FIRST RATOON RESULTS OF TWO IRRIGATION EXPERIMENTS AT PONGOLA

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Introduction

Approximately 53,000 acres of sugarcane are grown under irrigation in the low-rainfall regions north of Mtubatuba, mainly at Pongola and in the Eastern Transvaal. The number of acres which limited supplies of irrigation water should serve in these areas has not been clearly defined. The area in acres to be irrigated with one cusec of water pumped or available at the source, for a given proportion of the total time, is conventionally termed the "WATER DUTY".

In experiments on the Natal coast, maximum farm productivity on a Clansthal sand was achieved using 1 cusec per 200 acres, when water was available 24 hours per day and overhead irrigation was assumed to be 80% efficient. On a Windermere clay, total farm productivity increased up to a water duty of at least 442 acres per cusec in a dry year (Thompson et al[4]; Thompson and de Robillard[5]). Economic assessment of the experimental results showed that maximum farm RETURNS were obtained when a limited amount of water was used to serve a larger acreage than could be irrigated if maximum yields of sucrose per acre were aimed at. When, however, the area of irrigable land is limited but water supplies are plentiful, maximum farm productivity will be achieved by irrigating to produce maximum yields of sucrose per acre.

The plant crop results of the two irrigation experiments referred to in this paper were described by Thompson and Boyce[6]. In a season with a well-distributed summer rainfall of 27.5 inches, the application of 2 inches of effective water every 19 days to this crop, which was grown on a deep Makatini series soil, was sufficient to produce maximum yields of cane and sucrose per acre. This treatment represents a water duty of 182 acres per cusec with continuous delivery and 80% efficiency or 98 acres per cusec at Pongola, where water normally is available for only 5 days each week, and the furrow irrigation employed is assumed to be 60% efficient.

Drying off sugarcane which initially had been irrigated to estimated maximum requirements, produced a statistically significant increase in both sucrose per cent cane and tons sucrose per acre. Although complete suspension of irrigation for two months prior to harvesting gave a significantly greater yield of sucrose than gradual drying off, it was suggested that gradual drying off might prove to be superior if water applications just prior to harvesting were avoided.

The rainfall for the first ratoon crop was well-distributed in summer but the total was only 13.92 inches compared with the mean of 25.1 inches at Pongola for the previous 17 years. The results presented here therefore, apply to a season of relatively low rainfall.

Designs and treatments

Experiment I

This experiment was originally aimed to compare irrigation cycle times of 5, 7, 11 and 19 days in six replications of a randomised block design. In view of the plant crop results, cycle times were changed to 7, 14, 21 and 28 days per two acre/inches of effective water. It was convenient to introduce a comparison of "trashing" and "burning" in the first ratoon crop, so the design was modified to provide three replications of each superimposed treatment.

The four irrigation treatments were identified in terms of the minimum number of days in which an irrigation cycle could be completed when two acre/inches of effective water were applied per cycle. The conversion of cycle times in days to water duties in acres per cusec was carried out as described by Thompson and Boyce[6] for any selected water application efficiency, or period of water delivery. Water duties for typical sets of conditions are shown in Table 1 for the cycle times used in the plant and first ratoon crops in this experiment.

TABLE 1

Experiment I. Minimum cycle times per 2-inch application of water, and equivalent water duties for selected irrigation and delivery efficiencies, including all water treatments for both plant and first ratoon crops

Minimum cycle times in days per 2 inches	Water duties acre/cusec								
	100% efficiency			80% efficiency			60% efficiency		
	168 hr/wk	144 hr/wk	120 hr/wk	168 hr/wk	144 hr/wk	120 hr/wk	168 hr/wk	144 hr/wk	120 hr/wk
5	60	51	43	48	41	34	36	31	26
7	84	72	60	67	57	48	50	43	36
11	132	113	94	106	91	76	79	68	57
14	168	144	120	134	115	95	101	87	72
19	228	195	163	182	156	131	137	117	98
21	252	216	180	202	173	143	151	129	107
28	336	288	240	269	230	191	202	173	143

Experiment II

This experiment consisted of 6 replications of four treatments in a randomised block design. In view of the plant crop results, treatments C and D were modified to include periods of suspended irrigation prior to harvesting. Treatments therefore were as follows:

A. No drying off; irrigated throughout to estimated maximum requirements.
B. Irrigated to estimated maximum requirements for 10 months; all irrigation suspended for the final two months.
C. Irrigated to estimated maximum requirements for 7 months; soil moisture depleted by 1.5 inches per month for 4 succeeding months; all irrigation suspended for the final month.
D. Irrigated to estimated maximum requirements for 7 months; soil moisture depleted by 1.5 inches per month for 4 succeeding months; all irrigation suspended for the final 2 months.

The estimated total available moisture content or T.A.M., of 4 inches, which in this case is held in the top 2 ft of the soil profile was arbitrarily increased to 8 inches to avoid negative values in the profit and loss accounts for each treatment. The principle of equal availability of soil moisture was adhered to, even when apparent depletion exceeded the estimated T.A.M.

Experimental methods

The plant crops in both experiments were harvested when 12 months old, on 28 November 1967. The first ratoon crops were harvested almost 12 months later, on 19 November 1968. The cane in Experiment II was "trashed", and the trash in both experiments was not parted over the row. Irrigation water was again applied by means of a single 40 ft length of "Perf-o-Rainer" pipe raised gradually on telescopic masts as the crop developed.

One irrigation of 2.4 inches of effective water was applied by means of circular sprinklers to both experiments after harvesting the plant crop, in order to replenish the soil moisture reserves to the estimated T.A.M. of 4 inches. The effective rooting depth of the crop was assumed to be 2 ft and 2 inches of available water was held between field capacity and wilting point in each 1 ft. depth of soil (Thompson and Boyce[6]). Irrigation was controlled by means of soil moisture profit and loss accounts, as described by Thompson and Boyce[6].

Estimates of potential evapotranspiration (E_t) for Pongola, which were adjusted according to Class A Pan evaporation data for the previous season, are shown separately for "burnt" and "trashed" conditions in Table 2. The measured value for August was 0.15 inches per day, compared with the estimate of 0.12 inches. The estimate for September was increased from 0.19 to 0.24 inches per day in the middle of the month, for which the mean was also 0.24 inches per day.

Both "trashed" and "burnt" treatments were irrigated according to the soil moisture profit and loss account for "trashed" conditions. In effect, this accentuated the difference between the soil moisture deficits of the "burnt" and "trashed" treatments because the "burnt" treatments were then under-irrigated. In order to calculate the effective water for the "burnt" treatments, separate profit and loss accounts were kept, using the estimates of E_t for "bare soil" during the period of incomplete canopy.

TABLE 2

Estimated mean daily evapotranspiration (E_t) for various degrees of canopy development during each month of the year for Pongola.

Month	Mean daily E_t values (inches per day)								
	Trash blanket				Bare soil				Full
	0 Canopy-	¼ Canopy-	½ Canopy-	¾ Canopy-	0 Canopy-	¼ Canopy-	½ Canopy-	¾ Canopy-	Canopy-
Jan.	0.04	0.10	0.19	0.26	0.13	0.18	0.22	0.27	0.32
Feb.	0.04	0.10	0.16	0.21	0.11	0.15	0.19	0.23	0.27
Mar.	0.04	0.09	0.14	0.19	0.09	0.12	0.16	0.20	0.23
April	0.03	0.09	0.10	0.14	0.07	0.10	0.13	0.16	0.18
May	0.03	0.06	0.09	0.11	0.06	0.09	0.10	0.12	0.15
June	0.03	0.05	0.08	0.09	0.04	0.06	0.08	0.10	0.11
July	0.03	0.05	0.08	0.10	0.05	0.08	0.09	0.10	0.12
Aug.	0.03	0.05	0.08	0.10	0.05	0.08	0.09	0.10	0.12
Sept.	0.03	0.06	0.11	0.15	0.08	0.10	0.14	0.16	0.19
Oct.	0.04	0.09	0.14	0.19	0.10	0.14	0.16	0.20	0.24
Nov.	0.04	0.09	0.15	0.20	0.10	0.14	0.18	0.21	0.25
Dec.	0.04	0.10	0.18	0.24	0.12	0.16	0.21	0.26	0.30

During the development of the crop, stalk height measurements, shoot and stalk counts and vertical ground cover estimates, were carried out. Readings were taken twice weekly from gypsum soil moisture blocks with a Bouyoucos moisture meter. In Experiment II, stalk samples were removed at monthly intervals from June onwards from rows 2 and 5 of the 6-row plots. These samples were used for determination of sucrose per cent cane, juice purity and percentage moisture content of the 3-6 leaf sheaths.

Harvesting procedures for both experiments were described by Thompson and Boyce[6]. Data were again collected from individual rows in order to assess water distribution by the "Perf-o-Rainer" irrigation system. In Experiment I, sheath samples from leaves 3-6 were taken from the net plots for percentage moisture determinations, in order to relate the natural drying off effects of extending irrigation cycles to the drying off treatments in Experiment II. In Experiment II, only the two centre rows 3 and 4 constituted the net plots, but before cutting out rows 2 and 5, the final monthly stalk samples were removed for determination of sucrose per cent cane, juice purity and moisture percentage of the 3-6 leaf sheaths. Duplicate samples of stalks were taken from the net plots before harvest in order to compare the sucrose analyses from the different rows.

Results

Experiment I

(1) *Irrigation method*

The distribution of water from the overhead "Perf-o-Rainer" pipes was apparently satisfactory for the plant crop when the differences between treatments were small. The much greater differences between treatments in the first ratoon crop, however, resulted in the guard rows exploiting moisture in adjacent plots. This is illustrated by comparing the mean cane yields from individual rows of the 28-day cycle plot:

Row 1 — 64.2 T.C.A.
Row 2 — 52.9 T.C.A.

Row 3 — 44.7 T.C.A.
Row 4 — 41.1 T.C.A.
Row 5 — 47.0 T.C.A.
Row 6 — 87.0 T.C.A.

The relationship between treatments remained the same using the data for rows (3 + 4), (2 + 5) and (2 + 3 + 4 + 5). Although rows 3 and 4 gave lower yields than rows 2 and 5, the water distribution tests carried out prior to installation of the system showed that rows 3 and 4 received slightly more water than rows 2 and 5.

(2) *Irrigation treatments*

The yield results given in Table 3 show large differences due to decreasing amounts of applied water. Maximum yields of cane were produced with both the 7- and the 14-day cycles but there was a highly significant reduction in cane yield with the 21-day cycle. This reduced yield was accounted for by shorter stalks rather than any effect on number of stalks or stalk diameter. The statistically highly significant reduction in yield with the 28-day cycle was accounted for mainly by shorter stalks, but also by a lower stalk population, which was associated with slightly thicker stalks.

In contrast to the results of Thompson and de Robillard[5], there were statistically significant increases in sucrose content of cane with decreasing application of water in the 14-and 21-day cycles, compared with the 7-day cycle. With the 28-day cycle, however, there was a highly significant reversal of the trend. The increased sucrose content with the 14-day cycle compared with the 7-day cycle, resulted in a satistically significant increase in the yield of sucrose per acre. The reduced cane yield with the 21-day cycle was offset by a corresponding increase in sucrose content. The markedly reduced yield with the 28-day cycle was accompanied by a large reduction in sucrose content and therefore by a highly significant reduction of sucrose yield expressed in tons per acre.

The 3-6 leaf sheath moisture contents shown in Table 3 correspond with the changes in sucrose content, except in the case of the 28-day cycle. This measure of plant moisture status did not appear to be sensitive enough to identify the decline in sucrose content decisively.

The depletion of soil moisture, the irrigation applications and the rainfall for Experiment I are depicted in Figure 1. The shaded areas represent the percentage of available moisture in each stratum of the soil profile between the moisture tension limits of 1 and 15 bars, as given by the gypsum blocks. It is apparent that the soil profile for the 28-day cycle was not saturated at the beginning of the cropping period below a depth of 4 ft. Since the gypsum block data also show that soil moisture depletion in other treatments occurred to a depth of at least 8 ft this deficiency of antecedent soil moisture reserves could partly account for the marked reduction in cane and sucrose production per acre. The gypsum block data confirm the observation of Thompson and Boyce[6], that large soil moisture deficits could develop in the deeper strata of a profile whilst the shallower strata were replenished by regular irrigation applications.

The growth of the cane in Experiment I which is shown in Figure 2, indicates that the cane subjected to a 28-day cycle suffered severely from moisture stress from April onwards. The initial depression of growth coincides with the stage at which most of the available moisture in the soil profile had been exploited (Figure 1).

TABLE 3

Experiment I. Harvest data

Treatments & cycle times in days	T.C.A.			Suc. % cane			T.S.A.			Stalks/acre $\times 10^3$		
	Burnt	Trash	Mean	Burnt	Trash	Mean	Burnt	Trash	Mean	Burnt	Trash	Mean
W_1—28	38.6	42.6	40.6	14.0	13.0	13.5	5.41	5.56	5.49	58.0	45.8	51.9
W_2—21	56.1	57.5	56.8	15.2	14.9	15.0	8.52	8.57	8.55	58.7	49.1	53.9
W_3—14	62.6	63.0	62.8	14.6	13.7	14.2	9.15	8.63	8.89	60.8	52.1	56.4
W_4—7	65.1	62.7	63.9	13.1	12.8	12.9	8.52	7.99	8.26	60.2	50.1	55.2
Means	55.6	56.4	56.0	14.2	13.6	13.9	7.90	7.69	7.79	59.4	49.3	54.4
S.E. of mean (6 plots)			±1.32			±0.25			±0.16			
S.E. of diff. of mean			±1.86			±0.36			±0.23			
L.S.D. (0.05)			4.1			0.8			0.50			
(0.01)			5.7			1.1			0.70			
C.V.%			5.8			4.4			5.1			
Treatments & cycle times in days	**Stalk Weight lb**			**Stalk length feet**			**Mean stalk diam. mm**			**Sheath moisture per cent**		
	Burnt	Trash	Mean	Burnt	Trash	Mean	Burnt	Trash	Mean	Burnt	Trash	Mean
W_1—28	1.33	1.86	1.60	4.53	5.18	4.86	23.1	26.0	24.6	78.7	80.9	79.8
W_2—21	1.91	2.34	2.13	6.44	6.37	6.40	22.8	24.6	23.7	80.2	80.6	80.4
W_3—14	2.06	2.42	2.24	7.10	6.99	7.05	22.3	23.9	23.1	81.6	83.5	82.6
W_4— 7	2.16	2.50	2.33	7.11	7.04	7.07	22.4	24.7	23.6	84.2	84.2	84.2

Table 4 shows the water use data for Experiment I. To provide the potential requirements of the crop, 50.4 inches of irrigation water were applied, taking efficient rainfall into account. Much smaller amounts of irrigation water were applied with the longer irrigation cycle-times. The amounts of effective water were calculated from the soil moisture profit and loss accounts as the sum of daily potential E_t for all days when moisture was available within the specified T.A.M. of 4 inches. According to the profit and loss accounts, the soil in the "trashed" plots with the 7-day cycle, never reaching wilting point, so that, assuming equal availability of soil moisture between the limits of field capacity and wilting point, the estimated effective water of 62.6 inches represents the total potential E_t for the duration of the crop.

Rainfall efficiency was determined from soil moisture profit and loss accounts as that amount of rainfall which, theoretically, was accepted by the soil to the limit of field capacity, expressed as a percentage of total rainfall. The rainfall efficiencies shown in Table 4 confirm that efficiencies will approach 100% with longer cycle times. They also show that rainfall efficiency with short cycle times can be very high in years of relatively poor, but well-distributed rainfall. These data do not include any allowance for the effects of rainfall intensity on water acceptance by the soil.

(3) *"Trashed" vs "burnt" treatments*

Although there was no statistically significant difference between cane yields from "trashed" and "burnt" treatments, the measured difference of 4.0 tons cane per acre in Table 3 was expected on the strength of visual observations during the cropping period and on gypsum block and stalk height data. Figure 1 shows the difference in soil moisture conditions with the 14-, 21- and 28-day cycle times for the "trashed" and "burnt" cane. The stalk height data in Figure 2 show the difference in the 28-day cycle between "trashing" and "burning". Because of the large antecedent soil moisture reserves, there was little difference between treatments during the early stages of growth. It is apparent that the difference in evaporation from trash-covered soil and bare soil during the period of incomplete canopy, showed in the soil and crop growth only after full canopy had been achieved.

There was statistically significant evidence of a reduction in the sucrose content of cane in the "trashed" treatments compared with cane in the "burnt" treatments. This was to be expected in view of the earlier soil moisture exhaustion (Figure 1) and the lower leaf sheath moisture percentage in the "burnt" treatments (Table 3). There was, however, no statistically significant difference in tons sucrose per acre between the mean yields found in the "trashed" and "burnt" treatments. Table 3 shows in addition that populations of harvested stalks differed markedly. Corresponding treatment differences are to be seen in figures for weight per stalk and mean stalk diameter, but stalk length was only affected by the 28-day cycle. The relatively small differences between the effects of "trashing" and "burning" on water use efficiency are shown in Table 4.

Experiment II

The results for Experiment II, which are given in Table 5, show that only treatment D resulted in a statistically significant loss in yield of cane, compared with the control treatment (A). Whilst statistically, there was a highly significant increase in sucrose content due to drying off, there was no resultant significant increase in the yield of sucrose per acre. The major benefit of drying off was that in treatments B and C, irrigation requirements were reduced by 8 inches and in treatment D by 14 inches. Yield, expressed in tons sucrose per acre, appears to decline in treatment D but, because of the limitations of experiment design, this effect was not statistically significant. The drying off treatments did not affect the number of harvested stalks per acre, but weight, length and upper diameter of the stalks decreased with decreasing yields of cane.

The gypsum block data in Figure 3 show that soil moisture was depleted at depths of at least 8 ft wherever drying off was practised. Moisture in the surface layers of the soils in treatments B and D had been well depleted by the time the crop was harvested. With treatment C, one month of complete suspension of irrigation was apparently not long enough to deplete the soil moisture in the surface layers. This implies that the last two irrigation applications (4 inches of water) in October should have been avoided.

Figure 4 shows that there was a normal seasonal

TABLE 4
Water use data for Experiment I

	'Trashed'				'Burnt'			
	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
Cycle time in days/2 inches	28	21	14	7	28	21	14	7
Mean T.C.A.	42.6	57.5	63.0	62.7	38.6	56.1	62.6	65.1
Mean T.S.A.	5.56	8.57	8.63	7.99	5.41	8.52	9.15	8.52
Irrigation applied (inches)	24.4	32.4	44.4	50.4	24.4	32.4	44.4	50.4
Effective rain (inches)	13.92	13.92	13.02	12.30	13.92	13.92	13.92	13.66
Rainfall efficiency (%)	100	100	93.5	87.6	100	100	100	98.1
Effective water (inches)	38.32	46.32	57.42	62.60	38.32	46.32	58.32	64.06
Total water (inches)	38.32	46.32	58.32	64.32	38.32	46.32	58.32	64.32
Tons cane/inch applied water	1.74	1.77	1.42	1.24	1.58	1.73	1.41	1.29
Tons cane/inch effective water	1.11	1.24	1.10	1.00	1.01	1.21	1.07	1.02
Tons suc./inch applied water	0.228	0.264	0.194	0.158	0.222	0.263	0.206	0.169
Tons suc./inch effective water	0.145	0:185	0.150	0.128	0.141	0.184	0.157	0.133

TABLE 5
Harvest data and water applied in Experiment II

	Treatment				C.V. %	S.E. treat. mean ±	L.S.D.	
	A	B	C	D			P=0.05	P=0.01
Irrig. applied (inches) ..	46.4	38.4	38.4	32.4				
Yield T.C.A.	70.9	65.1	64.8	59.4	8.4	2.23	6.7	9.3
Yield T.S.A.	9.31	9.43	9.24	8.92	10.7	0.40	1.22	1.68
Sucrose % cane (net plot)	13.1	14.5	14.3	15.0	3.8	0.27	0.80	1.10
Sucrose %cane(guard rows)	13.2	14.6	14.8	15.1				
Sheath moisture %	84.1	79.3	82.1	79.2				
Stalks/acre ($\times 10^3$)	52.0	51.7	52.3	52.2				
Stalk weight (lb.)	2.73	2.52	2.48	2.28				
Stalk length (ft.)	7.28	6.86	6.90	6.43				
Upper stalk diam. (mm) ..	25.4	25.3	24.6	24.1				

Treatment comparisons:
Responses and S.E.'s:

Comparison	T.C.A.		Suc. % cane		T.S.A.	
A—B	5.8	S.E. ±3.15	−1.4	S.E. ±0.39	−0.12	S.E. ±0.57
B—C	0.3		0.2		0.19	
C—D	5.4		0.7		0.32	

increase in sucrose content from June onwards. Concerning the drying off period in treatments B and D, sheath moisture and sucrose content were not greatly affected during the first month, but during the final 21 days, percentage sheath moisture declined sharply and sucrose content increased. During this final period, the effects were more marked in the B treatment, because cane in the D treatment had already been dried off gradually. With treatment C, the irrigation and rainfall received in October caused a rise in sheath moisture content and a decrease in sucrose per cent. cane, in accordance with soil moisture status (Figure 3).

The leaf sheath moisture contents, even in treatment D which suffered severe soil moisture depletion, never fell below 79%. In the plant crop, they never fell below 80%. In Experiment I, the sheath moisture of the ratoon crop was only 79.8 per cent. in the 28-day cycle when the sucrose content had already declined significantly below the peak value. These findings differ from those of Clements[2] in Hawaii, who found that sucrose levels reached a maximum when sheath moisture content had fallen to 73%.

Discussion

Experiment I

It is evident from the results that on a Makatini sandy clay soil, in a year of low but well-distributed rainfall (13.92 inches), maximum yields of sucrose per acre were produced when 2 inches of effective water was applied every 21 days. The soil profile, with the exception of that for the 28-day cycle, was saturated to a depth of at least 8 ft following harvest of the plant cane crop. The soil water in these circumstances was held at 1 bar moisture tension or less. Table 1 shows that this treatment represents a water duty of 202 acres per cusec when water is delivered for 168 hours per week and applied with an efficiency of 80%. It represents a water duty of only 107 acres per cusec when the water is delivered for 120 hours per week and applied with an efficiency of 60%, as is the case at Pongola. However, Thompson and Boyce[6] have already pointed out that the water available for the Pongola Irrigation Settlement could be utilised much more efficiently if it were available to all farms continuously for 7 days a week and if application efficiencies were increased by improving furrow irrigation techniques or changing to systems of overhead irrigation.

The areas under cane on farms at Pongola range from 58 to 130 acres per farm, and all farms are limited to a maximum water delivery rate of 1 cusec which normally is available for only 120 hours each week. The corresponding water duties would therefore range from 81 to 182 acres per cusec. Thompson and Boyce[6] have, however, pointed out that the MINIMUM average water duty calculated for the 15,600 acres of cane at Pongola during any four-week month over a three-year period (1965-1967), was 135 acres per cusec. These estimates of current water duties employed at Pongola tend to exceed the water duty of approximately 100 acres per cusec (60% efficiency, 120 hours/week) which, for two crops in this experiment, has given maximum yields of sucrose per acre.

When, on a deep Makatini series soil, the area of land available is limited but water supplies can be increased, there may be potential for stepping up the production of sucrose per acre to the maximum level attainable. This suggestion is practicable on small farms at Pongola as additional delivery time can be obtained over the weekends, the extra water at the farm sluice gates costing 30 cents per acre/inch. Assuming that one ton of cane is produced per inch of effective water, that the efficiency of application is 60% and that the gross value of cane at 13.5% sucrose is R4.51 per ton (average price for 1968-69 season), then the 30 cents required to purchase 1 acre/inch of water will give a gross return of R2.71.

Usually it is the amount of water available for irrigation that is limiting rather than the area of the land. In these circumstances it is important to evaluate water duties in terms of total farm productivity and economic returns. Table 6 shows the total farm productivity per annum when 1 cusec of water is used to irrigate different areas of land with different efficiencies and delivery periods. Since rainfall in the Pongola and Eastern Transvaal sugarcane areas is usually inadequate for the production of rain-fed sugarcane, the yield of a rain-fed crop was assumed to be zero. Total farm productivity is also given in terms of sucrose because, statistically, variations in sucrose content were highly significant.

TABLE 6

Total farm productivity per annum per cusec of water used to irrigate different areas of land with different irrigation systems

Treatments & cycle days	Yield		60% eff. 120 hr/week			80% eff. 168 hr/week		
	T.C.A.	Suc. %	Area ac.	Tons cane	Tons suc.	Area ac.	Tons cane	Tons suc.
W_1—28	40.6	13.5	143	5,806	784	269	10,291	1,474
W_2—21	56.8	15.0	107	6,078	912	202	11,474	1,721
W_3—14	62.8	14.2	72	4,522	642	134	8,415	1,195
W_4—7	63.9	12.9	36	2,300	297	67	4,281	552

The estimates of total farm productivity were calculated using the actual experimental yields. Thompson and de Robillard[5] calculated total farm productivities from a linear regression equation describing the relationship between cane yield and estimated effective water. Unfortunately, this approach could not be adopted for the results of this experiment because of the probable errors in estimating the amount of effective water. Table 6 shows that the 21-day cycle gave maximum yields of cane and sucrose in spite of the fact that with the 28-day cycle, 1.06 tons of cane were produced per inch of estimated effective water.

The effects of increasing application efficiency and the period of water delivery are also given in Table 6, expressed as tons cane and tons sucrose per cusec of water.

The yield of cane and sucrose per inch of estimated effective water tended to increase with longer cycle times, up to 21 days (Table 4). With the 28-day cycle, however, water use efficiency declined sharply. These results do not confirm those of Chang et al[1] in Hawaii and Thompson and de Robillard[5] on the coast of Natal. These authorities showed that approximately 1 ton of cane was produced per inch of estimated effective water, over a wide range of water duties. The probable errors in the estimation of effective water can be evaluated in terms of errors in the estimation of the T.A.M. for this soil, the actual E_t and rainfall efficiency.

(1) *Error in estimation of T.A.M.*

The estimated T.A.M. of 4 inches was probably seriously in error when the crop was not irrigated to supply maximum water requirements. It can be seen from Figure 1 that at the beginning of the cropping period the soil profile for the 21-day cycle was saturated to a depth of at least 8 ft, water being held at moisture tensions of 1 bar or less. By the end of September this soil moisture was almost completely exhausted. The moisture characteristics for this soil, presented by Thompson and Boyce[6], showed that a total of 14.50 inches of water was available to a depth of 6 ft. By basing the T.A.M. on an effective rooting depth of 2 ft, the estimates of effective water were obviously underestimated when the crop was no longer irrigated to supply estimated maximum water requirements. This would largely account for the apparent increase in water use efficiency with increasing cycle times up to 21 days, shown in Table 4.

(2) *Error in estimation of E_t*

If actual E_t at any time fell below the potential rate this may also have contributed to errors in the estimation of effective water. It is acknowledged that the moisture held in the soil was probably not equally available between the limits of field capacity and wilting point, and that availability may also have been affected by the considerable depth from which soil moisture was extracted. In any event, errors would only have been incurred if soil moisture had been replenished to field capacity before the specified T.A.M. could be fully exhausted. An analysis of the soil profit and loss accounts showed that this error was likely to have been relatively small.

(3) *Error in estimation of rainfall efficiency*

This possible source of error in the estimation of effective water can be assessed by examining the rainfall data in Table 4. The errors were probably very small because the total rainfall of only 13.92 inches was well-distributed and hence largely effective.

The indications, therefore, are that the estimates of effective water in the drier treatments were in error mainly because of the obvious underestimate of the effective rooting depth of the crop and the consequent error in estimating that the T.A.M. for this soil is only 4 inches. This T.A.M. value was satisfactory when the crop was irrigated to meet maximum requirements but not when larger water duties were employed. It follows, therefore, that there is an urgent need for revision of the current method of estimating T.A.M. values by a method based on direct measurements of available soil moisture. Such measurements would need to be carried out in conjunction with measurements of relative crop performance on different soil types, at different stage of crop development and at different levels of evaporative demand.

A justifiable criticism of the yield results shown in Table 3 is that the crops with the shorter cycle times would have benefited more from a period of drying off than would the crops with the longer cycle times. The results of Experiment II provide a means of assessing this criticism, as the 7-day cycle in Experiment I amounted to provision of sufficient water to meet maximum crop requirements. They show, in fact, that there would probably not have been a marked increase in tons sucrose per acre due to drying off, although sucrose content would have increased and water savings could have been large. Secondly, even a marked increase in sucrose content to the apparent peak value of 15% without any reduction in yield would only have increased the total farm productivity for the 7-day cycle (Table 6), from 297 tons sucrose to 345 tons sucrose (60% efficiency, 120 hr/week).

Experiment II

In contrast to the plant crop results, drying off did not increase tons sucrose per acre, although a cane yield of 70.9 tons per acre for treatment A was surprisingly high. Drying off did, however, result in considerable savings in irrigation water and therefore potential handling costs. The results indicate that maximum yields of sucrose can be achieved without irrigating to estimated maximum water requirements.

Whilst the plant crop results indicated that complete suspension of irrigation for two months prior to harvest gave best results, gradual drying off procedures were just as effective with the first ratoon. This was achieved by avoiding applications of water prior to harvest, so that the surface layers of the soil profile were more effectively depleted of moisture. However, it was evident that even after depletion of 6 inches of water, complete suspension of irrigation for only the final month was not long enough. The implication of these findings is that the accumulated water deficit at harvest is probably more important than the rate of drying off.

Since, in two successive seasons in both Experiments I and II, maximum yields of sucrose were produced without irrigating to supply maximum demand, there is no point in irrigating to the latter level and then drying off. Drying off occurred automatically with increasing cycle times in Experiment I, but the need for drying off procedures with a particular cycle would depend mainly upon rainfall during the months prior to harvest. Obviously, applications of water just prior to harvest must also be avoided.

Procedures for drying off sugarcane in the field must retain a considerable degree of flexibility. Both the rates of drying off and maturation will vary with soil type, rainfall, evaporative demand, irrigation system, variety, temperature and age of crop. Johnson[3] described a system of routine maturity testing combined with irrigation control measures and determinations of plant moisture status, which takes all these factors into account.

Conclusions

The results of these experiments are only applicable to the deep Makatini sandy clay soil at Pongola, which was initially saturated with water held at 1 bar moisture tension or less to a depth of at least 8 ft. There was evidence that the estimated T.A.M. of 4 inches for this soil was satisfactory for irrigation control procedures when the crop was irrigated to maximum demand, but that it was not with larger water duties. This was because the T.A.M. did not take into account the ability of sugarcane, when it is no longer irrigated to maximum demand, to exploit the soil moisture to a depth of at least 8 ft. There is an urgent need for revision of the current method of estimating T.A.M. values.

The application of 2 inches of effective water every 21 days was sufficient to produce maximum yields of SUCROSE per acre, even in a season with well-distributed, but relatively low rainfall of 13.92 inches. Maximum yields of SUCROSE per acre have, therefore, been achieved in two successive seasons without irrigating to meet the estimated maximum water requirements of the crop. The results do not suggest, however, that potential E_t exceeds the water requirements for maximum CANE production per acre. The 21-day cycle represents a water duty of 107 acres per cusec, when 1 cusec is available for only 120 hours per week and furrow irrigation is employed which is assumed to be 60% efficient. By increasing the delivery time to 168 hours per week and the application efficiency to 80%, this water duty could be almost doubled to 202 acres per cusec.

On similar deep profiles at Pongola, there appears to be potential for maximising farm productivity by adjusting water duties to approximately 100 acres per cusec (60% efficiency, 120 hours/week) or 200 acres per cusec (80% efficiency, 168 hours/week). These water duties can be recommended only providing that the soil profile is re-filled during the period of incomplete canopy of the following crop. When water is limited and the area of irrigable land is plentiful, it is important to evaluate water duties in terms of total farm productivity and the concurrent economic returns. Interpretation of the results in these terms has not, however, been attempted because of probable errors involved in estimating effective water.

Drying off sugarcane which initially was irrigated to meet maximum demand did not, from a statistical viewpoint, significantly increase the yield of sucrose per acre. It did, however, result in considerable savings in irrigation water and potential handling costs. The complete suspension of irrigation for the final two months before harvest did not prove better in terms of sucrose yield per acre than gradual drying off procedures. By avoiding water applications for two months prior to harvest, the soil moisture in the surface layers was effectively depleted. One month of complete suspension of irrigation following gradual drying off, was not long enough to allow depletion of the soil moisture in the surface layers.

There is no point in irrigating initially to supply estimated maximum water requirements and then drying off just prior to harvest, because equally high yields of sucrose per acre can be achieved over a much larger acreage with the same amount of water. Drying off occurred automatically with increasing cycle times in two successive seasons. When the optimum water duty is specified, drying off procedures may or may not be required in any particular season, depending upon several factors. For this reason, drying off procedures under field conditions must remain flexible, and a routine system of maturity testing and drying off is essential.

Acknowledgements

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Discussion

Dr. Thompson: It is mentioned that Clements, in Hawaii, got down to 73% sheath moisture at maximum sucrose whereas at Pongola the lowest figure is about 79%. However, at Illovo, sheath moisture as low as 73% was recorded with both N:Co376 and N:Co310. Our extension officers claim that in the North, e.g. Swaziland, particular attention should be paid to this as owing to the different climate it is difficult to get sheath moistures down.

The estimates of current water duties employed by farmers at Pongola seem to exceed the water duty of approximately 100 acres/cusec (60% efficiency; 120 hours week) which, for the two crops in this experiment, has given maximum yields of sucrose per acre. This seems to confirm what has already been mentioned by du Toit and Murdoch that irrigated areas such as Pongola have better yields in years of good rainfall.

The author queries whether in fact more than one ton of cane was produced per inch of effective water, because of probable errors in estimating the amount of effective water. I do not think that we should ignore the possibility that we are getting higher water use efficiencies at the larger water duties.

I wish to stress the importance of the statement on page seven that "these water duties (100 acres/cusec) can be recommended only provided that the soil profile is refilled during the period of incomplete canopy of the following crop". Less water may be put on the current crop provided the facility is there to refill the profile after the harvest. If, during this period, rainfall fills the profile then water has been saved—otherwise water will have to be made up.

Dr. Le Roux: Would it not be more correct to add the quantity of water required to replenish the profile in calculating the water duty?

Mr. Boyce: The reason we could not do this was the large error involved in our T A M value. As a consequence our balance sheet was incorrect at the beginning of the cropping when the soil profile was saturated with water held at 1 bar tension or less to a depth of at least 8 feet.

Mr. Andries: I am puzzled to know why a T A M of 4" was chosen. In a soil six feet deep the root zones must be five to six feet so the T A M should be in the region of ten to twelve inches if 2 inches of water are held in each 1-foot depth.

Mr. Boyce: When a crop is irrigated to maximum estimated requirements then about 75-90% of the water is removed from the top two feet.

On a Clansthal sand it has been shown that water can be removed from a depth of seven feet.

However, in this experiment the T A M was based on the fact that the water would be removed from the top two feet when irrigating to potential but the T A M did not take into account that this would not be the case when the crop was no longer irrigated to potential.

Dr. Thompson: Mr. Andries knows the capabilities of Swaziland soils but in Natal we have not previously found soils where 4" could be exceeded for T A M.

This paper, with a 28 day cycle, shows that under the conditions at Pongola a T A M of 4" will be exceeded when the crop is subject to large moisture deficits.

Dr. Gosnell: In our experiments in Rhodesia we have found that under dry irrigation treatments, the trashed plots are far superior in yield to the burnt ones, but with wet irrigation treatments the reverse applies.

Fig. 1: Gypsum block, irrigation, and rainfall data for the 7, 14, 21 and 28 day cycles, and for 'burnt' and 'trashed' conditions in Experiment I.

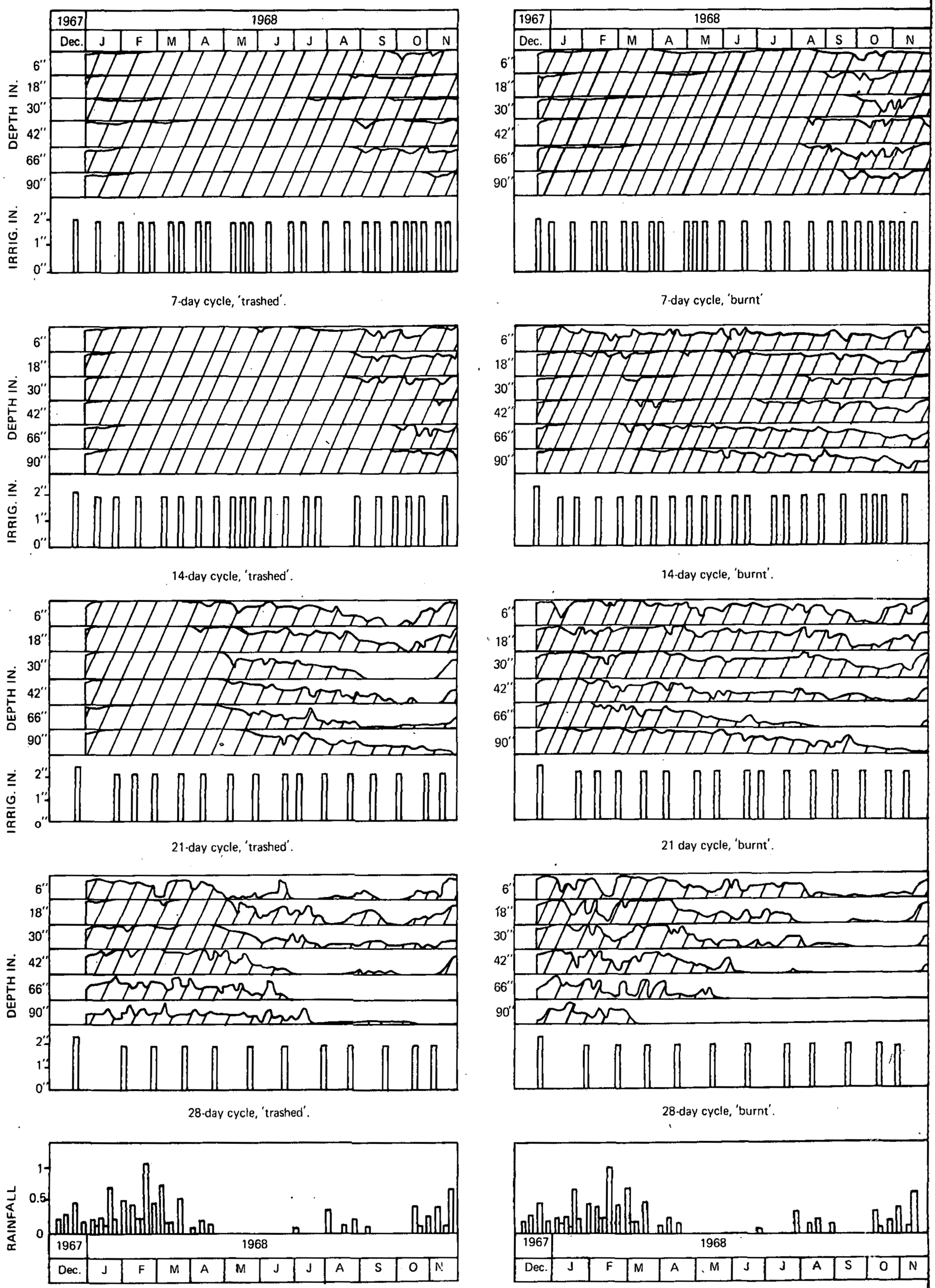

Fig. 2: EXPERIMENT I. Growth measurements in terms of stalk height.

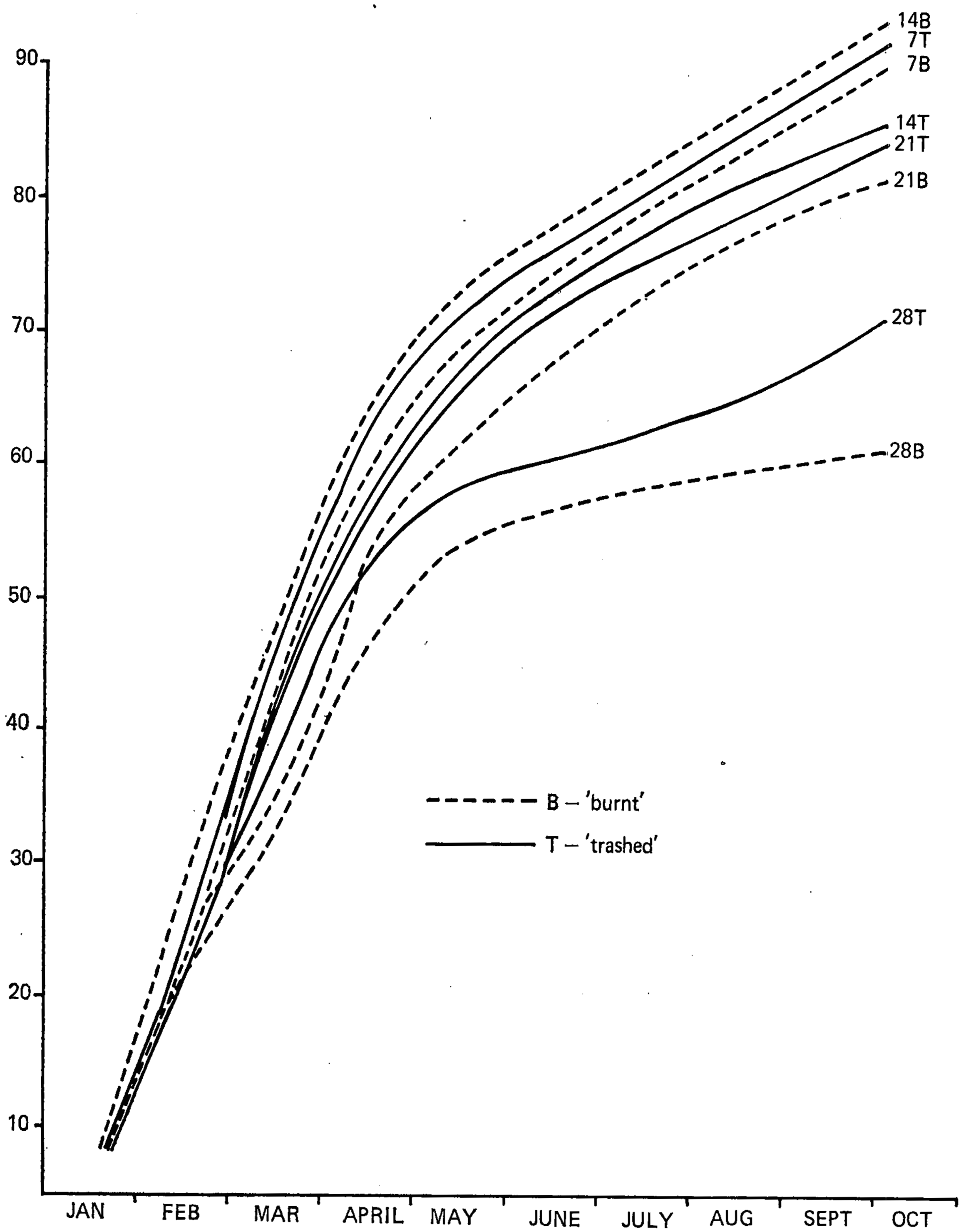

Fig. 3: Gypsum block and irrigation data for Experiment II for the final six months of the first ratoon crop.

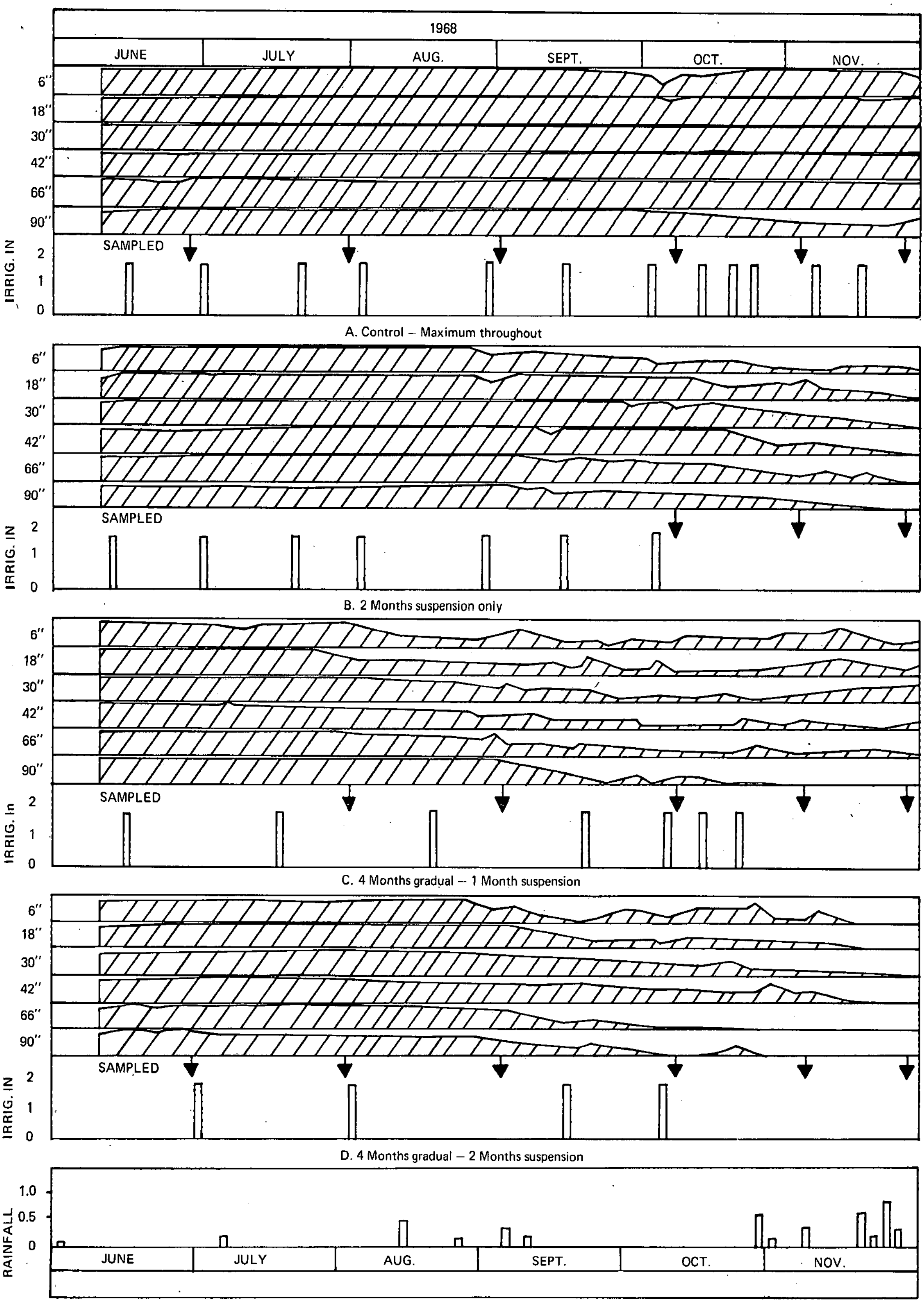

Fig. 4: Sheath moisture per cent and sucrose per cent cane (using a constant Java ratio of 80.00) of monthly samples from Experiment II.