TIME OF APPLICATION AND RATE OF DEPLETION OF SPRINKLER IRRIGATION WATER FOR SELECTED CROPS

by

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Thesis

Submitted to the Graduate Faculty of the

Virginia Polytechnic Institute

in candidacy for the degree of

MASTER OF SCIENCE

in

Agricultural Engineering

Approved:

Director of Graduate Studies

Dean of Engineering

Approved:

Supervisor or Major Professor

May, 1951

Blacksburg, Virginia

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ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to all those who have contributed to the fulfillment of this study.

Special recognition is given to Mr. J. H. Lillard and Mr. T. W. Edminster of the Agricultural Engineering Department for suggesting the study, offering suggestions and continuous encouragement, and providing the necessary equipment and facilities.

The writer wishes to recognize Mr. J. E. Moody of the Agricultural Engineering Department for his suggestions and guidance in the laboratory phase of the study and Mr. J. N. Jones, Jr. for his cooperation in the field work.

The author is indebted to associate Professors S. H. Byrne and U. F. Earp of the Agricultural Engineering Department for their helpful criticisms and suggestions in preparing the outline and thesis, respectively.

INTRODUCTION

One of the perplexing problems of supplemental irrigation is the proper time to irrigate to produce maximum plant growth. Most water applications in the past have been made according to experience, arbitrary rules or guess work without the proper determination of soil moisture conditions and without the knowledge of the optimum moisture content of the soil at which to irrigate. For example, it is common practice in some areas to apply one inch of water per week to crops when the rainfall is less than that amount. When such a practice is followed there is danger of either over-irrigating or under-irrigating.

The water needs of the crop are of paramount importance in determining the time of irrigation. There are several indices of the need of water by plants during their active growing season. Those accepted and in common use are appearance of the crop, the permanent wilting point, stage of crop growth, and soil moisture tests. It is essential to maintain readily available water in the soil as long as it is desired to have plants make satisfactory growth. Crops should be irrigated before they show visual evidence of the need for water. Therefore, it is obvious to use soil moisture content of the soil as the basis for time of irrigation.

Readily available moisture is considered as that water held by soil between the permanent wilting percentage and the field capillary-water capacity. Hendrickson and Veihmeyer (11) state that water held by soil below the permanent wilting point is unavailable to plants at a rate sufficient to prevent a retardation of growth. Plants obtain some water from the soil below the permanent wilting percentage, but the rate at which they can obtain it is not sufficient to enable the plant to remain turgid. Wilting under field conditions probably occurs within a certain restricted zone or range of moisture content rather than a precise moisture percentage for a given soil. Knowledge of what is the upper limit of the wilting zone for a particular soil is of practical importance.

At what soil moisture content above the wilting point then is the moisture percentage at which plants make their maximum growth? Investigators believe that a point will be reached in most soils where an excessive amount of water forces out essential air and results in growth retardation from lack of oxygen for root respiration. As stated previously, Hendrickson and Veihmeyer have shown that plant growth is reduced at and below the permanent wilting point. It has been thought by Israelsen (13) that the maximum growth rate of plants occurs at rather definite moisture percentages between permanent wilting percentage and field capacity. Experimental data are available confirming and contradicting this belief.

Kiesselbach (14) in experiments with corn as early as 1916 found that the maximum yield of dry matter occurred with a percentage of available moisture of 70. Lewis (17) found that fruit of pear trees growing on heavy soil was reduced whenever the soil moisture in the major portion of the root zone was reduced below 70 percent of available capacity. Their work has later been confirmed by Work (28), Haynes (10), Schneider and Childers (21), Allyn and Work (1), and Cykler (5). Schneider and Childers concluded that, under favorable conditions of soil fertility and aeration, rates of growth of corn increase markedly with increasing soil moisture within the range from near permanent wilting percentage to near saturation of the soil. Other workers, Bartholomew (2), Furr and Degman (8), Furr and Magness (9), and Taylor and Furr (23), have concluded that different varieties of fruit trees suffer for lack of moisture before the soil moisture reaches the permanent wilting point.

On the contrary, studies of soil moisture and plant relations by other workers seem to warrant the belief that the growth rate of plants is not reduced by lack of available water as long as the soil moisture content is above the wilting zone. Veihmeyer and Hendrickson (25) have recently defined "readily available moisture" as the entire range of soil moisture between field capacity and permanent wilting and have recommended that orchards be irrigated just above the wilting percentage. Studies by Shull (22), Thomas (24), and Magistad and Breazeale (18) support the work of Veihmeyer and Hendrickson. Shull found that, at moisture contents above the wilting point, a large change in water content causes but a slight change in tension. At moisture contents below the wilting point, however, a slight change in the soil moisture very greatly changes the tension with which the water is held. Israelsen (13) also concludes that the growth rate, so far as it may be influenced by moisture content of the soil, does not change appreciably as the moisture content increases from the wilting point to field capacity.

Just where in the range of available moisture should irrigation water be applied is a question of vital importance. If different crops vary as to the time at which they should be irrigated to produce maximum growth, the irrigator should know. With a knowledge of the percentage of available moisture at which water should be applied for each crop, soil moisture determinations may be more useful as a guide in irrigation. More economical irrigation of present-irrigated crops may be realized and irrigation may become a profitable practice for other crops not irrigated now. A study was made during the 1950 growing season to determine the level of available moisture at which corn should be irrigated.

OBJECTIVES

This study was planned to meet the following objectives:

1. To determine the percentage of available moisture in the soil at which corn should be irrigated to produce maximum yields.

2. To determine the most economical level of available moisture at which corn should be irrigated.

3. To determine the rate of depletion of soil moisture by selected crops at different times during the growing season.

FACILITIES

The following equipment and facilities were made available by the Soil and Water Conservation Research Division, Virginia Agricultural Experiment Station:

1. Laboratory with Freas circulating-type oven and other equipment for making soil moisture determinations.

2. Bouyoucos Soil Moisture Meter, 150 plaster of paris electrical resistance blocks, 5 tensiometers, and 40 Slater gravimetric plugs.

3. One standard rain gage.

4. Tillage equipment

5. One 7½ hp electric motor

6. Size 2 Deming centrifugal water pump

7. Quick-coupling irrigation pipe, valves, pressure gages, risers, nozzles, and other miscellaneous items

8. Experimental plots on the Smithfield Farm, Virginia Agricultural Experiment Station

9. Water supply from Strubbles Creek

PROCEDURE

The field area used for the study is the same as that on which the continuous irrigation plot experiment was located in 1949. This area is on the Smithfield Farm, Virginia Agricultural Experiment Station. A layout of the plot area is shown in Figure 1.

The continuous irrigation experiment consists of 2 tiers (A and B) of irrigated and 2 tiers (D and E) of non-irrigated plots, giving 2 replications for each treatment. The annual crops are grouped and rotated within each group. The first group is burley tobacco, wheat, and clover; the second group is corn, wheat, and clover. The other crop, alfalfa, is not rotated.

Nine additional plots were located between the original irrigated and non-irrigated tiers, forming the tier C, in order to provide a sufficient number of plots for the study on corn. These plots, combined with the original corn plots, totaled 13. The corn experiment was designed for 4 treatments with 3 replications, leaving one extra plot. As a matter of interest, the author thinned this plot (C5) to note the effect of plants per acre on yield and quality. It was thinned to 8,000 stalks per acre, other plots having approximately 13,000 stalks, and was irrigated at 50 percent available moisture.

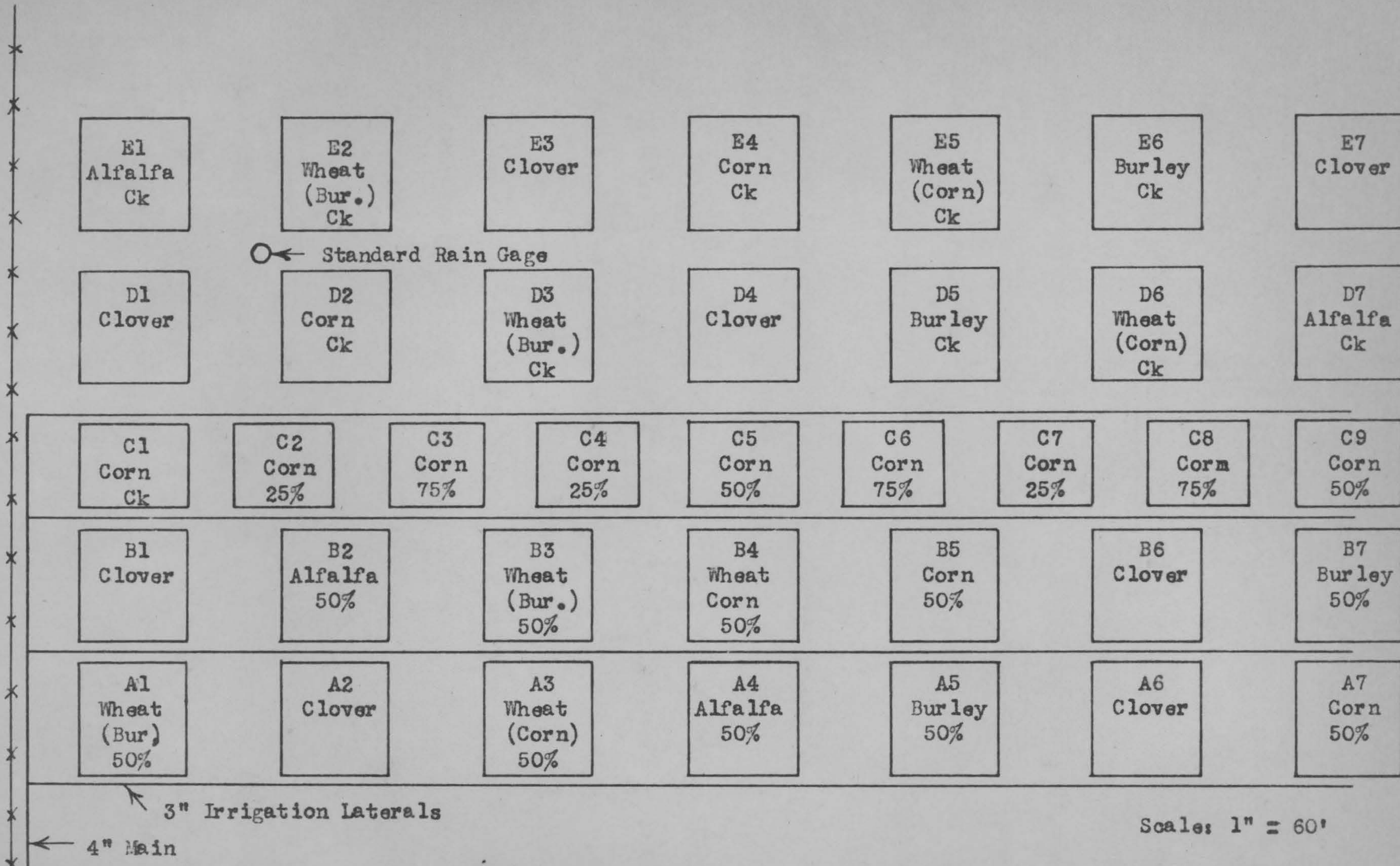

Fig. 1 - Irrigation Plot Experiment, 1950 Cropping Plan

As stated in the first objective, it was desired to determine the level of available moisture at which corn should be irrigated. One of the 4 treatments being non-irrigated, the other 3 treatments were arbitrarily divided into percentages of available moisture at which water should be applied, namely 25, 50, and 75. Replications were randomized except for the corn plots in the original irrigation experiment, which were randomized previously. It was decided to irrigate tiers A and B at 50 percent available moisture. The treatments are indicated for each plot in Figure 1.

Water applications were made with a system consisting of quick-coupling, 4-inch main, 3-inch laterals, 1-inch risers, 3 feet high, and part-circle sprinkler nozzles. Plots in tiers A and B were 40 by 45 feet and required 3/16 inch nozzles while plots in tier C were 35 by 40 feet and required 1/8 inch nozzles. Part-circle sprinklers were necessary due to the close spacing and individual plot control of tiers B, C, and D.

The rate of application was approximately 0.3 inch per hour which was well below the percolation rate (see appendix). The 7½ horsepower electric motor operated against a total head of approximately 160 feet. The nozzle pressure was 40 psi, while the pump pressure was 60 psi. Considerable difficulty was encountered due to high wind velocities. This difficulty was partially eliminated by making some applications during early morning or late afternoon when the wind velocity was usually lower.

The amount of water to be applied at each irrigation, expressed in inches depth, was calculated from values of volume weight, permanent wilting point, and field capacity. The amounts of water received by the individual plots from natural precipitation and artificial applications are given in Table 1. It is noted that plot C7 received no irrigation water since the available soil moisture did not reach 25 per cent. The dates in the table indicate only the period during which data were taken.

The plot area is composed of several soil types: Greendale silt loam, Needmore silt loam, and Litz silt loam. Volume weight determinations were made from samples taken within the plot areas after the soil was plowed. The volume weights given in the appendix are somewhat higher since the core samples were taken in between-plot areas. An average of 86 samples, taken at the depth range of 4 to 7 inches, yielded a value of 1.38.

The permanent wilting point used represented the moisture content of a composite sample of soil, taken from 4 to 7 inches below the surface, when the electrical resistance of a plaster of paris block was 100,000 ohms. This value,

TABLE 1.

Amounts of Water Received by Irrigated Crops During Their Respective Growing Seasons

Crop	Plot	Treatment*	No. of times Irrigated	Total Irrigation water (in.)	Precipitation (in.)	Total water (in.)	Inclusive Dates
Wheat	A1	50%	2	2.4	7.8	10.2	Apr.1-Je.1
"	A3	50%	2	2.4	7.8	10.2	"
"	B3	50%	2	2.4	7.8	10.2	"
"	B4	50%	2	2.4	7.8	10.2	"
Alfalfa	A4	50%	5	6.0	22.2	28.2	Apr.1-Sept.15
"	B2	50%	5	6.0	22.2	28.2	"
Burley	A5	50%	3	3.6	13.8	17.4	Je.10-Sept.15
"	B7	50%	2	2.4	13.8	16.2	"
Corn	A7	50%	1	1.2	17.6	18.8	May 9-Sept.1
"	B5	50%	3	2.6	17.6	20.2	"
"	C2	25%	1	1.8	17.6	19.4	"
"	C3	75%	7	3.4	17.6	21.0	"
"	C4	25%	1	1.8	17.6	19.4	"
"	C5	50%	3	3.6	17.6	21.2	"
"	C6	75%	8	4.5	17.6	22.1	"
"	C7	25%	0	0.0	17.6	17.6	"
"	C8	75%	7	3.9	17.6	21.5	"
"	C9	50%	2	1.4	17.6	19.0	"

*Treatment refers to the percentage of available moisture that was maintained.

10.55 percent, was determined by Dr. G. J. Bouyoucos.*

Field capacity (25.7 percent) was determined from soil samples taken 24 hours after a saturating rain as suggested by Thorne and Peterson (25). This has been the generally accepted method for field determination for many years. Recently, however, contradictory evidence was presented by Veihmeyer and Hendrickson (27) in which they stated that from 2 to 3 days are required for some soils to drain to field capacity after a saturating rain. It is conceived that the value used in this study may be too high, but it was found that approximately 8 days (May 15-23) were required under wheat cover for the moisture content to reach moisture equivalent. Certainly moisture during this period was available. Unfortunately, it is difficult to obtain a perfect determination for the single-valued field capacity. Since 25.7 percent was the value used in the first part of the experiment it was used throughout to avoid a reduction in the value of the results.

From the values of field capacity, volume weight, and permanent wilting point it was determined that approximately 0.6 inch of water was required to increase the available moisture 25 percent in the top foot of soil.

To determine quickly the soil moisture content at any time during the growing season it was desirable to use soil

*Letter from Dr. G. J. Bouyoucos, Michigan State College June 20, 1950 moisture measuring instruments. An attempt was made to calibrate gravimetric plugs, tensiometers, and Bouyoucos electrical resistance blocks with soil moisture content. These instruments were placed at the 6-inch depth. Soil samples were taken within a radius of one foot around each instrument with a King tube at each reading and oven-dried to determine the moisture content.

The only instruments found to be reliable were tensiometers. When individually calibrated, they gave good results in the plots irrigated at 75 percent available moisture. Oven-dried soil samples served to indicate the proper time to irrigate all other plots and to check the tensiometers. Moisture conditions were followed throughout the growing period of each crop except clover, which was not followed because of poor stands. The moisture content at the 6-inch depth was used as indicative of the average for the first foot of soil.

The soil was prepared for planting by turning with a moldboard plow 6 to 7 inches, disking with a tandem disk harrow to pulverize the sod, and loosening with a field cultivator just before planting.

Hybrid corn, Illinois 200, was planted approximately 11 inches apart on May 9 with a row spacing of 42 inches. An initial fertilizer application, 500 pounds of 4-12-4, was made at planting. The plots were chopped June 2 and the three cultivations were June 3, June 28, and July 4. A top dressing, 500 pounds of 16-0-0, was applied during the second cultivation when the corn was 3½ to 4 feet tall.

Three yield samples were taken per plot on September 28. Each sample consisted of 2 rows, the length of each row being 14.67 feet. The corn was dried in a drier which was designed especially for the purpose of processing corn samples. The corn was shelled October 3 and 4 and weighed as sound or defective. The sound weights were used in the analysis of variance to test for significance among treatment means.

Moisture conditions for the other crops were followed just as for corn. Data from these plots were used to determine the rate of depletion of soil moisture at different stages of growth. Wheat samples for yield data were taken June 28. The last irrigation of plot A1 on May 25 caused a considerable portion of the wheat to lodge.

The alfalfa was cut and sampled June 14, July 28 and September 6. The growth of alfalfa was affected by the presence of foreign plants. Plot E1 competed with highland cress (Barbares vulgaris) during the early part of the season. Plot A4 was heavily infested with quack grass (Agropyron repens), plot B2 containing a lesser amount. The green weights were recorded during sampling and moisture samples were taken to determine the dry weights of alfalfa.

The burley tobacco was handled by the plant pathology department at Virginia Polytechnic Institute except for land preparation and irrigation. The plants were transplanted 12 inches apart on June 9 and 10. Two varieties, Kentucky 16 and Virginia 111 were used in each plot, one-half of each plot being used for each variety. The crop was harvested September 19-22, inclusive.

Records of the soil moisture content of each plot were kept throughout the growth period of each crop. Precipitation data were taken from an automatically recording rain gage located in the area (see Fig. 1). A soil thermograph was obtained and installed July 16 to record continuously the soil temperature which was previously taken once each day.

From the moisture records curves were drawn showing fluctuations in soil moisture throughout the season for representative plots (Figures 2-11). The amount of natural precipitation by date and the amount of irrigation water applied are shown in each figure. The inadequacy of definitely accurate soil moisture percentages is the reason for designating the curves as estimates of the soil moisture conditions. The frequency of rains was proportional to the time interval between soil moisture determinations; therefore, the rates of depletion were more reliable when determined during periods of less frequent rains.

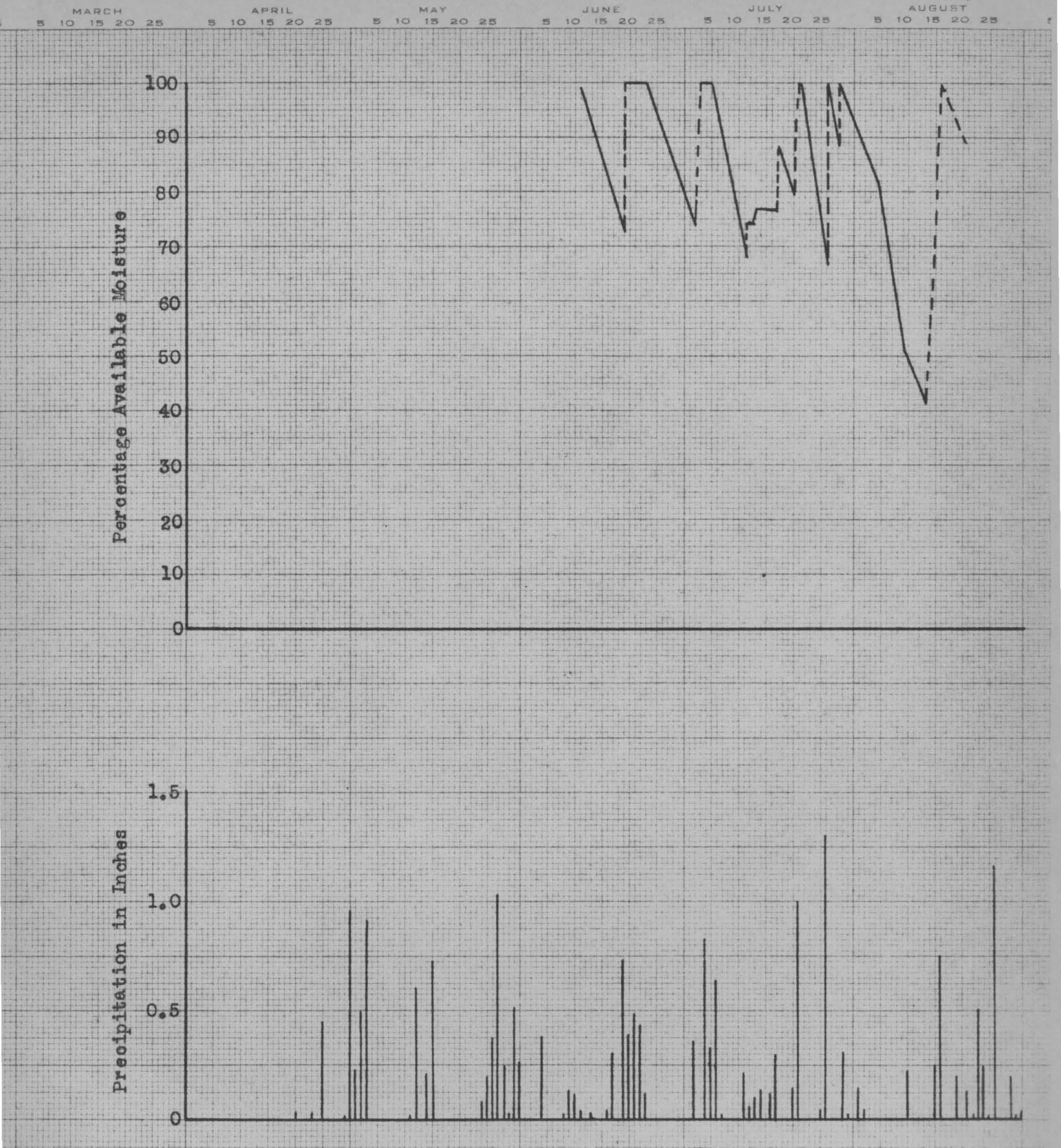

Fig. 2 - Estimated Soil Moisture Fluctuations and Water Received by Corn Plot D2 (Ck) During Major Portion of Growing Season

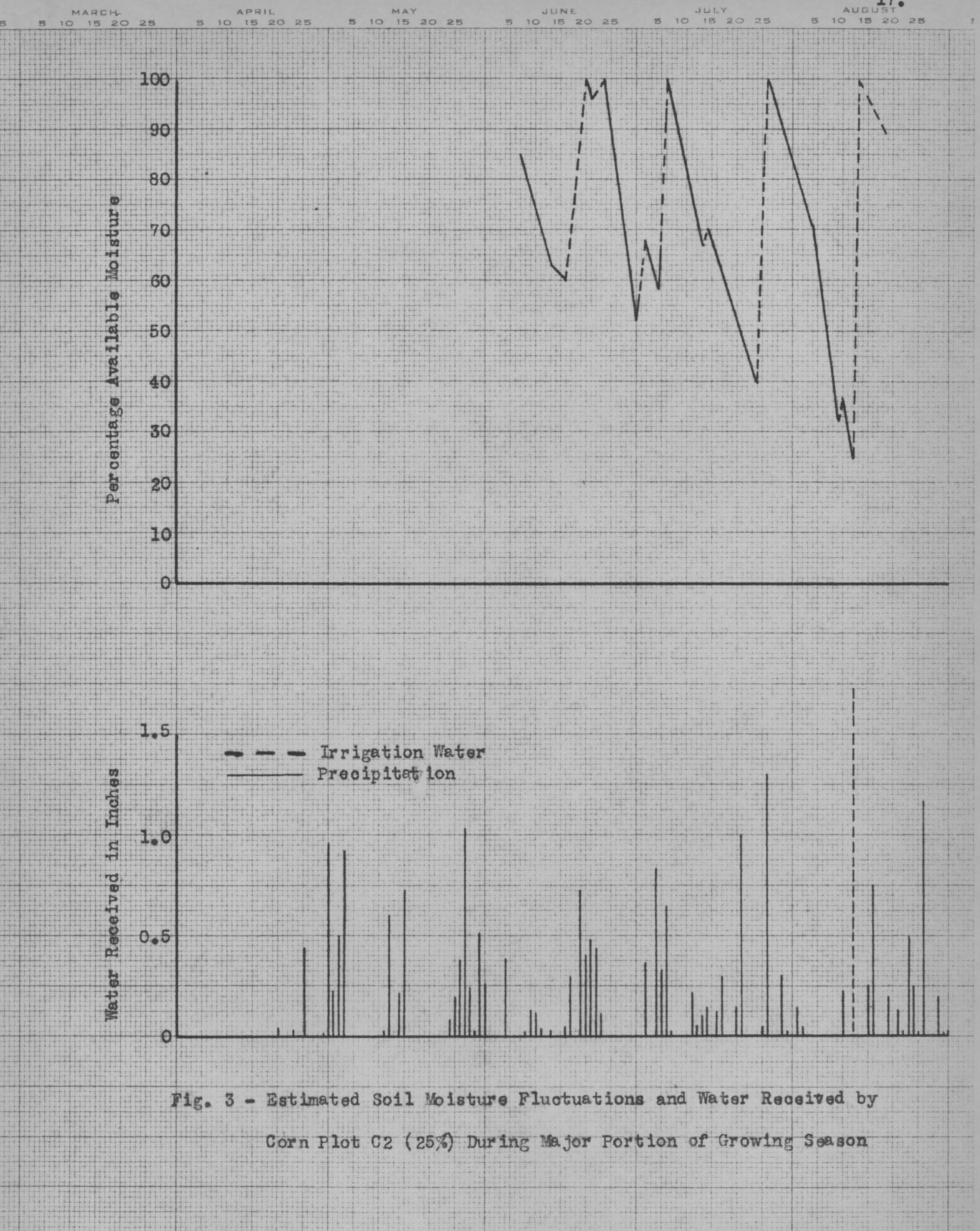

Fig. 3 - Estimated Soil Moisture Fluctuations and Water Received by Corn Plot C2 (25%) During Major Portion of Growing Season

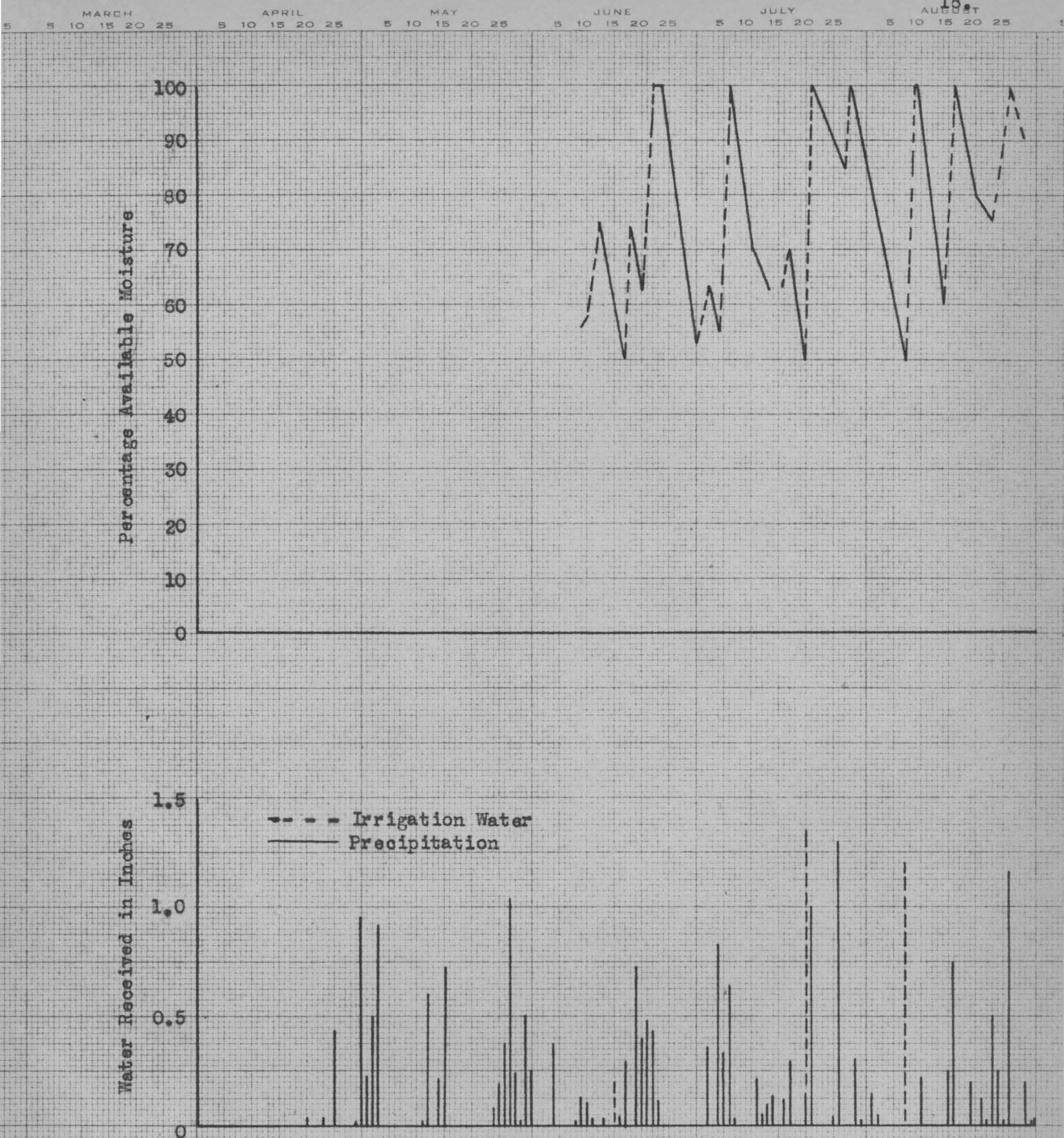

Fig. 4 - Estimated Soil Moisture Fluctuations and Water Received by Corn Plot B5 (50%) During Major Portion of Growing Season

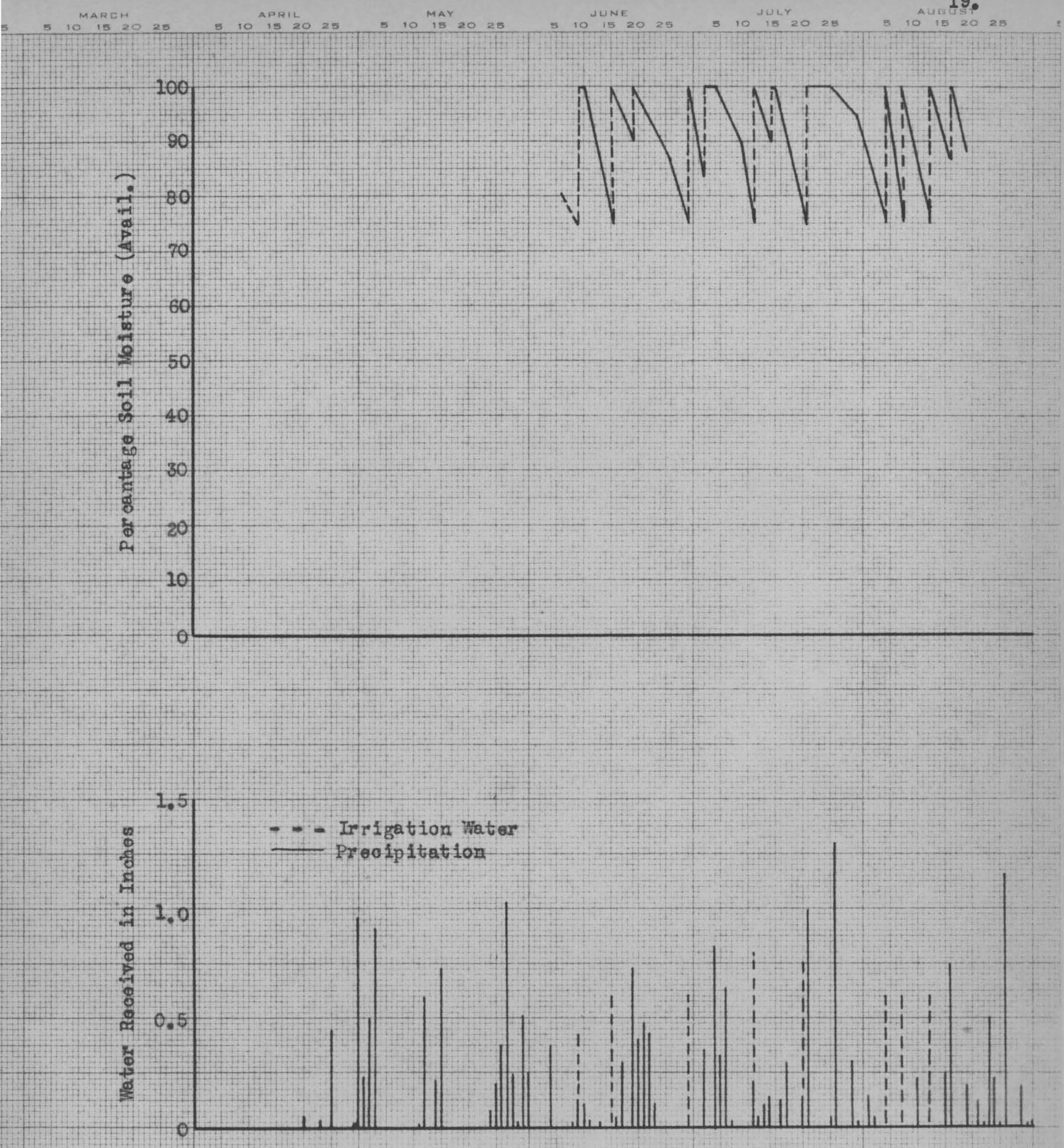

Fig. 5 - Estimated Soil Moisture Fluctuations and Water Received by Corn Plot C6 (75%) During Major Portion of Growing Season

5 10 15 20 25 MARCH 5 10 15 20 25 APRIL 5 10 15 20 25 MAY 5 10 15 20 25 JUNE 5 10 15 20 25 JULY 5 10 15 20 25 AUGUST

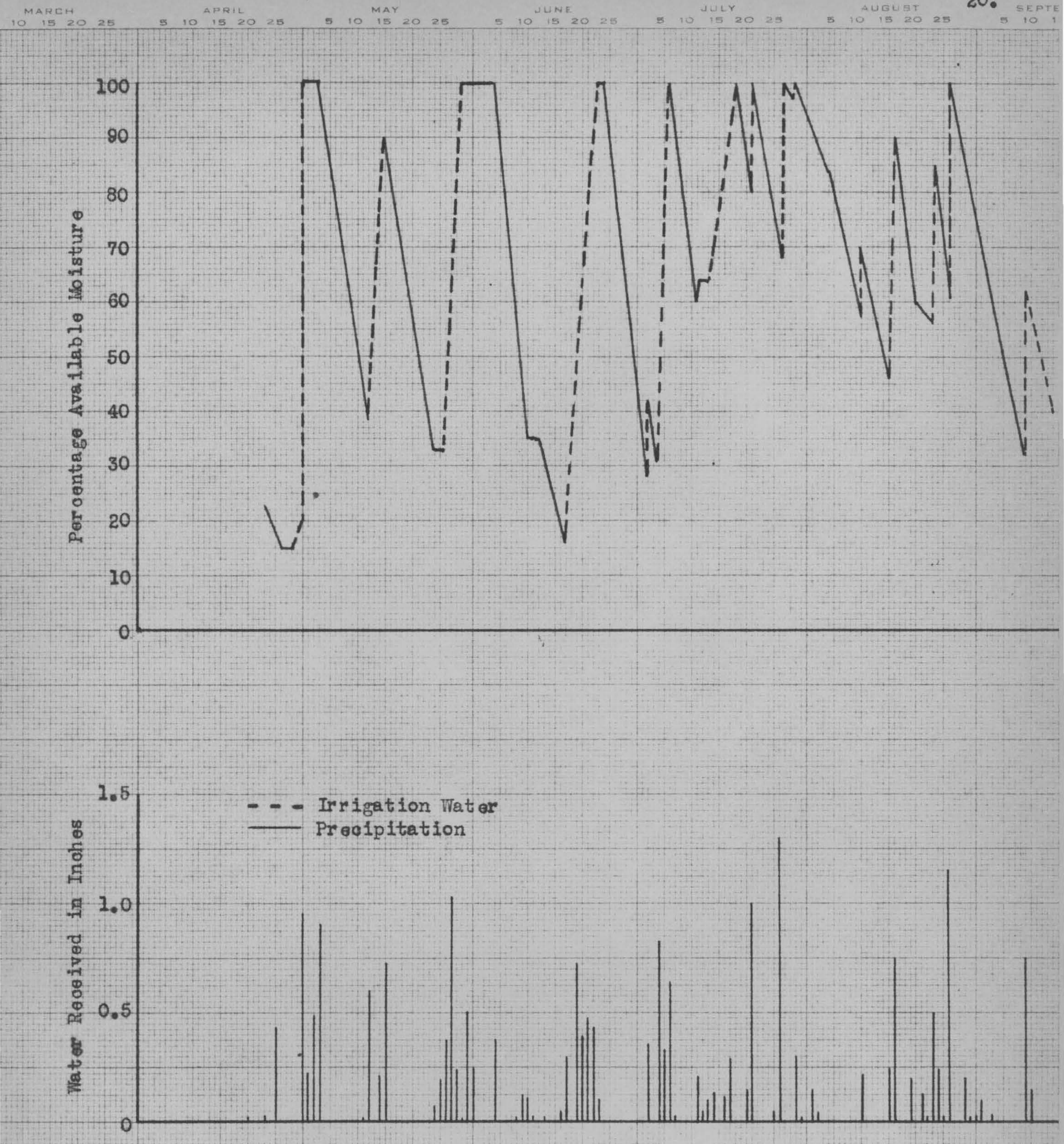

Fig. 6 - Estimated Soil Moisture Fluctuations and Water Received by Alfalfa Plot D7 (Ck) During Major Portion of Growing Season

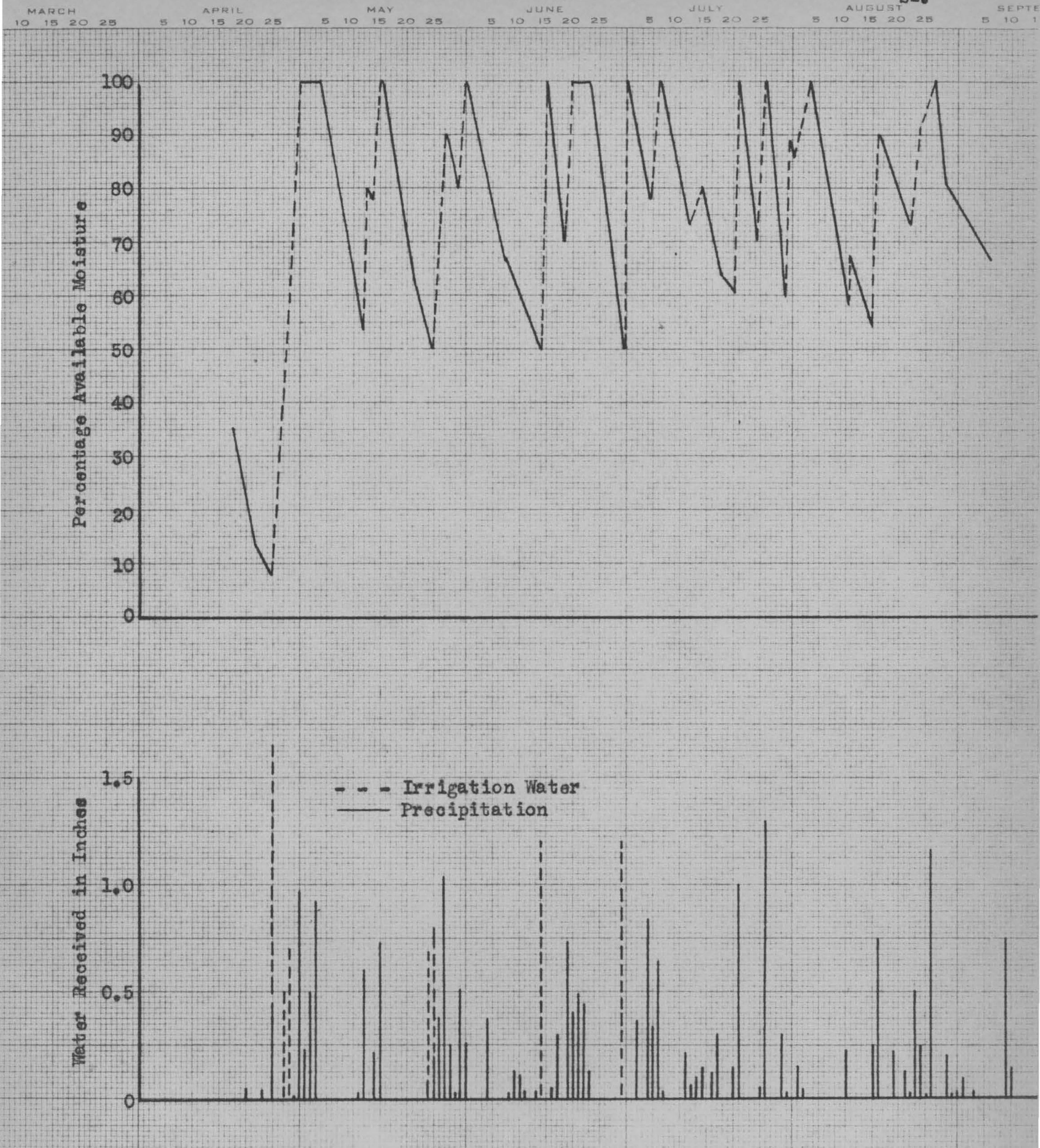

Fig. 7 - Estimated Soil Moisture Fluctuations and Water Received by Alfalfa Plot B2 (50%) During Major Portion of Growing Season

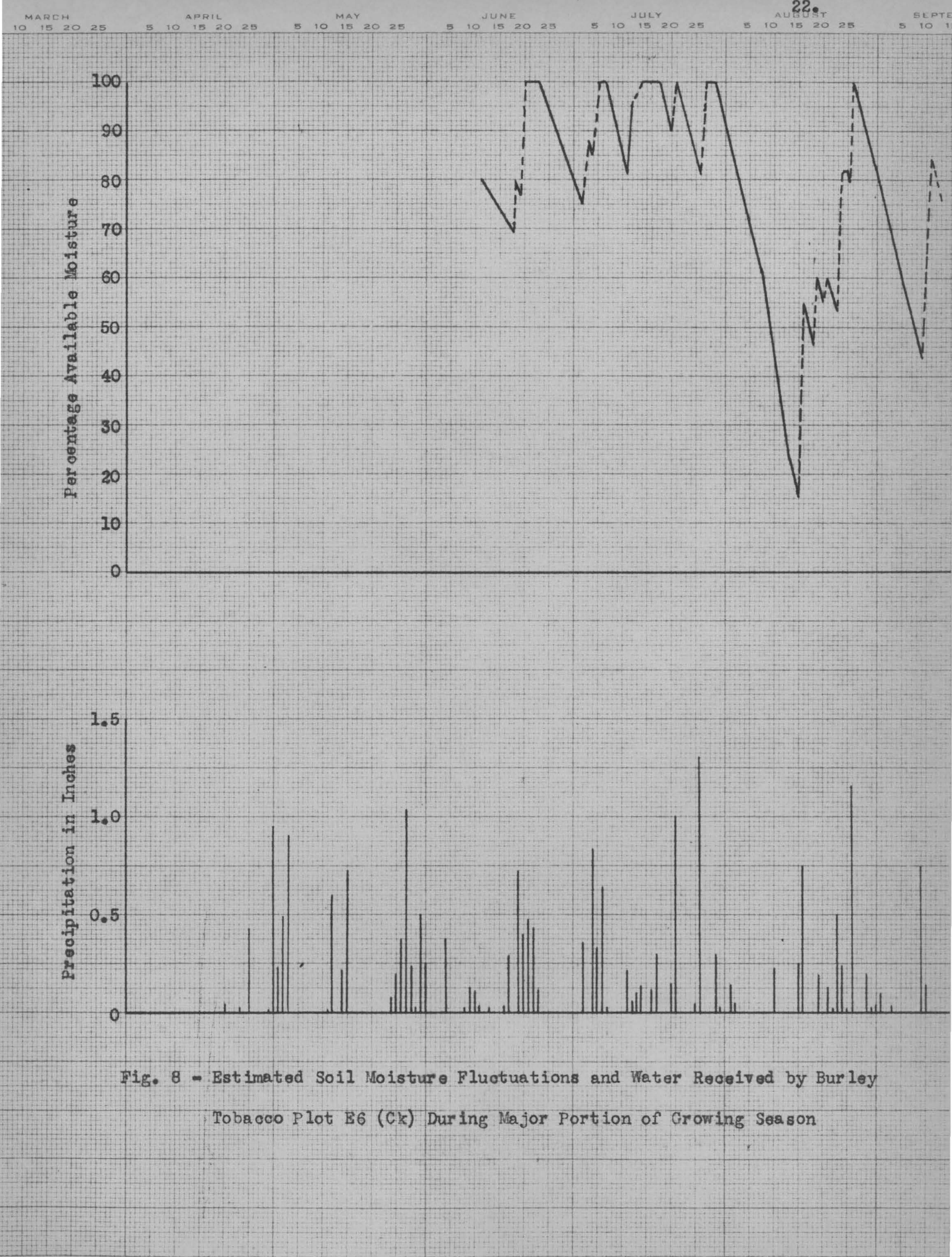

Fig. 8 - Estimated Soil Moisture Fluctuations and Water Received by Burley Tobacco Plot E6 (Ck) During Major Portion of Growing Season

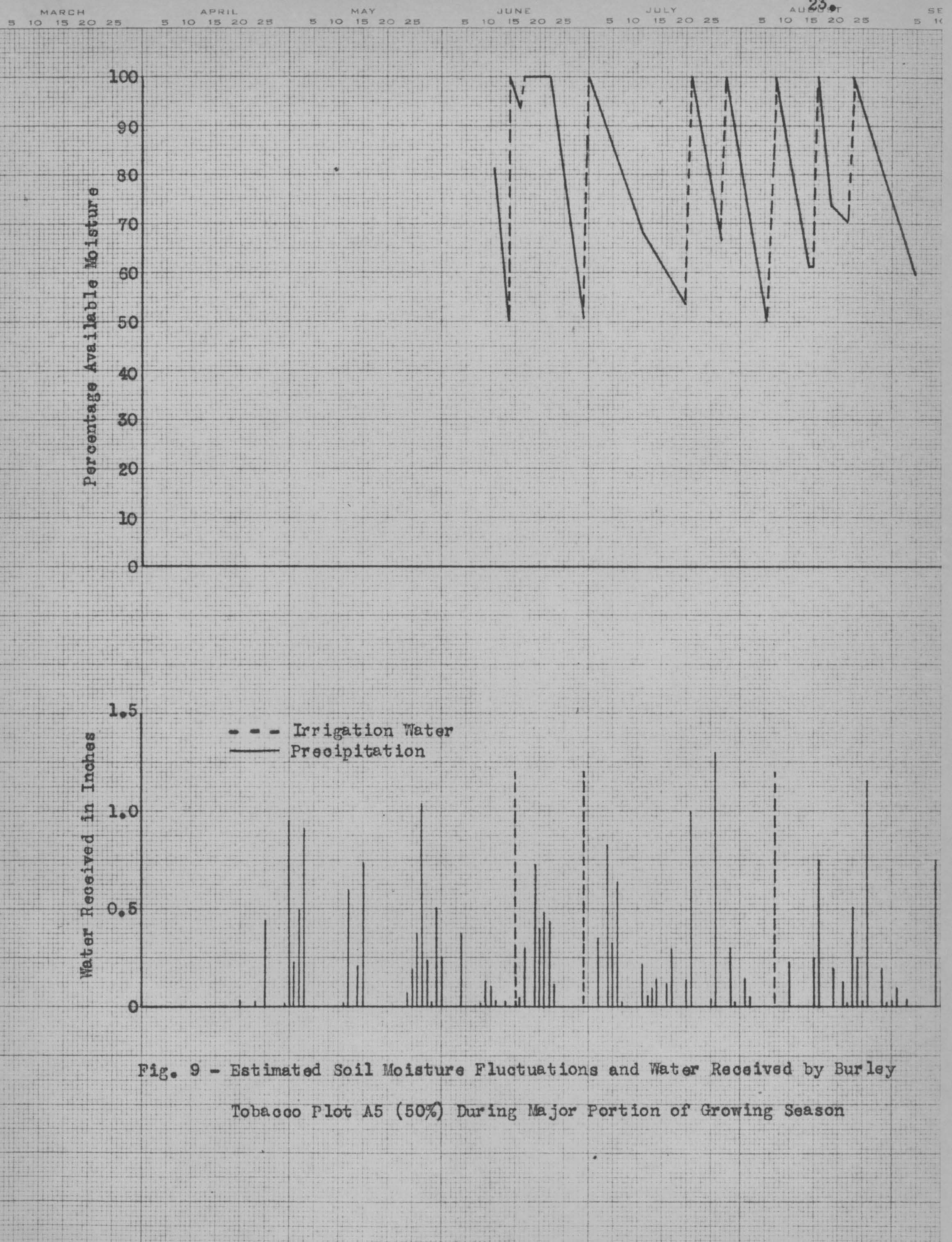

Fig. 9 - Estimated Soil Moisture Fluctuations and Water Received by Burley Tobacco Plot A5 (50%) During Major Portion of Growing Season

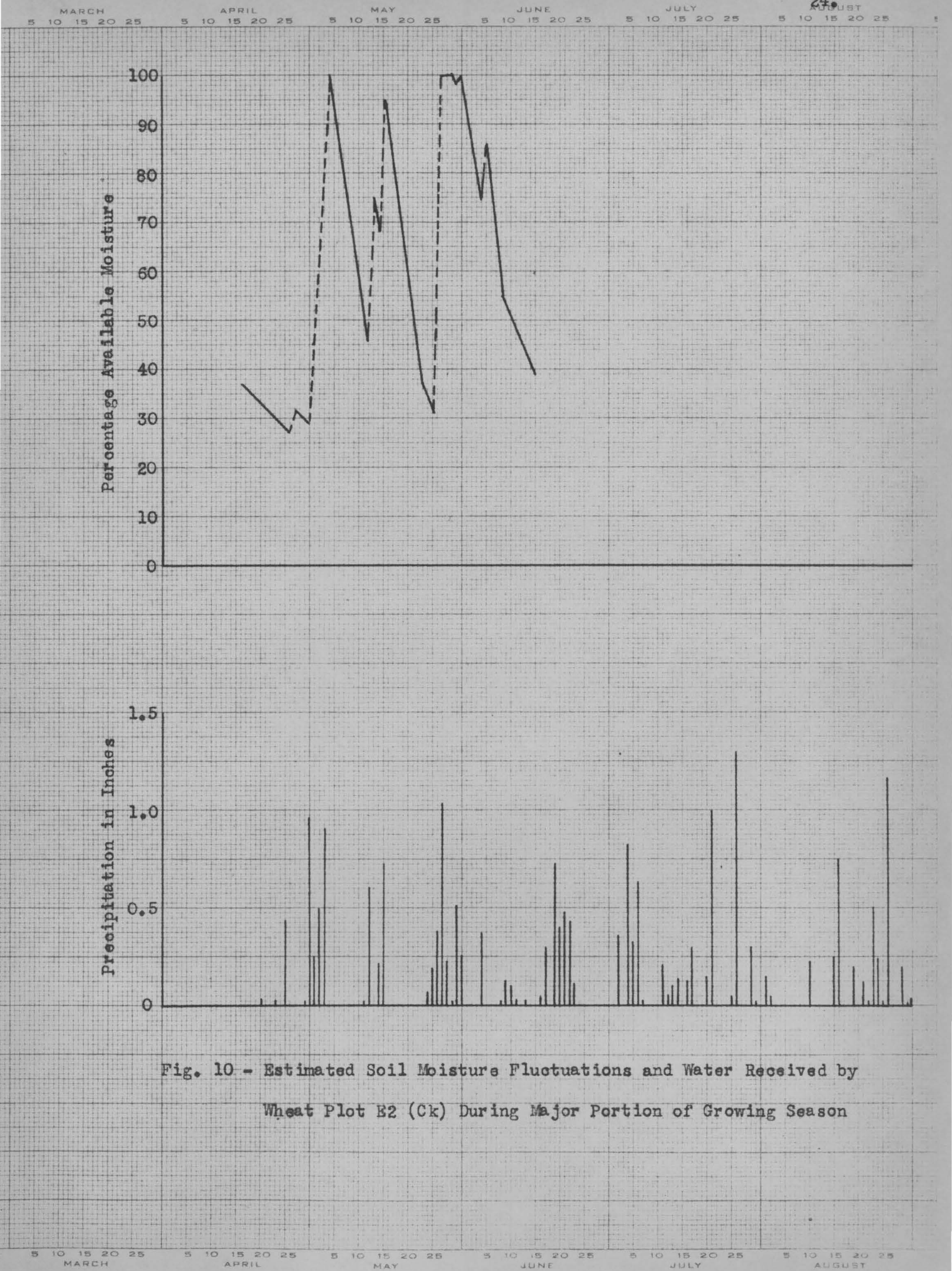

Fig. 10 - Estimated Soil Moisture Fluctuations and Water Received by Wheat Plot E2 (Ck) During Major Portion of Growing Season

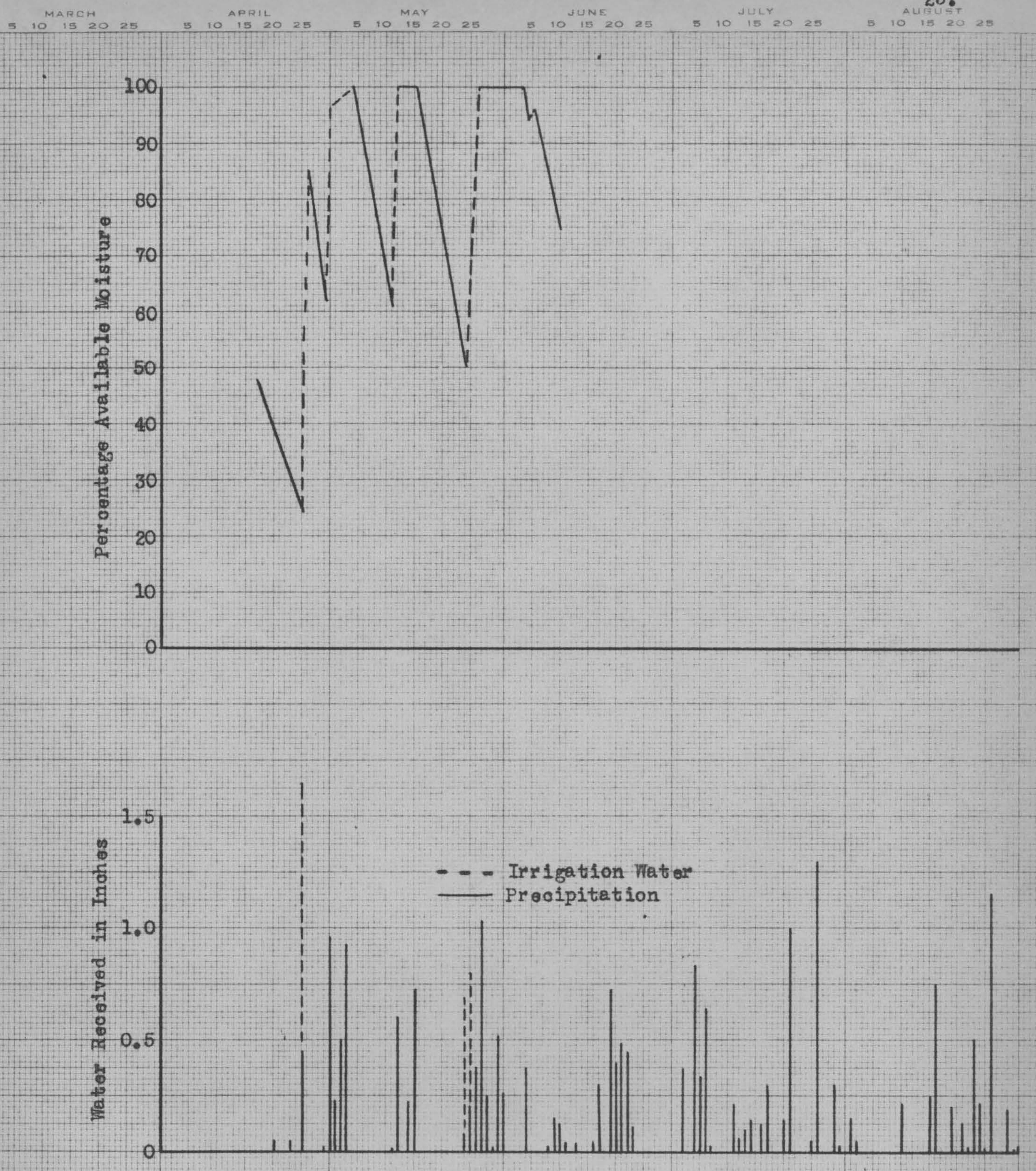

Fig. 11 - Estimated Soil Moisture Fluctuations and Water Received by Wheat Plot Al (50%) During Major Portion of Growing Season

Table 2 gives the estimated peak rates of soil moisture depletion by months for the various crops. It is noted that the highest rates were by alfalfa. Practically, these values may serve as guides to the frequency of irrigation.

TABLE 2

Estimated Peak Rates of Depletion of Soil
Moisture by Selected Crops at
Blacksburg, Virginia, 1950*

Crop	Treat**	Percentage Drop in Available Moisture Per Day					
		April	May	June	July	Aug.	Sept.
Alfalfa	50%	4.0	5.9	8.7	7.8	6.2	---
"	CK	---	5.6	6.5	6.5	5.2	4.6
Burley	50%	---	---	5.3	5.3	5.8	---
"	CK	---	---	5.2	5.2	6.6	6.6
Corn	CK	---	---	4.8	4.8	4.5	---
"	25%	---	---	5.8	5.8	5.1	---
"	50%	---	---	5.2	5.2	5.5	---
"	75%	---	---	5.3	5.3	6.1	---
Wheat	50%	5.4	5.9	---	---	---	---
"	CK	---	5.7	---	---	---	---

*Data represents average of all replicates within each treatment

**Treatment refers to the percentage of available moisture that was maintained.

RESULTS

Figures 2-11 show that the total natural precipitation of 19.27 inches from May 1 to September 1 was well distributed. The curves of soil moisture fluctuations show that the available moisture percentage was well above the wilting percentage throughout the growing season, even on the check plots. The lowest percentage of available moisture on any corn plot was 18, which occurred after corn passed the milk stage. In Figure 6 the percentage reached 15 during the dry period in April for the alfalfa plot D7. The drier periods occurred either before or after periods of peak consumptive use by the several crops. Also, it is noted that most irrigation applications were made just prior to natural precipitation, likely resulting in excessive water.

Pittman and Stewart (19), after 28 years of irrigation experiments in Utah, reported best yields of corn at about 20 inches of irrigation water yearly on a well-aerated soil, the yields tending to decrease above 30 inches. Most of the annual rainfall of 17 inches occurred in winter or early spring with only a few widely scattered rains during the summer. The evaporation from a free water surface was 33 inches per year. For soils in this study which are not so well aerated and where evaporation is lower, it would seem logical that there was ample precipitation at Blacksburg for maximum corn growth. A total of 23.39 inches was recorded at the irrigation plot area for only a 6-month period from April through September. Since the distribution of precipitation throughout this period was good, it is very probable that artificial application of irrigation water represented only excess water, tending to be detrimental rather than beneficial.

Tests have indicated that there is no excessive use of water where soil aeration is good. Schneider and Childers (21) concluded that, under favorable conditions of soil fertility and aeration, rates of growth of corn increase markedly with increasing soil moisture within the range from near permanent wilting percentage to near saturation of the soil. A clear definition of just what constitutes optimum soil aeration with respect to crop growth is needed for each of the common crops as a prerequisite for efficient soil moisture management.

Kopecky (15) has proposed the following air-capacity (non-capillary pore space) ranges for the optimum growth of several farm crops: Sudan grass, 6 to 10 percent; wheat and oats, 10 to 15 percent; barley and sugar beets, 15 to 20 percent. The air capacity of the soils in this study was 3.6 percent. Although a value for corn was not proposed by Kopecky, the air capacity under the conditions in this study does not compare favorably with the optimum air capacities given for the other crops. More information is needed on optimum aeration for plant growth and the effects of deviations from the optimum. Since the rate of plant growth is determined by the weakest factor, a balance between irrigation and other factors should be sought.

Table 1 gives the amounts of precipitation and irrigation water received by each irrigated plot. The values are for the period May 10 to September 1 since that corresponds to the period during which soil moisture samples were taken and irrigation considered. It is noted that for plot C6 (irrigated at 75 percent available moisture) a total of 22.1 inches was received for the less-than-five-month period.

Throughout the growing season there was very little observed difference in rate of growth and apparent vigor between treatments. Figures 12-15 show representative plots in each treatment after approximately 8 weeks from the planting date, May 9. The check plot E4 (Fig. 12) appears equally, if not more, vigorous than the plots having other treatments. The photos were taken 4 days after sidedressing at which time a definitely greener color was noted on the check plot corn plants, although it is impossible to detect the difference in the figures. Figures 16-19 show the same plots 14 weeks after planting. No difference was detected either in the photographs or in the field at the time they were taken.

The greatest non-uniformity of appearance in the field resulted from poor stands in spots of several plots. Wet areas in plots C1, C2, C3, and C8 decreased the germination on

Fig. 12 - Corn Plot E4 (Ck) on July 2

Fig. 13 - Corn Plot C4 (25%) on July 2

Fig. 14 - Corn Plot A7 (50%) on July 2

Fig. 15 - Corn Plot C3 (75%) on July 2

Fig.16-Corn Plot E4(CK)
on August 14

Fig.17-Corn Plot C4(25%)
on August 14

Fig.18-Corn Plot A7(50%)
on August 14

Fig.19-Corn Plot C3(75%)
on August 14

approximately one-third of each plot area. Some of the wet spots were due to wind-blown spray from nozzles adjacent to the plots. Replanted hills failed to produce enough to correct the difficulty.

All plots of corn appeared to "fire up" around the lower half of the stalks near the end of the growing season. The writer believes that the variety, Illinois 200, is not well adapted to Blacksburg conditions. Other corn varieties in the same area did not have the same appearance.

Corn was sampled for yield September 28. Three samples per plot were taken. Each sample consisted of 2 row lengths 14 2/3 feet each. The number of stalks and sound ears were recorded for each sample. After drying in a drier constructed especially for the purpose, the corn was shelled and the sound weights in pounds were recorded. These data are recorded in Table 3. Yields in pounds per sample were converted to bushels per acre.

The weights of sound corn were used in the analysis of variance to determine whether there was a significant difference among treatment means as given in Table 4. From the treatment averages of Table 3 it is noted that the non-irrigated plots yielded more than the irrigated plots. Table 4 shows this difference to be significant at the five percent level. The treatment sum of squares was broken down into linear, quadratic, and cubic effects. None were significant; therefore, no definite

TABLE 3

Corn Yield Data from 1950 Irrigation Plot Experiment*

Treat-ment	Plot	Sample No.	No. Stalks	Sound Ears	Wt. of sound corn (lbs.)	Bushels per acre	Treat-ment Average (Bu/Ac)
Check	C1	1	30	32	13.94	105.62	
		2	32	32	13.44	101.83	
		3	25	25	8.87	67.20	
	D2	1	34	27	11.68	88.49	
		2	34	30	13.46	101.98	
		3	34	30	12.80	96.98	
	E4	1	28	29	11.48	86.98	
		2	28	31	11.11	84.10	
		3	31	31	13.29	100.69	92.65
25%	C2	1	32	30	11.44	86.68	
		2	32	28	12.96	98.19	
		3	18	14	5.21	39.47	
	C4	1	27	25	9.69	73.42	
		2	33	25	10.01	75.84	
		3	29	24	11.41	86.45	
	C7	1	32	29	10.54	79.86	
		2	36	32	10.65	80.69	
		3	36	31	9.33	70.69	76.81
50%	A7	1	40	31	12.41	94.03	
		2	34	29	10.98	83.19	
		3	39	33	10.58	80.16	
	B5	1	33	33	11.58	87.74	
		2	37	25	11.19	84.78	
		3	24	28	8.11	61.45	
	C9	1	33	29	10.18	77.13	
		2	35	29	9.96	75.46	
		3	39	34	10.68	80.92	80.54
75%	C3	1	31	32	14.15	107.21	
		2	42	32	14.40	109.10	
		3	22	21	7.48	56.67	
	C6	1	30	36	9.58	72.58	
		2	35	28	10.02	75.92	
		3	30	27	8.41	63.72	
	C8	1	29	25	8.12	61.52	
		2	32	31	11.69	88.57	
		3	40	41	11.01	83.52	79.86

*Length of row per sample 28.33 ft.

TABLE 4

Analysis of variance of Corn Yield Data*

Source	D/F	S.S.	M.S.	F
Treatments	3	22.96	7.65	4.25 *
Linear	1	9.43	9.43	5.24
Quadratic	1	9.02	9.02	5.01
Cubic	1	4.51	4.51	2.51
Within Treatments	8	14.39	1.80	
Sampling Error	24	105.16	4.38	
Total	35	142.51		

*Based on sample weights in pounds of sound corn statement is permissible concerning the trend of the results.

The significant difference among treatment means in favor of non-irrigation shows that water was not a limiting factor in the production of corn under the conditions of the experiment. It also indicates that applied irrigation water was excessive. These data confirm the work of Pittman and Stewart who, as previously stated, found that maximum yields of corn resulted from approximately 20 inches of irrigation water per year with the yields tending to decrease when the irrigation water exceeded 30 inches.

Plot C5, which was not included in the statistical analysis, was thinned to approximately 8,000 stalks per acre compared to 13,000 for other plots to note the effect of plants per acre on yield and quality. The plot yielded an average of 9.39 pounds per sample from an average of 21 stalks, other irrigated plots of like treatment yielding a sample average of 10.57 pounds from an approximate average of 33.8 stalks. Although the yield was lower for C5, the size of kernels was noticeably larger. The weight per ear for C5 was 0.441 pound compared to 0.348 pound for the other plots.

Due to the negative nature of the results the second objective was impossible and could not be fulfilled. Since there was a significant difference among treatment means in favor of non-irrigation, no treatment was so economical as non-irrigation under conditions of the experiment.

Figures 2-11 show the estimated soil moisture fluctuations for representative plots in each treatment for corn, wheat, alfalfa, and burley tobacco. From those curves and from data of replicate plots the estimated peak rates of depletion of soil moisture, expressed as percentage drop in available moisture per day, were calculated for each treatment. These results are given in Table 2. The depletion rate was calculated for each month during the growing season of each crop where sufficient data were taken to give a good estimate. These data represent estimated depletion rates due both to transpiration by the plants and evaporation from the ground surface.

Referring to Table 2 it is noted that the peak depletion rates were for alfalfa, occurring in June and July. The peak rates for wheat occurred in May, for corn in July, and for burley tobacco in August. Since the water requirement for alfalfa is higher than for the other crops, it is to be expected that the transpiration rate will be affected and that the depletion rate will be higher.

Values of rate of depletion of available moisture in Table 2 may be used to determine the peak use frequency of irrigation for the several crops. Using the peak rates of depletion the approximate peak use frequency of irrigation for the crops based on the top foot of soil are as follows: alfalfa, 11 days; burley tobacco, 15 days; corn, 16 days; and wheat, 17 days. These values may be of practical value in designing irrigation systems in areas where evapotranspiration rates and soil conditions are similar to those in this study.

Yield data for alfalfa, burley tobacco, and wheat are given in the appendix. For wheat and alfalfa there was no significant difference between irrigated and non-irrigated treatments. The yield and value of non-irrigated burley tobacco were definitely higher than for the irrigated. These results indicate that burley tobacco is more sensitive to excess water than either wheat or alfalfa.

SUMMARY

This study was made on a portion of the Smithfield Farm, Virginia Polytechnic Institute during the 1950 growing season. A special study was made on hybrid field corn, Illinois 200, to determine the proper time to irrigate for maximum yields. The treatment index used was percentage of available moisture in the soil. Four treatments, one non-irrigated, with three replications were randomized. The three irrigated treatments were application of sprinkler irrigation water when the soil moisture reached 25, 50, and 75 percent of available capacity.

Yields were taken by obtaining three samples per plot. Weights of sound corn were used in the analysis of variance which showed a significant difference among treatment means in favor of non-irrigation. It was concluded that the maximum yield of corn is obtained when the available moisture percentage is maintained at some value between 25 percent and zero.

Soil moisture conditions were followed for other crops in the same area to determine the rate of depletion of soil moisture. The crops other than corn were wheat, alfalfa, and burley tobacco. From the curves (Figures 2-11) showing the fluctuations in soil moisture throughout the growing season, the rate of depletion, expressed as percentage of available moisture decrease per day, was determined for each crop at different stages of growth

(Table 2). These values may serve as an indication of the practical frequency of irrigation under conditions similar to those at Blacksburg.

CONCLUSIONS

In formulating conclusions for this study it is emphasized that, in some instances, only tendencies are indicated and that further investigation on certain phases of the problem is necessary to make definite statements of facts.

This study, however, warrants the following conclusions:

1. For conditions similar to those at Blacksburg, Virginia, the results of this study indicate that maximum yields of corn are obtained when the available moisture percentage is maintained by irrigation at some value between 25 percent and zero.

2. The amount and distribution of rainfall at Blacksburg, Virginia in 1950 were such that irrigation was not profitable and even detrimental. Decreased yields of corn under irrigation showed that water was not a limiting factor in corn production and indicated a lack of oxygen for root respiration.

3. The rate of depletion of soil moisture was greater for alfalfa than for corn, wheat or burley tobacco; therefore the peak use frequency was less for alfalfa than for the other crops.

4. Burley tobacco appeared to be more sensitive to excess water than either wheat or alfalfa.

RECOMMENDATIONS FOR FUTURE STUDY

There is a definite need for further investigations relative to the interrelation of irrigation and other factors affecting crop growth and yield. In connection with the factors studied here, the author suggests the following possible investigations which would prove useful:

1. Correlation of rate of fertilization with rate and time of irrigation.
2. A study of the interrelationship of aeration, depth of irrigation water applications, and time of irrigation. A clear definition of just what constitutes optimum soil aeration with respect to crop growth is needed for each of the common crops as a prerequisite for efficient soil moisture management.
3. A study of the effect of time of irrigation on crop yields for soils with varying degrees of aeration.
4. The effect of early season applications on root growth and consumptive use of water at later dates.
5. Further studies on practical methods to determine quickly and accurately soil moisture.

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APPENDIX

Alfalfa Yield Data from Irrigation Plot Experiment,

Blacksburg, Virginia, 1950

Plot	Cutting	Estimated Percent Desirable	Percent Dry Matter	Yield on Dry Weight Basis (lbs./acre)	Average wt. per cutting
Irrigated					
A4	1	70	25.7	3320	
	2	15	23.0	2070	
	3	50	21.6	1365	
B2	1	80	22.9	4120	
	2	60	20.5	2050	
	3	70	20.2	1550	2419
Non-irrigated					
D7	1	80	20.3	3250	
	2	50	24.0	1680	
	3	50	18.9	1323	
E1	1	85	18.8	3890	
	2	85	24.2	2340	
	3	80	20.1	1405	2315

Wheat Yield Data from Irrigation Plot Experiment,

Blacksburg, Virginia, 1950*

	Irrigated		Non-irrigated	
	Grams per sample for plots:		Grams per sample for plots:	
After Burley	A1	B3	D3	E2
	781	1276	931	875
	829	1328	1036	1058
	939	1313	835	928
	965	821	779	974
	3514	4738	3581	3835
After Corn	A3	B4	D6	E5
	985	942	699	917
	878	1006	724	698
	1055	784	924	814
	471	717	834	788
	3389	3449	3181	3217

*Size of wheat sample plots 39" by 20'

Analysis of Variance

Source	D/F	S.S.	M.S.	F
Irr. vs. Non-irr.	1	50,165	50,165	0.79
Burley vs. Corn	1	183,467	183,467	2.90
Sampling Error	24	452,817	18,867	0.30
Error	5	316,134	63,227	
Total	31	1,002,583		

DATA OBTAINED ON THE 1950 TOBACCO TEST CONDUCTED BY THE DEPARTMENTS OF PLANT PATHOLOGY AND PHYSIOLOGY AND AGRICULTURAL ENGINEERING

Yield in pounds per plot*

		Rep. 1	Rep. 2	Total
Non Irrigated	Ky. 16	36.37	33.43	69.80
	Va. 111	35.87	33.87	69.74
		72.24	67.30	139.54
Irrigated	Ky. 16	29.77	30.21	59.98
	Va. 111	24.31	24.32	48.63
		54.08	54.53	108.61
TOTAL				248.15

Value per plot*

		Rep. 1	Rep. 2	Total
Non Irrigated	Ky. 16	$18.19	$17.33	$35.52
	Va. 111	18.17	16.63	34.80
		36.36	33.96	70.32
Irrigated	Ky. 16	15.51	14.74	30.25
	Va. 111	11.70	11.55	23.25
		27.21	26.29	53.50
TOTAL				123.82

*Sub-plot size 20' x 45' or 1/48 acre

Permeability Data For Sites on Irrigation Plot Area*

Site No.	Soil Type	Sample Depth	Volume Weight	Percolation Rate (In./hr)	Location Between Plots
261	Greendale Silt Loam	1-4"	1.483	2.33	B6 and B7
262	Needmore Silt Loam	1-4"	1.438	10.91	B4 and B5
263	Litz Silt Loam	1-4"	1.360	30.36	A1 and A2
264	Litz Silt Loam	1-4"	1.547	49.39	C1 and C2

*Data from joint SCS operations and Research and Virginia Agricultural Experiment Station, 1950.