EFFECTS OF FLOODING ON SUGARCANE GROWTH.

1. STAGE OF GROWTH AND DURATION OF FLOODING

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ABSTRACT

Lysimeters growing var B 49119 sugarcane were flooded for 1, 4, 14 or 30 days at 1 month and 3 months of age, and again after harvesting the cane. The newly harvested ratooning plants were killed when flooded for 30 days. Flooding at any stage reduced the production of new tillers and tiller elongation rate of established tillers. Tiller elongation rate in the post-flooding period was greater than in the non-flooded controls, and cumulative elongation tended to equalise. There was no significant difference (P=0.05) between shoot yields at 5 months of age. Transpiration varied chiefly with differences in leaf area resulting from differences in tiller number and age. Roots in the flooded treatments remained unsuberised and were aerotropic, but there was no significant difference (P=0.05) in total root weight at 5 months of age.

INTRODUCTION

Flooding the soil can have both harmful and beneficial effects on sugarcane growth. The results presented in this paper illustrate effects of duration of flooding at different stages of growth on tiller production, tiller elongation rate, leaf area, transpiration and yield of shoots and roots. A second paper in these proceedings reports beneficial effects of drainage limitation and waterlogging on subsequent growth during a drought.

Frequently, observations on the effects of flooding in the field are confounded with those due to acidity and salinity. The soils used in these experiments were calcareous coralline clays and those interactions are therefore excluded.

MATERIALS AND METHODS

Cylindrical lysimeters were constructed from 30-cm diameter plastic drain tubes (Fig. 1). They were leakproof, but drainage water could be collected through an outlet pipe so that drainage losses could be accounted for in transpiration determinations. A perforated vertical drainage tube inside each lysimeter allowed measurement and control of the water level. Hudson's (2) system of weighing and transporting the lysimeters was used. Each unit could be moved on a spider cart to a platform scale, which was sunk so that the weighing platform was level with the floor.

An elliptical glass window was built into the inside of the top of each lysimeter so that the growing roots could be observed up to 9 in. below the soil surface. These windows were provided with removable covers to keep out light.
Evaporation losses from the soil surface were minimised by a plastic sheet covered with bagasse chips. Tests showed that these losses were negligible even when flooded.

Initial soil moisture content was measured by oven drying soil samples while the lysimeters were being filled. The soil was a montmorillonitic clay (Barbados soil type 30). Bulk density and gas filled porosity were calculated using the final volume obtained after wetting the soil. Changes in soil volume during the experiment were small. The weight of each lysimeter at approximately field capacity was obtained by wetting the soil thoroughly and allowing it to drain to a nearly constant weight.

The plants were obtained from young ratooning stools (var B 49119) which were dug from the field and divided. The stool sections were graded for uniformity so that all plants established in any replication were similar. Tiller elongation and water loss by transpiration and drainage were measured daily beginning 3 weeks after planting. Hudson's method for measuring tiller elongation rate was used. The measurement was made from a reference point near the base of the tiller to a clothes peg clipped on the central spindle leaves. Dillewyn (1) showed that the young leaves in the spindle elongate from the base at the same rate; by continually altering the position of the clothes

Fig. 1. Diagrammatic trans-sections of lysimeter used in experiment.
peg (daily or at 2-day intervals) comparative and sensitive measurements of
growth were obtained. The tiller elongation measurements presented in this
paper refer to spindle leaf elongation plus stem elongation and are derived from
the averages for 5-8 tillers in each lysimeter each day.

Some continuous tiller elongation measurements were also made using
Hudson's (2) converted thermograph pen recorder method. The pen arm was
attached to the leaf spindle with non-elastic twine.

Tiller counts were made at weekly intervals. Leaf area estimations were
facilitated by using sample leaf outlines drawn on squared paper. Every leaf
from 4 selected lysimeters in each replicate was matched with an outline of
known area, and the total leaf area of the plant was calculated. The leaf area
of the remaining plants in each replicate was then estimated by comparison with
the ones accurately measured. Each week the leaf area of different plants was
measured so that all plants were accurately measured every 3 weeks.

Hourly transpiration losses from field capacity and flooded plants were
also determined during 2-day periods to examine changes during day and night
and the effects of flooding. At the end of each experiment the fresh weights and
oven dry weights of the shoots were determined. The root systems were separated
from the soils by washing and were dried to constant weight.

There were 12 treatments in the experiment each of which was replicated
3 times, to give 36 units. The factors, duration of flooding and age of the plants
when flooding commenced, were factorially combined as follows:

<table>
<thead>
<tr>
<th>Duration of flooding in days</th>
<th>1</th>
<th>4</th>
<th>14</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding started:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Treatment ref. no.</td>
<td></td>
<td></td>
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<tr>
<td>1 month after planting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3 months after planting</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>After harvesting 3-month old plants</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Effects of flooding on tiller production, rate of tiller elongation, leaf area,
transpiration, root development and yield were investigated.

Effects on Tiller Production

The most harmful effects were obtained by flooding the recently harvested
stools. Table 1 shows that 30 days of flooding at this stage killed the plants.

Table 1. No. of tillers present at various times after the commencement of flooding harvested
stools.

<table>
<thead>
<tr>
<th>No. days after start of flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of flooding (days)</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>


Fourteen days of flooding also greatly reduced subsequent tiller production. In no case did any tillers emerge until after drainage. Stools flooded for 1 day produced tillers 4 days after drainage; stools flooded for 4 days produced tillers 7 days after drainage; and stools flooded for 14 days required 14 days of drainage before tillers emerged. Time taken to emerge after drainage was dependent on duration of flooding.

When the plants were flooded at 1 month of age, 1 day of flooding did not significantly (P = 0.05) affect tiller production, but the increase in tiller number during 4 days of flooding was 75% less than in the non-flooded controls. During 14 and 30 days of flooding the increase in tiller number was 66% less in both cases. At 3 months of age only 30 days of flooding significantly reduced the rate of tiller production; at this stage tiller production was much less in all treatments.

**Effects on Leaf Area and Transpiration**

Leaf area was related to tiller number and the rate of increase was less in flooded plants. At 1 month of age, the rate of increase in leaf area was 25% less in plants flooded for 14 and 30 days compared to the controls. At 3 months of age flooding did not result in a significant reduction. The differences in leaf area probably resulted in the observed variation in transpiration.

Transpiration was similar in flooded and control plots if the duration of flooding was short, but there was a reduced transpiration rate in treatments flooded for more than 21 days. Both transpiration rate and leaf area increased markedly with the age and size of the plants. Records of transpiration losses at 15-minute intervals throughout day and night did not reveal any significant reduction due to flooding where the plants were of approximately the same size. These results did not substantiate reports that flooding leads to a reduction in transpiration and increased wilting (3). The increase in age was associated with an increase in the ratio $\frac{E_t}{E_o}$ (Fig. 2) and this was probably associated with both increase in leaf area and root development.

**Effects on Tiller Elongation**

During the period of flooding there were significant (P = 0.05) reductions in tiller elongation rates. Flooding for 1 day at 1 month of age or 3 months of age, reduced tiller elongation rate by 17 and 9%, respectively, compared with the unflooded controls. Flooding for 4 days at 1 month and 3 months of age, respectively, caused a 9 and 7% reduction (P = 0.05) in tiller elongation rate, which over the period of flooding resulted in a total reduction of 2.5 and 1.9 cm, respectively. Flooding for 14 days at 1 month of age caused a 12% reduction in tiller elongation rate and resulted in a total reduction of 12.3 cm compared with the unflooded controls.

Continuous pen recordings of elongation of individual tillers throughout day and night did not reveal any variation between flooded and non-flooded plants. In both cases the nighttime growth rates were less than the daytime growth rates. During overcast days elongation was less than during bright days, indicating that lack of light may have limited growth. There were no effects attributable
Flooded treatments—3-43 days after planting.
Non-flooded treatments—3-43 days after planting.
FERTILIZATION, ETC.

Fig. 2. Relationship between transpiration, evaporation from an open water surface and age of plants.

to water stress, and it is, therefore, assumed that flooded and control treatments (at field capacity) were transpiring water at the potential rate, even during the brightest days.

During the period following flooding tiller elongation rates were enhanced as compared with the treatments which had remained not flooded throughout. Plants flooded for 1 day at either 1 or 3 months of age caught up with the controls within 2 days. Plants flooded at 1 month of age for 4 days and 14 days equalised with the controls 6 and 10 days after drainage. The recovery was accentuated by the application of fertiliser to all plots on day 30 (Fig. 3). The non-flooded plants immediately responded with an increase in tiller elongation rate, but no response to fertiliser occurred in the flooded plants until flooding was terminated; thereafter the response was very marked and particularly noticeable in the dark green colour of the leaves. Response to fertiliser was very small during flooding but very marked immediately after drainage. The practical significance of this is that it would be advisable to apply fertiliser
Fig. 3. Comparison between tiller elongation rate in flooded and non-flooded plants and recovery and response to fertiliser after 30 days flooding.

at the end of a period of flooding, when the soil has recently drained, in order to maximise response.

**Effects on Root Development**

Root systems developed under flooded conditions differed greatly from those developed mainly under drained conditions. The latter had fewer roots and a greater proportion of large diameter roots. Under flooded conditions the root systems consisted of a dense mat of small diameter roots. These roots were observable through the glass observation window to a depth of 9 inches. All the new white roots were small in diameter and apparently new large diameter roots were unable to survive under these conditions. The proliferation of thin roots probably resulted from successive death of primary, secondary, tertiary, etc., root tips and stimulation of laterals of a higher order which were thinner and, thus, able to survive.

Nearly all the young roots observed during flooding were aerotropic, growing vertically upwards to the soil surface. These new roots remained unsuberised and white for at least 30 days after their formation, whereas in the non-flooded controls the roots quickly suberised.

In the period immediately following flooding there was a surge in root growth and large diameter roots reappeared. This period coincided with the enhanced growth rate of the tillers, and the root system was apparently efficiently utilising nutrients at this time. The recovery in shoot growth may, therefore, be indirectly related to the stimulation of root growth in the post-flooding period.
In practice this rapid utilisation of nutrients may lead to the exhaustion of available nutrients and a need for additional fertiliser in the field.

Although root systems differed, there was no significant difference \((P=0.05)\) in the weight of roots in the different treatments at the end of the experiment (Table 2).

Table 2. Weight of shoots and roots at harvest (g/treatment).

<table>
<thead>
<tr>
<th>Duration of flooding (days)</th>
<th>Age at which flooding commenced</th>
<th>1 month</th>
<th>3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot</td>
<td>Root</td>
<td>Shoot</td>
</tr>
<tr>
<td>1</td>
<td>843</td>
<td>74</td>
<td>831</td>
</tr>
<tr>
<td>4</td>
<td>823</td>
<td>71</td>
<td>831</td>
</tr>
<tr>
<td>14</td>
<td>866</td>
<td>83</td>
<td>827</td>
</tr>
<tr>
<td>30</td>
<td>749</td>
<td>73</td>
<td>734</td>
</tr>
</tbody>
</table>

Differences non-significant \(P=0.05\)

**Effects on Yields of Shoots**

The plants were harvested prematurely at 5 months of age. Plants established under drained conditions and flooded for 1, 4, 14 and 30 days at 1 or 3 months of age, did not vary significantly \((P=0.05)\) in yield (Table 2). This was chiefly due to the ability of the plants to recover in the post-flooding period.

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**REFERENCES**