ATTEMPTS TO CONFIRM IRRIGATION CONTROL FACTORS BASED ON METEOROLOGICAL DATA IN THE CANE BELT OF SOUTH AFRICA

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Summary

A co-operative experiment which is being carried out by the S.A. Sugar Experiment Station, The Tongaat Sugar Company and Illovo Sugar Estates, to study the consumptive use of water by sugarcane, is reported. The consumptive use has been related to the evaporation from a Standard British Evaporation tank and, for the plant cane crop, a factor obtained which appears to e in excess of Penman factor of 85 per cent. The experiment is continuing and detailed discussion of the results will take place when results for ratoon crops are available.

The fundamental problem in irrigation is to know how much water to apply, and at what interval, to produce the maximum economical yield from the crop being irrigated. It is only upon this estimate that an irrigation scheme can be designed to suit the moisture requirements in a particular crop. Instruments are available to help determine the moisture status of soils, but in recent years a new approach, known as the evaporation approach, has become popular. Penman (1950)[1] used meteorological data to calculate the moisture lost to the soil under a crop, giving complete cover, when the soil was at Field Capacity, and he related this to the evaporation from an open surface of water. Working with five gallon drums sunk into a plot of mown grass and by watering and weighing these throughout the year a figure of 85 per cent. of the water evaporation from an open tank was assumed to be the water evaporated and transpired by a complete cover of short mown grass under temperate climatic conditions in England.

This factor has been widely adopted to calculate the soil moisture deficiency under a number of crops by measuring the evaporation from a standard tank.* It has been used with some success for irrigation control with sugarcane in Natal.[2] Workers in Jamaica and Hawaii have, however, undertaken experiments to relate open tank evaporation to the actual consumptive use of water by cane in these countries. Their results, as will be seen below, show a high degree of divergence between each other and also with Penman results. It was therefore decided to carry out similar experiments in Natal and the purpose of this paper is to record that these experiments are under way, to describe them and to report the results obtained during the first crop of cane, i.e. from planting to harvest at 12 months.

*Note.—There are two types of standard evaporation tanks. A British one which is 6 ft. x 6 ft. x 2 ft. deep painted black and sunk in the ground, and an American or U.S. tank which is approximately 4 ft. in diameter and 9 inches deep. It is painted silver and stands 6 inches above the ground.

In Jamaica 40 gallon metal barrels were used in place of Penman's 5 gallon drums and water was applied in greater quantities than that demanded by the crop. The surplus water was extracted from the barrels and the difference between water applied to the cane and water extracted as leachate represented the water consumed by the growing crop, or what is referred to hereafter as its consumptive use.

In the Hawaiian Islands a metal tank was let into a field and cane planted through the field so that one line of cane ran through the centre of the tank. These tanks, as in Jamaica, received surplus water and the consumptive use of the crop was again calculated by recording the differences between applied and leachate water.

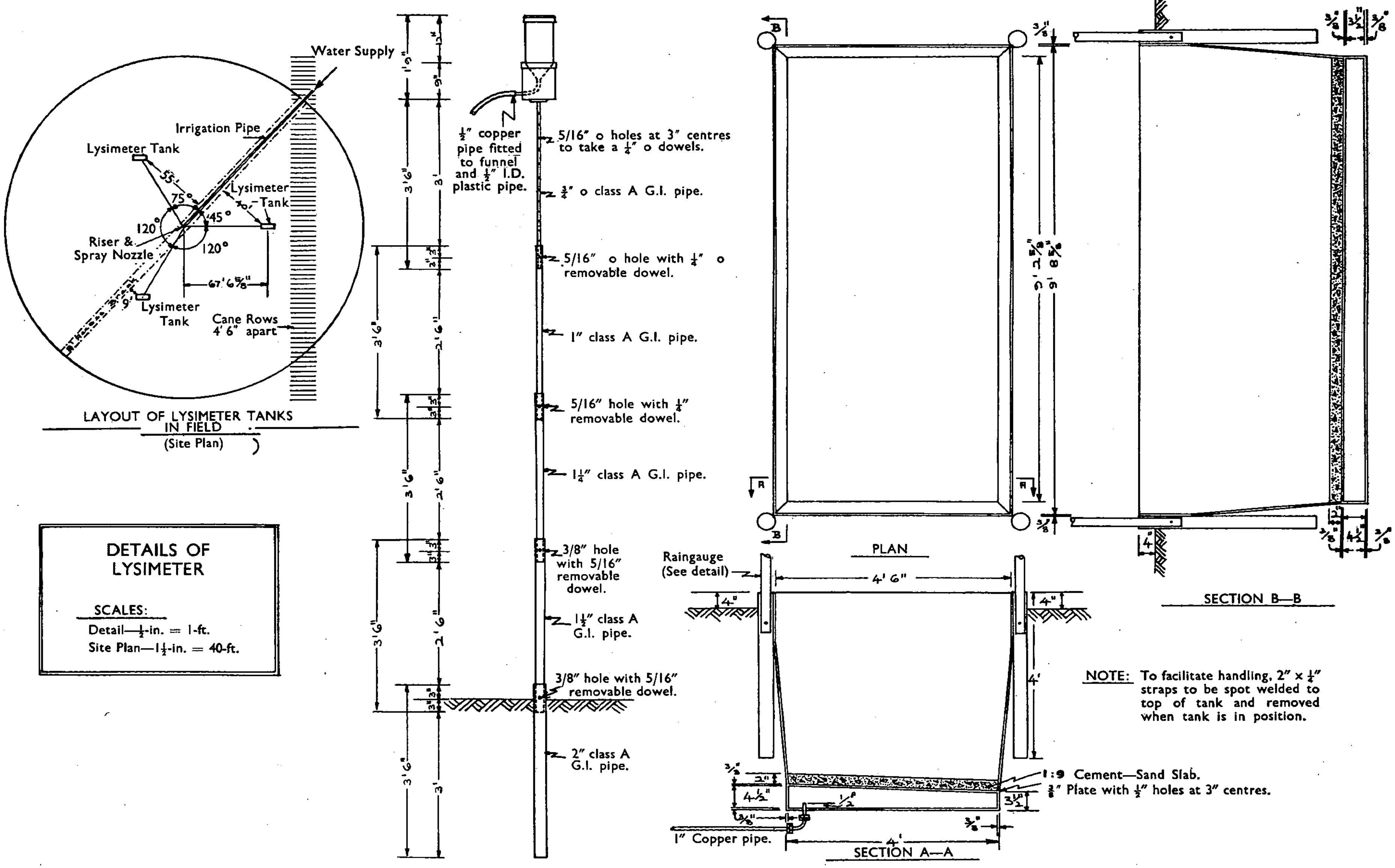
Cowan and Innes from Jamaica in the 9th I.S.S.C.T. Proceedings[3] showed the consumptive use for a closed-in crop of cane to be 57 per cent. of the evaporation from a Standard British evaporation tank, whilst Campbell, Jen-Hu Chang, Doak C. Cox reporting the Hawaiian results in the 10th I.S.S.C.T. Proceedings[4] showed a figure of 110 per cent. The latter workers used an American or U.S. type evaporation tank, held at the level of the cane leaves throughout. The different type of tank used in the two experiments rules out direct comparison, but it can be confidently surmised that if the Hawaiian results had been related to a Standard British tank the factor would have been higher than 110 per cent.

In the experiments which are being carried out in Natal, it was considered advisable to take the greatest possible care with the construction of the tank to be buried in the soil. The rapid corrosion factor and the long period of the crop growth necessitated a rugged construction with a low corrosive material. Ultimately aluminium tanks 9 ft. 8-5/8 ins. long by 4 ft. 6 ins. wide and 4 ft. 4 ins. deep, were constructed with slightly tapering sides and ends and with a perforated 3/8 inch aluminium plate 4½ inches from the bottom, on which porous concrete slabs could be laid to form a false bottom to ensure free drainage of the leachate. The area of the tanks represented 1/1,000th acre and a drawing has been reproduced in figure 1.

The bottom of the tank was sloped slightly to one end where a plastic drainpipe enabled the leachate to be drawn off and measured. To ensure the correct measurement of rainfall and irrigation falling on the tank, rain gauges were fitted to each corner on telescopic rods, so that the lip of the gauges could always be kept just above the leaf area of the growing cane.

Figure 1 also shows the field layout of the experiment. It consisted of three of the aluminium tanks

FIG. I


Water Supply
Irrigation Pipe
Lysimeter Tank
Lysimeter Tank
Riser & Spray Nozzle
Lysimeter Tank
Cane Rows 4' 6" apart
67' 6⅝"
LAYOUT OF LYSIMETER TANKS IN FIELD
(Site Plan)
DETAILS OF LYSIMETER
SCALES:
Detail—½-in. = 1-ft.
Site Plan—1½-in. = 40-ft.
½" copper pipe fitted to funnel and ½" I.D. plastic pipe.
5/16" o holes at 3" centres to take a ¼" o dowels.
¾" o class A G.I. pipe.
5/16" o hole with ¼" o removable dowel.
1" class A G.I. pipe.
5/16" hole with ¼" removable dowel.
1¼" class A G.I. pipe.
3/8" hole with 5/16" removable dowel.
1½" class A G.I. pipe.
3/8" hole with 5/16" removable dowel.
2" class A G.I. pipe.
PLAN
SECTION B—B
Raingauge (See detail)
4' 6"
NOTE: To facilitate handling, 2" x ¼" straps to be spot welded to top of tank and removed when tank is in position.
1:9 Cement—Sand Slab.
⅜" Plate with ½" holes at 3" centres.
1" Copper pipe.
SECTION A—A

described above, situated 67 ft. 6 ins. from a large rainer position. The rainer was of the type capable of throwing water over a radius of 100—120 ft. when operated at a pressure of 70—90 pounds per square inch.

The tanks were let into the ground and filled with 4 feet of the removed soil, care being taken to replace the soil, foot by foot, in the order in which it was dug out. As already mentioned, three tanks were used in each experiment. This layout was then replicated at three different centres, and recordings made by three separate observers working to a common plan.

The three centres were:

1. The Chaka's Kraal Experimental Farm, on a dwyka soil, with an Easterly aspect and a slope of 9 degrees in an exposed position on the edge of a cliff.
2. The Umhloti Section of The Tongaat Sugar Company on an alluvium sandy soil with a South Easterly aspect and a slope of 9 degrees in a wide valley bottom not too exposed to the prevailing winds.
3. The Illovo Sugar Company on a flat deep alluvium soil with surrounding protective hills to the North West, North and North East, and the wide valley bottom to the South.

N.B.—Sites 1 and 3 were 45 miles apart.

The leachate was collected from sites 1 and 2 by plastic pipes leading from the bottom of the tanks to a sump, or sumps, so placed that the gravity flow drained the tanks. At site 3 the level nature of the ground would have necessitated extremely deep sumps and to avoid this the leachate was initially extracted by attaching a diaphragm suction pump to the drainage pipe. This ultimately proved unsatisfactory and sumps were constructed at a later date.

After positioning the tanks they were left for a few months to allow the soil to settle.

During the first week of October 1959 all three sites were planted with cane of the variety N:Co.376. The tanks were so placed that one line of cane went through the centre of each tank along its length. When the site was accurately furrowed at 4 feet 6 inch intervals a fertiliser treatment of 525 lbs. superphosphate per acre and 108 lbs. urea per acre was applied in the furrow at the time of planting.

Good steady rains fell after planting and irrigation water was not needed until the end of November at No. 1 and 2 sites and the end of October at No. 3 site. In order to ensure that excess water was applied to the tanks throughout the experiment it was agreed that they should receive a minimum of 1½ inches per week either as rain or irrigation, the latter to be given in two applications. When the rainfall fell short of ¾ inch for the 4 or 3 day period, then irrigation water was applied on Wednesday and Saturday to make up the deficiency for the period.

Leachate at site 1, was collected daily whilst at sites 2 and 3 it was collected twice a week on each Wednesday and Saturday before irrigation. Evaporation tank readings were taken at sites 2 and 3 whilst the figures from the tank at the Experiment Station, Mount Edgecombe were applied to site 1. This latter arrangement was not the most satisfactory, and arrangements were subsequently made to have a British Standard evaporation tank installed at site 1. Other meteorological data, such as maximum and minimum temperatures, wet and dry bulb readings and 12 inch soil thermometer readings were taken at sites 1 and 2 both outside and inside the cane, while the total wind was also recorded at site 1. At site 2 recordings were also taken with a Gunn-Bellani solar radiation integrator.

In December, 1959, when the cane was three months old, a top-dressing of 108 lbs. urea per acre and 83 lbs. muriate of potash was applied to each site and similar dressing was applied in February, 1960, when the cane was five months old and again in May, 1960, when the cane was 8 months old.

Thus the total fertiliser applied was:

Fertiliser	Planting October 1959	3 months December 1959	5 months February 1960	8 months May 1960	TOTAL. lbs. p.a
Superphosphate ..	525 lbs. p.a.				525
P_2O_5	100 „ „				100
Urea	108 „ „	108 lbs. p.a.	108 lbs. p.a.	108 lbs.	432
N.	50 „ „	50 „ „	50 „ „	50 „	200
Muriate of Potash ..	—	83 „ „	83 „ „	83 „	249
K_2O	—	50 „ „	50 „ „	50 „	150

The cane growth was very satisfactory, as would be expected with the application of unlimited water and high fertiliser, and cutting took place in October, 1960 when the cane was exactly 12 months old.

The yield in tons cane per acre was recorded at each site by harvesting 1/80th acre plots around each tank and weighing the line of cane in the tank separately. The yield and consumptive use date has been summarised below in Table 1.

Table 1

	Tons Cane P/A from 1/1,000th acre Tank	Tons Cane P/A from 1/80th Acre Plot incl. tank	Tons Sucrose P/A from 1/80th acre Plot	Total Rain ins.	Water Irri-gation ins.	Added Total ins.	Leach-ate ins.	Con-sumptive use of water by Cane ins.	Open tank Evap-oration ins.
Site 1 tank a	102.51	69.84	8.82	26.65	50.01	76.66	22.42	54.24	
„ „ „ b	91.00	56.60	7.39	26.45	53.13	79.58	27.12	52.46	
„ „ „ c	87.00	58.40	7.69	25.58	49.48	75.06	19.84	55.22	
MEAN	93.50	61.61	7.97	26.23	50.87	77.09	23.12	53.97	46.63
Site 2 tank a	86.50	63.96	6.93	23.28	52.44	75.74	24.24	51.28	
„ „ „ b	68.00	55.68	6.01	23.26	51.17	74.43	27.17	47.26	
„ „ „ c	70.50	56.44	7.06	23.20	44.39	67.59	18.88	48.71	
MEAN	76.00	55.84	6.62	24.80	46.24	71.01	28.42	42.80	45.83
Site 3 tank a	76.00	59.96	6.88	24.80	46.24	71.01	28.42	42.80	
„ „ „ b	84.50	58.84	6.84						
„ „ „ c	67.50	50.72	6.15						
MEAN	75.00	58.69	6.66	23.25	49.33	72.58	23.43	49.08	46.32
GENERAL MEAN ..	81.50	58.94	7.08	24.74	49.55	74.29	24.01	50.28	46.26

RESULTS:

1. Rainfall, irrigation and yield

The mean rainfall for the crop was 24.74 inches and an additional 49.5 inches of irrigation was applied. The actual amount of effective water received by the crop was 50.28 inches, made up from the total rainfall and irrigation, less the amount of leachate collected from the tanks.

This produced a mean crop of 58.94 tons cane per acre in 12 months, representing a standard of production far in excess of that at one time thought possible on the North or South coasts of Natal.

It also appears that 0.85 inches of water were required to produce one ton of cane, or 7.10 inches to produce one ton of sugar. The distribution of the rainfall and irrigation has been represented in the form of a histogram in figure 2.

2. Consumptive Use data

The consumptive use, i.e. the water consumed by the crop, for consecutive 28 day periods during the plant cane crop has been shown in figure 3. The mean consumptive use from each centre, the mean for the project and the mean evaporation from the three Standard British Evaporation tanks have been graphed. The soil moisture throughout the experiment was maintained at or near field capacity so the consumptive use recorded may be referred to as maximum or potential consumptive use.

Table 2 shows the mean factors which relate the consumptive use to the evaporation from the Standard evaporation tanks for the same 28 day periods which were used above.

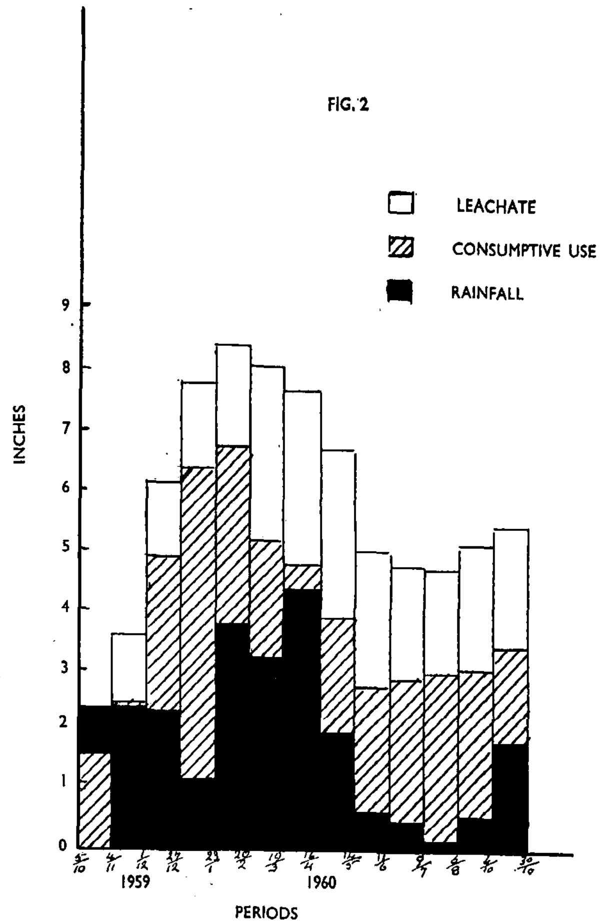


FIG. 2

Comments

The results for the consumptive use at each centre are in good agreement as shown by figure 3. It must be mentioned, however, that in the case of site 3, data was available from only one tank as it was found, late in the crop, that faults had occurred in the leachate lines from the other two tanks. The sudden drop in consumptive use during the period ending 3rd September, 1960, might not have been so pronounced, if figures had been available for the three tanks at this site.

The period from the 2nd October, 1959 to 27th December, 1959, represents the early growth of the plant cane up to the stage when it had more or less completely closed-in. At this stage the evaporation from the surface of the soil is a major factor in the consumptive use and transpiration an increasing factor as the young crop closes in.

From the 27th December, 1959, the consumptive use date refers to cane which has closed in when transpiration is the major factor in the moisture lost to the soil and evaporation a minor one. During this period, the relationship between the consumptive use and the evaporation from a Standard tank appears to be greater than Penman's factor of 85 per cent.

From the above results the consumptive use for the whole plant cane crop is 109 per cent. of the evaporation from a Standard tank, and for the period from 27th December when the cane had closed in, 139.7 per cent.

The investigations are proceeding.

References

[1]Penman H. L. 1950, Evaporation over the British Isles. *Quart. J. Roy. Meterol. Soc.* 76 pp. 372-83.

[2]Thompson G. M., 1960, *Proc. 34th Annual Congress S.A. Sugar Tech.* p. 161.

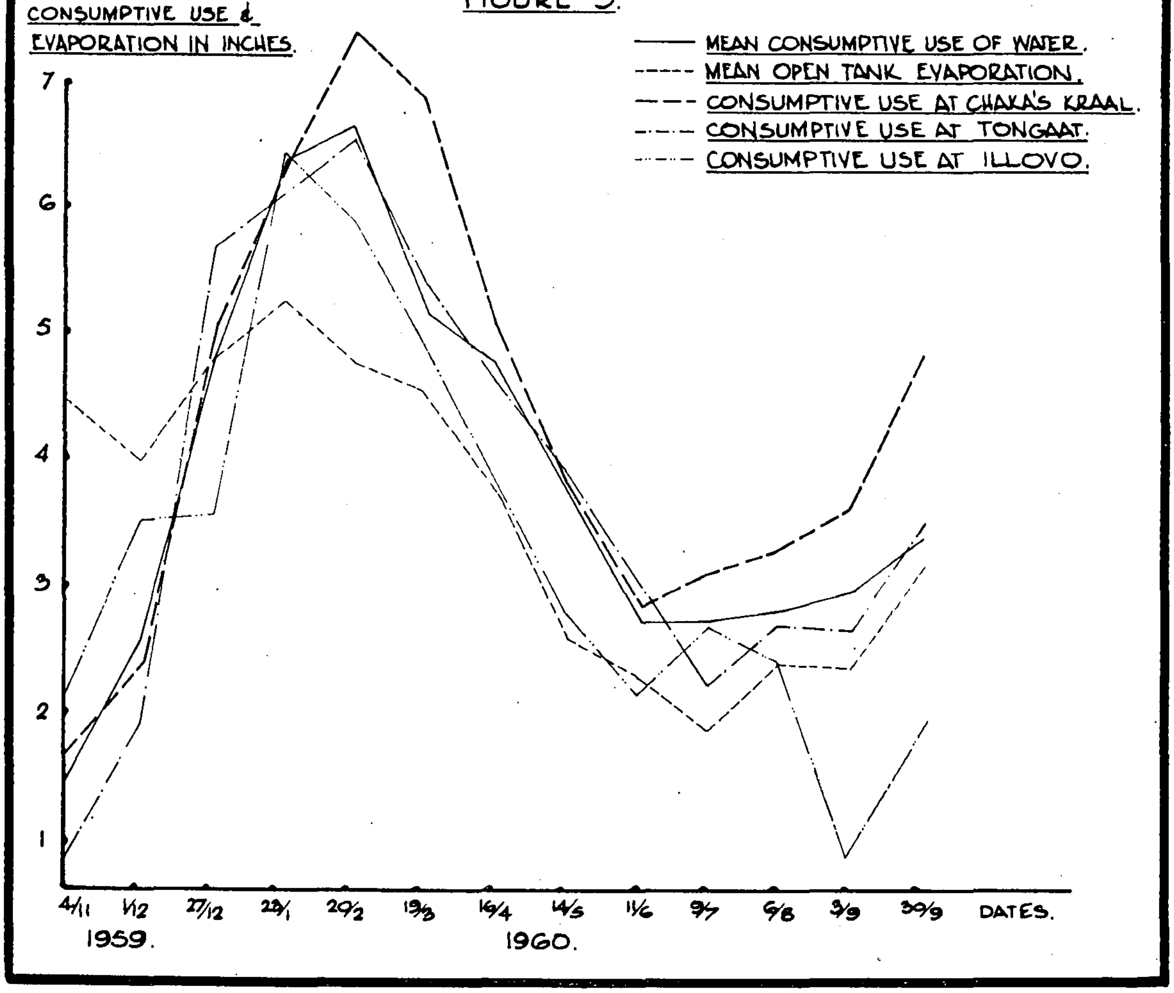
[3]Cowan, I. R. and Innes R. F. 1956, Meteorology, evaporation and water requirements of sugarcane. *Proc. International Soc. Sugar Cane Tech.* 9th Congress.

[4]Campbell R. B. Jen-Hu Chang. Cox Doak C., 1959, Evapotranspiration of sugarcane in Hawaii as measured by in-field lysimeter in relation to climate. *Proc. International Sugar Cane Tech.* 10th Congress.

Table 2

DATE	CHAKA'S KRAAL			TONGAAT			ILLOVO			MEAN		
	Con. Use	Evaporation	F.	Con. Use	Evaporation	F.	Con. Use	Evaporation	F.	Con. Use	Evaporation	F.
Oct. 5—Nov. 4	1.72	4.86	0.35	0.85	3.83	0.22	2 22	4.57	0.49	1.59	4.42	0.35
Nov. 5—Dec. 1	2.43	3.84	0.63	1.97	4.29	0.46	3.56	3.88	0.92	2.65	4 00	0.67
Dec. 2—Dec. 27	5.04	4.68	1.08	5.70	4.61	1.24	3.59	5.00	6.72	4.77	4.76	1.01
Dec. 28—Jan. 23	6.28	4.91	1.28	6.14	5.65	1.09	6.48	5.33	1.22	6.30	5.29	1.19
Jan. 24—Feb. 20	7.41	4.95	1.50	6.54	5.26	1.26	5.91	4.18	1.41	6.62	4.79	1.39
Feb. 21—Mar. 19	6 85	4.47	1.53	5.41	4.77	1.13	3.11	4.41	0.71	5.12	4.55	1.12
Mar. 20—April 16	5.12	3.92	1.31	4.34	3.10	1.40	4.97	3.54	1.40	4.81	3.52	1.37
April 17—May 14	3.84	2.55	1.51	4.34	3.10	1 40	2.81	2.16	1.30	3.66	2.60	1.40
May 15—June 11	2.88	2.39	1.21	3.08	2.19	1.41	2 20	2.52	0.87	2.72	2.36	1.16
June 12—July 9	3.15	2.02	1.56	2 28	1.81	1.26	2 76	1.95	1.42	2.73	1.92	1.41
July 10—Aug. 6	3.33	2.58	1.29	2.72	2.68	1 29	2.48	2.68	0.93	2.84	2.45	1.16
Aug. 7—Sept. 3	3.61	2.33	1.55	2.69	2.26	1 19	2 48	2 68	0.93	2 93	2.42	1.22
Sept. 4—Sept. 30	4 84	3.13	1.55	3.47	3.37	1 03	1.89	2.93	0.65	3.40	3.14	1.08

FIGURE 3.



The President (in the Chair) said this was an excellent example of co-operative effort and he hoped that there would be more papers like this in the future. Irrigation usage had increased rapidly in South Africa and some areas now depended entirely on irrigation.

The consumptive use of water at its maximum economical level was of practical import and he had no doubt that this point would be explored later. He asked the authors why there was such a big difference between the Innes figure of about 0.6 and that obtained by themselves (and also in Hawaii), of about 1.2.

Mr. G. D. Thompson related that he had been to Jamaica and the plant used by Innes and Cowan did not conform to the requirements of the Department of Climatology in Pretoria, which necessitated this type of work being done under conditions simulating those well within a field of growing cane.

Dr. G. W. Shuker asked if Innes kept the soil at field capacity, and Mr. Thompson replied in the affirmative.

Dr. T. G. Cleasby in answer to a query by Mr. Webster, said that the sides of the tank were at least 4 inches above ground level so that no run-off water could flow into them. He said that the drum system used by Innes in Jamaica severely limited the root area, although Innes claimed that the cane grew normally, implying that this was not a factor. Evaporation from a British tank was less than that from a Hawaiian tank.

Mr. C. H. O. Pearson said that using the American tank the figure obtained here was similar to the Hawaiian figure.

Dr. A. McMartin was pleased that this work had been done here, since the use of the figure of 0.85 had caused some projects using irrigation to find themselves in a somewhat difficult position. He himself had taken the Hawaiian figure as being more realistic than 0.85. At a figure of 1.39 the amount of water required to be pumped would be considerable however. He had heard moreover doubts expressed as to whether the evaporation from a free water surface was a satisfactory guide, for it was affected largely by wind, whereas transpiration was affected mostly by solar radiation. The Gunn Bellani instrument, he was pleased to note was being tried, as it was stated to be the most useful instrument for assessing water requirement.

An important point was the variety effect; for example, Co.421 transpired less water than did the wild canes.

Mr. R. R. Maud said it was interesting to note that in Uganda a figure of 1.4 had been obtained on cotton, which was close to that determined locally on cane. He asked if acreage of leaf was compared with acreage of soil.

Mr. T. A. F. Sexton made reference to the leachate obtained from the tanks and asked if there were any figures obtained on the plant foods which were leached out. In Hawaii, he believed, all the fertiliser was applied in one application, but in this case 4 applications were made.

No mention of sucrose content was made in Table I but he felt this might be of economic importance.

Mr. C. H. O. Pearson said that the sucrose content was not considered because the maximum amount of water was applied right up to the time of harvesting. Sucrose per cent cane was determined, as could be seen from the table, to arrive at tons of sucrose per acre.

The President said that the leachate was tested for nitrogen, potash and calcium recently, although not over the whole period, and the nitrogen in the leachate increased considerably after nitrogen application, but apart from this, the leachate was poor in all other plant foods.

Dr. G. W. Shuker asked if the authors could recommend a figure for maximum potential consumption which could be used for irrigation purposes.

Mr. G. D. Thompson replied that there was no indication from an experiment of this nature of the relationship between potential and field evap-transpiration. At Illovo they used a figure as high as 1.26 in the summer, reducing this to 0.6 to 0.7 in the winter months to control irrigation.

Mr. K. W. L'Ange said he could not see any farmer going to the expense of installing lysimeters and meteorological instruments and he asked if there were more simple means of knowing if the soil required irrigation. He had been told of a means such as taking the soil from a depth of six inches below the surface and rolling into a ball, and if this ball remained as such, no irrigation was required.

Mr. G. D. Thompson replied that any such test in the case of, say 600 acres, all under cane, would lead one to assume that the whole area required irrigation at one time. A system based on meteorological data gave the opportunity of pre-planning irrigation so that one could know when to start irrigating so that the last part of the field or fields would be irrigated before wilting point was reached.

Dr. T. G. Cleasby said that the system devised by Mr. Thompson at Illovo and published in his paper last year, was, more or less, the one adopted at Tongaat. It was a simple system which could be used by the farmer and worked extremely well on the North and South coasts of Natal. He did not know if it would work so well in the hotter regions further North. At Tongaat they took the evaporation from an open tank and assumed that in the soil there was an amount of moisture available equivalent to three inches. Irrigation application was started at one inch per application, and this was applied when the soil deficiency as measured by evaporation was one inch below field capacity. It was endeavoured to complete an irrigation cycle before the soil moisture deficiency reached three inches.