A REVIEW ON SUGARCANE IRRIGATION

Elpidio R. Octura

Sugarcane requires large amounts of water for successful production. Without irrigation, a minimum effective depth of rainfall[1] of 1.5 m. (annual), which is equivalent to a total of 2 to 2.5 m., during the growing period is required to attain good yields. It surface irrigation method will be used at least 2.75 m to 3.0 m. must be provided for a growing period of 12-14 months for the first production (planting) and 2.25 m. - 2.5 m for a growing period of 10-12 months (ratoon - 2nd & 3rd production).

Looking at the composition of the crop, a standing mature sugarcane has 70% free water, 30% dry matter including sucrose and other sugar, cellulose, small amounts of mineral salts and silica, and nitrogenous compounds in small amounts and other substances (A.C. Barnes, 1974). A survey conducted by Van Dilliivyn (1952) of the several published data on sugarcane concluded that 1 part of dry matter is equivalent to 250 parts of water by weight. And the plant retains only 1/500 of the total amount of water consumed. The rest of the water is passed out by transpiration and to small extent by exudation in liquid form.

Thompson (1960) in his experiment for a period of two years concluded that one part of dry matter requires 447 parts of water. To produce one ton of sucrose at least 800 tons water is needed.

Although the plant needs a large amount of water for its growth, it cannot tolerate very wet conditions for a longer period. The crop thrives well on relatively high temperature. When the temperature approaches 21^{o}c the rate of growth decreases;

16°C, the growth of tne crop will be retarded. It needs warmth and air underground and overground. Since water-logged land is cold and airless, cane seldom survives in it. Furthermore, prolonged wetness of the soil in the root zone favours the attack of root-destroying organisms and the incidence of certain diseases of the aerial parts of the plant.

Sugarcane crop also needs good water quality. Water containing not more than 600 parts of sodium chloride (NaC l) per million is safe; 600 to 1000 ppm risky, and over 1000 ppm dangerous to the crop. H_2O containing sodium carbonate ($NaCO_3$) is practically dangerous, especially in loam and clay soils.

Water Intake

Water is taken in by the plants principally through the roots, but sugarcame has the unusual ability to absorb water through the leaves and to a minor extent through the surface of the stalk. This unusual characteristic of this plant plays an important role when the cane is growing in humid regions, when dew is deposited on the leaves and when overhead irrigation is applied. Water can be exuded by the roots as well as by the leaves (which appears as small droplets on the surface). This happens especially during rainfall. Water is passed out as vapor through the leaves and to a very small amount through the stem by the process of transpiration.

Methods of Irrigation

The common methods of irrigation are furrow, overhead (sprinkler system) and sub-surface. Furrow is the most common, but the overhead system is getting popular nowadays, especially in areas where water is very expensive and labor costs are high. It is very important to use the available water to the best advantage and to exercise close control over its application.

E.A.C. Huie (1971) in his paper on the irrigation of sugarcane in Jamaican conditions stated that properly managed surface and overhead irrigation have equal abilities to grow cane. Under certain conditions, overhead irrigation is not only better in terms of water economy, conservation and management but also the only wise method of irrigation to practice. However, in the same research department after the experiment conducted on the comparison of overhead and furrow system, he concluded that under the right conditions and with re-blocking and land levelling, surface irrigation can be as economical in terms of water use as overhead irrigation and can be more efficient than overhead irrigation under high and advective windy conditions. He also concluded that where conditions allow the proper use of either surface or overhead irrigation, surface would normally be recommended because it is less expensive to operate.

Controls of Irrigation

The term "control" used here refers to the determination of the times when irrigation should be applied and the quantity of water required at those times. Effective control requires known data relating moisture status of the upper layer of the soil in which the main root zone of the cane is situated, variation under the condition of cane growth, evaporation from the soil surface, evaporation and the incidence of effective rainfall.

The use of gypsum blocks for irrigation internal control has been successfully used in most Hawaiian Sugar Industry for the past 10 years. This simple moisture measuring device can easily be constructed. Blocks of gypsum, glass fibre, or nylon are formed round a pair of electrodes connected to electrical leads. The blocks are moistened and carefully installed in the ground, with at least one face in contact with undisturbed soil.

The moisture suction in the blocks then gradually comes into equilibrium with that in the surrounding soil. As the moisture content of the block changes so does the electrical resistance between the electrodes and this can be measured by a resistance meter. (See Fig. 1, 2, 3 for the construction and calibration of gypsum/porous block.)

In practice, a number of standard blocks are buried at selected parts of the fields with insulated wires leading from the terminals to a convenient height above the soil surface. Readings are to be taken at a given intervals. Each block should be calibrated in the field and provided its own curve, i.e., soil suction vs. log. of block resistances.

Using a resistance/soil moisture calibration (derived from local tests), the daily value of resistance indicates the rate of moisture depletion from the soil.

The useful range of these blocks is from .1 to 15 bars and therefore in some circumstances they are more useful than tensiometers. However, disadvantages are that the resistance in the block is affected by the salt content of the soil, the calibration may drift in time, and the blocks may be soluble in the soil moisture.

F.E. Robinson, in his experiment on sugarcane stalk elongation, soil moisture tension and irrigation interval control used gypsum blocks in the control of water application. Six treatments were carried out using 6 ranges of soil moisture tension as to determine when to apply irrigation which corresponds to different intervals. It was found out that the rate of elongation of the stalks decline as soil moisture tension approached 2 bars, as recorded from the blocks at 12 inches depth. Accordingly, as long as the moisture suction did not exceed 2 bars in any cycle after irrigation, the plant increased the rate of elongation compensating for the decrease in rate before irrigation and no real decrease in the average growth was observed. But when two (2) bars moisture stress was exceeded at 12 inches depth, a real reduction in the average growth rate occured.

(1 bar = 1 atm = 14 psi Pressurer suction)

The second common methods in the control of irrigation is by the use of evaporation pan. i.e., U.S. Weather Bureau Class A pan. This gives a good approximation of the potential evapotranspiration of sugar cane. In most sugar cane industries, Kc factor[2] taken were from 0.4 for the newly planted cane to about 1.0 for the matured crop with full canopy after 5 months.

One of the typical examples of this method of control is the experiment conducted by Jen-Hu Chang et. al. (1974) on the relationship between water and sugar cane yield in Waipio Field Hawaii. Six plots were treated with different consumptive use rates. The consumptive use rates of these plots were assumed to be 1.30, 1.15, 1.00, 0.85, 0.70 and 0.55 times the pan evaporation respectively or expressing it in equation (Econsumptive use = F Pan) evaporation Where : F is the ratio used above. As soon as the estimated total loss would be equal to *available soil moisture*[3] irrigation is applied immediately. The result was that maximum cane yield is obtained by applying water at the same rate as potential evapotranspiration[4] would deplete it when (F - 1.0). See fig. 4. The yield at 1:1 ratio represents the potential of the area when water is not limiting.

Irrigation Intervals

The normal irrigation interval is 10-21 days depending on the weather and soil conditions and crop requirements, or as determined from the method of control employed. A research conducted by Durandt and N.S. Calder (1974) from the South Association Experimental Station on the yield from the six fields on Tambankulu estates suggested that frequent and short irrigation cycles with the application rate of 27 mm. for 6 hours at 3-day cycle marked an appreciable increase of yield compared to longer day irrigation cycle (7 days) and heavy water application. The greatest response are obtained from a shallow low water holding capacity of soils.

It was also found out that in the uniformity in growth for all fields, complete absence of lodging, which was the characteristic of the field prior to the introduction of the 3-day cycle, prolific ramification of roots throughout the profile and very erect and healthy stands of cane were obtained. From these positive results further advantages were drawn, like increase in output per cane cutter (because the sane was erect, resulting in less wastage of cane), 7.5 percent saving in labor required for irrigation (by adopting the semi-solid system), a 60 percent saving on in-field subsurface drainage, and maintenance of ideal conditions for the application of herbicides, etc.

The principle is that constant high moisture ensures no "stop-growth"in crop growth because the crop is not subjected to moisture stress.

Crop Responses to Irrigation

J.M. Gosnell (1970) of the Rhodesia Sugar Association Experiment Station, Cheridzi, Rhodesia, conducted an experiment on the optimum level of water application to sugarcane to investigate the effects of various levels of irrigation application under both burnt and trashed condition.

The treatments were based on evaporation from a class A pan (Modified) with the following treatments (six treatments were conducted but – only 5 are shown here) :

% of Pan evaporation	*Deficit (mm)*
100	50
84	60
68	74
53	96
37	135

At 100% Pan evaporation the crop is irrigated as the moisture deficit reached 50 mm. At 37% pan evaporation, the crop is irrigated immediately as the moisture deficit reached 135 mm.

The computed available moisture in this type of soil (clay, depth 914 mm) is 116 mm. At each irrigation, 50. mm. (2 inches) net quantity of water was applied; the intervals between irrigations being varied between treatments to give the deficits required.

The following crop responses are observed from the J .M. Gosnell Experiment.

1) *Cane yield* responds to the levels of water from 37% of pan to 84% of pan (linearly). From 84% to 100% the additional yield increment was slight. (As the degree of moisture stress decreases the yield increases linearly). Fig. 6-A.

2) In Fig. 6-A, there is a linear increase in yield of sucrose from 37% to 68% Pan;[5] with a curvilinear response up to 84% and no further yield increase with 100% Pan.[6].

3) The highest *sucrose content* was obtained with a moderate severe degree of moisture stress (53 to 68% of Pan), while both wetter and drier treatments resulted in significantly lower sucrose content. (Fig. 6-B).

4) *Efficiency of Water use* may be regarded as the highest yield per unit volume of total water (rainfall + irrigation) from Fig. 6-C, the intermediate levels of 68 or 84% Pan were the most efficient in terms of water use. The efficiency of water use was poorer at the highest irrigation level due to less efficient use of rainfall.

5) *Cane Quality*

i) Maximum sucrose content was obtained at around 68% Pan, this being more marked with burnt than with trashed cane. There was a pronounced drop in sucrose content at the 37% Pan level; however, the brix with this treatment was similar to that of the 68% Pan. If is evident therefore that conversion of sucrose to non-sucrose solids occured with severe moisture stress, which resulted in a marked decline in purity from 88% – 83.5% (see Fig. 6-D).

With higher levels of irrigations, a drop in sucrose content was accompanied by a drop in brix (one detriment of maturity) resulting in a much smaller drop in purity. This drop in sucrose may be due to several factors: 1) dilution by a higher moisture content, ii) more vigorous vegetative growth resulting in lower sucrose accumulation and iii) the effect of lodging which caused considerable decrease in sugar cane variety No. CO. 376 (anon 1969).

6) *Lodging* – A significant increase of lodging between the 84% and 100% Pan Treatment was observed and this may account for the very small increase in cane yield produced by the additional water application, and the reduction of sucrose content with the 100% Pan treatment.

7) There was an increase in flowering with increase in irrigation. (observed only in the 2nd ratoon production).

8) *Stalk height* – increasing levels of irrigation produced a curvilinear response in height growth; the 100% Pan treatment resulting in very slight additional stalk length over 84% Pan treatment.

Conclusion and Recommendation

1. Irrigation is vitally essential in growing the sugarcane crop as clearly shown from the results of the experiments cited in this paper. Sugarcane crop is very sensitive to moisture stress. Yields increase if the crop is not subjected to high moisture stress; thus, frequent light irrigation is desirable especially for shallow and light soil.

2. Decision on what method of irrigation and what control to be adapted usually involves choices from among other known techniques. Hence, pilot projects should be conducted first for the particular soil type and climatic conditions to determine the right irrigation interval that would give maximum yield and maximum benefit.

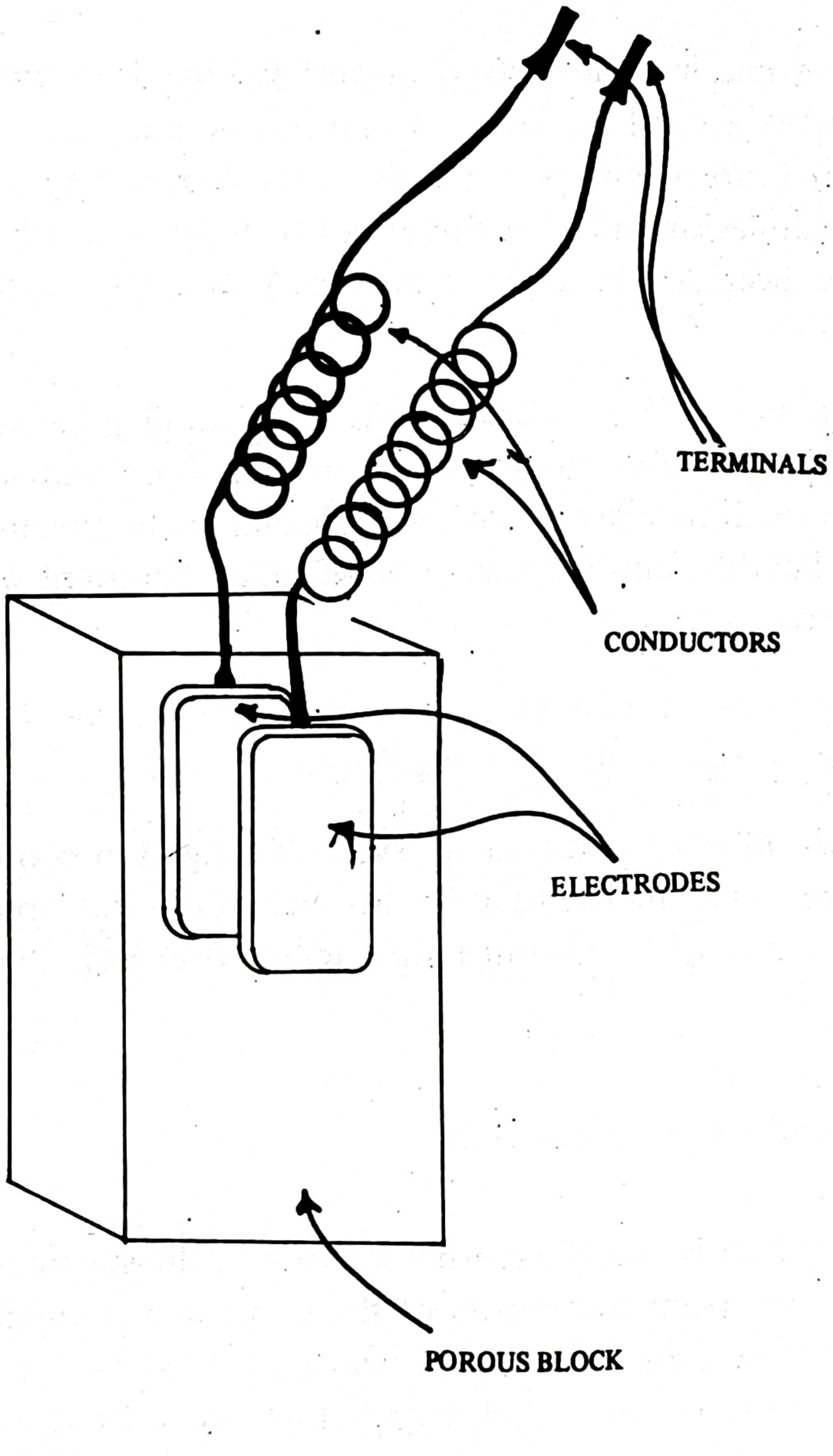


FIG 1.CONSTRUCTION OF POROUS BLOCK

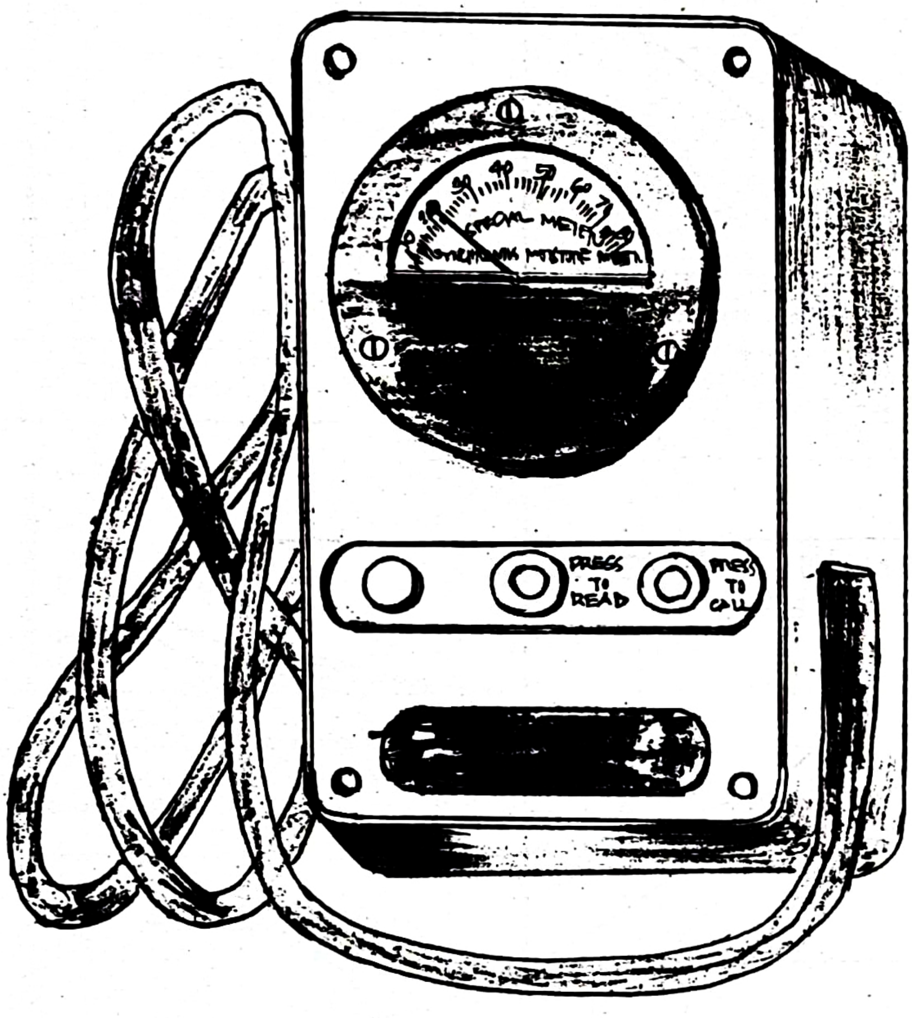


FIG. 2

• PORTABLE METER •

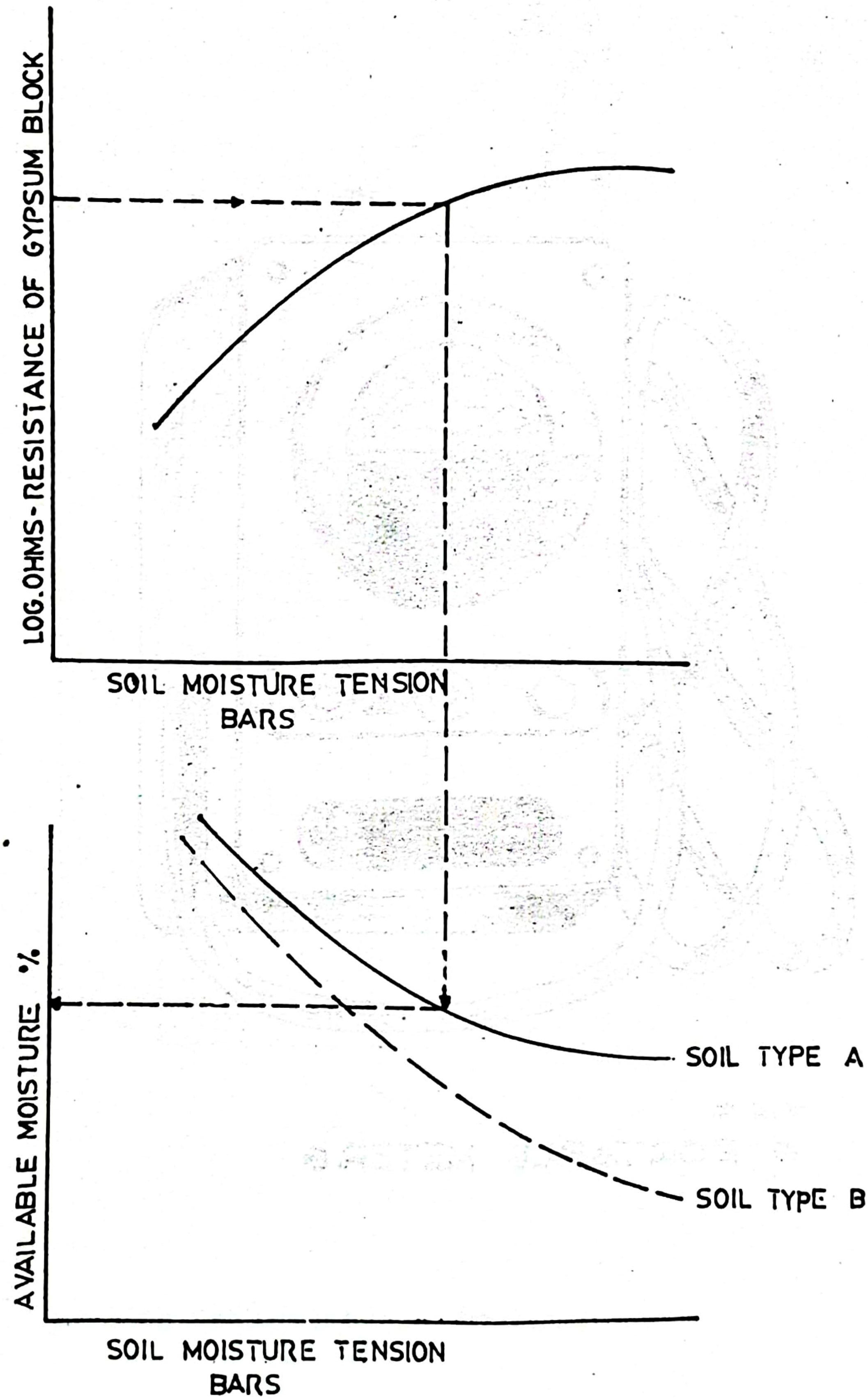
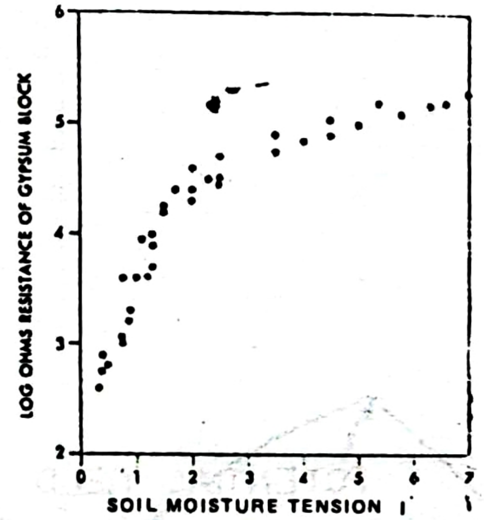


FIG.3. CALIBRATION OF GYPSUM BLOCK



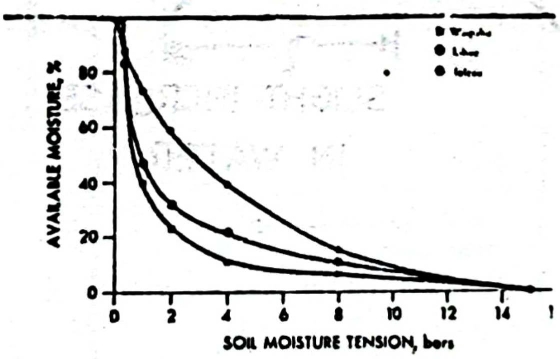


Figure – Tension distribution of available moisture in IoLihue, and Waipahu silty clays.

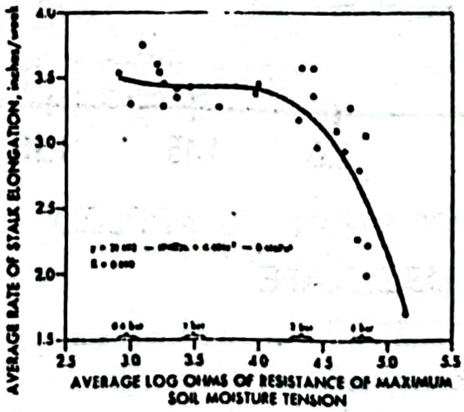


Figure –Stalk elongation from 4/24/61 to 9/19/61 as a function of soil moisture tension well-defined critical point.

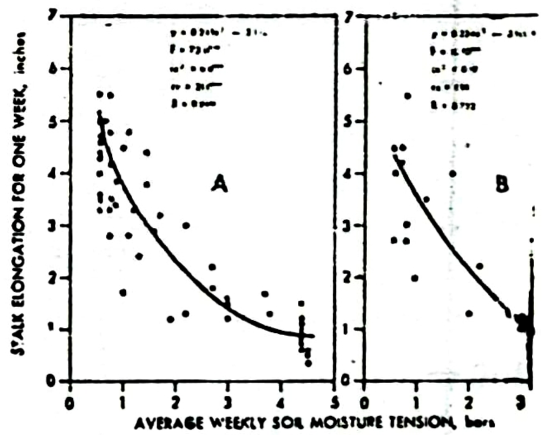


Figure –Stalk elongation as a function of the average with soil moisture tension in Lihue (A) and Ioleo (B) silty *** 1% ** 5% * 10% significance.

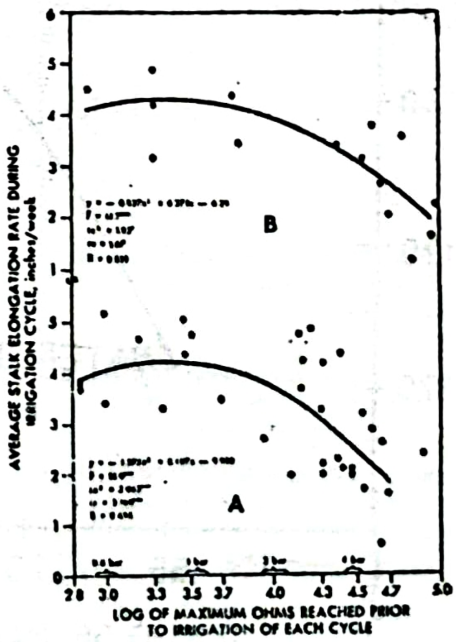


Figure –Average elongation rate of cane during irrigation cycles as a function of the maximum soil moisture tension in Lihue (A) and Ioleau (B) sitly clays. *** 1% ** 5% * 10% significance.

Fig. 4. The result of experiment conducted by F.E. Robinson 1962.

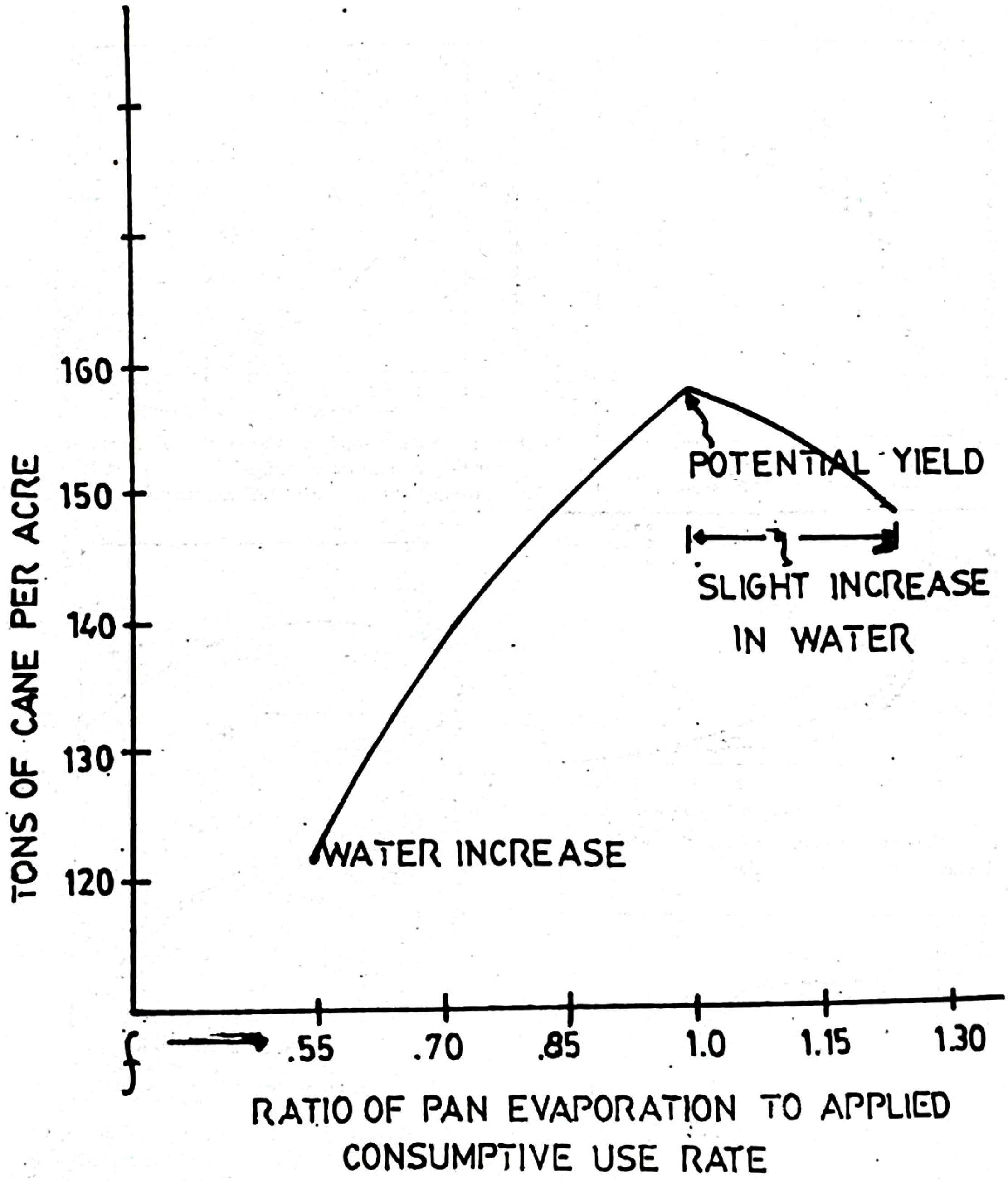


Fig. 5 – The effects on the different consumptive use rates to the yield of cane. Adapted from the proceedings of the South African sugar Technologists Association.

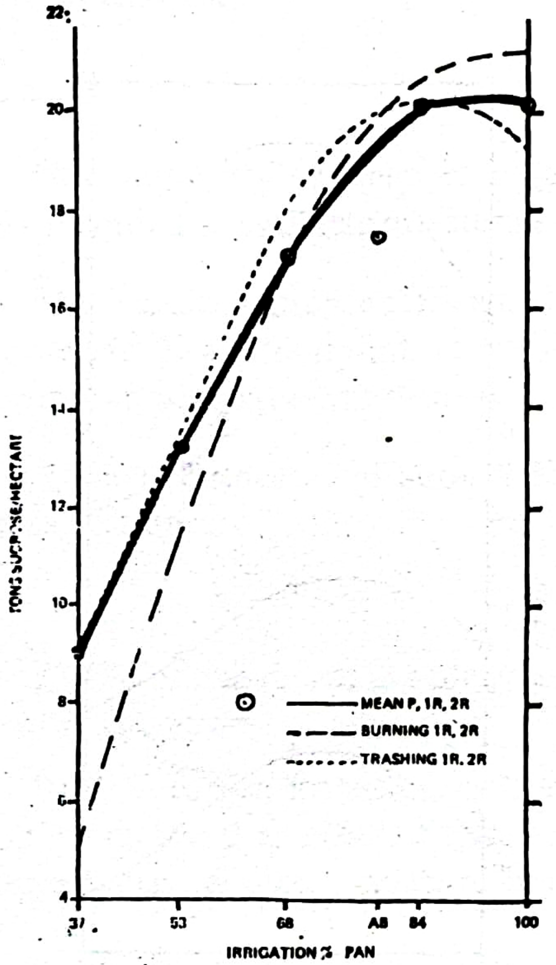


FIG. 6-A Effect of irrigation level and trash management on sucrose yield.

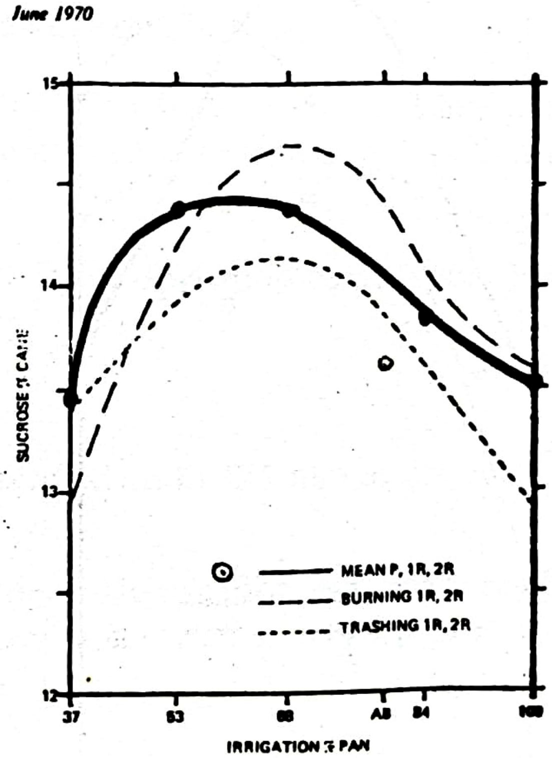


FIG. 6-B Effect of irrigation and trash manaement on sucrose % cane.

FIG. 6 The result of experiment conducted by J.M. Gosnell taken from the proceeding of the south African sugar technologist's association June 1970.

Proceedings of The South African Sugar Technologists Association

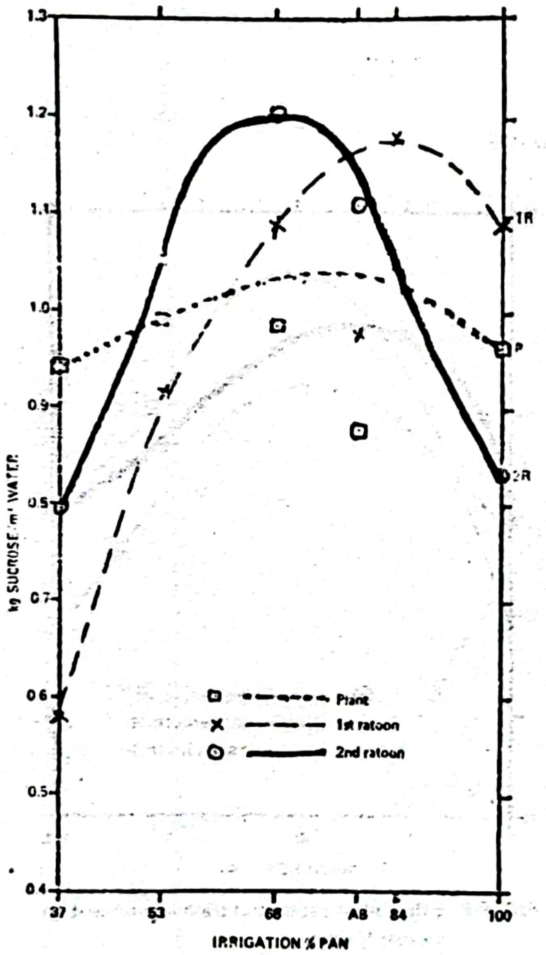


FIG. 6-C Effect of irrigation level on water use efficiency.

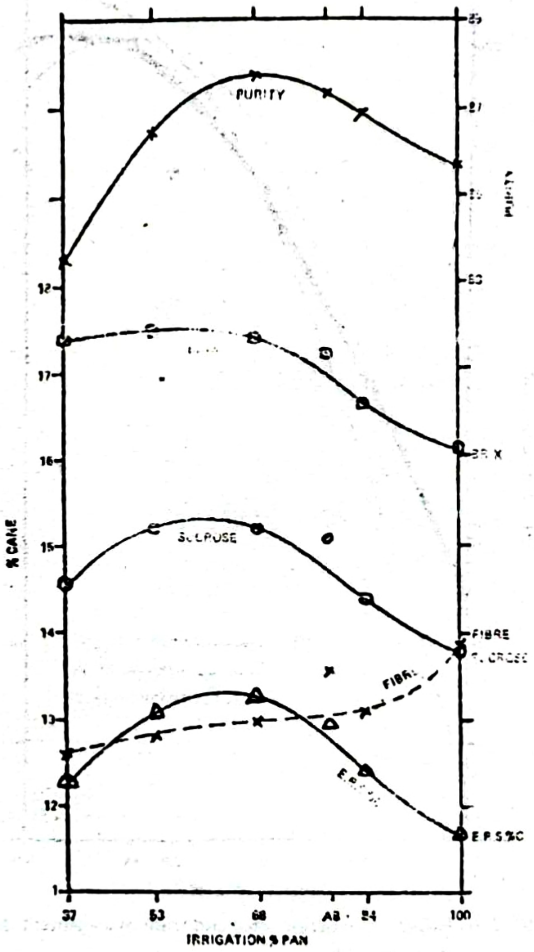


FIG. 6-D Effect of irrigation level on cane quality.

NOTES

[1]The term effective depths of rainfall used here means the depth of rain penetration in the soil to a sufficient depth to be available to the root sy system of the cane.

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[2]Moisture held between F. C. (Say 0.1 bar tension) and 15 bars is classically regarded as available moisture depending on soil type.

[3]Kc factor = Crop coefficient factor. The factor to be multiplied by the potential Evapotranspiration or Pan evaporation to obtain actual Evapotranspiration or consumptive use.

[4]Actual Evapotranspiration = Kc x Pan evaporation or potential Evapotranspiration.

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[5]37% of pan means the plant is subjected up to 135 mm moisture deficit before irrigation.

[6]100% of pan means the crop is irrigated as the moisture deficit reaches to 50 mm. less than 50% of total available soil moisture. (In this expt. the soil type is clay, available moisture 116 mm).

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