IMPROVED WATER-USE MANAGEMENT
BY USING WIDE-SPACED
FURROW IRRIGATION

By

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IMPROVED WATER-USE MANAGEMENT

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FURROW IRRIGATION

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CHAPTER I

INTRODUCTION

Water is usually the principal limiting factor for crop production in the Great Plains. Cropping patterns in the drylands are also determined by average rainfall timing within the year. Increased irrigation in the last 30 to 40 years enhanced crop production in the Great Plains. In the Oklahoma Panhandle over the past three decades, irrigated land area increased from 11,500 acres to about 750,000 acres between 1950 and 1983 (Schwab, 1983). In this region the main source of irrigation water is the Ogallala aquifer, which is recharged only by the small annual rainfall and snow (Harris et al.,1983).

As the irrigated acreage increased, the ground water level of the aquifer declined, and irrigators faced high cost of energy and shortage of irrigation water. The increase in cost of irrigation production has forced irrigators to re-evaluate the strategy of irrigation in the last 3 to 4 years. To reduce pumpage requirements and cost of energy without limiting the water supply to the crop, irrigators are looking for efficient methods of application of irrigation water which can produce acceptable yields with less water.

There are many methods of applying irrigation water. Furrow irrigation is a common means of application of water in Oklahoma. With any irrigation scheme water not taken up by plants can be lost from the soil surface to evaporation (Ev) or can percolate out of the root zone. Furrow irrigation can have high Ev. A goal of this research was to seek a way to minimize Ev loss of water and thus increase water availability to plants while maintaining yield with less water applied. The purpose of this research was to compare the effectiveness of a given amount of water applied as wide-spaced furrow irrigation (WSFI) and every furrow irrigation (EFI).

CHAPTER II

LITERATURE REVIEW

While water is the most limiting factor to crop production in the U.S. Great Plains, irrigation has been extensively practiced in the region to minimize drought stress. Irrigated agriculture expanded in the last 30 to 40 years as a result of:

1) increased research efforts on irrigation water management and development of new methodologies of irrigation water application.
2) development of new pumping techniques.
3) the availability of a relatively cheap energy supply.

(Harris et al., 1983 and Kanemasu et al. 1983). Irrigated area has declined only recently owing to lowered water tables and increased energy cost.

Wide-spaced furrow irrigation (WSFI) is the application of irrigation water to furrows spaced by more than 2.5 m, and it requires a medium to fine textured soil where the potential for lateral as well as vertical movement of water is very high (Stone et al., 1979, 1985).

WSFI and every furrow irrigation (EFI) water application mechanisms were extensively studied by Stone and others at Goodwell, Altus, and Chickasha, Oklahoma from 1967 to 1979 (Stone et al., 1982, 1985). Related research was conducted in Bushland, Texas (Jensen and Sletten, 1965), and Garden City, Kansas (Musick and Grimes, 1961).

A cotton study carried out at Altus, Oklahoma from 1969 to 1979 indicated a higher yield potential for WSFI over EFI. This result was obtained by applying half the amount of water in the WSFI as the EFI treatments over the growing season (Stone et al., 1982; Keflemariam, 1974).

Newman (1968) compared EFI with the alternate furrow irrigation mechanism on a 1.02 m furrow spacing by applying the same quantity of water to each furrow. The result of this study indicated the average amount of water applied to alternate furrow was reduced by one-half and also indicated an increase in water use efficiency (WUE) of cotton plants. However, his alternate furrow irrigation was not WSFI.

Hodges et al.(1983) compared the amount of water used by WSFI and EFI using an irrigation interval of 9 days. They found that the WSFI treatment used half as much water as the EFI treatment and produced a reasonable yield.

Alternate furrow irrigation under limited water supply was studied by Musick and Dusek (1974). They reported that alternate furrow irrigation would allow fields to be irrigated within a short period of time and offered an opportunity to reduce the size of irrigation.

Grain yield of sorghum is most significantly correlated with soil moisture availability during the growth stage of boot to bloom (Nix and Fizpatrick, 1969; Shipley and Regier 1975). Further, Shipley and Regier (1975) determined yield responses from irrigation applied to grain sorghum. Their result indicated a single irrigation applied at the boot stage gave the highest grain yield per unit of water.

Increasing or decreasing row width has an effect on evaporation and the WUE of plants. When a soil surface is covered by a plant canopy, evaporation can be reduced and WUE of plants would be increased. Newman (1967) studied the effect of solid and skip row systems on cotton yields under minimum soil moisture supply. The plant two and skip one system with 1 m-spaced rows and plant two and skip two system both increased irrigation WUE.

Ramig and Rhoades (1963) indicated that WUE increased as the soil water content increased to 0.15 m at the time of planting.

Crabtree et al.(1985) studied the effect of alternate furrow irrigation on Soybean. Analysis of four years of data showed that varieties Essex and Sohoma gave 16% and 18% lower yields under an alternate furrow irrigation treatment when compared to an every furrow irrigation treatment. The lower yield of the alternate furrow treatment was due to smaller seed size, lower number of pods, and lower number of seeds. By following this procedure they reduced the irrigation water requirement by 50% and also produced an acceptable yield.

Transpiration and plant growth are strongly influenced by weather factors. Research conducted at different locations has shown dry matter production and transpiration to be directly proportional to one another (Hanks, 1969; DeWit, 1958).

Al-Khafaf et al. (1978) and Ritchie (1972) showed that the rate of evaporation was higher initially and decreased with time right after irrigation.

Grain sorghum is less affected by sequencing of evapotranspiration (ET) deficit with respect to its growth stages than is corn. However, Stewart et al. (1975) found that an early ET deficit could cause a significant reduction of yield of grain sorghum.

Yields of sorghum differ from year to year. In order to account for these variations, it is necessary to look to the total environment of the plant, both external and internal. The genetic components control many phases of the sorghum plant and its development (Jordan and Sullivan, 1982). Under dry conditions, sorghum plant water absorption from a soil is dependent on the location and density of roots (Jordan and Miller, 1980).

Most frequently variability of yield occurs as a result of treatment differences (mode of water application, and water amounts). Cultural practice and environment have an effect. The potential and actual yield of sorghum to some degree is a function of environmental factors such as temperature, radiant energy, wind and humidity (Trogdon, 1965).

The amount of water available to a dryland crop depends both on the amount stored in the soil profile at planting and the precipitation during the growing season. The worth of light rainfall depends greatly on the texture of the soil. Usually light rainfalls will be lost to evaporation before the roots extract the water (Passioura, 1982). Further, he indicated that the more water the root of a plant collects the greater will be its yield, and also that the greater growth of roots may in turn result in the extraction of more water from the soil.

Frequent irrigation resulted in shallow root development with most water-use from the surface to 0.40 m of the soil depth, and the depth of soil water extraction increased with plant age and with less frequent irrigation (Myers et al., 1984).

CHAPTER III

MATERIALS AND METHODS

Research was conducted at the Panhandle Research Station at Goodwell, Oklahoma during the summers of 1984 and 1985. Grain sorghum (*Sorghum bicolor* L. Moench. cv.Pioneer 8501) was used in both years. The soil type was Richfield clay loam (fine montmorillonitic, mesic, Aridic Argiustoll). The soil type where this research was conducted appeared to be uniform across the field except at 1.80 m a caliche soil layer was observed in one plot of EFI Trt. 3.

A randomized complete block design (RCBD) with three replications, two modes of water application and two seasonal amounts of water was used.

In this study the two modes of water application were:

1- Every furrow irrigation (EFI)

2- Wide-spaced furrow irrigation (WSFI)

Grain sorghum was planted two rows to the bed. Planting dates are shown in Figures 1 and 2. Each bed was 1.42 m wide and 46 m long. Row spacing on the bed was 0.71 m between rows. Plots of WSFI had 6 beds/plot and plots of EFI had 5 beds/plot. "Miloguard" preplant herbicide at 2.24 kg/ha and 224 kg of nitrogen per hectare was applied.

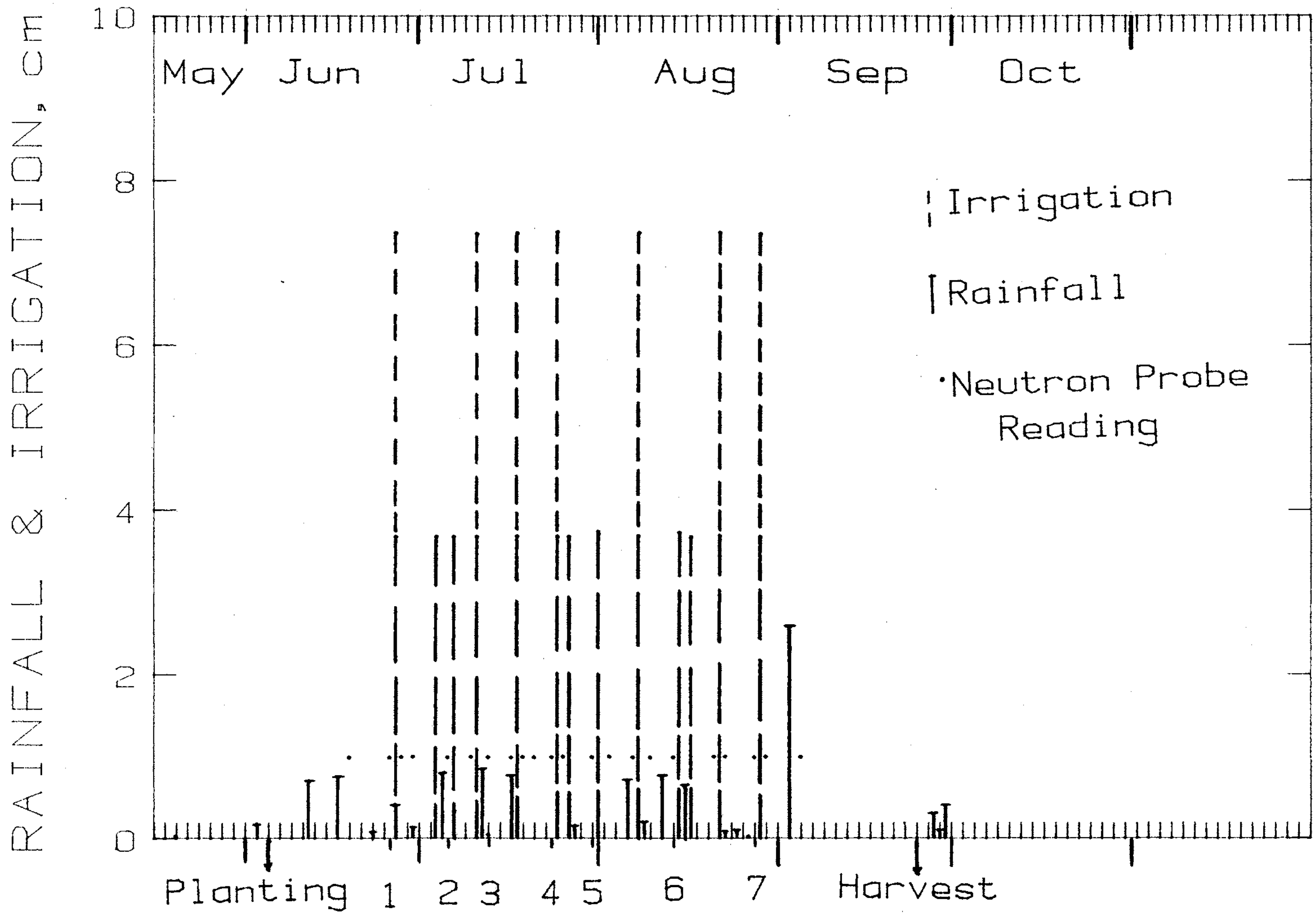

Figure 1. Rainfall, Irrigation, Neutron Probe Reading, Growth Stages, Planting and Harvesting Dates, 1984.

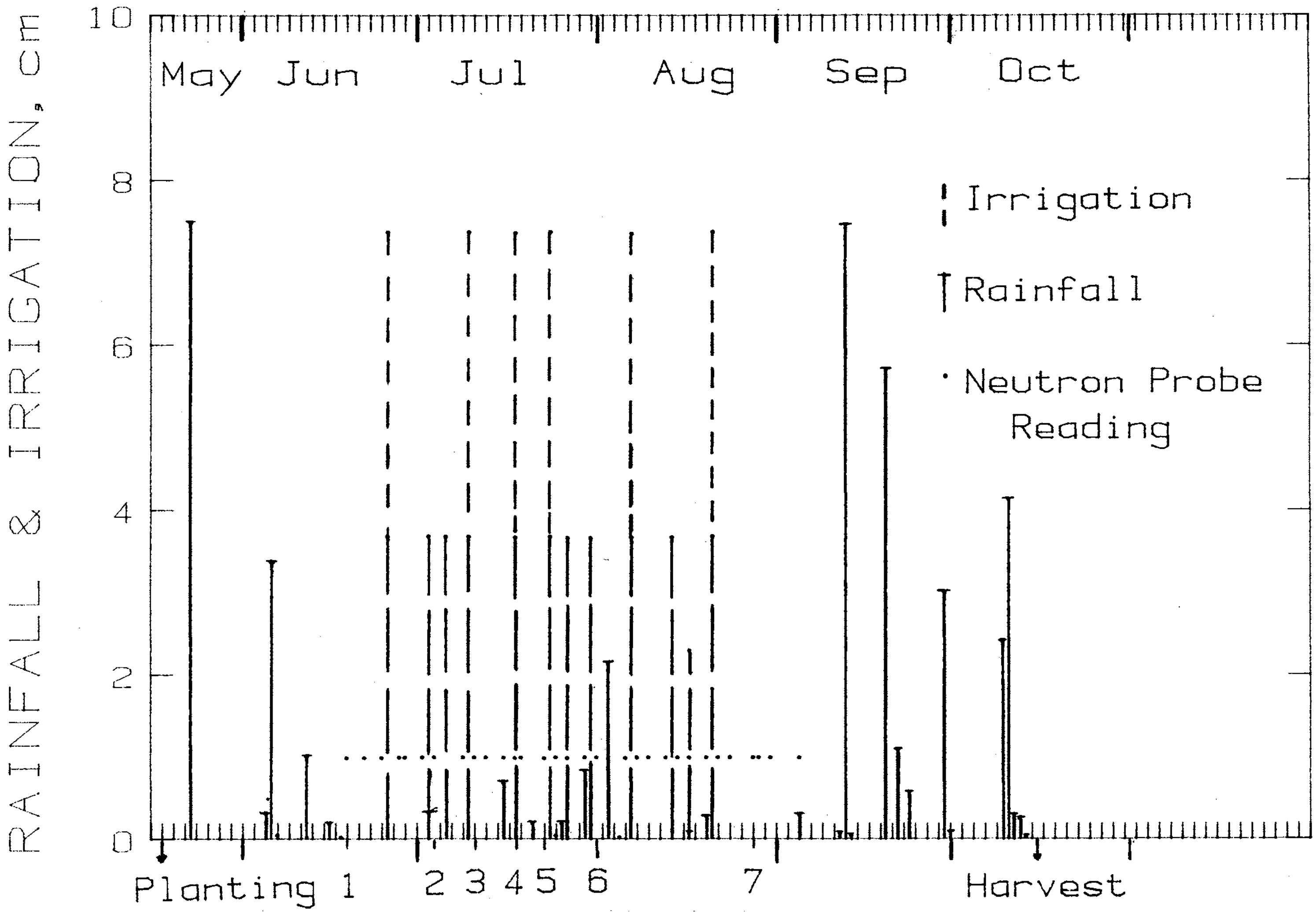

Figure 2. Rainfall, Irrigation, Neutron Probe Reading, Growth Stages, Planting and Harvesting Dates, 1985.

Two seasonal amounts of water were used.

Water Amount A:

Mode 1, Trt. 1- Irrigate alternate furrows alternately every 10.5 days.

Mode 2, Trt. 2- Irrigate every furrow every 21 days.

Water Amount B:

Mode 1, Trt. 3- Irrigate alternate furrows alternately every 7 days.

Mode 2, Trt. 4- Irrigate every furrow every 14 days.

All irrigated furrows received the same amount of water during each irrigation. The flow rate into each furrow was measured with a bucket and stop watch. Gates were adjusted to ensure the same water delivery. The plots were bordered so runoff did not occur from the plot area.

On a given irrigation day, half of the furrows of Trt. 1 were irrigated, which means the irrigation water to the plot was one-half of the water applied to Trt. 2. The same water application technique was followed for Trt. 3 and 4, where Trt. 3 gets only one half of the water applied to Trt. 4 on each irrigation day. At the end of the growing season Trt. 1 and 2 would have received equal amounts of water, and Trt. 3 and 4 would receive greater but equal amounts of water.

Soil moisture measurements were made with a Troxler neutron scattering soil moisture meter, model 3223. Two neutron access tubes were placed on each side of a bed near the center of a plot. On the WSFI plots, tubes were placed near the plant rows, one on the wet furrow side and one on the dry furrow side of the bed. These tubes were placed to evaluate the effect of the dry and wet furrows. On the EFI plots, tubes were placed similarly on each side of the beds. These tube placements were designed to give the same precision of water estimates in all plots.

In the 1985 study netting was used to protect sorghum plants from bird damage. When the sorghum plants started heading, the heads in the harvest area were covered with the net. The net was tied to the bottom part of the stalk of the plants.

The harvest area was 4 rows wide and extended 5.69 m from each side of the neutron tubes. Harvest was by hand.

Figures 1 and 2 show date of planting, irrigation, neutron probe readings, harvesting, and growth stages of plants. The growth stages were: 1) 6-leaf, 2) 9-leaf, 3) 10-leaf, 4) flag leaf, 5) half bloom, 6) full bloom, and 7) hard dough. They also show the quantity of rainfall and the amount of irrigation water applied to each treatment on each irrigation day.

<u>Measurements of Soil Water and Its Use</u>

A water budget based on soil water change was attempted. In 1984 tubes were extended to 1.20 m and in 1985 tubes were extended to 1.80 m. Neutron probe readings were taken at 0.15 m increments down the soil profile. To estimate how much water was applied at each irrigation to each treatment, the water content data was used to plot total water in the profile (m) vs time (days). The slope of the curve of water use after each irrigation was extrapolated to the time of the neutron reading made just prior to irrigation.

Net soil water extraction (NSWE) refers to water extraction between neutron reading dates and was calculated by subtraction of water content data before irrigation from water content data after the previous irrigation, using the extrapolation procedure described above.

Net soil water depletion (NSWD) refers to the net change in profile water over the season and was determined from the neutron probe data. To calculate NSWD, the water content data of the first neutron probe reading was subtracted from the last reading of the season.

Neutron probe data were used to determine seasonal evaporation (Ev) from the surface of the soil. To get an estimate of Ev for each treatment, the water in the top 15 cm of the soil was considered to be lost to evaporation. By taking the difference of water content data after irrigation from the previous reading before the next irrigation for the 0 to 15 cm depth, the Ev values were determined.

To determine vertical water penetration, the differences in water content through the profile before and after each irrigation were analyzed. Treatments which received irrigation water on the same day and which received irrigation water within 21 and 14 days interval were tested for differences in irrigation water penetration.

CHAPTER IV

RESULTS

Meteorological Data

The total amount of rainfall and irrigation water added to the crop is given in Tables I and II. The rainfall events for the two growing seasons are also given in Figures 1 and 2. The highest amount of rainfall recorded in 1984 was 30 mm on 2 September. From the date of planting, 4 June, to 4 September 1984 a total of 98 mm of rainfall was recorded. A total amount of 174 mm of rainfall was recorded between 17 May 1984 and 20 August 1985. The above periods were selected on the basis of the importance of the rainfall to the crop, i.e., from date of planting to nearly the last date of irrigation (just prior to the hard dough stage). The highest 1985 rainfall amount was 75 mm on 22 May.

The water content data of 1984 revealed that at the beginning of the growing season there was a slightly higher soil moisture content in 1985 than 1984 (Figures 3 a through d & 4 a through d). Harvesting was delayed until 15 October due to a record wet September of 1985. It was observed that the average wind speed for the month of August to be higher for 1984 than 1985, that is, 194 miles/day for 1984 and

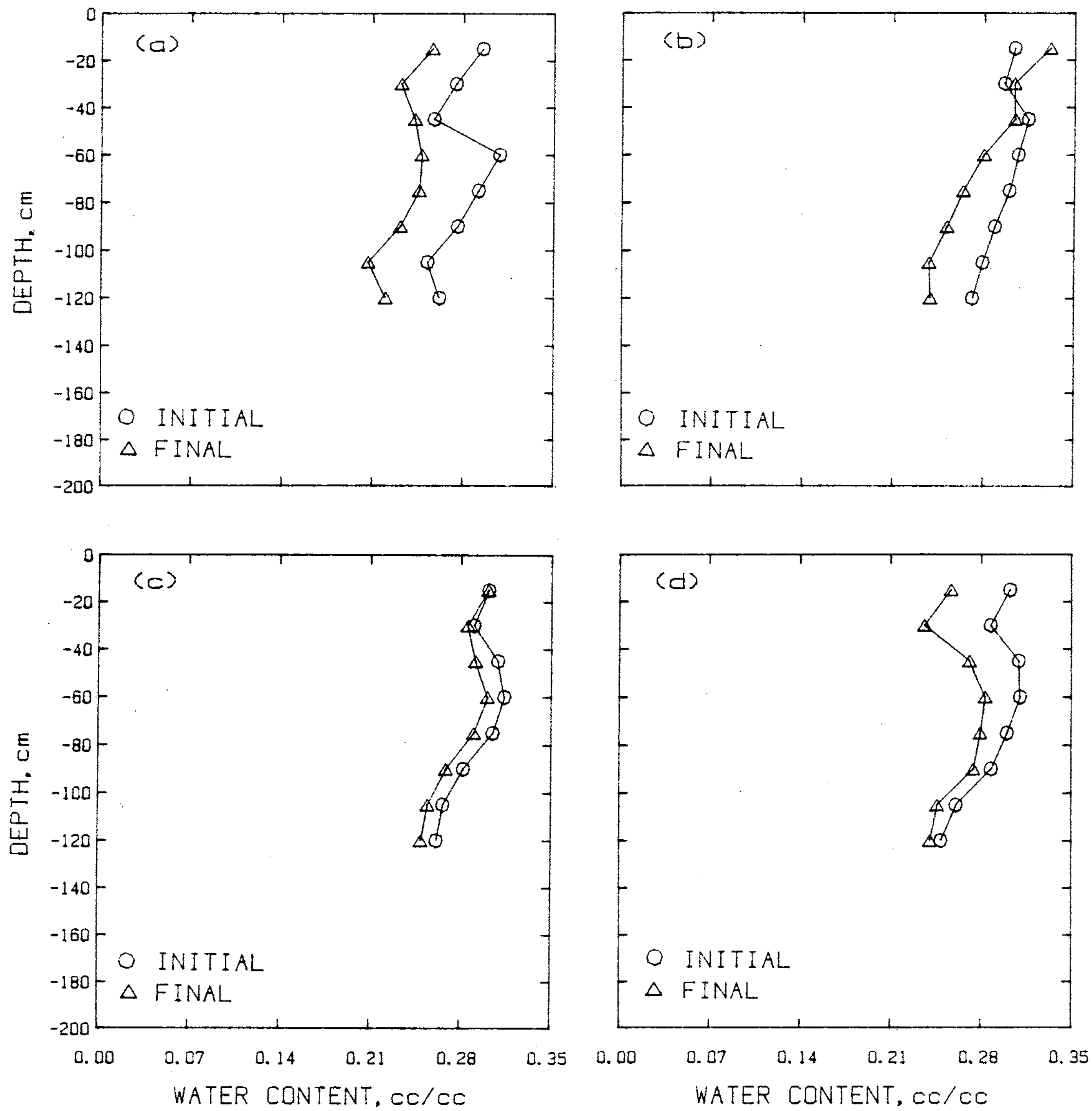

Figure 3. **Initial and Final Soil Water Content within Profile on 18 June 1984 and 4 September 1984 a) Trt 1, b) Trt 2, c) Trt 3, and d) Trt 4.**

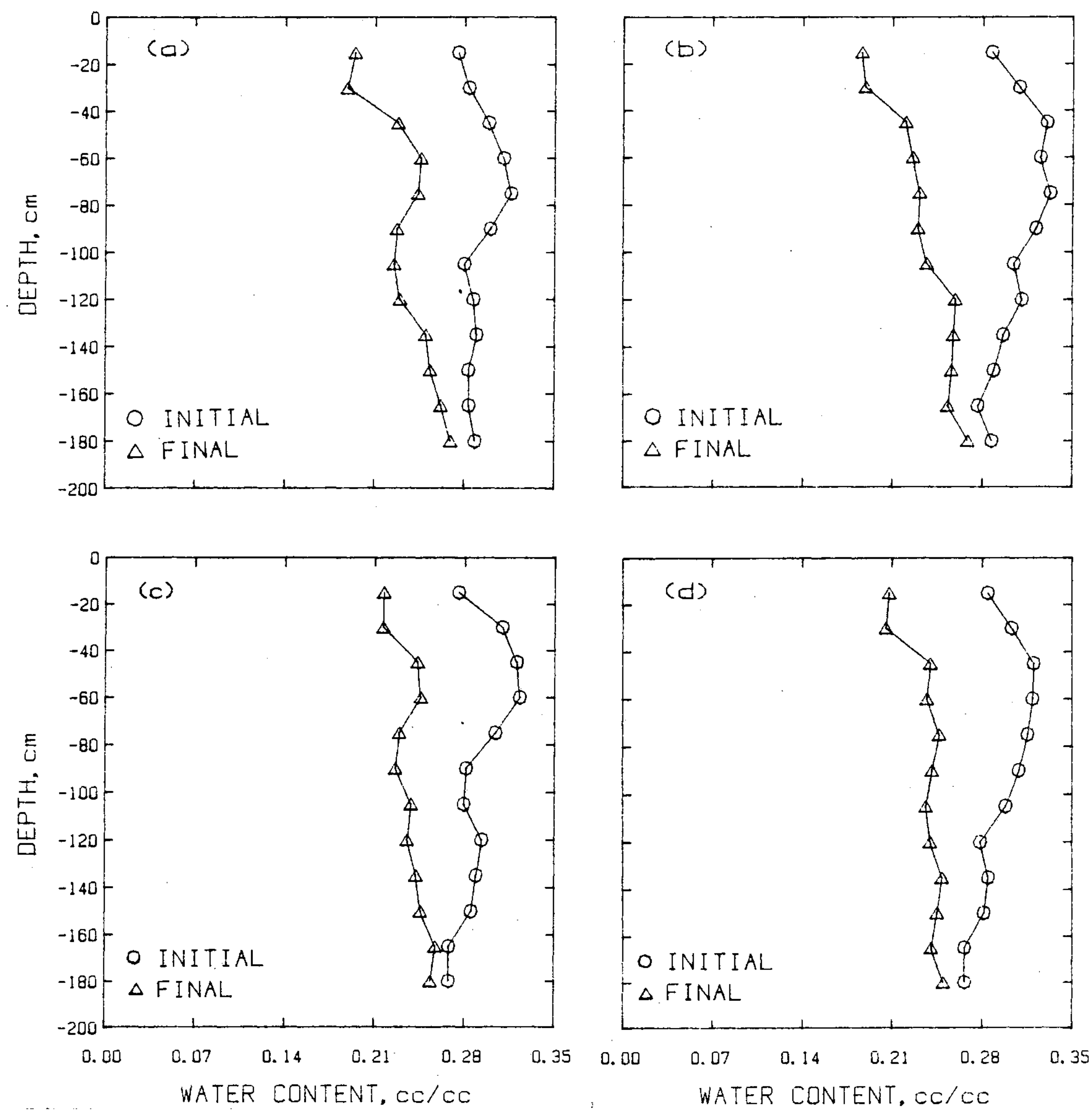

Figure 4. Initial and Final Soil Water Content within Profile on 18 June 1985 and 3 September 1985 a) Trt 1, b) Trt 2, c) Trt 3, and d) Trt 4.

132 miles/day for 1985 in the units originally reported (Appendix Table IX).

Yield

Grain yield and total irrigation water applied in the 1984 and 1985 growing seasons are summarized in Tables I and II. Harvested plot yield and moisture content of grain sorghum at harvest for each plot replication are given in the Appendix Tables XI and XII.

TABLE I

IRRIGATION WATER APPLIED, RAINFALL, AND YIELD DATA (GRAIN MOISTURE CONTENT ADJUSTED TO 13%) GOODWELL, OK., 1984

Trt & Mode	Irr Interval (days)	Water Amount	Irr Water Applied (m)	Rainfall (m)	Total Water Irr+Rain (m)	Yield (kg/ha)
1-WSFI	10.5	A	.26	.098	.36	7070ab
2- EFI	21	A	.30	.098	.39	6410 b
3-WSFI	7	B	.37	.098	.47	7360a
4- EFI	14	B	.37	.098	.47	7340a

LSD 0.05 for yield = 905 kg/ha
LSD 0.01 for yield = 1372 kg/ha

The analysis of variance and coefficient of variation (c.v.) for treatments are given in the Appendix Tables XIII and XIV. The c.v. was 6.97% for 1984 and 6.84% for 1985. Graphic results of the yield (kg/ha) vs irrigation water applied (m^3/ha) for the two years are given in Figure 5.

TABLE II

IRRIGATION WATER APPLIED, RAINFALL, AND YIELD DATA
(GRAIN MOISTURE CONTENT ADJUSTED TO 13%)
GOODWELL, OK., 1985

Trt & Mode	Irr Interval (days)	Water Amount	Irr Water Applied (m)	Rainfall (m)	Total Water Irr+Rain (m)	Yield (kg/ha)
1-WSFI	10.5	A	.21	.17	.38	6250a
2- EFI	21	A	.22	.17	.39	5270 b
3-WSFI	7	B	.33	.17	.50	6930a
4- EFI	14	B	.37	.17	.54	6510a

LSD 0.05 for yield = 803 kg/ha
LSD 0.01 for yield = 1216 kg/ha

In the 1984 growing season a significant yield difference (at the 0.05 level) was not observed between Trt. 1 and Trt. 2 (each with water amount A) and between Trt. 3 and Trt. 4 (water amount B), however WSFI seemed to have a higher yield potential than EFI (Table I). In 1985 the yield

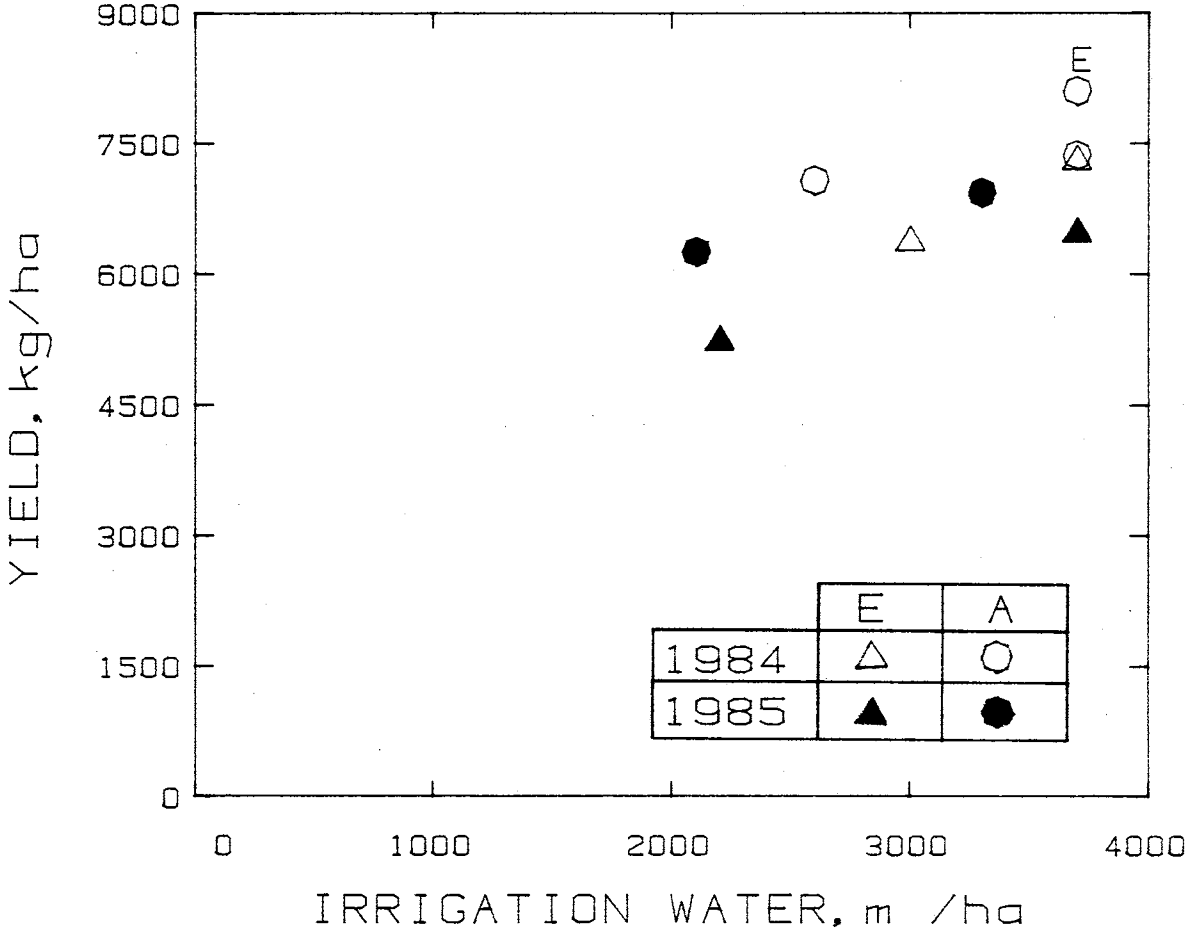

Figure 5. **Average Yield of Treatments for 1984 and 1985 E(EFI) and A(WSFI).**

data showed no significant difference between Trt. 3, and Trt. 4 (at the 0.05 level), but there was a significant yield difference between Trt. 1 and Trt. 2 (Table II).

Seedling emergence was uniform in both years. However, visual observation in both years showed that Trt. 2 plants were by far the shortest and latest in heading, and the leaves of the plants were stressed at mid day (compared to Trt. 3 plants). Trt. 3 plants showed fast growth, a good canopy cover and early heading.

The early head formation and greater height of plants in Trt. 3 exposed them to more bird damage than the other treatments. The bird damage was estimated by taking the head from a plant with damage and a head from a plant that was not damaged, but of equal development. The comparison of the weights of the head and grain resulted in approximately 10% more bird damage in Trt. 3 than to the other treatments. The adjusted treatment yield is indicated as E in Figure 5. In 1984 the plant population was 87,700 plants/ha and in 1985 it was 77,400 plants/ha.

The seasonal amount of irrigation water applied to treatments in the two growing season is tabulated in Tables I and II. For both water amount A (Trt. 1 and 2) and water amount B (Trt. 3 and 4) the same quantity of water was applied to each furrow at each irrigation by adjusting the flow rate. In 1984, Trt. 3 and Trt. 4 received 0.37 m of irrigation water and Trt. 1 received one less irrigation than Trt. 2. The Trt. 1 plots received less water because the plants had reached the hard dough stage before the last planned irrigation for Trt. 1. Trt. 3 received one less irrigation than Trt. 4 (Table II). The treatment reached the hard dough stage before the last scheduled date of irrigation.

In each irrigation 0.074 m of irrigation water was applied to EFI treatments and 0.037 m of irrigation water applied to WSFI treatments. Application of water in both studies was carefully measured, but in the 16 August 1985 irrigation, Trt. 1 furrows could not hold as much water as scheduled and received 0.015 m less water (Table II).

Irrigation Water Use Efficiency

Irrigation WUE of plants was determined for both years. The WUE values were determined on the basis of total irrigation water applied throughout the growing season, i.e., total yield (kg/ha)/total irrigation water applied (m^3/ha). Irrigation WUE values are given in Tables III and IV. In 1984, Trt. 1 irrigation WUE was significantly different from Trt. 2 and no significant irrigation WUE difference was observed between Trt. 3 and Trt. 4 (at the 0.05 level).

In 1985, WUE in Trt. 1 was significantly different from Trt. 2 and Trt. 3 was significantly different from Trt. 4. Higher irrigation WUE was obtained from WSFI than EFI. The total WUE (irrigation water + rainfall) is also given in Tables III and IV.

TABLE III

IRRIGATION WATER USE EFFICIENCY OF PLANTS, 1984

Treat-ment	Yield (kg/ha)	Water Amount	Total Irr (m^3/ha)	Total Irr+Rain (m^3/ha)	Irr WUE (kg/m^3)	Total WUE (kg/m^3)
1-WSFI	7070	A	2600	980	2.72a	1.97
2- EFI	6410	A	3000	980	2.14 b	1.61
3-WSFI	7360	B	3700	980	1.99 b	1.57
4- EFI	7340	B	3700	980	1.98 b	1.57

LSD 0.05 for IRRIGATION WUE = 0.30

TABLE IV

IRRIGATION WATER USE EFFICIENCY OF PLANTS, 1985

Treat-ment	Yield (kg/ha)	Water Amount	Total Irr (m^3/ha)	Total Irr+Rain (m^3/ha)	Irr WUE (kg/m^3)	Total WUE (kg/m^3)
1-WSFI	6250	A	2100	1700	2.98a	1.64
2- EFI	5270	A	2200	1700	2.39 b	1.35
3-WSFI	6930	B	3300	1700	2.10 b	1.39
4- EFI	6510	B	3700	1700	1.76 c	1.21

LSD 0.05 for IRRIGATION WUE = 0.31

This research was further aimed at investigating the difference between WSFI and EFI in water-use of plants. The following results which discuss water-use of plants were obtained from the neutron probe data.

Water Intake

Total amount of water applied to each treatment calculated from the actual water content data (not using the extrapolation method) is given in the Appendix Table X. Several days were skipped between the irrigation day and the next neutron probe reading. The table values in the Appendix consider only the water present in the soil profile at the time of neutron probe reading. The calculated total amount of water applied based on neutron moisture data is given in Table V. This method accounts for the evapotranspiration (ET) loss between irrigation day and the next neutron probe reading day. In both years the extrapolation technique gave a reasonably accurate estimation of total amount of irrigation water applied.

The net soil water depletion (NSWD) and net soil water extraction (NSWE) values for the two growing seasons are given in Table VI. These can be used to determine how much water was taken up by the plants as estimated by the neutron probe.

TABLE V

SEASONAL IRRIGATION WATER INTAKE AS INDICATED BY NEUTRON PROBE DATA FOR THE 1984 AND 1985 GROWING SEASONS

Trt #	Mode	Water Amount	Year 1984 Actual Applied (m)	Year 1984 Water Intake (m)	Year 1985 Actual Applied (m)	Year 1985 Water Intake (m)
1	WSFI	A	.26	.24	.21	.21
2	EFI	A	.30	.26	.22	.23
3	WSFI	B	.37	.28	.33	.33
4	EFI	B	.37	.29	.37	.30

TABLE VI

NET SOIL WATER DEPLETION AND NET SOIL WATER EXTRACTION FOR 1984 AND 1985 GROWING SEASONS

Treatment #	Mode	Water Amount	1984 Yield (kg/ha)	1984 (NSWD) (m)	1984 (NSWE) (m)	1985 Yield (kg/ha)	1985 (NSWD) (m)	1985 (NSWE) (m)
1	WSFI	A	7070ab	.053a	.27	6250a	.14a	.31
2	EFI	A	6410 b	.019 c	.28	5270 b	.14a	.37
3	WSFI	B	7360a	.013 c	.29	6930a	.11a	.38
4	EFI	B	7340a	.036 b	.30	6510a	.10a	.39

LSD FOR 1984 NSWD 0.05 LEVEL = 0.010, FOR 1985 = 0.028 LSD

Net Soil Water Extraction

The difference in mode of water application and frequency of irrigation brought about NSWE differences among treatments. In both years the EFI treatments extracted more water from the soil profile than the WSFI treatments (Table VI). The length of tubes in 1984 was not enough to detect the soil water content throughout the root zone. Therefore the EFI treatments took up more water than the WSFI but the apparent differences in 1984 was due to the shallowness of tubes.

In 1985 tubes, were extended to 1.80 m and water content of the soil was measured throughout the root zone. Measured NSWE values did show important differences between treatments.

Net Soil Water Depletion

The water content of the soil at planting time was higher in 1985 than in 1984 (Figures 3 a through d and 4 a through d). The higher water content in 1985 was the result of rainfall activity prior to planting (Appendix Table IX). In both years the water content of the soil profile gradually decreased at the later stages of plant growth, that is, irrigation did not totally replace ET.

In 1984 tubes extended to 1.20 m and total water throughout the profile was not detected. However, the results obtained from 1984 indicated that the WSFI Trt. 1

NSWD value was significantly different from Trt. 2 and Trt. 3 was also significantly different in NSWD from Trt. 4 (Table VI).

In the 1985 growing season however the two drier treatments (Trt. 1 and Trt. 2) depleted more water from the soil than Trt. 3 and 4. A significant difference in NSWD was not observed between the two modes of water application in 1985 (Table VI).

Water Loss to Evaporation (Ev)

The seasonal loss of water to evaporation (Ev) for the 1984 and 1985 growing seasons is estimated in Table VII. The seasonal loss of water to Ev is assumed to be the water loss from the 0 to 15 cm soil depth.

TABLE VII

LOSS OF WATER FROM THE SOIL SURFACE, Ev

		Year	
Treatment #	Mode	1984 Surface Ev (m)	1985 Surface Ev (m)
1	WSFI	.07 c	.08 c
2	EFI	.09 b	.10 b
3	WSFI	.10 b	.11 b
4	EFI	.13a	.13a

LSD FOR 1984 Ev LOSS AT 0.05 LEVEL = 0.02, FOR 1985 = 0.013

Water loss to Ev from each treatment is given in Table VII. In 1984 water loss to Ev was higher from EFI treatments than WSFI treatments. A significant difference in Ev (at the 0.05 level) was found between Trt. 1 and 2, and also between Trt. 3 and 4. In 1985 similar trends of water loss to Ev were observed as 1984, that is, significant difference of water loss to Ev was observed between treatments at the 0.05 level.

Irrigation Water Penetration

Under drought conditions this type of soil will develop large cracks. Soil wetness will affect the development of cracking. Irrigation which followed dry periods for given furrows may have had opportunity for deep penetration along cracks. Table VII shows data results of a search for such phenomena.

In 1984, due to the shallowness of the neutron tubes, it was hard to tell how deep water penetrated into the soil profile. However, Table VIII suggests the potential for deep penetration of water to be higher for EFI than WSFI.

In 1985 irrigation water did not penetrate below 0.90 m on the average, and significant differences in irrigation water penetration was not observed. The reasons for absence of difference were the high water content in the soil profile at the beginning of the growing season and the lack of large cracks.

TABLE VIII

IRRIGATION WATER PENETRATION FOR
1984 AND 1985 GROWING SEASONS

Date of Irr	Treatment #	Mode	Tube #	Irrigation #	Ave Depth of Penetration (m)
26 Jul 1984	1	WSFI	2	2	.65
24 Jul 1984	3	WSFI	1	3	.50
24 Jul 1984	4	EFI	2	3	.85
6 Aug 1985	1	WSFI	1	3	.55
6 Aug 1985	2	EFI	1	3	.90
6 Aug 1985	3	WSFI	1	4	.55
6 Aug 1985	4	EFI	1	4	.80

CHAPTER V

DISCUSSION

The main objective of this research was to test whether WSFI will give a higher yield than EFI for the same amount of water supply in a given growing season. The hypothesis was tested on grain sorghum in 1984 and 1985 and higher yields were obtained from the treatments of WSFI than EFI for a given water input (Figure 5).

In 1984 a significant difference of yield (at the 0.05 level) was observed between Trt. 1 and Trt. 2 and significant difference of yield was not observed between Trt. 3 and 4. In 1984 under water amount A the WSFI treatment gave 10% more yield than the EFI treatment and under water amount B the WSFI treatment gave 0.30% more yield than the EFI treatment. The bird damage to the WSFI Trt. 4 in 1984 caused the percent yield increase of water amount B to be low (Table I). In 1985 the WSFI treatments showed a 19% and a 7% yield increase over the EFI treatments (Table II).

In both years water applied as WSFI showed an effect on yield improvement. Thus, yield differences include differences caused by changing the method of water application.

The second part of the study evaluated the wetting differences of the two modes of water application. The movement of water and the wetting pattern of each mode of water application was different. The WSFI method wet only half way across the surface of the bed at each irrigation and the remainder of the surface stayed dry. This mode of water application evidently reduced water loss to evaporation (Ev) by keeping the surface drier (Table VII, Figures 6a & b and 7a & b). In the EFI method of water application, wetting occurred from the furrows on both sides of the beds and wet across the entire bed. This wetting behavior kept water on the surface longer. When the water remains on the surface, the water can be lost to Ev and this water loss to Ev keeps the EFI treatments at a disadvantage (Table VII).

Grain yield did not necessarily depend on the total amount of water used or applied, because yield is a function not only of the amount of water used during the growing season, but on timing of application, be it rain or irrigation.

In the 1985 growing season, treatments received more water (rainfall and irrigation water) than in 1984, average treatment yield of 1985 was lower than 1984 (Tables I and II). The cumulative effect of early planting, high demand of Ev, plant population, late harvesting, and suboptimal timing of rains might be reasons for the low average treatment yield of 1985.

Planting dates for the two growing seasons were different. Planting was on 4 June 1984 and 17 May 1985. In 1985 early planting increased the number of days from

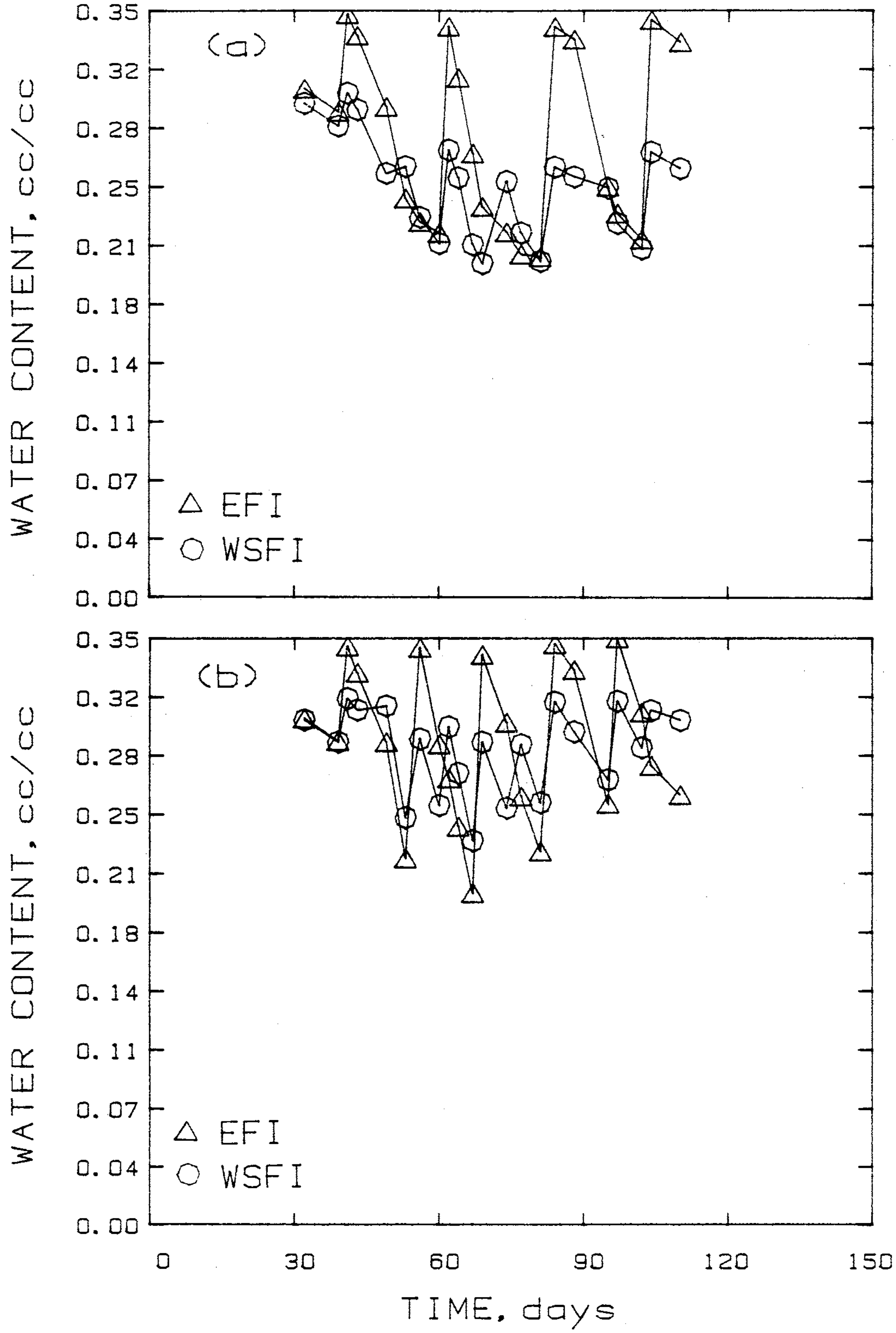

Figure 6. Soil Water Content at 0.15 m depth, 1984
a) Trts 1 & 2 and b) Trts 3 & 4.

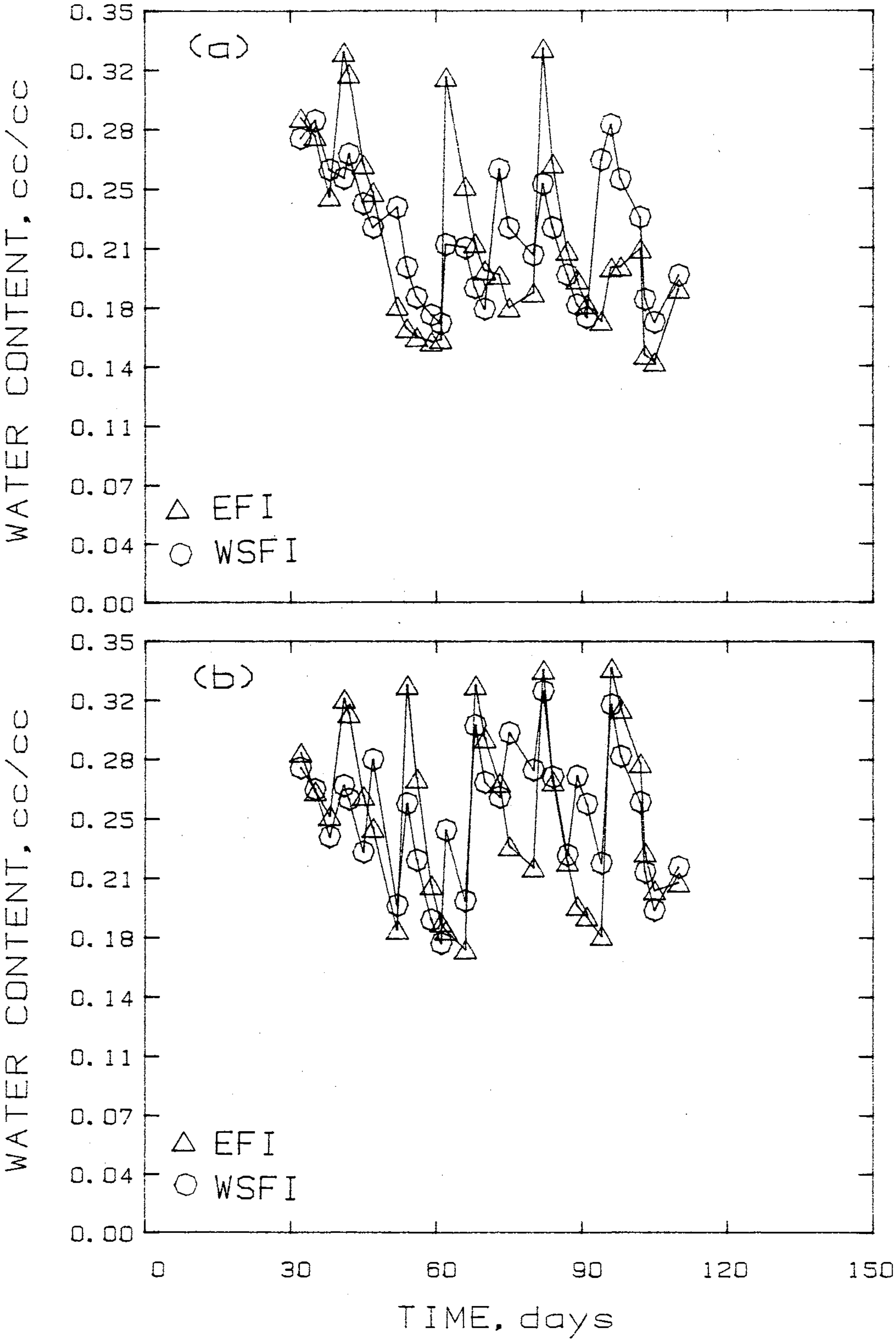

Figure 7. Soil Water Content at 0.15 m depth, 1985
a) Trts 1 & 2 and b) Trts 3 & 4.

emergence to heading, and unfortunately the wet September in 1985 delayed harvesting. The early planting and late harvesting contributed to the low treatment yields of 1985.

In the 1984 growing season, water loss to Ev was less than 1985 (Table VII). The degree of water loss to Ev varies according to the frequency and amount of water applied to each treatment. The less frequently irrigated treatments lose less water to Ev than the more frequently irrigated treatments. However, the water loss to Ev was higher for EFI treatments than WSFI. High yields were achieved from WSFI treatments (Tables I and II) mainly because of the low Ev loss.

The WUE of plants was higher for treatments of WSFI than EFI (Tables III and IV). Due to less Ev and efficient use of water, more grain was produced per amount of water applied when applied as WSFI than EFI. The WSFI treatments, which produced high yield, therefore resulted in higher WUE of plants.

Water Intake

The particular objectives of a research project are a factor in selecting the length and location of neutron access tubes. The neutron probe moisture meter was very dependable in these studies. In the 1984 growing season 76 to 92% of the total irrigation water applied to each treatment was accounted for by the extrapolation of the actual water content data to irrigation dates. In 1985 better results were obtained due to the extension of the neutron access tubes to 1.80 m (Table V). In fact, the length of neutron tubes is very critical to make an accurate measurement of total water intake. These data show in 1984 that the shallowness of neutron tubes might have caused the underestimation of the total water intake.

In 1984, water penetrated below the 1.20 m depth (Figure 8). The shallowness of neutron tubes caused the water intake measurement to be less than the actual amount of water added (Table X). Largely, these data did not account for evapotranspiration (ET) between the irrigation and the neutron probe measurement.

The time interval between one irrigation day and the first neutron probe reading was the other factor which caused the water intake value to be different from the actual amount of water added. According to Ritchie (1972) evaporation of water from the surface of a soil is high in the first day or two. In both years neutron probe readings were taken two to three times a week. Soil moisture measurement was delayed until the field was dry enough for foot traffic. The delaying of soil moisture measurement caused the water intake value to be less than the actual amount of water applied (Table V) by not accounting for the high ET during this period.

Overall, in the 1984 and 1985 studies the extrapolation method gave a very good estimation of total water intake by each treatment. If one wants to avoid extrapolation of

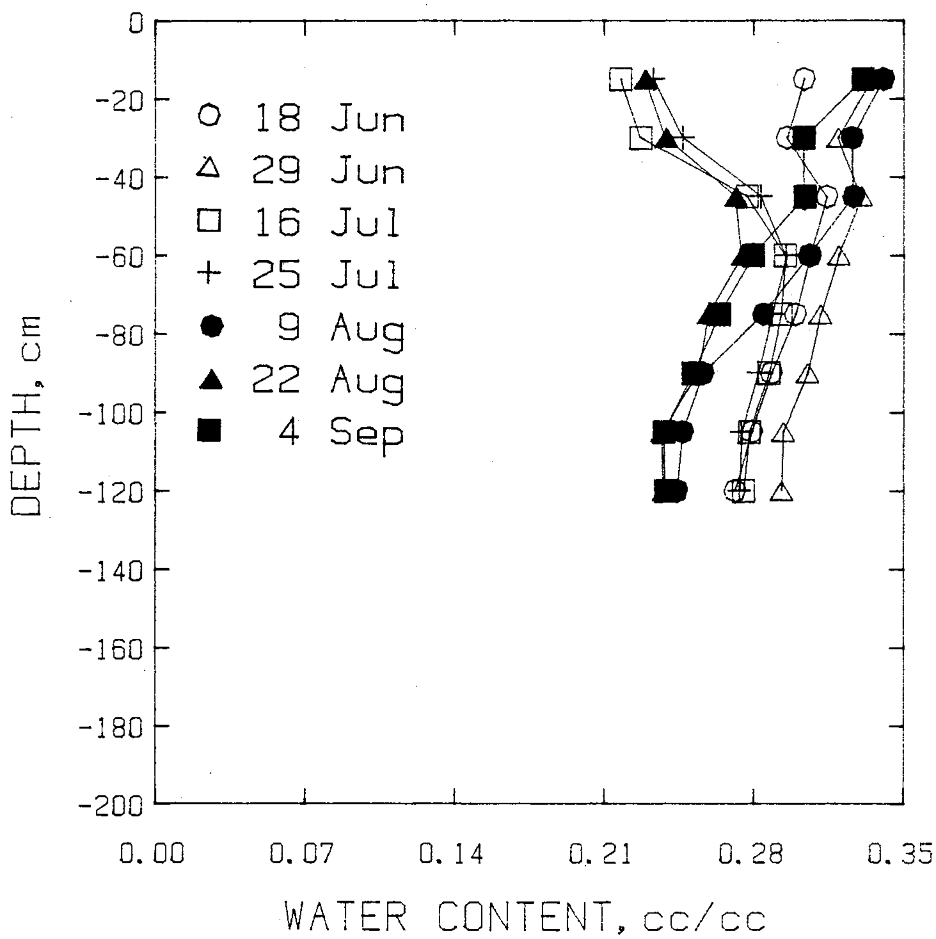

Figure 8. Soil Water Distribution within the 0-1.20 m profile in 1984.

neutron probe data, it would probably be necessary to take daily measurements of soil water content.

Extraction

In both years the NSWE values obtained from the neutron probe data (Table VI) showed that treatments of WSFI extracted less water from the soil than treatments of EFI. Water extraction from the soil profile changes with growth stage of plants, frequency of irrigation, and root distribution. According to Wright et al. (1983) water extraction during early growth was from the top 0.40 m where most of the plant roots concentrated. Gradually the zone of extraction of water advances downwards at the later growth stages.

In both years the EFI treatments showed the tendency of higher seasonal extraction. The high evaporation (Ev) rate from the surface of EFI treatments may have caused high extraction. The frequency of irrigation contributes to how much water evaporated from the soil surface. In both years the most frequently irrigated treatments lost more water to Ev than the less frequently irrigated treatments, that is, Trt. 3 and 4 lost more water to Ev than Trt. 1 and 2. Trt. 3 and 4 lost more water to Ev because of more moisture at the soil surface than the less frequently irrigated treatments.

The difference in mode of water application, wetting behavior, and frequency of irrigation have a strong influence on the distribution of roots and the depth of soil water extraction. By extending the length of the neutron tubes to 1.80 m in 1985 the depth of soil water extraction for each treatment could be determined (Figure 5 a through d). Most of the extraction by the WSFI treatments in 1985 occurred between depths of 0.60 and 1.20 m in the soil profile (Figures 5a and 5c). The EFI treatments extract water from near the surface as well as deeper. The difference in depth of soil water extraction indicated the root distribution to be different for each treatment, that is, WSFI treatments might have a short and highly concentrated root zone, between the 0.60 and 1.20 m depths.

In general, the water content of the soil profile declined at the latter growth stages, because the irrigation could not meet the demand of evapotranspiration. However, from the water content data of 1985 one sees that the WSFI treatments had more water in the lower depth of the soil profile than EFI treatments (Figures 9a & b and 10a & b). The higher soil water extraction for EFI treatments over the WSFI treatments was evident. The yield superiority of WSFI was due to low Ev loss.

Depletion

In 1984, Trt. 1 (WSFI) was significantly different from Trt. 2 (EFI) in net soil water depletion (NSWD) and it depleted 0.034 m of water more than the EFI treatment, Table VI. The short length of neutron tubes, and deep penetration of irrigation probably caused most of the treatment

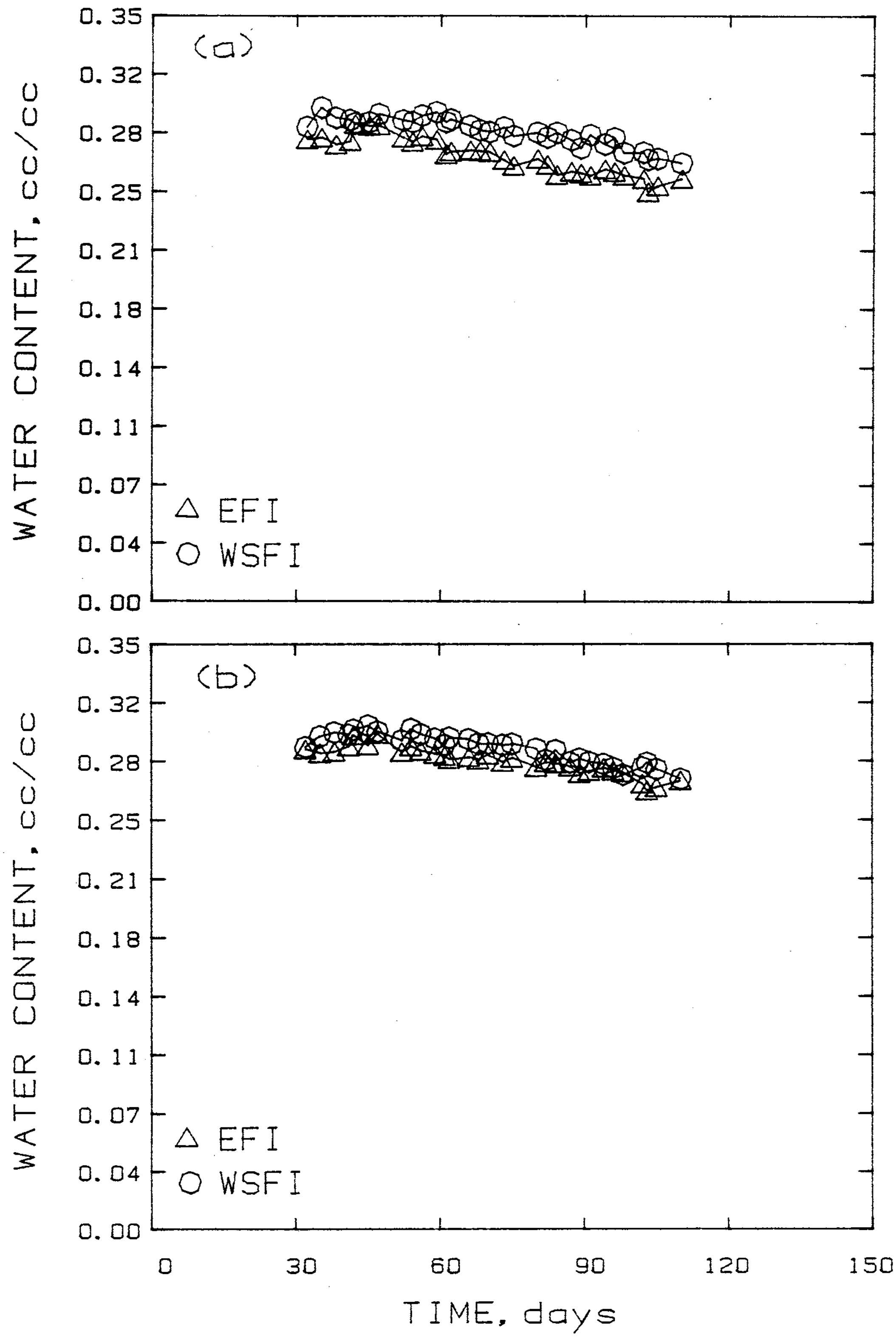

Figure 9. Soil Water Content for Trts 1 and 2 at a) 1.65 m and b) 1.80 m depth, 1985.

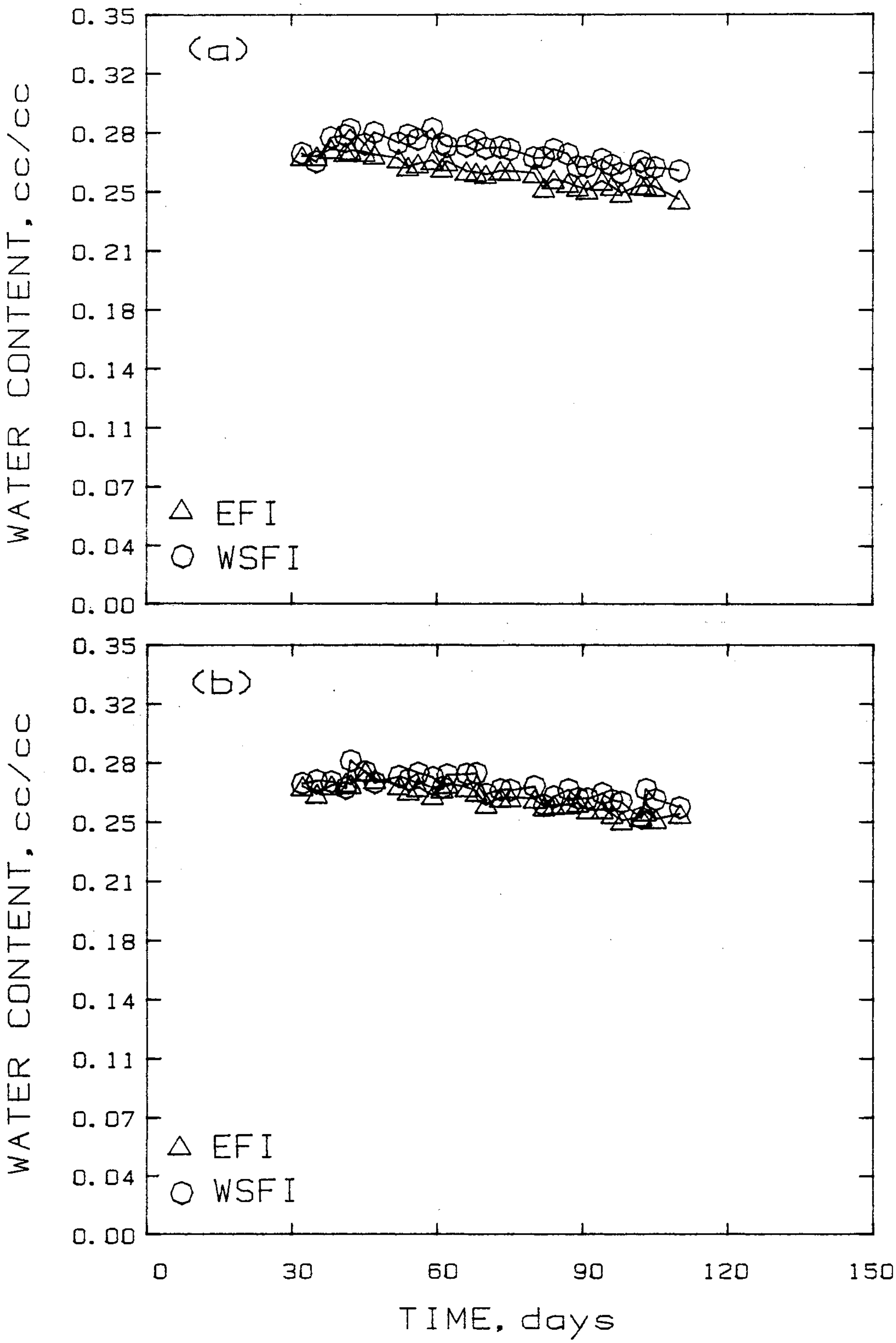

Figure 10. Soil Water Content for Trts 3 and 4 at a) 1.65 m and b) 1.80 m depth, 1985.

differences in 1984. Due to this problem, changes in the water content in the entire root zone were not accounted for in the 1984 NSWD measurement (Figure 8).

In 1984, Trt. 3 and Trt. 4 received the same amount of water and the EFI Trt. 4 depleted more water than the WSFI Trt. 3. Table V indicates that Trt. 1 received one less irrigation than Trt. 2. The shortage of one irrigation in addition to the shallowness of the neutron access tube brought the NSWD value of Trt. 1 (WSFI) to be higher than the Trt. 2 EFI. Since NSWD is the difference of the final and initial water content of the soil profile, the application of one last irrigation could make the NSWD value of Trt. 1 seem much smaller than what was observed in Table VI.

In 1985, tubes were extended to a depth of 1.80 m and the results obtained from 1985 were more reliable than 1984 (Figure 11). Unaccountably, the root zone was more shallow in 1985 and water penetration depth was less also. In 1985, due to the application of less irrigation water, the drier treatments, Trt. 1 and 2, depleted more water from the soil than the most frequently irrigated treatments, Trt. 3 and 4 (Table VI). However, a significant difference in NSWD was not observed between the two modes of water application.

The shortage of one irrigation in Trt. 3 in 1985 showed 0.01 m more water depletion than Trt. 4. This effect was similar to Trt. 1 of 1984.

NSWD is related to the amount of irrigation and the degree of evaporative demand (Myers et al., 1984). Higher

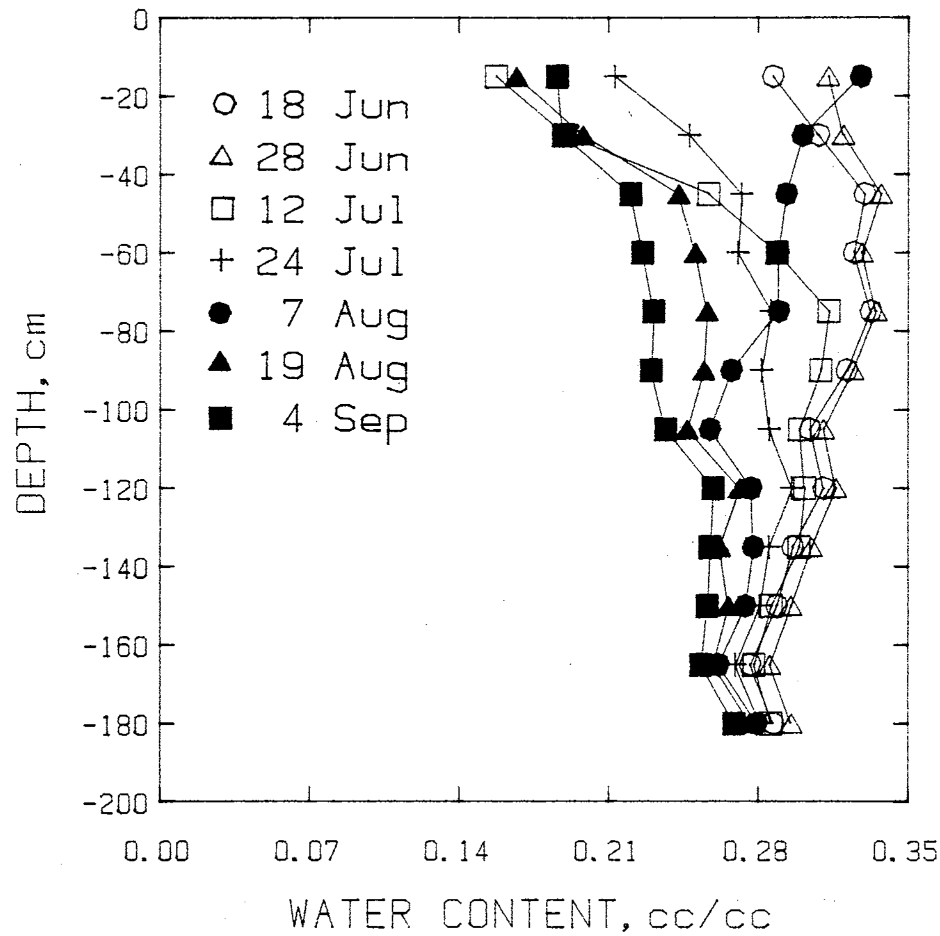

Figure 11. **Soil Water Distribution within the 0-1.80 m profile in 1985.**

evaporative demand and fewer irrigations resulted in higher NSWD in 1985 (Tables V, VI, and VII). In general, soil water depletion was relatively high for the EFI treatments and increased as the number of irrigation decreased.

<u>Penetration</u>

Small cracks were observed in Trt. 1 and 2 plots in both years. However, these cracks did not cause significant irrigation penetration difference between the EFI and WSFI treatments.

When irrigating an EFI treatment, water will move laterally and vertically. After a few hours, the vertical movement will dominate as horizontal wetting meets that of the next furrow. In 1984 penetration below 1.20 m was evident (Figure 8), but the shallowness of neutron tubes affected our measurement by masking any differentiation of water penetration between treatments. In 1985 the length of tubes was extended to 1.80 m, but the penetration of water was not as deep as 1984 (Figure 11).

Overall, in the absence of large cracks the tendency for deep penetration was higher for EFI treatments than WSFI treatments, as would be expected.

CHAPTER VI

CONCLUSIONS

In both years a given amount of water produced higher yield of grain sorghum when applied as WSFI than EFI. The water-use-efficiency of plants was also found to be higher for WSFI than EFI.

Water loss to evaporation from 0 to 15 cm of the soil depth was determined for each mode of water application. The result revealed that water loss to Ev was 0.03 m higher for EFI treatments than WSFI treeatments. The net soil water extraction values showed that EFI treatments extract more water from the soil than WSFI treatments, evidently to meet the demand of Ev.

Net soil water depletion was related to the number of irrigations. Therefore, the two treatments which received water amount A depleted more water than treatments which received water amount B. Soil water depletion was higher for drier treatments than relatively wet treatments.

In the absence of large cracks, irrigation water penetrated deeper in EFI treatments than WSFI treatments.

In 1985 by extending the length of the neutron access tubes to 1.80 m it was determined that the soil water content below 1.65 m was higher for WSFI than EFI.

Total water applied to each treatment was accounted for by extrapolating neutron probe data. The value determined with this method was close to the actual amount of water applied.

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APPENDIX

TABLE IX

METEOROLOGICAL TOTALS FOR 1984 AND 1985 GROWING SEASONS
MAY 1 TO SEPTEMBER 30

	Month	Average Maximum (F°)	Average Minimum (F°)	Rainfall (mm)	Average Wind Movement (miles/day)
1984:					
	May	77	48	31	143
	June	90	60	23	164
	July	94	63	26	155
	August	92	63	25	194
	September	82	52	34	143
1985:					
	May	79	51	100	62
	June	86	58	50	184
	July	85	60	23	157
	August	93	61	26	132
	September	81	54	185	207

TABLE X

SEASONAL IRRIGATION WATER INTAKE CALCULATED FROM ACTUAL
NEUTRON PROBE DATA FOR 1984 AND 1985 GROWING SEASONS

Treat-ment #	Mode	Water Amount	Year			
			1984		1985	
			Actual Applied (m)	Water Intake (m)	Actual Applied (m)	Water Intake (m)
1	WSFI	A	.26	.10	.21	.12
2	EFI	A	.30	.23	.22	.16
3	WSFI	B	.37	.13	.33	.19
4	EFI	B	.37	.24	.37	.21

TABLE XI

GRAIN SORGHUM PLOT YIELD, % MOISTURE CONTENT AND TEST WEIGHT, 1984 GROWING SEASON

Rep #	Plot #	Trt #	Plot Yield (gm/plot)*	% Moisture Content	Test Weight
1	1	1	5538	13.0	59
1	2	2	5456	13.0	60
1	3	4	6558	14.4	59
1	4	3	6442	14.4	59
2	5	3	6886	14.2	58
2	6	1	5382	12.8	60
2	7	4	6781	14.0	59
2	8	2	5711	14.7	60
3	9	1	6168	13.0	60
3	10	4	6308	14.6	61
3	11	3	6640	15.0	60
3	12	2	5930	15.2	59

* Harvested area/plot = 1/500 of an acre

TABLE XII

GRAIN SORGHUM PLOT YIELD, % MOISTURE CONTENT AND TEST WEIGHT, 1985 GROWING SEASON

Rep #	Plot #	Trt #	Plot Yield (gm/plt)*	% Moisture Content	Test Weight
1	1	3	5352	13.5	60
1	2	4	5342	13.1	60
1	3	2	4468	12.5	58
1	4	1	5371	13.2	60
2	5	3	6130	13.5	59
2	6	1	5126	13.2	60
2	7	4	5233	13.6	60
2	8	2	3907	13.0	58
3	9	1	4827	13.1	60
3	10	4	5693	13.4	60
3	11	2	4115	12.7	56
3	12	3	5950	13.7	61

* Harvested area/plot = 1/500 of an acre

TABLE XIII

ANALYSIS OF VARIANCE FOR YIELD, 1984

SOURCE	DF	SS	MS	F-R
Mean	1	595203930	595203930	
Blocks	2	52600	26300	
Treatments	3	1751900	583967	2.952
Error	6	1187010	197835	
Total	12	598195440		

Coefficient of variation = 6.32%

TABLE XIV

ANALYSIS OF VARIANCE FOR YIELD, 1985

SOURCE	DF	SS	MS	F-R
Mean	1	466934760	466934760	
Blocks	2	104120	52060	
Treatments	3	4484510	1494836	9.256
Error	6	968990	161498	
Total	12	472492380		

Coefficient of variation = 6.44%

2

VITA

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