ALTERNATE FURROW IRRIGATION IN GRAIN SORGHUM

By

MARK EUGENE HODGES

Bachelor of Science

Oklahoma Panhandle State University

Goodwell, Oklahoma

1978

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1983

ALTERNATE FURROW IRRIGATION

IN GRAIN SORGHUM

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to thank Dr. John F. Stone, my major adviser for his patience, guidance, friendship, and advice throughout my graduate program. I would also like to express appreciation to Dr. J. E. Garton for his suggestions and advice during this study. I would also like to thank Dr. L. I. Croy for suggestions in the preparation of the final manuscript. Special thanks is expressed to Mr. Harold Gray who offered friendship and help whenever it was needed. I wish to thank Mr. Joe Williams for assistance on computer programs and printouts.

Special gratitude is expressed to my mother, Dr. Paula Hodges, for encouragement and support during my graduate study.

I am deeply indebted to my parents, Mr. and Mrs. Albert Hodges Jr., for their guidance, interest, and strong support of my education.

I wish to especially thank my wife, Sharon, for her understanding and patience during the course of my study. A special appreciation to my wife and sons, Brandon, and Clayton, for their personal sacrifices.

This research was supported in part by the Oklahoma Agricultural Experiment Station, Oklahoma State University, and the Water Resources Board.

Finally, I wish to thank all my friends who have contributed in many ways to the completion of my graduate program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

The economics of different irrigation practices is based mainly on increasing profits of the producer. However, by increasing profits through more efficient production the producer can pass these savings on to consumers and ultimately raise the standard of living. In the case of the irrigation farmer this is not only true in the United States but throughout the world.

The result of a rapid depletion of groundwater, declining well yields, and an increase in pumping cost in the Great Plains have lead to an immediate need to more efficiently manage the use of irrigation water. For this reason, many irrigators have shifted emphasis to maximizing production while minimizing use of the limited resource, water.

The conventional furrow irrigator in Great Plains plants, with the exception of wheat, two rows of field crop per bed, bed width being 30, 40, or 56 inches. Thus, furrow spacing is the same as bed width. Water is then applied to every furrow.

A modification of this conventional method of irrigation has been studied as a means of conserving water. Wide-spaced furrow irrigation is the application of water to furrows at least 80 inches apart (Stone et al., 1982). Wide-spaced furrows, are generally 112 inches apart. Closely-spaced furrows, which are 30 to 40 inches apart, use more water and are essentially applying water to one side of each plant row. Stone had furrow spacings of 56 inches, this made irrigation furrows 112 inches apart. On alternate irrigation dates, previously dry furrows were irrigated and the previously irrigated furrows were left dry. This method applied approximately one-half the water to the field per irrigation as would have been applied under conventional irrigation techniques. Stone et al. (1982) provided ground work for this study.

The overall objectives of this study were to:

1. Determine differences in the amount of water used by wide-spaced furrow irrigation compared to narrow furrow irrigation in a field scale (1/2 mile) study.
2. Develop criteria for irrigation water application based upon differences and irregularities noted.

These studies were conducted on the Panhandle Research Station at Goodwell, Oklahoma, in 1980 and 1981.

CHAPTER II

LITERATURE REVIEW

Irrigation techniques in the Great Plains, due to aquifer drop, higher energy prices, and high evaporative demand, have been geared toward better management. One management improvement is reduction of pumping cost and water use by pumping less water without significantly reducing yield.

Stone et al. (1979) showed that wide-spaced furrow irrigation could be used on medium to fine textured soils. Grain sorghum was planted on 56 inch beds, using two rows per bed. This practice tended to make water move the same distance lateraly as downward and to use about one-half the water without seriously depressing yield during years of near normal rainfall and wind movement. Stone also introduced a method by which to predict when a season will show a reduced yield.

Musick and Dusek (1974) reported that alternate furrow irrigation, on closely spaced furrows, had little or no effect on water intake rates or yield on a silty clay loam soil when using a 30 or 40 inch furrow spacing. However, they did note a reduction in intake rates and yields on clay loam soil. These reductions were concentrated to the lower one-half of 900 ft. and 1800 ft. runs.

In alternate furrow studies, on closely spaced furrows, in the San Joaquin Valley of California, Grimes, Walhood, and Dickens (1968), found when using the alternate furrow method of irrigation on sandy loam soil that total lint yields were as good or better than those yields obtained from every furrow irrigation. The alternate furrow irrigation treatments not only received less water producing a higher yield, but yielded more lint per inch of water applied.

Fishbach and Mulliner (1974) stated alternate furrow irrigation on 30 inch beds of corn in Nebraska on a wide range of soil types and under various rainfall condition showed no significant differences in yield at the 5% level. Water moved to a depth of 3 ft. in the dry furrow as well as the irrigated furrow, even when a 2.33 hour set was used.

Skip row planting and irrigation is another means of conserving water, as well as achieving a high water use efficiency (Newman, 1967). Musick and Dusek (1982) suggested that using this method reduces the potential loss of profile drainage. The water use efficiency of skip-row irrigation as reported by Stewart et al. (1981) was 2.02 kg/m^3, while alternate furrow irrigation water use efficiency was 2.14 kg/m^3. Musick and Dusek (1982) reported alternate furrow method of irrigation may be superior.

Musick, Sletten, and Dusek (1973) stated deep percolation is insignificant on a slowly permeable clay loam. Therefore, duration and quantity of intake can be reduced on the lower end of graded furrows. In most cases runoff can be reduced to below 10%.

Alternate furrow irrigation of 36 inch furrow spacing, as Box et al. (1963) reported, did not affect the total yield of potatoes on a Pullman clay loam, a soil type common to the Texas High Plains. Water application was reduced by 30%.

Allen and Musick (1972) showed wheat and grain sorghum irrigated in a side bed furrow system, 60 inches vs. standard 40 inches, yielded similarly, with water intake averaging 23% less during three spring irrigations and 19% less during two seasonal irrigations. Also, an increase in recession flow improved wetting of lower end of the field with greater uniformity of yields.

Musick and Dusek (1972, 1975) reported with irrigation of grain sorghum and winter wheat, in 15 foot alternating strips on 40 inch beds, significantly increased yield of both crops. With good root development water stored in adjacent strips is also available, thus delaying moisture stress conditions and possibly reducing irrigation requirements.

In studies using variable row spacing in irrigated cotton, Longenecker, Thaxton, and Lyerly (1969) found partial skip-row effects of higher yields due to outside rows receiving additional light and root area without skipping any rows. Early maturity of plants was attributed to lower rates of water application. Water use efficiency was greatly increased due to the summer shading effect of the irrigated furrows. The summer shading effect also reduced tillage for weed control, with furrows becoming completely shaded by late summer.

Stone et al. (1982) showed wide-spaced furrow irrigation can be adapted to field scale (1/2 mile) length of runs. No differences in rate of advance of irrigation water down wide and narrow spaced furrows was observed. However, Musick and Dusek (1974, 1975) showed differences should be expected.

CHAPTER III

MATERIALS AND METHODS

Field studies were located at the Oklahoma Agricultural Experiment Station, Goodwell, Oklahoma. Grain sorghum (Sorghum bicolor Moench) was used in both 1980 and 1981. Plots were approximately one-half mile long. Length of harvest row was 18.5 ft., with four such adjacent rows harvested in each plot at four distance intervals from the gated pipe.

Soil type for the 1980 study was Richfield clay loam (fine montmorillonitic, mesic, Aridic Argiustoll) and Pullman clay loam (fine, mixed, thermic, Pachic Paleustol). The plots for the 1981 study were on Richfield clay loam and Mansker clay loam (fine-loamy, carbonatic, thermic, Calciorthidic Paleustoll).

The studies in both years were in a randomized block design with three replications. Each plot had 10 beds with two rows per bed. Bed width was 56 in., thus, furrow spacing was 56 in.

A 9-day irrigation interval was designed in both years. However, due to poor availability of irrigation water dates varied widely from the 9-day optimal (Stone et al. 1965, 1966).

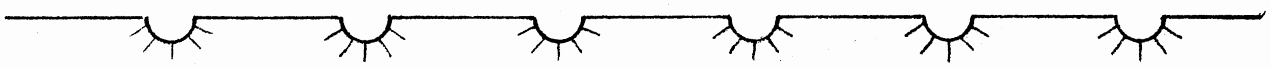
Irrigation treatments were the same for both 1980 and 1981 as shown in Figure 1: Irrigate every furrow (E); in which every furrow was irrigated on the first irrigation and on each succeeding irrigation. Irrigate alternate furrows alternately (A-A); in which alternate furrows were irrigated after crop the had been established and then on the next irrigation the previously dry furrows were irrigated. This alternating irrigation then continued throughout the remainder of the irrigation season.

On the irrigation dates all plots were watered, with time and duration of application being the same. Portable HS flumes were used to determine and set the flow rate of water being applied to each furrow at initiation of irrigation and again at approximately one-half of the scheduled irrigation time. The flumes were calibrated prior to the irrigation season.

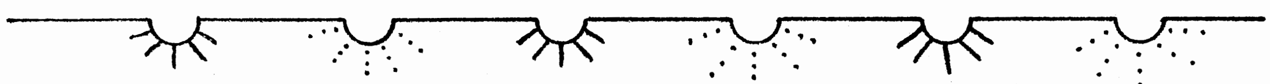
Since each irrigated furrow received the same water, at each irrigation the A-A plots received approximately one-half the water applied as did the every furrow plots. Tailwater was kept to a minimum and all water applied was considered added to the soil profile.

Study of 1980

"Prairie Valley 535GR" grain sorghum was planted on 4 June and emerged on 9 June. All plots received one preplant watering in which all furrows in each treatment received water. All plots again received a postplanting irrigation in which all furrows were watered to insure a uniform stand



1. Every Furrow Irrigation



2. Alternating Alternate Furrow Irrigation

Figure 1. Irrigation Treatments Used in 1980 and 1981

across the study area. Fertilizer was applied on 18 May at the rate of 120 pounds of nitrogen per acre in the form of anhydrous ammonia. "Milo Guard" herbicide was applied at the rate of 2.5 pounds per acre propazine, as a premergent on 18 May.

Neutron access tubes were installed in late June, to a depth of 4.5 ft. Access tubes were installed in the left row of the center bed of each E plot as shown in Figure 2. A single tube was installed in each row of the center bed of the A-A plots, two tubes per bed. Tubes were installed at each distance increment as shown in Figure 3. A Troxler Model 3223 neutron moisture probe was used to measure volumetric water content on 29 July, 15 August, and 3 September to determine soil moisture in the profile before the start of each irrigation. Soil moisture content readings were also taken on 14 July, 4 August, 20 August, and 20 September to determine soil moisture content in the soil profile after each irrigation. Irrigation dates were 26 June, 10 July, 31 July, 18 August, and 4 September.

On 4 September measurements of distance of water advance vs. time since start of irrigation were taken. Measurements of distance were taken using a measuring wheel.

All plots were harvested by hand in October.

Study of 1981

"Prairie Valley 734G" grain sorghum was planted on 8 June and emerged on 13 June. All plots received one

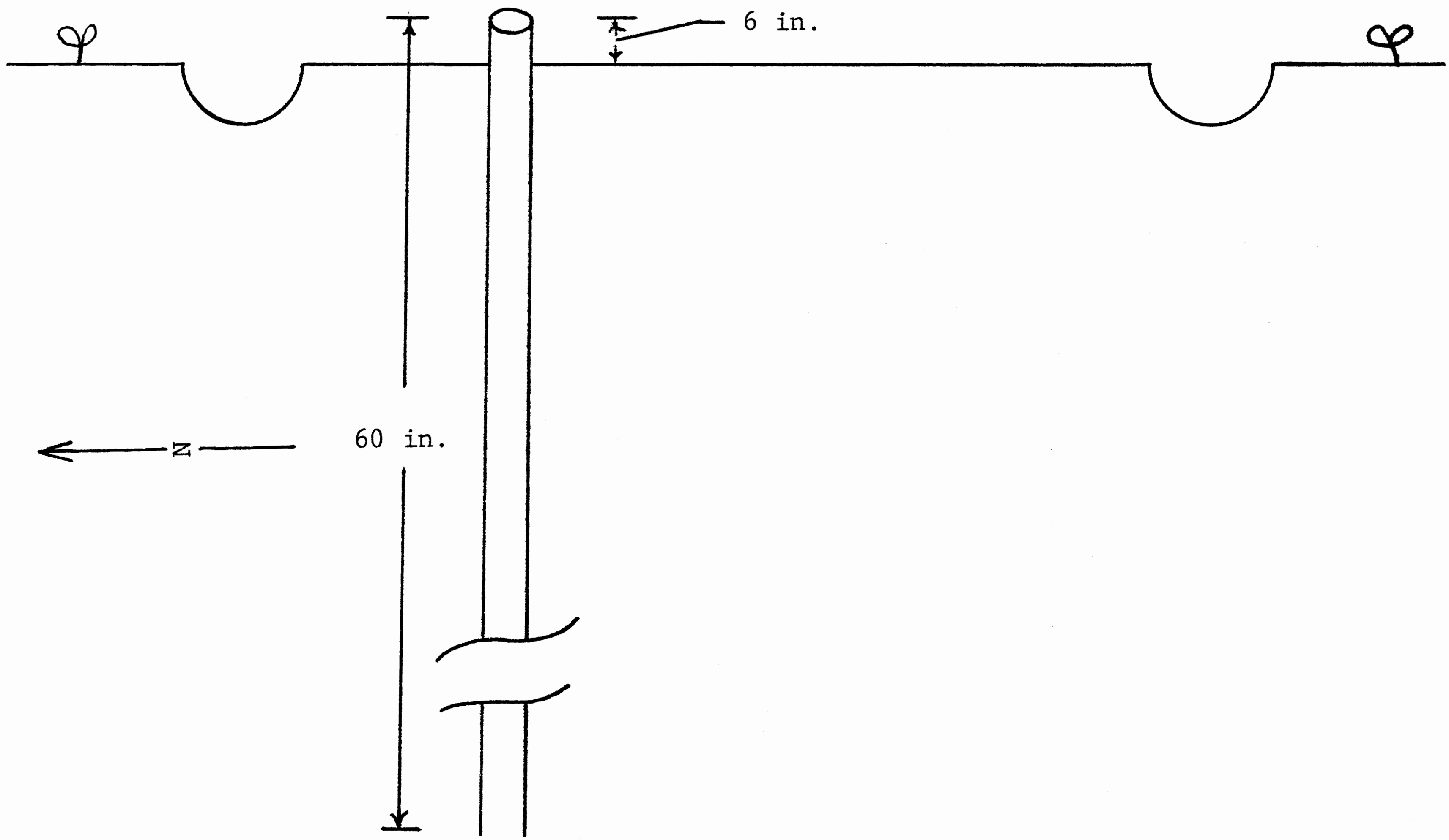


Figure 2. Neutron Access Tube Distribution

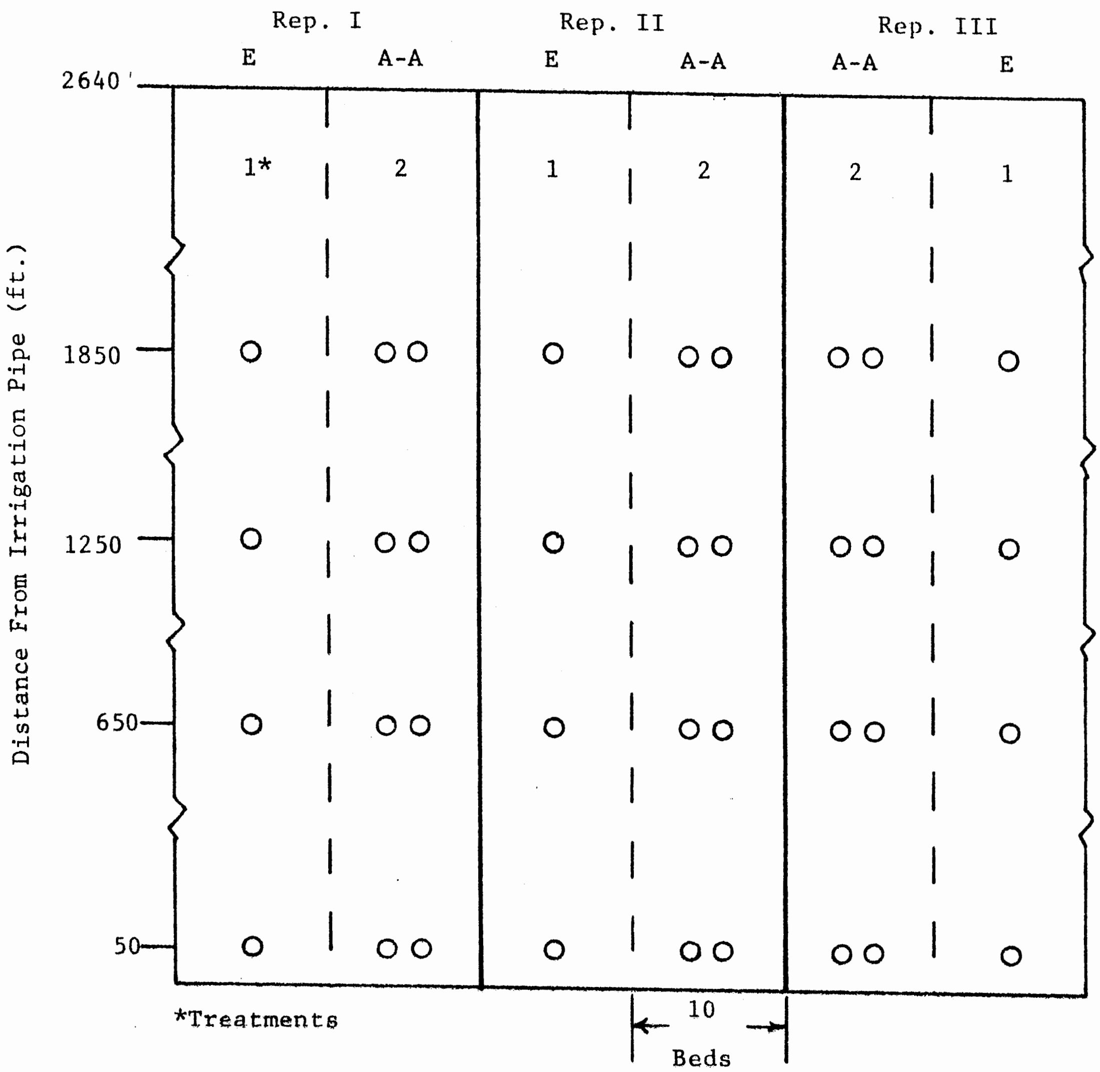


Figure 3. Field Plot Layout and Tube Location 1980

preplant and one postplant irrigation in which all furrows received water to insure a uniform stand across the study area. Anhydrous ammonia fertilizer was applied in May at the rate of 120 lbs. nitrogen per acre. "Milo guard" herbicide was applied at the rate of 2.5 pounds of active ingredient propazine per acre, as a permergence treatment on 18 May. Neutron access tubes were installed in late June to a depth of 4.5 feet. Single access tubes were installed in the left row of the center bed of each plot receiving an every furrow irrigation. A single tube was installed in each row of the center bed of each plot at the 50 foot and 2150 foot distance increments and a single tube in the left row of the center bed at the 750 foot and 1450 foot increments, as shown in Figure 4. A Troxler Model 3223 neutron moisture probe was used to measure volumetric water content through neutron access tubes on 1 July, 20 July, and 25 August to determine soil moisture in the profile before the start of each irrigation. Soil moisture content readings were also taken on 10 July, 28 July, and 1 September to determine soil moisture content in the profile after each irrigation. Irrigation dates were 18 May, 1 July, 21 July, 26 August, and 24 September.

On 24 September measurements of distance of water advance vs. time since start of irrigation were taken. Measurements of distance were taken using a measuring wheel.

All plots were harvested by hand in October.

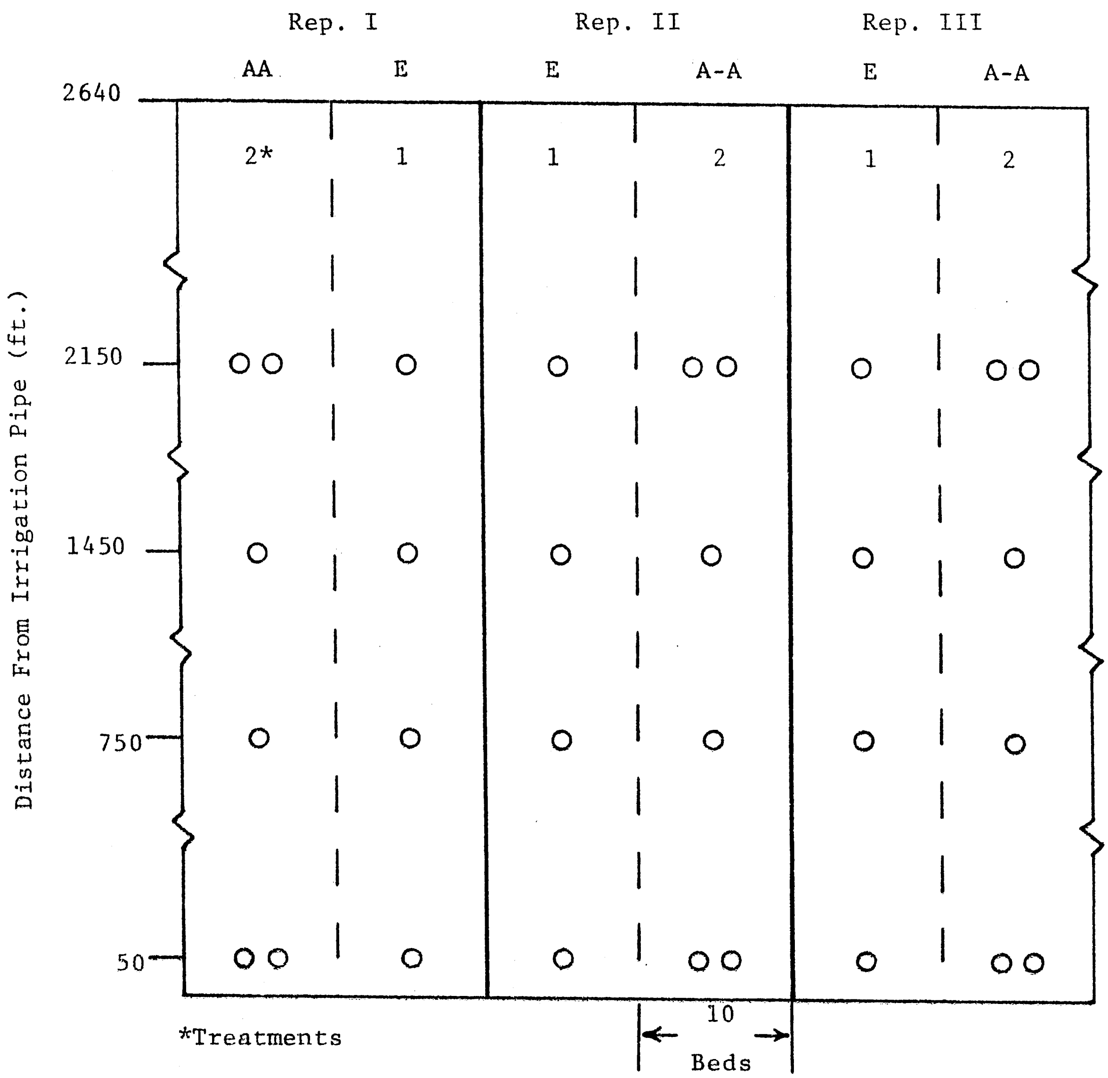


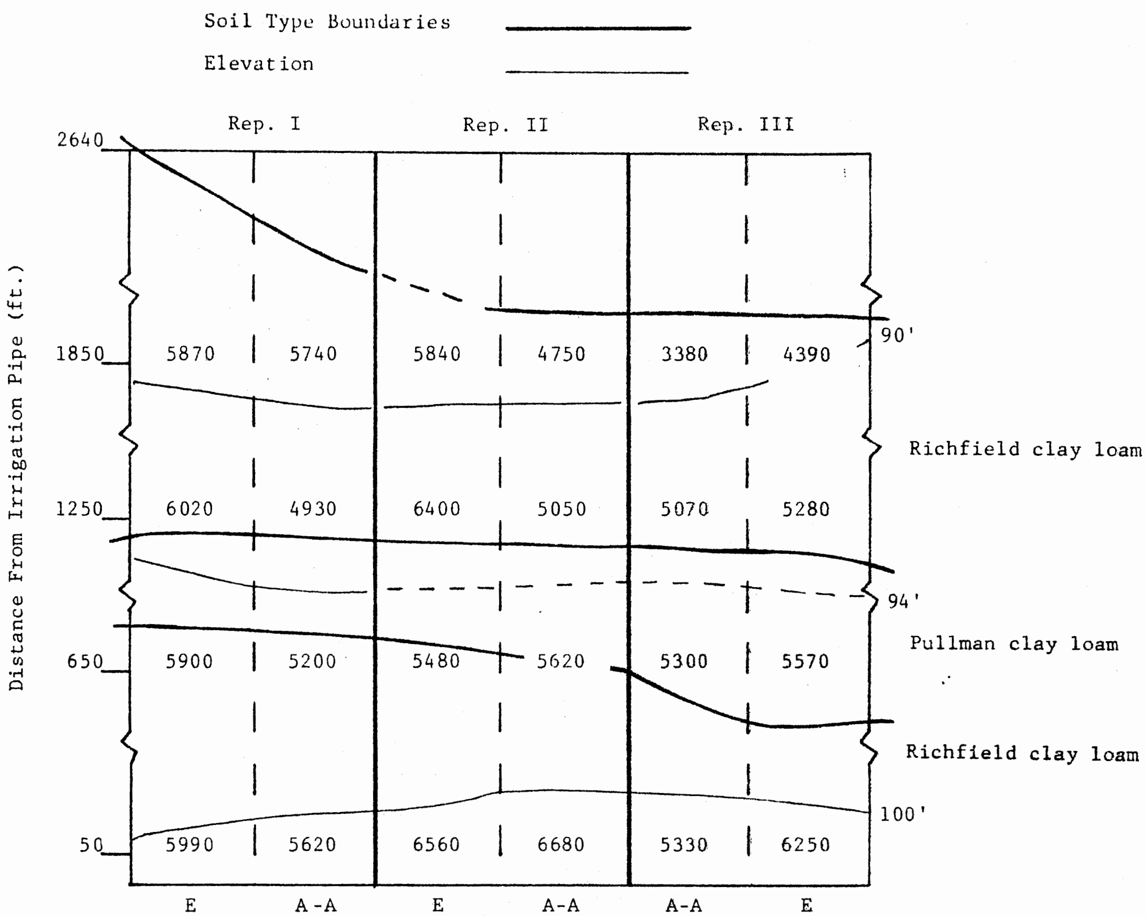
Figure 4. Field Plot Layout and Tube Location 1981

CHAPTER IV

RESULTS

Study of 1980

Yields are shown in Figure 5. Yields in the E plots were higher than those for the A-A plots. The yield reduction from the reduced water of the A-A treatments, however, was only 10%. Average yield for the E plots was 5800 lbs/acre, while the A-A plots averaged 5220 lbs/acre. Yields for both treatments were high in comparision to other area yields. Such high yields were not expected because of low growing season rainfall and limited availability of irrigation water, as is evident by the irrigation interval. Table VII (see the Appendix) shows average maximum temperature, precipitation, and average wind movement during the growing season of 1980. Yields, while variable, tended to decrease as distance from the head ditch was increased, as does generally all graded furrow delivery systems. Yield decreases were of the same general proportion in the A-A plots as the E plots. As seen in Figure 5, there was a significant difference in yields due to distance at 1250 and 1850 ft. This would suggest yield is more severely depressed by wide-spaced furrow irrigation as distance from the head ditch is increased. However, since the irrigation interval was not



LSD (.05) Irrigation Treatment 460 Lb/Acre
LSD (.05) Distance 650 Lb/Acre

Figure 5. Yield in 1980 (lbs/acre), Soil Type and Elevation (ft.) Reference 100 (ft.) for Irrigation Study of Alternate and Every Furrow Irrigation

optimum, and on several occasions twice the optimum, yield may not be a good tool by which to measure differences because of the added stress factors. The figure also shows a significant difference due to treatments at the 1250 ft and 1850 ft. increments, which would again suggest the irrigation interval was not optimum. Individual row yields are shown in Table I. Yields of individual rows were highly variable and showed no consistent trends thoughout the study area. The coefficient of variation for yield in 1980 was 9.57%, as shown in Table II. Graphs of yields are shown in Figure 6. Analysis of variance of yield for 1980 is shown in Table II.

Time since start of irrigation vs. distance of advance from head ditch on 10 July 1980 and 4 September 1980 are shown in Figures 7 and 8. These figures show a remarkable consistency in advance rate in both the E plots and the A-A plots. The similarities persisted although advance of water measurements were taken at 4 time increments during the 4 September irrigation vs. 2 time increments on the 10 July irrigation. Regression equations and r^2 values for these figures are shown in Figures 7 and 8. Measurements of advance of water being taken only twice on 10 July would explain the poor fit of regression lines. Under conditions of minimum slope variance, uniform soil type, and uniform soil compaction, one would expect rate of water advance down the furrow, when initially different, to progressively decrease with duration of irrigation.

TABLE I

GRAIN SORGHUM INDIVIDUAL ROW YIELD (LBS/ACRE) IN 1980

	REP I EVERY FURROW				REP II EVERY FURROW				REP III EVERY FURROW			
	1	2	3	4	1	2	3	4	1	2	3	4
50'	5350	7016	6513	5094	7362	5431	7441	6000	6897	5975	6454	5678
650'	4657	7278	5718	5946	5730	3475	6842	5862	5635	5872	5378	5389
1250'	5228	6004	7021	5842	6487	6269	6725	6103	4739	6487	4547	5350
1850'	5745	6180	6032	6517	5956	5345	5570	6491	4570	4118	4404	4458
$\bar{x}$	4995	6620	6321	5850	6384	5130	6645	6114	5460	5613	5196	5219

	REP I EVERY FURROW				REP II EVERY FURROW				REP III EVERY FURROW			
	1	2	3	4	1	2	3	4	1	2	3	4
50'	6673	4543	5342	5918	7219	6821	5386	7277	4871	4796	6453	5216
650'	4254	5846	4966	5734	5256	5815	4955	6440	5070	6119	5437	4593
1250'	5670	3685	4396	5960	4299	4032	5820	6063	4391	5767	4808	5296
1850'	5782	6320	4393	6470	5383	4940	4154	4538	3975	3456	3390	2689
$\bar{x}$	5595	5099	4774	6021	5539	5402	5079	6080	4577	5035	5022	4449

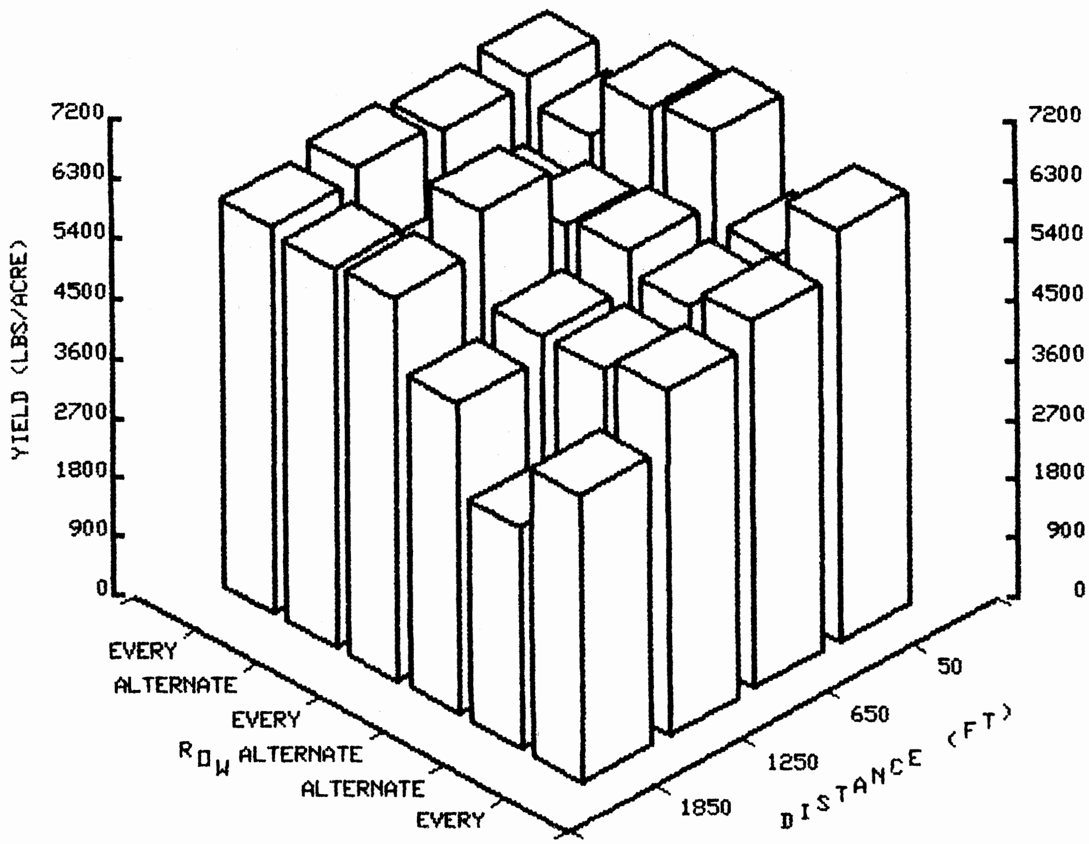


Figure 6. Grain Sorghum Yield (lbs/acre) in 1980 in Response to Irrigation Treatments

TABLE II

ANALYSIS OF VARIANCE OF YIELD FOR 1980

	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F	Tabulated F
Total	23	193710000			
Replications	2	37998000	18999000		
Treatments	1	31520000	31520000	7.094	4.60
Distances	3	56050000	18683333	4.205	3.34
Rep. X Tret.	3	5937000	1979000	.445	3.34
Error	14	62205000	4443214.3		

Coefficient of Variation = 9.57%

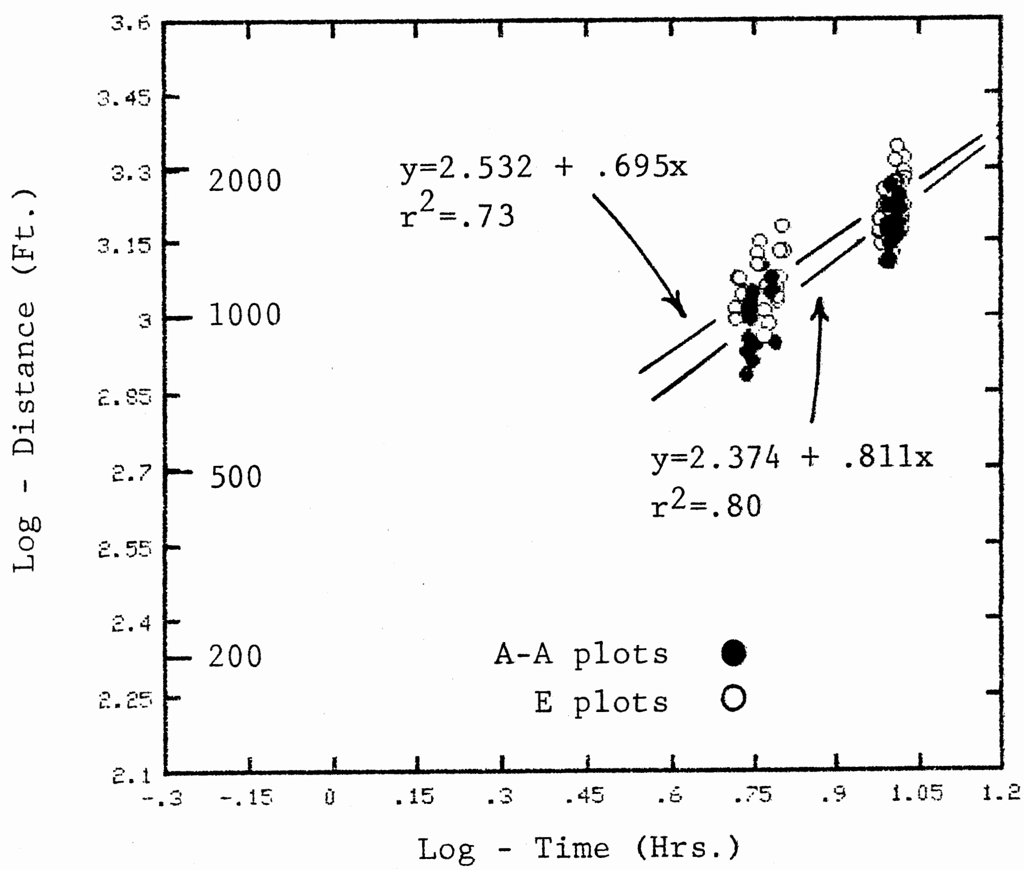


Figure 7. Distance of Irrigation Water Advance as Function of Time Since Start of Irrigation 10 July, 1980

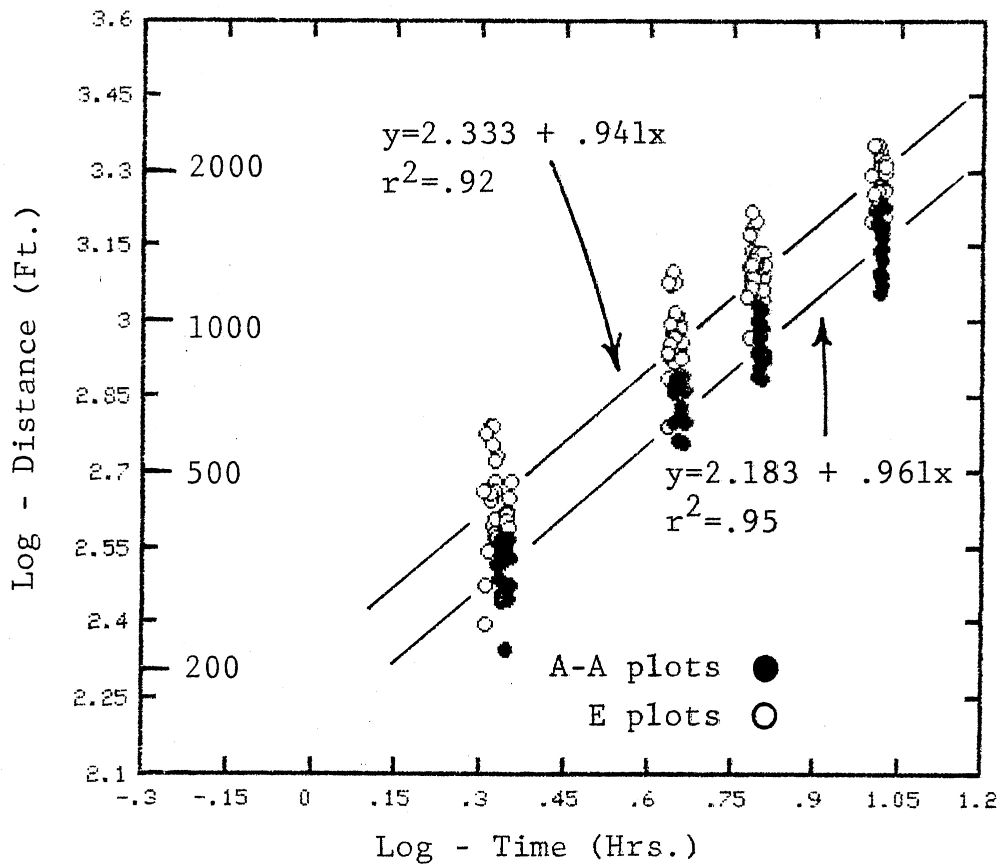


Figure 8. Distance of Irrigation Water Advance as a Function of Time Since Start of Irrigation 4 September, 1980

Tables III and IV show coefficients of variation for each of the two irrigation dates. The differences between treatments is minimal and remains nearly constant as water advanced down the furrow. This data supports the close similarities of regression line slopes between treatments in Figures 7 and 8. The average depth of irrigation water applied vs. time graphs on 10 July 1980 and 4 September 1980 shown in Figures 9 and 10 show non-uniformity in the 10 July irrigation and some uniformity in the 4 September irrigation. The slopes of the regression lines are obviously different with no overlap of data points between E-irrigation and A-A irrigation. However, on 4 September the slopes of the regression lines are generally the same with an overlap of data points at every measurement time.

Penetration depth of irrigation water is shown in Figures 11 and 12 of two irrigation dates in which no rainfall was received between the time water content measurements were made before irrigation and after irrigation. Thus, all measurements of increased water content are attributed to irrigation water. Measurement of soil water contents were made on 29 July, before irrigation, 4 August, after irrigation, 15 August, before irrigation, 20 August, after irrigation. It is seen that as a whole the A-A plots had deeper water penetration than did the E-plots. The deeper penetration in the A-A plots is more pronounced in the later irrigation of 15 August to 20 August. The depth of penetration data were obtained by using water content

TABLE III

ANALYSIS OF VARIABILITY OF DISTANCES FOR TWO
DIFFERENT TIMES ON 10 JULY, 1980

	PERIOD 1*			PERIOD 2*		
Furrow Number and Treatment	Mean (ft.)	Period 1* Standard (ft.) Deviation	Coefficient (%) of Variation	Mean (ft.)	Standard (ft.) Deviation	Coefficient (%) of Variation
1-10 E	1279.0	159.3	12.5	1822.6	208.4	11.4
12-20 A-A	1111.0	112.5	10.1	1643.2	124.7	7.6
21-30 E	1181.3	157.4	13.3	1751.1	262.6	15.0
32-40 AA	955.0	119.2	12.5	1503.8	223.6	14.9
42-50 AA	913.4	96.9	10.6	1509.2	127.3	8.4
51-60 E	1074.0	76.3	7.1	1554.0	111.8	7.2
Average E			11.0			11.2
Average A-A			11.1			10.8

*Period 1 is 5.25 to 6.75 hours and period 2 is 9.50 to 10.50 hours since start of irrigation, respectively.

TABLE IV

ANALYSIS OF VARIABILITY OF DISTANCES FOR TWO DIFFERENT TIMES DURING IRRIGATION ON 4 SEPTEMBER, 1980

	PERIOD 1*			PERIOD 2*		
Furrow Number and Treatment	Mean (ft.)	Standard (ft.) Deviation	Coefficient (%) of Variation	Mean (ft.)	Standard (ft.) Deviation	Coefficient (%) of Variation
1-10 E	385.3	91.2	23.6	1952.8	154.7	7.9
11-19 AA	341.6	22.0	6.4	1590.6	80.0	5.0
21-30 E	397.4	41.8	10.5	1795.9	197.6	11.0
31-39 A-A	327.4	32.6	10.0	1335.6	126.7	9.5
41.49 A-A	292.4	43.6	14.9	1324.6	149.4	11.3
51-60 E	515.2	60.0	11.8	1844.0	234.0	12.7
Average E			15.3			10.5
Average A-A			10.4			8.6

*Period 1 is 2.0 to 2.4 hours and period 2 is 10.0 to 10.5 hours since start of irrigation, respectively.

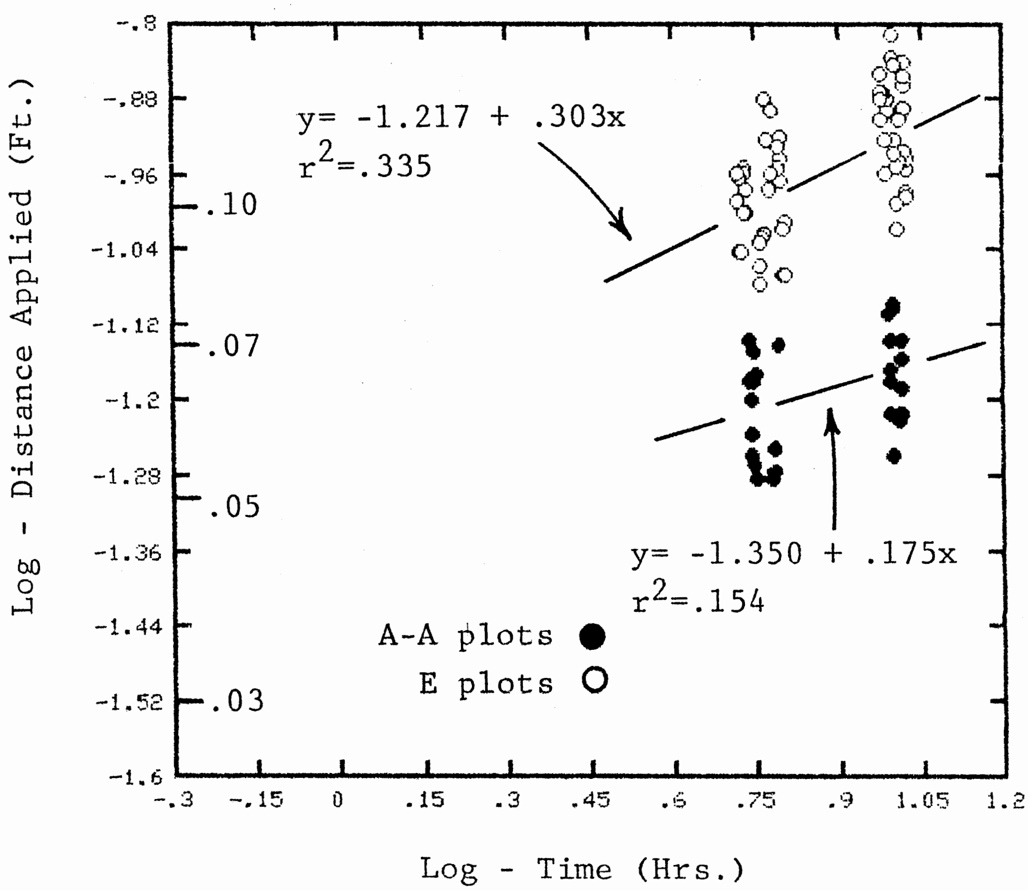


Figure 9. Average Depth of Irrigation Water Applied as a Function of Time Since Start of Irrigation 10 July, 1980

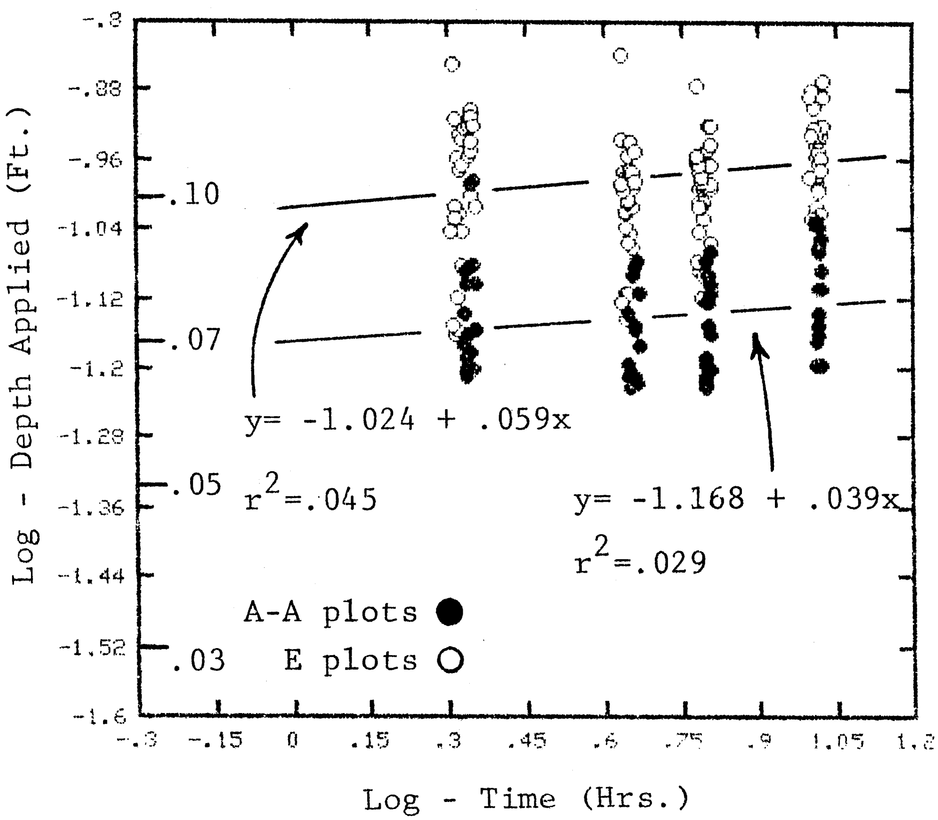


Figure 10. Average Depth of Irrigation Water Applied as a Function of Time on 4 September, 1980

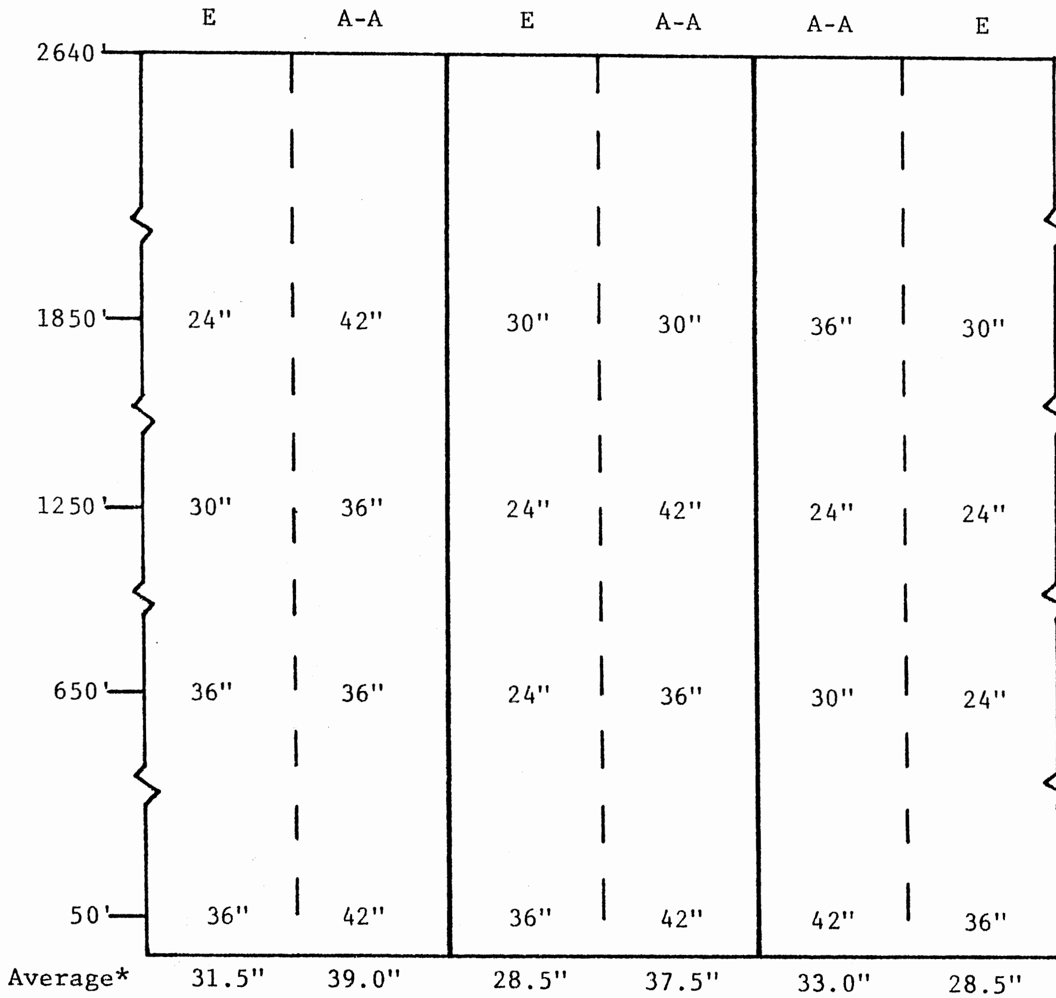
	E	A-A	E	A-A	A-A	E
2640'						
1850'	24"	36"	30"	24"	18"	--
1250'	18"	36"	24"	24"	18"	24"
650'	30"	24"	24"	30"	30"	24"
50'	24"	30"	36"	36"	36"	30"
Average*	24.0"	31.5"	28.5"	28.5"	25.5"	26.0"

LSD (.05) Distance = 5.2 inches

LSD (.01) Distance = 7.2 inches

*Overall average depth of penetration was 26.2 inches for E plots and 28.5 inches for A-A plots.

Figure 11. Depth of Penetration of Irrigation Water on 29 July and 4 August, 1980 for Irrigation Study of Alternate and Every Furrow Irrigation



LSD (.05) Distance = 4.2
LSD (.01) Distance = 5.9

*Overall average depth of penetration was 29.5 inches for the E plots and 36.5 inches for A-A plots.

Figure 12. Depth of Penetration of Irrigation Water on 15 August and 20 August, 1980 for Irrigation Study of Alternate and Every Furrow Irrigation

readings from neutron data, then by inspection picking the point to which water penetrated.

The average depth of water penetration between 29 July and 4 August was 26 inches for the E plots and 28 inches for the A-A plots. The LSD (.05) was 5.2 inches. In comparison, average depth of penetration between 15 August and 20 August was 29.5 inches for the E plots and 36.5 in the A-A plots. The LSD (.01) was 5.9. Estimated mean water added to the root zone through analysis of neutron data between 15 August and 20 August, 1980 was 2.06 inches in the E plots and 2.20 inches in the A-A plots. Statistical differences in water added was not significant as shown in Table V. This would indicate usable water in the soil profile was approximately the same in the A-A plots as the E plots. Differences in water added may be due to a higher evaporative loss in the E plots. Weather data indicates only 1.75 inches of precipitation was received between 10 July, which was last irrigation date of these A-A furrows, and 18 August. Soil in the study area has a high tendency to crack when dry. This could account for the unusually deep penetration of water in the A-A plots.

Study of 1981

Yields are shown in Figure 13. Again, as in 1980 the E irrigation treatments out yielded the A-A treatments. The yield reduction in this study was 28%. Average for the E plots was 4060 lbs/acre, while the A-A plots averaged 2790

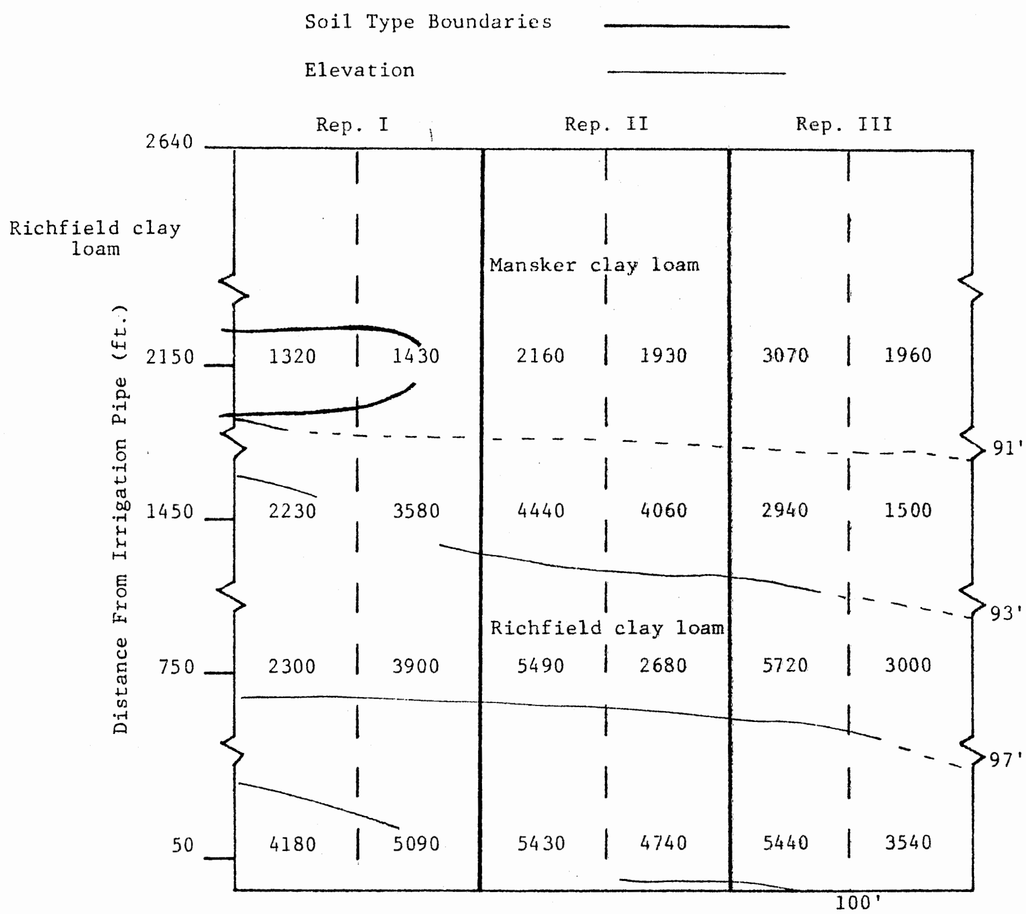
TABLE V

ANALYSIS OF VARIANCE OF WATER ADDED TO THE ROOT ZONE FROM 15 AUGUST TO 20 AUGUST, 1980

	Degress of Freedom	Sum of Degrees	Mean Square	Calculated F	Tabulated F
Total	23	11.833			
Replications	2	1.491	.745		
Treatments	1	.115	.115	.382	4.60
Distances	3	4.226	1.409	4.683	3.34
Rep. X Treat.	3	1.790	.597	1.984	3.34
Error	14	4.211	.301		

Coefficient of Variation = 25.72%

LSD (.05) = .480



LSD (.05) Irrigation Treatment 580Lb/Acre
LSD (.05) Distance 830Lb/Acre

Figure 13. Grain Sorghum Yield in 1981 (lbs/acre), Soil Type, Elevation (ft.) Reference (100 ft.) for Irrigation Study of Alternate and Every Furrow Irrigation

lbs/acre. As in 1980, the yields in general tended to decrease as distance from the head ditch was increased, with some isolated cases of yields increasing from one distance increment to the next farther increment. LSD values in Figure 13 shows, unlike in 1980, there was no significant difference in yields at the 1450 ft. and 2150 ft. distance increments. This would indicate wide-spaced furrow irrigation is not a factor in yield depression in relation to increasing distance increments. Again however, as in 1980, due to long irrigation interval yield is not a good device by which to measure differences. Coefficient of variation for yield in 1981 is 19.5%, as shown in Table VI. Graphs of yields are shown in Figure 14. The A-A plot in replication I at the 2150 ft. distance increment was completely enveloped by the caliche outcrop which suppressed grain yield. However, a missing data component was calculated and used in all analysis of yields. Analysis of variance for yield in 1981 is shown in Table VI.

Time since start of irrigation vs. distance from head ditch graphs are shown in Figure 15. As on both measurement dates in 1980, uniformity of advance is remarkable with slopes of E-treatment regression lines being virtually parallel with the A-A treatment regression line. This is also evidenced by regression and r^2 values shown in Figure 15. This data strongly supports the 1980 data, as does Table VII, analysis of variance of 1981 rate of advance data. Ratio of average E to average A-A coeffecient of variation are closely related as they were in 1980.

TABLE VI

ANALYSIS OF VARIANCE OF YIELD FOR 1981

	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F	Tabulated F
Total	23	40658649			
Replications	2	2972050	1486025		
Treatments	1	9690110	9690110	21.762	4.60
Distances	3	24507690	8169230	18.346	3.34
Rep. X Tret.	3	2865410	955136.67	2.145	3.34
Error	14	6233890	445277.86		

Coefficient of Variation = 19.50%

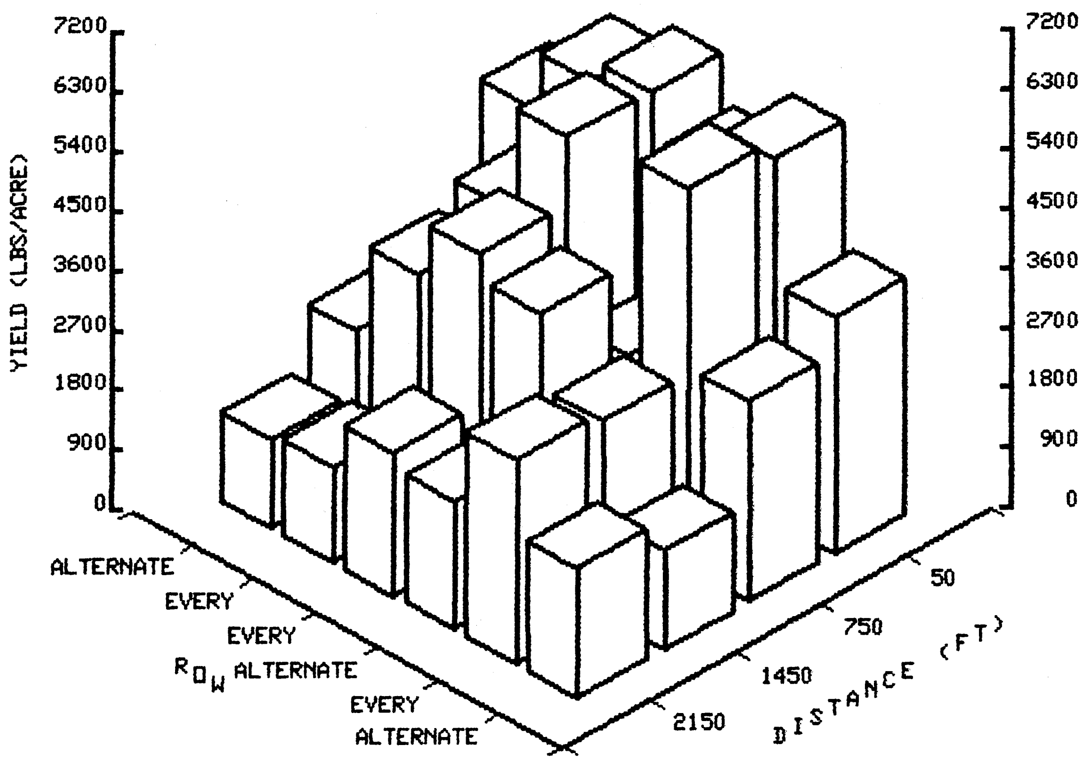


Figure 14. Grain Sorghum Yield (lbs/acre) in 1981 in Response to Irrigation Treatments

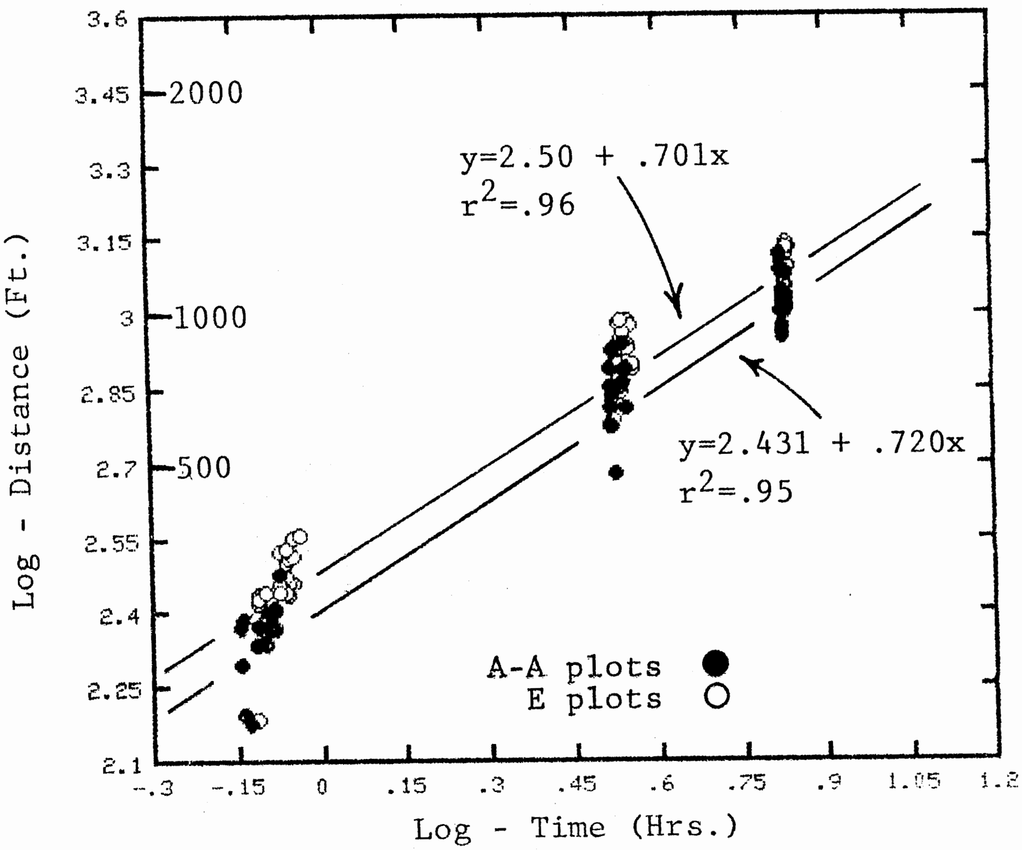


Figure 15. Distance of Irrigation Water Advance as a Functin of Time Since Start of Irrigation 24 September, 1981

TABLE VII

ANALYSIS OF VARIABILITY OF DISTANCES FOR TWO DIFFERENT TIMES ON 24 SEPTEMBER, 1981

Furrow Number and Treatment	PERIOD 1* Mean (ft.)	Standard (ft.) Deviation	Coefficient (%) of Variation	PERIOD 2* Mean (ft.)	Standard (ft.) Deviation	Coefficient (%) of Variation
2-10 AA	229.2	13.2	5.8	979.4	69.0	7.1
11-20 E	279.1	28.1	10.1	1078.5	51.9	4.8
21-30 E	316.7	28.3	8.9	1249.7	114.0	9.1
32-40 AA	257.6	24.2	9.4	1087.8	60.3	5.5
41.50 E	243.5	33.9	13.9	1201.1	87.4	7.3
52-60 AA	197.2	39.0	19.8	1083.2	159.7	14.7
Average E			11.0			7.1
Average A-A			11.7			9.1

*Period 1 is 0.7 to 0.9 hours and Period 2 is 6.6 to 6.9 hours since start of irrigation, respectively.

Average depth of irrigation water applied vs. time since start of irrigation are shown in Figure 16. As on the 4 September irrigation date in 1980, the slope of the regression lines for E-treatments and A-A treatments is generally the same. However, unlike the later irrigation date in 1980, none of the data points overlap at any of the three times of measurement. Table IX (see the Appendix) shows average maximum temperature, precipitation, and average wind movement during the growing season 1981.

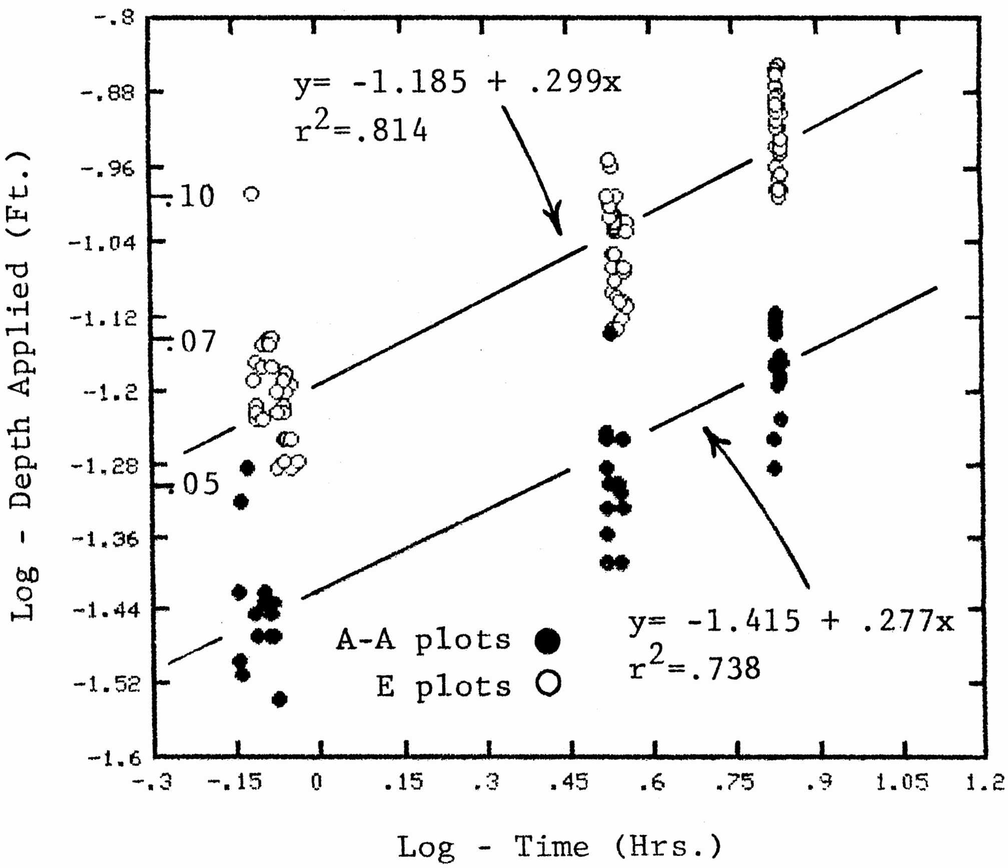


Figure 16. Depth of Irrigation Water Applied as a Function of Time Since Start of Irrigation 24 September, 1981

CHAPTER V

DISCUSSION

Yields for both years, although substantially lower in 1981, showed a general decrease as the distance from the head ditch increased. In both 1980 and 1981, yields across replications and at given distances from the head ditch were highly variable. Although there was high variability, there were no obvious differences in yield of individual rows harvested, alternating alternate or every furrow irrigation, in 1980. This would indicate, as did Stone et al. (1979), the method of irrigation every other furrow alternately is an effective means of reducing pumping cost and conserving water. An average of each replication at each distance interval from the head ditch showed in all cases the E plots yielded more pounds per acre than the A-A plots. The 1980 A-A treatment yielded 10% less than the every furrow treatment, while in 1981 the alternating alternate treatment yielded 28% less than the every furrow treatment.

The high yields in 1980 were not anticipated due to the limited availability of water. The limited availability of water caused an irrigation interval which was longer than the optimal as originally planned, in most cases twice the 9-day optimal. Approximately 8 inches of water was applied by irrigation to the E plots and 4.5 inches applied to the A-A plots during the growing season. The 26 June irrigation was not included in the total water because it was an irrigate every furrow irrigation used to establish the crop. Also, the 4 September irrigation was not tallied as it probably had no effect on grain yield due to the late stage of plant growth.

Yield data, although important, were not a major concern of this study, rather it was the ability to manage water application on large fields using wide-spaced furrow methods. Distance of water advance down the furrow data, shown in Figures 7, 8, and 15, strongly indicates successful management is possible. In fact, the consistency of measurements for both years suggest the distance of water advance is proportional to the distance advanced. The implication is that measurements of rate of advance can be made at short time after the start of an irrigation to determine flow rates of water down the furrows. Uniformity of compaction, degree of slope, and soil type are considerations before application.

Large cracks within the furrow of the A-A treatments, caused by the nature of the clay soil and compounded by long irrigation intervals, was a contributing factor in the slower advance rate and would suggest, because of small variance, cracks were fairly uniform in size, shape, and area throughout the plots. This seems to be due to the long irrigation interval, as these furrows had not received irrigation water in excess of 5 weeks with very little precipitation over this time period. Had it not been for the high clay content, which resulted in large cracks down the A-A furrows under long dry periods, it would be expected the E treatment plots would generally have deeper penetration than the A-A plots because of the tendency of water to move laterally in the wide-spaced system. This is exhibited by penetration data in Figure 11 when the A-A furrows had received water less than 5 weeks earlier plus a precipitation total of over 6 inches in May and June.

Figures 11 and 12 show the 1980 water penetration data from 19 July to 4 August and 15 August to 20 August, no rainfall was recieved during these time increments so all water movement through the profile could be attributed to application of irrigation water. Depths of water penetration was not consistent in either the E plots or the A-A plots for each irrigation. The 31 July irrigation data shows the average depth of penetration of the A-A plots, in all but one case, is of the same depth or greater as the E plots. The 18 August data shows in every case a much deeper average depth of penetration in the A-A plots.

It is suggested the large cracks down the A-A treatment furrows could cause such an infiltration pattern. There were no obvious correlations between yield and depth of water penetration.

Missing data in the 1981 study prevented a comprehensive study of the water penetration into the soil profile.

CHAPTER VI

CONCLUSIONS

Due to the unavailability of water on a near optimum irrigation interval, no conclusions can be made based on yield. However, a contrast of rate of advance of water down the furrow between the E furrows and the A-A furrows, indicates furrow streams can be adjusted to produce a uniform application of irrigation water. Rate of advance measurements can be made at the start of an irrigation with the furrow stream being adjusted at this time. Congenial soil type, uniform compaction and slope are necessary for accurate adjustments.

The variability of water advance down furrows in the A-A plots was no greater than that of the E plots both years on half mile lengths of runs.

Using wide-spaced furrow irrigation on clay soils, which tend to crack under long irrigation intervals, could result in deeper water penetration with less water being applied.

LITERATURE CITED

Allen, R. R., and J. T. Musick. 1972. Wheat and grain sorghum irrigation in a wide bed-furrow system. Trans. Amer. Soc. Engr. 15:61-63.

Box, J. E., W. H. Sletten, J. H. Kyle, and Alexander Pope. 1963. Effects of soil moisture, temperature, and fertility on yields and quality of irrigated potatoes in the Southern Plains. Agron. J. 55:492-494.

Fischback, P. E., and H. R. Mulliner. 1972. Every other furrow irrigation of corn. Amer. Soc. Engr. Paper No. 72-722. A.S.A.E., St. Joseph, Mich. 49085.

Grimes, D. W., V. T. Walhood, and W. L. Dickens. 1968. Alternate-furrow irrigation for San Joaquin Valley Cotton. Calif. Agric. 22:4-6.

Longenecker, D. E., E. L. Thaxton, Jr., and P. J. Lyerly. 1969. Variable row spacing of irrigated cotton as a means for reducing production costs and conserving water. Agron. J. 61:101-104.

Musick, J. T., and D. A. Dusek. 1974. Alternate-furrow irrigation of fine textured soils. Trans. Amer. Soc. Agric. Engr. 17:289-294.

Musick, J. T., W. H. Sletten, and D. A. Dusek. 1973. Evaluation of graded furrow irrigation with length of run on a clay loam soil. Tran. Amer. Soc. Agric. Engr. 16(6):1075-1080, 1084.

Musick, J. T., and D. A. Dusek. 1972. Irrigation of grain sorghum and winter wheat in alternating double bed strips. Jour. Soil Water Conserv. 27:17-20.

Musick, J. T., and D. A. Dusek. 1975. Limited irrigation of grain sorghum in alternating strips with wheat. Trans. Amer. Soc. Agric. Engr. 18:544-548.

Musick, J. T., and D. A. Dusek. 1982. Skip-row planting and irrigation of graded furrows. Trans. Amer. Soc. Agric. Engr. 25:82-87, 92.

Newman, J. S. 1967. Yields and fiber properties of cotton planted in solid and skip-row systems under minimal soil moisture levels, Texas high plains, 1963-1965. Texas Agric. Exp. Sta. Bull. MP-843.

Stewart, B. A., D. A. Dusek, and J. T. Musick. 1981. A management system for the conjunctive use of rainfall and limited irrigation of graded furrows. Soil Sci. Soc. Amer. J. 45:413-419.

Stone, J. F., J. E. Garton, B. B. Webb, H. E. Reeves, and J. Keflemariam. 1979. Irrigation water conservation using wide-spaced furrows. Soil Sci. Soc. Amer. Jour. 43:407-411.

Stone, J. F., H. E. Reeves, and J. E. Garton. 1982. Irrigation water conservation by using wide-spaced furrows. Agric. Water Manage. 5:309-317.

Stone, J. F., James E. Garton, and B. B. Webb. 1966. Alternate row irrigation. Research Progress Report, Oklahoma Irrigation Research Station, Altus, Oklahoma, Processed Series, P-548.

APPENDIX

WEATHER DATA FOR GROWING SEASON

1980 AND 1981

TABLE VIII

WEATHER DATA - MAY 1 - SEPTEMBER 30, 1980

Month	Average Maximum Temperature (F^{o})	Precipitation (inches)	Average Wind Movement (miles/day)
May	69.1	4.28	113.3
June	91.0	2.08	135.5
July	100.9	.48	158.0
August	93.8	1.73	107.2
September	84.3	.39	148.8

TABLE IX

WEATHER DATA - MAY 1 - SEPTEMBER 30, 1980

Month	Average Maximum Temperature (F^{o})	Precipitation (inches)	Average Wind Movement (miles/day)
May	75.6	2.93	187.0
June	92.4	2.09	165.7
July	92.4	3.46	132.6
August	87.2	4.11	127.4
September	85.5	.96	155.9

VITA

Mark Eugene Hodges

Candidate for Degree of

Master of Science

Thesis: ALTERNATE FURROW IRRIGATION IN GRAIN SORGHUM

Major Field: Agronomy

Biographical:

Personal Data: Born in Liberal, Kansas, August 11, 1953, the son of Albert E., and Vivian P. Hodges.

Education: Graduated from Forgan High School in Forgan, Oklahoma, May, 1971; received Bachelor of Science degree in Agronomy from Oklahoma Panhandle State University, Goodwell, Oklahoma, August, 1978; completed requirements for the Master of Science degree in Agronomy at Oklahoma State University, Stillwater, Oklahoma, May, 1983.

Professional Experience: Employed by Oklahoma Agricultural Experiment Station, Panhandle Research Station, Goodwell, Oklahoma, September, 1976 to May, 1978; employed by Oklahoma State University, Research Assistant, Stillwater, Oklahoma, September, 1979 to May, 1981.