SOIL MOISTURE STUDIES WITH COASTAL BERMUDA GRASS RECEIVING VARIOUS NITROGEN FERTILIZER TREATMENTS

By

DONALD P. PROPHET

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1947

Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May 30, 1955

SOIL MOISTURE STUDIES WITH COASTAL BERMUDA GRASS RECEIVING
VARIOUS NITROGEN FERTILIZER TREATMENTS

Thesis Approved:

J. Q. Lynd
Thesis Adviser

Wayne W. Huffine

Robert MacVicar
Dean of the Graduate School

ACKNOWLEDGEMENT

The writer wishes to express his appreciation to the staff of the Agronomy Department of Oklahoma Agricultural and Mechanical College for helpful advice and criticisms, and especially to Doctor J. Q. Lynd for his inspiration, encouragement, and helpful criticisms in connection with this research study and in the preparation of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

APPENDIX

I. INTRODUCTION

The importance of available soil water in plant growth cannot be too strongly emphasized. Water is essential to all of the complex chemical and physical processes in soil-plant relations and many factors determine the amount of soil moisture available to growing plants. The complex dynamic relationship of soil moisture and its availability to growing plants involves the physiology of the plant and soil physical properties including soil aeration, soil structure, and surface evaporation.

One of the most important factors governing crop production in Southwest Oklahoma is the availability of soil moisture to the growing plants. Crop production in this area is usually limited by a deficiency of available soil moisture during some period of each growing season.

The study herein reported was undertaken with the objective of obtaining additional information on factors affecting availability of soil moisture in the production of Coastal Bermuda grass receiving various nitrogen treatments under irrigation.

II. REVIEW OF LITERATURE

Methods and procedures for the determination of soil moisture under field conditions have received considerable study by soil scientists for many years. Most workers (15, 25, 31)* consider the electrical resistance method of determining soil moisture as being among the most practical methods now used in the field. However, Scofield (30) proposes the tensiometric method as the most accurate method now in general use to show the available soil moisture.

A method of determining soil moisture continuously under field conditions by means of electrical resistance was first investigated by Whitney (3) in 1887. Whitney used alternating copper and zinc plates buried in the soil as electrodes for measuring electrical conductivity and resistance. He found this method not satisfactory because of polarization in the system. Electrodes made of carbon were later used in similar experiments (40) and proved more satisfactory than the zinc and copper plates. It was found that the electrode units were more satisfactory when permanently placed in porous materials allowing the movement of soil moisture similar to that taking place in an undisturbed soil. Gypsum blocks (1, 9) were found to be satisfactory for this purpose.

Bouyoucos (8) found nylon moisture units more sensitive than the gypsum moisture blocks under most soil conditions in Michigan.

Colman and Hendrix (12) found the fiber glass electrical soil

*Figures in parenthesis refer to "Literature Cited."

moisture unit to be more accurate and to have a wider range of sensitivity than the gypsum blocks.

Korty and Kohnke (26) found that nylon moisture units did not give accurate information on small changes in soil moisture in the lower soil moisture range, but they did give good results indicating changes in soil moisture at soil moisture ranges above the moisture equivalent. Tanner and Hanks (33) found unpredictable variation between different gypsum moisture blocks at a given tension both on wetting and drying. Weaver and Jamison (39) found the nylon and fiberglass electrical soil moisture units to reproduce approximately the same resistance at recurring tensions when the soil conditions were held constant but gave erratic results in soils having high salt concentrations. Bouyoucos (6) suggested that the electric automatic irrigation system utilizing various soil moisture units be employed only in greenhouses at the present time.

Bouyoucos and Mick (9) and Peel and Beale (27) agreed that moisture equivalent and field capacity for all practical purposes has approximately the same moisture content in fine-textured soils. Veihmeyer and Hendrickson (38) found that the moisture content of fine-textured soil, two to three days after a rain or irrigation, was at field capacity. This was not true of sandy soils. Corey and Blake (13) found the capacity of the soil moisture reservoir depends on the characteristics of the soil and of the crops growing on them. Since field capacity cannot be determined exactly, it is necessary to determine soil moisture equivalent percentage to obtain a close approximation of field capacity. The moisture equivalent of a soil (4) is obtained by subjecting a sample of saturated soil to a centrifugal force of 1000 times gravity.

The amount of moisture that the soil contains when a growing plant permanently wilts is termed "permanent wilting point." Veihmeyer and Hendrickson (36, 37) define the permanent wilting point as:

(a) A point where plants permanently wilt but further extraction of water will continue in small amounts

(b) A characteristic of the soil and not of the plant

(c) Not affected by climate or a change of evaporation conditions

(d) The size and quality of the fruit and growth is not changed as long as the moisture is above the permanent wilting point

The accepted method of determining permanent wilting point of the soil (36, 37) is by actually growing plants in small containers of the soil concerned. Briggs and Shantz (5) covered the soil in impervious pots with wax to allow escape of water only through the plant. Tanner, Abrams, and Zubricki (32) found the permanent wilting point to have approximately 75,000 ohms resistance in most soils. Bouyoucos and Mick (10) proposed the average resistance of permanent wilting point as approximately 100,000 ohms. Bouyoucos and Mick (10) considered 10,000 ohms resistance as the proper time to apply irrigation water while Tanner, Abrams, and Zubricki (32) used the resistance of all 11,000 ohms. This variation may be due to difference in the blocks themselves (33). Although there is a variation within blocks that reduces the accuracy below that of field sampling, Ashcroft and Taylor (2) propose increasing the number of blocks to obtain accuracy since block data is much faster than field sampling.

Holt, Potts, and Fudge (22) found that the yield of Bermuda grass can be greatly increased by the use of proper fertilizer and the lack of nitrogen is most often the fertilizer limiting plant growth while phosphorus applied alone seldom increases the growth of grass plants. Harlan and Kneebone (20) in working with seed yields of Switch grass and nitrogen fertilization reported data indicating that heavier rates than 100 pounds of nitrogen per acre, in the form of ammonium nitrate, might be used effectively. Burton and Devane (11) found the annual hay yields of Bermuda grass ranged from one ton of hay per acre with no nitrogen to eight tons of hay per acre where 400 pounds of nitrogen were used. They found that the most economical hay production was obtained by applying 200 pounds of nitrogen per acre. Their results also indicated that splitting the application of sodium nitrate and ammonium nitrate in wet seasons increased the yields of hay but had no effect in a season of average rainfall. Gausman and Cowley (17) found that nitrogen fertilizer increased the hay yields of Coastal Bermuda grass in Harlingen Clay Soil while phosphate fertilizers did not give an increase. Devane, Stelly and Burton (14) showed that there was an efficient increase in yields of Bermuda grass hay when they used 752 pounds of nitrogen per acre.

Hagan and Peterson (19) found large differences in yields obtained under the several clipping frequencies with pasture mixtures, for which the consumptive-use rates are nearly equal, and led to corresponding large differences in forage production per unit of water consumed with the longest clipping periods consistently giving the highest yields. Peterson and Hagan (28) in their clipping experiments, reported that grazing intensively at intervals of 25 to 28 days might be suitable for mixtures containing Ladino clover as the primary legume but with trefoil or alfalfa as the dominant legume, slightly longer intervals between grazing should prevail. Hubbard and Harper (23) reported that severe clipping of cereals produced slightly less forage yields than did moderate clipping, and that cereals were not affected so adversely by severe clipping in favorable as in unfavorable growing seasons.

Robertson (29) in his presidential address to the American Society of Agronomy stated that a knowledge of the critical stages in plant growth when adequate water is necessary will aid in the more efficient use of water. Hagan and Peterson (19) irrigated pasture results indicated that for a given soil and climate, the frequency with which irrigation will be required depends directly upon the effective depth of rooting and that the consumptive-use rates of the soil moisture did not increase with height of the stand as long as the soil surface is covered. Haddock (18) found that the total amount of irrigation water required to produce a crop of sugar beets in Utah may be of less importance than the time at which the water is applied, and split applications of nitrogen fertilizer did not appear to be of great importance.

III. EXPERIMENTAL PROCEDURE

The objective of this study was to obtain information concerning moisture content of soil under field conditions supporting Coastal Bermuda grass treated with various amounts of nitrogen fertilizer. This study was particularly concerned with the range of available soil moisture during the growing season and the effects of nitrogen fertilization on water utilization by Coastal Bermuda grass.

The soil used in this study was Foard Clay Loam. The Foard series (34) are Reddish Chesnut soils developed from calcareous clays of the Red Beds. Topography is relatively smooth or flat with occasional rough broken land. The surface drainage is medium to slow and the internal drainage is very slow. The native vegetation is largely short grasses with scattered mesquite and brush. These soils are highly productive in seasons of high rainfall but have occasional crop failure due to drought in spite of their good moisture holding capacity and are well suited to general farm crops.

The Foard series used in this study was in a field on the Cameron State Agricultural College farm located near the west edge of Lawton in Comanche County, Oklahoma.

A field experiment was established in which Coastal Bermuda grass was sprigged in twelve inch rows on April 24, 1953, and eleven foot square plots were delineated within the field. No fertilizer was applied at the time of sprigging. During the first week of June, all fertilized plots received the first application of ammonium nitrate. Plot numbers 6 and 7 received ammonium nitrate at the rate of 400 pounds per acre each week until the desired amounts were applied. Plots 3, 4, and 5 received their respective nitrogen fertilizer treatments in one application.

Nitrogen fertilizer treatments on the established Coastal Bermuda grass plots were as follows:

DESIGNATION	TREATMENT NH_4NO_3 LBS / ACRE
1 (fallow)	No treatment
2	No treatment
3	100
4	200
5	400
6	800
7	1200

The Coastal Bermuda grass was harvested with a lawn mower. The air dried forage yields are reported in Figure 9.

On May 12, 1953, three groups of gypsum resistance blocks were placed in the soil of each experimental plot. In each group a block was placed at the depth of 6 inches and 15 inches. The resistance readings at each depth in each experimental plot were averaged to give an average depth reading for each plot. All of the resistance readings taken in the field were measured in ohms which were later converted to percentage of soil moisture and reported in the Appendix. The moisture blocks were calibrated by methods of Bouyoucos and Mick (8,9) and Kelley (24). The results of block calibration are reported in Table 2.

Physical and chemical characteristics of the soil used in this experiment are presented in Table 1. Soil texture was determined essentially by the method of Bouyoucos (7). Soil pH, organic matter, extractable phosphorus and exchange capacity were determined according to methods of Harper (21). Permanent wilting percentage of the soil was determined by the method of Briggs and Shantz (5) and moisture equivalent was determined by the method of Briggs and McLane (4).

Table 1. Physical and Chemical Characteristics of the Foard Clay Loam Used in Moisture Studies.

Soil Depth Inches	Soil Texture (1) Sand %	Silt %	Clay %	Soil pH (2)	Permanent Wilting (3) %	Moisture Equivalent (4) %	Organic Matter (2) %	Phos-phorus ppm (2)	Exchange Capacity m.e./100gms. Soil (2)
0-6	40.5	30.5	29.0	7.2	12.03	25.03	2.01	19.2	22.0
6-12	37.5	31.6	30.9	7.7	13.05	25.76	1.59	6.9	23.4
12-18	37.8	27.3	34.9	7.8	12.08	26.23	0.98	6.9	25.0
18-24	39.0	26.7	34.3	7.9	-	-	0.69	6.9	25.5
24-36	36.1	24.1	39.8	8.2	-	-	0.48	18.1	26.8

1. Determined essentially by the method of Bouyoucos. (7)
2. Determined essentially by the methods of Harper. (21)
3. Determined by the method of Briggs and Shantz. (4)
4. Determined by the method of Briggs and McLane. (4)

Table 2. Calibration of Electrical Resistance of Gypsum Moisture Blocks and Corresponding Soil Moisture Content of Foard Clay Loam.*

Resistance Ohms	Soil Moisture Percent	Resistance Ohms	Soil Moisture Percent
300	40.5	1000	22.7
400	38.5	1100	21.7
450	34.5	1250	19.8
500	33.0	1500	18.0
550	31.0	1750	15.9
600	29.6	2000	14.2
650	28.2	3000	12.2
700	26.6	4000	10.9
750	25.9	5000	9.7
800	25.4	10000	8.6
850	25.0	50000	6.2
900	24.2	100000	6.1
950	23.8	1000000	4.3

* Determined essentially by the method of Bouyoucos and and Mick. (9)

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The Coastal Bermuda grass grew slowly after being sprigged due to unusually dry weather conditions. A complete coverage of Bermuda grass in all the experimental plots was obtained by July 1, 1953.

The relation of soil moisture percentage and ohms resistance at 6 and 15 inch depths, water received, and forage yields of the vegetated plots are shown in Figures 1 through 7.

All of the experimental plots were located on Foard Clay Loam, and were given equal amounts of irrigation water. Different rates of ammonium nitrate were applied to each of the vegetated plots. The nitrogen did not increase the yield of forage when 100, 200 and 400 pounds of ammonium nitrate was added. There was an increase in forage yield over the no nitrogen treatment when 800 and 1200 pounds of ammonium nitrate were applied. Most workers (11, 14, 17) found that the forage yields of Bermuda grass corresponded to the amount of nitrogen applied. Freeman and Beaty (16) found an exception to this trend in that their results indicated one hundred pounds of nitrogen produced the greatest yield of any nitrogen level for both Coastal and Common Bermuda grasses. However, the increase of nitrogen per acre up to one hundred pounds did show uniform increases in forage growth while larger applications of nitrogen fertilizer did not increase the yield of Bermuda grass forage. The results of this study did not follow either of these trends. No notable gains in forage yield were obtained until more than one hundred pounds of nitrogen were applied.

In comparison of the affect of the application of different rates of ammonium nitrate on the yield of air-dried forage as compared to the yield of air-dried forage with no nitrogen, the plot treated with 400 pounds of ammonium nitrate per acre had the largest reduction in yield, which was 1477 pounds of air-dried forage, or a reduction of 3.66 pounds of forage per pound of ammonium nitrate applied. The area that received 800 pounds of ammonium nitrate gave the greatest forage gains per pound of fertilizer applied while the 1200 pound per acre application of ammonium nitrate gave the largest total yield of air-dried forage over no nitrogen.

The need for additional moisture after a complete stand of Coastal Bermuda grass was obtained, varied little between different nitrogen treatments and fallow. The fallow plot did not lose soil moisture as rapidly as did the vegetated plots during the season when the plants were growing. This trend was reversed toward the end of the growing season while the rate of soil moisture loss continued to be approximately the same in the vegetated plots. Hagan and Peterson (19) found that the consumptive-use rates of soil moisture did not increase with increased yields of forage. When pasture clippings were frequent vegetation was kept at short height and this condition resulted in increased soil surface evaporation during the hot dry summer months. The yields of forage were less than where the hay was allowed to grow tall reducing the amount of surface evaporation. The consumptive-use rates were nearly the same in spite of the large difference in yield of forage caused by the different clipping schedule. It was indicated in their results that land exposed to surface evaporation during unusually hot dry periods will loose soil moisture similar to land producing heavy vegetation. Their results were similar to results obtained in this study in that the loss of soil moisture was nearly equal regardless of the yield of forage, nitrogen treatment or fallow.

Table 3 shows the number of times the moisture content of the soil under each treatment recorded below twelve percent moisture, twelve to twenty percent moisture and more than twenty percent moisture at 6 and 15 inch depths. During the period from June 1, to September 30, 1953, the soil receiving 1200 pounds of ammonium nitrate was below twelve percent moisture, the approximate permanent wilting point of the soil, seven times at both 6 and 15 inch depths. This was the same number of times that the fallow area recorded the low moisture levels. The plot receiving the highest nitrogen treatment also recorded the highest number of times in the high moisture range of above twenty percent at 6 inch depth. The plot that received 400 pounds of ammonium natrate per acre went below twelve percent moisture more times than any other plot and was above twenty percent moisture less than any other plot at both the 6 and 15 inch depths.

The amount of air-dried forage an inch of moisture produced with various nitrogen treatments is reported in Figure 10. The amount of precipitation and irrigation water received during the period from June 1 to September 30, 1953, was approximately 23.66 inches. The plot receiving 1200 pounds of ammonium nitrate per acre produced nearly 345 pounds of air-dried forage per acre-inch of water. The area treated with 400 pounds of ammonium nitrate had the lowest efficiency producing 220 pounds of forage per acre-inch of water.

The apparent rate in which the water moved through the soil after a rain or irrigation was approximately the same for all vegetated and

Table 3. Moisture Content of Foard Clay Loam at 6 and 15 Inch Depths as Affected by Coastal Bermuda Grass Receiving Various Nitrogen Treatments.*

Treatment	20% H_2O		12 to 20% H_2O		12% H_2O	
	6 Inches	15 Inches	6 Inches	15 Inches	6 Inches	15 Inches
Fallow No Fertilizer	29	29	4	4	7	7
Bermuda Grass No Fertilizer	28	35	3	0	9	5
Bermuda Grass 100#/A NH_4NO_3	26	35	5	0	9	5
Bermuda Grass 200#/A NH_4NO_3	27	28	5	4	8	8
Bermuda Grass 400#/A NH_4NO_3	24	26	4	2	12	12
Bermuda Grass 800#/A NH_4NO_3	28	32	2	2	10	6
Bermuda Grass 1200#/A NH_4NO_3	31	31	2	2	7	7

* The number in each column represents the number of times out of forty electrical resistance readings taken that the soil moisture content was at the moisture percent indicated at the head of the column. The electrical resistance blocks were buried at the depths of 6 and 15 inches.

nitrogen treated plots. The fallow plot was nearly always a day or two behind the other plots in indicating large moisture changes in the soil. This lag in indicating soil moisture changes may have been due to moisture hysteresis in the gypsum blocks or some repression of water movement in the fallow soil.

The period from June 12 to 17 had a daily maximum temperature of above 100 degrees and minimum of above 70 degrees Fahrenheit. The moisture content of the top 6 inches of the soil was reduced from field capacity to below permanent wilting in that period. It is believed that this rapid loss of soil moisture was due mainly to surface evaporation caused by the unusually high temperatures (see Figure 8) of that period. A knowledge of these high temperatures and the approximate time it takes to reduce the moisture content of the soil below normal growing conditions for plants should aid in determining the size of the irrigation equipment needed to irrigate a certain area, as well as to act as an aid in determining the proper time to irrigate.

It can be noted in Figures 1 through 7 that the 1.31 inch rain the last part of June was not sufficient to increase the moisture content at the soil depth of 15 inches while the moisture content at the depth of 6 inches changed to above field capacity. However, this moisture in the top layer of soil was reduced to nearly permanent wilting within five or six days. When more than three inches of water was added the moisture content came up to above field capacity at the depth of 15 inches. This indicates that more than 1.31 inches of rain or irrigation water was needed to bring about a desirable growing condition for the plants in this soil under the conditions of this experiment.

Figure 1. Soil Moisture at 6 and 15 Inch Depths and Amount of Water Added in the Fallow Plot Receiving No Fertilizer, 1953.

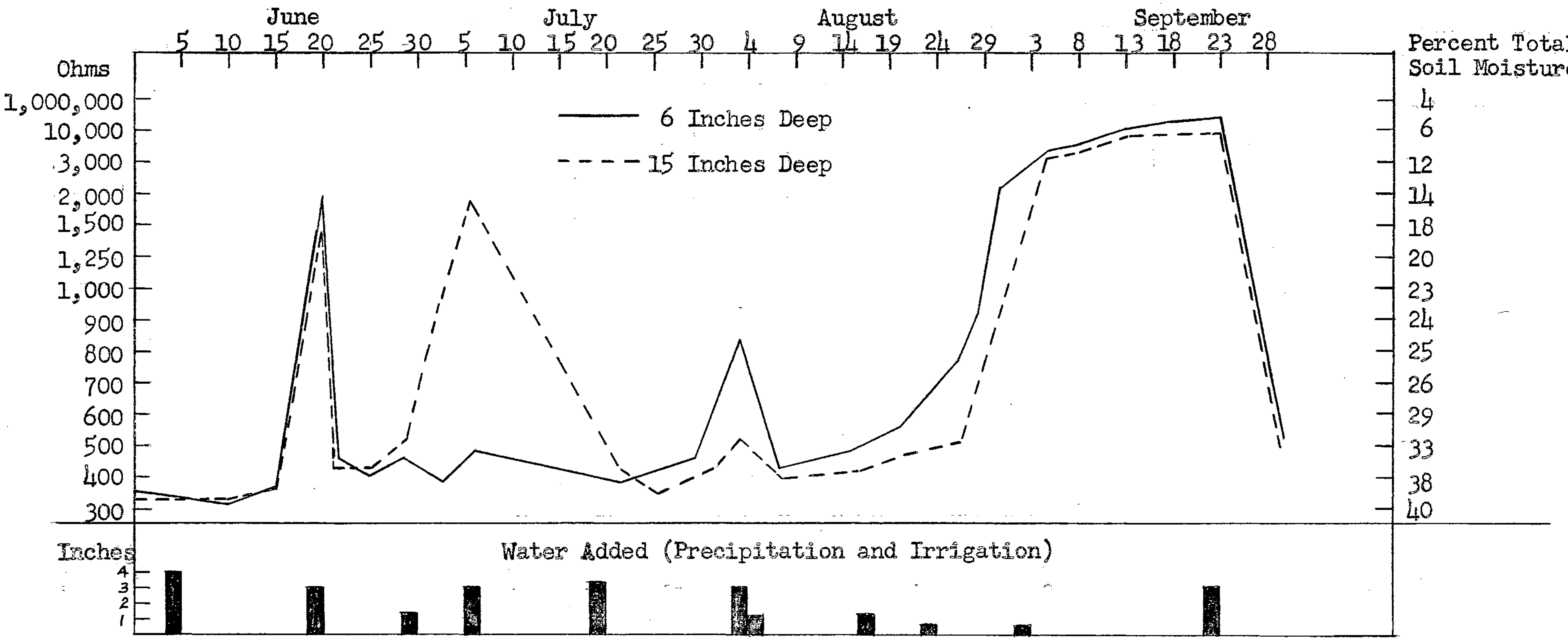
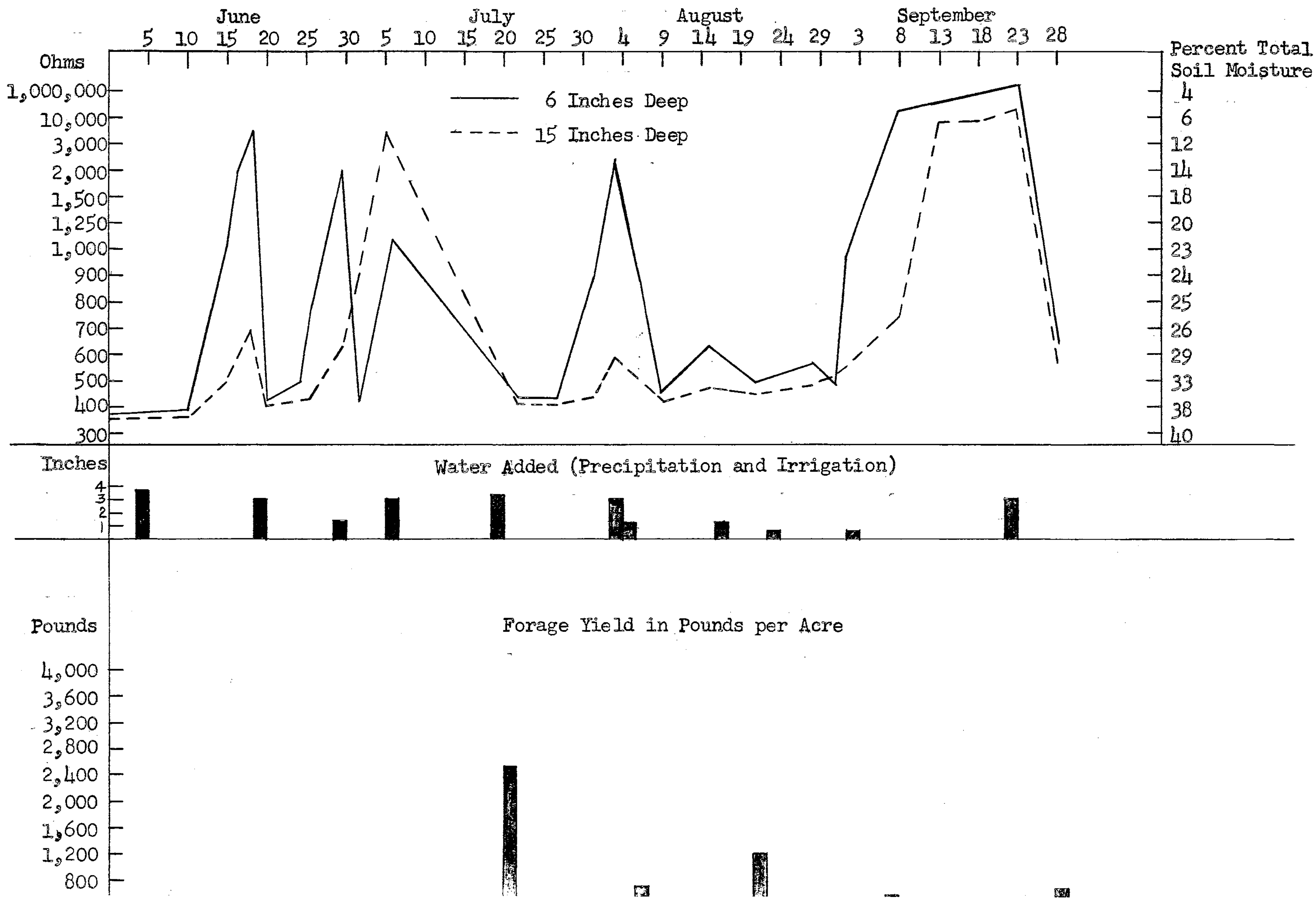
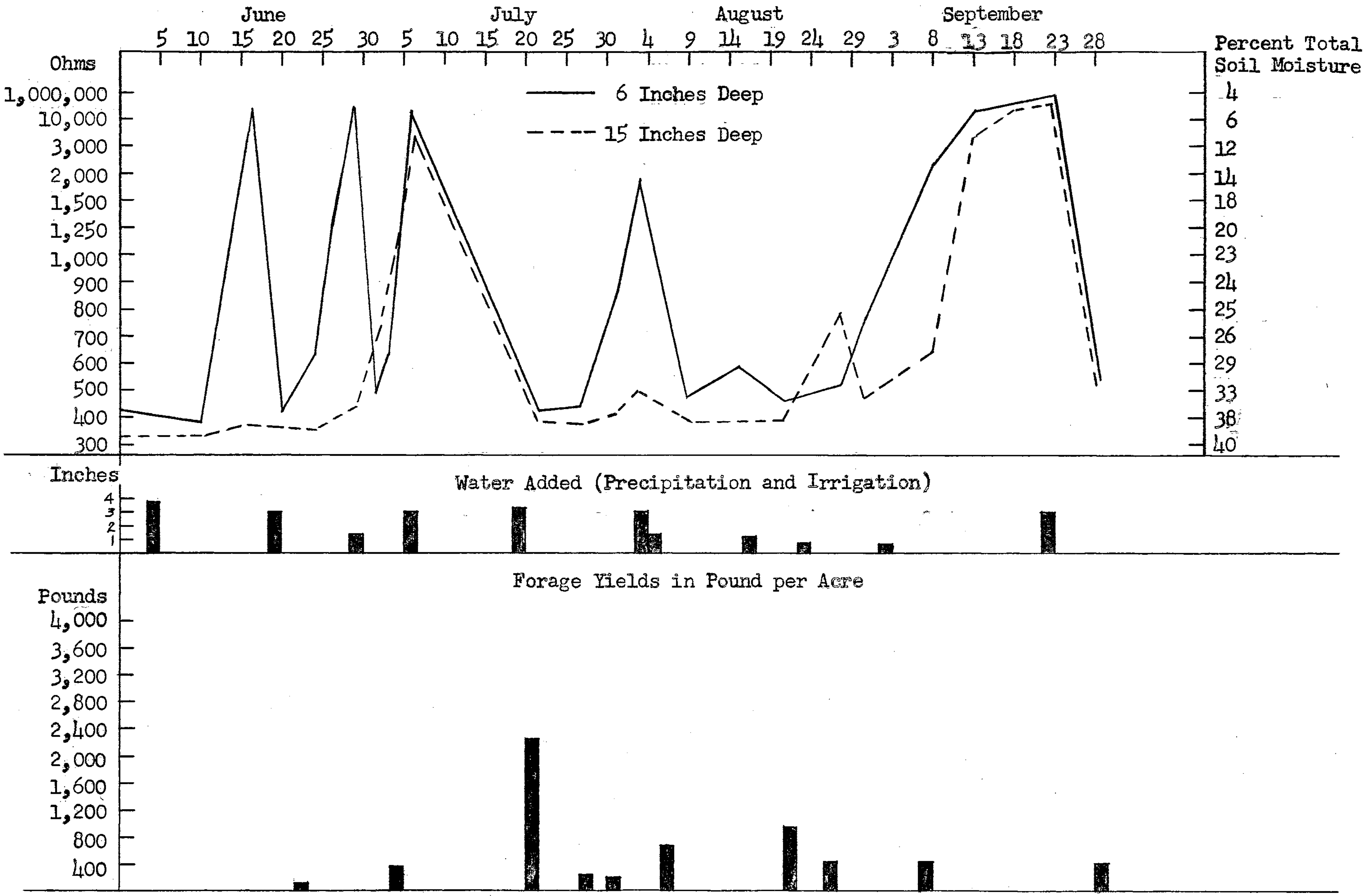


Figure 2. Soil Moisture at 6 and 15 Inch Depths, Amount of Water Added, and Yield of Coastal Bermuda Grass Receiving No Nitrogen Fertilizer, 1953.



Bermuda Grass Receiving 100 Pounds per Acre of Ammonium Nitrate, 1953.



Bermuda Grass Receiving 200 Pounds per Acre of Ammonium Nitrate, 1953.

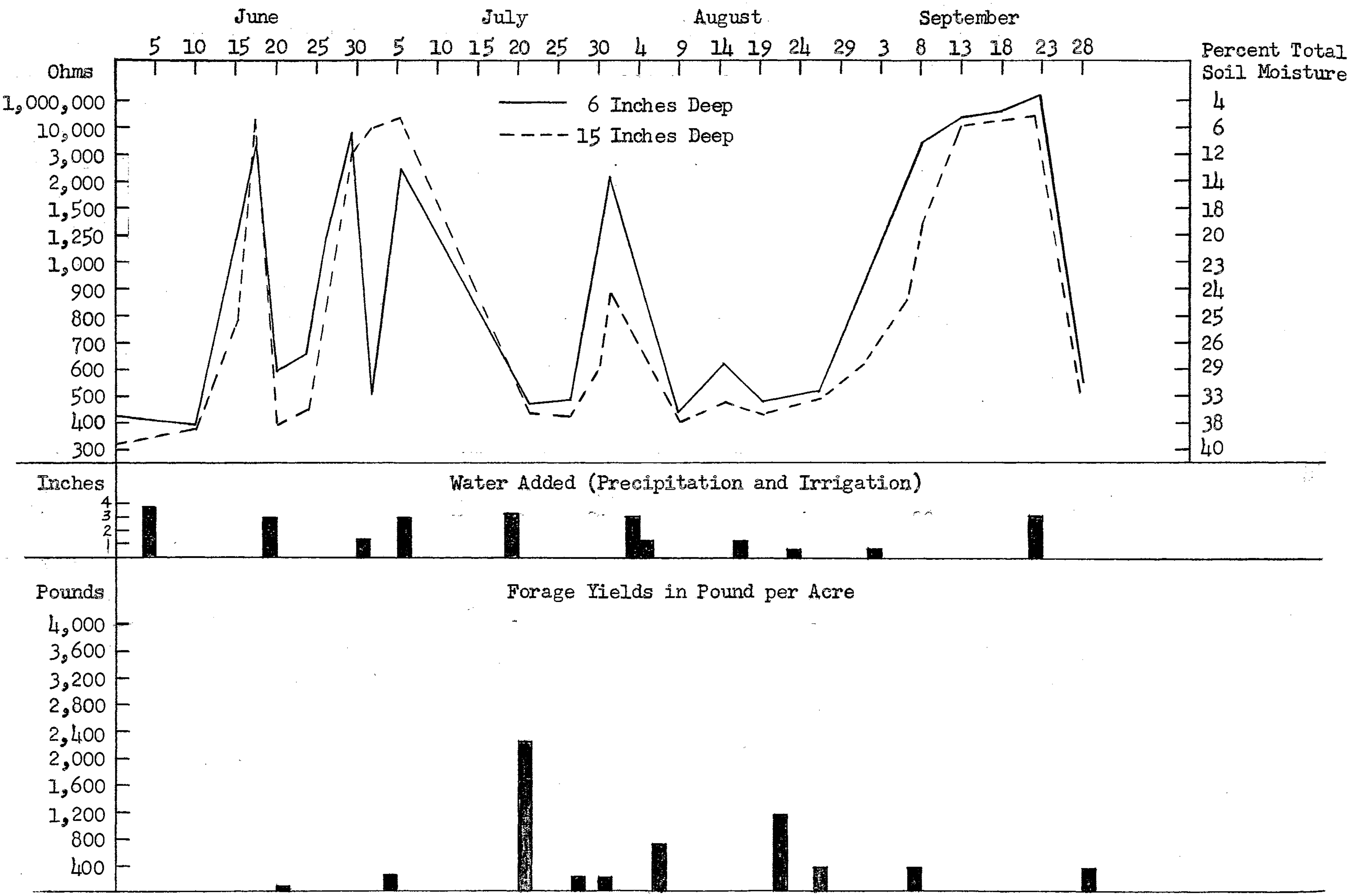
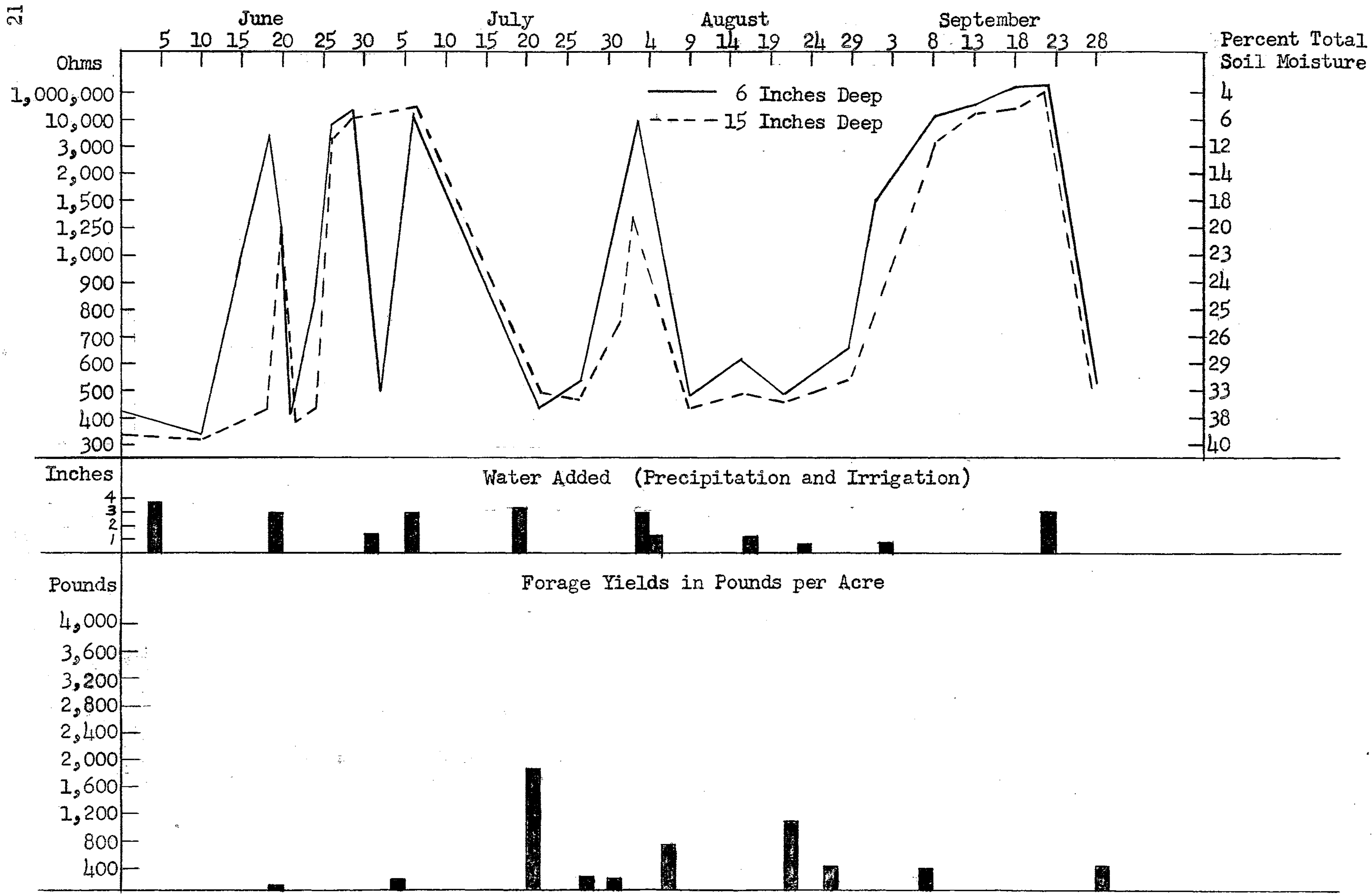


Figure 9. Soil Moisture at 6 and 15 Inch Depths, Amount of Water Added, and Yield of [illegible]
Bermuda Grass Receiving 400 Pounds per Acre of Ammonium Nitrate, 1953.



Bermuda Grass Receiving 800 Pounds per Acre of Ammonium Nitrate, 1953.

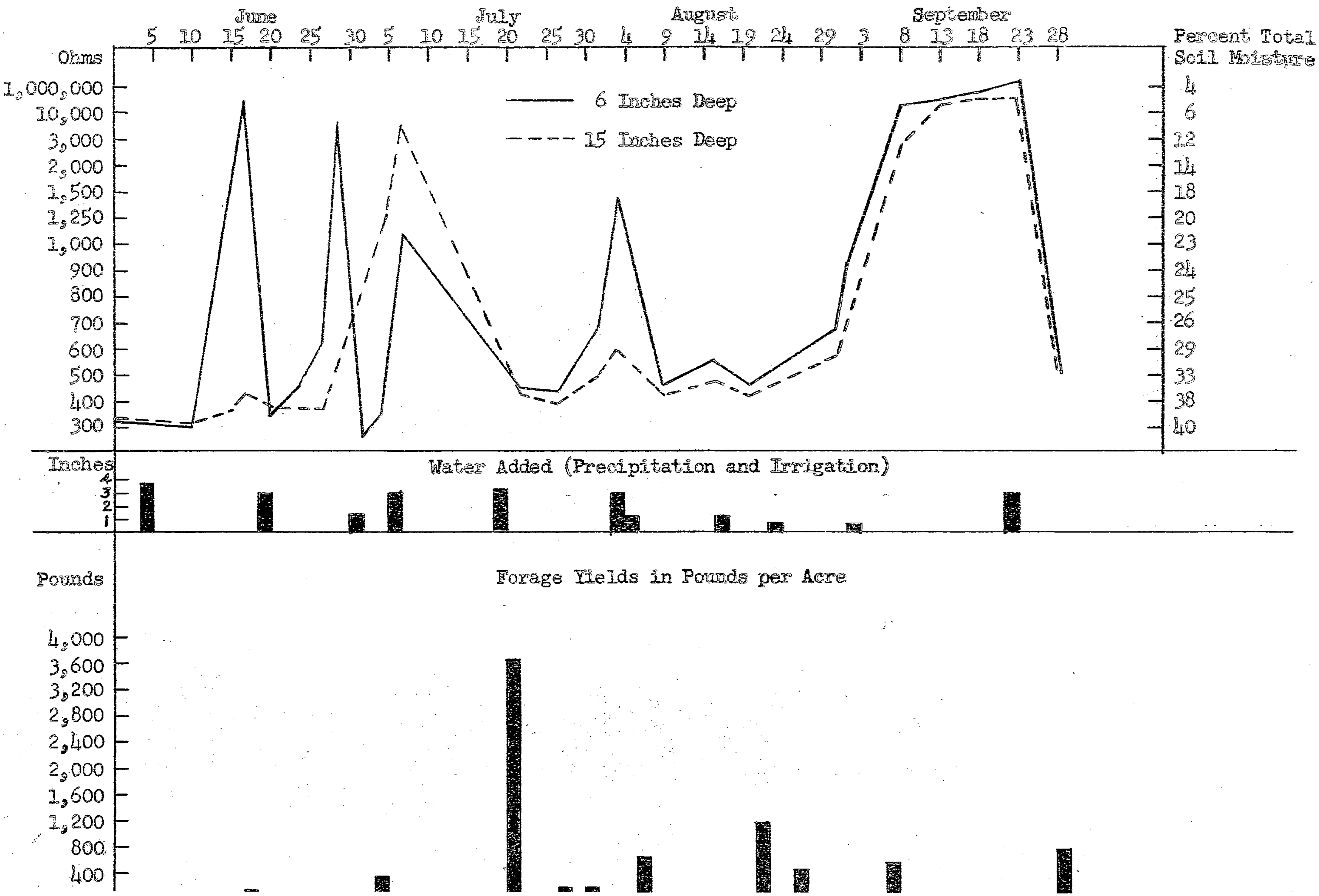


Figure 7. Soil Moisture at 6 and 15 Inch Depths, Amount of Water Added, and Yield of Coastal Bermuda Grass Receiving 1200 Pounds per Acre of Ammonium Nitrate, 1953.

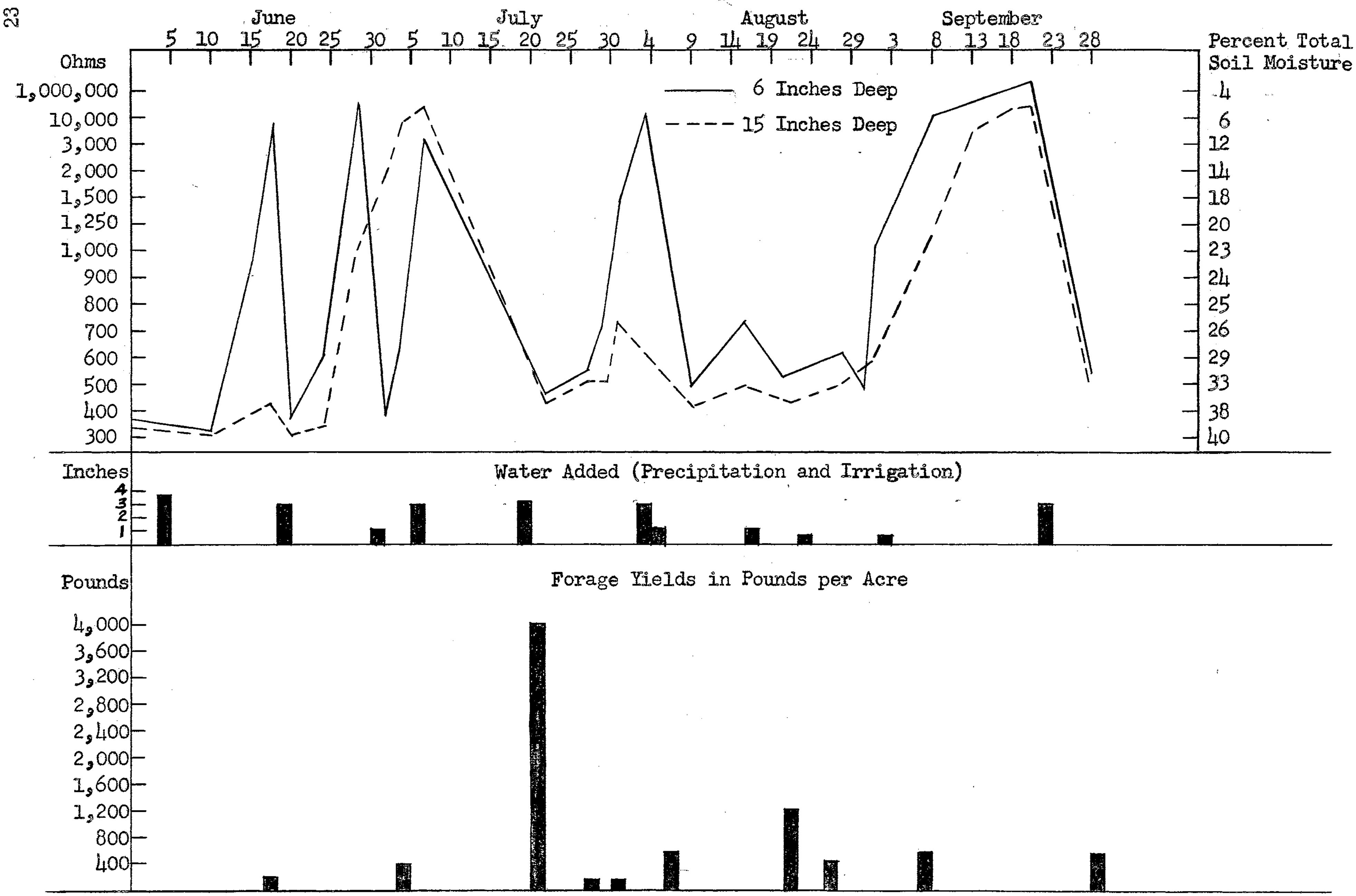


Figure 8. Daily Maximum and Minimum Temperature, Lawton, Oklahoma, June 1 to September 30, 1953.

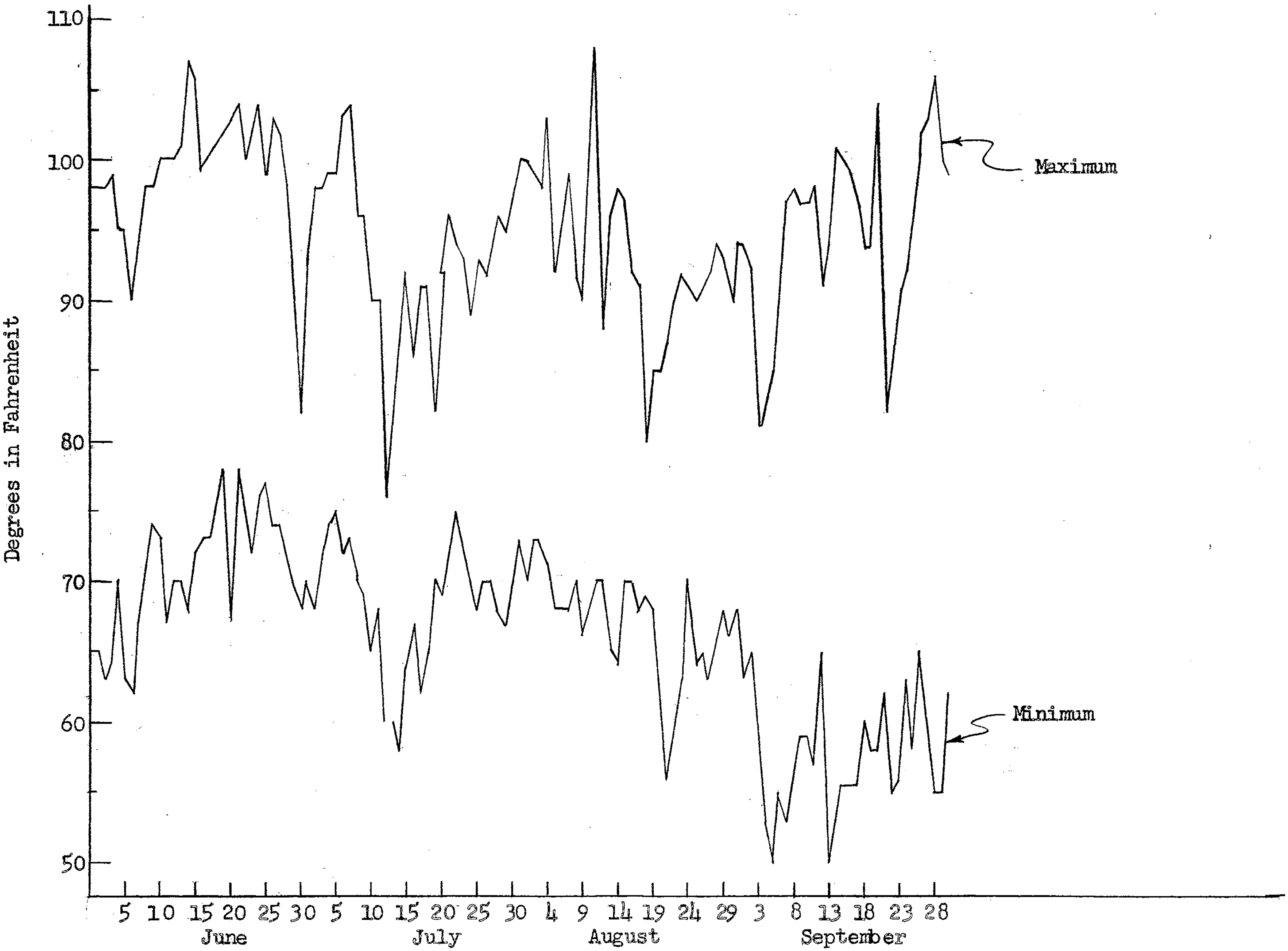


Figure 9. The Effects of Various Nitrogen Treatments on the Yield of Coastal Bermuda Grass.

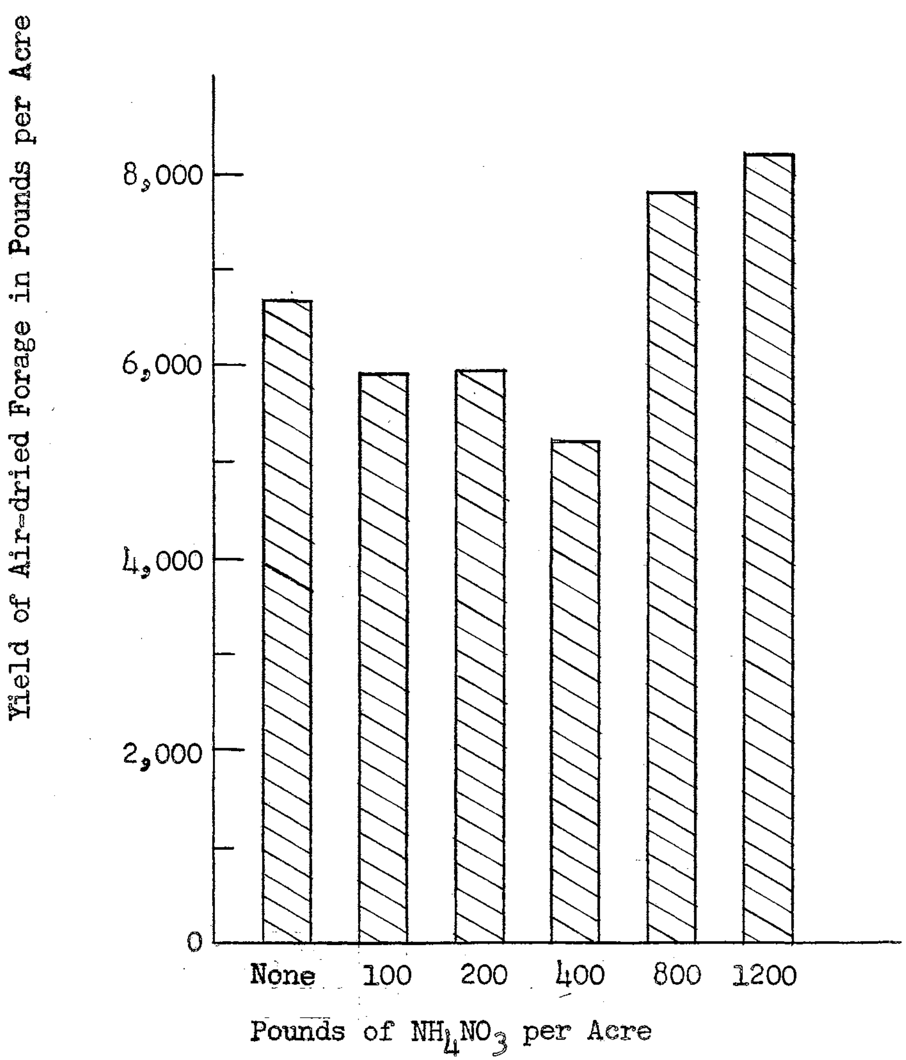
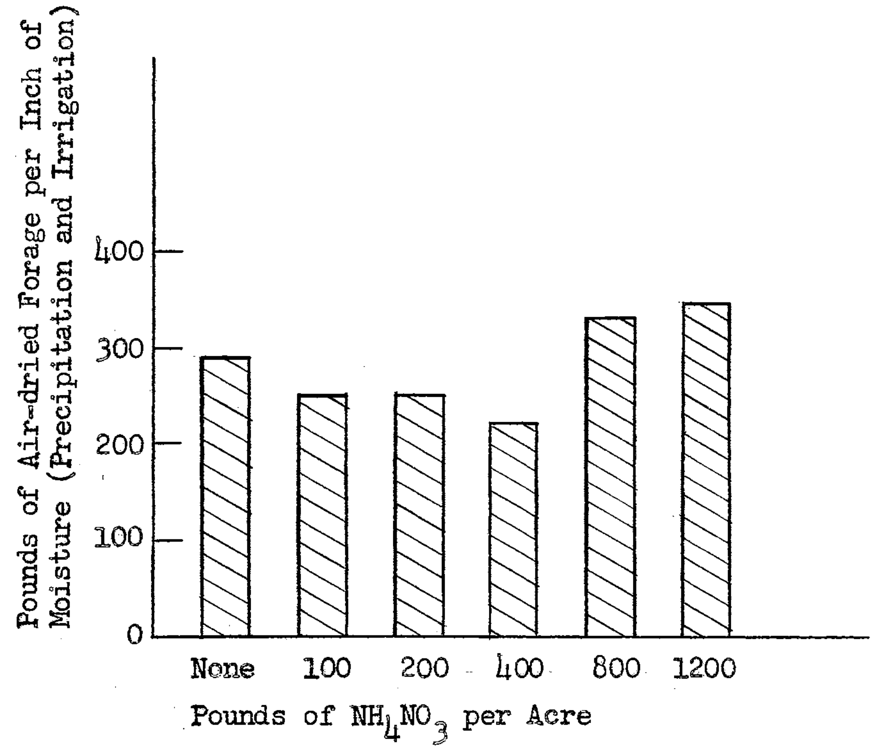


Figure 10. Pounds of Coastal Bermuda Grass Produced per Inch of Water Added with Various Nitrogen Treatments.



V. SUMMARY AND CONCLUSIONS

This study was undertaken with the objective of evaluating various factors that influence changes in soil moisture of a Foard Clay Loam under field conditions. The gypsum block electrical resistance method was used for continuous measurement of moisture in undisturbed soil at 6 and 15 inch depths throughout the growing season. The moisture studies were made on this soil type under fallow conditions with no nitrogen fertilizer added and under Coastal Bermuda grass receiving various rates of nitrogen fertilization. All experimental plots were irrigated by the sprinkler method. Relationships were studied between moisture trends in the fallow soil, the vegetated plots, forage yields with various nitrogen treatments and temperature extremes during the period of the experiment.

The trends in soil moisture content under fallow conditions were similar to that of the vegetated plots throughout the experiment with the exception of higher moisture levels in the upper six inches of the soil during the early summer months. Water movement downward following irrigation and rainfall was slower in the fallow soil than in the vegetated plots.

The application of high rates of nitrogen fertilizer did not influence greatly the need for additional soil moisture through the growing season. However, the plots receiving over 200 pounds of nitrogen were more efficient in utilizing available soil moisture.

In this study the increased rates of nitrogen fertilization did not result in corresponding increases in yields of Coastal Bermuda grass forage.

Atmospheric temperatures appeared to influence the loss of soil moisture through soil surface evaporation with equal importance as the loss of soil water by transpiration.

Results of this study indicate the need for additional research to characterize fundamental factors that influence the efficiency of irrigation and determine favorable soil management practices in irrigated agriculture.

VI. LITERATURE CITED

1. Anderson, A. B. C., and Edlefsen, N. E. Laboratory Study of the Response of 2- and 4- Electrode Plaster of Paris Blocks as Soil Moisture Content Indicators. Soil Sci., 53:413-428. 1942.

2. Ashcroft, Gaylen, and Taylor, S. A. Soil Moisture Tension as a Measure of Water Removal Rate from Soil and Its Relation to Weather Factor. Soil Sci. Soc. of Amer. Proc., 17:171-174. 1953.

3. Briggs, L. J. Electrical Instruments for Determining the Moisture, Temperature, and Soluble Salt Content of Soils. U. S. D. A., Div. of Soil, Bul. 15. 1899.

4. _____ and McLane, J. W. The Moisture Equivalent of Soils. U. S. D. A., Bur. of Soils, Bul. 45. 1907.

5. _____ and Shantz, H. L. The Wilting Coefficient for Different Plants and Its Indirect Determination. U. S. D. A., Bur. Plant Ind. Bul. 230. 1912.

6. Bouyoucos, G. J. A New Electric Automatic Irrigation System. Agron. Jour., 44:448-451. 1952.

7. _____. Directions for Making Mechanical Analysis of Soil by the Hydrometer Method. Soil Sci., 42:225-229. 1936.

8. _____. Nylon Electrical Resistance Unit for Continuous Measurement of Soil Moisture in the Field. Soil Sci., 67:319-330. 1949.

9. _____, and Mick, A. H. An Electrical Resistance Method for the Continuous Measurement of Soil Moisture under Field Conditions. Mich. Agr. Exp. Sta. Tech. Bul., 172:1-38. 1948.

10. _____, _____________ Improvement in the Plaster of Paris Absorption Block. Electrical Resistance Method for Measuring Soil Moisture under Field Conditions. Soil Sci., 63:455-465. 1947.

11. Burton, Glenn W., and Devane, Earl H. Effect of Rate and Method of applying Different Sources of Nitrogen upon the Yield and Chemical Composition of Bermuda Grass, Cynodon dactylon (L) Pers., Hay. Agron. Jour., 44:128-132. 1952.

12. Colman, E. A., and Hendrix, T. M. The Fiber Glass Electrical Soil-moisture Instrument. Soil Sci., 67:425-438. 1949.

13. Corey, A. T., and Blake, G. R. Moisture Available to Various Crops in Some New Jersey Soils. Soil Sci. Soc. of Amer. Proc., 17: 314-317. 1953.

14. Devane, Earl H., Stelly, Matthias, and Burton, Glenn W. Effect of Bermuda and Bahis Grass Sods on the Nitrogen and Organic Content of Tifton Sandy Loam. Agron. Jour., 44:176-179. 1952.

15. Edlefsen, N. E., and Smith, W. O. The Determination of Moisture in Undisturbed Soil. Soil Sci. Soc. of Amer. Proc., 8:112-115. 1943.

16. Freeman, K. C., and Beaty, Elvin. Unpublished data. Coastal Plain Branch. Exp. Sta. (Newton, Miss.). 1954.

17. Gausman, H. W., and Cowley, W. R. Response of Coastal Bermuda Grass to Fertilizer. Texas Agr. Exp. Sta. Progress Report No. 1639. 1954.

18. Haddock, Jay L. The Influence of Plant Population, Soil Moisture, and Nitrogen Fertilization on Sugar Content and Yield of Sugar Beets. Agron. Jour., 41:79-84. 1949.

19. Hagan, Robert M., and Peterson, Maurice L. Soil Moisture Extraction by Irrigated Pasture Mixtures as Influenced by Clipping Frequency. Agron. Jour., 45:288-292. 1953.

20. Harlan, Jack R., and Kneebone, William R. Effects of Various Methods and Rates of Nitrogen Application on Seed Yields of Switchgrass. (Panicum virgatum L.) Agron. Jour., 45:385-386. 1953.

21. Harper, H. J. Tentative Methods for the Analysis of Soil and Plant Material. Oklahoma A. and M. College. 1948.

22. Holt, E. C., Potts R. C., and Fudge, J. F. Bermuda Grass Research in Texas. Tex. Agr. Exp. Sta. Cir. 129. 1951.

23. Hubbard, V. C., and Harper, H. J. Effect of Clipping Small Grains on Composition and Yield of Forage and Grain. Agron. Jour., 41:85-92. 1942.

24. Kelley, O. J. A Rapid Method of Calibrating Various Instruments for Measuring Soil Moisture in Situ. Soil Sci., 58:433-440. 1940.

25. ________, Hunter, A. S., Haise, H. R., and Hobbs, C. H. A Comparison of Methods of Measuring Soil Moisture under Field Conditions. Jour. Amer. Soc. Agron., 38:759-784. 1946.

26. Korty, B. L., and Kohnke, H. Recording Soil Moisture Automatically. Soil Sci. Soc. of Amer. Proc., 17:307-310. 1953.

27. Peele, T. C., and Beale, O. W. Relation of Moisture Equivalent to Field Capacity and Moisture Retained at 15 Atmospheres Pressure to the Wilting Percentage. Agron. Jour., 42:604-607. 1950.

28. Peterson, Maurice L. and Hagan, Robert M. Production and Quality of Irrigated Pastures Mixtures as Influenced by Clipping Frequency. Agron. Jour., 45:283-287. 1953.

29. Robertson, D. W. Irrigated Agriculture. Agron. Jour., 44:597-602. 1952.

30. Scofield, C. S. The Measurement of Soil Water. Jour. Agr. Res., 71:375-402. 1945.

31. Slater, C. S., and Bryant, J. C. Comparison of Four Methods of Soil Moisture Measurements. Soil Sci., 61:131-156. 1946.

32. Tanner, C. B., Abrams, E., and Zubrizki, J. C. Gypsum Moisture-block Calibration Based on Electrical Conductivity in Distilled Water. Soil Sci. Soc. of Amer. Proc., 13:62-65. 1949.

33. ______________, and Hanks, R. J. Moisture Hysteresis in Gypsum Moisture Blocks. Soil Sci. Soc. of Amer. Proc., 16:48-51. 1952.

34. U. S. D. A. Soils and Man, Yearbook of Agriculture, Soils of the United States. P. 1087-1088. 1938.

35. U. S. D. C. Climatological Data. Oklahoma Vol. LXII. 1953.

36. Veihmeyer, F. J., and Hendrickson, A. H. Methods of Measuring Field Capacity and Permanent Wilting Percentage of Soils. Soil Sci., 68:75-94. 1949.

37. ______________ and ______________ Some Plant and Soil Moisture Relations. Amer. Soil. Sur. Assoc. Bul. 15:76-80. 1933.

38. ________ and________. The Moisture Equivalent as a Measure of the Field Capacity of Soils. Soil Sci., 32:181-193. 1931.

39. Weaver, H. A., and Jamison, V. C. Limitations in the Use of Electrical Resistance Soil Moisture Units. Agron. Jour., 43:602-605. 1951.

40. Whitney, Melton, Gardner, F. D., and Briggs, L. J. An Electrical Method of Determining the Moisture Content of Arable Soils. U. S. D. A., Div. of Soils, Bul. 6. 1897.

APPENDIX

VII. APPENDIX

Table 4. Temperature Extremes, Water Added, and Soil Moisture Content of Experimental Plots.

Date	Temperature Max. (%)	Temperature Min. (%)	Water Added Inches (2)	Plot 1 Soil Moisture (3) 6 In. %	Plot 1 Soil Moisture (3) 15 In. %	Plot 2 Soil Moisture (3) 6 In. %	Plot 2 Soil Moisture (3) 15 In. %	Plot 3 Soil Moisture (3) 6 In. %	Plot 3 Soil Moisture (3) 15 In. %
June 1	98	65	--	38.9	39.6	36.1	36.1	37.7	39.6
10	96	67	3.78	39.9	39.3	38.6	38.9	38.8	39.6
11	99	70	--	39.3	39.3	38.5	38.7	37.7	38.9
12	100	70	--	38.9	39.3	33.9	38.6	32.3	39.3
15	104	70	--	38.7	38.8	22.2	33.3	14.2	38.9
16	99	73	--	38.5	38.9	15.4	12.2	12.2	29.6
17	100	73	--	35.3	38.6	10.9	37.3	6.3	38.9
20	102	73	3.00	14.8	16.4	35.3	37.7	36.9	34.2
21	104	78	--	34.2	36.9	35.3	36.1	26.9	38.5
22	100	75	--	38.6	38.7	34.5	36.1	34.5	39.0
24	103	74	--	38.7	38.9	33.6	35.3	28.7	39.0
26	101	76	--	37.7	37.7	25.4	33.3	19.8	28.0
28	100	73	--	34.2	32.8	15.4	29.3	7.2	36.1
July 2	91	69	1.31	38.5	23.6	38.5	24.9	33.3	26.0
3	98	72	--	38.6	23.6	31.0	32.9	29.6	24.2
4	99	74	--	37.7	17.1	27.5	19.8	25.1	18.0
6	101	74	3.00	33.9	14.8	21.0	10.9	7.3	12.2
22	90	67	3.13	38.9	36.1	35.3	36.1	36.9	38.6
24	91	71	0.09	38.5	39.3	35.3	37.7	38.5	38.9
27	93	69	--	38.5	38.9	36.1	37.7	35.3	38.8
29	96	68	--	34.5	38.7	29.9	36.9	31.0	38.8
31	99	71	--	30.9	38.5	24.2	36.1	25.2	27.7
Aug. 3	99	72	--	25.1	32.6	14.2	30.6	15.4	33.3
9	95	69	4.29	36.1	38.6	34.2	36.9	35.3	38.9
11	105	69	--	38.5	38.5	33.6	35.3	33.3	38.6
15	95	67	0.23	33.3	37.7	28.7	33.9	30.6	38.7
21	87	65	1.23	31.0	34.2	33.6	34.5	34.2	38.6
25	91	63	0.50	25.6	32.8	35.3	33.6	33.9	38.5
28	92	64	--	24.2	26.6	31.0	33.3	33.0	37.7
30	92	67	--	18.0	24.2	26.6	32.4	29.3	26.6
Sept. 1	94	66	--	14.2	19.3	23.9	31.0	25.6	34.5
6	86	57	--	9.7	10.9	9.7	28.2	19.3	32.8
8	98	55	--	9.7	9.7	7.2	26.0	14.2	28.7
10	97	59	--	8.6	9.7	6.2	24.9	9.7	25.8
13	94	57	--	8.6	9.7	6.1	8.6	6.1	10.9
15	101	55	--	8.6	9.7	5.9	12.2	5.5	7.2
17	98	56	--	7.0	9.7	4.8	8.6	5.5	6.5
20	97	59	--	7.0	9.7	4.3	6.2	4.2	6.1
25	89	59	3.00	12.2	14.2	29.3	31.0	30.3	33.6
27	103	63	--	32.6	33.0	30.6	32.8	32.3	33.0
29	103	55	--	32.6	33.9	28.7	31.0	30.3	33.3

1. Average of the daily temperatures between reading dates. (35)
2. Listed on the next reading date after the water was added, except July 6 and it is listed on the date applied.
3. Converted from readings in ohms.

Table 4. Temperature Extremes, Water Added, and Soil Moisture Content of Experimental Plots (continued)

Date	Temperature Max. (1)	Temperature Min. (1)	Water Added Inches (2)	Plot 6 Soil Moisture (3) 6 In. %	Plot 6 Soil Moisture (3) 15 In. %	Plot 7 Soil Moisture (3) 6 In. %	Plot 7 Soil Moisture (3) 15 In. %
June 1	98	65	--	39.9	39.6	38.9	40.2
10	96	67	3.78	40.5	39.6	39.3	39.6
11	99	70	--	39.9	39.3	38.9	39.9
12	100	70	--	39.6	39.3	38.7	39.3
15	104	70	--	18.6	38.8	23.9	38.9
16	99	73	--	10.5	38.6	16.4	38.8
17	100	73	--	6.2	36.1	8.6	36.1
20	102	73	3.00	39.6	38.9	38.7	39.9
21	104	78	--	39.6	38.7	38.7	40.2
22	100	75	--	39.0	38.7	36.9	40.2
24	103	74	--	34.5	38.9	29.3	39.6
26	101	76	--	28.4	38.9	15.4	38.8
28	100	73	--	8.6	32.4	6.2	23.6
July 2	91	69	1.31	40.5	25.4	38.7	14.2
3	98	72	--	40.5	25.2	33.3	10.9
4	99	74	--	39.0	21.7	29.0	9.7
6	101	74	3.00	22.7	9.7	12.2	6.2
22	90	67	3.13	34.5	36.9	34.5	36.9
24	91	71	0.09	36.1	37.7	37.7	37.7
27	93	69	--	26.1	38.6	30.6	37.7
29	96	68	--	34.5	37.7	26.6	37.7
31	99	71	--	27.5	33.3	18.3	28.7
Aug. 3	99	72	--	18.6	29.9	8.6	26.2
9	95	69	4.29	36.1	38.5	33.6	27.7
11	105	69	--	36.1	37.7	32.8	35.3
15	95	67	0.23	31.0	33.9	26.0	33.3
21	87	65	1.23	34.2	36.9	32.8	35.2
25	91	63	0.50	33.9	33.9	32.4	34.2
28	92	64	--	33.0	33.0	29.3	33.6
30	92	67	--	28.4	31.0	33.6	31.0
Sept. 1	94	66	--	24.0	26.6	22.2	29.3
6	86	57	--	9.7	19.1	12.2	25.1
8	98	55	--	7.2	12.2	8.6	21.7
10	97	59	--	6.2	9.7	6.2	18.3
13	94	57	--	6.1	6.2	6.1	9.7
15	101	55	--	6.1	6.1	4.3	7.2
17	98	56	--	6.1	6.1	4.3	7.2
20	97	59	--	4.3	6.1	3.0	6.1
25	98	59	3.00	32.8	33.0	31.1	32.8
27	103	63	--	33.0	32.6	32.8	32.3
29	103	55	--	32.8	32.4	29.9	32.8

1. Average of the daily temperatures between reading dates. (35)
2. Listed on the next reading date after water was added, except July 6 and it is listed on the date applied.
3. Converted from readings in ohms.

Table 4. Temperature Extremes, Water Added, and Soil Moisture Content of Experimental Plots. (continued)

Date	Temperature		Water Added	Plot 4 Soil Moisture (3)		Plot 5 Soil Moisture (3)	
	Max.	Min.	Inches	6 In.	15 In.	6 In.	15 In.
	(1)		(2)	%	%	%	%
June 1	98	65	--	36.7	39.9	36.1	39.3
10	96	67	3.78	38.8	38.9	39.3	39.9
11	99	70	--	38.5	39.0	38.8	39.3
12	100	70	--	36.1	38.9	38.7	38.9
15	104	70	--	21.0	25.8	23.9	38.7
16	99	73	--	18.3	16.4	14.2	38.5
17	100	73	--	10.9	7.2	10.9	36.1
20	102	73	3.00	32.3	38.6	19.8	21.0
21	104	78	--	35.3	38.8	38.5	38.7
22	100	75	--	34.2	38.8	36.1	38.9
24	103	74	--	28.2	35.3	25.2	36.1
26	101	76	--	19.2	28.2	8.6	10.9
28	100	73	--	8.6	12.2	8.6	8.6
July 2	91	69	1.31	32.6	8.6	33.3	8.6
2	98	72	--	28.4	8.6	28.0	8.6
4	99	74	--	25.6	8.6	23.6	7.2
6	101	74	3.00	14.2	6.2	8.6	6.1
22	90	67	3.13	34.2	35.3	36.1	33.6
24	91	71	0.09	35.3	36.9	35.3	34.5
27	93	69	--	33.3	37.7	32.4	34.2
29	96	68	--	39.3	35.3	25.2	31.0
31	99	71	--	28.1	31.0	18.0	26.0
Aug. 3	99	72	--	14.2	24.9	8.6	19.3
9	95	69	4.29	35.3	36.9	34.2	36.1
11	105	69	--	34.5	36.9	33.9	35.3
15	95	67	0.23	29.3	33.9	29.3	33.6
21	87	65	1.23	33.6	36.1	33.3	34.2
25	91	63	0.50	33.9	34.5	33.0	33.0
28	92	64	--	32.4	33.6	28.2	31.0
30	92	67	--	27.5	32.6	23.9	28.4
Sept. 1	94	66	--	24.9	29.6	18.0	25.4
6	86	57	--	14.2	24.9	10.9	26.4
8	98	55	--	10.9	19.8	6.2	10.9
10	97	59	--	7.3	14.8	6.1	8.6
13	94	57	--	6.1	8.6	4.2	6.2
15	101	55	--	6.1	6.5	4.2	6.1
17	98	56	--	4.3	6.1	4.2	6.1
20	97	59	--	4.3	6.1	4.2	4.2
25	89	59	3.00	31.0	32.6	31.0	33.0
27	103	63	--	32.4	33.0	32.8	33.0
29	103	55	--	31.0	32.6	31.0	32.6

1. Average of the daily temperatures between reading dates. (35)
2. Listed on the next reading date after the water was added, except July 6 and it is listed on the date applied.
3. Converted from readings in ohms.

VITA

DONALD P. PROPHET
candidate for the degree of
Master of Science

Thesis: SOIL MOISTURE STUDIES WITH COASTAL BERMUDA GRASS RECEIVING VARIOUS NITROGEN FERTILIZER TREATMENTS

Major: Soils

Biographical and other Items:

Born: July 3, 1918 at Buffalo, Oklahoma

Undergraduate Study: Northwestern State College, Alva, Oklahoma, 1938-1940; Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma, 1945-1947

Graduate Study: Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma, 1949-1954

Experience: Reared on a farm; United States Army, 1940-1945; Laboratory technician (student), Oklahoma Soil Conservation Laboratory, Stillwater, Oklahoma, 1946-1947; Instructor of Agronomy, Cameron State Agricultural College, Lawton, Oklahoma, 1947-1954

Member in the Agronomy Club, Sponsor of the Aggie Club, Cameron State Agricultural College, Lawton, Oklahoma

Date of Final Examination: January, 1955

THESIS TITLE: SOIL MOISTURE STUDIES WITH COASTAL BERMUDA GRASS RECEIVING VARIOUS NITROGEN FERTILIZER TREATMENTS

AUTHOR: Donald P. Prophet

THESIS ADVISER: Dr. J. Q. Lynd

The content and form have been checked and approved by the author and thesis adviser. The Graduate School Office assumes no responsibility for errors either in form or content. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: E. Grace Peebles