainfall the irrigation practice reduces the percentage of sugar by 0.5 to 1% (Dragović *et al*., 2006). In this study, there was no significant difference in sugar content between the irrigated and the nonirrigated variants.

Table 6 – Effect of irrigation scheduling on sugar content (%)

Irrigation Sheduling	Years				
	2002	2003	2004	2005	*Average*
A-60-65% FWC	13.02	13.51	15.29	16.67	14.62
B-75-80% FWC	13.23	13.31	15.91	17.19	14.91
C-Control	13.17	13.71	15.35	17.03	14.81
Average	13.14	13.51	15.52	16.96	14.78

Conclusion

In changeable climatic conditions, with fluctuating rainfall, irrigation scheduling in dry years significantly affects sugarbeet yield.

In this study, the highest yield was obtained in the variant of irrigation at 75-80% FWC, 94.44 t/ha, which exceeded the yield in the variant of irrigation at 60-65% FWC by 5.1% and that in the nonirrigated control variant by 26%.

The annual yield fluctuations were high, especially in the nonirrigated variant, from 63.56 t/ha obtained in the very dry year of 2003 to 87.12 t/ha obtained in the moderately dry year of 2004.

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