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Improved Water and Nutrient Management Through High-Frequency Irrigation

T.A. Howell
K.W. Brown
R.J. Newton
D.L. Reddell
M.J. McFarland

Texas Water Resources Institute

Texas A&M University

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IMPROVED WATER AND NUTRIENT MANAGEMENT THROUGH HIGH FREQUENCY IRRIGATION

Principal Investigators

Terry A. Howell
Kirk W. Brown
Ronald J. Newton

Co-Investigators

Donald L. Reddell
Marshall J. McFarland

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INTRODUCTION

High frequency irrigation implies the uniform, frequent application of water to crops. The fequency may range from several irrigations per week to daily irrigation to even several irrigations per day in greenhouse and nursery settings. Most of the high frequency irrigationin the United States is through necessity; i.e., the limited water holding capacity of the soils or a limited water supply make irrigation application of more than a few centimeters impractical.

Irrigation of field crops in sandy soils (such as in the Nebraska Sand Hills) with traveling or outer pivot sprinkler systems is a classic example of high frequency irrigation dictated by a limited water holding capacity. Another widespread use of high frequency irrigation is found in the various low pressure systems such as drip, trickle, bi-well, and bubbler. These systems deliver relatively small amounts of water to the root zone as a consequence of factors such as limited water, shallow soils, limited water holding capacity, and high erosion potential.

The increased frequency of irrigation is not commonly a goal in itself, but several advantages of high frequency irrigation have been identified (Rawlins and Raats, 1975; Howell, et. al., 1976). These include:

1. Improved plant internal water balance,
2. Decreased drainage from the root zone,
3. Decreased runoff from the crop,
4. Decreased importance of soil hydraulic characteristics,
5. Improved salinity control,

6. Increased enhancement of rainfall utilization,
7. Reduction of high temperature stress, and
8. Reduction of nutrient leaching

The results of these advantages are usually increased crop yield or quality, decreased water use, and decreased pollution from drainage and runoff. The yield expected under high frequency irrigation may not be significantly increased over well-managed conventional irrigation, but increased efficiency of water, energy, fertilizer, and labor make even modest yield increases important.

Nutrient management is critical with high frequency irrigation. Nitrogen in particular is susceptible to loss from the root zone by leaching, so high frequency irrigation systems require frequent, light nitrogen applications. This is facilitated by distribution of nutrients through the irrigation system. Other chemicals such as soil fumigents for nematode control, systemic insecticides, and herbicides can also be injected into the irrigation system and applied very uniformly to the crop.

This research was directed toward defining the best management practices for irrigation timing and fertilizer applications under high frequency irrigation. The specific objectives were to:

1. quantitatively determine plant nutrient requirements for specific crops grown under high frequency irrigation, under optimum soil-water metric potential, and
2. evaluate the impact of high frequency irrigation on water quality and water and energy consumption.

PLAN OF RESEARCH

This research was conducted in three phases: evaluation of water requirements by peach trees under trickle irrigation, comparison of peanut water use efficiencies under differing sprinkler irrigation regimes, and determination of nutrient and water requirements of sorghum and wheat under high frequency irrigation.

The peanut irrigation research is presented in Volume II of Texas Water Resources Institute Technical Report 113, entitled "Response of Peanuts to Irrigation Management at Different Crop Growth Stages," by P. G. Dahmen, M. J. McFarland, and D. L. Reddell.

The peach irrigation research is presented in Volume III of Texas Water Resources Institute Technical Report 113, entitled "Determination of the Transpiration Rate of Peach Trees Under Two Trickle Irrigation Regimes," by P. B. Rodrigue, T. A. Howell, and M. J. McFarland.

The major thrust of the research was the high frequency irrigation of sorghum and wheat, conducted at the Texas A&M University Research Farm in the Brazos River Bottom, west of College Station. One aspect of the research is presented in Volume I of Texas Water Resources Institute Technical Report 113, entitled "Comparison of Methods for Determining Soil Hydraulic Properties," by K. B. Humphreys and T. A. Howell. An investigation of sorghum irrigation will be presented in Volume IV to Texas Water Resources Institute Technical Report 113, entitled "Response of Grain Sorghum to Varying Nutrient and Irrigation Trials," by L. F. Guzmen and M. J. McFarland.

Other aspects of the major research effort are described briefly in the ensuing paragraphs. The objectives of the research were not attained, due primarily to interference by the weather.

RESEARCH DESIGN

Field plots were designed and laid out according to Figure 1. The experimental treatments were:

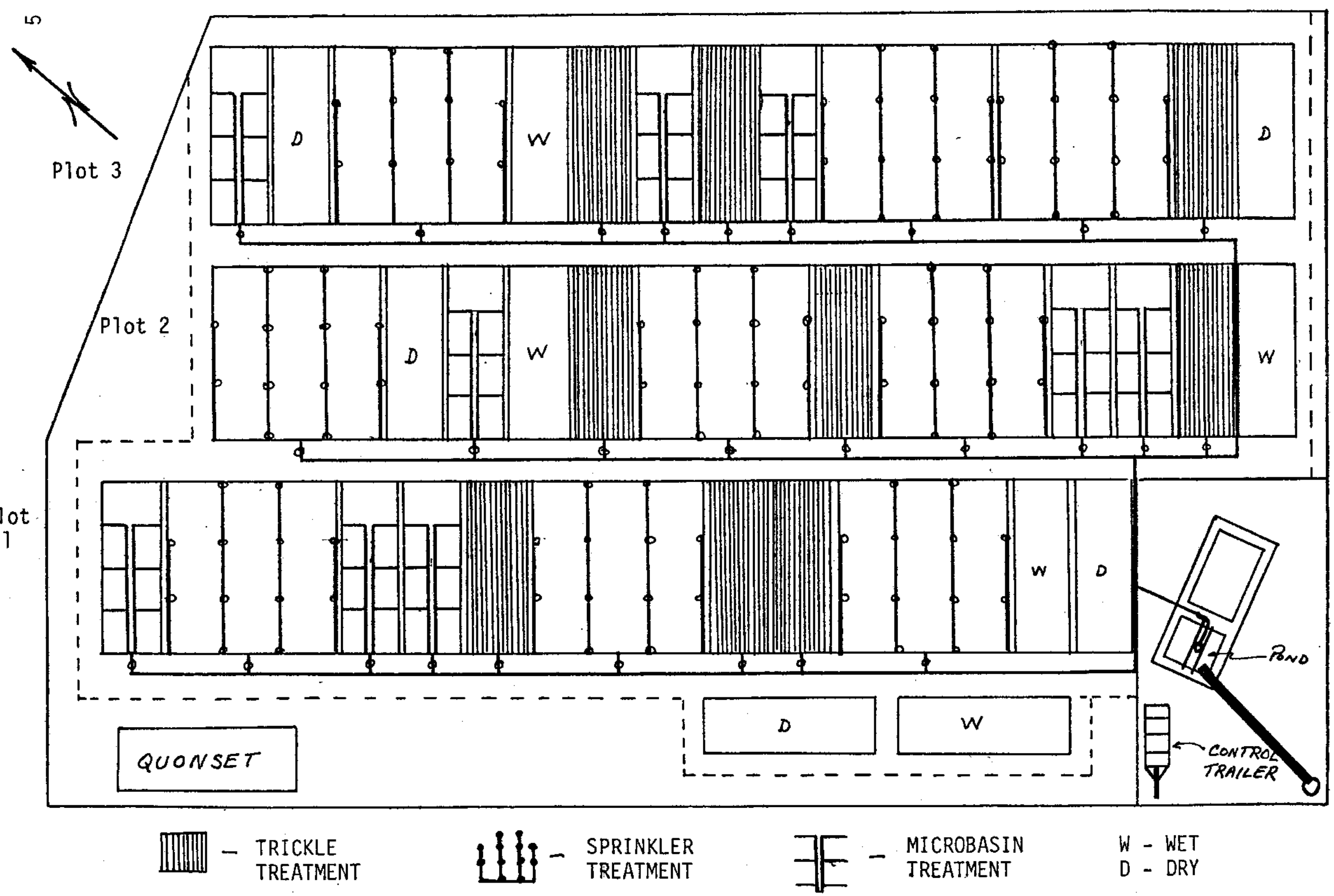
1. Sprinkler Irrigated, High Nitrogen Fertility
2. Sprinkler Irrigated, Medium Nitrogen Fertility
3. Sprinkler Irrigated, Low Nitrogen Fertility
4. Trickle Irrigated, High Nitrogen Fertility
5. Trickle Irrigated, Medium Nitrogen Fertility
6. Trickle Irrigated, Low Nitrogen Fertility
7. Micro-basin Irrigated, High Nitrogen Fertility
8. Micro-basin Irrigated, Medium Nitrogen Fertility
9. Micro-basin Irrigated, Low Nitrogen Fertility
10. Furrow Irrigated, High Nitrogen Fertility
11. Furrow Irrigated, No Fertilizer
12. Dryland, High Nitrogen Fertility
13. Dryland, No Fertilizer

Each treatment had three replications. Each plot was 12 m x 36 m (40 ft x 120 ft) except the sprinkler treatments which were 36 m x 36 m (120 ft x 120 ft). The "High" fertility treatments were equivalent to soil testing recommendations for high yields. "Medium" treatments were 0.5 times "High" and "Low" was defined as 0.25 times "High".

The sprinkler treatments had a design gross application rate of 8.5 mm hr^{-1} (0.33 inches hr^{-1}), the micro-basin treatments had a design gross application rate of 25.5 mm hr^{-1} (1.0 inches hr^{-1}), and the trickle treatments had a design gross application rate of 4.1 mm hr^{-1} (0.16 inches hr^{-1}). Each plot was independently controlled with a time-clock irrigation controller. Each plot was equipped with electric sorghum in the area. Efforts to recover yield from other plant parameters were inconclusive.

Grain sorghum was planted in April 1980 and harvested in August 1980. Research results are contained in Volume IV to this Technical Report. Irrigation was not required until after the grain sorghum reached the last stage, normally the stage when the greatest yield response to irrigation is noted. Consequently, the yield apparently was more a function of nutrient availability, including carry over from fertilizer trials the preceding year, than water availability.

PLOT LAYOUT


Plot 3
Plot 2
Plot 1
D
W
D
D
W
W
W
D
D
W
QUONSET
POND
CONTROL TRAILER
TRICKLE TREATMENT
SPRINKLER TREATMENT
MICROBASIN TREATMENT
W - WET
D - DRY

controlled solenoid valves (24 V., 2 Watts) and switching tensiometers to "override" the controller. Event counters and running time meters continuously monitored each plot.

Irrigation water was pumped from the Brazos River into a lined pond that served as the water supply for the irrigation. The water was filtered at the pond and pumped by a submersible turbine for the trickle system and by a vertical turbine for the sprinkler, micro-basin, and furrow plots.

An automatic weather station was installed at the research site. Temperature, humidity, soil temperature, rainfall, wind run, and solar radiation were automatically recorded on paper tape and on cassette. The cassette containing weather observations could be replayed directly into the computer disk files of the Texas A&M University computer system.

Twenty-seven lysometers were installed below plow depth in treatments one through nine. Tubing lines were run underground to a central vacuum pump shelter for collection of leachate samples for nitrogen content. Soil samples from each plot were collected to depths of 2.5 meters at least once each cropping season for each plot. These were analyzed for nitrogen content.

The underground water delivery system was installed during the growing season of 1978. Wheat was planted in November 1978 and harvested the following spring. Irrigation opportunities were severely limited by abundant rainfall that supplied the wheat with all water requirements. Consequently, yield data was inconclusive.

Grain sorghum was planted in June 1979, but was not harvested due to extreme damage to the maturing grain from migratory blackbirds and grackles. The sorghum was two months later than commercial grain

RAINFALL AND WATER REQUIREMENTS

This research emphasized that rainfall climatology must be taken into account in the design of irrigation research. The rainfall climatology for the Brazos farm area is contained in Table 1.

Table 1. Rainfall Climatology for Cameron, Texas (Climatography of the United States No. 20, April 1978, NOAA-Environmental Data Service, National Climatic Center, Asheville, NC)

Month	Mean * Rainfall	Probability Levels ** 20 %	50 %	80 %
January	2.15	0.66	1.69	3.35
February	2.74	1.47	2.45	3.77
March	1.96	0.66	1.54	2.99
April	3.77	1.95	3.35	5.26
May	3.79	1.71	3.25	5.48
June	2.75	0.79	2.11	4.31
July	1.31	0.19	0.91	2.19
August	1.90	0.24	1.13	3.14
September	4.24	1.56	3.43	6.40
October	3.74	1.20	2.97	5.79
November	2.84	1.08	2.31	4.26
December	2.54	1.19	2.20	3.64
Totals	33.73			

* presented in inches, the units of the referenced source.

** rainfall with probability equal or less than the amount indicated.

The water requirements for wheat and sorghum in southeastern Texas are contained in Table 2. These figures were computed with the Blaney-Criddle method.

Table 2. Consumptive Use of Water by Wheat and Sorghum (McDaniels, L. L., 1960. Consumptive use of water by major crops in Texas. Texas Board of Water Engineers, Bulletin 6019, Austin, Texas)

Month	Wheat	Sorghum
January	1.3*	—
February	2.3	—
March	5.7	—
April	7.2	2.1
May	5.5	5.0
June	—	7.1
July	—	4.6
August	—	—
September	—	—
October	—	—
November	1.3	—
December	1.3	—
Totals	24.6	18.8

* units are in inches, the units of the referenced source

A comparison of the water available from precipitation and the water requirements of wheat and sorghum strongly indicates that irrigation will not be needed every year at the research site. Supplemental irrigation will be required, especially during the mid-summer months, in perhaps five or six years of ten in order to obtain the yield potential of the crops. The period of research of this project simply was not long enough to coincide with weather conditions favorable for high frequency irrigation. The rainfall totals for the period of field crop growth are shown in Table 3.

Table 3. Rainfall at the Brazos Farm Area

Months	1978	1979	1980
January	——	1.03	2.70
February	——	3.42	1.98
March	——	4.76	5.32
April	——	3.98	1.86
May	——	9.89	6.54
June	——	1.31	.70
July	——	5.53	.42
August	——	1.80	.17
September	5.33	3.83	——
October	.35	1.47	——
November	6.15	3.42	——
December	2.86	2.89	——
Totals	14.69	43.33	19.69

SUMMARY

High frequency irrigation is a proven management system with several advantages. It has the potential to significantly increase yield by the application of a relatively small percentage of the total water requirement. However, the rainfall regime must be favorable for high frequency irrigation studies or else the period of the research must be multi-year if the research objectives are to be obtained.

REFERENCES

Howell, T. A., E. A. Hiler, and D. C. Reddell, 1976. Optimization of Water Use Efficiency Under High Frequency Irrigation. II. System Simulation and Dynamic Programming. Trans ASAE 18 (5): 879-887.

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