Determination of irrigation interval for sugarcane by monitoring changes in soil moisture in the field at the Guneid Scheme

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Abstract

A field trial was conducted for two consecutive seasons during the period 1974 to 1977 at the Guneid Sugarcane Research Station on a heavy cracking clay (Vertisol). The objective of this experiment was to study the effects of irrigation intervals on sugarcane during summer and winter seasons. There were three irrigation treatments, namely M_1: irrigating sugarcane when 40-50 % of the available soil moisture was depleted; M_2: irrigating sugarcane when 80-90% of the available soil moisture was depleted and M_3: irrigating sugarcane when 90-100% of the available soil moisture was depleted.

Intensive cane growth was observed from April to August while from August to maturity the rate of growth decreased. Irrigation treatments significantly affected the length of the irrigation intervals, number of irrigations, cane and sugar yields and the percentage sucrose recovery. Treatment M_1 gave the highest cane yield in both seasons. Irrigation intervals for plant cane are recommended for the winter and summer seasons in this paper.

Delaying irrigation beyond 70% depletion of available soil moisture is detrimental to the growth of sugarcane and will result in economic losses of sugar yield.

Introduction

Sugar production in Sudan is the largest and most profitable industry in the country where five sugar factories are now operating. All the sugar produced in the Sudan is from sugarcane (*Saccharum officinarum*). The oldest of these factories is Guneid factory which was established in 1962. The total area of Guneid Scheme is 16800 ha and is located at Gezira State 120 km South east of Khartoum.

With the exception of New Halfa sugar factory, all the others receive irrigation water by pumping. Thus irrigation represents one of the production factors that cost highly. Therefore, judicial use of irrigation water to arrive at the highest water use efficiency is mostly required.

Water deficit during the establishment period and early vegetative period (tillering) has an adverse effect on yield as compared to water deficits in later growth periods. Water deficit during the vegetative period (stem elongation) and early yield formation causes a lower rate of stalk elongation. On the other hand, water deficit during the later part of yield formation forces the crop to ripen; while very low available soil water content during the ripening stage will negatively affect the sugar content.

Rege (1952) found that the highest yield of sugarcane could be obtained in India when the crop was watered at 8 day interval during early growth and at 16-day interval during tillering and then every 12 days to maturity. In the Sudan short interval of 7 days was found to be the one that gave the highest cane yield at Guneid when compared with 10 or 14 day interval (Abuzeid, 1971). Water duties of 750, 1125 and 1500 m^3/ha had no significant effect in this trial. Recently, Abdel Wahab (2004) working at Kenana Sugarcane Scheme, found that irrigating at 50% of the available soil moisture depletion gave the highest cane yield.

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The objective of this work was to find out the optimum irrigation intervals for sugarcane during the different seasons of the year (i.e. summer and winter) by monitoring the available soil moisture in the field.

Materials and methods

This trial was conducted for two different seasons during the period 1974-77 at Guneid Sugarcane Research Station, which is located within the farm of the Guneid Sugar Factory.

The soil is dark brown, heavy clay, belonging to the Vertisol order and predominantly montmorillonitic. The pH of the top 20 cm was 9.5 (1:5 soil/water), ECe 1.0 ds/m, ESP 10.5, bulk density 1.34 g/cm^3 and 55% clay (Ibrahim, 1970). These soils are classified according to the soil classification system of 1996 as chromic Haplusterts, fine, smectictic, is hypothermic.

Soil samples were taken from 10 random holes which were within an area of three ha and augured to a depth of 0-25 and 25-50 cm. The available water of these soil samples was determined by the difference between $^1/_3$ atmosphere percentage (field capacity) and the 15 atmosphere percentage (permanent wilting point percentage, Richards, 1954). The mean values for the field capacity and permanent wilting point were 40 and 21% respectively. The $^1/_3$ and 15 atmosphere % values are useful for determining field capacity and permanent wilting point, respectively, for comparison between different soil types or different locations.

Irrigation treatments

There were three irrigation treatments namely:

1. Water was applied when 40-50% of the available soil moisture was depleted (M_1).
2. Water was applied when 80-90% of the available soil moisture was depleted (M_2).
3. Water was applied when 90-100% of the available soil moisture was depleted (M_3).

For the first four months of growth, the available soil moisture was calculated for the top 0-25 cm depth, whereas from the age of four month to maturity the depletion of the available soil moisture was calculated for the depth 0-50 cm. Ibrahim (1996) working at Guneid found that most of the active roots of sugarcane (90%) were located at 0-50 cm depth of soils. Table 1 shows the mean maximum depth of sugarcane grown on the two major soil units (14a and 17a) at Guneid. There were no significant differences between these two soil units. The maximum depth was attained by sugarcane at about 8 month old and it was 50 cm. The sugarcane yield of these two plots representing soil unit 14a and 17b were 60.2 and 60.0 ton/fed, respectively. Soil moisture for the top 25 or 50 cm was gravimetrically determined daily for all the treatments using an oven set at 105ºC for 24 hours or constant dry weight.

Each sub-plot had an area of 72 m^2 (8x9 m) with four replications in a randomized complete block design and was planted with sets of sugarcane, variety NCO 310 and fertilized with urea at the rate of 176 kg N/ha, applied at 2 months from planting.

All plots received four initial irrigations during the first 50 days from planting in the first season. In the second season, the sub-plots received three irrigations before applying the treatments, 50 days later.

Stalk elongation (height) was measured every 15 days up to maturity. Irrigation continued for 13 month of growth and sugarcane was harvested at 14 month of age similar to the practice of Ibrahim (1978).

The two experiments were similar except that the first one was planted on 5 October 1974 and the second one on 23 December 1975. The results and the metrological data are represented in Fig. 1 and 2, and Tables 1, 2, 3, 4 and 5.

Results and discussion

Stalk Elongation

Stalk elongation was taken as a measure of growth. There were no significant differences in stalk elongation between the irrigation treatments until after 5.5 month from planting in both seasons, indicating that all levels of irrigation were adequate for that initial stage of growth (Fig. 1). In the first season the differences were significant at 5.5 month of growth, but from May until 10 July 1975, the differences in height were highly significant. On the other hand, the differences between the treatments were highly significant from 5 July to 5 August 1976 (Fig. 2). This period coincided with intensive vegetative growth, which was longer in the first season (about 3 months) than in the second (about 2 months), and this was probably due to differences in planting dates. Differences in stalk elongation decreased in the different irrigation treatments from the start of rains in late July and early August until maturity. This was expected, since rains interfered with the pre-determined irrigation frequency and therefore relieved the stress to which the less frequently irrigated treatments would have been subjected.

Irrigation intervals and numbers

Generally, irrigation intervals during the summer months (March - mid July) for treatment M_1 were short, whereas those for the winter months (November - February) were rather long, particularly for irrigation treatments M_2 and M_3. The irrigation intervals during the rainy season (late July - September) were intermediate (Table 2).

It was found that the irrigation intervals were shorter in the second season than the first (Table 2), probably due to the higher temperatures which prevailed in the second season. Moreover, the first season had more precipitation than the second season (Table 3a). Mean maximum and mean minimum temperature for the seasons 1974-75 and 1975-76 were 38 and 18.2ºC, respectively. Sugarcane in treatment M_1 received the highest number of irrigations in both seasons (43), followed by treatment M_2 and M_3 which had the lowest number of irrigations (30) (Table 2). The mean irrigation intervals for the different treatments is presented in Table 4. From the data presented in this table, the irrigation intervals for the different seasons (i.e. winter and summer) were determined and presented in this Table.

The difference between treatment M_1 and M_3 during the winter was more pronounced (10 days).

Cane yields

Irrigation at different depletion levels of available soil moisture, significantly affected the yield of cane in both seasons (Table 5).

The differences in cane yield were significant ($P = 0.05$) and highly significant ($P = 0.01$) in the first and second seasons, respectively. In both seasons treatment M_1 resulted in the highest cane yield, followed by M_2 and M_3.

Sucrose recovery percentage and Sugar yield

There were no significant differences between the treatments with respect to the sucrose recovery percentage in the first season, but the differences in the second season were very highly significant ($P = 0.001$) and also much higher (Table 5). With respect to the sugar yield, the differences between the irrigation treatments were highly significant in both seasons. Treatment M_1 gave the highest yield of sugar in both seasons whereas treatment M_3 gave the lowest sugar yield in both seasons.

Because there is a considerable time between the results of this experiment and the present time the following assumption have to be made so as to come with valuable recommendations:

1. First assumption is that there are no big differences in the water requirements of the sugar varieties grown in this experiment and the varieties existing now at the Gunied Sugar Scheme.
2. Second assumption is that there are no significant changes in weather parameters (temperature and rainfall) between the time of experiment and the present as indicated in Table 3b.
3. Third assumption is that there are no significant changes in the agronomic practices for sugarcane production at the time of the experiment and the present.

Recommendations

Based on the previous results and the assumptions already given, the following irrigation intervals are recommended for plant cane grown at Guneid Sugarcane Scheme:

1. Applying irrigation at 40-50% depletion of the available soil moisture. This corresponds to summer irrigation interval of 8-9 days and winter irrigation interval of 10-16 days.
2. Delaying irrigation after 70% depletion of available soil moisture is detrimental to the growth of sugarcane and will result in economic losses of sugar yield.

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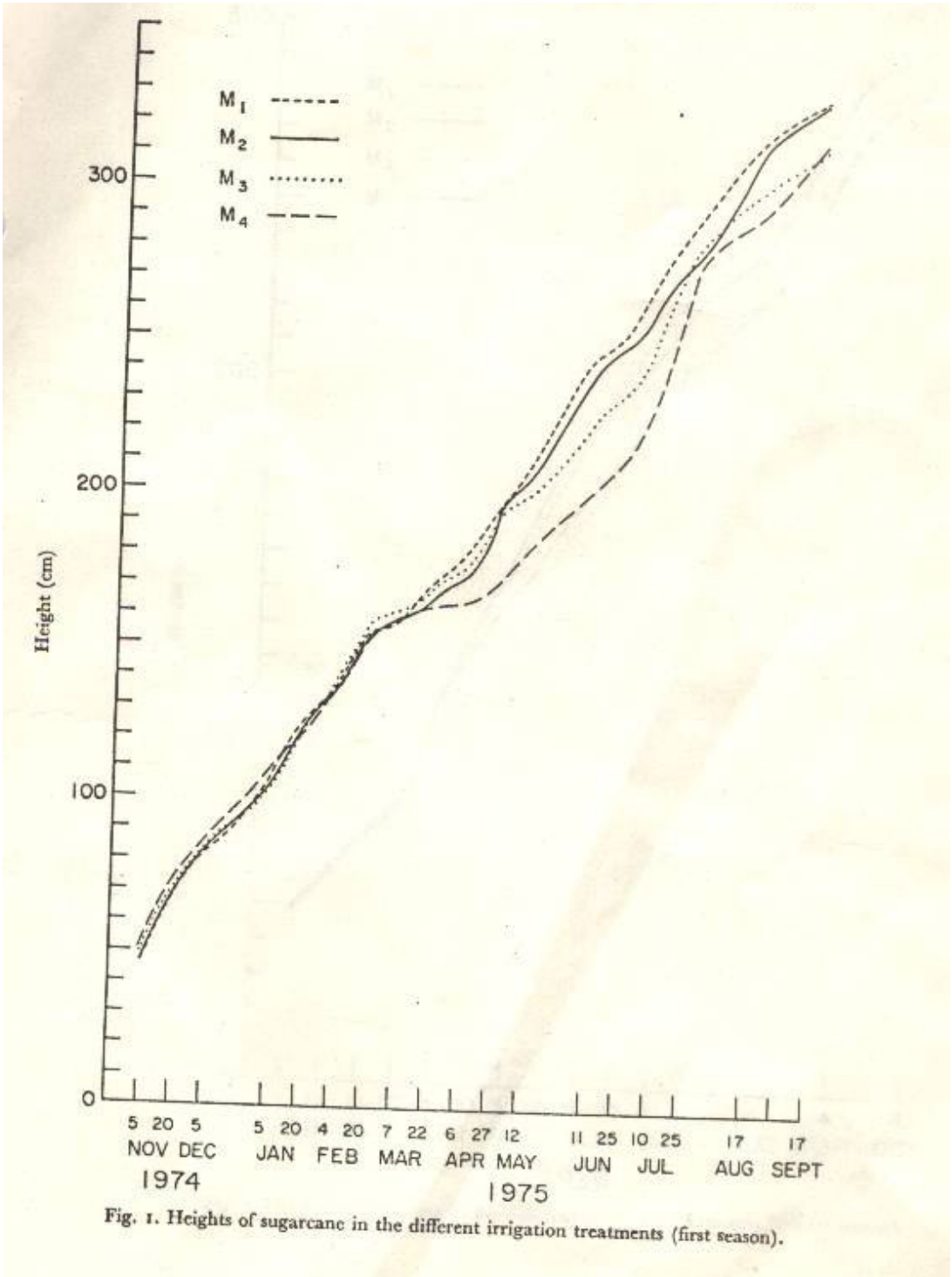

Fig. 1. Heights of sugarcane in the different irrigation treatments (first season).

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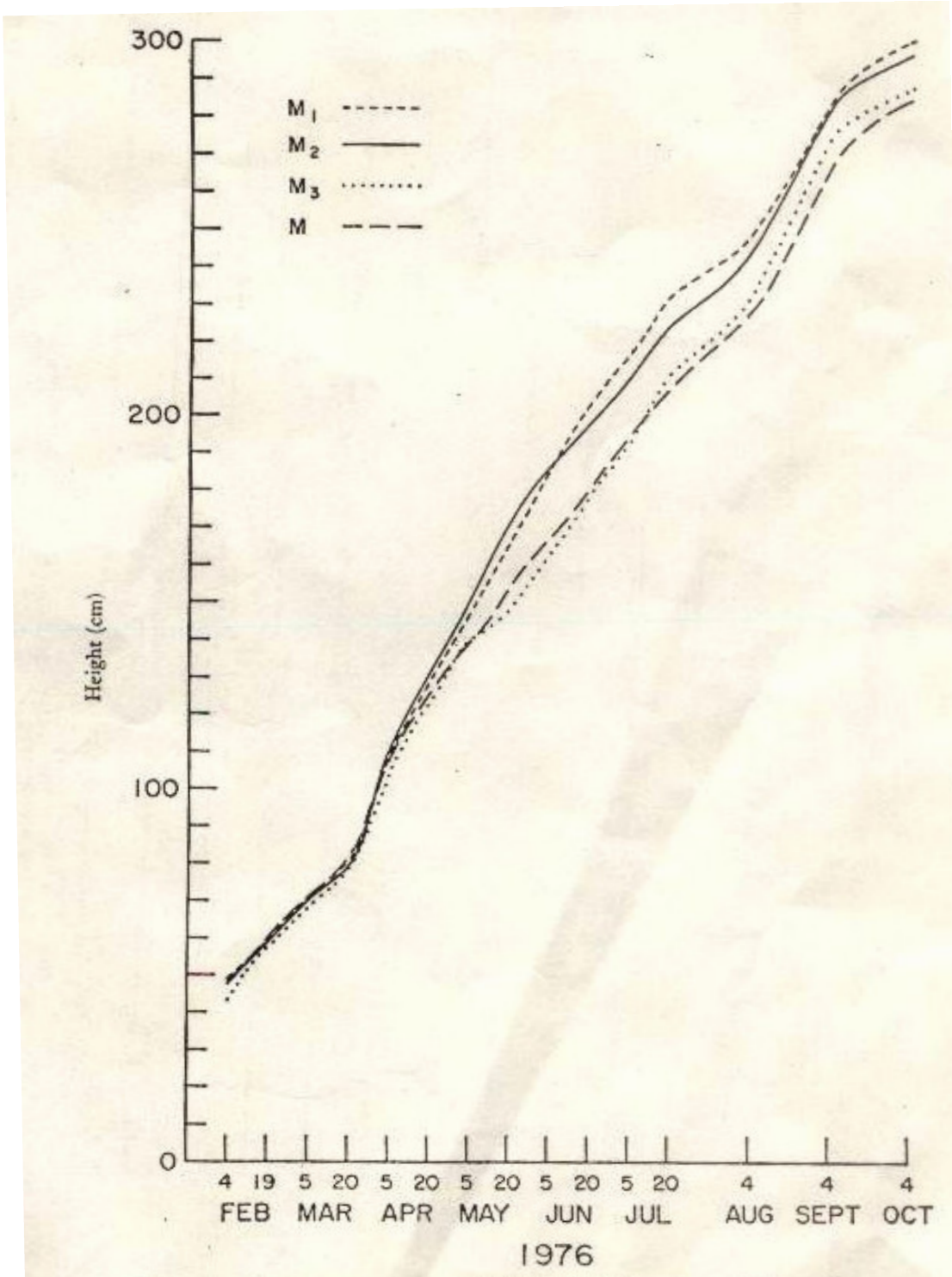

Fig. 2. Heights of sugarcane in the different irrigation treatments (second season).

Table 1. Maximum depth of sugarcane roots with age in the two soil units, 14a and 17a at Guneid Scheme.

Date of sample	Soil unit root depth (cm)	
	14a	**17a**
17 Dec. 1969	19.0	20.5
24 Dec.	25.5	22.0
12 Jan. 1970	30.0	35.6
5 Feb.	34.0	37.8
24 Feb.	39.0	45.7
14 March 1970	47.3	40.7
31 March	48.7	43.0
26 April 1970	35.7	36.0
11 May	48.7	49.3
2 June	42.7	50.0
21 June	50.0	51.0
7 July	51.3	47.7
30 Aug.	52.3	47.3

Source: Ibrahim, H.S. (1970-71).

Table 2. Effect of irrigating at different soil moisture levels on length of irrigation intervals (days) and numbers of irrigations from planting to harvest of sugarcane.

Month	First season			Second season		
	M_1	M_2	M_3	M_1	M_2	M_3
December	10	20	23	(1 basic irrigation)		
January	10	17	22	(2 basic irrigations)		
February	9	16	19	9	16	19
March	9	11	14	9	10	15
April	7	10	13	7	10	12
May	9	11	13	7	9	12
June	8	11	12	6	9	10
July	9	11	12	8	10	11
August	11	15	18	9	11	12
September	11	14	16	10	12	15
October	(2 basic irrigations)			9	12	14
November	(2 basic irrigations)			9	14	15
Total number or irrigation	42	33	29	43	34	30

Table 3a. Meteorological data during 1974-77 at the Guneid Sugarcane Research Station.

Month	Temperature (º C)				Rainfall (mm)		Evaporation from Piche evaporimeter (mm)	
	Maximum		Minimum					
	1975	1976	1975	1976	1975	1976	1975	1976
January	32.5	34.8	10.5	13.7	0.0	0.0	9.5	11.3
February	36.5	34.8	13.4	12.8	0.0	0.0	16.1	13.2
March	39.0	38.2	15.2	17.7	0.0	0.0	17.3	17.1
April	41.3	41.8	17.5	20.0	2.5	3.0	17.5	17.8
May	42.9	41.8	22.3	22.3	6.5	-	17.1	15.8
June	39.9	42.8	22.6	23.9	7.5	3.0	13.8	16.3
July	38.1	41.1	22.8	23.3	20.0	11.0	11.1	11.3
August	33.3	36.3	21.5	23.0	91.0	23.0	5.7	11.9
September	35.5	37.2	22.6	22.4	28.5	23.0	7.3	15.4
October	39.7	39.1	21.2	22.2	0.0	0.0	12.2	14.1
November	38.2	37.5	18.9	18.9	0.0	0.0	11.1	13.6
December	33.5	33.0	14.6	13.8	0.0	0.0	12.4	11.1

Table 3b. Average maximum, minimum temperature and rainfall for seasons (1974-77) and seasons (1995 – 2003).

Year	Temperature º C		Rainfall (mm)
	Maximum	Minimum	
1974-77	38	18.2	110
1995-2003	38	20.2	165

Table 4. Average length (first and second seasons) for the irrigation intervals during the growing season and the average length for irrigation interval for the treatments during winter, summer and autumn.

Month	M_1	M_2	M_3
December	10	18	23
January	10	17	22
February	9	16	19
March	9	10	14
April	7	10	12
May	8	10	12
June	7	10	11
July	8	10	12
August	10	13	15
September	11	13	16
October	9	12	14
November	9	14	15

	Average irrigation interval (days)	
	Winter	Summer
M_1	10	8
M_2	16	10
M_3	20	12

Table 5. Effect of irrigating at different soil moisture levels on yield of cane, sucrose recovery percentage and yield of sugar.

Treatment	Yield of cane (t/ha)	Sucrose recovery (%)	Yield sugar (t/ha)
First season			
M_1	171.3	10.35	17.73
M_2	118.6	10.48	12.43
M_3	106.0	10.48	11.11
SE±	12.95*	0.63	1.66*
Second season			
M_1	157.4	12.7	19.99
M_2	127.0	14.45	18.35
M_3	112.1	12.43	13.93
SE±	7.1	0.22***	1.1**
Average of seasons			
M_1	164.4 (69.1)	11.5	18.9 (7.9)
M_2	122.8 (51.6)	12.5	15.4 (6.5)
M_3	109.1 (45.8)	11.5	12.5 (5.3)

*, **, *** significant at 0.05, 0.01 and 0.001, respectively. Values in parenthesis indicate sugarcane yield in ton/fed.