SUBSURFACE DRAINING JEANERETTE SOIL TO INCREASE CANE AND SUGAR YIELDS

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ABSTRACT

An experiment was conducted in Iberia Parish, Louisiana during 1980-1990 to determine soil and crop response to subsurface drainage. Three subsurface drain spacings, 45-ft, 90-ft, and 135-ft, were tested on Jeanerette silty clay loam soil. The soil responded favorably to subsurface drainage. In the subsurface drained areas, the average SEW_{12} values, which is a measure of the magnitude and duration of the water table within 12 inches of the soil surface, were from 63 to 89 percent less than the average SEW_{12} values from the non-drained area. Cane and sugar yield also improved with subsurface drainage. Average cane yields from the subsurface drained treatments were from 2.0 T/A to 4.2 T/A greater (up to 16 percent greater) than yield from the non-drained check and the differences were significant. Average sugar yields from the subsurface drained treatments were from 711 lbs/A to 937 lbs/A greater (up to 21 percent greater) than yield from the non-drained area and the differences were highly significant. The recommended drain spacing for Jeanerette silty clay loam soil for increasing cane and sugar yields is 135 feet. Using 1994 drain installation costs and sugar prices, installing subsurface drainage systems with drains spaced 135-ft was justified because the value of the increase in sugar yields exceeded the cost of installing subsurface drainage at that spacing.

INTRODUCTION

Relatively low and variable crop yields in Louisiana are attributed to weather more than any other factor. Although little can be done about the weather, there are several farming practices that deal with the consequences of weather and will certainly aid crop production. For example,the practices of irrigating during droughts, surface draining to remove excess water from the soil surface, subsurface draining to remove excess water from the soil profile, selecting varieties for proper maturity, selecting varieties for disease control, and selecting varieties for crop tolerance to cold temperatures all tend to reduce the adverse effects of weather on crop production.

During the past 20 years, sugarcane growers in Louisiana have placed much emphasis on surface drainage and variety selection for disease resistance and cold tolerance. Little effort has been made to improve soil profile drainage or to irrigate. An analysis of weather variables in the sugar cane growing area of Louisiana indicates that the average annual evapotranspiration demand is about 42 inches/year, yet average annual rainfall is 57 inches and greater (Thornthwaite 1957, Carter 1977a, US Dept. of Commerce 1992). Monthly evapotranspiration varies from less than one inch in January, February, and December to approximately seven inches in June, July, and August (Carter 1977a). During most years, rainfall in June, July, and August is not sufficient to meet the evapotranspiration demand, indicating the need for irrigation. On the other hand, rainfall during the remaining months of the year usually exceeds evapotranspiration. This excess water (rainfall volume less evapotranspiration volume) will either pond on the soil surface, runoff, or infiltrate into the soil and cause the water table to rise. The consequences of a high water table are inhibited crop growth, reduced stand longevity, reduced crop yield, and interference with timely field operations.

Because surface drainage of sugarcane land is reasonably good, poor soil profile drainage appears to be a factor that could be causing or contributing to the leveling off of average annual sugarcane yields. The average sugarcane yield in Louisiana has been relatively constant at approximately 24 tons/A for the past 10 years (USDA 1985-1993).

To determine the soil and crop response to subsurface drainage, several experiments were conducted beginning in the mid-1960's. The first experiments were conducted on small (0.01 acre) concrete bordered plots located near Baton Rouge, LA where the water table could be precisely controlled (Carter, et al. 1970, Carter 1977b). These experiments showed that subsurface drainage increased cane and sugar yields and increased cane stubble longevity (Carter and Floyd 1973, Carter 1975). Because these experiments were conducted on very small plots on a Mhoon/Commerce silt loam with precise water table control, there was a need to conduct subsurface drainage experiments on field-size areas with field subsurface drainage systems on different soils. Field-size experiments were installed in Tensas, Iberville, St. James, St. Mary, and Iberia parishes in the late 1970's. This paper reports the results from the experiment in Iberia Parish, the objective of which was to determine soil and crop response to subsurface drainage of a Jeanerette silty clay loam planted in sugarcane.

MATERIALS AND METHODS

A Jeanerette (Typic Argiaquoll) silty clay loam site at the William Patout III farm in Iberia Parish, Louisiana was selected for this subsurface drainage experiment. Four tracts, each approximately 3.7A (800 by 200 feet) were used (Figure 1). Subsurface drains were installed on three tracts in 1978. One tract not subsurface drained was used as a check. The perforated, corrugated, polyethylene subsurface drains were four inches in diameter and were wrapped with Typar[1] filter material. The drains were installed approximately 3 ft deep with a drain-tube plow equipped with a laser grade control system. The first tract had four drains spaced 45-feet apart, the second tract had three drains spaced 90-feet apart, and the third tract had two drains spaced 135-feet apart. Drains in the three tracts were connected to two steel sumps, each approximately 4 by 4 by 10 ft deep, that were equipped with two 0.5-hp pumps each. These discharged drain effluent into a surface drainage ditch. Drain effluent was measured after February, 1981 with commercial-type water meters. Consequently, no drain outflow data were collected during the early part of this experiment.

The non-drained tract was located across a drainage ditch from the 135-ft drain spacing treatment (Figure 1). Each tract was bordered on the sides by surface drainage ditches approximately two-ft deep and on the downslope end by a surface drainage ditch approximately three-ft deep (Figure 1). The tracts were bordered on the up-slope ends by field roads.All tracts were planted to sugarcane in the fall of 1979. Conventional cultural practices were used throughout the experiment, which included planting on 12-inch high beds with rows spaced 70-in apart. Fertilizer and pesticides were applied at rates recommended by the Louisiana Cooperative Agricultural Extension Service.

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[1]Trade and company names are listed for the readers' benefit and do not imply endorsement or preferential treatment by USDA.

At harvest time, a whole-stalk mechanical harvester was used to cut, top, and place the cane stalks in either three- or four-row heaps after which the leaves remaining on the stalks were burned. Sugarcane stalks from four sites (each approximately 0.3 A in size) in each tract were transported to the factory, weighed for yield estimates, and tested for sucrose content. Sugar yield was determined from cane weight and sucrose content. Mean treatment yields were compared to determine crop response to drainage and drain spacings.

At or prior to harvest time each year, plant population estimates were determined by counting the number of harvestable stalks on 200 ft of four rows in each tract. Stalk weights were determined by dividing cane weights by stalk populations. Normally, three annual sugarcane crops are harvested from one planting in Louisiana. During this experiment, a new crop was planted three different times, in the falls of 1979, 1983, and 1988. Sugarcane cultivar NCo-310 was planted in 1979 and CP 70-321 was planted in 1983 and 1988. Three crops were harvested from the first planting, four crops from the second planting and only two crops from the third planting. Below-freezing temperatures in December 1989 severely damaged the stubble of the 1988 planting, which severely reduced 1990 crop yields. Consequently, the landowner chose to destroy the stubble and replant in the fall of 1991. Because the objectives of this experiment had been met, the project was terminated after crop harvest in 1990.

Rainfall was measured with a weighing-type rain gauge located at the site. Water table depths were measured with water stage recorders, one recorder installed in each tract. Water stage recorders were located midway between two parallel subsurface drains in the drained areas and near the middle of the tract in the check area. Each recorder was positioned over a 6-ft length of 6-in diameter PVC pipe that was inserted vertically in a 5-ft-deep hole augered into the soil; the well casing extended 12-in above the soil surface. The deepest 4-ft section of pipe was perforated so that water could readily flow through the PVC well casing. The soil surface was sloped away from the well casing to prevent surface water from entering the wells. Recorders were supported by stands positioned over the pipe which also insured that the float and counterweight remained within the PVC pipe. Recorders were installed in 1979 and remained in place throughout the experiment except for periods in November and December each year when they were removed for harvest, and all year during 1983 and 1988 when the land was fallow plowed and seedbeds were prepared for re-planting. Water table data from recorder charts were mechanically digitized and stored in computer files. These data were used to determine the number and duration of events when the water table was within 12 inches of the soil surface.

Because only two sumps were available for outlets for the three subsurface drained tracts, flow from each tract could not be measured separately. One sump collected drainage effluent from the four drain lines in the 45-ft spacing treatment and one drain line in the 90-ft drain spacing treatment. The other sump collected effluent from two drains in the 135-ft drain spacing treatment and two drain lines in the 90-ft spacing treatment. The effluent discharge from each sump was measured and the two discharge volumes were combined to provide the total drain outflow volume from the subsurface drained tracts.

A term commonly used to report effectiveness of subsurface drainage is SEW_{12}, the summation of excess water (Wesseling 1974). This term expresses the magnitude and duration of the water table within the top 12 inches of the soil surface. SEW_{12} is determined by plotting water table depth vs time, drawing a line on the graph at 12 inches below the soil surface, and then summing the daily magnitude values when the water table was closer than 12 inches to the soil surface. For example, if the water table rose to eight inches below the soil surface and remained there for three days, the excess water for this three-day period would be $3(12 - 8) = 12$ inch-days. If the water table were 4 inches from the soil surface for three days, the excess water would be $3(12 - 4) = 24$ inch-days. SEW_{12} , is the summation of excess water calculated during a given period, usually during a growing season. Sieben (1964), who developed the SEW concept in the Netherlands, determined that yield of cereal grains began to decline as SEW_{12} values, during the growing season, increased above 40 inch-days. Because sugarcane is a ratoon crop, SEW should be calculated for the entire year rather than for the growing season. For the calculations in this paper, the soil surface was assumed to be the average of the cane row top and the furrow bottom elevations.

The rainfall and water table recorders were equipped with clocks that ran for several months between servicing. However, we checked the recorders and changed the charts much more frequently, usually at two- or three-week intervals. When the charts were changed, the water meter readings were recorded. Occasionally the electric power meter, which measured the power used by the sump pumps, was observed and these data were recorded. The water and electric meter data were used to determine the volume of water drained from the plots and the amount of electricity used to pump the water from the sumps into a surface drainage ditch.

The cost of installing the subsurface drainage system was estimated. The material costs, based on 1994 prices and quoted by a plastic drain tubing company representative, were $0.29/ft for 4-in perforated plastic drain tubes with filter fabric, $4.80 each for tee adapters, $0.70 each for drain tube couplers, $0.80 each for end caps, and $0.45/ft for 6-in diameter main drain tubing. The cost for a sump and pump for drainage outlet was estimated at $100/A. Because no subsurface drainage contractors are currently located in Louisiana, the drain line installation cost was estimated at $0.28/ft, based on the average cost for several drain installations in the Midwestern area of the United States.

Because of the size and nature of this experiment, it was not feasible to replicate the drain spacing treatments. However, years were used as replications (nine years of yield data) and these data were analyzed statistically for normality, interactions, differences, and trends using univariate analysis, plotting programs, and ANOVA methods available from the Experimental Statistics Department at Louisiana State University.

RESULTS AND DISCUSSION

Annual rainfall amounts varied considerably during this experiment, ranging from 42.99 inches in 1990 to 70.52 inches in 1982 (Table 1). Average annual rainfall for the period 1980-1990 was 57.20 inches, which was slightly lower than the long-term average for Iberia Parish of 59.10 inches (U. S. Dept. of Commerce 1993). Monthly rainfall varied from 0.59 inches in February 1981 to 18.82 inches in October 1984.

Rainfall raised the water table to near the soil surface on many occasions. In the non-drained tract, the water table remained near the soil surface for several days following significant rainfall while the water table in the drained tracts receded to a depth of 12 inches and more, soon after rainfall (Figures 2, 3, and 4).

The time period that the water table was within 12 inches of the soil surface averaged 3.8, 7.1, and 13.1 days in the 45-, 90-, and 135-ft drain spacing treatments, respectively (Table 1). In the non-drained check, the water table was within 12 inches of the soil surface an average of 49.4 days during the nine years that water table measurements were made (Table 1). In 1982, the water table in the non-drained tract was within 12 inches of the soil surface 70.9 days; in the subsurface drained tracts the water table was within 12 inches of the soil surface only 25.3, 7.3 and 0 days in the 135-, 90-, and 45-ft drain spacing treatments, respectively (Table 1). This measure, however, provides only one dimension, time.

SEW_{12} values reflect not only the presence of the water table within the top 12 inches of the soil but also how close it was to the soil surface. Annual SEW_{12} values varied considerably, but, like the time period, they were less for the 45-ft spaced drains and increased as drain spacing increased in all cases. The SEW_{12} values were greatest in the non-drained tract (Table 1). Because SEW is more comprehensive in quantifying the water table's effect on crop growth, SEW_{12} rather than time periods, will be used to indicate the response of Jeanerette soil to subsurface drainage.

The Jeanerette silty clay loam soil responded favorably to subsurface drainage as indicated by the differences in SEW_{12} values among the four treatments (Table 1). Average annual SEW_{12} values for the subsurface drained tracts were significantly less than values for the non-drained check for all drain spacings (Table 1). Average annual SEW_{12} values were 63 percent less (from 253 inch-days to 95 inch-days) for drains spaced 135-ft apart, 81 percent less (from 253 inch-days to 48 inch-days) for drains spaced 90-ft apart, and 93 percent less (from 253 inch-days to 18 inch-days) for drains spaced 45-ft apart.

The average water table depth during the times that the water table was within 12 inches of the soil surface can be calculated by dividing mean SEW_{12} values by the number of days in the period and subtracting this value from 12 inches. For example in 1980, the SEW_{12} value for the non-drained check was 337 inch-days while the time period that the water table was within 12 inches of the soil surface was 57.6 days (Table 1). Consequently, the average water table depth was $(12 - (337/57.6)) = 6.15$ inches from the soil surface during this time period.

Sugarcane requires a large amount of water, but saturated soil conditions in the soil profile for long time periods can reduce yield. Cane yields varied considerably during this study (Table 2) with the highest yields from the subsurface drained tracts being produced in 1981 and the lowest yields being produced in 1990. The highest yield from the non-drained tract was produced in 1980 and least yield was produced in 1990 (Table 2). Our main interest, however, is yield differences between drain spacing treatments and between the subsurface drained and non-drained treatments.

Average cane yields were 30.5, 30.4, 28.3, and 26.3 T/A from the 45-, 90-, and 135-ft spacings and the non-drained check, respectively (Table 2). Differences in average cane yields among the three drain spacing treatments were not significant but differences in average yields between drained and non-drained treatments were significant at the five-percent significance level. Average yields from the subsurface drained treatments were 3.43 T/A (13 percent) higher than yields from the non-drained treatment (Table 2). Individually, cane yield differences between drain spacing treatments and the non-drained check were 4.2 T/A (16 percent higher) from the 45-ft spacing, 4.1 T/A (15.6 percent higher) from the 90-foot spacing, and 2 T/A (7.6 percent higher) from the 135-ft spacing.

For three years (1984, 1986, and 1987) there was little or no yield response to subsurface drainage while for six years (67 percent of the time) there was a positive cane yield increase for subsurface drainage. The greatest yield differences between subsurface drained and non-drained treatments occurred in 1990 when cane yields from the drained treatments were from 76 to 100 percent greater than yields from the non-drained treatment. This large yield difference occurred the growing season following a severe freeze in December, 1989, after harvest. This freeze was followed by above-average rainfall in the early part of 1990 and high water table (high SEW_{12} values) in the non-drained tract (Table 1 and Figure 4). The combination of freezing temperatures and wet soil damaged the cane stand in the non-drained area severely, consequently cane yield from this treatment was very low in 1990, only 13.8 T/A (Table 2). Cane yields from the subsurface-drained tracts in 1990 were below normal for first-stubble yields but were much higher than those from the non-drained check (Table 2). Yield differences between drained and non drained treatments in 1990 were attributed to improved drainage during the rainy, wet periods following the freeze rather than by any effect during the freeze. Apparently the subsurface drained areas provided a favorable environment for the sugarcane after the freeze, while the high fluctuating water table and wet soil in the non-drained treatment created an unfavorable environment. Consequently, yields were less from the non-drained treatment.

Significantly greater cane yields for subsurface drainage occurred in three other years (1981, 1982, and 1989) during the test period. Cane yield increases attributed to subsurface drainage were 10.5 T/A in 1981; 10.4 T/A in 1982; and 6.9 T/A in 1989. The higher yields in 1981 and 1982 are attributed to the effects of drainage as indicated by SEW_{12} (Tables 1 and 2). In 1989, the SEW_{12} may not have been a factor in yield since it was only 33 inch-days in the non-drained treatment and 0 in the drained treatments, which is not enough difference to adversely affect yields. The higher yields from the subsurface drained tracts, however, could result from cumulative soil profile improvement during the 11-year period with subsurface drainage, such as improved aeration.

Although the threshold SEW_{12} value to cause significant sugarcane yield decrease is not known, data from this experiment indicate that it is probably greater than 95 inch-days annually (Table 1 and Table 2). Unlike most crops that have 75 to 120-day growing seasons, sugarcane has a growing season in Louisiana of approximately 270 days (nine months). Furthermore, two ratoon crops are normally grown following the first crop; consequently, annual SEW_{12} values, rather than 270-day SEW_{12} values (growing season only), should be used to determine threshold SEW_{12} values to prevent decline of sugar yield. Also particular emphsis should be placed on SEW_{12} values during the time when sugarcane is most susceptible to high water tables, such as during the dormant-to-early-growth stage when the crop susceptibility factor is 0.40 (Gayle, et al., 1987).

Stalk population and stalk weight are parameters that influence cane yield. Stalk population data collected during this experiment are shown in Table 3 and stalk weight data are shown in Table 4. Overall statistical analysis indicated that stalk populations and stalk weights were not significantly different among drain spacing treatments (Tables 3 and 4). When individual years were considered, stalk populations were much higher in the drained areas than in the non-drained areas in other years (Tables 3 and 4). For example, in 1980, 1989, and 1990, all drained treatments had higher stalk populations than did the non-drained tract (Table 3). In 1981, 1982, and 1985, all drained treatments had higher stalk weights than did the non-drained tract (Table 4). In 1990, the stalk weight of the non-drained treatment was much higher, more than one-pound per stalk higher, than the drained treatments (Table 4). The stalks were larger and heavier partially because of the low stalk populations, but some of the stalk weight came from the excess green leaves that were left on the stalks. The height of the stalks in the non-drained area was not sufficient for the mechanical harvester to top normally, thus, green leaves were left on the stalks and this caused an unusually high (biased) stalk weight for the non-drained treatment in 1990. Burning, after cutting and placing the cane on heap rows, removed the relatively dry leaves but not the moist green ones. Consequently, the stalk weight of the non-drained treatment was unusually high in 1990.

It was not clear why stalk populations in the drained treatments were much greater than those in the non-drained treatment some years while stalk weights in the drained treatments were higher than those in the non-drained treatment in other years. It appears that sugarcane is like many other crops in that stalk weight varies inversely with stalk population. To further explore this relationship, the stalk population and stalk weight data were regressed. The square of the correlation coefficient (r^2) for this regression was 0.26 when all nine years of data were used and

0.55 when only the six years when cane yields were increased (1980, 1981, 1982, 1985, 1989, and 1990) were used. The slope of the line that fit the data best was negative in both cases, indicating that the weight of the stalks decreased as plant population increased. A regression of cane yields (X) and stalk population (Y) showed a linear correlation with an r^2 of 0.59. A regression of cane yield (X) and stalk weight (Y) data showed a linear correlation with an r^2 of only 0.177.

Sugar yields varied considerably with the highest yields being produced in 1989 and the lowest yields being produced in 1990 (Table 5). Yields from the 45-ft and 90-ft drain spacings were similar most years. In the first crop cycle (1980-1982), yields from the 135-ft spacing were consistently higher than those from the non-drained area but less than yields from the 45-ft and 90-ft drain spacings. In the second crop cycle (1984-1987), yields for the non-drained treatment were slightly greater than yields for the drained treatments some years (Table 5). In general, differences in sugar yield among treatments were small during the second crop cycle.

In the third crop cycle (1989-1990), yields among the three drain spacings were similar, but they were consistently greater than those from the non-drained area (Table 5). The highest sugar yields during the entire experiment occurred in 1989 and were caused by an unusually high sugar content rather than high cane weight. The high sugar content was attributed to favorable weather (dry, cool weather conditions) and low water table during the cane ripening period.

Average sugar yields from all nine crops during this experiment were 5383, 5372, 5157, and 4446 lb/A from the 45-, 90-, and 135-ft spacings, and the non-drained check, respectively (Table 5). Yields among the three drain spacing treatments did not differ significantly at the five-percent level of significance (Table 5). However, average sugar yields from the subsurface drained treatments were 858 lb/A (19.3 percent) greater than yield from the non-drained treatment and this difference was significant at the one-percent significance level (Table 5). Individually, sugar yield differences between drain spacing treatments and the non-drained check were 937 lb/A (21 percent) greater for the 45-ft spacing, 926 lb/A (20.8 percent) greater for the 90-foot spacing, and 711 lb/A (16 percent) greater for the 135-ft spacing.

To determine any negative bias that might be caused by the 1990 crop, which was a ratoon crop following a severe freeze, all yield data were analyzed both including and excluding the 1990 crop. These analyses indicated no adverse influence of the 1990 crop.

The two parameters that determine sugar yield are cane biomass and the sugar concentration in the cane. Cane mass is shown in Table 2 while sugar concentration of the cane is shown in Table 6. Sugar concentration of the cane, reported in Table 6, is a commercially recoverable value, which is 13 percent less than the theoretical sugar content. Average sugar concentrations of the cane from the drained treatments were greater than that from the non-drained treatment (Table 6) but only the sugar concentrations from the 45-ft and the 135-ft spacing treatments were significantly greater than those from the non-drained treatment at the five-percent level of significance. Apparently the low sugar concentration of the cane from the 90-ft spacing treatment in 1986 was the primary reason the sugar content of the 90-ft spacing treatment was not significantly greater than that from the non-drained treatment (Table 6).

A regression of cane on sugar mass resulted in a relationship described by equation $Y = 449.5 + 60.8X$, where Y = sugar yield in lbs/A and X = cane mass in T/A. This equation is valid only for a range of cane yields between 13.8 T/A and 41.3 T/A. The r^2 value was 0.639, which means that 64 percent of the variation in sugar yield was explained by this relationship. A regression analysis of sugar yield and cane sucrose content was performed but a linear relationship was not readily evident.

The volume of water drained from the experimental sites via subsurface drainage was relatively large. Observations indicated that the cane might be suffering from drought stress at some times during the summer but water flowed readily from the subsurface drains, which were located less than three feet from the cane's roots. We observed on only two occasions during the 12-year period no flow from the drain outlet.

Flow from the drained tracts varied from 12.8 inches in 1981 to 37.9 inches in 1983 (Table 7). Average annual drain outflow was 23 inches, which was 48 percent of rainfall (Table 7). The subsurface drains were, no doubt, draining water from more than just the soil profile above the drain lines. This was readily evident during some months when the volume of water measured from the drain lines exceeded the combined volume of rainfall and the volume of thewater storage capacity of the soil. The experimental site is relatively low in elevation, less than 5 feet above sea level, and it is located within a few miles of the marshes along the edge of theGulf of Mexico. It is apparent that the subsurface drains impacted the water table outside the experimental areas far more than just half the distance between drains, which is normally used to estimate the area of influence of subsurface drains.

The amount of electrical power required to pump drain outflow from the sumps into a surface drainage ditch during the experimental period are shown in Table 7. The annual average electrical power used was 2059 kwh (176 kwh/A). The average volume of drain outflow pumped per unit of electrical energy was 3471 gal/kw. If electrical energy cost $0.08/kwh, the average annual cost for pumping drain outflow into a surface drainage ditch would be $14/A/yr.

The sugar yield increase measured during this experiment and attributed to subsurface drainage, may encourage farmers in Louisiana to install subsurface drainage if the cost can be justified. Subsurface drainage installation costs were determined for several drain spacings and soil types in Louisiana by Carter et al. (1992), and Carter and Camp (1994a,b). System costs and justification requirements for the Jeanerette soil drainage system similar to the one used in this experiment are summarized in Table 8. Only the value of crop yield increases attributed to subsurface drainage was considered in determining whether subsurface drainage can be justified. Although recognized as benefits, the value of improved cropping efficiency and improved machinery trafficability were not considered in the analysis.

Average sugar yield increases attributed to improved drainage were 936 lb/A from the 45-ft spacing, 926 lb/A from the 90-ft spacing, and 711 lb/A from the 135-ft drain spacing (Table 2). Using 1994 sugar prices for a owner/operator, the values of these yield increases were $124/A, $122/A, and $94/A, from the 45-, 90-, and 135-ft drain spacings, respectively. As with any capital expense, the cost for installing subsurface drainage must be paid by the increased sugar yield before a return on the investment is achieved with length of the pay-back period depending upon the useful system life. The number of crops (average yields) required to offset installation costs for subsurface drainage (before a return on the investment can be achieved), is six for the 45-ft spacing, and four for the 90-ft and the 135-ft spacings.

Often cash is not available to fund drain installation and a loan is required to pay initial costs. In this case, income from increased sugar yields is used to pay the loan and the amortization period will probably be limited to 10 years (decided by the lending institution) instead of the useful life of the drainage system, which is usually more than 20 years. Assuming an interest rate of 10 percent and an amortization period of 10 years, the costs of the drainage systems used in this experiment are $1077/A, $644/A, and $498/A for the 45-ft, 90-ft, and 135-ft spacings, respectively (Table 8). Because eight sugar crops are normally grown in a 10-year period in Louisiana, the yield increase in eight sugar crops must be sufficient to make ten annual payments before the system installation cost is justified. The average crop yield increase needed to justify the system installation cost is 1022 lb/A, 606 lb/A, and 473 lbs/A for systems with drains spaced 135-, 90-, and 45-ft, respectively (Table 8). The required yield increase was exceeded on the 90-ft and 135-ft drain spacing treatments but not on the 45-ft spacing treatment (Table 8). Consequently, the cost of installing subsurface drainage can be justified for the 90-ft and 135-ft drain spacings but not for the 45-ft spacing.

In addition to installation costs, there is a cost for maintenance, pump replacement, and electricity at sites where pumped (rather than gravity) drain outlets are used. Electricity cost is approximately \$14/A/yr. Pump replacement and maintenance cost is estimated at about \$10/A/yr. Consequently an additional increase of 237 lbs/A of sugar would be required to offset these operating costs. Yield increases from the 90- and 135-ft drain spacing treatments were sufficient to justify both the cost of installing drains and operating costs.

The statistical analysis showed no significant difference in cane and sugar yields among the three drain spacing treatments, which means there was no significant yield advantage to spacing drains closer than 135-ft. Thus, the recommended drain spacing for Jeanerette silty clay loam soil is 135 ft unless the trafficability benefit of closer spacing is desired: then the 90-ft drain spacing is recommended. The 1994 cost of systems with drain spacings of 135-ft and 90-ft was readily justified by increased sugar yields at the 1994 price for sugar (Table 8). In some cases, the ability to perform field operations soon after a rain may be as important as a yield increase and would allow more efficient use of farm machinery and labor.

SUMMARY

Three subsurface drain spacings were evaluated on Jeanerette silty clay loam soil planted to sugarcane. The number of days the water table was within 12 inches of the soil surface (high water table) and calculated SEW_{12} values were used to evaluate effectiveness of subsurface drainage. The average number of days the water table was within 12 inches of the soil surface annually was 3.8, 7.1, 13. 1, and 49.4 days for the 45-ft, 90-ft, 135-ft, and non-drained areas, respectively. Average annual SEW_{12} values were 18, 48, 95, and 253 inch-days for the 45-ft, 90-ft, 135-ft, and non-drained areas, respectively. Differences in average days of high water table and SEW_{12} values among three drain spacing treatments were not significantly different but differences between drained and non-drained treatments were significant, indicating that this soil responded favorably to subsurface drainage.

Average cane yields from the subsurface drained areas varied from 28.3 to 30.5 T/A but were not significantly different among the three drain spacing treatments. Yields from the subsurface drained treatments were significantly greater (2.0 T/A to 4.2 T/A greater) than those from the non-drained check. Average sugar yields (5157 - 5383 lbs/A) were not significantly different among the three drain spacing treatments. Sugar yields from the subsurface drained treatments were 711 - 937 lbs/A and significantly greater (up to 21 percent greater) than yields from the non-drained check.

From the yield standpoint, there was no advantage to spacing subsurface drains closer than 135 ft. Thus, the recommended drain spacing for Jeanerette silty clay loam is 135 feet. If the ability to perform field operations with machinery soon after a rainstorm is important, a 90-foot drain spacing is recommended. Subsurface drainage system costs with drains spaced 90-ft and 135-ft were justified by the value of increased sugar yields attributed to subsurface drainage, assuming the 1994 price for sugar and costs for drainage installation.

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Table 1. Anual rainfall, SEW_{12}, and the number of days the water table was within 12 inches of the soil surface.

		Drain spacing						Non-drained	
		---- 45-ft ----		---- 90-ft ----		----135-ft ----		----Check-----	
Year	Rain	SEW	days	SEW	days	SEW	days	SEW	days
	(in.)	inch-days (number)							
1980	66.50	78	(22.3)	165	(23.4)	292	(42.5)	337	(57.6)
1981	46.02	0		15	(1.8)	33	(5.4)	204	(29.7)
1982	70.52	0		34	(7.3)	122	(25.3)	384	(70.9)
1983	64.72	--		--		--		--	
1984	51.42	36	(3.5)	42	(5.0)	52	(6.4)	343	(57.1)
1985	61.14	9	(1.6)	51	(6.0)	77	(9.9)	259	(51.4)
1986	50.71	0		7	(1.3)	17	(4.0)	45	(10.7)
1987	57.60	42	(7.0)	119	(19.5)	266	(24.6)	420	(82.4)
1988	59.96	--		--		--		--	
1989	57.64	0		0		0		33	(10.7)
1990	42.99	0		0		0		248	(74.2)
Mean	57.20	18	(3.8)a*	48	(7.1)b	95	(13.1)c	253	(49.4)d

* Mean SEW_{12} and days followed by the same letter are not significantly different at P =0.05.

Table 2. Cane yields from subsurface-drained and non-drained treatments

Year	Drain Spacing 45-ft	Drain Spacing 90-ft	Drain Spacing 135-ft	Non-drained Check
	tons cane per acre			
1980	35.8	34.8	29.2	33.6
1981	40.1	41.3	34.8	30.8
1982	29.6	28.2	24.6	19.2
1983	--	--	--	--
1984	29.5	29.0	30.3	31.5
1985	28.1	28.2	24.6	25.7
1986	29.5	30.3	27.5	29.3
1987	18.8	17.7	19.0	20.6
1988	--	--	--	--
1989	38.7	38.8	36.9	31.9
1990	24.2	25.2	27.7	13.8
Mean	30.5a*	30.4a	28.3a	26.3b

*Mean cane yields followed by the same letter are not significantly different at $P = 0.05$.

Table 3. Stalk populations from subsurface-drained and non-drained treatments.

Year	Drain Spacing 45-ft	Drain Spacing 90-ft	Drain Spacing 135-ft	Non-drained Check
	stalks per acre			
1980	38850	37147	34858	33517
1981	37331	31218	33568	37679
1982	23875	28958	30652	25991
1983	--	--	--	--
1984	27872	27405	29851	28208
1985	27200	26547	24571	28040
1986	28955	26099	28899	27499
1987	24456	23000	23130	24941
1988	--	--	--	--
1989	35220	34286	33767	28241
1990	18444	19714	19956	7234
Mean	29134a*	28264a	28806a	26817a

*Mean stalk populations followed by the same letter are not significantly different at $P = 0.05$.

Table 4. Stalk weights from subsurface-drained and non-drained treatments.

Year	----- Drain Spacing ----- 45-ft	90-ft	135-ft	Non-drained Check
	---(lb/stalk)---			
1980	1.85	1.90	1.68	2.00
1981	2.15	2.65	2.08	1.65
1982	2.50	1.94	1.62	1.47
1983	--	--	--	--
1984	2.13	2.13	2.02	2.25
1985	2.07	2.13	2.03	1.83
1986	1.98	2.26	1.84	2.04
1987	1.54	1.56	1.74	1.66
1988	--	--	--	--
1989	2.20	2.27	2.18	2.26
1990	2.73	2.78	2.80	3.89
Mean	2.13a*	2.18ab	2.00a	2.12a

*Mean stalk weights followed by the same letter are not significantly different at $P = 0.05$.

Table 5. Sugar yields from subsurface-drained and non-drained treatments.

Year	---------- Drain Spacing ---------- 45-ft	90-ft	135-ft	Non-drained Check
	--------------- lbs per acre ---------------			
1980	5251	5270	5053	4603
1981	7100	7105	6687	5349
1982	4810	4969	3511	2776
1983	--	--	--	--
1984	4826	5176	5602	5137
1985	5701	6041	5123	5296
1986	5252	4857	5159	5116
1987	4860	4149	4728	4712
1988	--	--	--	--
1989	7495	7190	7293	5710
1990	3150	3592	3261	1319
Mean	5383a*	5372a	5157a	4446b

*Mean sugar yields followed by the same letter are not significantly different at $P = 0.05$. Yield differences between drained and non-drained treatments were significant at $P = 0.01$.

Table 6. Sugar content of cane from subsurface-drained an non-drained treatments.

Year	Drain Spacing 45-ft	Drain Spacing 90-ft	Drain Spacing 135-ft	Non-drained Check
	lbs sugar per ton of cane			
1980	147	151	173	137
1981	177	172	192	174
1982	163	176	143	145
1983	--	--	--	--
1984	164	178	185	163
1985	203	214	208	206
1986	178	160	188	175
1987	258	234	249	229
1988	--	--	--	--
1989	194	185	198	179
1990	130	143	118	96
Mean	179 a*	179ab	184a	167b

*Mean sugar contents followed by the same letter are not significantly different at $P = 0.05$.

Table 7. Drain outflow from subsurface-drained tracts and electrical power required to pump outflow into a surface drainage ditch.

Year	Rainfall (inches)	Drain Outflow (inches)*	Electricity (kwh) Total	Electricity (kwh) Per Acre
1980	66.50	**	**	**
1981	46.02	12.83	1146	98
1982	70.52	30.68	2761	236
1983	64.72	37.94	3405	291
1984	51.42	28.68	2562	219
1985	61.14	29.88	2644	226
1986	50.71	19.82	1825	156
1987	57.60	18.44	1696	145
1988	59.96	20.05	1778	152
1989	57.64	17.54	1591	136
1990	42.99	13.99	1205	103
Mean	57.20	22.98	2059	176

* Equivalent depth of drain outflow for area drained.

** Drain outflow measurements began in 1981.

Table 8. Sugar yield increases needed to justify the cost of installing subsurface drainage in Jeanerette silty clay loam soil.

Drain Spacing	Drain Install Cost	Interest Cost*	Total Cost	Annual Payment	Yield Increase Needed**	Yield Increase Observed
(ft)	($/A)	($/ha)	($/ha)	($/yr)	(lb/A)	lb/A
45	679	398	1077	108	1022	936
90	406	238	644	64	606	926
135	314	184	498	50	473	711

* Based on 10 percent interest and 10-year amortization period.

** Eight sugar crops are normally grown in a 10-year period in Louisiana. Thus, the needed yield increase in eight sugar crops must be sufficient to make ten payments to justify the cost of installing subsurface drains.

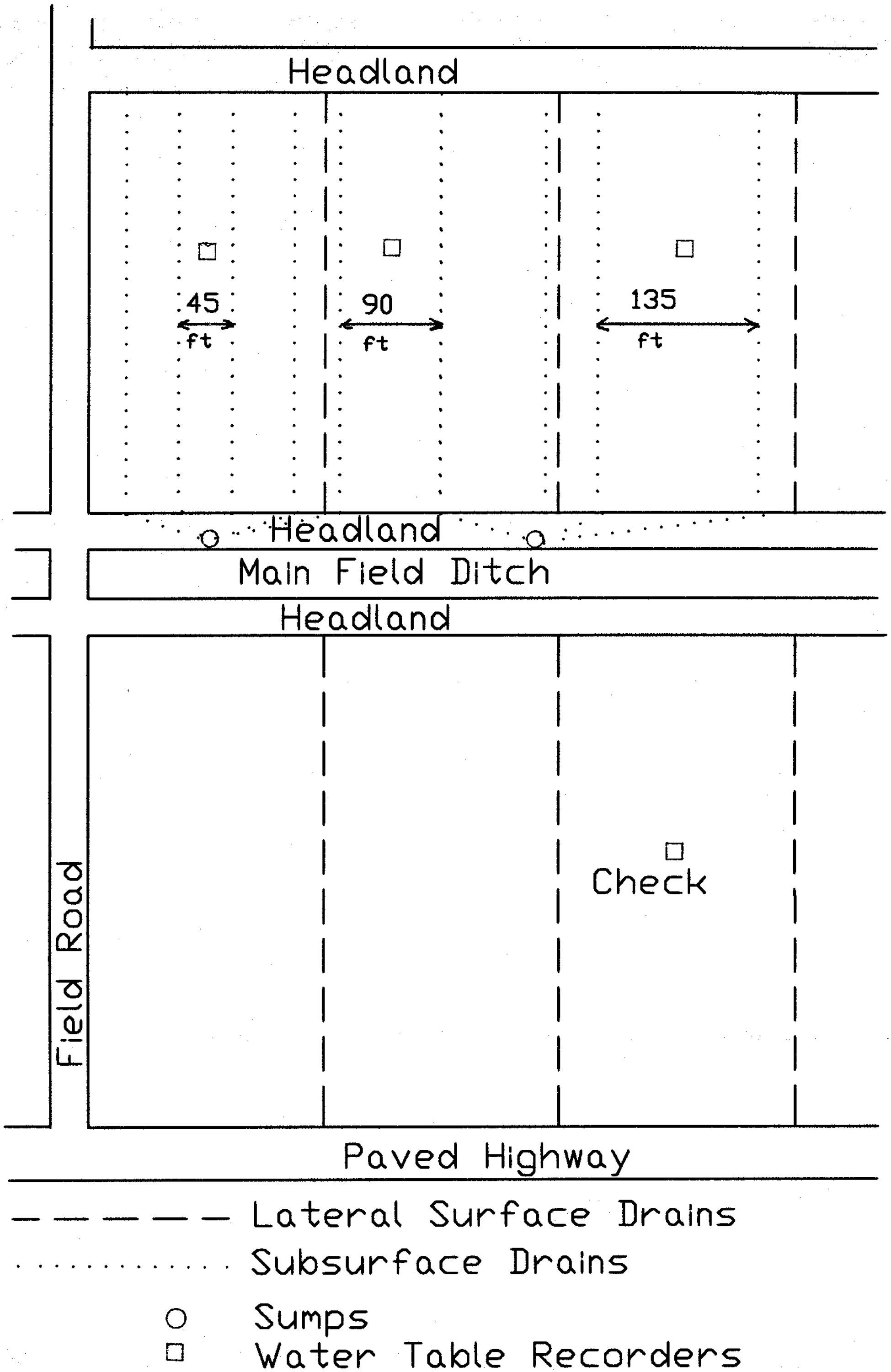

Figure 1. Layout of subsurface drainage experiment in Iberia Parish, LA

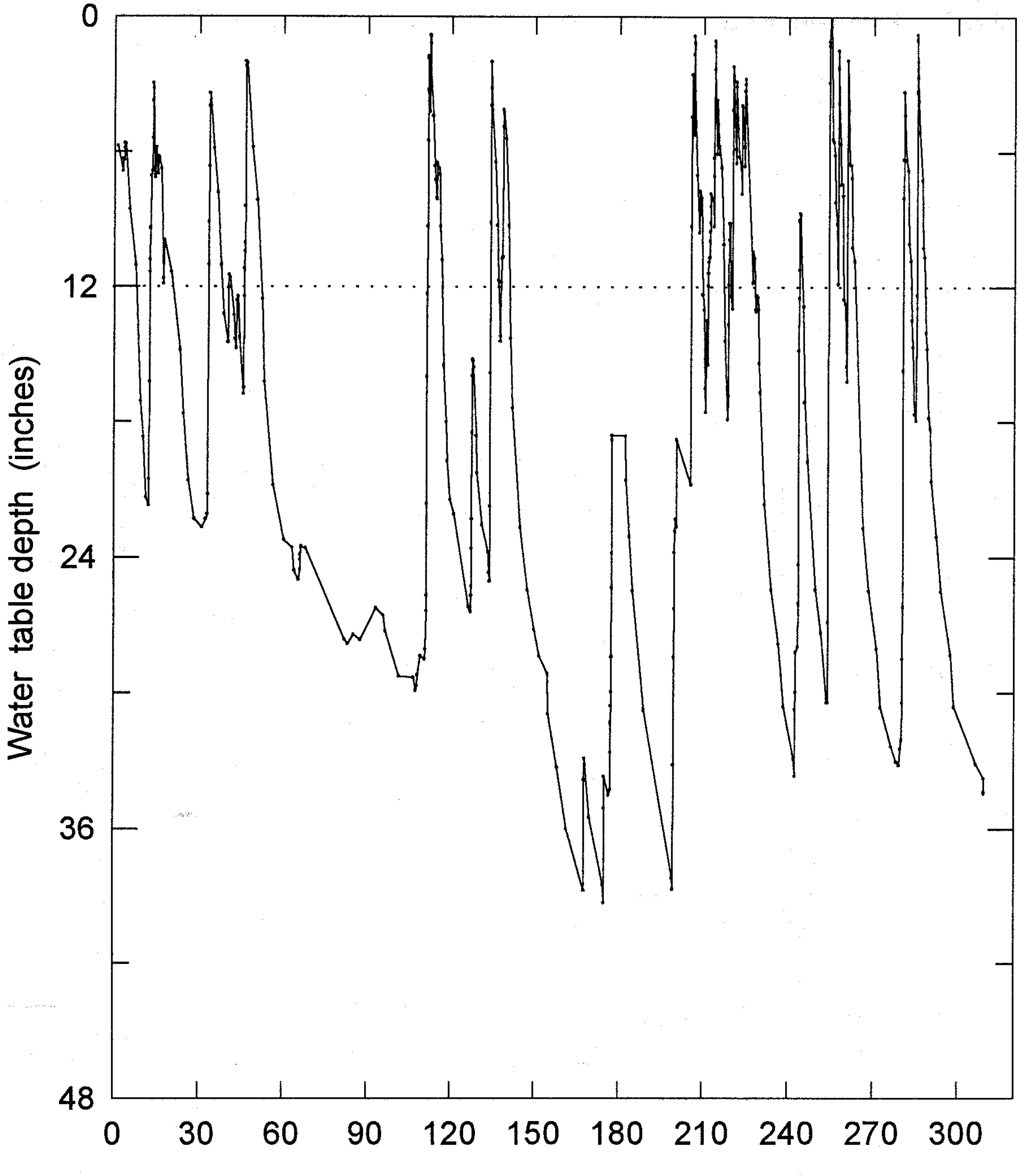

Figure 2. Water table depth for the check treatment in 1982. The water table was within 12 inches of the soil surface 17 times for a total of 70.9 days. SEW_{12} was 384 inch-days.

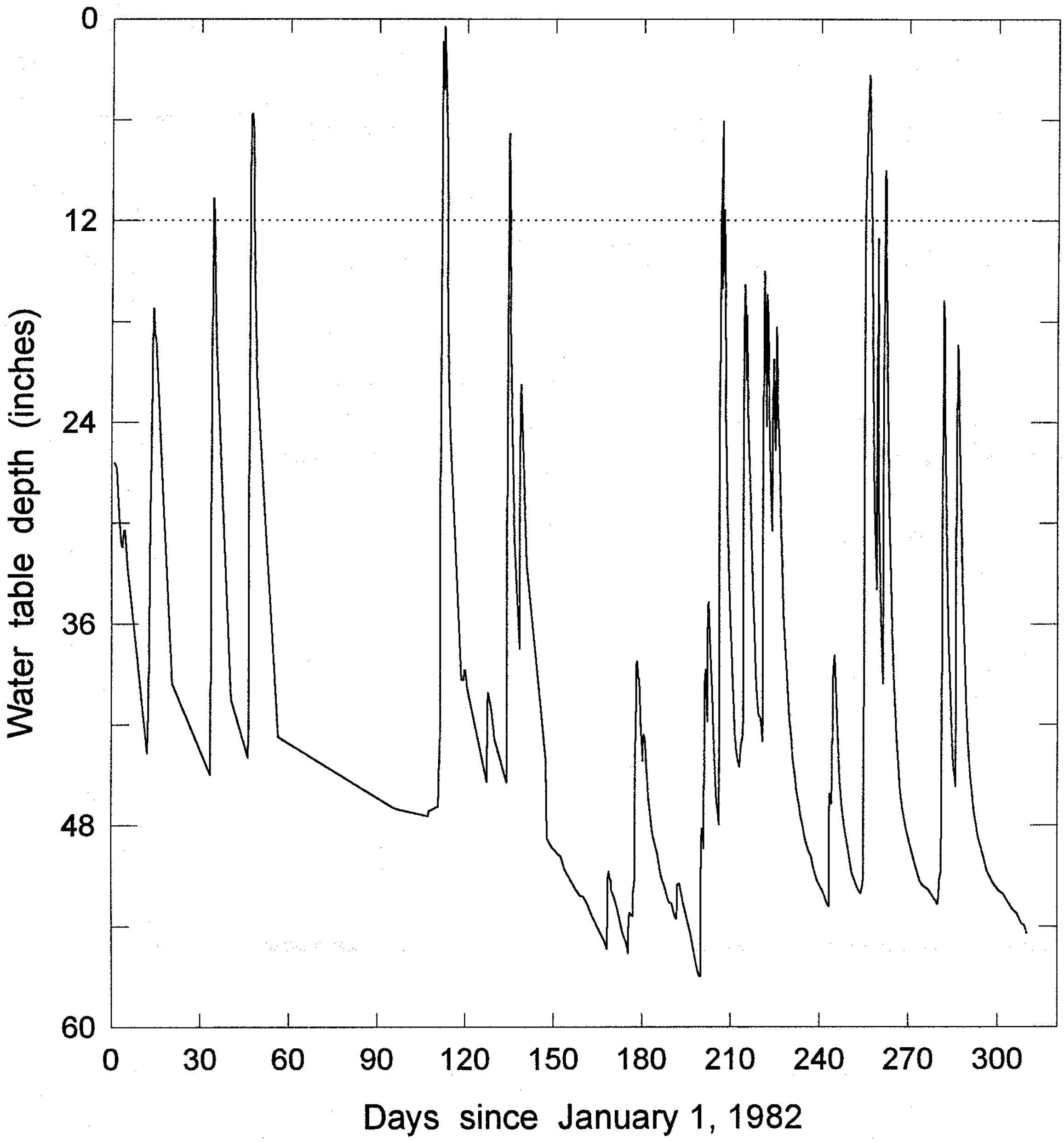

Figure 3. Water table depth for the 90-foot drain spacing treatment in 1982. The water table was within 12 inches of the soil surface eight times for a total of 7.3 days. SEW_{12} was 34 inch-days.

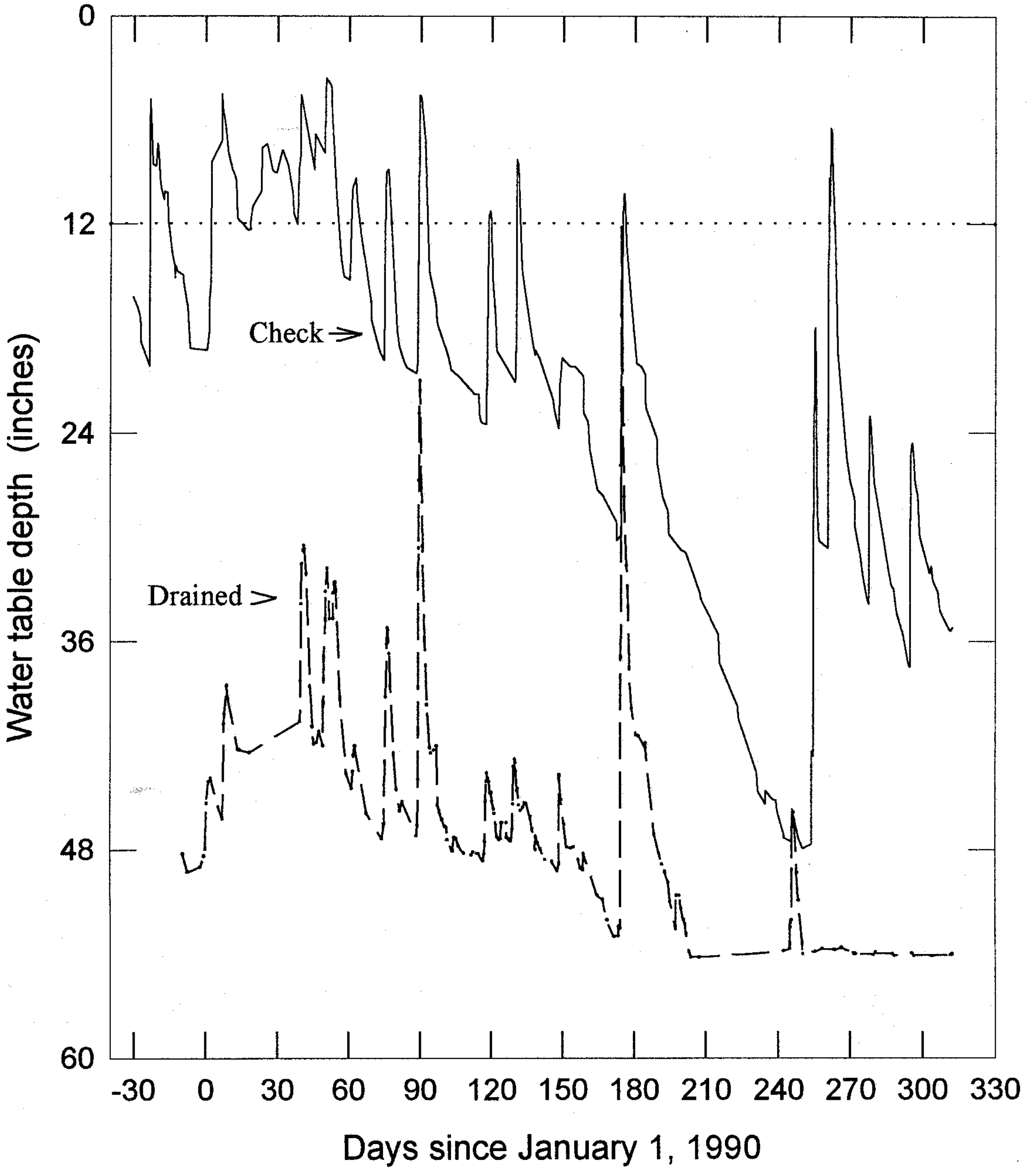

Figure 4. Water table depths for subsurface drained (90-ft spacing) and non-drained (check) in 1990. The water table in the drained area never came within 12 inches of the soil surface while the water table in the check was within 12 inches of the soil surface 10 times for a total of 74.2 days. SEW was 248 inch-days.