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PRESENTATION

# DRAINAGE AND IRRIGATION EFFECTS ON COTTON PRODUCTION

by

C. R. Camp, Agricultural Engineer
W. M. Thomas, Research Entomologist
C. W. Doty, Agricultural Engineer (deceased)
USDA-ARS
Florence, South Carolina 29502-3039

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**SUMMARY:** Three controlled drainage treatments, both with and without micro irrigation, were evaluated for cotton on a Coastal Plain soil in 1987-88. Cotton lint yields for micro-irrigation treatments were significantly higher both years. Water requirement was high for the controlled drainage/subirrigation treatment, but yields were not different from other drainage treatments.

**KEYWORDS:** Controlled drainage, Subirrigation, Micro irrigation, trickle irrigation



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## INTRODUCTION

Erratic rainfall distribution and low water storage capacity of the coarse-textured soils in the southeastern Coastal Plain can cause both excessively wet and excessively dry soil conditions in the same growing season. Most soils can store enough water to support plant growth for only 5 to 10 days. Although annual, and often seasonal, rainfall is equal to or greater than evapotranspiration (ET), the distribution is so erratic that drought periods occur most years. Because periods of high rainfall can cause high water tables that fluctuate within 2 m of the surface of some soils, drainage is often required; however, these same soils can dry excessively during low rainfall periods, causing crops to suffer from drought stress if irrigation is not used. Water management system that provide drainage during wet soil conditions and irrigation during dry soil conditions are ideal.

Several controlled drainage/water table management systems have been proposed and evaluated in recent years. Doty et al. (1975), Doty and Parsons (1979), Skaggs (1972) and Skaggs et al. (1972) showed that controlled drainage systems work in Coastal Plain soils. Investigations by Doty et al. (1975), Rogers and Harrison (1974), Williamson and Gray (1973), Hiler et al. (1971), Campbell and Seaborn (1972), Williamson and Kriz (1970), and Follett et al. (1974) indicate that best crop yields are obtained when water tables are maintained from 0.6 to 1.0 m below the soil surface. Skaggs (1977) found that overdrainage could occur in coarse textured soils of the Coastal Plain and suggested closer drain line spacings (30 m) for subirrigation systems to minimize this effect during drought. Follett et al. (1974), Tovey (1969), and Carter and Floyd (1972) found that providing surface irrigation in systems where the water table was maintained within 1 m of the soil surface produced no increase in crop yield; however, the soils in these systems had higher water storage capacities than soils of the Coastal Plain.

Most research with controlled drainage/water table management systems has been with water-intensive crops such as corn, or with soybean. With the possible eradication of the boll weevil, and improved market price, cotton has again become an attractive crop in the Coastal Plain. The objectives of this study were (1) to determine yield response of cotton for three different controlled drainage systems, (2) to determine yield response of cotton to surface micro irrigation in combination with three controlled drainage systems, and (3) to determine water requirements for both controlled drainage and micro-irrigation systems.

## MATERIALS AND METHODS

The experiment was conducted on a 1.7-ha site of Goldsboro sandy clay loam (Aquic paleudults) that had a surface slope of 0.75 percent in the direction of the subsurface drains but had no side slope. The three controlled drainage treatments included controlled drainage/subirrigation (CDSI), controlled drainage (CD), and subsurface drainage (SSD) (Fig. 1). In the CDSI treatment, water was maintained in the control sump at an elevation sufficient to maintain the water table in the experimental area at a specified elevation throughout the growing season. Water was pumped into the sump whenever necessary to maintain the desired water table elevation. In the CD treatment, the drainage outlet was set at an elevation above the field drain elevation, but no additional water was added. In the SSD treatment, water was allowed to drain freely from all drains throughout the season. Drain lines in all treatments were 65 m long. In the CDSI treatment, the drain lines were 80-mm diameter, perforated, corrugated PVC conduits wrapped in coconut fiber and were installed with a laser-controlled drain-tube plow in 1974. These drain lines were spaced 8 m apart and had a slope of 0.2 percent. The drain-line depth varied from 0.9 m to 1.2 m from the lower to upper sides of the plot area. The three drain lines were connected to a non-perforated 200-mm diameter main that was perpendicular to the perforated laterals. The main was connected to a constant head tank, which controlled the water entering or leaving the plot area. Water was supplied to the head tank by an electrical pump submerged in an adjacent pond. The amount of water pumped was measured by an in-line flow meter which was observed daily.

Inside the constant head tank, a V-notch weir box was connected to the tank drainage outlet with a flexible tube. The water table in the plot area was managed by adjusting the height of the weir box within the tank. A float control was mounted on the weir box so that when it was raised or lowered, the float control was adjusted appropriately. Drainage occurred when the weir box was lowered or when the water level in the tank rose above the V-notch weir. Drainage volume from the plot area was calculated from measurements of water elevation inside the tank. When subirrigation was required, water flowed from the tank into the field through the main and perforated lateral drains. When the tank water level dropped about 60 mm, the float-controlled electrical switch activated the pump and refilled the tank to the bottom of the V-notch weir. Additional details regarding drain line installation and operation of the constant head tank can be found in Doty and Parsons (1979).

Drain lines in the CD and SSD treatments were 100-mm diameter, corregated polyethylene tubing and were spaced 16 m apart. These tubes were installed with a trencher in 1978 and replaced the original, coconut-fiber-wrapped drain lines in this portion of the experimental site. Drainage water from the CD treatment flowed from the drain lines into a collection sump. The sump drainage outlet was 0.5 m above the bottom of the field drain line so that the water table midway up the drain line was about 0.6 m below the soil surface before drainage occurred, provided sufficient rainfall occurred. During low rainfall conditions, the water level was allowed to drop below this control point. Drainage water volume from the CD treatment area was calculated from sump water level measurements recorded with a water level recorder. Drainage water in the SSD treatment flowed continuously through a gravity drain. Drainage volume in the center drain of the SSD treatment was measured using a slotted tube inserted into the drain line, which was connected to a stilling well where the water elevation was measured continuously with a water level recorder.

Within each treatment area, two blocks of plots, each 24 m wide (25 rows) and 32 m long were located over the drain lines with row direction perpendicular to drain lines. In 1987, each block consisted of 20 plots, each five rows wide and 8 m long. In 1988, each block consisted of 24 plots, each four rows wide and 8 m long which provided two plots for each treatment in each replication. Each controlled drainage treatment was split to provide either surface micro-irrigation or no irrigation. Dual-chamber micro-irrigation tubing that had outlets spaced 0.2 m apart and a delivery rate of 9.5 L/min per 100 m was installed on the surface in each row. Irrigation timing and amounts were determined using a water balance technique with daily ET being estimated from screen-covered pan evaporation measurements and crop coefficient values obtained from SCS (1970). Irrigation to refill the soil profile was applied any day the soil-water deficit was at least 12 mm. The experimental design provided four replications with each replication extending across all rows in a direction parallel to drain lines.

Rainfall and pan evaporation were measured with a standard U.S. Weather Service recording rain gauge and a screen-covered Class A evaporation pan adjacent to the site. Water table level within each treatment area was measured continuously with water level recorders at nine locations within each treatment area.

Five cotton cultivars were planted on 30 April 1987, and three cotton cultivars were planted on 4 May 1988 to provide a plant population of about 88,000 plants/ha. Cotton cultivars, DPL50, DPL90, and Coker 315 were planted both years, but PD2 and PD3 were planted in 1987 only because of unavailability of seed in 1988. Broadcast preplant fertilizer included 98 kg/ha N, 36 kg/ha P, and 105 kg/ha K in 1987 and 42 kg/ha N, 18 kg/ha P, and 35 kg/ha K in 1988. One additional N application of 75 kg/ha was made each year. Temik was applied at planting each year to control thrips, and weekly applications of Pydrin and Fundal were made beginning in June each year to control *Heliothis* spp. Defoliant (DEF + PREPP) was applied on 14 September 1987, but no defoliant was applied in 1988 because of extreme variation in maturity.

A 2-$m^2$ sample from one row in each plot was harvested by hand on 17 September 1987 and 18 October 1988 to determine yield. Cotton yields were analyzed as a split-split plot design with four replications using analysis of variance (ANOV) and least significant difference (LSD) procedures each year. Cotton lint yield was calculated from lint percentages determined from samples collected from each plot. Tensiometers were installed at five depths at each of four locations within each controlled drainage-irrigation treatment. Tensiometer measurements were recorded three times each week and serviced as required. Rainfall, pan evaporation, irrigation amount, water added to or removed from CDSI treatment, and water table depths in all treatments were recorded at least daily.

## RESULTS AND DISCUSSION

Seasonal rainfall and irrigation for all controlled drainage treatments and seasonal subirrigation amounts for the CDSI treatment during both years are included in Table 1. Daily rainfall and micro-irrigation amounts during the growing season for the three controlled drainage treatments are shown in Figures 2 and 3 for 1987 and 1988, respectively. Rainfall amounts were about 25 percent higher in 1988 than in 1987 and irrigation amounts were also slightly higher in 1988. Rainfall was also better distributed throughout the growing season in

1988, which resulted in more uniform irrigation applications. In order to maintain the water table at the desired level in the CDSI treatment, 1477 and 2841 mm of water, calculated as equivalent rainfall for the area, was pumped into the system in 1987 and 1988, respectively (Table 1). These amounts are considerably higher than those reported for a comparable treatment operated on the same site in 1975-77 (Doty and Parsons, 1979). Also, the large difference in water volume pumped for the two years cannot be fully explained. The CDSI treatment was started more than a month later in 1987 than in 1988, but this would not account for all the difference measured. The total amount of water available in the CD and SSD treatments was similar for both years, but the amount of water required for the CDSI treatment was three to five times that required by the other two treatments. Although the pump in the CDSI treatment operates at a very low pressure and has a lower power requirement, the significantly higher water volume required (even if the amount is reduced by the amount needed for micro irrigation) would result in higher operating cost.

Table 1. Seasonal irrigation and rainfall amounts for three controlled drainage treatments, all with and without micro irrigation, for a Coastal Plain soil.

| Controlled drainage treatment* | Rainfall | Micro Irrigation | Subirrigation | Total |
|---|---|---|---|---|
| | mm | | | |
| 1987 | | | | |
| CD | 423 | 278 | - | 701 |
| CDSI | 423 | 290 | 1477 | 2190 |
| SSD | 423 | 270 | - | 693 |
| 1988 | | | | |
| CD | 559 | 314 | - | 873 |
| CDSI | 559 | 312 | 2841 | 3712 |
| SSD | 559 | 299 | - | 858 |

* CD=controlled drainage; CDSI=controlled drainage, subirrigation; SSD=subsurface drainage.

Water table depths at the midpoint between drain lines in three controlled drainage treatments are shown in Figures 4 and 5 for the 1987 and 1988 growing seasons, respectively. As expected, the water table was nearer the soil surface in the CDSI treatment both years, but the differences in water table depths were not closely related to the water volumes available in each treatment. Water tables in the CD and SSD treatments were only 0.3-0.6 m deeper that in the CDSI treatment in 1987, and no supplemental water was added to these treatments. In 1988, the differences in water table depths were even less although considerably more water was available in the CDSI treatment. The large volume of water required for the CDSI treatment could have been caused by lateral and vertical losses through the coarse-textured subsoil. Doty and Parsons (1979) experienced difficulty in maintaining a shallow water table in this system during a previous experiment. It is also possible that water losses from the CDSI treatment were sufficient to influence the water table in the CD and SSD treatments. No drainage outflow was measured during the growing season either year for any controlled drainage treatment. Some drainage from the CDSI treatment occurred when the weir box was adjusted to a lower elevation in anticipation of rainfall, but this discharge was not measured. A trace of drain outflow was recorded for the SSD treatment on one or two occasions.

Cotton lint yields for six controlled drainage-micro-irrigation treatments in 1987 and 1988 are included in Tables 2 and 3, respectively. In 1987 there were no significant differences in yield among the three controlled drainage treatments; however, for rainfed conditions, yield was numerically higher for the CDSI treatment than for the CD and SSD treatments. Mean cotton lint yield across all controlled drainage treatments was significantly higher for the micro-irrigated treatment (1127 kg/ha) than for the rainfed treatments (492 kg/ha). In 1988 differences in cotton lint yields among the controlled drainage treatments were numerically greater than in 1987 but were not significantly different. Yields were lowest for the CDSI treatment and about equal for the other two controlled drainage treatments. Yields for the rainfed treatments (801 kg/ha) were higher in 1988 but were again significantly lower than for the micro-irrigation treatments (1116 kg/ha). The greater variance in yields in 1988 may have been caused by unfavorable weather and soil conditions at planting time which caused difficulty in obtaining adequate plant population and resulted in poor seedling vigor. There were no significant cotton lint yield differences among cultivars either year nor were there any significant interactions among treatments.

Table 2. Cotton lint yield for three controlled drainage treatments, all with and without micro irrigation, in 1987 on a Coastal Plain soil.

| Controlled drainage treatment* | Irrigated | Rainfed | Mean |
|---|---|---|---|
| | ---------------- | kg/ha | ------------ |
| CD | 1224 | 485 | 854a |
| CDSI | 1013 | 603 | 808a |
| SSD | 1143 | 387 | 765a |
| Mean | 1127a | 492b | |

* CD=controlled drainage; CDSI=controlled drainage, subirrigation; SSD=subsurface drainage.

Table 3. Cotton lint yield for three controlled drainage treatments, all with and without micro irrigation, in 1988 on a Coastal Plain soil.

| Controlled drainage treatment* | Irrigated | Rainfed | Mean |
|---|---|---|---|
| | kg/ha | | |
| CD | 1157 | 886 | 1022a |
| CDSI | 1013 | 658 | 836a |
| SSD | 1177 | 858 | 1017a |
| Mean | 1116a | 801b | |

* CD=controlled drainage; CDSI=controlled drainage, subirrigation; SSD=subsurface drainage.

## SUMMARY AND CONCLUSIONS

Cotton lint yield was determined for three controlled drainage treatments, two irrigation treatments, and five or three cotton cultivars for 1987 and 1988 on a Coastal Plain soil. There were no significant differences in yield among the controlled drainage treatments or among cotton cultivars either year. A large volume of water had to be pumped into the controlled drainage-subirrigation (CDSI) treatment both years in order to maintain the water table, but cotton lint yield was not significantly improved. Micro irrigation significantly improved yields for the CDSI as well as the other two controlled drainage treatments.

Based on these preliminary results (1987-88), significant cotton yield increases can be obtained with micro irrigation, even where the water table is maintained within 1 m of the soil surface during the growing season. For the coarse-textured soils in the Coastal Plain, it may be necessary to maintain the water table closer to the soil surface, particularly when rainfall amounts are lower than normal. In view of the large water requirement for the CDSI treatment, this may not be a profitable alternative for this soil-crop combination. If subsurface drainage is required, these results indicate that the SSD or CD treatments with micro irrigation would provide equivalent yields and would not require nearly as much water.

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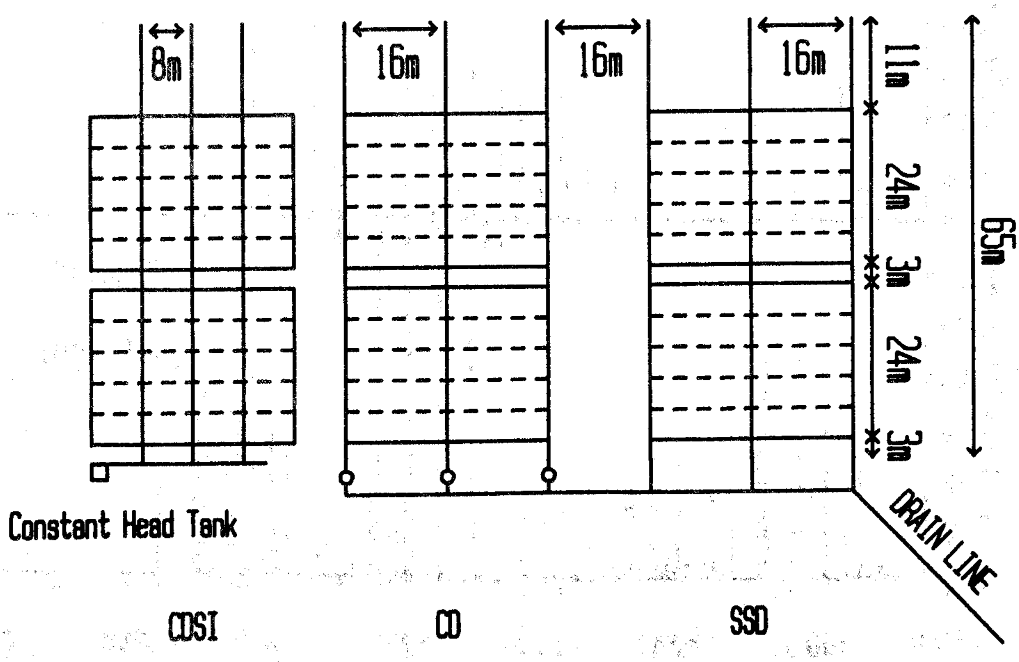


Figure 1. Schematic diagram of experimental area on a Coastal Plain soil showing three controlled drainage treatments and plot boundaries.

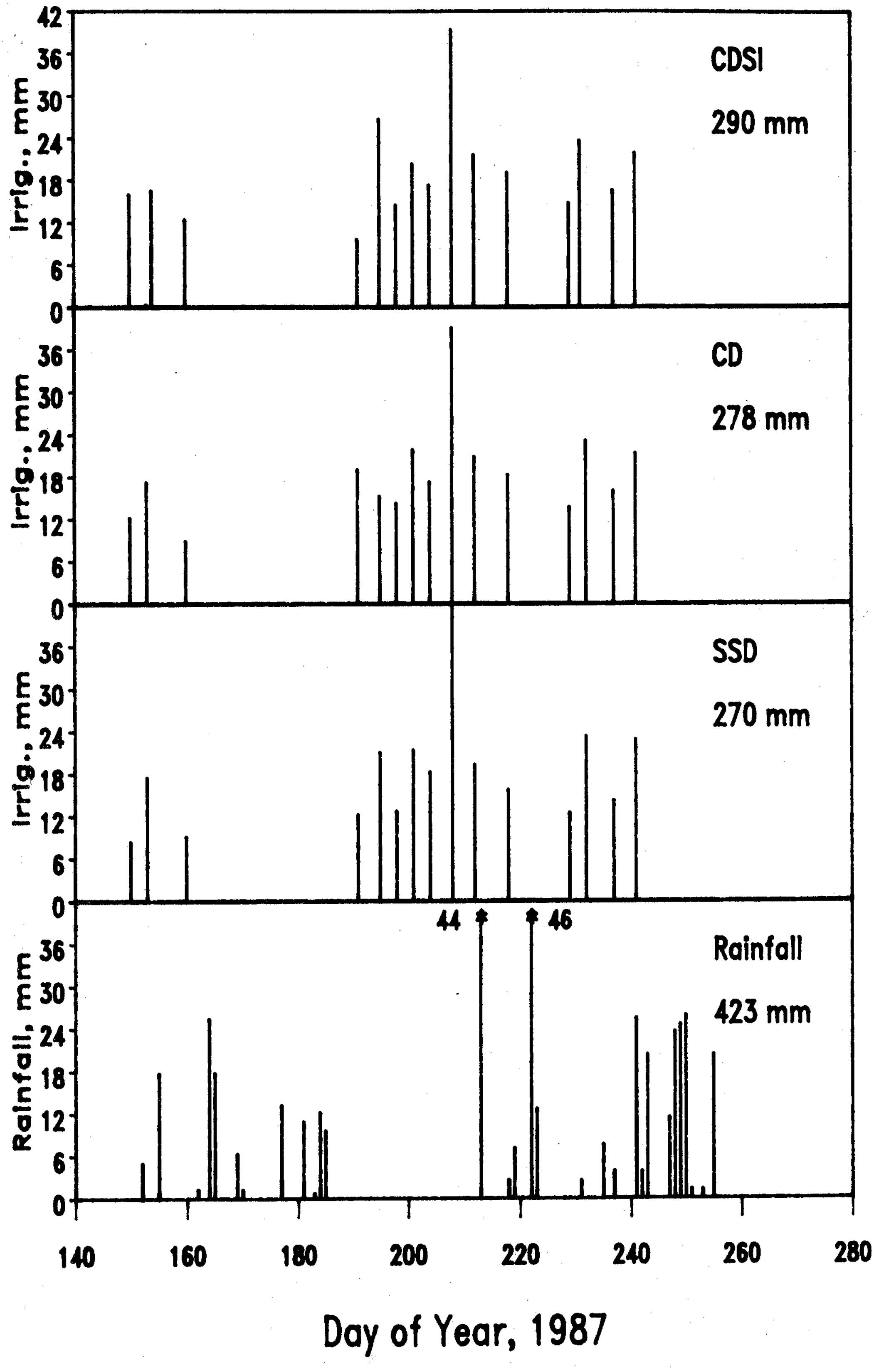


Figure 2. Daily rainfall and micro-irrigation amounts during the growing season for three controlled drainage treatments on a Coastal Plain soil in 1987.

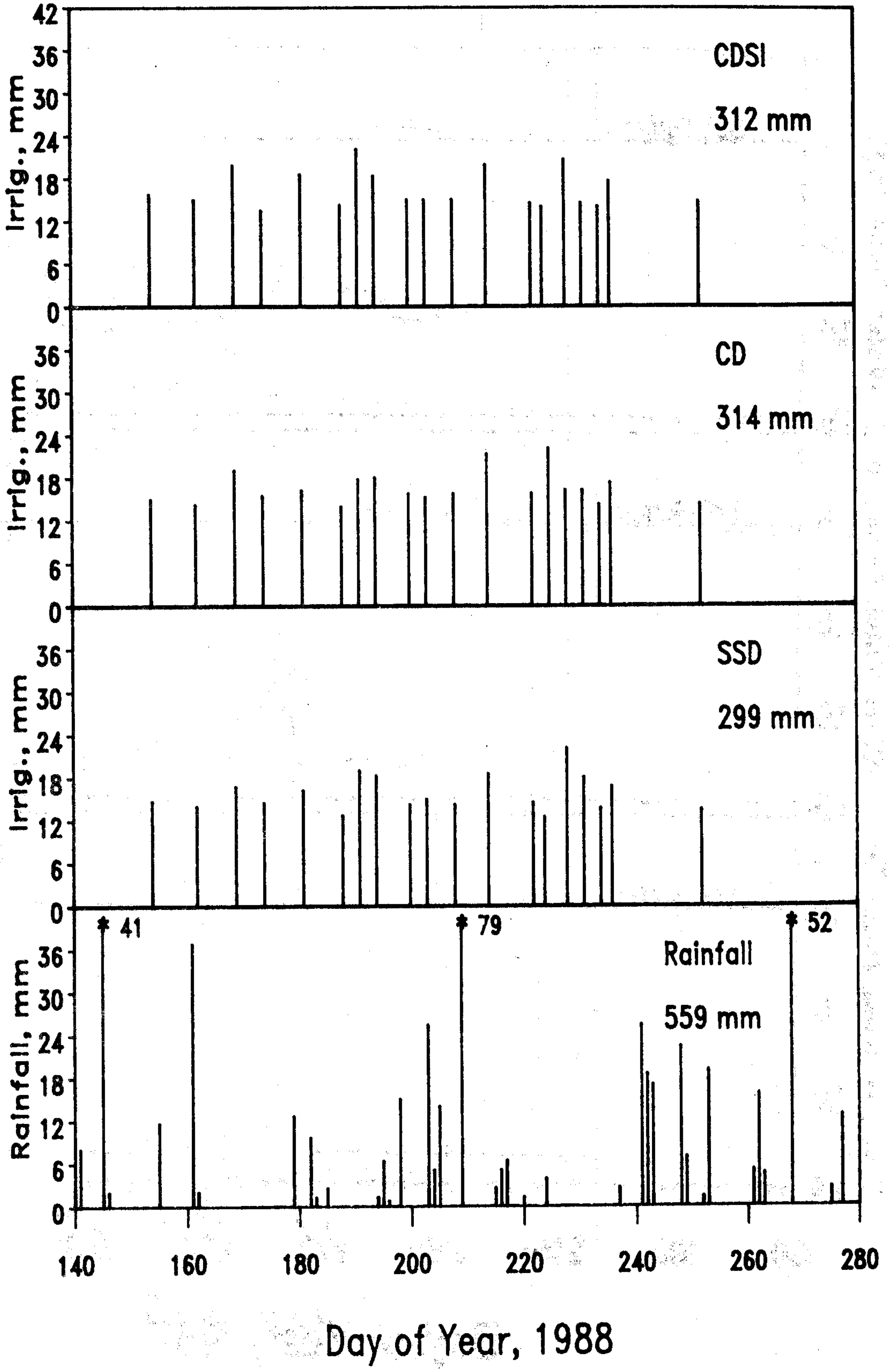


Figure 3. Daily rainfall and micro-irrigation amounts during the growing season for three controlled drainage treatments on a Coastal Plain soil in 1988.

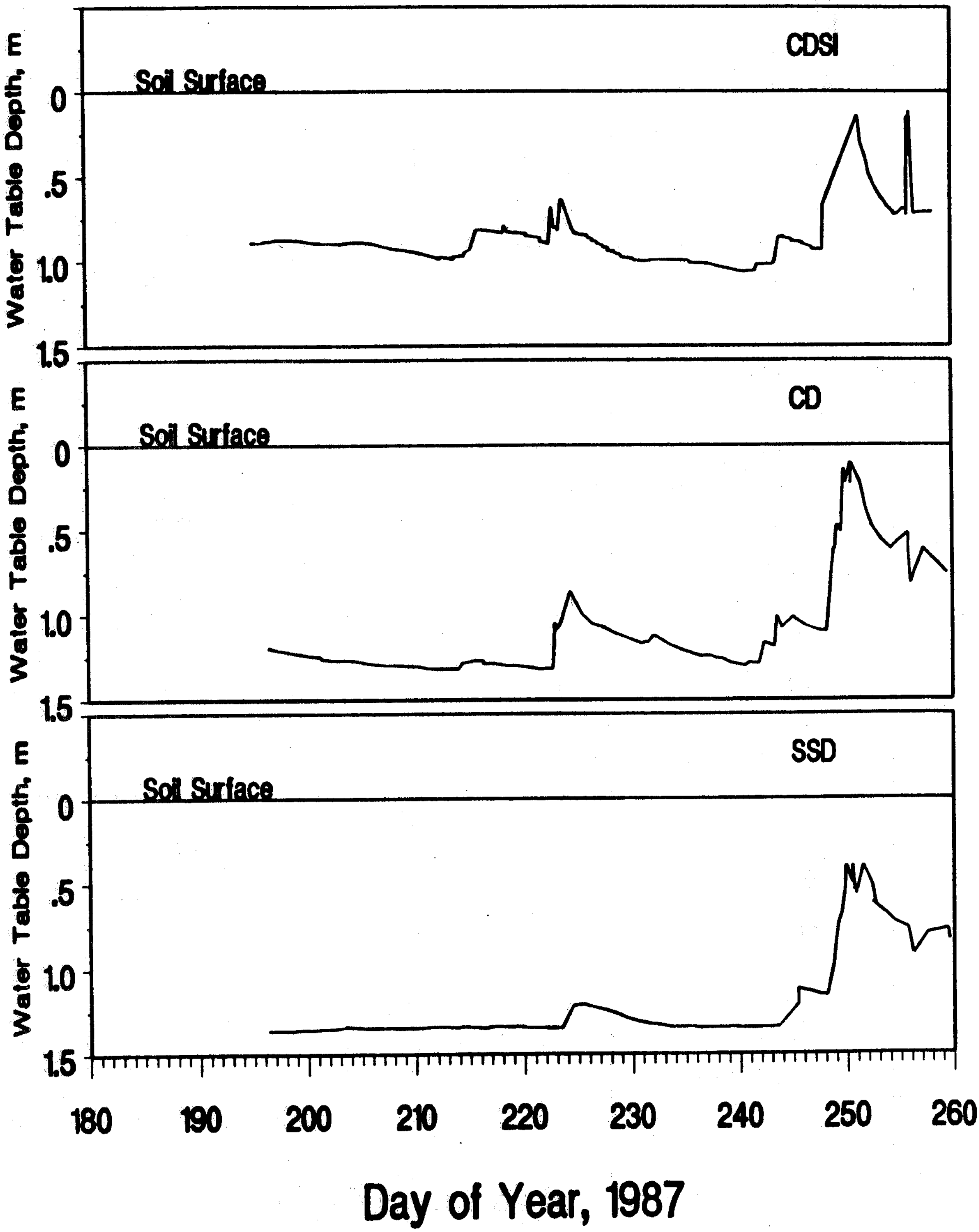


Figure 4. Controlled drainage depths for three controlled drainage treatments on a Coastal Plain soil during the growing season in 1987.

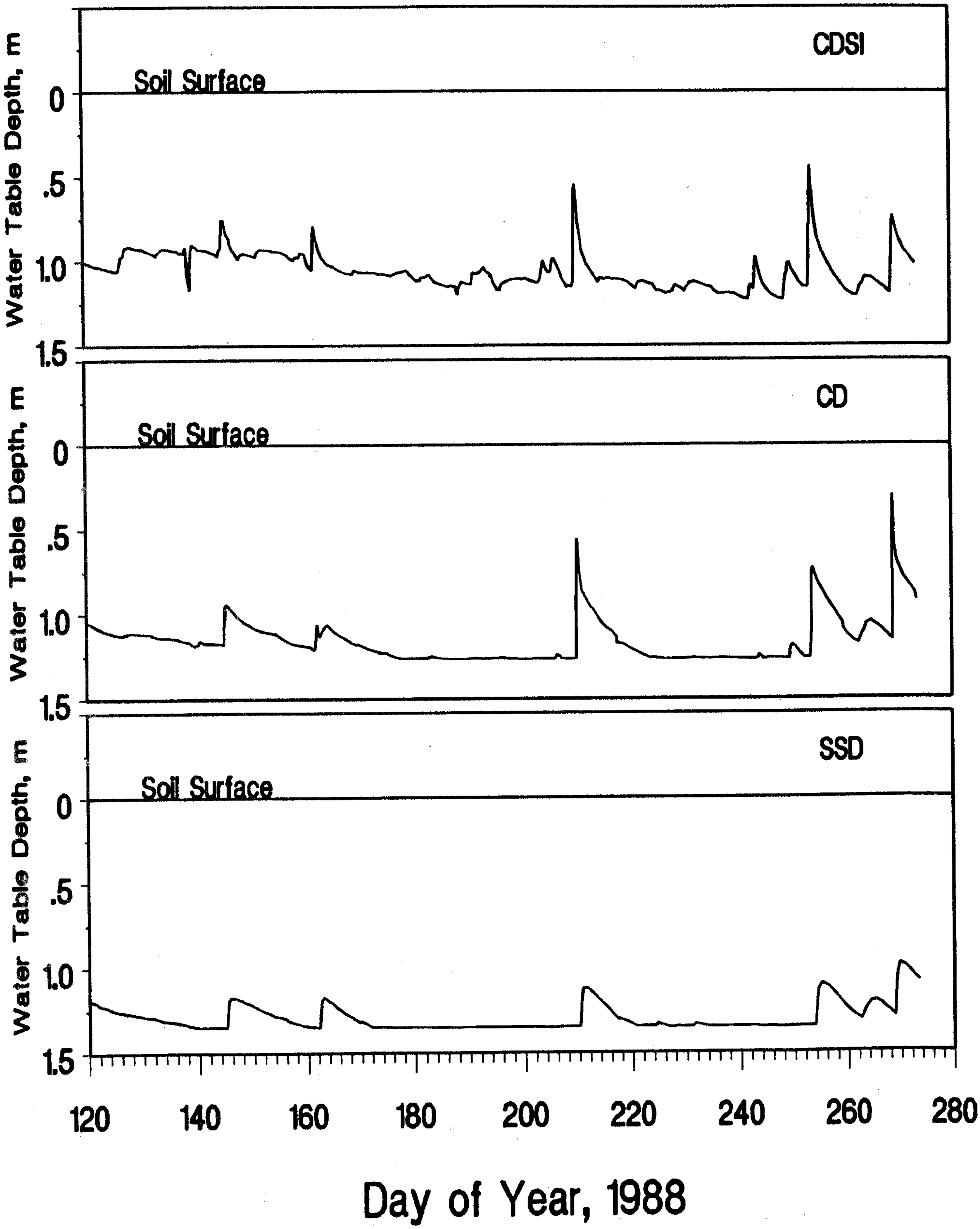


Figure 5. Controlled drainage depths for three controlled drainage treatments on a Coastal Plain soil during the growing season in 1988.