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INFLUENCE OF IRRIGATION STRATEGY ON WATER USE AND YIELDS OF CORN (*ZEA MAYS* L.)

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Keywords: Irrigation strategy, Water use, Yields, Corn (*Zea mays* L.).

RINGKASAN

Satu percubaan telah dijalankan dalam tahun 1978 di atas tanah 'Lake Fine Sand' (Typic quartzip-samment, hyperthermic, coated). Tujuannya ialah untuk mengkaji kesan strategi pengairan (kekerapan dan kuantiti) ke atas penggunaan air semusim dan kecekapan penggunaan pengairan bagi jagung.

Empat perlakuan pengairan telah dikaji iaitu (1) tanpa pengairan, (2) pengairan yang kerap dengan kuantiti air yang sedikit, (3) pengairan yang jarang dengan kuantiti air yang sederhana dan (4) pengairan yang jarang dengan kuantiti air yang sedikit. Penggunaan air semusim bagi jagung dalam petak yang ada pengairan adalah 10 hingga 200% lebih tinggi daripada jagung yang tidak diberikan pengairan. Hitung panjang hasil bagi buah jagung dari perlakuan (1), (2), (3) dan (4) adalah 2112, 7723, 7084 dan 7071 kg/ha. Hasil daripada perlakuan dengan pengairan adalah sangat tinggi dibandingkan dengan perlakuan tanpa pengairan pada 1% paras kemungkinan. Kecekapan penggunaan pengairan berdasarkan kepada hasil buah jagung bagi perlakuan (2), (3) dan (4) adalah 220, 205 dan 223 kg/ha/cm.

INTRODUCTION

The total rainfall for Florida is sufficiently high for growing agricultural crops, ranging from about 132 cm in the central and northern peninsular to nearly 165 cm in the panhandle West of Tallahassee (BUTSON and PRINE, 1968). Severe drought commonly occurs during the spring growing season followed by heavy rains during summer when the state receives approximately 60% of its rainfall (JONES, 1967). However non-uniformity of rainfall distribution throughout the year plus low water retention in sandy soils result in periodic drought unfavorable to plant growth.

For agronomic crops growing on deep, well-drained and sandy soils, irrigation is usually required during spring and fall months. Water for irrigation is pumped from lakes, streams and aquifers in competition with municipal and industrial users (PIERCE, 1975). Management of irrigation to obtain the most efficient use become particularly difficult because of two complicating factors: (1) rainfall distributions are typically erratic during dry period and individual rains are difficult to forecast and (2) large, intense rainfalls that occur soon after an irrigation may result in leaching losses of nutrients and water with deep seepage from rooting zone of sand soils.

One of the most practical means for increasing the efficiency of irrigation is to use shallow and frequent irrigations. Thus not only will crop yields be increased, but drainage and nutrient leaching from the rooting zone will be minimized. Small quantities of water per irrigation can be applied such that soil water removed from the rooting zone during evapo-transpiration and drainage will be replenished only in the upper portion of the rooting zone. During crop production season, the amount of rainfall and its distribution become deciding factors for determining whether to irrigate and how much water should be applied. Most well-drained sandy soils in the state temporarily store less than 2.54 cm of water per 0.3 meter of soil depth, so that the growing crop can develop water stress within 3 to 7 days following rainfall or irrigation (RHOADS and RUSSELL, 1977).

When the soil water deficit is replenished with irrigation, the possibility always exist that following rainfall will displace the infiltrated irrigation water so that it

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will be lost from the rooting zone as deep seepage. This is serious economic loss to the grower and could be a loss to the aquifer system as well. The severity of deep seepage loss of irrigation water under the humid subtropical climate of Florida increases as the water retaining capacity of the soil decreases.

The potential exists to minimize the problem by careful management of timing and quantity of irrigation. High frequency irrigation with small amounts of water and shallow wetting of the rooting zone may be sufficient for near maximum plant growth during short droughts. In this system, rainfall will replenish water depleted from deeper portions of the rooting zone and thus not be subjected to deep seepage loss.

The objectives of this experiment were:–

1) to determine if the irrigation-use efficiency for corn (*Zea mays* L.) grown on deep sandy soils can be increased by small, frequent irrigations to wet only a portion rather than the entire rooting zone and

2) to determine periodic water depletion rates for this crop.

MATERIALS AND METHODS

Experimental Method

Field corn De Kalb XL–80 variety was planted on March 17, 1978 on a Lake Fine Sand (Typic quartzipsamment, hyperthermic, coated) at the experiment station farm in Gainesville. Depth to fine textured material was 210 to 270 cm. The experiment was a randomized complete block design with four water management treatments and four replications. Plots size was 5.54 x 5.54 m^2. The plants emerged on March 24, 1978. Planting distince was 30.48 cm in north-south rows spaced at 45.72 cm. The total number of plants was 72,000 per hectare. A commercial fertilizer 13:0:44 ($N:P_2O_5:K_2O$) was applied broadcast to the soil surface on March 17, 1978 at the rate of 509.6 kg/ha. The soil was plowed to 15 cm depth when the fertilizer was applied. The second fertilizer application on May 5, 1978 was ammonium nitrate (35% N) at the rate of 224 kg/ha. Sutan (herbicide) was applied on the date of planting. Bladez (herbicide) was applied about 10 days after planting. Weeding was also done by hand when needed. Corn plants were thinned on April 24, 1978. Missing plants were replanted on April 5, 1978. The crop tasseled on May 20, 1978 (64 days after planting) and was harvested on August 8, 1978 (144 days after planting). Two samples were taken from each plot. Each sample consisted of two rows 3.05m long. The corn ears were dried at 70°C in the drying house. Corn grain yields were determined and adjusted to 15.5% moisture.

The irrigation system was installed immediately after planting. The four treatments were (1) control (rainfall only), (2) light, frequent irrigation – irrigate to 30 cm depth when soil water suction at 15 cm was between 150 and 500 cm of water, (3) medium, infrequent irrigation – irrigate to 45 cm depth when suction at 15 cm was between 150 and 500 cm of water and (4) light, infrequent irrigation – same schedule and rate as (2) except irrigation frequency reduced during grain filling.

Polyvinylchloride (PVC) pipe with 2.54 cm outside diameter was used to deliver water from a municipal source to the plots. Each experimental plot consisted of five lines of black polyethylene tubes (1.27 cm outside diameter) connected to a PVC header pipe. The irrigation system was laid on the soil surface. Eight full circle yellow base 'Microjet' sprinklers were inserted into each line of polyethylene tubing at 0.62m intervals. Each sprinkler had a discharge rate 9.46 litres of water per hour at 138 kPa. The depth of irrigation water applied was calculated on the basis of a $(0.91 \times 0.62)m^2$ area – a unit cell of overlapping sprinkler patterns.

The neutron scattering method was used to measure soil water content at depths ranging from 30 cm to 240 cm in 15 cm increments. In each replicate a thin-walled aluminium access tube (5.0 cm outside diameter and 250 cm length) and a set of tensiometers were installed vertically around the center of a treatment plot. A Troxler portable scaler and neutron probe (100 mc Am–Be) model 1651 was used with half-minute counts at each depth.

The following calibration equation was used to calculate the soil water content θ as a volume fraction:

$$\theta = 26.998 \qquad b - 3.331 \qquad (1)$$

where b is the quotient of the average value of the field counts for a given depth to the average value of the standard count with the probe in the shield.

Hydraulic head profile was measured with tensiometers to a depth of 180 cm. Single unit plastic tube tensiometers (1.9 cm diameter, porous ceramic cup) with mercury manometers were installed about 30 cm from the neutron access tube. The tensiometer readings were recorded every day including weekends except during the first 55 days after planting when readings were taken at weekly intervals. The neutron readings were obtained weekly. Rainfall data were collected by a recording rain gauge which was installed adjacent to the experimental plots. All the data were collected until the crop was harvested.

Periodically soil water content was determined gravimetrically on 5.0 cm diameter soil samples taken at 15 cm increments and dried at 105°C in the oven for at least 24 hours. Soil core samples were collected from a plot before the crop was planted to determine the bulk densities of the soil at various depths. The volumetric water content θ can be calculated by multiplying the water content by weight with bulk density of the soil of the depth concerned.

Soil water content-pressure relationship for this oil was determined in the laboratory by using Tempe pressure cells. Equilibrium extraction pressures were 4, 30, 60, 80, 100, 150, 200 and 345 cm of water on soil cores. Extraction at 15 bar (15,000 cm of water) pressure was made on disturbed soil samples.

Methods of Data Analysis

The moisture content of a specific length of a soil profile expressed as a surface depth of water W, was then calculated for different depths (x) and different times:

$$W = \sum_{x=0}^{x=L} \theta \Delta x \qquad (2)$$

Where: L is 240 cm,

θ is the volumetric water content cm^3/cm^3.

The depth increments (Δx) were 15 cm except for a surface increment of 30 cm.

To estimate the water depletion rate during different periods throughout the crop season the following water balance equation was used.

Water Depletion = Rainfall + Irrigation $\pm \Delta$Storage (3)

= Evapo-transpiration $\pm$ Drainage.

Estimated evapo-transpiration was calculated by the Penman method (PENMAN 1948) based on full plant canopy. The drainage component was calculated by substracting the estimated evapo-transpiration (ET) from the amount of water depletion. If the ET value was higher than the water depletion it was assumed that no drainage occurred below 240 cm soil depth.

The irrigation-use efficiency was calculated by substracting the yield in the non-irrigated plot from the yield in the irrigated plot and dividing the result by the total amount of irrigation water applied. The water-use efficiency was determined by dividing the yields from each treatment by the respective total water inputs (irrigation + rainfall).

Data from the field experiments were subjected to analysis of variance. Duncan's multiple range test was used to compare the differences between individual treatment means (DUNCAN, 1957). Calculations were performed with the aid of the North East Regional Center Computer in Gainesville.

The following model was used in the analysis of variance of the corn grain yields.

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_{ik} + \epsilon_{ijk} \quad (4)$$

Where Y_{ijk} = corn grain yields (kg/ha)

μ = overall mean

α_i = effect of i^{th} treatment, i = 1, 2, 3, 4

β_j = effect of j^{th} replication, j = 1, 2, 3, 4

$(\alpha\beta)_{ij}$ = interation between i^{th} treatment and j^{th} replication, i and j are defined as above.

γ_{ik} = effect of k^{th} sample within i^{th} treatment, k = 1, 2 and i is defined as above and

ϵ_{ijk} = random error.

RESULTS AND DISCUSSION

Soil-Water Retention and Bulk Density

Soil water characteristic data in *Table 1* shows that the retention of water within 1–187 cm depth in the Lake Fine Sand was low especially at high suctions. Implications from the data in *Table 1* is that it can be a serious problem to grow crops which have shallow roots on this soil especially during dry season. But, for the crops which have longer and deeper roots, production may not be reduced by short droughts.

The bulk density and saturated hydraulic conductivity values of the Lake Fine Sand used in this study are shown in *Table 2*. The bulk density values were slightly

TABLE 1: WATER RETENTION CHARACTERISTICS OF A LAKE FINE SAND PROFILE

Horizon	Core Depth	Volumetric Water Content at Various Suctions (cm of water)								
		4	30	60	80	100	150	200	345	15,000
	cm	%								
A_p	1–4	31.6	24.8	9.7	7.4	6.4	5.1	4.7	3.9	1.8
	6–9	32.8	22.1	10.2	8.1	7.2	5.9	5.5	4.7	2.0
A_{21}	33–36	32.7	24.4	10.3	7.8	6.8	5.5	5.1	4.4	2.1
	37–40	33.1	23.7	10.4	7.8	6.7	5.4	5.1	4.4	2.2
A_{22}	67–70	34.2	20.6	10.0	7.4	6.3	5.1	4.7	4.1	1.9
	71–74	35.1	21.2	9.6	7.3	6.3	5.1	4.7	4.0	2.0
A_{23}	113–116	35.5	27.7	10.8	7.3	6.0	4.8	4.4	3.0	2.1
	117–120	36.4	25.0	10.0	7.3	6.2	5.0	4.6	3.9	2.1
A_{24}	137–140	36.6	21.4	9.6	7.1	6.1	5.0	4.6	3.9	2.2
	141–144	35.9	23.8	10.3	7.9	6.9	5.7	5.3	4.7	2.6
A_{25}	180–183	37.3	25.2	12.9	10.4	9.5	8.3	7.9	7.2	4.4
	184–187	35.7	25.5	14.0	11.7	10.7	9.5	9.1	8.3	4.8
B_{21t}	223–226	33.4	27.6	18.0	15.4	14.4	13.1	12.5	11.7	7.2
	227–230	32.1	28.6	25.3	23.4	19.0	15.6	15.0	14.0	8.0

TABLE 2: BULK DENSITY AND SATURATED HYDRAULIC CONDUCTIVITY OF A LAKE FINE SAND PROFILE

Horizon	Core Depth	Bulk Density	Hydraulic Conductivity
	cm	gm/cm^3	cm/hr
A_p	1–4	1.63	28.9
	6–9	1.61	28.3
A_{21}	33–36	1.61	24.3
	37–40	1.58	30.2
A_{22}	67–70	1.54	44.7
	71–74	1.53	42.1
A_{23}	113–116	1.53	53.9
	117–120	1.56	51.3
A_{24}	137–140	1.53	56.5
	141–144	1.53	51.9
A_{25}	180–183	1.51	39.4
	184–187	1.53	32.9
B_{21t}	223–226	1.62	12.5
	227–230	1.67	7.4

high (1.61 to 1.63 gm/cm^3) from 1 to 36 cm soil depths due to compaction of Ap horizon. Between 37 and 187 cm soil depths (A_{21} to A_{25} horizon) the bulk density values ranged between 1.51 to 1.58 gm/cm^3. Within this depth the texture was fine sand. But, at depths greater than 210 cm (B_{21t} horizon) the bulk density values increased within a range of 1.62 to 1.67 gm/cm^3. The increased values were due to the sandy clay texture of the soil.

The saturated hydraulic conductivity values were lower within B_{21t} horizon compared to higher values in A_p, A_{21} to A_{25} horizon. The different textures accounted for the different hydraulic conductivity values (HILLEL, 1971; ROSE, *et al.*, 1965).

Water Input and Water Use

Figure 1 shows the distribution and amount of rainfall and irrigation water from the date of corn planting, March 17, 1978 until harvested, August 8, 1978. These dates for the season (134 days, planting to maturity) are summarized in *Table 3*. Total water input was highest in treatment 2 (71.8 cm) and lowest in the treatment 1 (46.3 cm). The difference in amount of total water input between treatments 2 and 3 were only 0.6 cm but the irrigation frequency differed by six.

Water depletion rates within 0–240 cm soil depth are shown in *Table 4*. The irrigation period was between 42 to 110 days. Prior to the beginning of irrigation (three depletion periods) the variation between treatments reflects the site to site differences in soil water content as determined by the neutron scattering method. These early water depletion values probably contained some drainage since the canopy was not fully developed. Correlation of the water depletion data with water inputs can be seen by comparing *Table 4* and *Figure 1*. The irrigation treatments were planned to avoid or minimize drainage loss. Thus one would like to know how closely the measured water depletion rates represent the actual evapotranspiration (ET). Drainage values were estimated from the differences between depletion rates and potential ET calculated from meteorological data.

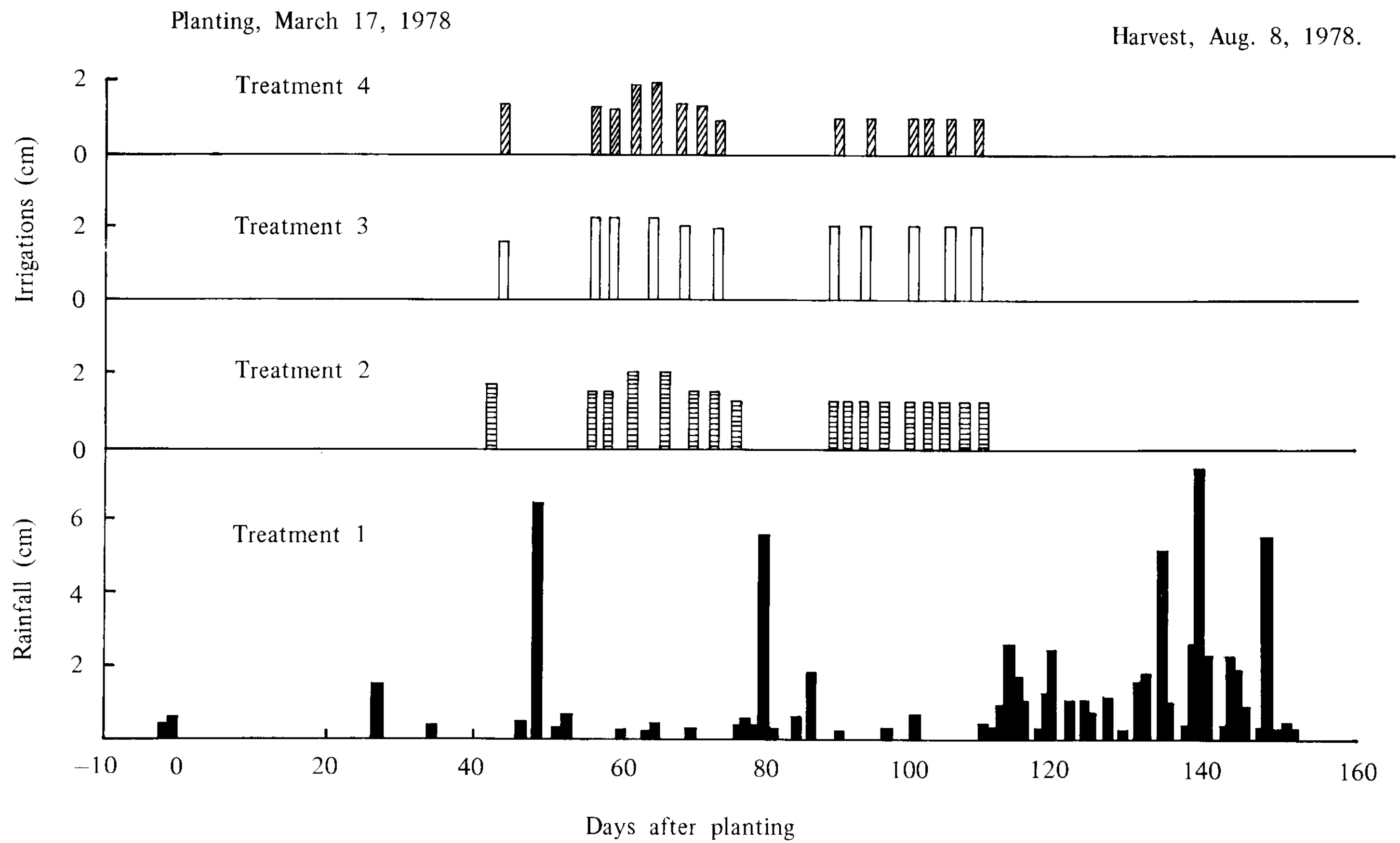

Figure 1: The distribution and amount of rainfall and irrigation during the corn growing season. Spring 1978

TABLE 3: WATER INPUT DURING 0–134 DAYS AFTER THE DATE OF PLANTING, CORN, SPRING 1978

	Treatment	Irrigation		Total
		cm		
1.	Control (Non-irrigated)	0		46.3*
2.	Light frequent irrigation	25.5	(17)**	71.8
3.	Medium infrequent irrigation	24.3	(11)	70.6
4.	Light infrequent irrigation	21.7	(14)	68.0

* Amount of rainfall (March 17–July 29)

** Numbers in parentheses are the numbers of irrigation applications.

TABLE 4: PERIODIC WATER DEPLETION RATES FROM FOUR WATER MANAGEMENT TREATMENTS. CORN, SPRING 1978

Day*	Water depletion rate (mm/day)			
	(1) Control	(2) Light	(3) Medium	(4) Light infrequent**
4–11	3.66	2.92	3.64	
12–26	2.29	2.57	1.70	–
27–40	2.08	1.79	2.52	–
41–68	3.71	4.02	5.88	6.69
69–77	3.65	9.86	7.34	8.93
78–89	6.19	6.66	5.56	6.60
90–102	3.31	9.62	7.77	8.01
103–138	5.62	8.05	8.27	8.27

* Days after planting (March 17, 1978)

** Values between 4–40 days in the light, frequent irrigation treatment were not calculated due to a lack of soil water content data.

In *Table 5*, data for irrigated plots show a considerable drainage loss except during 12–40 days (dry period before irrigation). In the 78–89 and 103–138 day periods, drainage was due to high rainfall *(Figure 1)*. The water depletion data and drainage estimates were highly uncertain. The choice of soil depth for calculation of water depletion rates is critical especially if the entire soil profile is not at field capacity at the beginning of any period. The field capacity is defined as the amount of water held in the soil after the excess gravititional water has drained away and after the rate of downward movement of water has materially decreased.

Soil Profile Water Content

Figure 2A shows the changes of volumetric water content with time in the non-irrigated treatment during a dry period.

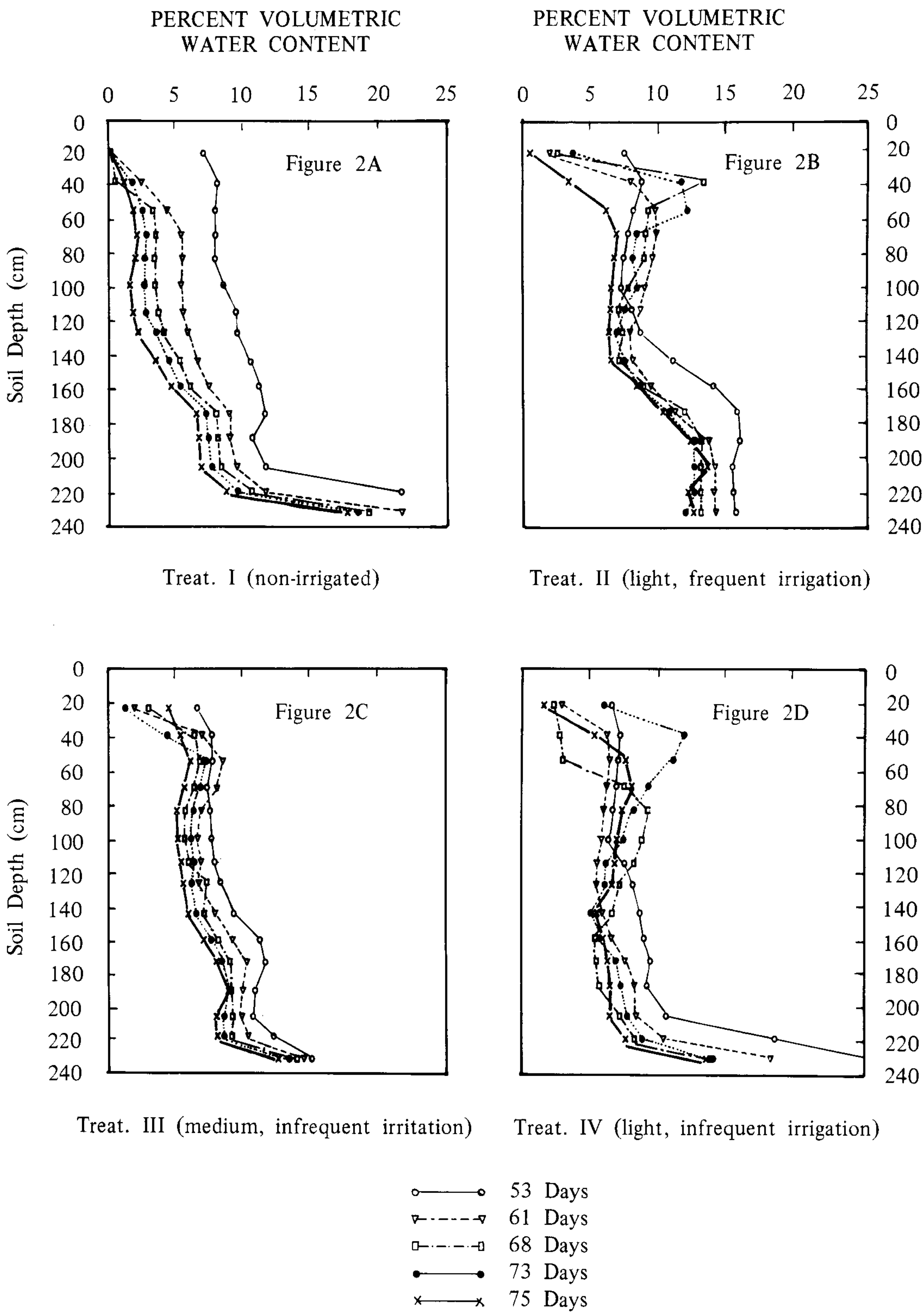

Figure 2: Volumetric soil-water content distribution with depth under corn during a dry period-spring 1978

The high water contents in the lower part of the profile reflect a perched water table and the presence of a sandy clay layer beginning at a depth of around 220 cm. Water losses from the profile were greatest during the first 8-day period when drainage and evapo-transpiration were taking place. These data indicate that root extraction of water occurred to a depth of at least 160 cm.

Water content data for the irrigated treatments are shown in *Figures 2B, 2C* and *2D*. Data at 53 days show the near field capacity water contents in approximately the upper 100 cm of soil profile (also *Figure 2A*). This occurred about 4 days after 6.7 cm of rainfall *(Figure 1)*.

Figures 2A, 2B, 2C and *2D* show site to site variation in the water content profiles. *Figures 2A* and *2D* are similar with high water contents below 220 cm due to a perched water table and sandy clay layer. The profiles were fairly uniform above 220 cm. *Figures 2B* and *2C* are also similar with non-uniformity below 140 cm. Water content increased with depth but not to the extent shown in *Figures 2A* and *2D*. These differences relate to the variable clay content with depth and the spatial variability in drainage conditions. Water storage level above the well drained field capacity of around 7 to 8% water content could have a significant beneficial effect on the later stages of plant growth if roots have developed into these deeper soil horizons.

The periodic increases in water content at 30 to 60 cm depths in *Figures 2B, 2C* and *2D* show the effect of irrigation. A second peak zone of redistributing irrigation water shows at 80–100 cm (68 days) in *Figure 2D*. The true water content in the 0–30 cm depth was probably higher than recorded since neutrons are lost through the soil surface and less shallow depths.

The changes in water content with time in *Figures 2B, 2C* and *2D* also indicate that drainage losses occurred below the active rooting zone (approximately 100 to 130 cm). This is supported by hydraulic head data discuss in the following section.

Soil Profile Hydraulic Head

The water content and water movement status of the soil profile can be shown by hydraulic head distribution with depth (RHOADS and STANLEY, 1973). *Figure 3A* shows the hydraulic head values in the non-irrigated soil profile during the dry period (53–75 days). Above 150 cm soil depth hydraulic head decreased markedly with time in response to evapo-transpiration. The hydraulic head gradients were downward in the 150–180 cm zone throughout the period indicating a downward flow of water and little if any root activity.

In the irrigated plots, the drying occurred only to a depth of about 45 cm as shown in *Figures 3B, 3C* and *3D*. Hydraulic gradients were downward from 45 cm depths except in treatment (4) where the 90 cm tensiometer predicted water uptake at 73 and 75 days. The supply of irrigation water kept the 45–180 cm zone always wet. There were 12.3, 11.9 and 12.3 cm of irrigation water applied in treatments 2, 3 and 4 respectively during the 53–75 day period.

Effect of Water Management on Corn Growth and Yields

The effect of irrigation on the growth performance of corn plants was obvious at 50 days after planting. In the non-irrigated plot the leaves were curled as plants were under severe water stress. Plant size was already reduced. In irrigated plots, corn plants were tall and the leaves were broad and completely covered the surface in between plant rows. In addition, the irrigated plants had dark green leaves while the non-irrigated had yellowish green leaves. The yellow corn indicated nitrogen difficiency. Although the nitrogen fertilizer (NH_4NO_3) was applied at the same rates in all plots, the non-irrigated plants could not utilize it due to the lack of moisture in the soil. Since the area covered by the plants in the non-irrigated plot was

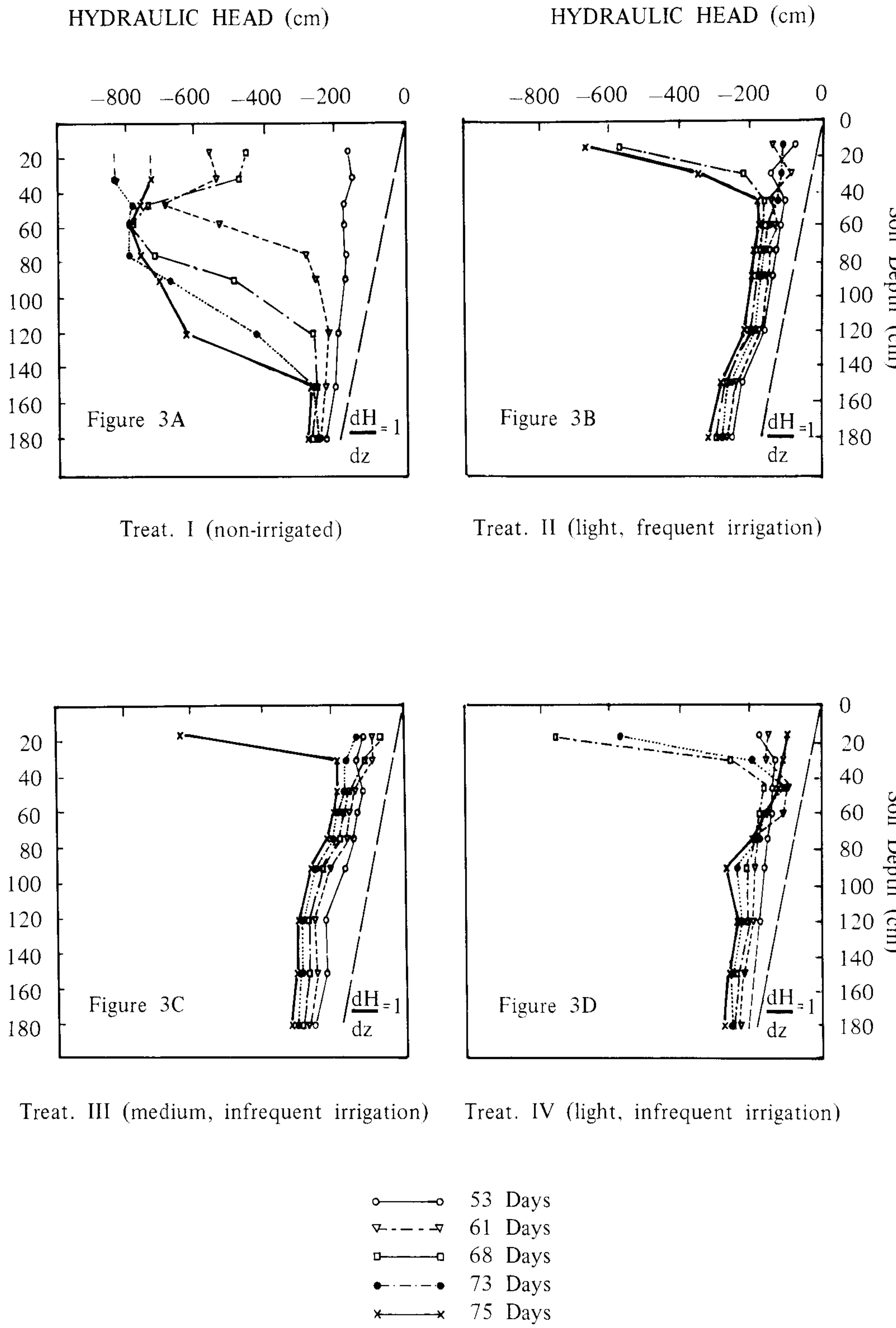

Figure 3: Hydraulic head distribution with depth under corn during a dry period – spring 1978.

TABLE 5: THE RATES OF WATER DEPLETION, ESTIMATED EVAPOTRANSPIRATION (ET) AND DRAINAGE IN CONTROL (NON-IRRIGATED) AND IRRIGATED PLOTS. CORN, SPRING 1978

Days**	Estimated ET***	Water Depletion		Estimated Drainage	
		Control	Irrigated*	Control	Irrigated*
	(mm/day)				
4–11	2.30	3.66	3.29	1.36	0.99
12–26	3.16	2.29	2.14	nd	nd
27–40	3.40	2.08	2.16	nd	nd
41–68	4.00	3.71	5.53	nd	1.53
69–77	4.11	3.65	9.04	nd	4.93
78–89	4.20	6.19	6.27	1.99	2.07
90–102	4.20	3.31	8.47	nd	4.27
103–138	4.29	5.62	8.20	1.33	3.91

** Days after planting (March 17, 1978)

*** Penman method by using long-term weather data. Unpublished data, Florida Agricultural Experiment Station.

* Average of three treatments.

nd No drainage; estimated ET greater than water depletion.

less than in the irrigated plot, the rate of evaporation of water from the soil surface should be higher in the non-irrigated compared to the irrigated plots.

In this study, there was a significant increase in grain yield for the irrigated corn *(Table 6)*. Treatment 2 (light, frequent irrigation) produced the highest grain yield 7723 kg/ha. Treatment 1 (non-irrigated) gave the lowest grain yield 2112 kg/ha. The Duncan's multiple range test in *Table 6* showed a non-significant difference in grain yield between irrigated treatments (2, 3 and 4), but, their yields were highly significant compared to the yield from the non-irrigated (treatment 1). Treatments 3 and 4 produced 7084 and 7071 kg/ha respectively. The respective yield increase over treatment 1 for treatments 2, 3 and 4 were 266, 235 and 235%.

Analysis of variance of the corn grain yields is shown in the *Appendix*. The replication effect was significant at 3% probabiity level. The treatment effect was highly significant (PR>F = 0.0001). We note that the sample effect is not significant. Hence the γ_{ik} term in equation (4) can be included in the error term ϵ_{ijk}. By pooling the error mean square with that of the sample effect, we obtain a new mean square for error with 16 degrees of freedom. Irrigation-use efficiencies for treatments 2, 3 and 4 were 220, 205 and 228 kg/ha/cm respectively *(Table 6)*. The water-use efficiencies for treatments 1, 2, 3 and 4 were 46, 108, 100 and 104 kg/ha/cm respectively.

From this study the three schemes for irrigation management did not make any difference in terms of yield or water-use efficiency. The reason might be due to the nature of rainfall distribution and the fact that all irrigation treatments met the ET needs without causing much drainage water loss *(Figure 1, Tables 4* and *5)* except during the high rainfall period.

TABLE 6: AVERAGE GRAIN YIELDS, IRRIGATION-USE AND WATER-USE EFFICIENCIES OF CORN, SPRING 1978

	Irrigation treatment	Grain yield*	Irrigation-use efficiency**	Water-use efficiency***
		(kg/ha)	——— kg/ha/cm	———
1.	Non-irrigated	2112 b****	–	45.62b
2.	Light, frequent	7723 a	220	107.56a
3.	Medium, infrequent	7084 a	205	100.41a
4.	Light, infrequent	7071 a	228	103.99a

* Average of four replicates

** Calculated by subtracting grain yields for the unirrigated from those for the irrigated plots and dividing the results by the total amount of irrigation water applied.

*** Average grain yields divided by the total water input (March 17–July 29, 134 days)

**** Values in column not followed by the same letter differ significantly at the 0.05 probability level according to the Duncan's Multiple Range Test.

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SUMMARY

An experiment was conducted in 1978 on a Lake Fine Sand (Typic Quartzipsamment, hyperthermic, coated). The objective was to determine the effect of irrigation strategy (frequency and quantity) on periodic water depletion rates for corn (*Zea mays* L.) and on irrigation water-use efficiency.

Four water management treatments were applied: (1) control, no irrigation, (2) light, frequent irrigation, (3) medium, infrequent irrigation and (4) light, infrequent irrigation. Periodic water depletion rates were 10 to 200% higher in the irrigated plots compared to non-irrigated plots. Average corn grain yields were 2112, 7723, 7084 and 7071 kg/ha for treatments (1), (2), (3) and (4) respectively. The yields from irrigated treatments were significantly higher than from the non-irrigated treatment at 1% probability level. Irrigation-use efficiencies based on corn grain yields were 220, 205 and 223 kg/ha/cm for each of the treatments 2, 3 and 4.

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APPENDIX: ANALYSIS OF VARIANCE OF GRAIN YIELDS (KG/HA) CORN, SPRING 1978

Source	df	Sum of squares	Mean square	F-value	PR>F
Model	16	179362152.99	11210134.56	33.84**	0.0001
Treat	3	153269552.34	54423174.10	77.86**	0.0001
Rep.	3	9630114.09	3210038.03	4.59**	0.0326
Treat* Rep.	9	6290672.03	698963.56	2.11	0.0967
Sample	1	171844.53	171844.53	0.52	0.4852
Error	15	4969254.97	331283.66		
Total	31	184331407.97			
C.V. = 9.59%					
STD. DEV. = 575.57					

* Significant at 5% probability level.
** Significant at 1% probability level.