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Effect of Water Deficit on Yield, Quality and Water Productivity of Sugarcane

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ABSTRACT

Background and Objective: In Sudan, sugarcane crop is exposed to a certain level of water deficit during particular periods, usually before and after the rainy season caused by technical problems with irrigation pumps. This shortage of irrigation water that occasionally happens with different levels is expected to reduce yield and quality. The objective of the study was to evaluate the effect of water deficit caused by wide intervals before and after rainfall on yield, quality and water productivity of plant cane. **Materials and Methods:** A field experiment was conducted during seasons 20108/19 and 2019/20 at Guneid Sugarcane Research Center Farm, Sudan. The experiment led to a randomized complete plot design with four replications. The treatments involved three levels of water deficit before rainfall; WDI_1: 30 days, WDI_2: 50 days, WDI_3: 70 days and after rainfall; WDI_4: 30 days, WDI_5: 50 days WDI_6: 70 days compared with control WDI_0: 12 days. Cane yield and quality parameters were recorded. **Results:** The experimental results revealed significant effects on cane yield parameters. The quality parameters resulted in no significant difference ($p \leq 0.05$) in plant cane crops. Treatment WDI_1 gave significantly ($p \leq 0.05$) the highest cane and sugar yield values. However, WDI_3 and WDI_6 treatments resulted in significantly ($p \leq 0.05$) decreased in cane and sugar yield when compared with the other treatments. High values of water productivity were recorded when water deficit treatment was applied before rainfall. **Conclusion:** Water deficit treatments of 70 days before and after rainfall may be avoided in sugarcane irrigation scheduling.

KEYWORDS

Water deficit, yield, quality, Co 6806 cultivar, water productivity, sugarcane crop, *Saccharum offcinarum* L.

INTRODUCTION

Sugarcane (*Saccharum offcinarum* L.) is a field crop with a long growing season, normally 15 to 16 months and is grown between latitudes 35° north and south of the equator. Due to the high content of sucrose stored in the stalk. It is the first important crop in the production of sugar. It has been estimated that the total water requirement of a sugarcane crop varies from 20,000 to 30,000 m^3/ha/year and it is tasrestimated that 12,000 to 13,000 m^3 of water is required for a sugarcane crop of 12 months duration if used efficiently[1]. Sometimes sugarcane crop is exposed to a certain level of water deficit during particular periods, usually before and after rainy season caused by drops on irrigation pumps[2,3]. Water

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stress produced damage to crops and this damage depends on the stress duration, the crop and its development stage. The great damage to the productivity of stalks and sucrose is caused by longer and low water availability[4]. The crop growth pattern comprises three major stages, namely, early growth, grand growth and maturity growth[5]. The critical phases of cane growth were both tillering and elongation phases[6]. Kharif planted crop suffers due to water stress in its grand growth stage. The most important and sensitive phases were germination and tillering when exposed to soil moisture stress, which ultimately affects cane and sugar yield[7]. Thus, plants having different growth patterns result in different cane yields[8].

The plant's physiology, biochemical composition and sugarcane shape and structure are affected by sugar cane growth process[6]. Water stress affects biomass accumulation, the rate of water absorption, structural plant growth which changes the assimilation and sucrose accumulation[7]. The manner of production facing climate change in sugarcane management must promote an impellent efficient use of rainwater and minimize restrictive periods for crop development[9]. The most important factor reducing sugarcane production in the world is drought stress. Reduction in cane yield has been estimated at up to 60%[10]. In regions with high annual rainfall the water deficit is one of the main agriculture problems but with uneven distribution throughout the crop cycle, which has been intensified in crops under the influence of adverse climatic conditions[3]. Therefore, the objective of this study was to evaluate the effect of water deficit caused by wide intervals before and after rainfall on yield, quality and water productivity of plant cane crops, Co 6806 cultivar.

MATERIALS AND METHODS

Experimental site: A field trial was conducted at Sugarcane Research Center in the Guneid area during two growing seasons of 2018/19 started from 15/11/2019 and harvested after 15 months and 2019/20 started 15/11/2020 also harvested after 15 months. Guneid lies on latitude 14°S 48' and 15°0' N, Longitude 33°16' and 33°22' E and an altitude of 386 m above mean sea level. The soils of the area have been described as Suleimi soil series, vertisol with moderate fertility, due to high contents of smectitic clays, brown in colour, quite uniform and alkaline in reaction (pH ranged between 7.7 and 8.7). They are non-saline non-sodic, containing about 55 clay, 17 silt and 28% sand with a saturation of 61.5%, field capacity (FC) of 43.7%, welting point (WP) of 22.4% and available water content was 21.3%[11]. Guneid climate is classified as semi-arid with a maximum temperature of 43°C, relative humidity ranges between 19 to 80% and annual rainfall was 282 and 267 mm during two growing seasons respectively[11].

Experimental design: The experimental design for the plant cane experiment was a factorial (2×4 factorial in RCBD) with four replications. The treatments involved three levels of water deficit before rainfall; WDI_1: 30 days, WDI_2: 50 days, WDI_3: 30 days and after rainfall; WDI_4: 30 days, WDI_5: 50 days, WDI_6: 70 days compared with control WDI_0: 12 days, replicated four times. The field experimental unit size was 112.5 m^2 (15m×7.5m) composed of five ridges.

Crop water requirement: Sugarcane Co 6806 cultivar was planted on the month of December. Furrow irrigation was used for the experiment and a parshal flume version 3.0 software was used to measure the quantity of water entering the field plots. The reference evapotranspiration (ET_0) for the Guneid area was computed using the FAO-Penman-Monteith approach computed using the equation as described by Jangpromma *et al*[12]:

$$CWR = ET_0 \times k_c$$

Whereas; CWR is crop water requirement (mm/day^{-1}), ET_0 is reference evapotranspiration under specified conditions and k_c is the crop coefficient. The computation of the actual evapotranspiration (ET_a) in mm/day for each month of the growing season was done upon entry of meteorological data. Cane yield and quality parameters: Cane yield parameters were recorded; stalk height (cm), stalk diameter (cm), stalk population and the juice quality parameters including sucrose percent pol (%), purity (%) cane and fiber (%) were determined from juice analyzed according to ICUMSA methods of analysis[13]. Moreover, cane yield (tc/ha) and sugar yield were calculated.

Water productivity (WP): Water productivity is one way of irrigation performance indicators. It can be calculated according to the equation[13]:

$$WP = \frac{\text{Crop yield (kg)}}{ET_a\ (m^3)}$$

Statistical analysis: The collected data were analyzed using the Analysis of Variance (ANOVA) technique to evaluate the differences among treatments. Means were separated using the least significant difference (LSD) at a 5% level of significance. All statistical analyses were performed using Statistic 8.0-user guide-version 2.0 software USDA, NRCS March, 2007 USA.

RESULTS AND DISCUSSION

Crop water requirements (CWR): The length of the rainy season is related to the duration of the rainy season received by plants and irrigation needed to meet plant water requirements and production estimates. The average rainfall to support high productivity is 1100-1500 mm/year with equitable distribution. Evapotranspiration during the growth of sugarcane ranges from 800 mm to 2000 mm[14]. According to Vicente *et al.*[15] evapotranspiration is the main component of water loss to the atmosphere in a water balance, which is the relationship between canopy temperature and soil water potential. Table 1 shows the climatic data of the experimental area for the years 2017 to 2020. Table 2 shows the water requirements of sugarcane as a plant cane during the irrigation seasons. According to Vicente *et al.*[15], evapotranspiration is the main component of water loss to the atmosphere in a water balance, which is the relationship between canopy temperature and soil water potential. So that, results indicated that the highest period of sugarcane water needs was the mid-season stage with water requirements that ranged from 4.7 to 9.3 mm/day, This is followed by the late season stage with a value of 4.3 to 6.40 mm/day water requirements, the development stage with 3.7 to 7.30 mm/day and the initial stage with 2.9 mm/day to 3.2 mm/day, respectively. The effective rainfall (Re) was recorded in the months of June to October, the values ranged from 11 to 124 mm. The results also indicated that the actual evapotranspiration (ET_a) reached a maximum value in the months of April and May. A similar trend was reported by Elbasheir *et al.*[11] and Abu Alama *et al.*[16]. Therefore, the seasonal water requirement for sugarcane as plant cane was the highest amount at periods of sugarcane water needs at the mid-season stage.

Effect of water deficit on cane yield and quality of sugarcane: Effect of water deficit on cane yield and quality of sugarcane: Experimental results data in Table 3a-b and 4a showed there was no significant ($p \leq 0.05$) difference between water deficit treatments that were applied before and after rainfall in all cane yield and quality parameters. Mean while, Table 3b showed significant differences between water deficit treatments in cane yield parameters of cane length stem diameter and cane yield. So the poor irrigation interval can lead to the development of crop water deficit and result in a reduced yield due to water and nutrient efficiency[17].

Table 4b showed that there was no significant difference between water deficit treatments on cane quality parameters of pol (%) cane, purity (%) cane and fiber (%). WDI_1: 30 days treatment recorded significantly the highest cane length value the highest number of millable stalks ($\times 1000\ ha^{-1}$) and significantly recorded the highest cane yield compared to the other treatments. Rao *et al.*[7] concluded that soil moisture stress/drought affects cane yield and cane quality. Especially formative stage of this crop (45-150 DAP)

Table 1: Climatic data of the experimental area for the years 2017-2020

		Months												
	Climatic data	1	2	3	4	5	6	7	8	9	10	11	12	Annual
2017	Maximum temperature (°C)	36.5	33.8	38.8	42.2	41.1	40.8	37.9	34.8	34.4	37.6	36.4	35.5	
	Minimum temperature (°C)	18.0	15.8	18.8	25.3	25.1	25.4	24.0	23.1	22.8	21.9	19.0	17.6	
	Relative humidity (%)	43.2	25.6	18.5	20.9	43.8	50.7	64.2	76.4	75.4	54.7	37.9	48.7	
	Wind speed (m/sec)	2.5	2.2	2	2.2	2.4	4.4	4.2	3.3	3.1	1.3	5.8	4.8	
	Evaporation (mm)	13.7	15.6	19.8	22.3	17.3	17.8	14.6	8.9	7.3	11.1	14.7	12.7	
	Rainfall (mm)	-	-	-	-	22.5	20.9	23.8	107.2	42.3	46.8	-	-	263
2018	Maximum temperature (°C)	31.9	38.5	39.9	40.6	42.0	39.1	35.8	33.8	36.0	38.4	36.9	34.3	
	Minimum temperature (°C)	14.4	20.3	19.8	21.2	25.8	24.4	23.5	22.7	21.9	22.3	18.3	15.8	
	Relative humidity (%)	39.6	36.9	25.3	18.5	33.2	58.7	69.9	79.3	71.9	53.5	31.0	37.2	
	Wind speed (m/sec)	1.9	1.7	1.6	1.7	2.5	4.3	3.5	2.1	2.4	1.3	1.4	1.8	
	Evaporation (mm)	12.9	16.7	19.7	22.8	21.0	17.2	11.9	6.5	7.6	12.0	15.2	13.6	
	Rainfall (mm)	-	-	-	-	3.1	64.4	88.2	69.4	57.1	-	-	-	282
2019	Maximum temperature (°C)	36.1	36.1	37.5	41.7	43.1	38.5	37.4	32.7	34.9	35.0	37.2	33.9	
	Minimum temperature (°C)	17.2	19.1	18.8	22.5	25.7	24.4	23.5	22.8	23	22.1	18.8	15.1	
	Relative humidity (%)	41.7	32.2	23.1	19.7	30.7	60.2	68.6	80.6	76.6	70.2	42.6	41.6	
	Wind speed (m/sec)	1.9	2.1	1.9	1.7	2.4	4.0	4.0	2.5	2.8	1.0	1.1	1.5	
	Evaporation (mm)	14.4	16.8	18.1	22.8	22.0	20.9	16.9	6.7	6.4	6.4	12.0	12.1	
	Rainfall (mm)	-	-	-	-	-	15.6	43.4	129.7	69.7	8.4	-	-	267
2020	Maximum temperature (°C)	31.6	33.5	37.9	41.4	42.6	41.5	37.1	33.2	34.3	38.5	36.6	35.6	
	Minimum temperature (°C)	12.8	14.4	24.8	22.0	25.6	24.9	22.2	20.1	22.7	24.7	18.3	16.4	
	Relative humidity (%)	37.2	32.7	24.1	22.0	31.3	47.4	67.4	83.1	76.9	62.3	41.3	44.1	
	Wind speed (m/sec)	1.8	2.0	1.9	1.7	1.8	3.7	4.5	2.6	3.8	1.4	1.4	1.4	
	Evaporation (mm)	13.2	14.7	23.9	18.9	17.9	18.2	18.2	6.3	7.2	11.2	14.4	12.8	
	Rainfall (mm)	-	-	-	-	-	-	33.5	142.1	15.4	-	-	-	191

Table 2: Crop water requirements and rainfall (mm) during growing seasons

Date	Age	CWR 1st	CWR 2nd	Fall 1st	Fall 2nd	30 day	50 day	70 day	12 day	30 day	50 day	70 day	
15/12	1	2.9	3.0										Water deficit interval before fall
1/1	15	3.2	4.0										
151	30												
1/2	45	3.7	4.3										
15/2	60												
1/3	75	4.3	4.8										
15/3	90							3					
1/4	105	7.3	6.0				2						
15/4	120					I							
1/5	135	9.2	8.7										
15/5	150								0				
16	165	8.4	9.3	67	11								Rainfall (mm)
15/6	180												
17	195	6.6	9.2	88	45								
15/7	210												
1/8	225	6.1	8.8	69	124								
15/8	240												
1/9	255	5.9	6.8	57	66								
15/9	270												
1/10	285	4.7	5.0										Water deficit after fall
15/10	300												
1/11	315	4.8	5.3							4			
15/11	330										5		
1/12	345	4.3	5.4									6	
15/12	360												
1/1	375	5.5	6.4										
15/1	390												
1/2	405	Dry off	Dry off										
15/02/2019	420												

Table 3a: Effect of water deficit before and after rainfall on cane yield components

Treatment (WDI)	Height (cm) 1st Season	Height (cm) 2nd Season	Thickness (cm) 1st Season	Thickness (cm) 2nd Season	Population (1000/ha) 1st Season	Population (1000/ha) 2nd Season
Before rainfall	251.0[a]	210.0[a]	2.36[a]	2.36[a]	107.5[a]	105.0[b]
After rainfall	249.0[a]	198.0[a]	2.31[a]	2.31[a]	105.0[a]	92.0[a]
Mean	250.0	204.0	2.34	2.34	106.25	115.0
CV (%)	10.0	11.0	5.81	5.81	9.0	15.0
LSD ($p\leq0.05$)	18.0	29.0	0.1	0.1	7.5	5.0

Means sharing the same letters do not differ significantly at a 5% level of significance, WDI: Water deficit intervals, CV (%): Coefficient of variance and LSD: Least significant differences

Table 3b: Effect of water deficit before and after rainfall on cane yield components

Treatment (Intervals)	Height (cm) 1st Season	Height (cm) 2nd Season	Thickness (cm) 1st Season	Thickness (cm) 2nd Season	Population (1000/ha) 1st Season	Population (1000/ha) 2nd Season
12 days	264.0[a]	222.0[a]	2.44[a]	2.10[b]	105.0[a]	122.50[a]
30 days	258.0[a]	216.0[a]	2.28[b]	2.16[ab]	107.5[a]	117.5[ab]
50 days	246.0[ab]	200.0[ab]	2.38[ab]	2.20[ab]	105.0[a]	105.0[bc]
70 days	232.0[b]	177.0[b]	2.29[b]	2.29[a]	105.0[a]	95.0[c]
Mean	250.0	204.0	2.34	2.18	105.6	110.0
CV (%)	10.00	11.00	5.81	6.01	9.0	15.0
LSD ($p\leq0.05$)	25.00	23.00	0.14	0.14	8.0	17.5

Means sharing same letters do not differ significantly at a 5% level of significance, CV (%): Coefficient of variance and LSD: Least significant differences

Table 4a: Effect of water deficit before and after rainfall on sugarcane quality

Treatment	Pol (%) 1st Season	Pol (%) 2nd Season	Purity (%) 1st Season	Purity (%) 2nd Season	Fiber (%) 1st Season	Fiber (%) 2nd Season
Before rainfall (WDI)	11.4[a]	11.6[a]	86.24[a]	86.09[a]	18.0[a]	17.93[a]
After rainfal (WDI)	I11.4[a]	11.4[a]	85.41[a]	85.91[a]	18.3[a]	18.14[a]
Mean	11.4	11.51	85.82	85.10	18.14	18.03
CV (%)	3.89	7.22	3.35	5.50	4.16	4.12
LSD ($p\leq0.05$)	0.33	0.67	2.11	4.46	0.56	0.27

Means sharing the same letters do not differ significantly at a 5% level of significance, WDI: Water deficit intervals, CV (%): Coefficient of variance and LSD: Least significant differences

Table 4b: Effect of water deficit before and after rain fall on sugarcane quality

Treatment (Intervals)	Pol (%) 1st Season	Pol (%) 2nd Season	Purity (%) 1st Season	Purity (%) 2nd Season	Fiber (%) 1st Season	Fiber (%) 2nd Season
12 Days	11.6[a]	11.5[a]	84.70[bc]	84.70[a]	18.0[a]	17.8[a]
30 Days	11.4[a]	11.8[a]	83.85[c]	86.87[a]	18.1[a]	18.1[a]
50 Days	11.6[a]	11.6[a]	86.98[ab]	87.45[a]	18.6[a]	18.0[a]
70 Days	11.2[a]	11.1[a]	87.77[a]	84.96[a]	18.0[a]	18.3[a]
Mean	11.5	11.5	85.82	86.00	18.1	18.0
CV (%)	3.9	7.2	3.35	5.50	4.2	4.1
LSD ($p\leq0.05$)	0.46	0.87	2.99	4.97	0.79	0.78

Means sharing same letters do not differ significantly at 5% level of significance, CV (%): Coefficient of variance , LSD: Least significant differences and Treat.: Treatments

is the most sensitive stage to moisture stress and coincides with the summer period, depending on planting time. In general, moisture stress in soil affects cane yield by reducing photosynthetic leaf area, number of tillers, number of millable canes, length and girth of cane and finally the weight of individual cane[7]. The WDI_1 treatment cane age before rainfall (WDI_1 treatment) has significantly ($p\leq0.05$) increased cane and sugar yield when compared with other treatments due to the fact that deficit irrigation with a low level of water stress at tillering (WDI_1) increases sugarcane plant numbers[18]. Moreover, water deficit during the mid-season stage when water deficit treatments were applied after rainfall significantly ($p\leq0.05$)

Table 5a: Effect of water deficit before and after rainfall on sugar and cane yield

	TSH (ton/ha)		TCH (ton/ha)	
Treatment	1st Season	2nd Season	1st Season	2nd Season
Bfore fall (WDI)	9.70[a]	6.98[a]	114.4[a]	82.36[a]
Ater fall (WDI)	8.93[a]	7.30[a]	105.3[b]	86.08[b]
Mean	9.3	7.15	109.8	84.23
CV (%)	12.50	16.03	9.88	11.00
LSD($p\leq0.05$)	0.85	1.03	7.98	5.74

Means sharing the same letters do not differ significantly at a 5% level of significance, WDI: Water deficit intervals, TSH: Total sugar per hectare and TCH: Total cane per hectare, CV (%): Coefficient of variance and LSD: Least significant differences

Table 5b: Effect of water deficit intervals before and after rainfall on sugar and cane yield

Treatment	TSH (ton/ha)		TCH (ton/ha)	
(Intervals)	1st Season	2nd Season	1st Season	2nd Season
12 Days	9.98[a]	8.25[a]	116.1[a]	96.75[a]
30 Days	10.20[a]	8.38[a]	1120.65[a]	94.75[a]
50 Days	9.00[ab]	6.83[b]	114.6[b]	79.7[b]
70 Days	8.10[b]	5.2[c]	78.36[b]	64.58[c]
Mean	9.30	7.15	97.95	83.93
CV (%)	12.50	16.03	9.88	12.61
LSD ($p\leq0.05$)	1.20	1.20	11.28	11.13

Means sharing the same letters do not differ significantly at a 5% level of significance, TSH: Total sugar per hectare,TCH: Total cane per hectare, CV (%): Coefficient of variance and LSD: Least significant differences

decreased cane and sugar yield when compared to other treatments. This could mainly be due to the fact that the mid-season stage is most sensitive to water stress[17]. Generally, drought-tolerant canes maintain a higher relative water content than susceptible canes[19].

Soil moisture stress affects cane quality in terms of percent sucrose and purity, besides aggravating certain pests and disease problems[7]. Cane and sugar yield were affected significantly ($p\leq0.05$) with decrease in cane and sugar yield when water deficit irrigation treatments were applied Table 5(a-b). This was agreed with Rao *et al.*[7], who had reported, that water stress affects the rate of water absorption, biomass accumulation and structural plant growth and changes the assimilation and sucrose accumulation. Therefore, water deficit conditions show a negative response toward biochemical and physiological processes[20]. The combined analysis of two seasons and for water deficit before and after rain-fall showed non-significant difference in growth, yield and quality paramerters Table 6(a-b) while in seasons there was a significant difference in TSH (Table 6c).

Effects of water deficit on sugarcane due to reduction in yield: Sugarcane yield was affected by water deficit as shown in Table 7. Low yield was observed when WDI_3, WDI_6, WDI_2, WDI_5 and WDI_4 treatments were applied. Cane yield had a positive effect when water deficit treatment WDI_1 (30 days before rainfall) was applied at the plant age of four months. Thus, plants having different growth patterns result in different cane yields[8]. Increasing the plant's ability to hold water and improve productivity under water deficit as Wasson *et al.*[19] they were reported that the distribution of the root schemes depended strongly on the soil moisture. Moreover, Jangrunklang *et al.*[20] reported that longer roots in response to drought are important for plant resistance to drought.s Effect of water deficit on sugarcane water productivity: Table 8 shows the effect of water deficit on sugarcane water productivity. High values of water productivity were recorded when water deficit treatments were applied before rainfall, WDI_1 (30 days) and , WDI_2 (50 days), followed by WDI_4, WDI_0, WDI_5, W DI_3 and WDI_6. Yield reduction was not significant ($p\leq0.05$) when compared with the benefits of saved water. Ayana[21] reported that deficit irrigation saved significant irrigation water without significant yield losses.

Table 6a: Combine analysis factor A (WDI before and after fall)

Treatment (WDI)	Height (cm)	Thick.(cm)	Pol (%)	Purity (%)	Fiber (%)	TCH	TSH
WDI before fall	229.16[a]	2.26[a]	11.57[a]	85.75[a]	17.98[a]	94.05[a]	8.02[a]
WDI after fall	224.71[a]	2.25[a]	11.39[a]	85.95[a]	18.20[a]	92.83[a]	7.83[a]
Mean	226.94	2.26	11.49	85.850	18.10	93.43	7.93
CV (%)	10.29	5.90	5.63	4.63	3.83	11.82	14.34
LSD ($p \leq 0.05$)	11.742	0.07	0.3248	1.9968	0.35	5.55	0.58

Means sharing same letters do not differ significantly at a 5% level of significance WDI: Water deficit intervals, TSH: Total sugar per hectare, TCH: Total cane per hectare, CV (%): coefficient of variance and LSD: Least significant differences

Table 6b: Combine analysis factor B (Irrigation deficit)

Treatment (Intervals)	Height (cm)	Thick.(cm)	Pol (%)	Purity (%)	Fiber (%)	TCH	TSH
12 days	243.1[a]	2.3[a]	11.5[ab]	84.45[a]	17.8[a]	102.75[a]	8.75[a]
30 days	236.8[ab]	2.2[a]	11.6[a]	85.37[a]	18.0[a]	104.0[a]	5.63[a]
50 days	223.2[b]	2.3[a]	11.6[a]	87.22[a]	18.3[a]	88.75[b]	9.0[b]
70 days	204.6[c]	2.3[a]	11.2[b]	86.36[a]	18.1[a]	78.25[c]	6.5[c]
Mean	226.9	2.3	11.5	85.85	18.1	93.5	8.0
CV (%)	10.3	5.9	5.63	4.63	3.8	11.8	14.3
LSD ($p \leq 0.05$)	16.6	0.09	0.46	2.82	0.49	7.85	0.80

Means sharing same letters do not differ significantly at a 5% level of significance, TSH: Total sugar per hectare and TCH: Total cane per hectare, CV (%): coefficient of variance and LSD: Least significant differences

Table 6c: Season analysis on cance and sugar per hectare

Treatment (Intervals)	Height (cm)	Thick .(cm)	Pol (%)	Purity (%)	Fiber (%)	TCH	TSH
Season 1	250.0[a]	2.26[a]	11.5[a]	85.70[a]	18.14[a]	107.50[a]	8.73[a]
Season 2	204.0[b]	2.25[a]	11.5[a]	86.00[a]	18.03[a]	105.00[a]	7.15[b]
Mean	227.0	2.26	11.5	85.80	18.09	106.25	7.93
CV (%)	10.29	5.90	5.6	4.63	3.83	9.0	14.34
LSD ($p \leq 0.05$)	11.74	0.07	0.3248	2.00	0.35	7.5	0.58

Means sharing same letters do not differ significantly at a 5% level of significance, TSH: Total sugar per hectare and TCH: Total cane per hectare, CV (%): Coefficient of variance and LSD: Least significant differences

Table 7: Effects of water deficit before and after rainfall on cane and sugar yield

	Reduction (%)	
Treatment	TC	TS
WDI_0	0	0
WDI_1	+ 6.7	+8.0
WDI_2	-17.3	-16.4
WDI_3	-29.4	-25.1
WDI_4	-4.8	-4.2
WDI_5	-12.3	-11.5
WDI_6	-21.9	-27.3

WDI_0: Irrigated every 12 days (control), WDI_1: Water deficit was 30 days before fall (BF), WDI_2: Water deficit was 50 days (BF), WDI_3: Water deficit was 70 days (BF), WDI_4: Water deficit was 30 days after fall (AF), WDI_5: Water deficit was 50 days (AF) and WDI_6: Water deficit was 70 days (AF), TC: Total sugarcane and TS: Total sugar

Effect of water deficit on a number of irrigations and water saved: Data on irrigation water applied, saved CWR (m^3ha^{-1}\season^{-1} and water saved (m^3) when water deficit treatments were applied before and after rainfall is shown in Table 9. Water saved was in high amount when water deficit was applied before fall WDI_2: 50 days and WDI_3: 70 days, followed by WDI_6, WDI_1, WDI_5 and WDI_4. The yield reduction was small, compared with the benefits gained through diverting the saved water to irrigate other cane with different ages for which water would normally be insufficient under Guniedirrigation practices. However, Bhebhe[22], reported no significant difference between the stalk growth obtained between the 6-day and 12-day irrigation interval, the 12-day interval is recommended and could be used for irrigation to save water, resourcesand , inputs and at the same time reap higher yields. The efficiency of water use in sugarcane plants increased at irrigation rates from 56 to 83 kg/mm, which led to an increase in sugarcane yields ranging from 67.8 to 136.1 t/ha/year de[23].

Table 8: Effect of water deficit before and after rainfall on water productivity

Treatment ton/ha (WP)	CWR m^3/ha		Total sugarcane		Water productivity	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
WDI$_0$	24560^a	20490^a	108.75^b	96.74^a	4.4^c	4.7^{bc}
WDI$_1$	21390^c	17590^{cd}	122.25^a	97.75^a	5.7^a	5.6^a
WDI$_2$	20130^d	16050^e	103.50^{bc}	68.04^c	5.1^b	4.3^b
WDI$_3$	19000^e	14850^f	86.00^{cd}	60.00^c	4.5^{cd}	4.1^c
WDI$_4$	22500^b	19000^b	104.00^{bc}	91.74^a	4.6^c	4.8^{bc}
WDI$_5$	21440^c	18000^{bc}	94.00^{cd}	86.25^{ab}	4.4^{cd}	4.8^{bc}
WDI$_6$	20310^d	17040^d	86.25^d	75.50^{bc}	4.3^d	4.4^c
Mean	21280	18200	102.0	81.88	4.8	4.7
CV (%)	1.65	2.88	9.8	14.1	1.65	5.06
LSD ($p\leq0.05$)	630	900	5.0	5.75	0.14	0.42

WDI$_0$: Irrigated every 12 days (control), WDI$_1$: Water deficit was 30 days before fall (BF), WDI$_2$: Water deficit was 50 days (BF), WDI$_3$: Water deficit interval was 70 days (BF), WDI$_4$: Water deficit was 30 days after fall (AF), WDI$_5$: Water deficit was 50 days (AF) and WDI$_6$: Water deficit was 70 days (AF), CWR: Crop water requirement, means sharing the same letters do not differ significantly at a 5% level of significance, CV (%): Coefficient of variance and LSD: Least significant differences

Table 9: Effect of water deficit intervals on number of irrigations applied and water saved

Treatment	No. of irrigations applied	No. of irrigation saved	CWR m^3/ha/season	Water saved m^3/ha/season
WDI$_0$	32	0	22525	0
WDI$_1$	30	2	19488	3037
WDI$_2$	28	4	18088	4437
WDI$_3$	26	6	16925	5600
WDI$_4$	30	2	20750	1775
WDI$_5$	28	4	19719	2806
WDI$_6$	26	6	18675	3850

Means sharing the same letters do not differ significantly at a 5% level of significance WDI$_0$: was irrigated every 12 days (control), WDI$_1$: Water deficit was 30 days before fall (BF), WDI$_2$: Water deficit was 50 days (BF), WDI$_3$: Water deficit was 70 days (BF), WDI$_4$: Water deficit was 30 days after fall (AF), WDI$_5$: Water deficit was 50 days (AF), WDI$_6$: Water deficit was 70 days (AF) and CWR: Crop water requirement

For all watering involved in this area, the amount of water from rain-fall must be taken into consideration as acompmintary irrigation to save the amount of water and reduce the number of irrigation. For future recommendations; water deficit treatments of 70 days before and after rainfall may be avoided in sugarcane irrigation scheduling.

CONCLUSION

The treatments involved three levels of water deficit before rainfall; WDI$_1$: 30 days, WDI$_2$: 50 days, WDI$_3$: 70 days and after rainfall; WDI$_4$: 30 days, WDI$_5$: 50 days WDI$_6$: 70 days compared with control WDI$_0$: 12 days. The results revealed significant effects on cane yield parameters. The quality parameters resulted in no significant ($p\leq0.05$) in plant cane crops. Treatment WDI$_1$ gave significantly the highest cane and sugar yield values. However, WDI$_3$ and WDI$_6$ treatments resulted in significantly decreased cane and sugar yield when compared with the other treatments. High values of water productivity were recorded when water deficit treatment was applied before rainfall. Water deficit treatments of 70 days before and after rainfall may be avoided in sugarcane irrigation scheduling.

SIGNIFICANCE STATEMENT

Water plays a greater role in all developmental stages of crops. Sugar cane grows for more than years (12 months) until harvestand, water plays a vital role in growth if any shortage of water or overlogging during rains leads to a reduction in quality and quantity. This research is conducted to evaluate the effect of water deficit caused by wide intervals before and after rainfall on yield, qualityand , water productivity of plant cane. Results revealed significant effects water deficit caused by wide intervals before and after rainfall on cane yield parameters. High values of water productivity were recorded when water deficit treatment was applied before rainfall. Water deficit treatments of 70 days before and after rainfall should be avoided in sugarcane irrigation scheduling.

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