A STUDY OF THE BENEFICIAL USE OF IRRIGATION WATER ON SANDY LOAM SOILS

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Paul Edward Schleusener

1949

This is to certify that the

thesis entitled

A Study of the Beneficial Use of
Irrigation Water on Sandy Loam Soils

presented by

Paul Edward Schleusener

has been accepted towards fulfillment
of the requirements for

M.S. degree in Agr. Eng'r.

F. W. Peikert
Major professor

Date March 11, 1949

M-795

A STUDY OF THE BENEFICIAL USE OF IRRIGATION WATER ON SANDY LOAM SOILS

By

Paul Edward Schleusener

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

Master of Science

Department of Agricultural Engineering

1949

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the following:

Professor F. W. Peikert and other members of the Agricultural Engineering Department for their help in selecting and setting up the problem.

Professor R. L. Carolus of the Horticulture Department for his cooperation in conducting the experiment.

Professor H. M. Brown of the Farm Crops Department and Professor Leo Katz of the Mathematics Department for their advice in selecting the experimental design and making the statistical analysis.

Professor K. Lawton of the Soil Science Department for his help in solving soil, moisture, and nutrient problems.

Mr. R. T. Tribble formerly of the Agricultural Engineering Department at Michigan State College for his help in conducting the experiment.

Rev. O. E. Ames, owner of the land on which the experiment was conducted, for his cooperation.

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INTRODUCTION

The state of Michigan has an average rainfall of about 30 inches. During the growing season of May 15 to September 15 the average rainfall for the state is 12 inches. With proper distribution of this rain there should be sufficient moisture for obtaining maximum yields from the crops raised in Michigan. A study of the weather records reveals the fact that this ideal distribution scarcely ever occurs. Actually a number of drought periods can be expected during the growing season.

Definition of Drought Period

In this study a drought period is defined as a period of at least 14 days in which less than 0.25 inch of rain falls in any one day.

Thirty Year Record at Lansing

The average amount of rainfall for Lansing from May 15 to September 15 is 12.60 inches. It is distributed as follows: May, 1.71; June, 3.51; July, 3.10; August, 2.82; and September, 1.46 inches.

A study of the daily precipitation records at Lansing for the years 1918 to 1947 inclusive revealed that there were a number of drought periods during the growing season.

The droughts have been broken down into 2, 3, 4, 5, 6, 7, 8, and 11 week periods. The total number found in the 30 year period and the frequency of their occurrence are shown in Table 1.

Table 1

Occurrence of Droughts
over
Thirty Year Period

Length, weeks	2	3	4	5	6	7	8	11
Total number periods	53	18	5	1	1	2	1	1
Frequency of occurrence (in years)	7 in 4	3 in 5	1 in 6	1 in 30	1 in 30	1 in 15	1 in 30	1 in 30

This table indicates that each year an average of 7½ weeks of drought can be expected during the period of May 15 to September 15.

Need for Irrigation Based on Drought Study

The breakdown of drought periods that have occurred at Lansing indicates that there is a deficiency of soil moisture some time during the growing season every year. With the proper distribution of rainfall even the 7½ weeks of drought will not cause serious damage to the crops. However, it is highly improbable that an ideal distribution will ever occur. Under

normal circumstances, then, Michigan crops will suffer from lack of available soil moisture during the growing season. To obtain optimum yields it is necessary to apply irrigation water whenever the available soil moisture has been materially reduced.

Problems Associated with Irrigation

The application of irrigation water to Michigan crops presents a number of associated problems. They are listed as follows:

1. Determine what crops will produce a significant increase in yield.
2. Per cent of available moisture at which crops must be irrigated to produce the optimum yield.
3. Effect of irrigation on plant nutrients.

The material that follows presents exploratory data on the previously mentioned problems.

EXPERIMENT

Tests on the effect of different amounts and times of irrigation on the following vegetable crops were conducted in 1948: snap beans, tomatoes, and sweet corn.

The crops were grown on a Hillsdale sandy loam located near East Lansing, Michigan. The soil was rather low in

fertility. A preplanting application of 800 pounds of 3-12-12 fertilizer was drilled over the entire area. The water for irrigating the crops was pumped from a stream near the field. Figure 1 shows the pump, power unit, main supply line and suction line located by the stream.

Figure 1. Pump Located by Water Supply

Quick coupling portable pipe carried the water to the plots. The application of water was made through fixed type sprinklers fastened to a supply line supported on stands in the middle of each plot. Properly arranged sets of full, quarter and half circle sprinklers were used to obtain uniform distribution of water on the plots. Figure 2 shows some of the plots being irrigated. This type of equipment was used for its adaptability

for irrigating rectangular areas. The low angle of spray prevented excessive loss of water due to drift.

Figure 2. Irrigation of Experimental Plots

Plot Layout

The irrigation treatments were randomized in 15 by 35 foot plots and replicated three times. Ten foot alleys were left between each replication of plots. The plot layouts are shown in Figures 3, 4, and 5.

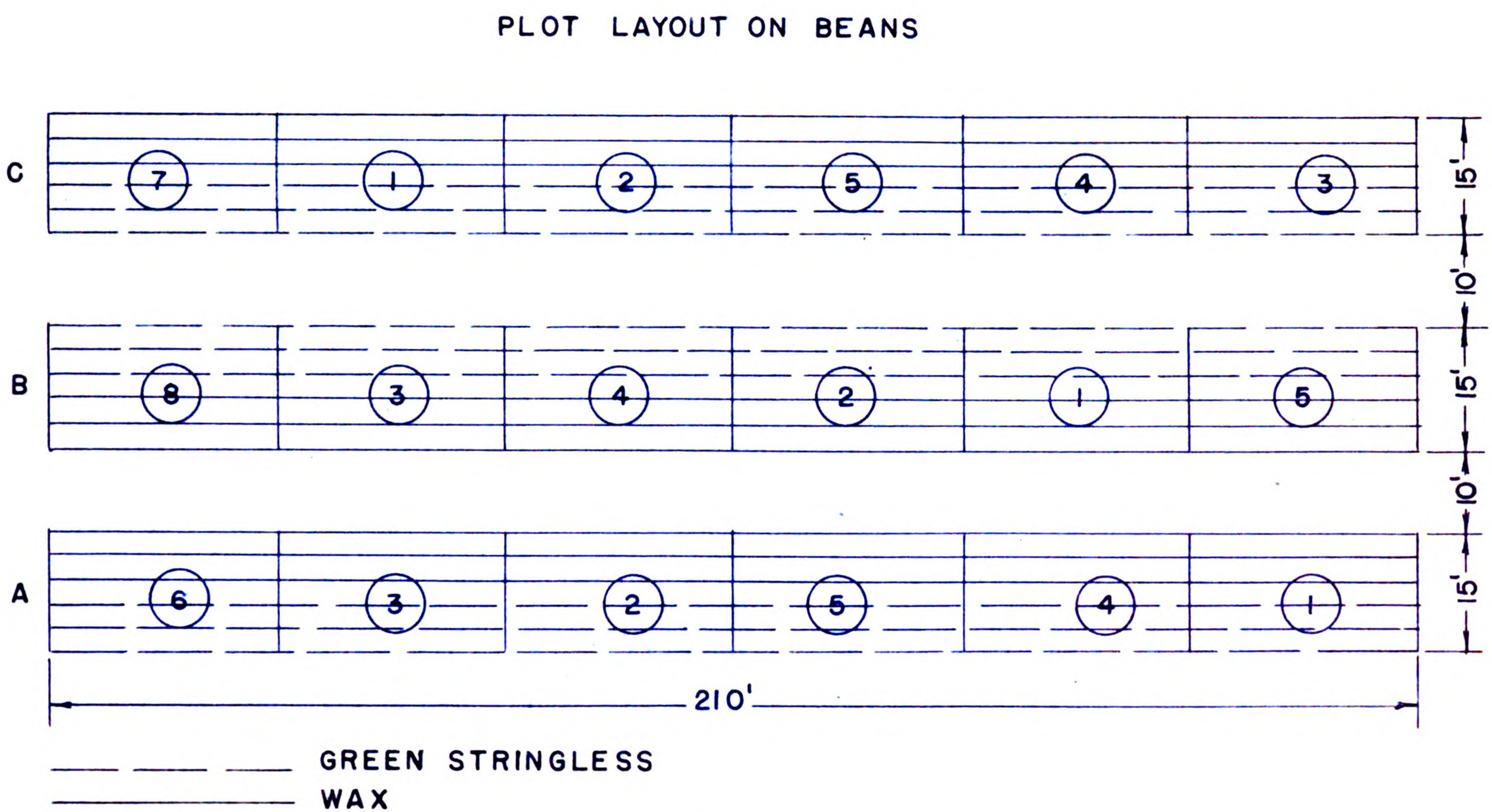

Figure 3. Plot Layout on Snap Beans

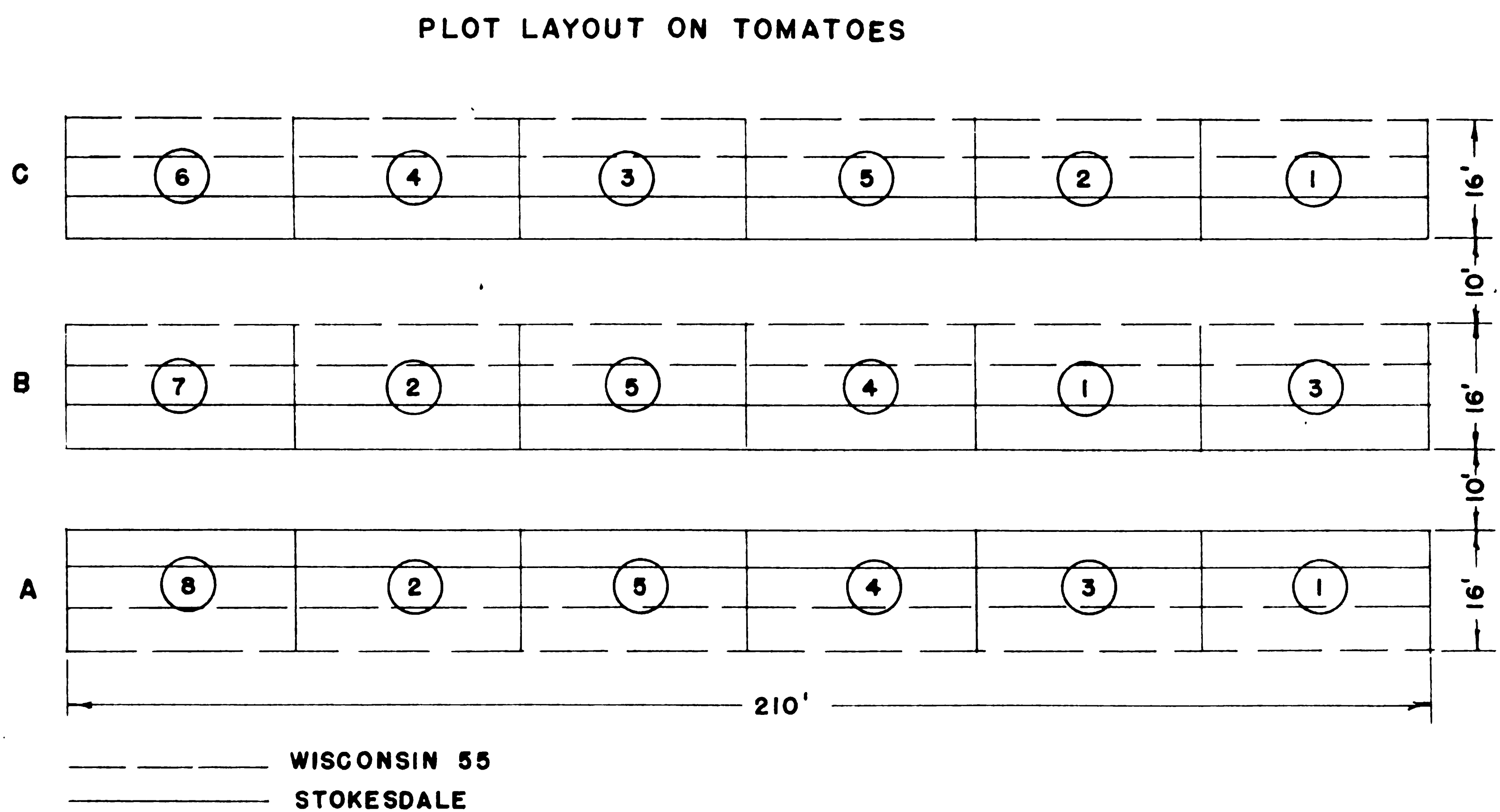

Figure 4. Plot Layout on Tomatoes

PLOT LAYOUT ON CORN

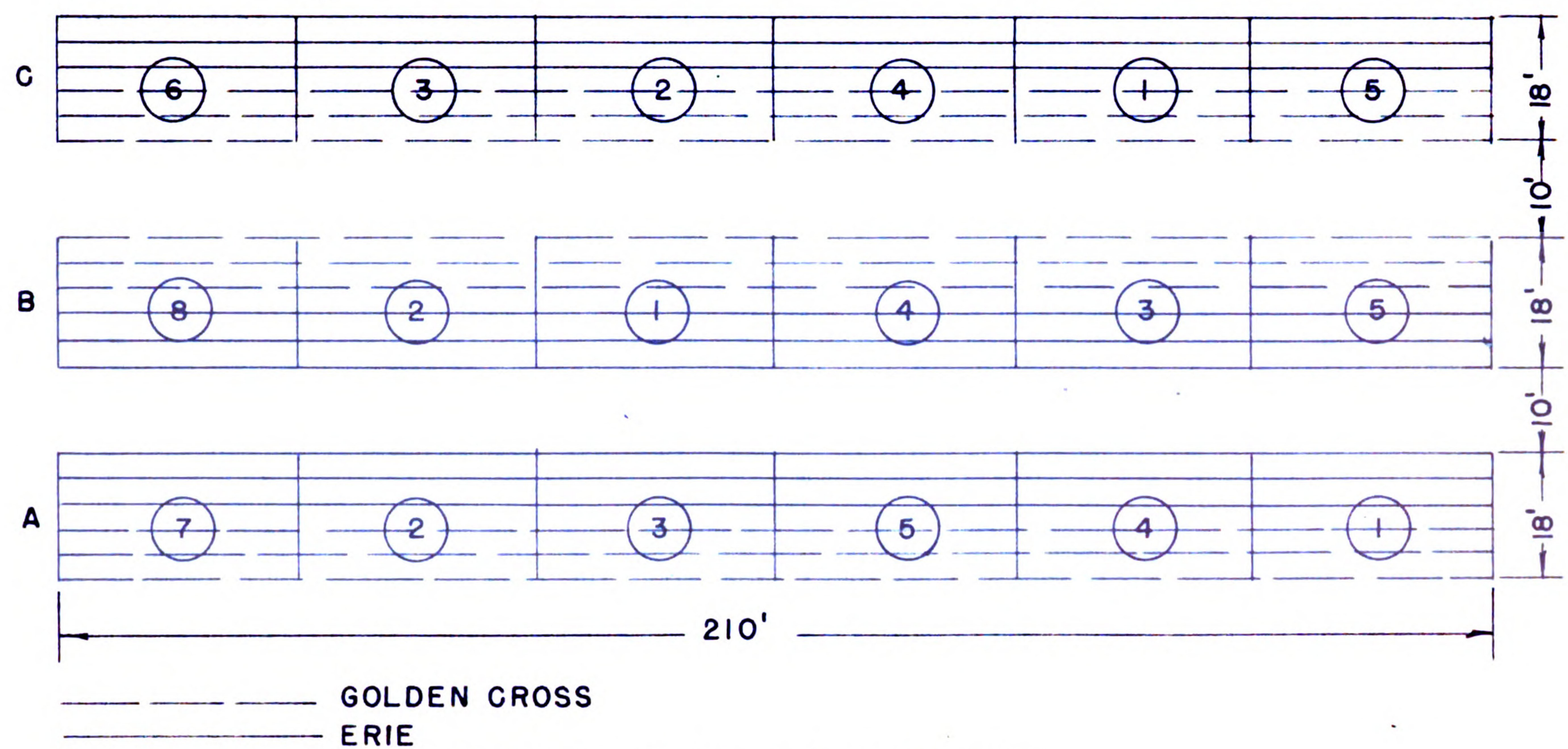

Figure 5. Plot Layout on Sweet Corn

Treatments

The following irrigation practices were compared:

1. Unirrigated.
2. Irrigation when needed as determined by gypsum moisture blocks placed in the soil at 4 and 8 inch depths. The per cent of available soil moisture was determined by measuring the intensity of an electric current passed through the buried block. When the available moisture was less than 50 per cent, water was applied. The blocks were used in an attempt to determine the practicability of their use in specifying the time for irrigation, based on the amount of moisture in the soil that is available to the plant.
3. One inch per week whenever the rainfall the previous week was less than one inch. This treatment was used to approximate the practice usually followed by irrigators in Michigan.
4. Same as number 2 with an additional inch of water at critical times in the growth of the plant. Critical times for snap beans were at full bloom and two weeks after full bloom. For tomatoes the critical times

were after the first and second clusters had formed and two weeks later. The critical times for sweet corn were at tasseling and at silking. Additional applications of water at critical times in the growth of the plant were made to determine whether this practice resulted in a material increase in yield.

5. One and one-half inches of water per week whenever the rainfall the previous week was less than one and one-half inches.

Treatments 6, 7, and 8 were unirrigated, light irrigation, and heavy irrigation, respectively. They were added for a study on root development not associated with this problem.

Moisture blocks were placed in two of the replications for treatments 1, 2, and 4. Block resistances were read with a portable ammeter constructed for this purpose. It is easier to read than the Wheatstone bridge (used for determining block resistances) but is not as accurate as the bridge. The portable ammeter reads directly in per cent of available moisture, thereby eliminating the necessity of converting resistance readings to per cent moisture.

RESULTS

Irrigation Practices and Yields

In every case the irrigated crops showed more vigorous growth than the unirrigated. Figures 6 and 7 show the difference between unirrigated and irrigated sweet corn. The quality of the fruit produced by the irrigated crops was markedly better than that produced by the unirrigated crops. Figure 8 shows the effect of two irrigations on sweet corn.

Figure 6. Unirrigated Sweet Corn

Figure 7. Irrigated Sweet Corn

Figure 8. Effect of Irrigation
on Sweet Corn

Comparison of yields

Yields from the small plots have been converted to yields per acre.

Snap beans. The first picking of beans was made on August 1. The data in Table 2 indicate that an application of as little as 2 inches of water increased the yield 19 per cent. With 6 inches additional water the yield was increased an additional 24 per cent. The greatest increase in yield per inch of water was obtained with an application of only 3 inches.

Tomatoes. Tomato plants were set in irrigated soil on May 31. As a result of sufficient moisture very little replanting was necessary. Harvesting extended from August 24 to October 1.

Climatic conditions were quite favorable and resulted in high tomato yields in this general area. The data in Table 2 show that the treatments receiving 4 inches of irrigation water during the season produced larger increases in total weight than others receiving three to four times as much water.

The number and weight of fruit on plots receiving either 11 or 16 inches of water were substantially lower than those on plots receiving 4 inches of water. In this experiment the heavy irrigations resulted in a lower fruit set. The size of fruit was increased up to 15 per cent by irrigation and was not influenced by the amount of water applied.

Sweet corn. The sweet corn was drilled in three foot rows on June 1. The plants were thinned to an average stand of 132 stalks per hundred feet of row.

Table 2

Comparison of Yields

Treatment	1	2	3	4	5
SNAP BEANS					
Water applied, inches		2	8	3	15½
Pounds per acre	4095	4884	5850	5340	5958
Per cent increase		19	43	30	45
Increase/inch of water, lbs. per acre		394	219	415	120
TOMATOES					
Water applied, inches		4	11	4	16
Number of tomatoes (thousand per acre)	88.4	127.2	98.2	104.2	101.1
Per cent increase		44	11	18	14
Average weight of fruit, lb.	0.34	0.39	0.39	0.38	0.38
Per cent increase		15	15	12	12
Bushels per acre	500	833	634	662	639
Per cent increase		67	27	32	28
Increase per inch of water, bushels/acre		83	12	40	9
SWEET CORN					
Water applied, inches		4	8	4	14½
Tons per acre harvested	2.69	6.07	4.96	4.79	2.90
Per cent increase		126	84	78	7.8
Dozens of ears per acre harvested	1167	1771	1446	1444	1073
Per cent increase		52	24	24	-0.8
Average weight of ear, lb.	0.39	0.58	0.58	0.55	0.46
Per cent increase		49	49	41	18
Dozens of ears per acre marketable	296	1482	1200	1208	746
Per cent increase		400	306	308	152
Increase per inch of water		296	113	229	31
Per cent marketable ears	25	84	83	84	70

During the latter part of August the unirrigated corn showed the effects of drought by the rolled leaves and a difference of about 12 inches in height. The corn was picked on August 30 and September 5.

The corn was weighed and counted. The data in Table 2 show the average weight per ear, the total weight, and dozens of harvested and marketable ears to the acre.

Corn was benefited more by irrigation than either of the other crops. An increase of 400 per cent in the number of dozens of marketable ears resulted from the application of 4 inches of water. About 25 per cent of the ears were marketable on the unirrigated plots while irrigation increased the marketable ears to more than 80 per cent.

Weight per ear was increased 49 per cent by an application of 4 inches of water. This increased size was due to a longer, better filled ear, resulting in better market quality.

Result of statistical analysis

The results of the statistical analysis are shown in Table 3. The crops grown, treatments used and the level of significance are shown.

Statistically, treatment 5 was better than 1 and 2 in the snap beans at the one per cent level.

In the tomatoes treatment 2 was the only one to show any statistical significance in the yields. All irrigated plants produced larger tomatoes than the unirrigated.

Table 3

Result of Statistical Analysis

Treatment	1	2	3	4	5
SNAP BEANS					
Plot yield, lbs.	98.7	117.7	141.0	128.6	143.6
Level of significance over tr. 1	--	5%	1%	1%	1%
Level of significance over tr. 2	--	--	1%	--	1%
TOMATOES					
Plot yield, lbs.	1158.4	1927.9	1466.1	1531.3	1478.3
Level of significance over tr. 1	--	1%	--	--	--
Plot yield, number	3407	4906	3786	4022	3897
Level of significance over tr. 1	--	5%	--	--	--
Av. wt./tomato, lb.	0.34	0.39	0.39	0.38	0.38
Level of significance over tr. 1	--	1%	1%	1%	1%
SWEET CORN					
Plot yield, lbs.	133.4	300.8	245.8	237.9	143.9
Level of signif. over tr.1	--	1%	1%	1%	--
Level of signif. over tr.3	--	5%	--	--	--
Level of signif. over tr.4	--	1%	--	--	--
Level of signif. over tr.5	--	1%	1%	1%	--
Plot yields, marketable ears	88	441	357	359	222
Level of signif. over tr.1	--	1%	1%	1%	1%
Level of signif. over tr.3	--	1%	--	--	--
Level of signif. over tr.4	--	1%	--	--	--
Level of signif. over tr.5	--	1%	1%	1%	--

The total weight of sweet corn and the number of marketable ears produced by plants receiving treatment 2 was significantly greater than those receiving any other irrigation treatment.

Yields with Different Levels of Available Moisture

It is evident that not all moisture present in the soil is available or suitable for rapid vegetative growth of a plant. Three divisions of soil moisture may be made on this basis: unavailable, available, and gravitational.

Plants begin to show permanent wilting when the moisture content of the soil approaches the hygroscopic coefficient. Since any water below this point cannot be used for rapid vegetative growth it may be called unavailable, though not entirely so.

When free water is present in the soil, conditions detrimental to growth are encouraged, the situation becoming more adverse as the saturation point is approached. The unfavorable effects of such moisture on the plant arise largely from the poor aeration. Not only are the roots deprived of their oxygen, but favorable bacterial activities, such as nitrification, nitrogen fixation, and ammonification, are much retarded. Moreover, adverse biochemical changes may be encouraged. This water is designated as gravitational.

It is very evident that the most favorable moisture conditions for growth of plants, and also for most micro-organisms, occurs in a soil when moisture is present is large enough amounts to be at a fairly low tension. This optimum is not found at

definite percentages of water, but exists between limits or as a zone, beginning near the hygroscopic moisture content and extending somewhat into the zone of gravitational water.

An abundant supply of rainfall during the early period of plant growth produces luxuriant foliage that cannot be supported during the drier days of late summer. Irrigation at low levels of soil moisture availability will keep sufficient moisture in the root zone of the soil to prevent the drought damage of the later part of the growing season. The following material shows the result of work done on a sandy loam soil. Crop yield data of three different irrigation practices are compared. Charts of moisture availability during the growing period show the seasonal variations. Treatments 1, 2, and 4 are compared.

Weather conditions

Table 4 shows the rainfall from June 1 to September 15. The rainfall during this period was 8.62 inches as compared with an average of 10.88 inches for Lansing.

There were two drought periods totaling almost seven weeks. The first period was from July 22 to August 10 and the second was from August 11 to September 9. This last period was particularly injurious to the sweet corn. The rainfall was well distributed during the remainder of the season.

Comparison of yields

Snap beans. The moisture record for the unirrigated snap beans shows that damage was done during two periods of the

Table 4

Rainfall on Irrigation Test Plots
1948

Date		Amount	Date		Amount
June	4	.17	July	16	.17
	7	.30		18	.15
	8	.10		20	T
	11	.21		21	.32
	12	.15		22	.04
	18	.19		25	.01
	21	.47		27	T
	22	1.33		29	.12
	23	.04	August	3	.04
	27	.39		4	.15
	28	.43		8	.02
	29	.16		10	.71
July	1	.65		11	.08
	10	T	September	5	.05
	11	.44		9	1.03
	15	.01		15	.69
			TOTAL		8.62 inches

	June	July	August	September
Monthly totals	3.94	1.91	1.00	1.77
Monthly normals for Lansing	3.51	3.10	2.82	2.91

picking season (Figures 9, 10, and 11). One period began about July 30 and ended with a drought breaking rain of 0.71 inch on August 10. The second began about August 18 and was broken by a rain of 1.03 inches on September 9. The available moisture in the soil during the last period fell to less than 10 per cent. This certainly damaged the possible yield on those areas.

The highest yield of beans was produced by adding water when the available moisture fell below 50 per cent and again at the critical time in the growth of the plant. The critical time in the growth of the plant indicated that additional moisture was required about August 6. This came after the first picking had been made. Although the available moisture in the soil was still above 60 per cent the additional water produced an increased yield of 30 per cent above the unirrigated.

Statistically there was no significant difference between the two irrigated treatments.

Tomatoes. Examination of the soil moisture data for the unirrigated tomatoes will reveal that at the end of the yielding season a severe deficit in the available moisture occurred at both 4 and 8 inch depths (Figures 12, 13, and 14). The dry period from August 1 to August 9 also caused damage to the plants and reduced their total yield.

The crop receiving water by the "by block" treatment yielded the highest number and weight of tomatoes (20 per cent better than the other irrigated crop). The next highest yielding crop received water "by blocks plus critical time".

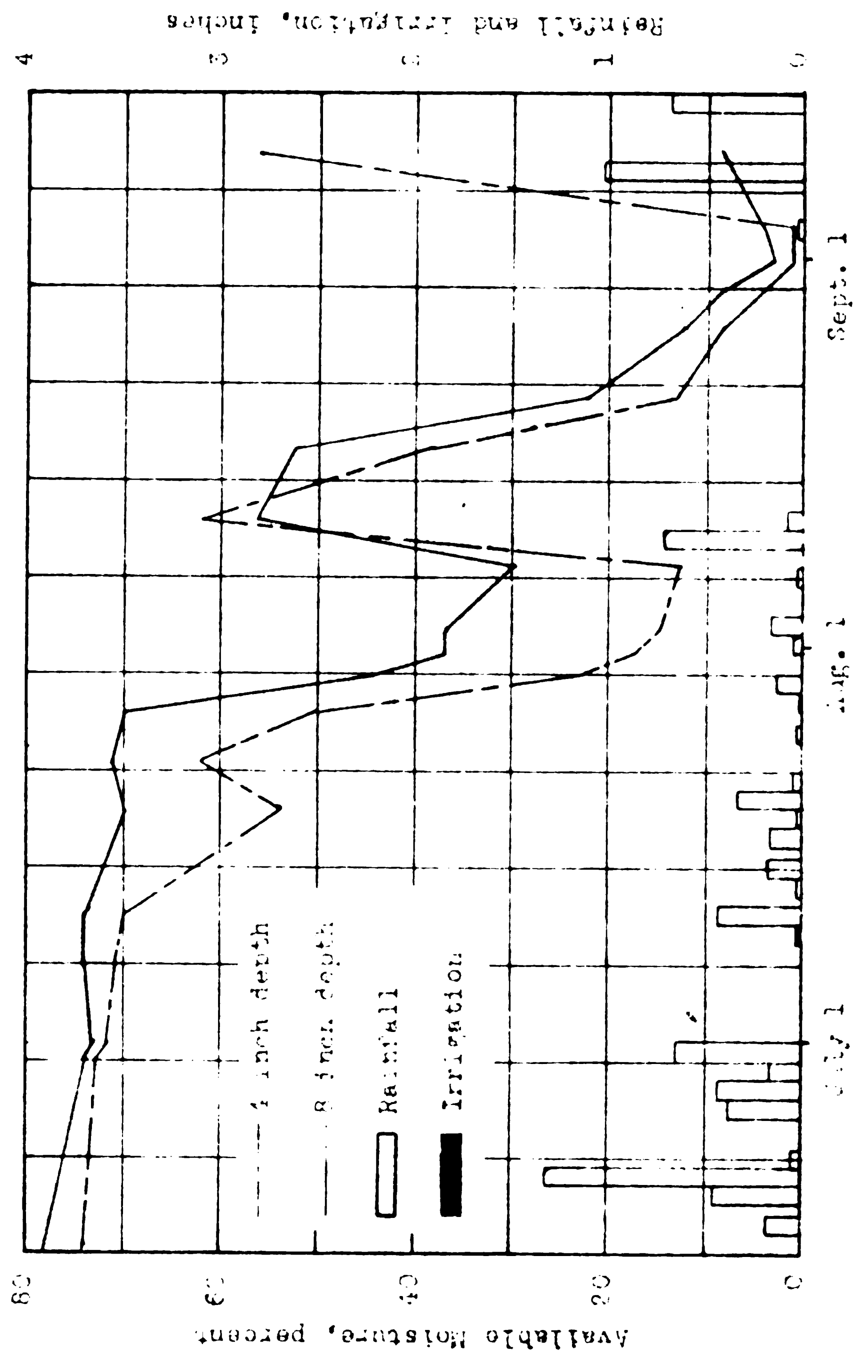

Figure 9. Available Moisture in Unirrigated Snap Beans

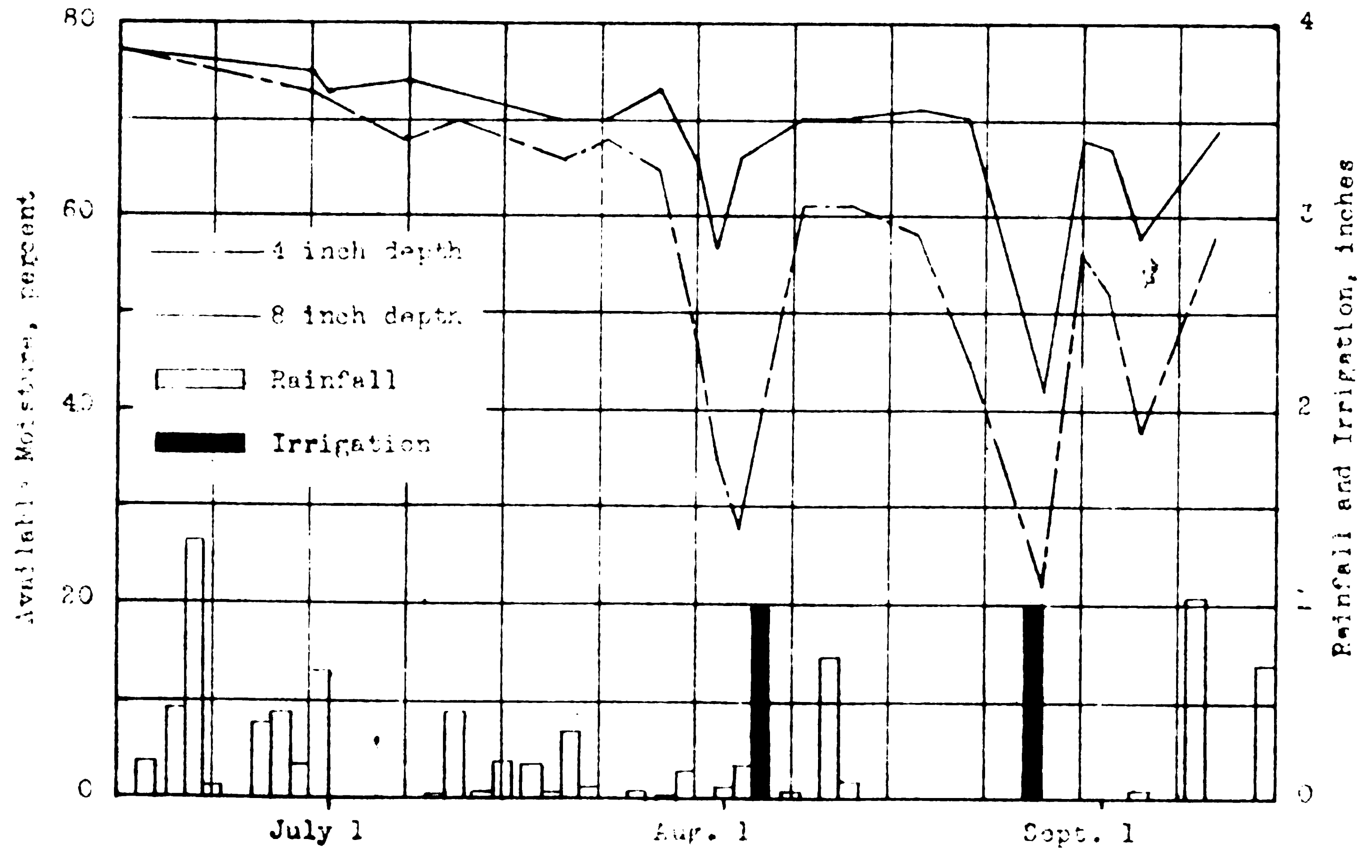

Figure 10. Available Moisture in Snap Beans Irrigated "by Blocks"

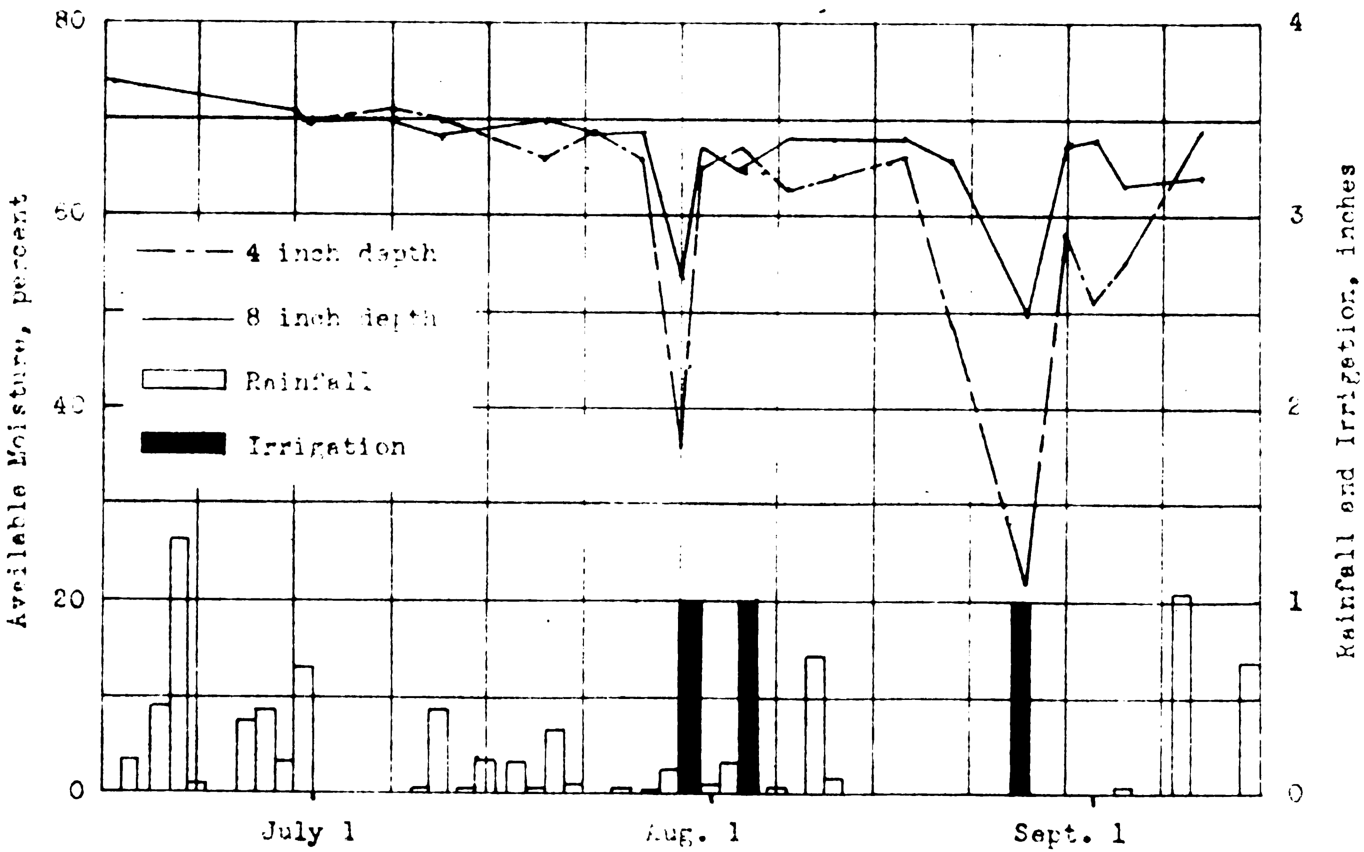

Figure 11. Available Moisture in Snap Beans Irrigated "by Blocks Plus Critical Time"

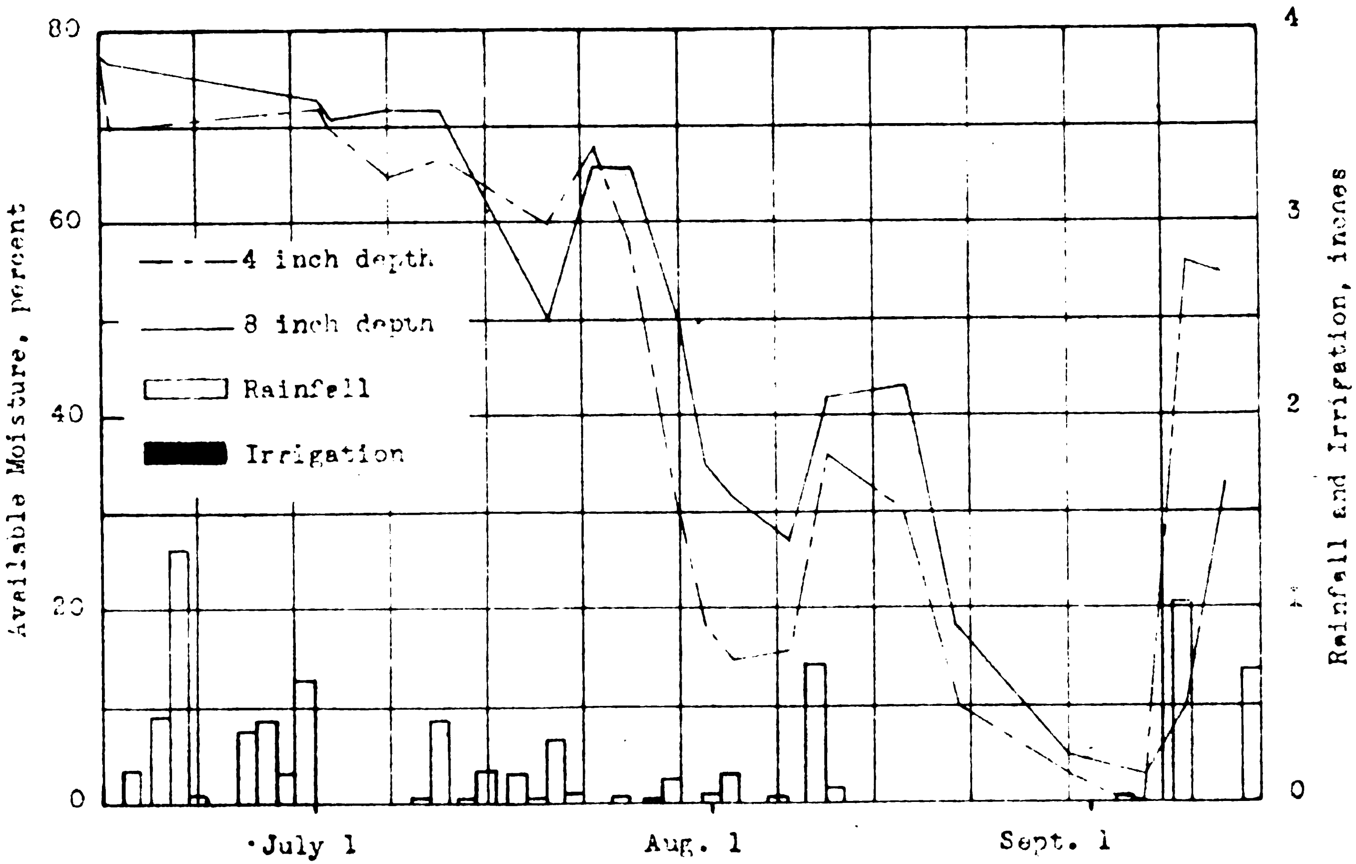

Figure 12. Available Moisture in Unirrigated Tomatoes

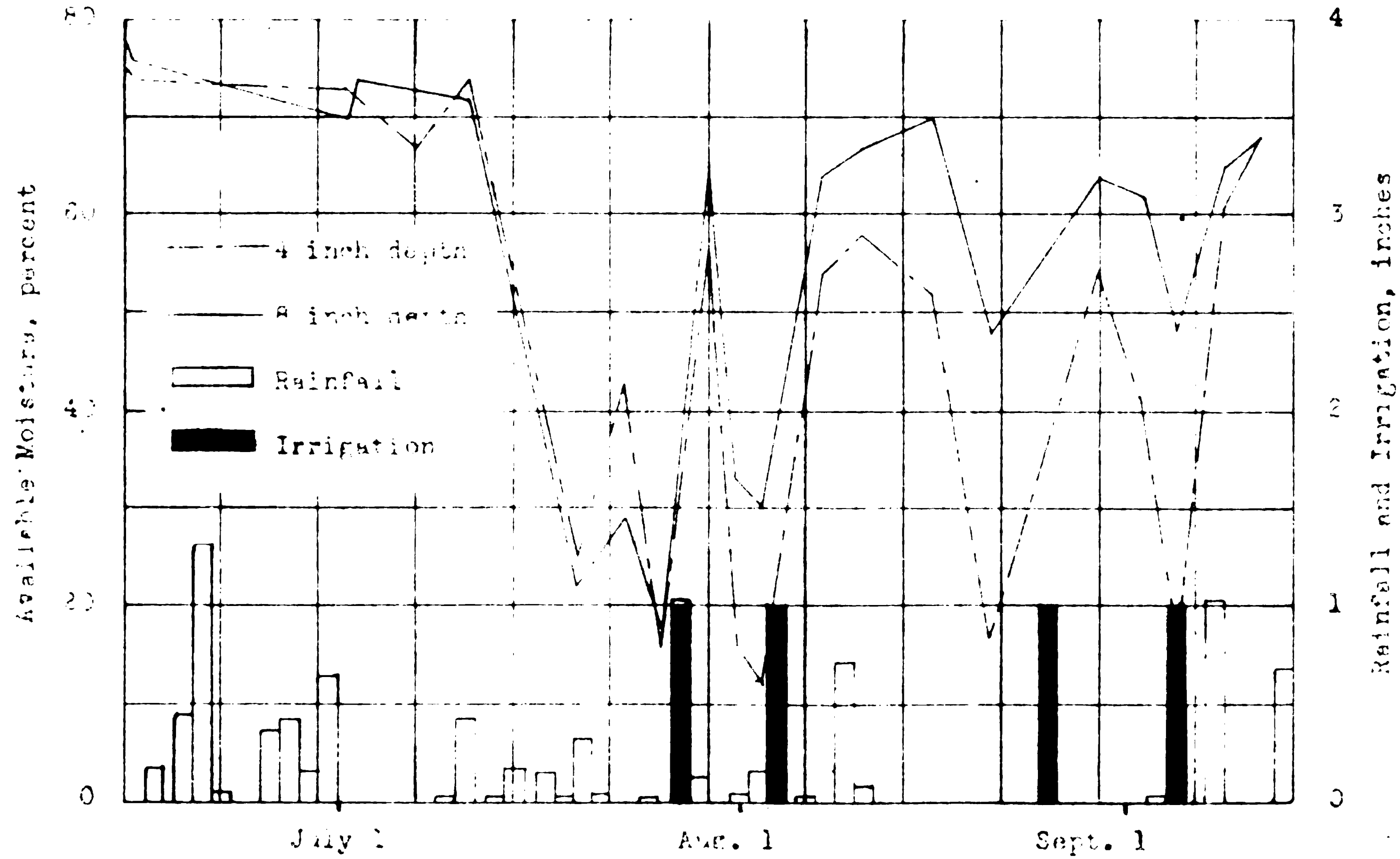

Figure 13. Available Moisture in Tomatoes Irrigated "by Blocks"

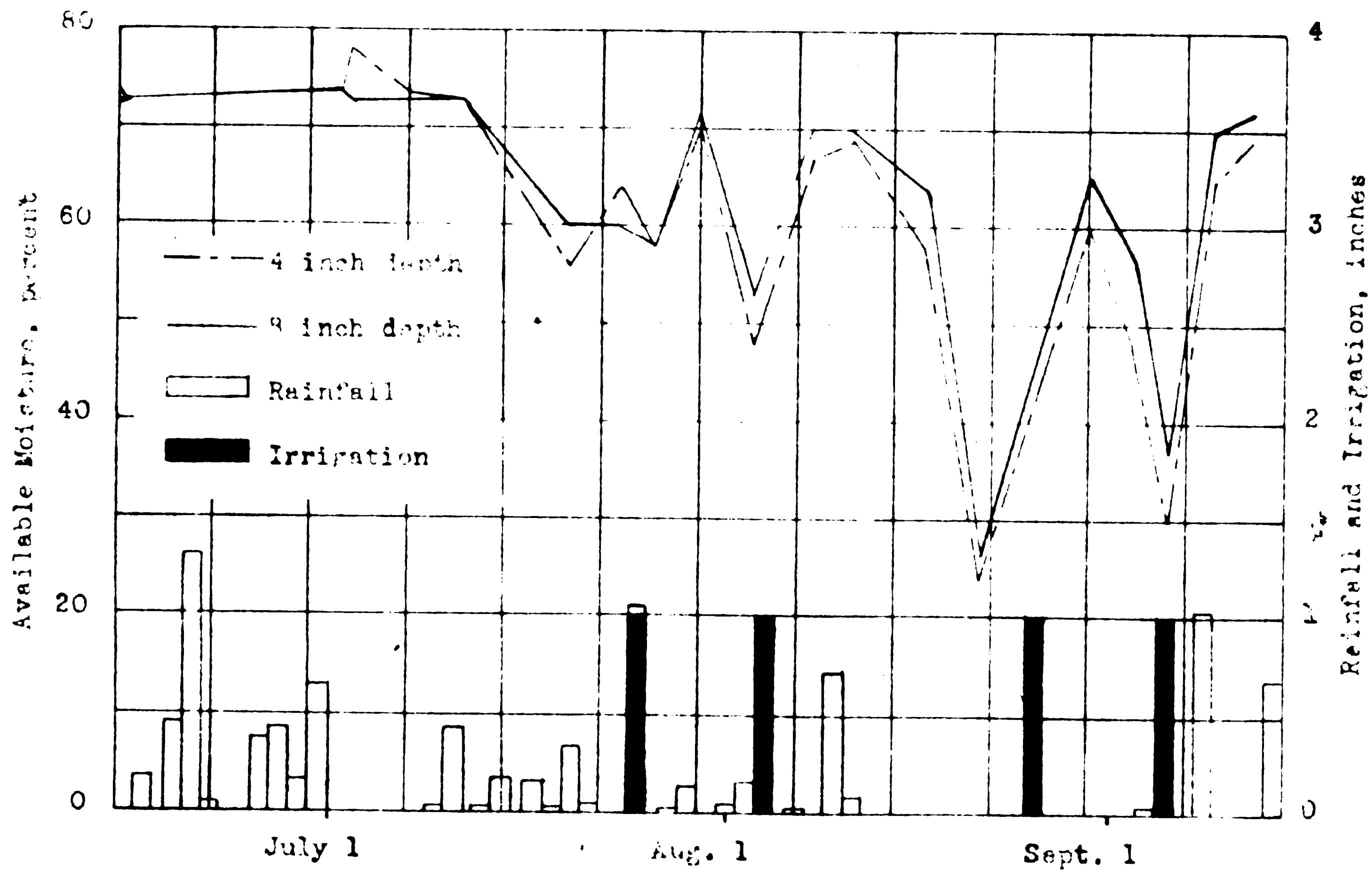

Figure 14. Available Moisture in Tomatoes Irrigated "by Blocks Plus Critical Time"

Comparison of the soil moisture data of the two irrigation treatments will reveal very little difference in the available moisture. They both received the same amount of irrigation water (four inches). However, the treatment with the application at the "critical time" received the first irrigation three days sooner than the other treatment. The moisture content of the soil in those plots must have been high enough that an addition of one inch of water reduced the yield rather than produced an increase. The "by block" treatment was permitted to become quite low in available moisture before applying the irrigation water. Apparently the conditions were more favorable for maximum tomato yields at the lower range of available moisture supply.

Sweet corn. The sweet corn was seriously damaged during the drought periods from July 22 to August 10 and August 11 to September 9 (Figure 15). Only the one rain of 0.71 inch on August 10 broke a continuous drought of seven weeks. This droughty condition shows clearly on the soil moisture record for the unirrigated plots.

Both irrigated treatments received the same amount of water during the season. The time of application did differ, however. The "critical time" treatment did not receive water soon enough during the first drought period to prevent permanent damage due to wilting (Figures 16 and 17). On August 22 the available moisture in these plots again became too low. As a result, the crop receiving the "critical time" treatment yielded 92 per cent less marketable ears, 48 per cent less

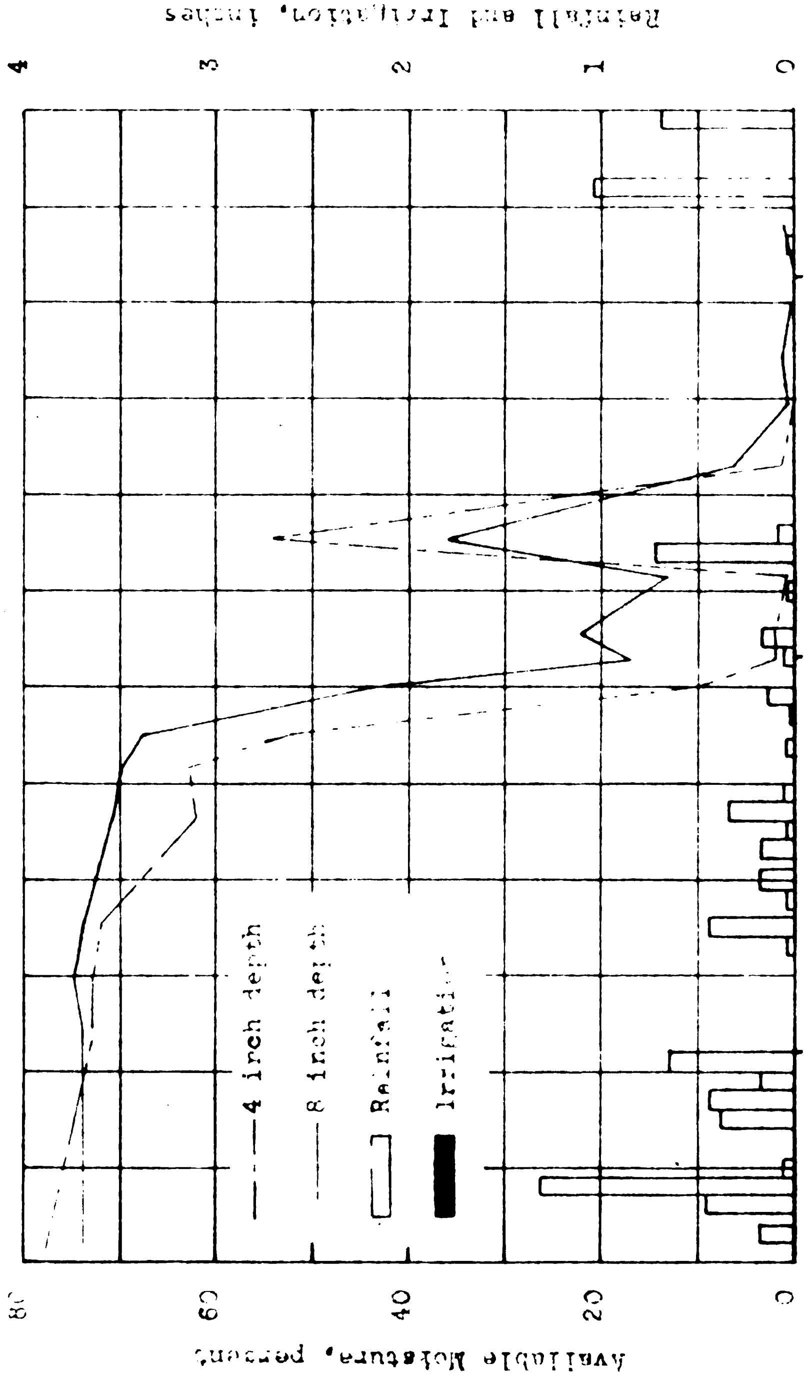

Figure 15. Available Moisture in Unirrigated Sweet Corn

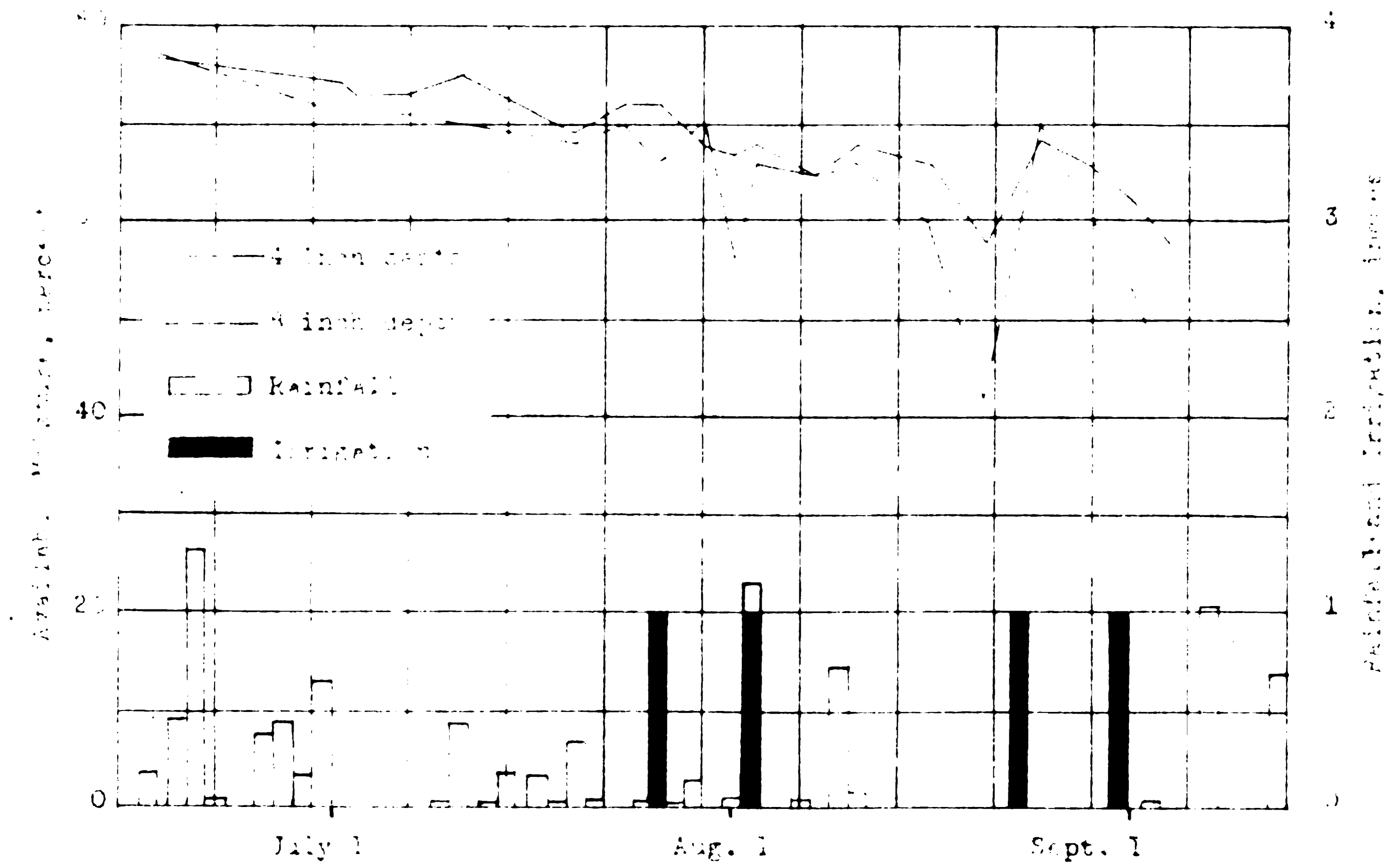

Figure 16. Available Moisture in Sweet Corn Irrigated "by Blocks"

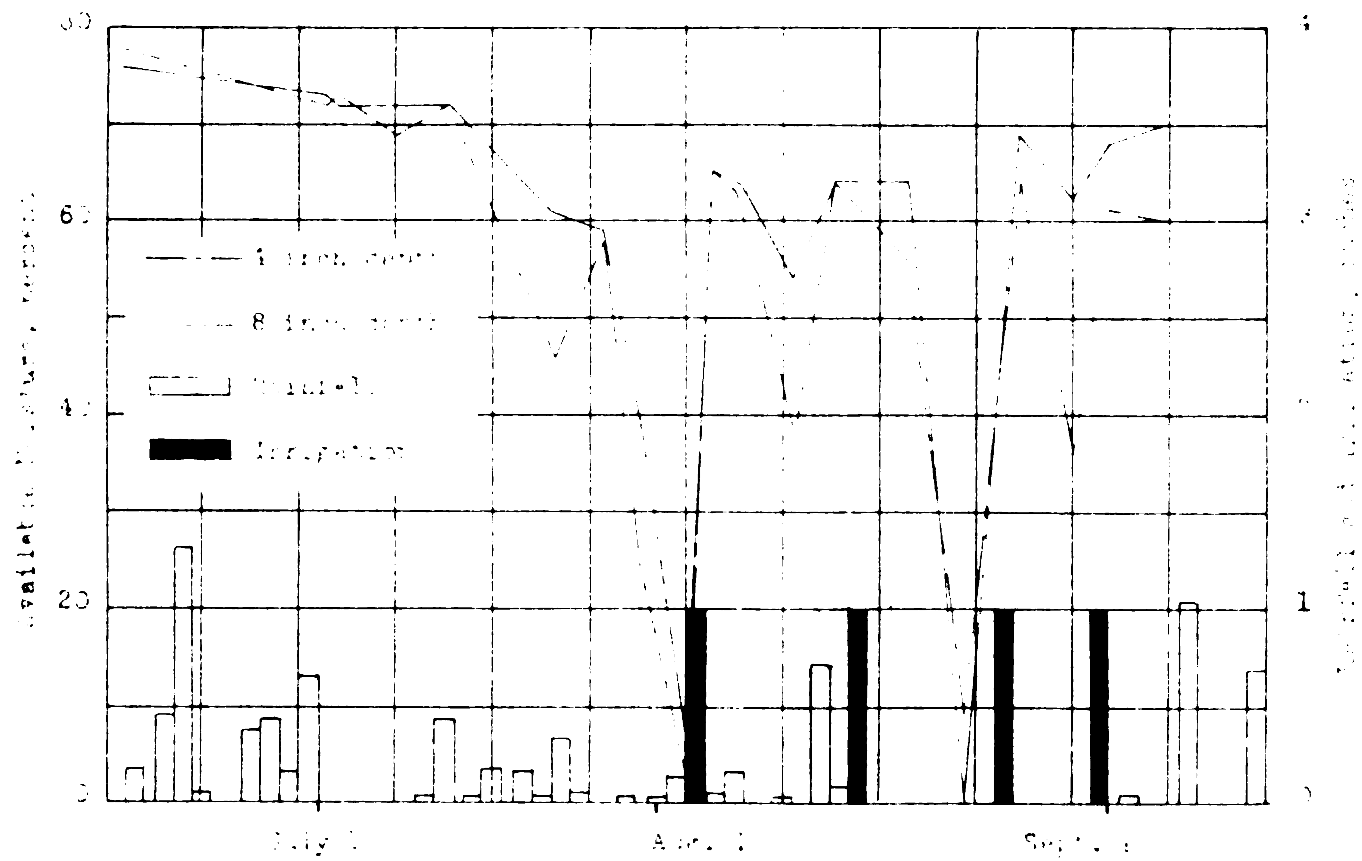

Figure 17. Available Moisture in Sweet Corn Irrigated "by Blocks Plus Critical Time"

total weight, and showed 8 per cent less weight per ear than the "by block" treated crop.

Both of the irrigated crops yielded a profitable increase over the unirrigated (over 300 per cent more marketable ears). They also yielded ears that were at least 40 per cent heavier than the unirrigated.

Statistically, the number of marketable ears produced by the crop irrigated by the "by block" method was greater than either of the other treatments. Corn irrigated "by blocks plus critical time" yielded more than the unirrigated -- all at the one per cent level.

A summary of the results of the statistical analysis is shown in Table 3.

Nutrient Supply

Water acts as the medium by which all nutrients are taken into the plant. It follows, then, that the nutrient materials must be in a soluble condition to become available to the plant roots. Being soluble the nutrients may be leached down to a depth where they cannot be effectively utilized after irrigation water is applied. Exploratory data were obtained on the amount of soluble nutrients in unirrigated and irrigated areas.

When applying irrigation water in the humid region it is desirable to apply only enough water so that the soil moisture is brought up to field capacity to the depth of the principal feeding roots of the plant. Over-irrigation is not only an unnecessary expense but may leach out the soluble nutrients. In this experiment these recommended practices were carried out. Therefore, excessive leaching should not have occurred.

<u>Procedure</u>

The field used for this part of the experiment had been in alfalfa the two previous years. The corn was planted about June 1 and 200 pounds per acre of 2-12-6 fertilizer applied in the conventional manner. On June 30 an additional application of 370 pounds per acre of 2-12-6 was made.

Three different treatments were set up on soil conditions as nearly alike as possible. The unirrigated plot was large enough and so located that the fine spray from the irrigations would not drift to the unwatered areas. Most of the field was irrigated and received an additional application of fertilizer through the water. A portion of the irrigated field was not treated with the fertilizer applied through the irrigation water.

On July 28 the corn received the first irrigation. Three-fourths of an inch of water was applied and 100 pounds per acre of ammonium sulfate was drawn through the irrigation water. One-half pound of fertilizer per gallon of water was mixed in a 55 gallon drum and picked up by the suction line of the pump. This set up is illustrated in Figure 18.

A second irrigation of one and one-half inches was made on August 3. Applications of water were made on the basis of gypsum moisture block readings. The time of irrigation happened to occur at the time of tasseling and silking of the corn plant.

Examination of the moisture record indicates that a third irrigation should have been made about August 17.

Figure 18. Applying Fertilizer through Irrigation Water

<u>Yield results</u>

All plots began with a uniform stand. By the end of July the unirrigated corn showed signs of moisture deficiency. At the end of the season the irrigated corn retained its vigorous appearance. The unirrigated corn was badly damaged by lack of moisture. The plants were shorter and had smaller ears than the irrigated corn.

Although the per cent of available moisture in the soil became quite low in the latter part of the season, irrigation

increased the yields 65 per cent. Application of nitrates with the irrigation water produced yields 98 per cent better than the unirrigated area and 19 per cent better than irrigation without nitrates. Comparative data for the three treatments are given in Table 5. Figure 19 shows the effect of two irrigations on field corn.

Table 5

Yield Comparisons

	Unirrigated	Irrigated	Irrigated plus Nitrates
Water added at tasseling	0	¾"	¾"
Water added at silking	0	1½"	1½"
Number ears per plot	250	409	422
Total weight per plot, lbs. (14% moisture)	68.2	113	134.5
Av. wt. per ear, lb.	0.27	0.28	0.32
Bushels per acre	32.9	54.3	65
Per cent increase	--	65	98

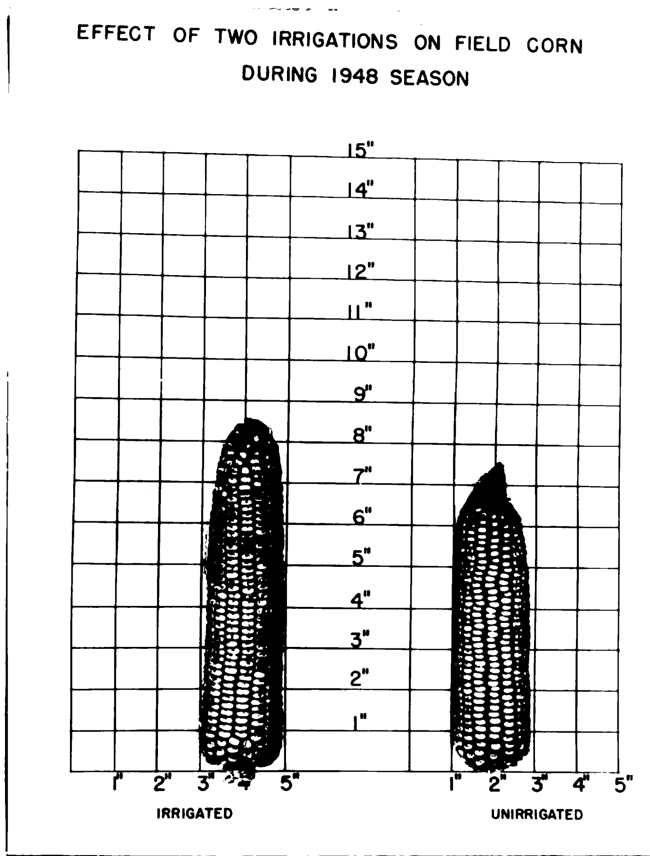

Figure 19. Effect of Two Irrigations on Field Corn

__Availability of nutrients__

__Field corn__. Composite soil samples from the three treatment areas were taken to a depth of eight inches. The soil contained enough nitrates for good plant growth all through the season. The plot receiving supplementary fertilizer through the irrigation water contained more nitrates than the other irrigated area. There was an inadequate supply of phosphates and potash in all field corn plots.

__Sweet corn__. Analyses were made of composite samples taken in sweet corn. This field had received a preplanting application of 800 pounds of 3-12-12 fertilizer. A side dressing at the rate of 100 pounds per acre of ammonium nitrate was made about July 1.

A month after the corn was planted all plots contained an adequate supply of nitrates and potash. Later in the season the amount of these two nutrients in the irrigated plots fell below the optimum most desirable for good plant growth. There was an insufficient quantity of phosphates in all plots.

Data on the amount of nutrients found in the various areas are shown in Table 6.

RECOMMENDATIONS FOR FURTHER WORK

The author has a number of recommendations for further work in supplementary irrigation.

Improvement of Experimental Procedure

The recommended practice for irrigation in this area is to apply only enough water to resupply the region in which the majority of plant roots thrive. This practice not only avoids the expense of over-irrigation but also prevents excessive leaching of plant nutrients. Insufficient data are available to indicate how deep different plant roots will penetrate in varying soil conditions in Michigan.

On the plots on which this experiment was performed, irrigation water was applied at the rate of one inch per hour.

Table 6

Nutrient Supply in Corn

Plot	Total Water Applied, Inches	Parts per Million in Soil (Reserve Extract)		
		NO_3	P	K
July 3, 1948				
Field corn, unirrigated		25	4	46
Field corn, irrigated		25	4	15
Field corn, irrigated (Nitrates)		10	4	12
Sweet corn, unirrigated		25	16	62
Sweet corn, irrigated "by block"		25	21	95
Sweet corn, irrigated 1½ inches per week	1½	25	18	60
July 28, 1948				
Field corn, unirrigated		25	2	30
Field corn, irrigated	¾	20	3	20
Field corn, irrigated (Nitrates)	¾	35	3	15
Sweet corn, unirrigated		35	13	54
Sweet corn, irrigated "by block"	1	12	15	68
Sweet corn, irrigated 1½ inches per week	7	7	11	36
August 18, 1948				
Field corn, unirrigated		25	4	20
Field corn, irrigated	2¼	15	4	12
Field corn, irrigated (Nitrates)	2¼	25	5	13
Sweet corn, unirrigated		30	18	48
Sweet corn, irrigated "by block"	2	9	14	35
Sweet corn, irrigated 1½ inches per week	11½	10	9	32

In many cases puddling and runoff were observed. To prevent any further occurrence of this the rate of application should be reduced to at least three-fourths of an inch per hour.

The attempt to apply water when the available moisture in the soil fell below 50 per cent was not always successful. Gypsum block readings were not taken at frequent enough intervals to prevent some drought damage. Blocks were available for only two of the three replications. On several occasions one of the replications showed a deficiency of moisture and the other contained enough available moisture for good plant growth. An application of water at this time benefited the dry plot but supplied more water than necessary on the other. Sufficient blocks should be obtained so that frequent readings may be taken and the proper level of moisture maintained on each replication.

The application of water at the critical time in the growth of the plant should be discontinued. This treatment did not show a significant increase in yield over the application of water "by blocks" for any crop. The additional application of water at this time was not needed and usually resulted in a decreased yield.

An additional irrigation practice should be tested. Some of the plants may produce maximum yields when the available moisture supply is above 50 per cent and others may thrive with less than 50 per cent available moisture. The "by block" treatment should be modified so that two ranges of available soil moisture may be maintained -- one between 50 and 70 per cent and the other between 30 and 50 per cent. This should provide valuable information concerning the amount of available moisture that crops require for maximum yields.

Soil Compaction

There is some doubt as to the extent to which the application of irrigation water to the soil will compact the surface or succeeding layers. If irrigation does compact the soil thereby reducing aeration any benefits derived from irrigation will be offset by reduced yields caused by poor soil structure. Additional work should be done to determine the amount of compaction caused by irrigation at different precipitation rates.

Nutrient Supply

The information obtained on the availability of nutrients on soils receiving different irrigation treatments was of an exploratory nature. If the amount of water applied is just enough to increase the moisture supply in the root zone leaching should be avoided. However, the increased moisture supply will produce greater foliage and fruit set thereby creating a demand for greater amounts of nutrients. Some of these nutrients may be applied with the irrigation water. Further study of the availability of nutrients applied as a side dressing or with the water should be made. This study will give information concerning the amount and time of additional applications of fertilizers necessary for optimum growth.

Statistical Analysis

A statistical analysis of research data of this kind is highly desirable. However, it is quite difficult for research personnel to become intimately acquainted with all the possible experimental designs, the requirements for their use, and the mechanics of their analysis. The time consumed by members of a research organization in making an analysis should be spent writing the report of the findings and planning further experimentation.

An advisory group should be established to perform the following duties:

1. Consult with the research scientist and recommend an experimental design for the problem at hand.
2. Help plan the type of data to be gathered and the methods of obtaining such data.
3. State the requirements necessary for tabulating the data to obtain complete information and for easier computation in the subsequent analysis.
4. Have equipment and statisticians to perform the required analysis and report the results of this analysis to the research organization.

It is further desirable that research personnel be sufficiently familiar with statistical methods that consultation with the advisory group can be had at the proper level.

SUMMARY

A study of the precipitation record at Lansing, Michigan, shows that every year an average of 7½ weeks of drought can be expected during the period of May 15 to September 15. Supplementary irrigation is required to prevent drought damage to crops. In 1948 studies were made on a sandy loam soil to determine the effect of irrigation water on (1) crop yields, (2) changes in the availability of soil moisture in the root zone and (3) nutrient supply.

The following information was obtained:

1. Yields of snap beans were increased 45 per cent in irrigated plots.
2. Tomato yields were increased 60 per cent in irrigated plots.
3. Irrigated sweet corn yielded four times as many marketable ears as the unirrigated.
4. Application of water when the available moisture was less than 50 per cent resulted in greatest increases per inch of applied water. The available soil moisture was determined by measuring the intensity of an electric current passed through gypsum blocks buried in the soil.
5. The plots that produced the highest yields

of tomatoes and sweet corn received water when the available soil moisture was less than 50 per cent.

6. Irrigated corn plots contained a lower supply of plant nutrients than the unirrigated. Nitrates added with irrigation water at time of tasseling produced a 19 per cent greater yield than the irrigated area not receiving additional fertilizer.

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