Exhibit 29, #3

# Subsurface Drainage of an Alluvial Soil Increased Sugarcane Yields

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## ABSTRACT

An experiment was conducted on a 10-ha tract of Commerce silt loam in St. James Parish, Louisiana during 1977-1980 to determine the response of sugarcane to subsurface drainage. Cane yields from a drained tract were compared to those from an undrained tract to estimate yield response. Cane yields were increased 3 of 4 years. The value of the increased cane yields was enough to pay for a subsurface drainage system at todays cane prices and drain installation costs.

## INTRODUCTION

Excess water due to high water tables may reduce crop yields. Subsurface drainage is widely recognized as a water management practice that will lower high water tables and restore production potential. Reasons for increased crop yields from lower water tables include: increased depths to which roots grow thus enhancing crop growth, improved soil aeration, warmer soil in the spring which promotes more vigorous early growth, and improved trafficability which allows timely planting and cultivations for weed control. Subsurface drainage is commonly used in the Midwestern U.S., an area of relatively high crop yields. In the Lower Mississippi Valley (LMV) yields for most crops are lower than the U.S. average (USDA 1976-1980). Although the presence of subsurface drainage in the Midwest is not completely responsible for high yields in that area and the absence of subsurface drainage in the LMV is not totally responsible for low yields there, it is known that high water tables can reduce production.

Due to precipitation and low lying, nearly level topography, problems with high water tables in the LMV may be even more severe than those in the Midwestern U.S. Precipitation is considerably higher in the LMV with annual averages of over 1200 mm in Arkansas, the northern part of the Valley, to over 1500 mm in Louisiana, the southern part of the LMV (USDC 1961-1980). Occasionally annual precipitation exceeds 2000 mm in this area. High water tables are closely associated with large amounts of precipitation. The water table frequently rises to within 30 cm of the soil surface and may remain there for extended periods, particularly during the winter and early spring months when precipitation is high and evapotranspiration is low (Carter and Floyd, 1971). Such a high water table adversely affects crops such as sugarcane which has seed stalks and stubble in the soil during this time.

Sugarcane is a major crop in Louisiana, and an important crop nationally since the U.S. imports approximately 50 percent of the sugar it consumes. Louisiana presently grows about 113,000 ha of cane. Sugarcane is usually planted during August, September, and October, the first crop of which is harvested in December of the following year. Usually two ratoon (stubble) crops are grown before the cane is replanted for another 3-crop cycle. Whole stalks of cane are seeded on high (30 cm or more) beds spaced about 1.8 m apart. The crop grows 1.8 to 3.5 m tall with most of the growth occurring between June and September.

Although considerable amounts of water are needed to produce sugarcane, the crop is susceptible to a prolonged high water table (Carter and Floyd, 1975). Several small plot experiments were conducted in the late 1960's and 1970's at Baton Rouge, LA to determine drainage requirements of sugarcane. These replicated tests showed that high water tables, particularly during the dormant season, reduced cane yields (Carter and Floyd, 1975). These tests also showed that subsurface drainage increased stand longevity. The number of crops harvested from one planting was increased from the normal 3 to 5 (Carter, 1977).

The purpose of the experiment reported in this paper was to determine in the field the response of sugarcane to subsurface drainage on a major soil type in the Lower Mississippi Valley.

## PROCEDURE

A Commerce silt loam site on Graugnard's farm in St. James Parish, LA was selected for this experiment. The site consisted of two adjacent blocks of land each about 5 ha in size. One block was subsurface drained and the other was not. Subsurface drainage was accomplished by installing 4 subsurface drain lines 100 mm in diameter and about 290 m long during the summer of 1967 using a drain tube plow equipped with a laser grade control system. The drains, furnished partially by Hancor.*, were corrugated, perforated tubes and were spaced 24, 36, and 48 m apart (Fig. 1). The drains were installed 1.2 m below the soil surface on a 0.17 percent slope which was about the same as the field slope. One drain was extended about 12 m beyond the others before changing direction and was continued at a

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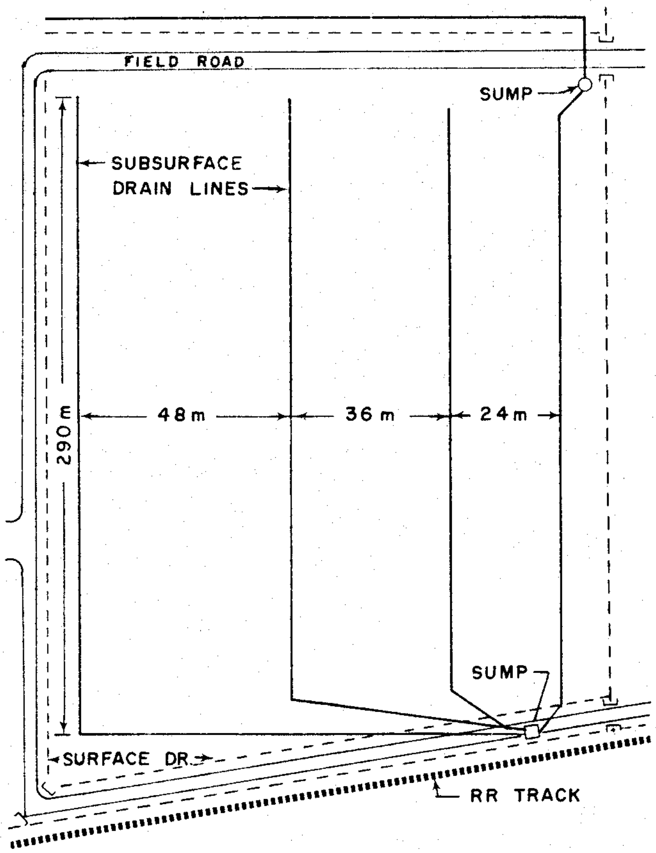


**Fig. 1—Schematic of subsurface drainage experimental area, St. James Parish, LA.**

right angle across the field about 109 m (Fig. 1). The surface drainage ditch on the lower side of the field was not deep enough to serve as a gravity drain outlet: therefore, a sump 1.2 × 1.2 × 3 m was installed to collect water from the drains. Electric pumps discharged the water from the sump into a surface drainage ditch.

A recording rain gauge was installed at the edge of the experimental site to measure precipitation. Data from the gauge and air temperature data from an official climatological weather data collection station located about 10 miles away were used in Thornthwaite's water balance model to estimate water excesses and deficits (Thornthwaite and Mather, 1957).

The response of the water table to subsurface drainage was evaluated in 1977 by measuring the water table depth using cased wells located in a line across the field perpendicular to the direction of the drains. In 1978 water level recorders were installed midway between the three drain spacings to monitor the water table. These recorders remained in place until harvest in 1980 except for short periods in the fall each year when they were removed for harvest.

Sugarcane, variety CP 48-103, was planted in both drained and undrained fields in the fall of 1976. Conventional practices were used which included planting on rows bedded 30 cm high and spaced about 1.8 m apart. Herbicide was applied at planting and again in the spring each year. In addition, the field was cultivated to ensure good weed control. Pesticides were applied as needed. Fertilizer was applied each spring using 180 kg of N, and 67 kg of $K_20$ per ha except in 1979 when no $K_20$ was applied. The first crop was harvested in December 1977 and the first, second, and third ratoons were harvested in December 1978, November 1979, and November 1980, respectively. A mechanical harvester cut, topped, and placed the cane stalks in 3-row heaps after which the leaves on the stalks were removed by burning.

For estimating yields, cane samples (trailer loads of cane) were taken from randomly selected areas approximately 0.1 ha in size. The cane was transported to the sugar mill, weighed, and subsampled for quality determinations. Yield samples were taken from 15 different heap rows in the two experimental fields. These samples were considered as replicates and were analyzed for differences due to treatments.

Cane yield is a function of plant population and stalk weight. Plant population was estimated by counting the number of stalks in several 15 m sections of the same 3-row heaps used to estimate yields. Stalk weights were calculated using crop yield and plant population estimates.

## RESULTS AND DISCUSSION

This four-year experiment included a wide range of soil water conditions due to the range in annual precipitation. Rainfall data in Table 1 show that annual precipitation varied from a low of 1612 mm in 1978 to a high of almost 1900 mm in 1980. Since monthly evapotranspiration varies considerably, a further analysis of the precipitation data was made to determine water excesses and deficits which may affect cane yields. Monthly water excess and deficits are shown in Table 2 for 1977, 1978, 1979, and 1980. Excess water either runs off the field or infiltrates and causes a rise in the water table. Deficits indicate a potential need for irrigation.

The water table in both the drained and undrained areas fluctuated considerably during this experiment. The effectiveness of the subsurface drains is indicated by the difference in depth of the water table for the drained and the undrained treatments as shown in Figs. 2 and 3 for 1978 and 1979, respectively. Since the water table depth in the drained area was measured midway between drain lines where the water table was highest, the maximum effectiveness of the drains was greater than the data in Figures 2 and 3 indicate. Water table depths for drains spaced 24 m and 48 m apart were similar to those presented for the 36 m drain spacing. Similar water table depths for differently spaced drains were not expected. Closely spaced drains were expected to lower the midplane water table more quickly than widely spaced drains. However, the hydraulic conductivity in the horizontal directions was twice that in the vertical

**TABLE 1. MONTHLY AND ANNUAL PRECIPITATION, ST. JAMES, LA**

| | Precipitation, mm | | | | |
|---|---|---|---|---|---|
| | Years | | | | |
| Month | 1977 | 1978 | 1979 | 1980 | Normal |
| January | 130 | 274 | 122 | 142 | 116 |
| February | 43 | 53 | 297 | 30 | 134 |
| March | 69 | 86 | 74 | 320 | 140 |
| April | 190 | 107 | 335 | 348 | 120 |
| May | 47 | 241 | 163 | 228 | 143 |
| June | 45 | 135 | 25 | 39 | 150 |
| July | 169 | 236 | 228 | 111 | 215 |
| August | 393 | 170 | 190 | 145 | 156 |
| September | 245 | 31 | 142 | 275 | 194 |
| October | 121 | 0 | 46 | 86 | 77 |
| November | 267 | 178 | 94 | 120 | 104 |
| December | 98 | 51 | 74 | 49 | 142 |
| Annual | 1817 | 1612 | 1790 | 1893 | 1691 |

TABLE 2. MONTHLY WATER EXCESSES AND DEFICITS BASED ON THORNTHWAITE'S WATER BALANCE MODEL

| | 1977 | | 1978 | | 1979 | | 1980 | |
|---|---|---|---|---|---|---|---|---|
| | Excess, mm | Deficit, mm | Excess, mm | Deficit, mm | Excess, mm | Deficit, mm | Excess, mm | Deficit, mm |
| January | 130 | | 267 | | 115 | | 114 | |
| February | 23 | | 47 | | 284 | | 17 | |
| March | 14 | | 47 | | 19 | | 273 | |
| April | 92 | | 8 | | 220 | | 266 | |
| May | | 34 | 80 | | 28 | | 75 | |
| June | | 105 | | 10 | | 61 | | 58 |
| July | | 26 | | | | | | 73 |
| August | 71 | | | 17 | | | | 47 |
| September | 79 | | | 31 | | | | |
| October | 32 | | | 62 | | 28 | | |
| November | 219 | | | | | | 58 | |
| December | 76 | | 19 | | 18 | | 22 | |
| Total | 736 | 165 | 468 | 120 | 684 | 89 | 825 | 178 |

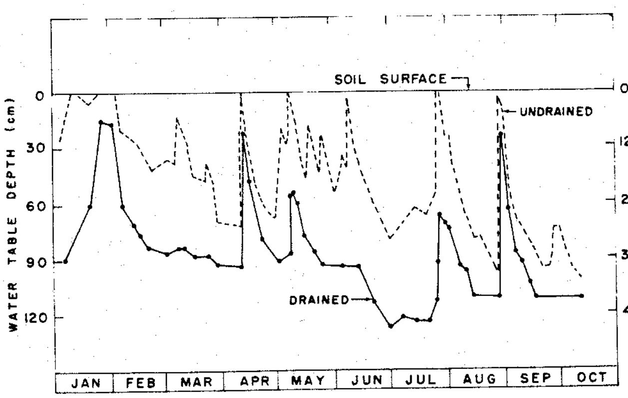


**Fig. 2—Water table depths in subsurface drained and undrained areas during 1978. The water table for the drained area was measured midway between drains spaced 36 m apart.**

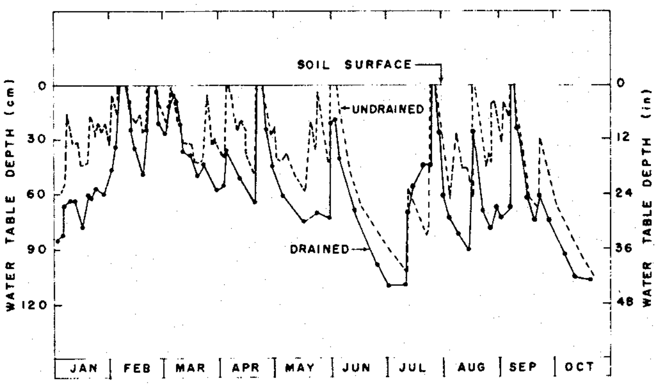


**Fig. 3—Water table depths in subsurface drained and undrained areas during 1979. The water table for the drained area was measured midway between drains spaced 36 m apart.**

direction at 1.2 m below the soil surface. Measurements indicated that the vertical hydraulic conductivity was 0.10 cm/hr and the horizontal hydraulic conductivity was 0.2 cm/hr. Thus, the rate of change in the water table may have been influenced considerably by the vertical distance through which water flowed.

Sugarcane yields from the subsurface drained area were significantly higher than yields from the area without subsurface drainage in 3 of 4 years (Table 3). Cane yields from the subsurface drained treatment were 10 percent, 17 percent, and 15 percent more in 1977, 1979, and 1980, respectively, than those from the undrained area. Sugar yield from the subsurface drained area was significantly higher only 1 of 4 years. In 1979, the drained area yielded 23 percent more sugar/ha than did the undrained area (Table 3).

Plant population in the subsurface drained treatment in 1977 was significantly higher (11 percent) at harvest than in the undrained area. Plant populations of the two treatments were about the same at harvest in 1978, 1979, and 1980 (Table 3). Plant populations of the 1979 and 1980 crops were 20 to 30 percent higher than those in the two previous crops.

Stalk weights from the subsurface drainage treatment in 1979 and 1980 were significantly heavier, 14 percent and 11 percent more, respectively, than those from the undrained treatment (Table 3).

The higher cane yields in 1977, 1979, and 1980 were attributed to subsurface drainage. Apparently high water tables in the undrained area during these years inhibited soil aeration or some other root growth factors which adversely affected yields. Earlier experiments with sugarcane in Louisiana showed that a high water table for long durations during the winter and early spring months adversely affected yields (Carter and Floyd, 1975). The exact reason for this was never determined

TABLE 3. CANE AND SUGAR YIELDS, PLANT POPULATIONS, AND STALK WEIGHTS.

| Treatment | Year | Cane yield, t/ha | Sugar yield† kg/ton | Sugar yield† kg/ha | Plant population, plants/ha | Stalk weight kg/stalk |
|---|---|---|---|---|---|---|
| Subsurface drained | 1977 | 76.2a* | 81.9a | 6244a | 72440a | 1.06a |
| Undrained check | 1977 | 69.0b | 82.2a | 5699a | 65188b | 1.08a |
| Subsurface drained | 1978 | 92.7a | 80.5a | 7493a | 65488a | 1.42a |
| Undrained check | 1978 | 102.4a | 83.5a | 8584a | 6866a | 1.50a |
| Subsurface drained | 1979 | 91.6a | 89.4a | 8179a | 84350a | 1.09a |
| Undrained check | 1979 | 78.6b | 84.0a | 6629b | 82408a | 0.96b |
| Subsurface drained | 1980 | 72.4a | 72.0a | 5189a | 84864a | 0.85a |
| Undrained check | 1980 | 63.2b | 80.0a | 5040a | 82622a | 0.77b |

*Data in each column for the same year followed by the same letter are not significantly different at the 95% level of probability.
†Commercial recoverable sugar based on laboratory data from core samples taken from each trailer load of sugarcane.

but damage to emerging cane buds in the spring is suspected. The data in Table 2 indicate excess water in the winter and spring months each year. The years when most excess water in February, March, and April occurred were 1979 and 1980. Subsurface drainage was needed most in 1979 as indicated by the cane and sugar increases due to subsurface drainage. On the other hand, the year with the smallest calculated excess water during February, March, and April was 1978. This was the year the yields for drained and undrained areas were not significantly different. Furthermore, the lower water table in the drained area during the summer 1978 had an adverse effect on cane stress due to drought. Apparently the higher water table in the undrained area in 1978 provided water in the root zone longer than did the drained treatment; consequently, yields were higher. These data indicate the need for a water management system which would prevent the water table from declining to relatively low levels during periods of drought or perhaps one in which water could be added through the drains when irrigation is needed.

The significant increase in cane yields in 3 of 4 years indicates the economic feasibility of subsurface drainage for sugarcane on silt loam soil. The mean yield increase during 1977, 1979, and 1980, years when drainage apparently was needed, was 29.3 t/ha which at the current price of cane is worth about $645. If the 1978 data were included, the difference in yields of the drained and undrained treatments becomes 19.7 t/ha which is worth about $434. In either case the extra cane due to subsurface drainage during this 4-year experiment was more than enough to pay for a drainage system, assuming 48 m drain spacing and $1.64/m for drain installation costs. The extra sugar yield due to subsurface drainage in 1979 was also worth more than enough to pay for a subsurface drainage system. Although significant yield increases may not occur every year, the magnitude of the yield increases when drainage is badly needed, such as in 1979, enhances the feasibility of subsurface drainage.

## SUMMARY

Subsurface drains 24, 36, and 48 m apart lowered the water table at about the same rate during a 4-year experiment in Commerce silt loam. Sugarcane yields were increased significantly in 3 of 4 years by subsurface drainage and sugar yields were increased significantly 1 of 4 years. Subsurface drainage for sugarcane is economically feasible, assuming subsurface drain spacing of 48 m and a cost of $1.64/m for installing drains.

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