T. CHINLOY, T. C. E. WELLS, N. J. CHIN, J. L. RAMSAY


DISCUSSIONS

C. J. Mongelard (Mauritius): The type of tissue from which extraction is made is certainly different in 12-day old and 312-day old shoots; is the picture obtained comparable?
A. J. Vlitos (Trinidad): In each case the dry weight of tissue used for chromatograms was the same.

Mr. Mongelard: Have you tried the specific test for IAA, i.e. the perchloric acid–ferric chloride reagent of Gordon and Weber?
Dr. Vlitos: We have tried many test reagents and are satisfied from the Rf values and colourimetric tests that the material is almost certainly IAA.

POSSIBILITY OF LONG-FURROW IRRIGATION UNDER HEAVY CLAY SOIL CONDITIONS

T. CHINLOY, T. C. E. WELLS, N. J. CHIN and J. L. RAMSAY

The Sugar Manufacturers’ Association (of Jamaica) Ltd.; Bernard Lodge Sugar Co.; The West Indies Sugar Co. Ltd.; Sevens Ltd.; Jamaica

(Presented by Mr. N. J. Chin)

INTRODUCTION

Surface irrigation is practised on about 50% of the cane-growing area of sugar estates in Jamaica at a cost ranging up to £20 per acre per annum for water and its application. It is of the greatest importance that water be efficiently used and at optimum rates of application; and in these considerations, the uniformity of distribution on the surface of the land, the quantity of soil recharge within the root range of sugar cane, and the wastage by runoff or deep penetration, are important.

Formerly, sugar cane culture and methods of reaping and infield transport permitted the use of a system which became general and which is illustrated in Fig. 1. The system consists of a ‘head’ main canal which feeds ‘infield mains’ running at right angles and parallel with the cane rows. ‘Twigs’ or smaller channels, spaced 11 to 22 yards apart, lead water across the cane rows from the ‘infield mains’. The comparatively close spacing of the ‘twigs’ caters for a fair degree of non uniformity of land surface; and on heavy soils the ‘twigs’ and ‘infield mains’ may be sunk to 18” depth to act as runoff drains. However, the extent to which such ‘drains’ bring about any effective draining of the subsoil mass is in doubt. The system can distribute water effectively over fairly uneven land but is very difficult to inspect and supervise, except from the air; the amount of manual ‘working’ of the water is high, i.e. the system is not easily rendered automatic, and the wastage of water by runoff is sometimes high, particularly at night. Aerial inspection shows that during periods of water
shortage the fields tend to look like a series of green combs on a lighter green background, and even where irrigation is good, under obtuse lighting quite distinct variations in height can be detected between that growing near the 'infield mains' and 'twigs' as compared with that inside the rectangle formed by the channels. The system is expensive where clearing of trash from mains and 'infield mains' is concerned, the weeding of water channels and the 'bracing' of sugar cane when it gets to a height sufficient to impede the movement of irrigators along water channels. The notorious variations in cane quality within the same field, and the cane-yield variations and higher standard errors of field experimentation on these irrigated lands all tend to confirm that irrigation distribution in practice leaves much to be desired.

Apart from the failings quoted above, the system has a major shortcoming in the light of the changes which must take place in methods of harvesting. Mechanized loading, and mechanized reaping when it arrives, will be greatly facilitated if irrigation cross-channels ('twigs') could be eliminated, and especially if the deepened 'twigs' which also feature as drains, could be done away with. A system of water distribution relying upon running water down long furrows the length of the field, with one row of cane between each furrow, should cater for mechanized harvesting operations, easy supervision of irrigation, minimum manual attention and hence high output per irrigator.

A series of experiments started in 1954 on heavy-clay soils at three plantations, had suggested that:
(a) when every furrow is irrigated in long lengths (110 yds.), plant-cane yields could be similar to those obtained using 'twigs' spaced 11 yds. apart;
(b) unless fields were uniform in grade and trash blankets, evenly spread ratoon results might be affected adversely when very long (110 yds.) furrows are irrigated;
(c) smaller volumes of water could be distributed per irrigation.

The account which follows deals with the results of a preliminary examination of this system on the heavy-textured, irrigated sugar cane soils of Jamaica and particularly with:
(i) the feasibility of using furrow lengths up to 220 yds. long – the common length of sugar cane fields in Jamaica;
(ii) determining the optimum stream size on the prevailing slopes, taking into account intake rate, rate of advance, and efficiency of water application;
(iii) the effect of long-furrow irrigation on the growth and tonnage of sugar cane.

EXPERIMENTAL LAYOUT

Four 10-acre fields were chosen situated on two soil types – March Pen 20 at Bernard Lodge and Mc. Vicar 11 at Innswood on Sydenham Clay^4, and Lime Piece 2 at Monymusk and Parnassus 55 at Sevens on Agualta Clay^4.

The fields had slopes of 0.3–0.5% and were reasonably uniformly graded. At Bernard Lodge, Sevens, and Innswood, the fields were prepared in the normal way and required no grading, but at Monymusk, two passes with a Land-Plane were required to obtain the desired evenness of grade. The importance of using fields with an even slope cannot be over-emphasized, and for the efficient use of 'long-line irrigation', it will probably be necessary to replan and regrade many existing fields.

The fields were furrowed at a spacing of 5′6″ between ridges and planted, the furrows running in the direction of the slope. A main supply ditch was cut mechanically along the top of each field, and at Bernard Lodge, Sevens, and Innswood, an equalizing ditch was cut parallel to the main supply ditch and connected to it by means of turn-out boxes. The banks of the main supply ditch were made and shaped by hand so that water in the ditch was raised about 15″ above the furrow bottom. In the fields with an equalizing ditch, water flowed from the main supply ditch through a connecting turn-out box, and over a one ft. rectangular weir into the equalizing ditch and then into each furrow by means of spiles projecting from the ditch into the furrow. The spiles, made of black polythene, galvanized iron piping, or bamboo, were placed about 2″ above the bottom of the main supply ditch, allowing a head of about 0″ to be maintained above them, if required.

The experimental layout consisted of 3 furrow stream rates replicated twice on each of the four fields. The length of furrows varied from 580′ at Bernard Lodge to over 600′ on the other fields, each plot having 15 rows at Bernard Lodge, 20 rows at Sevens and Innswood, and 12, 14 and 15 rows at Monymusk.

To obtain different furrow stream rates, spiles of different diameters were used at Bernard Lodge and at Sevens and 2″, 14″ and 13/″ spiles were calibrated to give stream flow rates of 30 gal./min, 20 gal./min and 15 gal./min. Spiles of a constant size were used in all the plots at Innswood, the different furrow streams being obtained by varying the head of water above the spiles. Stream flow rates of 20 gal./min, 15 gal./min, and 10 gal./min were considered. At Monymusk, although the basic layout was the same, the main supply ditch had no equalizing ditch. When water passed into a new plot the spiles in the plots already irrigated were blocked with grass.

Different methods of getting water from the main supply ditch to the furrows were tried at Monymusk. In two plots, 2″ metal pipes were used, in two other plots, different-diameter bamboo spiles, and in one plot 2″ polythene siphon tubes, whilst in the remaining plot a 9″ x 9″ turn-out box which fed 12 furrows was used. By using a constant water supply and varying the number of furrows irrigated at any period, furrow stream sizes of approx. 27, 29 and 33 gal./min were obtained.
The stream flow rates envisaged for Bernard Lodge, Innswood and Monymusk were never achieved in practice, but the actual figures were not greatly different from those proposed, e.g. at Bernard Lodge the actual stream flow rates were 26.7, 23.0 and 15.0 gal./min compared with the target of 30, 20 and 15 gal./min.

For experimental purposes, the metal spiles pushed through the bank were found to give best results, but suffered from the defect that it has to be stoppered when water passed to the next plot. For commercial irrigation the 2" polythene siphon is probably the best since one siphon can be used to irrigate several furrows in turn, the only disadvantage being that if the water level drops in the head main due to some defect in the water supply, the siphon stops and has to be restarted manually. If this happens at night or when the irrigators are absent from the field, irrigation of a field is stopped and the lines have to be restarted.

At Sevens, Innswood and Bernard Lodge, rectangular weirs were used at the bottom of each plot to measure run-off. Although valuable information was obtained from such measurements the presence of the weir in the collecting ditch caused the water to 'back up' the furrow and made stream-flow measurements difficult over the last 50 feet.

At Monymusk, the furrow ends were blocked and water allowed to 'back up' when it reached the bottom of the run. It would seem desirable to do this in commercial practice, otherwise too much water would be lost in run-off. The practice is objectionable unless the blocks are cleared before the season of heavy rains.

**STRUCTURES USED FOR CONTROL AND MEASURING OF WATER**

1. **Turn-out boxes**
   
   These structures were made from 1" pitch-pine wood. The amount of water put into a plot was controlled by an adjustable sliding gate at one end of the turn-out box. By raising or lowering the gate, more or less water was supplied.

2. **12" Rectangular weir**
   
   These structures were made from 1/8" sheet metal, strengthened at the edges with angle iron. A black-and-white scale graduated in tenths of a foot was riveted on one side and was used to measure the head of water passing over the notch. To obtain accurate measurements when using a rectangular weir, the following points should be noted. The weir must be placed at right angles to the direction of water flow with the face of the weir perpendicular, and the weir crest straight and level. The height of the crest of the weir above the bottom of the channel, upstream from the weir, should be at least twice, and preferably three times the head of water flowing over the crest. The length of the weir crest should be such that the head to be measured exceeds two inches and the maximum head is not greater than one-third the length of the weir crest. Finally, the crest of the weir should be so constructed that air can circulate freely beneath the overflowing water.

3. **Parshall flume**
   
   A concrete Parshall flume was used at Monymusk for measuring the amount of water going on to each plot. This structure has several advantages over the rectangular weir: it is self-cleaning, requires only a small amount of head loss in the stream
and allows accurate measurements even when submerged. It costs, however, considerably more to construct than the rectangular weir.

It consists of three parts (i) the upstream section, the floor of which is level and the walls converge toward the throat section (ii) the throat with parallel walls and a sloping floor and (iii) the downstream section with walls diverging towards the outlet and the floor inclined upward. The size of the flume is determined by the width of the throat of the flume. At Monymusk, a 6" throat was used. Under conditions of free-flow the head is measured either on a scale fixed on the wall near the mouth of the upstream section, or in a stilling well in a similar position.

(4) Siphons and spiles

As described earlier, spiles and siphons of various sizes and materials were used to deliver water from the supply ditch to the furrows. If the head of water above the spile or siphon is measured as shown in Fig. 2, the rate of discharge can be determined directly from hydraulic tables. Measuring the discharge from a few random spiles in each plot serves as a useful check that the spiles are set level in each plot and are discharging equal amounts of water.

**WATER MEASUREMENTS**

Having prepared the fields for 'long-line' irrigation the system of irrigation was evaluated by determining for each field

(a) furrow stream sizes;
(b) the intake rate of the soil;
(c) the time required for the water to run the length of the furrows for different stream sizes;
(d) moisture distribution at various intervals along the furrow.

Different-size streams were run into several furrows and the rates at which the stream fronts advanced were recorded. The stream flows were measured at one or
along the furrows. In each plot, a furrow was selected and measurements carried out at 100 ft.-stations along it. At Monymusk, levels were taken on each station to determine any variation in the average slope of the land. Out-flowing measuring points were placed in the test furrows. This was done with either a small Parshall flume or simply by damming across the furrow, and inserting a spile so that the discharge was measured volumetrically with a gallon tin and a stop watch.

The times when the water entered the test furrows were recorded: when it reached the stations, and when it finally reached the end of the furrows. The streams were checked periodically at the head of the furrows, as well as at the out-flowing measuring stations. The flow passing the out-flowing points increased from zero to a constant value. From recorded results, the instantaneous intake rates were determined. The field intake rate is defined as the rate at which water is absorbed, and is usually expressed in acre - inches per acre per hour. The physical characteristics of a soil, as well as the condition of its soil surface, determine the value of the intake rate.

In these experiments, the furrow stream sizes were measured in U.S. gallons per minute and it was convenient to express the furrow intake rate as gall./min/100' of furrow. By dividing the values of the furrow intake rates by the furrow spacing in feet, the approximate field intake rate in inches per hour was determined.

Table I illustrates the data recorded for the 'rate of advance' for an average

<table>
<thead>
<tr>
<th>Furrow no.</th>
<th>Elapsed time at stations</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>200'</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
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<tr>
<td>2</td>
<td>15</td>
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<tr>
<td>3</td>
<td>18</td>
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<tr>
<td>4</td>
<td>15</td>
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<td>5</td>
<td>16</td>
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<td>6</td>
<td>17</td>
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<td>7</td>
<td>18</td>
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<td>8</td>
<td>13</td>
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<td>13</td>
<td>14</td>
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<tr>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Total time</td>
<td>200</td>
</tr>
</tbody>
</table>

Average time from start of irrigation: 13.3  32  63.8  103  163.6  293.7
Average time taken to successive 100': 13.3  18.7  31.8  39.2  60.6  40.1
furrow stream size 22.3 gal./min. It will be observed that the average time taken by the water to travel the 193 yds. is about 34 hours for all furrows being operated at the same time, the slowest being about 44 hours and the fastest 22 hours. The speed of travel lessened, the further the distance away from the head main, water reaching the first 100' in less than 1 hour and taking over an hour to travel the last 100'.

Fig. 3 shows the rate of advance curves for three furrow stream sizes, viz., 15.7, 22.3 and 27.6 gal./min. As is to be expected, the rate of advance down the furrows was fastest for the biggest stream size and slowest for the smallest. The rate of advance is approximately proportional to stream size.

A typical data sheet for the measurement of furrow intake rates is given in Table II and Figs. 4 and 5 show the intake rate obtained at Monymusk and Bernard Lodge.

![Graph showing rate of advance curves](image_url)

**Fig. 3. Rate-of-advance curves at Bernard Lodge.**

**TABLE II**

TYPICAL MEASUREMENT OF FURROW INTAKE RATE

*Date: 5/9/60*

*Average head flow: 26.7 U.S. gal./min*

*Field: March Pen 20A (Plot 1 – Furrow no. 7)*

<table>
<thead>
<tr>
<th>Station - 100'</th>
<th>9.01</th>
<th>9.02</th>
<th>9.03</th>
<th>9.05</th>
<th>9.10</th>
<th>9.15</th>
<th>9.25</th>
<th>9.55</th>
<th>10.25</th>
<th>11.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed time (min)</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>14</td>
<td>24</td>
<td>54</td>
<td>84</td>
<td>144</td>
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<tr>
<td>Time in sec for 1 gal.</td>
<td>53.6</td>
<td>49.7</td>
<td>45.7</td>
<td>7.8</td>
<td>5.10</td>
<td>4.7</td>
<td>4.60</td>
<td>4.10</td>
<td>4.20</td>
<td>4.10</td>
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<tr>
<td>Outflow (gal./min)</td>
<td>1.12</td>
<td>1.20</td>
<td>3.8</td>
<td>7.7</td>
<td>11.76</td>
<td>12.78</td>
<td>13.03</td>
<td>14.63</td>
<td>14.25</td>
<td>14.63</td>
</tr>
<tr>
<td>Loss in furrow</td>
<td>25.6</td>
<td>25.5</td>
<td>22.9</td>
<td>19.0</td>
<td>14.9</td>
<td>13.9</td>
<td>13.7</td>
<td>12.1</td>
<td>12.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Intake/100'</td>
<td>4.65</td>
<td>4.65</td>
<td>4.16</td>
<td>3.46</td>
<td>2.71</td>
<td>2.53</td>
<td>2.49</td>
<td>2.20</td>
<td>2.27</td>
<td>2.20</td>
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<tr>
<td>Intake rate (in./h)</td>
<td>-</td>
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<td>-</td>
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</table>
At both sites, the intake rate was high for a short time after the water reached a fixed point, but decreased rapidly thereafter and remained fairly constant for the duration of irrigation. The intake rate varied directly as the stream size, and was higher for the Agualta Clay at Monymusk than for the Sydenham Clay at Bernard Lodge.
(1) Growth measurements

Growth measurements were taken at Monymusk and Bernard Lodge at two growth stations, one at the top of the field, approx. 1 chain from the head of the ditch, and the other approx. 1 chain from the drain at the bottom of the field. In each growth station, 20 canes from 20 different stools were measured and the mean height recorded. At Monymusk, the measurements were carried out at fortnightly intervals, whereas at Bernard Lodge they were carried out at intervals of two days to a fortnight. When the data are plotted graphically (Figs. 6 and 7), the similarity of growth
at the top of the field and at the bottom, is very striking. The similarity continued throughout the duration of the trial, and 7–8 irrigations were applied.

It would have been interesting to have recorded the rate of growth midway down the furrows and a growth station should be located here in future.

(2) Sheath moisture

Sheath-moisture determinations were carried out at Monymusk only, and are graphically displayed in Fig. 8. The results show that the moisture level was slightly higher in the station at the top of the field, compared to the bottom. Growth was greatest when the moisture exceeded 80%, but this coincided with the grand period of growth. As was to be expected the sheath moisture decreased as the cane grew older.

(3) Soil moisture

The electrical resistance of gypsum blocks was used to measure soil moisture at Bernard Lodge. The blocks were placed at depths of 6", 12" and 24" and their resistance read at regular intervals.

Fig. 8 shows that after each irrigation or after heavy rain the moisture returned to a constant value. As was to be expected the drop in level of moisture first occurred at 6" then 12" and finally at 24".

YIELD

The four fields were harvested in 1961. At Sevens the plots were divided into ten sub-plots each sub-plot being 22 yards in length. At Monymusk the canes in the first half chain from the intake canal in each plot were treated as discards, and the remainder of each plot was divided into ten sub-plots of equal furrow length. At Bernard Lodge the plots were divided into six sub-plots; the first five plots were 100 ft. in length and the sixth, situated at the bottom of the field was 80 ft. in length. One plot only was reaped at Innswood. This plot was divided into nine 22-yard-long sub-plots, the first 16 yards being treated as discards. In all the experiments the canes
in each sub-plot were weighed separately so as to give a measure of any variation in yield at different distances down the length of the cane furrows.

Table III shows that at Bernard Lodge and Innswood there was a decline in yield toward the middle of the furrow followed by a recovery at the end. At Monymusk the pattern was repeated but the decline was not as sharp as at Bernard Lodge and Innswood, nor was the recovery as good. The yield at Sevens was very uniform and there was no decline toward the middle. On average, cane yields tended to decrease from the head main to the 6th or 7th chain down the furrows followed by an upward movement in yield from that point to the end of the furrow.

**TABLE III**

<table>
<thead>
<tr>
<th>Cane Yield Relative to Yield of Sub-Plot Nearest Head Main*</th>
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<tbody>
<tr>
<td>Bernard Lodge</td>
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<td>---</td>
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<tr>
<td>1 chain</td>
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* Yield of sub-plot nearest head main = 100.

and there was no decline toward the middle. On average, cane yields tended to decrease from the head main to the 6th or 7th chain down the furrows followed by an upward movement in yield from that point to the end of the furrow.

**SUMMARY AND DISCUSSION**

1. Infield water distribution is of prime importance in surface irrigation, and the standard system of using 'twigs' separated by 11 yds. or 22 yds. is very difficult to supervise, particularly when the cane canopy is complete. Irrigators find the operation tedious when cane is overgrown, and there is a tendency to leave areas in the middle of fields either unwatered or unevenly irrigated. The system often leads to flooding and inefficient water use, and the cleaning of twigs and mains is becoming increasingly expensive. A long-furrow system offers a remedy for these drawbacks and in addition facilitates the use of mechanical equipment. There are however precautions to be observed in its introduction. A reasonably uniform flow of water is necessary at all times to ensure the continuous operation of the spiles or siphon pipes which feed the furrows. Stoppage for any reason means the restarting of furrows which are already partly wet. The grade down the furrows must be fairly regular to allow time for optimum and uniform wetting along the line, otherwise localized overwatering or inadequate wetting will result.

2. The rate of advance of water varies as the flow, and less water is used in furrows receiving the smaller stream sizes. From the data on rates of flow and duration of irrigation it is estimated that about 34" was applied to lines being wet with the smallest stream flow rates, and 47" with the highest stream flow rates. This is appreciably less than the 6" usually applied with the 'twig' system.

3. Moisture measurements derived from gypsum-block readings indicate that the lower ends of the furrows receive as much water as the ends nearest the head main, down to 24". Growth rates and cane yields confirmed this. Unfortunately, there was no growth rate or gypsum-block station midway down the furrows, but cane yields suggest that there is likely to be a decline in cane tonnage in the middle portions of the furrows if they are 220 yds. long. The decline would appear to be sharper on the Sydenham clays of Bernard Lodge and Innswood where the intake rate is smaller than on the Agualta clays of Monymusk and Sevens. Furrow length should therefore be taken into consideration on these soil types. Furrows 110 yds. long may have merit.

4. Intake rates are proportional to stream sizes and are quite high after irrigation starts but they drop sharply and approach a constant value after about one-half hour on Sydenham clay at
Bernard Lodge, and after one hour on the Monymusk Agualta clay, remaining so for the duration of the irrigation. Observations show that if the streams are allowed to run for some time afterwards, the downward movement of water ceases, and the intake rate decreases to zero. The apparent drop in yield in the middle of the long furrows does not necessarily mean that yields under this system will be less than those under the ‘twig’ system. There is every reason to believe that the latter leads to imperfect distribution resulting in uneven cane production and perhaps to smaller tonnages than the long-furrow irrigation. The two systems are difficult to compare in a formal layout because of the difficulty of getting irrigators to repeat the imperfections of commercial ‘twig’ irrigation in an experiment.

6. The practical advantages of long-furrow irrigation are so obvious, and important particularly in this era of increased mechanization, that it may have to be adopted even at the expense of possibly slightly decreased yields.

ACKNOWLEDGEMENTS

The authors are grateful to the managements and staff of Bernard Lodge, Innswood, Monymusk and Sevens for their whole-hearted co-operation in this venture. Their thanks are also due to Mr. M. Harrison of the Ministry of Agriculture and Lands, and to Mr. W. Hinz of the International Co-operation Administration for their advice and assistance.

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THE EVALUATION OF SOME LAND-PREPARATION OPERATIONS ON IRRIGATED HEAVY CLAY SOILS IN JAMAICA

T. Chinloy

(The Sugar Manufacturers' Association of Jamaica Ltd., Jamaica)

(INTRO)