EFFECT OF IRRIGATION REGIME ON CANE AND SUGAR YIELDS OF VARIETY NCo376 IN THE SOUTH-EAST LOWVELD OF ZIMBABWE

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Abstract

Various irrigation regimes were applied to NCo376 over five years of low rainfall (average 466 mm per annum). Cane yield increased, depending on amount of water applied, from 84 to 122 t/ha. There was no significant effect on quality. The lowest application of 660 mm of irrigation produced 69% of the yield produced by the standard (full) irrigation (1 520 mm) at 12 months of age. There were no plant deaths. Furthermore, irrigating according to an Et/Eo ratio of between 0,70 and 0,85 has shown potential for saving irrigation water without a large reduction in yield.

Introduction

The main objective of irrigating sugarcane (*Saccharum* spp. hybrids) in the past has been to ensure that cane and sugar yields are not reduced by soil moisture deficit. In a review of the irrigation requirements of sugarcane, Campbell (1967) determined that the evapotranspiration/evaporation (Et/Eo) ratio is a useful method for estimating potential evapotranspiration for various stages of canopy development in the tropics. His data indicated that the ratio changed from 0,40 for bare soil to 1,00 at full canopy.

In Zimbabwe, Gosnell (1970) demonstrated that increasing irrigation levels from 37% (0,37) to 84% (0,84) of class A pan evaporation produced a linear increase in cane yield from 65 to 146 tons per hectare. Ellis *et al.* (1985) developed an irrigation strategy with a potential 32% saving in water use. The recommendation for good soils was to withhold irrigation after the first full post-harvest irrigation and then irrigate when stalk elongation occurred in mid-August, when mean daily temperature exceeded 18,5°C. In addition, irrigation was stopped prior to harvest in accordance with soil moisture content (drying off was extended from two to three times Total Available Moisture (TAM) on good soils).

Drought has reduced the available water for irrigation in recent years and production has suffered. In addition, the main irrigation canal to the lowveld has not been able to supply sufficient water to meet peak demand when the normal rains have been delayed and periods of excessive temperature have occurred.

The cane farmer, faced with frequent restrictions in water supplies, must decide how best to use the water available for irrigation. This paper examines the effects on cane and sugar yields of six irrigation regimes using different Et/Eo ratios and makes practical recommendations on water use for different situations.

Materials and methods

Special flood irrigated beds were prepared to enable metered amounts of water to be applied to each plot. Adequate tile drainage was installed to dispose of surplus water accumulated on the beds after excessive rainfall.

The trial, on Zimbabwe Sugar Association Experiment Station (ZSAES), was planted to NCo376 on 5 July 1985 and included a plant and five ratoon crops. The soil was a Triangle PE.1 sandy clay loam derived from gneiss, with a TAM of 100 mm. Fertiliser was applied based on recommendations from soil analysis and amounted to 120 kg N, 100 kg P_2O_5 and 60 kg K_2O per hectare per annum for the plant crop. Ratoon crops received 180 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare per annum. Irrigation treatments are described in Table 1. The first full post-harvest irrigation was 100 mm, whereas all the remaining irrigations were 50 mm each for I-1, I-3, I-4, I-5 and I-6. Treatment I-2 received 100 mm when the deficit reached 100 mm.

Table 1

Irrigation treatments

Treatment No.	Pan or crop factor	Open pan evaporation deficit (mm)	Amount applied once deficit reached (mm)
I-1*	1,00	50	50
I-2	1,00	100	100
I-3	0,85	59	50
I-4	0,70	71	50
I-5	0,55	91	50
I-6	0,40	125	50

* Standard or full irrigation

Treatments were introduced in 1986 after the plant crop was harvested. The soil moisture was restored to field capacity in all plots soon after harvest (Ellis *et al.*, 1985), and irrigation was then applied according to the prescribed Et/Eo ratios with allowance for rainfall (Cackett, 1982). Drying off was done according to the established practice at 3 x TAM (Ellis *et al.*, 1985). The amount of water actually applied to each plot was recorded using a Kent flow meter and data are presented in Table 2. Irrigation efficiency was assumed to be 100% as plots were small (156 m^2) and there was no run-off when using this flood method of irrigation.

Rainfall averaged 466 mm and was below the long term mean of 544 mm. The treatment with most irrigation (I-1) received an average of 1 520 mm irrigation per annum and 466 mm rainfall to give a combined total of 1 986 mm. The driest treatment (I-6) received an average of 660 mm irrigation and 466 mm rainfall to give a combined total of 1 126 mm.

Variation in amount of water received was greatest between the driest year (1R with 328 mm) and the wettest year (2R with 728 mm rainfall)

Table 2

Water applied to each treatment over the five ratoons and annual rainfall

Treatments	Ratoon crop irrigation (mm)					
	1R	2R	3R	4R	5R	Mean
I-1	1 700	1 350	1 500	1 400	1 650	1 520
I-2	1 750	1 250	1 500	1 300	1 500	1 460
I-3	1 500	1 100	1 300	1 200	1 250	1 270
I-4	1 350	950	1 100	1 050	1 050	1 100
I-5	1 000	750	850	700	850	830
I-6	750	600	650	600	700	660
Rainfall (mm)	328	728	369	478	427	466

The experiment was designed as a 6 x 6 latin square. Each plot consisted of 8 rows, 1,5 m apart and 13 m in length. Prior to harvest, border effects were eliminated by removing one guard row from each side and one metre from each end. Samples were taken for quality analysis and sugar yield using Estimated Recoverable Crystals (ERC), stalk length and diameter measurements. Plots were hand harvested and weights of cane in each plot were determined after cutting.

Results

Survival

No stool mortality occurred in these trials. Despite the lower than normal rainfall the trials were free of Black Maize Beetle and Ratoon Stunting Disease.

Cane yields

Table 3 shows cane yield for each treatment over the five ratoon crops. The average cane yield produced with full irrigation (I-1) over the five ratoon crops was 122 t/ha, and was highest for the first ratoon (135 t/ha) and lowest for the fifth ratoon (111 t/ha). The driest treatment (I-6) suffered most from water stress in the first ratoon (74 t/ha) and recovered with rainfall to produce the highest yield (91 t/ha) in the second ratoon. This treatment was mostly affected by rainfall which was lowest in 1R and highest in 2R. Differences in yield between the four wettest treatments were not statistically significant. Yields were significantly reduced (P = 0,01) in I-5 (102 t/ha) and I-6 (84 t/ha).

Table 3

Cane yield for each treatment for the five ratoon crops (1R to 5R)

Treatments	Ratoon crop yield (t/ha)					
	1R	2R	3R	4R	5R	Mean
I-1	134,9	116,4	127,3	119,2	111,4	121,9
I-2	123,8	114,6	120,4	109,7	98,5	113,4
I-3	130,9	120,3	117,5	112,4	105,5	117,3
I-4	121,0	119,7	116,7	110,2	102,4	114,0
I-5	98,9	107,0	104,8	102,7	95,7	101,8
I-6	73,9	91,3	87,9	85,5	80,3	83,8
Significance	***	***	***	***	***	–
LSD 5%	15,31	10,51	13,72	13,31	12,5	–
CV %	11,16	7,82	10,13	10,36	10,50	–

Cane quality

Cane quality was lowest in the driest treatment (I-6), which averaged 14,09% ERC. Quality in the five wettest treatments was similar (14,28 to 14,43% ERC) and differences between these and the driest treatment (I-6) were only statistically significant in 1R, the driest year. However, trends were similar for all ratoons.

Sugar production

Sugar production measured as ERC t/ha (Figures 1 and 2) followed the pattern for cane yield and was only slightly modified by quality in the driest treatment (I-6) and an intermediate treatment (I-4). The latter produced significantly less sugar than I-1 and I-3 in the first ratoon crop when rainfall was poor and results were significantly different (P = 0,05). The driest treatment I-6 produced 32% less sugar than the fully irrigated treatment (I-1).

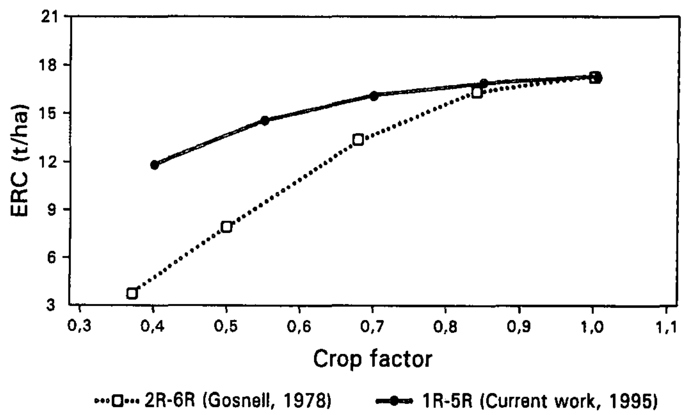

FIGURE 1: Increase in ERC (t/ha) with crop factor

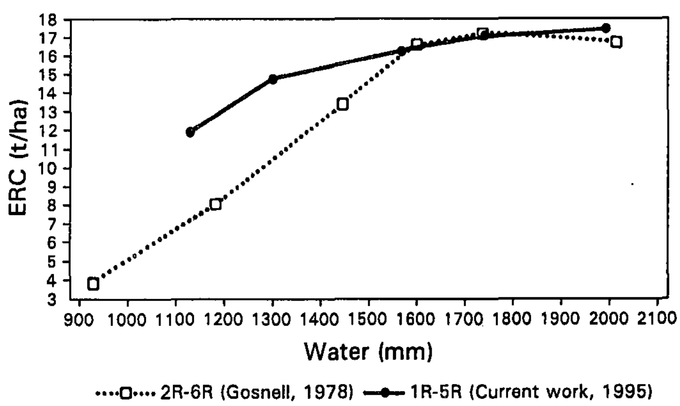

FIGURE 2: ERC yield (t/ha) comparing total water (irrigation and rainfall)

Water use

Table 4 relates irrigation to stage of growth meaned over the five ratoon crops. The period of stalk elongation from November to July accounts for between 68 and 83% of the total amount of irrigation received. The remainder was applied prior to full canopy and mainly during the period between germination and tillering (see Table 4).

When water is in short supply and a new water strategy has to be defined, production of sugar (ERC) per unit of water applied should be considered. Production of sugar per hectare and per mm of water applied is given in Table 5.

Table 4

Irrigation apportioned to stage of growth for each treatment when meaned for the five seasons

Stage of cane growth	Month	Treatment					
		I-1	I-2	I-3	I-4	I-5	I-6
Germination-tiller	Sept-Oct	270	250	250	240	230	210
Stalk elongation	Nov-Jul	1 230	1 210	1 010	860	600	450
Maturation	Aug-Sept	20	0	10	0	0	0
Total number of irrigations		29,0	15,4	23,6	20,4	15,0	11,6
Total irrigation (mm)		1 520	1 460	1 270	1 100	830	660
Total precipitation (mm)		1 986	1 926	1 736	1 566	1 296	1 126

Table 5

Comparison of water applied, cane and sugar production of different irrigation treatments

Irrigation treatment	Water applied (mm)	Cane yield (t/ha)	ERC yield (t/ha)	ERC kg/ha per mm Irrigation
I-1	1 520	121,9	17,4	11,4
I-2	1 460	113,4	16,3	11,2
I-3	1 270	117,3	16,9	13,3
I-4	1 100	114,0	16,1	14,7
I-5	830	101,8	14,6	17,6
I-6	660	83,8	11,8	17,9

Stalk characteristics

The driest treatments (I-5 and I-6) produced the shortest and thinnest cane stalks. Seasonal variations were small when comparing data from the first to the fifth ratoon crops. There were no significant differences in stalk population at harvest.

Discussion

Survival

The uniformity of application to small plots probably contributed to the survival of all stools in the trial. When application is made to large fields a factor for irrigation efficiency would have to be included.

Rainfall and irrigation

The results show the benefit of scheduling irrigation, particularly for the treatments which are most likely to be used in practise (I-1 to I-4). Results show that an average of 860 mm was saved during the five crops. Differences in the amount required between the wettest and driest years is likely to be about 400 mm, and justifies the proper scheduling of irrigation.

Sugar production

The main effect of irrigation was on cane yield, which was significantly reduced in the two driest treatments (I-5 and I-6). The results suggest that, if water is in short supply, it would be advantageous to irrigate to between 0,70 and 0,85 provided full account has been taken for efficiency of application of the irrigation system. Thus, an allowance for efficiency would have to be built in to produce a gross application per hectare. This is supported by earlier work on ZSAES by Gosnell and Lonsdale (1978), which is compared in Figure 1. Differences in responses between the two trials for the drier treatments (0,70 and below) could possibly be due to differences in irrigation methods. In the earlier trial (Gosnell and Lonsdale, 1978) the treatments were introduced at full canopy and less water was applied earlier, prior to full canopy. In the current trial, treatments were applied earlier and flood beds were used.

ERC yield when the Et/Eo ratio was close to 0,85 or above was similar to results obtained in earlier work (Gosnell and Lonsdale, 1978) (Figure 1). Below this value results differ, as Gosnell's results show progressively lower ERC yields to the lowest Et/Eo ratio of 0,37. This is not related to difference in total amount of water (irrigation and rainfall). There appears to have been benefit from the higher amount of water applied prior to full canopy in treatments receiving less than 1 500 mm of water (Gosnell and Lonsdale, 1978) (Figure 2).

The results also support the work of Ellis *et al.* (1985), as treatments I-3 and I-4 were based on their revised irrigation strategy. The results show that, on good soils, and provided water distribution is uniform, favourable yields can still be produced with small amounts of water (1 000 mm). The emphasis when water is in short supply must be on an initial full irrigation with correct scheduling and uniformity of application.

Water use efficiency

The production of sugar per mm of irrigation water increased in treatments I-1 to I-6 as the crop factor was reduced. This was because of the contribution made by rainfall. However, on a large scale, the ability to apply irrigation uniformly when using smaller amounts of water can present practical problems. These are addressed in the next section.

Practical considerations

This paper describes the efficient use of water in small plots where uniformity of application could be ensured. Irrigation efficiency for furrow is in the order of 75% (Ellis *et al.*, 1985). Applying small amounts (50 mm) by increasing flow rate is likely to affect efficiency of application along the furrow. Ellis *et al.* (1985) found that, to apply 50 mm of irrigation, it was necessary to widen the furrows and heighten the interrow ridges in order to contain the flow rate of 10 L/sec necessary for achieving uniform application.

Basing irrigation on complete depletion of soil moisture (I-2) produced satisfactory results on ratoon cane in this experiment. However, this was done on a small scale and further work is needed on a larger scale.

Conclusion

Results from this wide range of treatments show that irrigating to an Et/Eo of above 0,70 is satisfactory for cane and that, when water is in short supply, an Et/Eo of 0,85 (when work by Gosnell and Lonsdale (1978) is also taken into account) is close to optimum, and 1 500 mm of water is required to produce a good crop. An Et/Eo of below 0,70 caused a significant reduction in yield, but the amount of sugar produced per unit of water increased as a result of the effect of rainfall. Results show that there was benefit from introducing treatments prior to full canopy. These results are for good soils which show that reductions in irrigation can be made with minimal risk of cane death, provided irrigation is properly scheduled and allowance is made for the efficiency of irrigation when applied on a field or Estate scale. When lower Et/Eo ratios are used there is benefit in introducing these treatments after a full irrigation has been applied.

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