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COMPARISON OF IRRIGATION SCHEDULING TECHNIQUES FOR HIGH PRODUCTION CORN

by

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SUMMARY:
With proper water, nutrient, and cultural practices, it is feasible to produce high and profitable corn yields in the Southeastern Coastal Plain. Three irrigation scheduling methods provided different soil water regimes, required different amounts of irrigation water, but produced similar corn grain yields which were all higher than the nonirrigated yields.

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INTRODUCTION

Irrigation in the humid Southeast has increased rapidly during the past few years particularly in the Coastal Plain region where the coarse-textured soils have low water-holding capacities. Although annual rainfall equals or exceeds evapotranspiration, seasonal rainfall is not adequately distributed during the crop growing season. Also, because of the soils' low water-holding capacities, crops suffer from drought stress after 5-7 days without rainfall unless irrigation is provided. To justify the investment in irrigation equipment, landowners are planting more land area to water responsive crops such as corn and are multiple cropping. Failure to change cultural practices and improve water and nutrient management practices can result in yields which are insufficient to offset increased production costs.

Several irrigation scheduling methods have been suggested for the humid region, but few have been applied in irrigation management in the southeastern U.S. The use of soil water potential to manage irrigation is widely recognized and recommended (Bruce et al., 1980; Rhoads, 1982), but this technique is not being widely used (Lambert, 1980). Various adaptations of the water budget technique have been developed, but are often restricted to specific crops, soils, or climatic regions (Gregory and Schottman, 1982; Doty et al., 1982; Lambert et al., 1981). Development of a water budget procedure for the personal computer (Lambert, 1980) and increased availability of these machines provide another method for scheduling irrigation which offers the capability for a single computer to manage several irrigation systems under a wide variety of soil, crop, and climatic conditions.

The development and evaluation of several cultural and nutrient management practices have shown that corn yields of 14.5 t/ha are possible with irrigation in Coastal Plain soils (Rhoads, 1982). The objectives of our research were: (1) to compare two irrigation scheduling methods, (2) to compare corn yields from these two irrigated treatments with yield from a nonirrigated treatment, and (3) to compare new cultural management concepts with those currently recommended for corn production in the region.

MATERIALS AND METHODS

This research was conducted over a three-year period (1980-82) on a Norfolk loamy sand (Typic Paleudult). Four variables including water management, row configuration, plant population, and fertility were arranged in a split-plot design which was replicated four times. However, in this paper, only water management and row configuration results will be discussed. Water management treatments included scheduling irrigation by two different methods and a nonirrigated treatment. In 1980 tensiometers were used to manage irrigation on both irrigated treatments. Water was applied when soil water tension at any depth exceeded either 25 or 50 kPa. In 1981 and 1982 water was either applied when the soil water tension exceeded 25 kPa or when indicated by a computerized water balance (Lambert, 1980). The computerized water balance utilized daily maximum and minimum temperature, solar radiation, rooting depth, rainfall, and irrigation as inputs to calculate evapotranspiration (ET) and volumetric soil water content. The computerized water balance was operated twice weekly in an effort to maintain volumetric soil water in the root zone between 50 and 100 percent of total available water. Each time the computerized water balance was operated, ET and soil water content were calculated for the next five days using forecast data.

The two row configurations were conventional "single rows" spaced 96 cm apart and "twin rows" which were spaced close enough to allow the use of conventional equipment, but improved plant distribution. In 1980 the "twin rows" were spaced 35 cm apart with each pair of rows spaced 112 cm apart. In 1981 and 1982 the "twin rows" were spaced 30 cm apart with each pair of rows spaced 96 cm apart.

The two plant population treatments were: (1) equal to that currently recommended for commercial corn production (approximately 70,000 plants/ha), and (2) a higher population similar to that which has been reported as the maximum for intensively managed corn in the region (approximately 102,000 plants/ha) (Rhoads and Stanley, 1978). Although there were significant interactions among irrigation, plant population, and row configuration treatments in 1980 and 1981, mean yields for population treatments will be presented in this paper because the primary objective is to report results relating to irrigation scheduling methods.

Pre-plant fertilization rates were uniform for all treatments with 67, 29, and 168 kg/ha N, P, and K being applied in 1980 and 67, 29, 168, 53, 6.7, 3.3, and 2.8 kg/ha of N, P, K, S, Cu, Zn, and B in 1981 and 1982. All supplemental nutrients were applied through the irrigation system for irrigated treatments and applied to the soil surface as a solution for the nonirrigated treatments. Supplemental N was applied in either 2 or 4 applications to give a total of either 202 or 303 kg/ha N in 1980. In 1981 and 1982, 135 kg/ha of supplemental N was applied to one fertility treatment giving a total N of 202 kg/ha while the other treatment received supplemental N and K giving total applications of 303 and 249 kg/ha, respectively.

Prior to planting, the experimental site was subsoiled in two directions (each diagonal to the row direction, but perpendicular to each other) to a depth of 45 cm and at spacings of 96 cm to reduce restrictions to rooting caused by the E horizon. The site was subsequently disked two times to incorporate preplant fertilizer and herbicide. A commercial corn hybrid (Pioneer 3382) was planted on 10 April 1980, 7 April 1981, and 2 April 1982.

Tensiometers were installed at depths of 30, 60, 90, 120, and 150 cm at several positions relative to the row. They were serviced two or three times each week, and measurements were recorded three times each week. Irrigation water was applied through double-wall trickle irrigation tubing spaced 48 cm apart on the soil surface and with outlets spaced 30 cm apart along the line. The system was operated at maximum design pressure to provide a vertical stream of water which promoted uniform wetting. Water pressure was regulated and water volume was measured with positive displacement meters in each group of four plots. Rainfall was measured on site with a weighing-type recording rain gauge. Row sections 10 m in length were harvested by hand to determine grain yield, which was corrected to 15.5 percent moisture. Yield results were analyzed statistically using procedures described by Steel and Torrie (1960).

RESULTS AND DISCUSSION

Rainfall amounts during the growing season were 297, 330, and 485 mm, respectively, for 1980, 1981, and 1982 (Table 1). Irrigation amounts for each treatment and for all years are also included in Table 1. The treatment where irrigation was initiated at a soil water tension of 25 kPa received more irrigation water in each of the three years, but the amount applied each year was dependent on rainfall. The 50-kPa tensiometer treatment (1980) and the computerized-water balance treatment (1981 and 1982) received similar amounts of irrigation water. The computerized water balance treatment received 58 and 42 mm less irrigation water than the 25-kPa tensiometer treatment in 1981 and 1982, respectively. The 50-kPa tensiometer treatment (1980) received 164 mm less irrigation water than the 25-kPa tensiometer treatment.

In 1980 lengthy rain-free periods of 27 and 22 days occurred; the first occurred in the vegetative period, and the second occurred in the grainfill period. The major effect of these periods without rain was a significant reduction in plant height and a disruption of pollination timing. Seven rain-free periods of 5-8 days duration and one of 15 days duration occurred during the growing season in 1981. The early rain-free periods had little effect on vegetative growth, but those that occurred during pollination and grainfill had an adverse effect on yield. In 1982 one 11-day rain-free period occurred during grainfill, and two short rain-free periods of 5-6 days occurred during the vegetative period. These periods without rainfall had little effect on corn growth and yield.

The soil was so dry in 1980 that soil water tension at the 90-cm depth in the nonirrigated treatment was greater than 80 kPa most of the time, and tensiometers could not be maintained in service. On the other hand, soil water tensions at the 90-cm depth for the 25- and 50-kPa irrigation treatments were less than 20 and 40 kPa, respectively. In 1981 soil water tensions at the 90-cm depth in the nonirrigated treatment exceeded the tensiometer range much of the growing season, but remained less than 40 and 20 kPa, respectively, for the computerized water balance and tensiometer irrigation treatments (Fig. 2). Soil water tension at the 90-cm depth remained below 70 kPa in the nonirrigated treatment in 1982 and remained below 50 and 25 kPa in the computerized water balance and tensiometer scheduled irrigation treatments, respectively (Fig. 3). Soil water tensions in the computerized water balance treatment exceeded 40 kPa at the 90-cm depth once in 1982 because of delayed reinitialization of the computerized water balance using measured soil water content.

The computed soil water content in the root zone for the computerized water balance in 1981 is included in Fig. 4. The stepwise increase in soil water content between 0 and about 60 days after planting is caused by the increasing root depth. Ideally, the computed water content should remain within the region bounded by the freely-drained upper limit and allowable depletion curves. This was achieved except when irrigation was not provided as scheduled or when the computer program was reinitialized with measured soil water contents which resulted in a large change in the computed value. The discrepency often appears more severe since the reinitialization data is entered for the date the soil samples were collected although the water content values were not calculated and available until several days later. After these data are entered into the computerized water balance program, calculated soil water content for the days following reinitialization may be much different from the values which were used to make decisions regarding irrigation on a real time basis. In 1981 the first reinitialization occurred about 70 days after planting, but the soil water content data were actually entered into the computerized water balance 14 days later. In this case, the new computed soil water contents were much lower than the previously computed values, and the computerized water balance indicated the need for irrigation at an earlier date. Although irrigation had occurred during this period, it was not sufficient to raise the soil water content above the allowable depletion line until significant rainfall occurred about 85 days after planting.

In 1982 the first reinitialization occurred 60 days after planting, but was not actually entered into the program until 3 to 5 days later. Again, the computerized water balance procedure overestimated the soil water content of the profile, and the computed soil water content curve dropped abruptly upon reinitialization. Fortunately, rainfall occurred during the period, and the soil water content did not fall below the allowable depletion curve (Fig. 5). The second reinitialization was performed about 90 days after planting when the soil profile was in a drying cycle. Again, the computerized water balance procedure overestimated the soil water content, and the computed curve dropped abruptly after reinitialization. In this case, it dropped to a level significantly below the allowable depletion curve and may have caused moderately severe water stress in the corn. Again, the reinitialization data were not entered into the program until 5 days after the soil samples were collected. Problems of this type could be minimized through the development of a procedure to provide rapid soil water content determinations.

Corn grain yields were significantly higher for the irrigated treatments in all years except 1982 when rainfall was almost adequate (Table 2). There was no difference in yield between the two irrigation scheduling treatments each year although different amounts of irrigation water were applied. Corn grain yield for the "twin-row" configuration was higher for both irrigation scheduling treatments in 1980 and for the computerized water balance treatment in 1981 and 1982. Irrigation resulted in grain yield increases of 8.75, 7.10, and 0.99 t/ha (166, 147, and 9 percent), respectively, for 1980, 1981, and 1982. The mean grain yield for all irrigated treatments declined 2.11 t/ha the second year of the study and declined an additional 0.44 t/ha the third year. The reason for this decline is not known, but several possibilities exist. One possibility is that either air temperature, solar radiation, or both could have been significantly different among the three years of the study. Analysis of air temperature data indicated that the cumulative growing degree units declined each year of the study, but preliminary analysis of both parameters in a corn growth model indicated that the variance in these data could not produce the measured yield differences. Other variables will be further analyzed in an effort to determine the reason for yield decline.

SUMMARY AND CONCLUSIONS

The results of this study confirm the feasibility of producing high and profitable corn grain yields in the Coastal Plain region of the southeastern U.S. provided water, nutrient, and cultural practices are carefully executed. The irrigation scheduling methods provided different soil water regimes and required different amounts of irrigation water, but there was no significant difference in corn grain yield between irrigation scheduling methods within a crop year. From the yield standpoint, all scheduling techniques provided adequate irrigation management. The computerized water balance procedure (1981 and 1982) and the 50-kPa tensiometer treatment (1980) required less irrigation water than the 25-kPa tensiometer treatment. These scheduling methods may offer the potential for water savings since corn grain yields for these treatments were equal to the yield for the 25-kPa tensiometer treatment, but required less irrigation water. The computerized water balance consistently overestimated the soil water content both years, particularly during the pollination and grainfill growth stages when ET requirements were high. Delays in processing reinitialization soil water content data caused potentially damaging soil water stress conditions. A technique for rapidly determining soil water content is needed to reduce this delay. Managers must also insure prompt entry of these data into the computerized water balance program and reinitialization of the scheduling program. As these results are more completely analyzed, parameters such as the crop and soil coefficients may require modification which could improve the accuracy of the computerized water balance procedure. Additionally, any computerized irrigation scheduling technique developed for use in the humid region should consider rainfall probability in order to conserve energy and water and to prevent adverse wet soil conditions.

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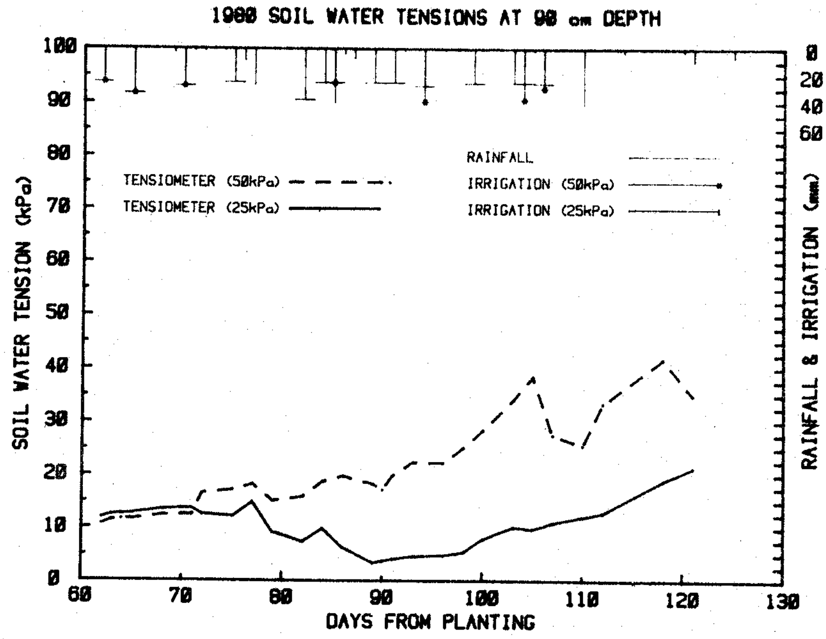

Fig. 1. Soil water tension at the 90-cm depth for the two irrigation treatments during the 1980 growing season.

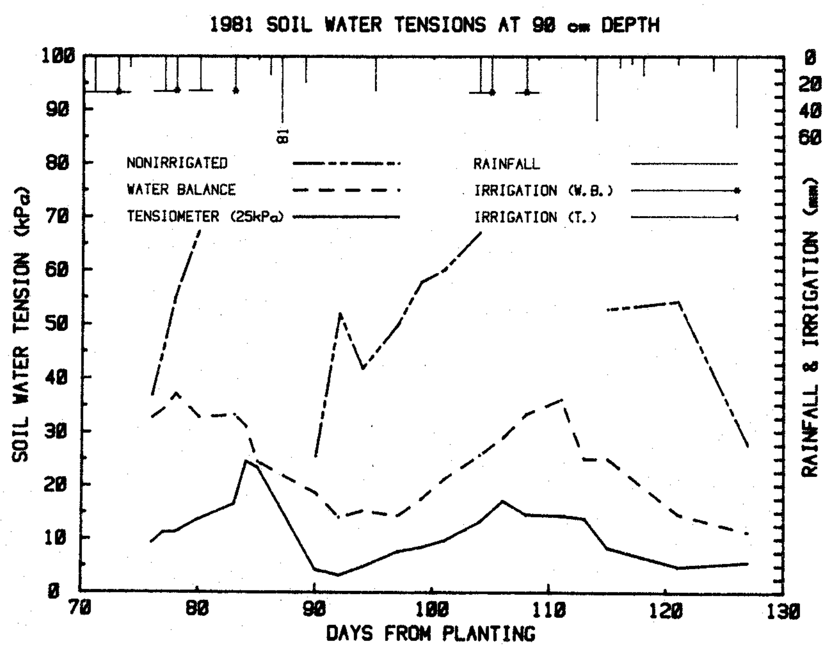

Fig. 2. Soil water tension at the 90-cm depth for the two irrigation treatments during the 1981 growing season.

TABLE 1. WATER RECEIVED BY CORN FROM IRRIGATION AND RAINFALL DURING THE GROWING SEASON IN EACH OF THREE YEARS (1980-82)

Treatment	Water received (mm)		
	1980	1981	1982
Tensiometer (25 kPa)	448	252	155
Tensiometer (50 kPa)	284	-	-
Computerized Water Balance	-	194	113
Rainfall	297	330	485

TABLE 2. CORN GRAIN YIELD FOR THREE WATER MANAGEMENT TREATMENTS AND TWO ROW CONFIGURATIONS IN EACH OF THREE YEARS (1980-82)

Irrigation Treatment	Corn Grain Yield (t/ha)					
	1980		1981		1982	
	Twin	Single	Twin	Single	Twin	Single
Tensiometer (25 kPa)	14.06a*	12.91b	12.14a	11.75ab	11.50a	10.95ab
Tensiometer (50 kPa)	14.00a	12.69b				
Water Balance			11.70ab	11.22b	11.46a	10.58bc
Nonirrigated	5.28c	5.43c	4.82c	4.13d	10.49bc	10.05c

* Number followed by the same letter within a year are not different by Duncan's multiple range test.

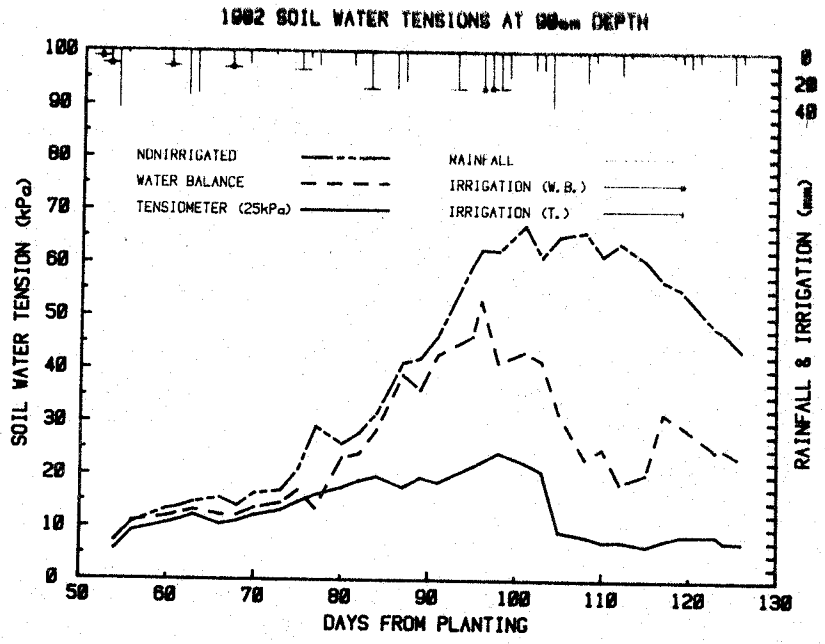

Fig. 3. Soil water tension at the 90-cm depth for the two irrigation treatments during the 1982 growing season.

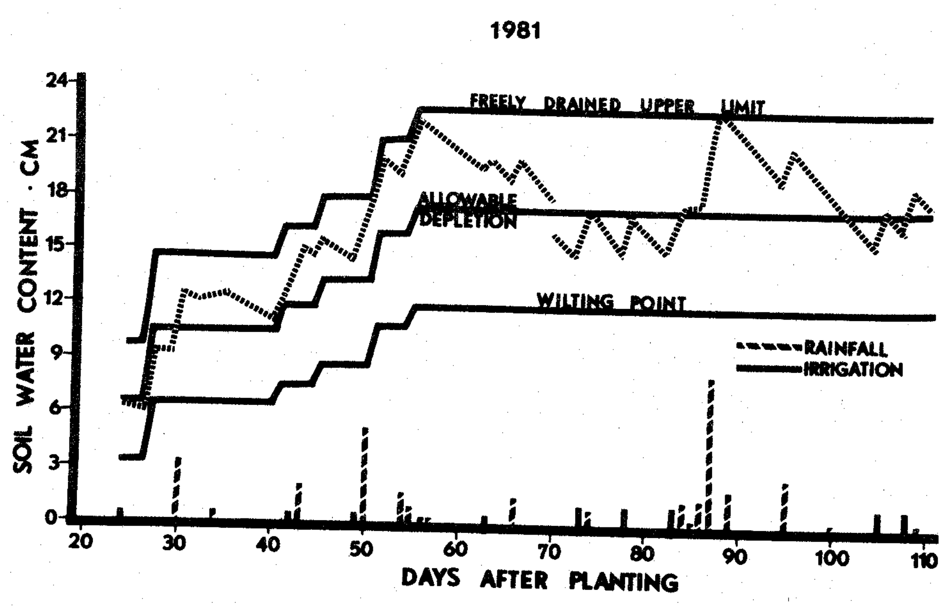

Fig. 4. Calculated soil water content, irrigation, and rainfall for the computerized water balance treatment during the 1981 growing season.

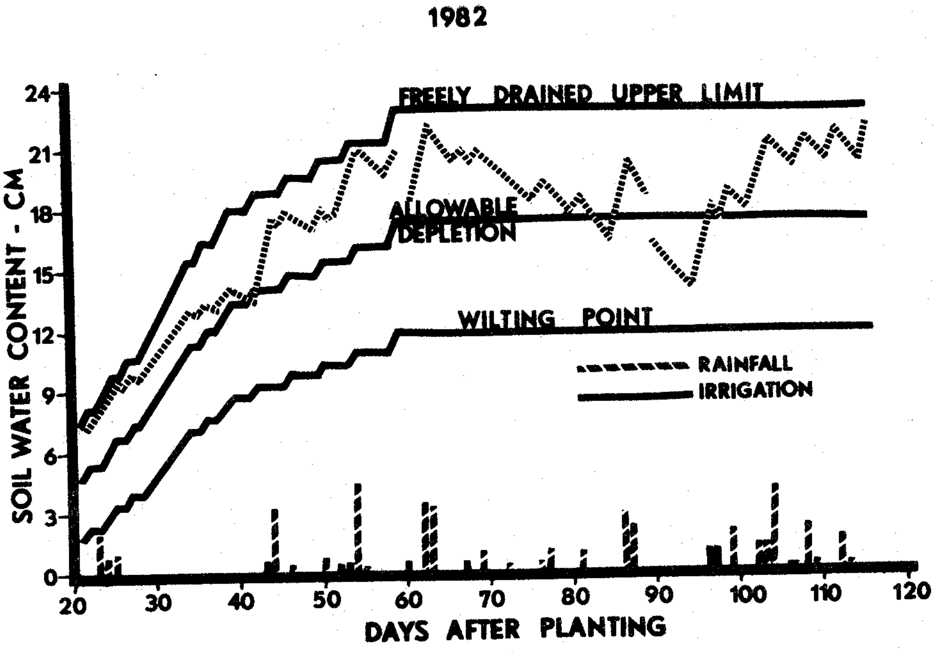

Fig. 5. Calculated soil water content, irrigation, and rainfall for the computerized water balance treatment during the 1982 growing season.