AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

# BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
0082

**1. SUBJECT CLASSIFICATION**

A. PRIMARY: Agriculture — AP12-0000-G476

B. SECONDARY: Drainage and irrigation--Cereals--Maize--Utah

**2. TITLE AND SUBTITLE**

A field evaluation of water used under trickle irrigation

**3. AUTHOR(S)**

Lavin,A.R.

| 4. DOCUMENT DATE | 5. NUMBER OF PAGES | 6. ARC NUMBER |
|---|---|---|
| 1971 | 92p. | ARC 631.7072.L412 |

**7. REFERENCE ORGANIZATION NAME AND ADDRESS**

Utah State

**8. SUPPLEMENTARY NOTES** *(Sponsoring Organization, Publishers, Availability)*

(Thesis M.S.--Utah State)

**9. ABSTRACT**

**10. CONTROL NUMBER**

PN-RAA-031

**11. PRICE OF DOCUMENT**

**12. DESCRIPTORS**

Field tests
Maize
Trickle irrigation
Utah,USA

**13. PROJECT NUMBER**

**14. CONTRACT NUMBER**

CSD-2167 Res.

**15. TYPE OF DOCUMENT**

AID 590-1 (4-74)

# A FIELD EVALUATION OF WATER USED UNDER TRICKLE IRRIGATION

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Irrigation Engineering

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1971

# ACKNOWLEDGEMENT

The author wishes to give thanks to the members of his committee, Dr. R. John Hanks, Dr. Larry G. King and Dr. Komain Unhanand, Thesis Director, for their technical help and encouragement to improve this work.

I would like especially to thank Dr. Jack Keller who gave me the idea for this research.

The author appreciates the help of Paul A. Mariani who supplied the trickle irrigation system used in this research.

Mrs. Gay Bernstein was indispensable as typist.

Finally, I dedicate this work to my parents Dr. Alfonso Ramirez Galindo and Mrs. Rosa Lavin de Ramirez Galindo for their moral support which enabled me to complete this degree.

Alfonso Ramirez Lavin

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# ABSTRACT

A Field Evaluation of Water Used Under Trickle Irrigation

by

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Utah State University, 1970

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Department: Agricultural and Irrigation Engineering

A field study was conducted with the purpose of evaluating the water used by sweet corn under trickle irrigation. The experiment was organized using a completely randomized block design.

The experimental area consisted of 24 plots on which 4 replications of 6 treatments were conducted. The amount of water applied by trickle irrigation in each treatment varied from 0, 40, 60, 80, 100, and 120 percent of the evapotranspiration computed by using data obtained from lysimeters.

The experimental data were analyzed by the analysis of variance (ANOVA) method which indicated that there was no significant difference of yields or water used due to treatments. However, the study revealed that the particular trickle irrigation system was simple to operate and the discharge of trickler was uniform requiring no adjustment during the entire experiment.

(85 pages)

# INTRODUCTION

Since there is a scarcity of water for irrigation in many parts of the world, a problem which everyday is becoming more important and difficult to solve, many attempts have been made by researchers to obtain information leading to a more efficient use of water which will, eventually, result in a development of an irrigation system contributing to the conservation of water. A new method of irrigation, based on an old concept of watering crops daily has been introduced. This method has been called "trickle irrigation."

Trickle irrigation systems consist of pipe lines with laterals equipped with special devices called tricklers or drippers which supply the water to the plant by dripping continuously or intermittently into a somewhat restricted region of soil around the plant. In this system the water is fed in a quantity which will maintain the water content in most parts of the root zone somewhere between field capacity and saturation.

Some of the numerous advantages claimed to be achieved by this new method of irrigation are as follows:

1. Significant water savings is an advantage stated in most of the literature on trickle irrigation. This is because not all of the surface is wetted, thus the evaporation from soil surface is minimized and wind drift losses of water do not occur in this system.

2. Increase in yield because a high water content is maintained in most parts of root zone.

3. The inter-row spaces remain dry which facilitates the spraying and harvesting operation, and reduces water losses to deep percolation, as well as evaporation. Furthermore, weed growth is greatly reduced and hence there is correspondingly less cultivation cost.

4. Manual labor is reduced below needs of most other irrigation methods, since the only labor involved is switching the system on and off and making periodical inspections to check the uniformity of discharge of each trickler.

5. Fertilizer can be dissolved in the irrigation water and fed directly into the root zone.

6. Water containing a considerably high salt content may be used to irrigate the plant without sacrificing reduction in yield.

Some disadvantages of this system are as follows:

1. High initial costs.

2. In some designs the discharge is not uniform from one trickler to another and needs adjustments.

3. The system has little advantage for crops solidly planted.

4. Considerable piping in the field makes mechanical cultivation difficult.

5. Requires nearly constant supply of water.

There is literature describing and discussing advantages and possible problems of this system; however, the information on the amount

of water which can be saved by using a trickle irrigation system has not been firmly established. Such information is needed in evaluation of the system. For this reason a study to investigate trickle irrigation was initiated and will be presented in this thesis.

The objectives of the study were:

1. To evaluate crop response to different levels of water application using a trickle irrigation system.

2. To determine if there was a significant saving of water by the use of this system and how much water was saved.

3. To evaluate the trickle irrigation system.

# REVIEW OF LITERATURE

## Development of Trickle Irrigation

Larkman (1969) defined trickle irrigation as the daily maintenance of an adequate section of the root zone of a plant at, or close to, field capacity for the duration of the growing season. Blass (1969) started to work on this method in 1959 by installing a small stainless steel tap at each tree and digging a circular, level-bottomed ditch around the tree. The ditch was then filled with gravel and covered with local soil. He encountered the problem of clogging of the taps by salts present in irrigation water and clogging of the spaces between the gravel particles by soil. This problem was partly solved by Isaiah (Blass, 1969) who introduced the idea of using a long capillary tube whose friction was large enough to allow only a small quantity of water to leave the pipe. However, Goldberg and Shmueli (1969) mentioned that burying the trickler lateral entained loss of control over system operation since blockage of the orifices, mainly by plant roots, often went undetected for some time. Zohar (Blass, 1969) was the first who laid the pipes on the surface instead of burying the installation underground. This way a more simple control which resulted in a more efficient performance was obtained.

The buried system is similar to sub-irrigation or sub-surface irrigation developed in the United States and other countries as reported by Davis and Nelson (1970). Considerable research has been conducted on the system.

Gustafson (1970a), Larkman (1969), Enciso and Lavin (1970) stated that the developmental work on this concept was not confined to Israel. Other countries such as England, Italy, Denmark, Australia, Japan, Mexico and the United States have been working on trickle irrigation to be applied to various crops under both field and greenhouse conditions.

Description of the System

A trickle irrigation system normally consists of the following parts (Driplex Manual, 1970):

1. A main unit or head unit joint which is directly connected to a source of water supply. The main unit usually consists of filters, control valves, water meter, pressure regulator and connection to a device for application of fertilizer in the irrigation water.

2. Main pipes of which the diameter is determined by the required discharge and other related factors. The main pipe is connected to the head unit.

3. Sub-mains which are pipes with branches where the laterals are inserted.

4. Laterals which are pipes of small diameter fitted with tricklers or drippers.

5. Tricklers or drippers which are devices allowing water, under pressure in laterals, to discharge into the root zone of crops normally in a drip form. Attention was initially directed toward the use of

microtubes having a bore of the order of 0.020 inch to a 0.030 inch for tricklers. The purpose of the microtube was to control the flow of the water onto the ground in drops. Further work showed that a more robust and accurate method of controlling flow was to pass the water through a plastical spiral called a dripper or trickler. Those tricklers were placed at calculated intervals along the planting rows and water dripped onto the ground to produce a particular wetting pattern for each soil and crop.

Table 1 shows the most commonly used tricklers and their characteristics (Mexican Ministry of Water Resources, 1970). From the table it may be observed that there are two main types of tricklers: manually operated and automatic type.

Advantages of the System

Enciso and Lavin (1970), Goldberg (1969), Gustafson (1970a) and Larkman (1969) indicated advantages of the trickle irrigation as follows:

1. Significant water savings.

2. Increase in yield and a better quality of crop (Table 2).

3. Requires small source of water supply. (Each trickler usually discharges approximately 1.0 cubic centimeter per second.)

4. Water with a high content of salts may be used to give better yields in comparison with other methods of irrigation.

Table 1. Different Tricklers and Their Main Characteristics

| Type of Trickler | Operation | Working Pressure (pounds per square inch) | Discharge (gallons per hour) | Observations |
|---|---|---|---|---|
| VENOCLYSIS with restrictor | Manual | 1.42 - 14.2 | 0.13 - 2.1 | The regulation is a major problem because it is necessary to adjust each trickler to obtain the discharge desired. The pipe material should be of black color to avoid the formation of algae. Uniformity of discharge is difficult to obtain. |
| SALTILLO (Mexican designed trickler | Manual | 1.42 - 14.2 | 0.13 - 2.1 | The main problem is the regulation of discharge because each trickler has to be adjusted to the desired discharge. As a result, good uniformity is hardly obtained. |
| SALCO (USA designed trickler) | Manual | 1.42 - 14.2 | 0.13 - 2.1 | It is necessary to make a regulation and calibration of each trickler at the beginning of the irrigation and each time the system is switched on and off. This involves excessive labor, and uniform discharge is rarely obtained. |
| CAPILLARY TUBE | Automatic | 1.42 - 14.2 | 0.07 - 2.1 | Very elastic. Information about its operation and uniformity of discharge are not available. |

Table 1. Different Tricklers and Their Main Characteristics (Continued)

| Type of Trickler | Operation | Working Pressure (pounds per square inch) | Discharge (gallons per hour) | Observations |
|---|---|---|---|---|
| ISRAEL | Automatic | 14.3 | 0.5 - 1.0 | The lateral has to be cut in small lengths to accommodate the tricklers. As a result, the spacing is fixed and cannot be changed. |
| AUSTRALIAN | Automatic | 20 | 0.5 - 1.0 | The pipe has to be cut in small lengths to accommodate the tricklers in the same manner as in the Israeli design. |
| SUBTERRAIN EMITTER (USA) | Automatic | 20-40 | 0.5 - 2.0 | The main problem is the high working pressure. But there is an advantage in that the discharge through the emitter is proportional to the square root of the head which makes it possible to lay the system on a hilly area where the pressure at emitters may vary without having large variation in discharge. |

Table 2. Yields of Crops Under Trickle, Sprinkler, and Furrow Irrigation

| Crop | Period of Growth | Irrigation Water Applied (inches) | Yields (tons/acre) | | |
|---|---|---|---|---|---|
| | | | Trickle | Sprinkler | Furrow* |
| Tomatoes | September to March | 38.7 | 26.0 | 15.6 | - - |
| Cucumbers | September to December | 26.4 | 19.6 | No yield | - - |
| Musk Melons | August to December | 25.8 | 17.2 | 9.6 | 9.6 |
| Peppers** | September to March | 55.8 | 3.8 | 1.9 | - - |
| Sweet Corn | February to May | 26.6 | 4.9 | 2.1 | - - |

*Furrow irrigation trials only carried out on musk melons.

**In the months of December and January the peppers were grown under plastic covers.

5. Control of weed growth between rows.

6. The fertilizer can be injected in the irrigation water and applied directly to crops at the same time that irrigation is given.

7. The irrigation can be carried out continuously 24 hours a day.

8. Accelerates growth in young trees or plants.

9. Far less labor involved in operation, especially when the trickle system is equipped with an automatic regulation in which the only labor required is to switch the system on and off and make periodical inspection of drippers or tricklers.

Disadvantages of the system have not been reported in any literature reviewed; however, by analyzing Table 1 some disadvantages can be observed in the regulation of the tricklers to obtain the desirable discharge and the non-uniformity of discharge in some tricklers.

Recent Studies in Trickle Irrigation

Branson (1970) explained in a theoretical way the movement of salts into soils under different types of irrigation. He pointed out that trickle irrigation, like any other method of irrigation, has its potential salinity problems. But he believed that with proper water and soil management, salinity damage can be prevented. He concluded that trickle irrigation provides a convenient method of maintaining soil moisture at a relatively high level. Thus the soluble salts in the soil are diluted more than is normally the case under conventional methods of irrigation which

make it possible to use water with high salt contents without damaging the crop. Goldberg, Gornat, Shmueli, Ben-Asher, and Rinot (1970) conducted a study in Israel to determine the effect of saline water applied to corn and tomatoes using various methods of irrigation. The results of their study are summarized as follows:

1. When saline water having electrical conductivity of 3000-3600 mmhos per cm was used to grow pepper, cucumber, tomato, and muskmelon, it was found that the yield from trickling was at least 66 percent higher than those by sprinkling for all crops.

2. The study of effect of irrigation method on growth and yield of corn when using waters of different quality indicated that the yield from trickle irrigation with a salinity level of 3000 micromhos per cm was equal to that obtained by sprinkling with the non-saline water. Goldberg et al. (1970) explained that the use of water of high salinity was possible because the trickle irrigation method had provided the possibility of controlling the moisture regime in the soil such that the amplitude of matric and osmotic potential fluctuation during the irrigation cycle remains within a favorable range for crop growth.

Voth (1970) showed a comparison of water used and yields when trickle and furrow irrigation were used for strawberries. Table 3 shows that with trickle irrigation the amount of water used is less than that used by furrow, and the yields are better with tricklers than with furrows.

Table 3. Comparison Between Trickle and Furrow Irrigation Using a Strawberry Crop

| Irrigation System | Acre Feet of Water | Conductivity mmhos/cm | | Yield in Grams/Plant | | Fruit Size* |
|---|---|---|---|---|---|---|
| | | Dec | July | Mar-Apr | May-June | |
| Standard furrow | 2.20 | 4.63 | 5.64 | 246 | 131 | 14.8 |
| Trickler irrigation | 0.95 | 4.22 | 1.86 | 244 | 188 | 15.6 |

*Unit is not given in the original paper.

Besemer (1970), Breece (1970), Gustafson (1970b) and Hall (1970) have reported many advantages of trickle irrigation under field plot experiments, such as increase in yields and improved quality of crops using vegetables, flowers, turf and citrus.

Moisture Content in the Root Zone

Enciso and Lavin (1970) defined the purpose of trickle irrigation as the daily maintenance of an adequate section of the root zone of a plant at or close to field capacity for the duration of the growing season. In order to accomplish this, reliable information on moisture condition in the soil as well as the rooting volume to be wetted, must be available. From such information the moisture consumed by the crop and the quantity of water to be added to maintain the moisture in the soil at field capacity could be estimated.

Lysimeter and neutron meters have been used to obtain information on the moisture consumed by the crop and the moisture condition in the soil.

Lysimeter

Tanner (1967) defined a lysimeter as a device in which a volume of soil, which may be planted with vegetation, is located in a container to isolate it hydrologically from the surrounding soil. It allows for accurate measurements of evapotranspiration from the soil and plants inside the lysimeter. It is of utmost importance that the lysimeter must be representative of the surrounding soil (thermal, moisture, and mech-

anical properties) and vegetation (height, density, physiological well-being). He also listed major factors affecting design of a lysimeter which include the type of measurements, whether maximum possible potential evapotranspiration, surface depth, under given micrometeorological conditions or measurements of actual evapotranspiration, surface depth, including periods of drouth are needed, the structure of vegetation and of the roots, and the period over which the evapotranspiration is to be measured. The lysimeters may be classified according to the design principle into two types: nonweighing and weighing lysimeters.

Rose (1969) stated that Slatyer and McIlroy (1961) had discussed important factors affecting the design of the installation of the weighing lysimeter. According to Rose, development in simplicity and accuracy in weighing lysimeters is still taking place. In some existing installations an accuracy in evaporation measurement equivalent to 0.002 cm rainfall can be achieved.

Hanks (1965 and 1969) described an economical lysimeter and a lysimeter for continuous recording of evapotranspiration. An economical lysimeter consists of an outer tank which is used to retain the soil around the lysimeter installation such that the inner tank can rest independently on rubber bags. A tube is connected to the rubber bags so that the change in pressure of the fluid in the rubber bags is indicated

by the change in the fluid level in the tube. With the known change of pressure in the rubber bags and the area of contact between the inner tank and the rubber bags, the change in weight of the inner tank may be computed. The lysimeter for continuous recording of evapotranspiration is constructed in a similar and economical way, but a pressure cell with a continuous recorder is used for recording pressure in the rubber bags instead of a tube.

Neutron Meter

A neutron meter is used to obtain measurements of water content of the soil. This method of measuring water content of the soil was used in this research, since already the neutron meter was available in the Soils and Meteorology Department at Utah State University, and was calibrated for the soil in the farm where the research was conducted.

Holmes, Taylor and Richards (1967) stated that the neutron meter was used extensively in the field for measuring water content of the soil. Rose (1966) described a neutron meter as a device consisting of a source of fast neutrons which is usually a mixture of radium and beryllium and a slow neutron detector or scaler which is an electronic counter. Fast neutrons emitted into the soil are slowed down principally by hydrogen nuclei, and thus by water in the soil. The flux of slow neutrons is most strongly affected by the water content of the soil. Thus for a particular source and detector, there exists a relationship between

slow neutron count rate and volumetric water content of a soil. Holmes, Taylor and Richards (1967) advised that the meter should be calibrated for each soil and showed a calibration curve in the following form:

$$r_\theta = r_1 \times \theta \times F$$

where

$r_\theta$ is the counting rate at the water content $\theta$

$r_1$ is the counting rate in an access tube in pure water

$F$ is an empirical factor

$\theta$ is the moisture content.

Taylor, Evans and Kemper (1961) described the portable neutron scattering equipment as being practically a counting unit and probe unit. Both units may be enclosed in the same container, which can be lowered down the hole with the electric cable supplying power to the detector and transmitting the pulses from it to the electronic counter.

# PROCEDURE

## Location of Research Field

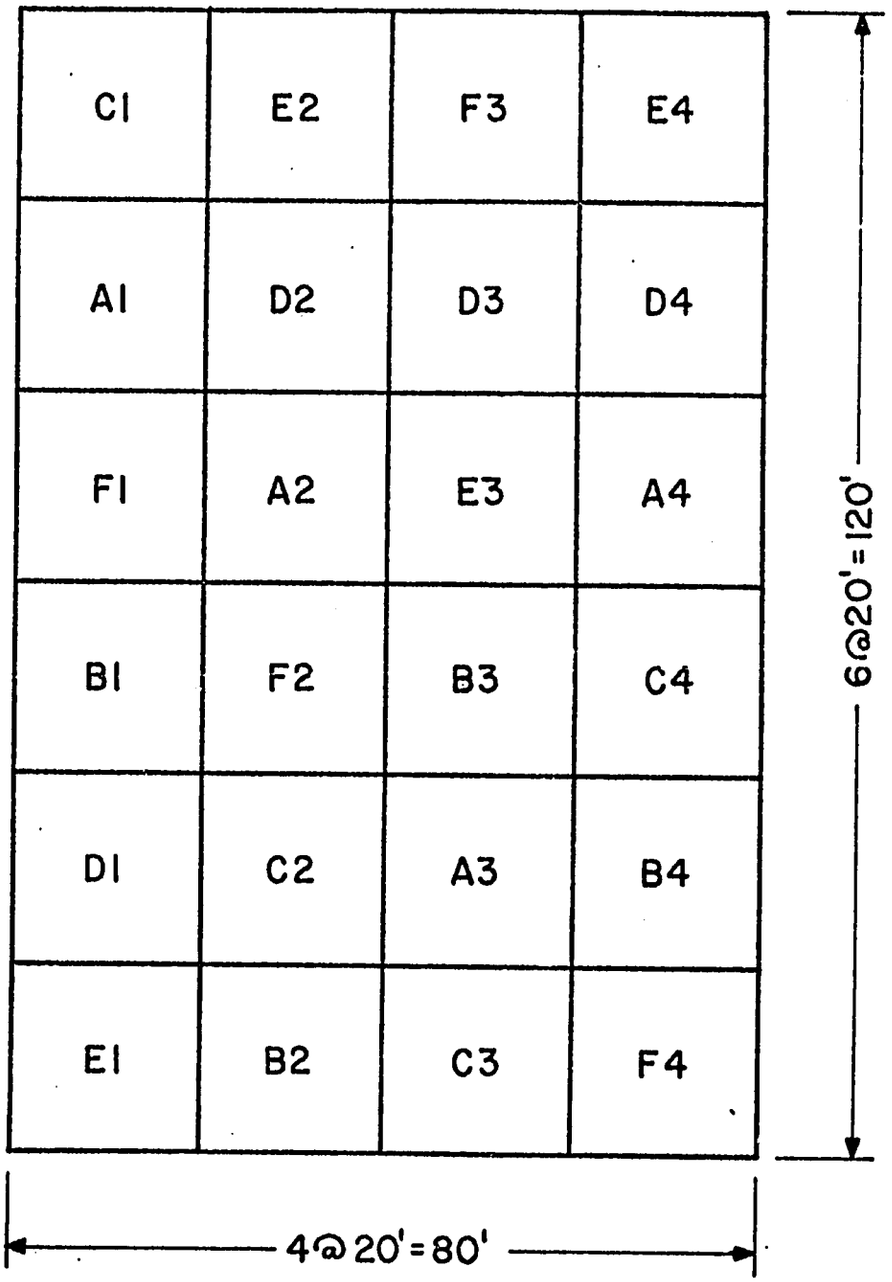
The experiment was conducted on the university farm located in North Logan, Utah. The soil may be described as Millvile silt loam, moderately well drained with 1 to 3 percent surface slopes. Detailed description of the farm location and soil properties are cited in Appendix A.

## Design of Experimental Plots

The layout of experimental plots used in this research was designed by applying a completely randomized block design method using four repetitions with six treatments. This method of experimental design was chosen to minimize the effect of variability in soil fertility and other factors affecting plant growth such as the differences in level of water table, soil profile, etc. (See Figure 1.) The research area was rectangular in plan with a dimension of 80 by 120 feet and was divided into 24 plots, each one 20 feet long and 20 feet wide. The treatments were achieved by applying water to the plant by trickle irrigation in the amount equal to 0, 40, 60, 80, 100, and 120 percent of actual evapotranspiration.

## Crop Used in Research

Sweet corn was selected for use in the research. It was planted with a spacing of 36 inches between rows, giving six 20-feet long




Note: The initials A, B, C, D, E, and F designate the treatment of the plots as described in Table 4.

Figure 1. Plan of Research Plots Using Randomized Block Design

rows of corn per plot. The planting date was June 15, 1970, and the harvest date was September 17, 1970.

Equipment

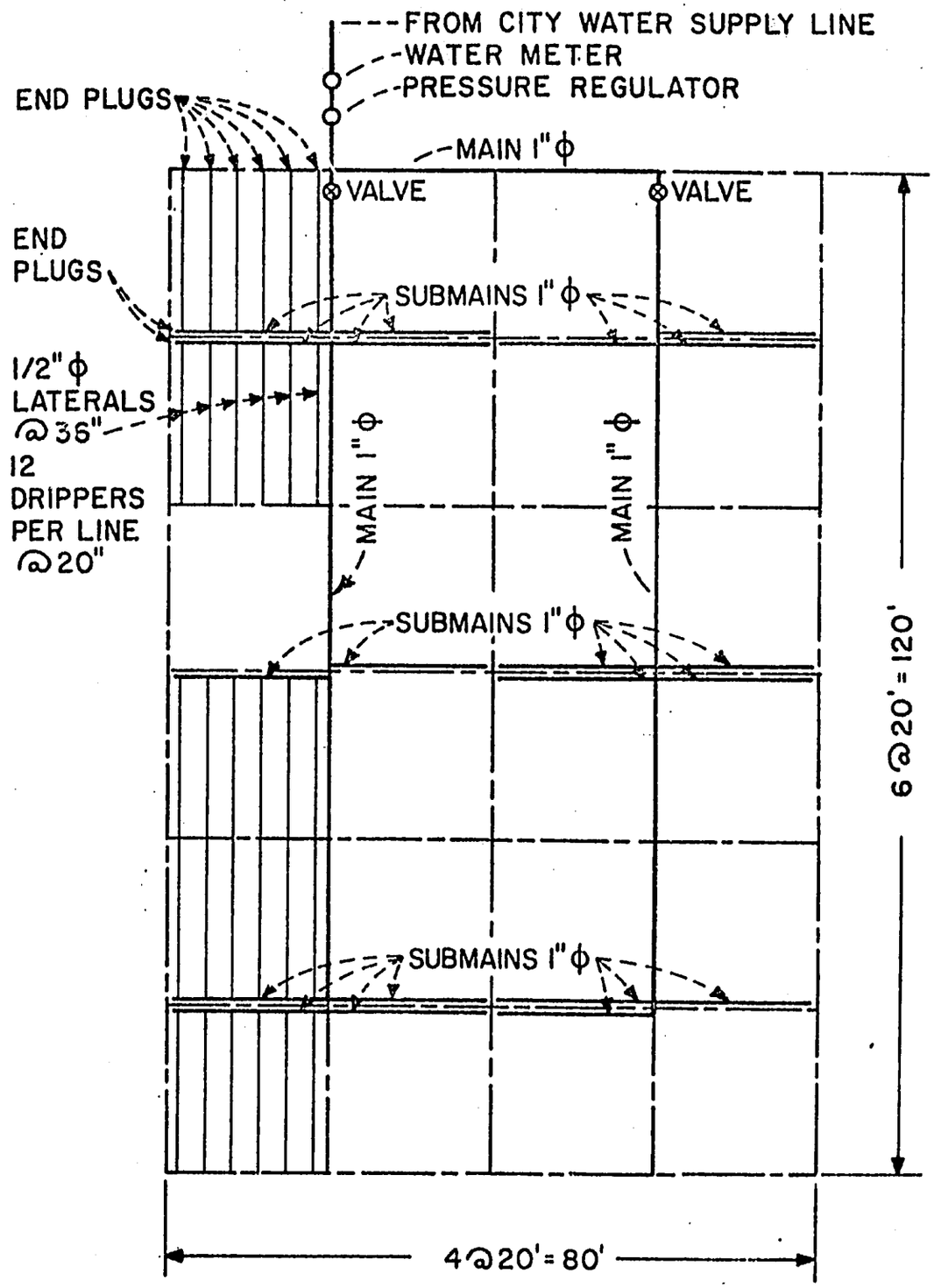
The equipment and trickle irrigation system employed to carry out this research consisted of the following components:

1. Source of water supply under pressure.
2. Water meter.
3. Pressure regulator.
4. Pressure gage.
5. Control valves.
6. Mains and submains poly-vinyl-chloride (PVC) pipes.
7. Half-inch polyethylene pipe for laterals.
8. Tricklers or drippers.

Figure 2 shows the trickle irrigation system used in the research. The detail of each component of the system may be described as follows:

1. The source of water supply. — The water from North Logan City Culinary Water Supply with a static pressure of approximately 120 pounds per square inch was used in this research. This water had a very low content of salts and sediments, which made it unnecessary to use a filtering unit in the system.

2. Water meter. — A water meter was placed at the head unit of the system for measuring the total amount of water applied by trickler irrigation.




NUMBER OF PLOTS 24
PLOT SIZE 20' x 20'

SPACING OF LATERALS 36"
SPACING OF DRIPPERS 20"

Figure 2. Trickle Irrigation System Used in the Research.

3. Pressure regulator. — Due to the high static pressure in the water line, a pressure regulator was installed in the system to maintain a pressure head of 10 pounds per square inch (psi), while the system was in operation.

4. Pressure gage. — The pressure gage having a range of 0 to 100 psi was used for checking the pressure in the line.

5. Control valves. — Control valves were installed in each submain to allow for independent control of discharge in each plot .

6. Mains and submains. — Main lines were made of 1-inch inside diameter (I. D.) poly-vinyl-chloride (PVC) pipe, having 200 psi pressure rating. The pipes came in lengths of 20 feet each and were connected by joint fittings 1-1/4-inch in outside diameter (O. D.) and 4 inches long.

7. Laterals. — The laterals consisted of 1/2-inch polyethylene pipe equipped with tricklers or drippers at 20 inch spacings. Metal end plugs were used to close the end of the laterals.

8. Tricklers. — Tricklers or drippers used in the research were of an Australian design and manufactured by Implex Plastic, Lty. (see Figure 3). They were operated under a pressure of 10 psi, with a discharge of 0.690 gallons per hour through each trickler.

The application rate of water in each plot by trickle irrigation may be computed by the following formula:

$$\text{Application Rate in inches per hour} = \frac{N_T \times Q_T \times CF}{\text{Total area of plot in sq. ft.}} \quad (1)$$

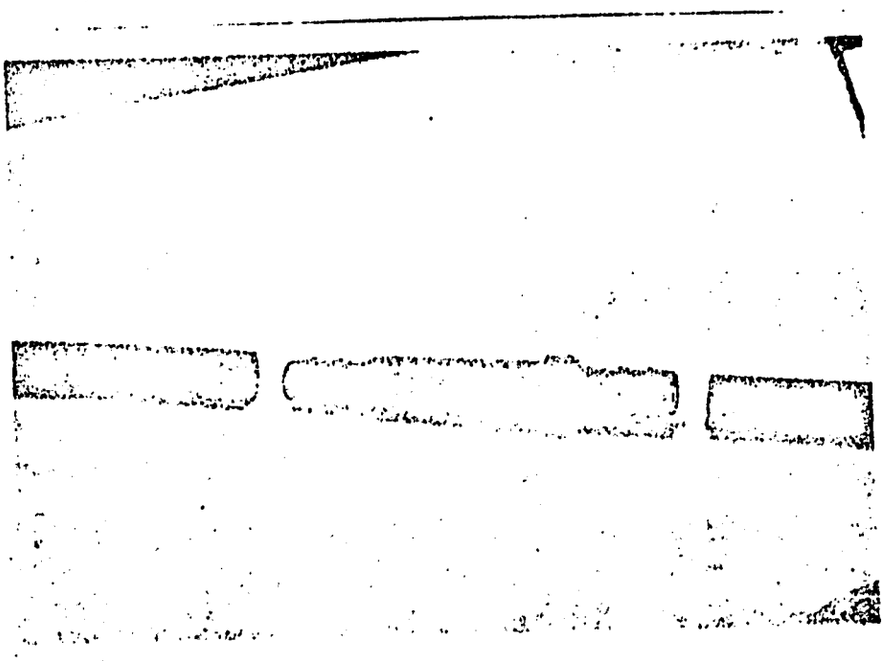


Figure 3. Trickler Used in the Research.

where

$N_T$ = number of tricklers per plot

$Q_T$ = discharge per trickler in gallons per hour

CF = conversion factor depending on the units of various terms in the equation. In this case CF = 1.605.

With $N_T$ = 72, $Q_T$ = 0.690 gallons per hour, and total area of plot of 400 square feet, the application rate was found to be 0.2 inch per hour.

Irrigation

The first irrigation water was applied on July 13, 1970, with a sprinkler system to the entire research field, including the 0 percent treatment plot. The total average depth of water applied during this irrigation was 1.87 inches.

The irrigation with the trickle irrigation system began on August 4, 1970, when the total depth of 3 inches of water was applied in an attempt to saturate the soil. Then the field was not irrigated for three days to permit the moisture content in the soil to reduce to field capacity.

During the period of August 7, 1970, and September 4, 1970, the field received trickler irrigation every Monday, Wednesday and Friday. The amount of water applied each time was proportional to the actual evapotranspiration taken from a lysimeter installed in the field.

Measurement of Evapotranspiration

The amount of water used by the plant and evaporated (i.e., evapotranspiration), was obtained from a lysimeter as explained by Sandberg (1971).

Nine lysimeters, using the same soil as in the experimental plots with sweet corn as the crop, were installed in the field. Each lysimeter was made of a circular 20-gallon can (Sandberg, 1971) with an outside diameter of 1.75 feet and hence a plan area of 2.4 square feet.

To obtain the amount of water consumed by the plant, the lysimeters were weighed daily. Sandberg (1971) developed a method for calculating the amount of water consumed by the plants from the difference in daily weights of the lysimeters. In the research the amount of water to add to each plot of treatment B was equal to the quantity given by the average of the nine lysimeters times the ratio of the area of one plot (400 square feet) and the area of the lysimeter (2.4 square feet).

Measurement of Yield

The crop was harvested on September 17 and 18, 1970. The wet weight was obtained for plants grown in the four middle rows of each plot, except for five feet from each end of these rows. On the same day that the wet weight of plants per plot was obtained, a more accurate scale was used to determine the wet weight of one plant taken from each plot. All these plants (i.e., twenty-four) were then put in an oven in order to find the dry weight of each plant.

The measurement of yield was determined on the dry weight basis. With the known ratio of the dry weight to the wet weight of the single plant in a plot, the dry weight of the plants from the particular plot was computed by the following equation:

$$DWP = \frac{DW_p}{WW_p} \times WWP \qquad (2)$$

where

DWP = dry weight of plants from certain plot

$DW_p$ = dry weight of single plant from the same plot

$WW_p$ = wet weight of single plant from the same plot

WWP = wet weight of plants from the same plot

Measurement of Water Content

In order to find the total amount of water used in each experimental plot, it was necessary to know the amount of water stored in the soil at the beginning of the research (i.e., when the crop was planted), and at the end of the research (i.e., on the same day of harvest).

To obtain this information a neutron scattering method was used. The moisture storage at the beginning of the research (June 15, 1970) was assumed to be uniform in all plots. The value of this volume

storage was obtained from data taken by Sandberg (1971) just south of the experimental plots.

On the same day the crop was harvested, measurements were made to find the water content in the soil profile in each plot. Appendix B shows the depth of the soil profile and the corresponding neutron meter readings for each plot.

The moisture content at various depths in the soil was determined from the neutron meter data in Appendix B by the equation

$$\theta = \frac{r\theta}{rs}(0.511) - 0.017 \tag{3}$$

where

$\theta$ = moisture content

$r\theta$ = count rate in the soil

$rs$ = count rate in the shield

Appendix D shows the computer program used in computing the total volume of water storage in the soil profile.

Table 4. Total Amount of Water Applied in Each Treatment

| Treatment | Sprinkler[1] Irrigation (centimeters) | Trickle[2] Irrigation (centimeters) | Rainfall[3] (centimeters) | Total Water Applied (centimeters) |
|---|---|---|---|---|
| A | 4.75 | 24.98 | 11.30 | 40.894 |
| B | 4.75 | 20.70 | 11.30 | 36.754 |
| C | 4.75 | 16.56 | 11.30 | 32.614 |
| D | 4.75 | 12.42 | 11.30 | 28.424 |
| E | 4.75 | 8.28 | 11.30 | 24.334 |
| F | 4.75 | 0.00 | 11.30 | 16.054 |

Notes:

For treatment A = depth of water applied equal to 120 percent of estimated actual evapotranspiration

For treatment B = depth of water applied equal to 100 percent of estimated actual evapotranspiration

For treatment C = depth of water applied equal to 80 percent of estimated actual evapotranspiration

For treatment D = depth of water applied equal to 60 percent of estimated actual evapotranspiration

For treatment E = depth of water applied equal to 40 percent of estimated actual evapotranspiration

For treatment F = depth of water applied equal to 0 percent of estimated actual evapotranspiration

1. All plots were equally irrigated by sprinkler irrigation on July 13, 1970.

2. The amount of water applied by trickle irrigation is shown in Table 7.

3. Rainfall data and other climatological data are shown in Appendix C.

# ANALYSIS OF DATA

## Data Obtained

The data obtained from this research were the total amount of water used in each plot and the yield in each plot.

1. Water used. — The total amount of water used in growing the crop in each plot was determined by the equation

$$W_u = W_a + W_{IS} - W_{FS} \tag{4}$$

where

$W_u$ = total amount of water used in each plot

$W_a$ = total amount of water applied to the plot

$W_{IS}$ = amount of water storage in the soil at the beginning of research

$W_{FS}$ = amount of water storage in the soil at the end of research (i.e., at harvesting time)

The total amount of water applied to the plot is shown in Table 4. The amount of water storage in the soil at the beginning and at the end of research is shown in Table 5, and the total amount of water used in each plot is shown in Table 6. The amount applied by trickle irrigation and the application dates are shown in Table 7.

2. Yields. — The yields from each plot on dry weight basis was determined by using Equation 2.

Table 5. Amount of Water Storage in the Soil at the Beginning and at the End of Research

| Plot | Water Storage[1] at Beginning (centimeters) | Water Storage[2] at End (centimeters) |
|---|---|---|
| A-1 | 27.135 | 29.718 |
| A-2 | " | 30.611 |
| A-3 | " | 29.386 |
| A-4 | " | 30.323 |
| B-1 | " | 29.334 |
| B-2 | " | 33.320 |
| B-3 | " | 27.557 |
| B-4 | " | 29.448 |
| C-1 | " | 24.068 |
| C-2 | " | 30.292 |
| C-3 | " | 25.657 |
| C-4 | " | 26.817 |
| D-1 | " | 22.143 |
| D-2 | " | 28.736 |
| D-3 | " | 23.227 |
| D-4 | " | 27.734 |
| E-1 | " | 27.405 |
| E-2 | " | 22.923 |
| E-3 | " | 19.987 |
| E-4 | " | 20.811 |
| F=1 | " | 14.713 |
| F-2 | " | 12.800 |
| F-3 | " | 14.144 |
| F-4 | " | 15.082 |

Notes:

1. Water storage at beginning of research was assumed to be uniform for all plots, and obtained from Sandberg (1971).

2. Obtained from Appendix D, Computer Program, for determination of water storage in soil.

Table 6. Total Amount of Water Used in Each Plot

| Plot | $W_{IS}$ (cm) | $W_a$ (cm) | $W_{FS}$ (cm) | $W_u$ (cm) | $\overline{W}_u$* (cm) |
|---|---|---|---|---|---|
| A-1 | 27.135 | 40.894 | 29.718 | 38.311 | 38.019 |
| A-2 | | | 30.611 | 37.418 | |
| A-3 | | | 29.386 | 38.643 | |
| A-4 | | | 30.323 | 37.706 | |
| B-1 | 27.135 | 36.754 | 29.334 | 34.554 | 33.974 |
| B-2 | | | 33.320 | 30.569 | |
| B-3 | | | 27.557 | 36.332 | |
| B-4 | | | 29.448 | 34.441 | |
| C-1 | 27.135 | 32.614 | 24.068 | 35.681 | 33.024 |
| C-2 | | | 30.292 | 29.457 | |
| C-3 | | | 25.657 | 34.092 | |
| C-4 | | | 26.817 | 32.932 | |
| D-1 | 27.135 | 28.424 | 22.143 | 33.416 | 30.099 |
| D-2 | | | 28.736 | 26.823 | |
| D-3 | | | 23.227 | 32.332 | |
| D-4 | | | 27.734 | 27.825 | |
| E-1 | 27.135 | 24.334 | 27.405 | 24.064 | 28.687 |
| E-2 | | | 22.923 | 28.546 | |
| E-3 | | | 19.987 | 31.482 | |
| E-4 | | | 20.811 | 30.658 | |
| F-1 | 27.135 | 16.054 | 14.713 | 28.476 | 28.104 |
| F-2 | | | 12.800 | 30.389 | |
| F-3 | | | 14.144 | 29.045 | |
| F-4 | | | 15.082 | 28.107 | |

*$\overline{W}_u$ is the mean amount of water used in each treatment.

The value of each term in Equation 2 and the determination of the dry weight of plants from various plots are shown in Table 8.

Statistical Analysis of Data Obtained in the Research

The analysis of variance or ANOVA method was used to analyze the data obtained in the experiment. Appendix E shows the computer program used in the analysis.

1. Amount of water used. — A hypothesis, "there is no difference of means of total amount of water used in various treatment combination," was tested to find the significance of treatment combinations. The result of tests based on confidence level of 90 percent is shown in Table 9.

2. Yields. — The mean of yield of each treatment was analyzed in the similar manner as in 1. above. The result of tests is shown in Table 10.

3. Ratio of yield and total amount of water used. — The hypothesis was tested to find the significance of treatment combination using means of ratio of yield and total amount of water used in the analysis. Table 11 shows the result of tests which was based on confidence level of 90 percent.

Table 7. Amount of Water Applied by Trickle Irrigation

| Treatment | Date | Water Applied (centimeters) |
|---|---|---|
| B* | August 4 | 3.81 |
| | August 5 | 3.81 |
| | August 7 | 0.76 |
| | August 10 | 1.78 |
| | August 12 | 0.76 |
| | August 14 | 1.02 |
| | August 17 | 1.27 |
| | August 19 | 0.76 |
| | August 21 | 1.02 |
| | August 24 | 1.27 |
| | August 26 | 1.14 |
| | August 28 | 0.51 |
| | August 31 | 1.27 |
| | September 2 | 0.76 |
| | September 4 | 0.76 |
| | TOTAL | 20.70 |

*B is the treatment of which the depth of water applied by trickle irrigation was equal to 100 percent of the estimated actual evapotranspiration.

Table 8. Determination of Dry Weight of Plants in Each Plot

| Plot | $WW_p$ [1] (grams) | $DW_p$ [2] (grams) | $DW_p/WW_p$ | WWP[3] (pounds) | DWP[4] (pounds) |
|---|---|---|---|---|---|
| A-1 | 653.1 | 255.1 | 0.3906 | 94.5 | 36.91 |
| A-2 | 703.5 | 217.6 | 0.3093 | 47.0 | 14.54 |
| A-3 | 988.7 | 282.9 | 0.2859 | 67.0 | 19.16 |
| A-4 | 593.1 | 253.3 | 0.4271 | 57.0 | 24.34 |
| B-1 | 929.2 | 279.0 | 0.3003 | 80.0 | 24.02 |
| B-2 | 434.6 | 159.4 | 0.3668 | 34.0 | 12.47 |
| B-3 | 636.3 | 220.5 | 0.3465 | 54.0 | 24.02 |
| B-4 | 1172.5 | 396.9 | 0.3385 | 74.0 | 25.05 |
| C-1 | 1801.1 | 365.6 | 0.2030 | 106.0 | 25.12 |
| C-2 | 304.8 | 156.2 | 0.5125 | 49.0 | 25.11 |
| C-3 | 444.5 | 185.2 | 0.4166 | 62.0 | 25.83 |
| C-4 | 942.2 | 351.2 | 0.3727 | 92.0 | 34.28 |
| D-1 | 1271.4 | 353.8 | 0.2783 | 80.0 | 22.26 |
| D-2 | 917.8 | 325.1 | 0.3542 | 63.5 | 22.49 |
| D-3 | 1234.8 | 380.0 | 0.3077 | 80.0 | 24.62 |
| D-4 | 1003.5 | 326.2 | 0.3251 | 67.0 | 21.78 |
| E-1 | 668.2 | 181.8 | 0.2721 | 60.0 | 16.33 |
| E-2 | 1454.2 | 481.8 | 0.3313 | 102.5 | 33.96 |
| E-3 | 766.3 | 293.3 | 0.3827 | 55.0 | 21.05 |
| E-4 | 1253.7 | 431.6 | 0.3443 | 75.0 | 25.82 |
| F-1 | 716.0 | 243.2 | 0.3397 | 51.0 | 17.32 |
| F-2 | 720.3 | 267.3 | 0.3711 | 36.0 | 13.36 |
| F-3 | 742.0 | 302.4 | 0.4075 | 63.0 | 25.67 |
| F-4 | 519.0 | 247.4 | 0.4767 | 24.0 | 11.44 |

Notes:

[1] $WW_p$ = wet weight of a single plant from certain plot.

[2] $DW_p$ = dry weight of the single plant from the same plot.

[3] WWP = wet weight of the plants from the same plot.

[4] DWP = dry weight of the plants from the same plot.

Table 9. Significance of Treatment Combinations On Water Used

| Treatment | F Ratio[1] | F[2] $\alpha$ = 90% | Results of[3] Hypothesis Tests |
|---|---|---|---|
| A, B | 16.988 | 5.54 | Rejected |
| A, B, C | 15.512 | 3.46 | Rejected |
| B, C | 1.655 | 5.54 | Accepted |
| B, C, D | 8.071 | 3.46 | Rejected |
| C. D | 8.915 | 5.54 | Rejected |
| C, D, E | 2.026 | 3.46 | Accepted |
| D, E | 0.371 | 5.54 | Accepted |
| D, E, F | 0.326 | 3.46 | Accepted |
| E, F | 0.037 | 5.54 | Accepted |

Notes:

1. Values obtained from Appendix F using computer program shown in Appendix E.

2. Values obtained from a cumulative F-distribution. $\alpha$ = confidence level.

3. The tested hypothesis: there is no difference between treatment means of total amount of water used.

Table 10. Significance of Treatment Combinations On Yields

| Treatment | F Ratio[1] | F[2] $\alpha$ = 90% | Results of[3] Hypothesis Tests |
|---|---|---|---|
| A, B | 1.383 | 5.54 | Accepted |
| A, B, C | 1,949 | 3.46 | Accepted |
| B, C | 9.629 | 5.54 | Rejected |
| B, C, D | 3.859 | 3.46 | Rejected |
| C, D | 3.422 | 5.54 | Accepted |
| C, D, E | 0.914 | 3.46 | Accepted |
| D, E, | 0.145 | 5.54 | Accepted |
| D, E, F | 1.538 | 3.46 | Accepted |
| E, F | 1 477 | 5.54 | Accepted |

Notes:

1. Values obtained from Appendix G using computer program shown in Appendix E.

2. Values obtained from a cumulative F-distribution tables. $\alpha$ = confidence level.

3. The tested hypothesis: There is no difference between treatment means of yields.

Table 11. Significance of Treatment Combinations On Ratio of Yields and Total Amount of Water Used

| Treatment | F Ratio[1] | F[2] $\alpha$ = 90% | Results of[3] Hypothesis Tests |
|---|---|---|---|
| A, B | 0.218 | 5.54 | Accepted |
| A, B, C | 2.699 | 3.46 | Accepted |
| B, C | 7.637 | 5.54 | Rejected |
| B, C, D | 3.093 | 3.46 | Accepted |
| C, D | 0.114 | 5.54 | Accepted |
| C, D, E | 0.092 | 3.46 | Accepted |
| D, E | 0.451 | 5.54 | Accepted |
| D, E, F | 1.647 | 3.46 | Accepted |
| E, F | 1.523 | 5.54 | Accepted |

Notes:

1. Values obtained from Appendix H using computer program shown in Appendix E.

2. Values obtained from a cumulative F-distribution tables. $\alpha$ = confidence level.

3. The tested hypothesis: There is no difference between treatment means of ratio of yield and total amount of water used.

# RESULTS AND DISCUSSION

In regards to the statistical analysis made in the preceding section, the results of the research lead to the following conclusions.

Tables 9, 10, and 11 show a large variability in the experimental data obtained and no conclusive inference on water saving or increased yield could be made. Factors attributed to the large variability of data may be described as follows:

1. The large moisture storage in the soil at the beginning of research plus rainfall and sprinkler irrigation during the growing period was almost sufficient for crop growing. Tables 4 and 6 show that even with no water applied by trickle irrigation, there was approximately 29 centimeters of water available for the crop. Sprinkler irrigation was applied to the plots when the crop needed irrigation in the early part of the experiment, but the trickle irrigation system had not arrived. As a result the amount of water applied by trickle irrigation varied from a minimum of 0 percent to about 57 percent of the total amount of water applied to the crop. Due to the comparatively small amount of water applied by the tricklers in comparison with the total amount applied to the crop, it was difficult to evaluate the water saving by trickle irrigation.

2. The assumption that the initial moisture storage was uniform in all plots might not be sufficiently true to the actual condition. This

error could result in significant change in the estimate of the total amount of water used by the crop.

Even though a conclusive inference could not be made on water saving and increased yield, it appears that for a fine textured soil having large moisture storage capacity and located where the moisture storage in the soil at the beginning of the growing season is high, trickle irrigation may not exhibit any advantage over other irrigation methods, unless a crop consuming a considerable amount of water is grown.

The performance of the system was carefully observed, and its characteristics are described below.

1. The discharge of all tricklers was uniform and needed no adjustment during the entire research period.

2. The operation was simple. With the known rate of water application, the irrigation time could be computed for applying the desired amount of water and the operation was only to open the valve and turn it off.

3. As the season progressed under trickle irrigation the inter-row space was practically dry which discouraged weed growth. Thus, weed problem was reduced.

4. The field assembly of the system was relatively simple due to the fact that all pipes were made of lightweight material (i.e., PVC and polyethylene), and laterals were already equipped with tricklers in the shop. For the system employed in this research, approximately 16 man-hours of unskilled labor was required for assembly.

# RECOMMENDATION FOR FUTURE STUDIES

Due to the fact that trickle irrigation has been developed only recently, information regarding its performance and efficiency is scarce and limited. Extensive studies should be conducted to obtain such information in order to enable the irrigator to evaluate the new method of irrigation or increase the efficiency of the system. The following studies are suggested:

1. The wetting pattern and water movement in various types of soils under different rates of discharge from tricklers. The information obtained from this study may be used in the determination of spacing of tricklers for various soil types and discharge rates of tricklers.

2. The effect of trickle irrigation on salt movement in a saline soil or the salt accumulation in a normal soil when water of high salt content is used for irrigation. The information obtained will enable irrigators to realize the nature of the probable salt-concentration problems resulting from the trickle irrigation.

3. The possibility of using water containing high salt content in trickle irrigation without causing significant reduction in yields. Some limited studies have been made but more intensive investigation is still needed.

4. The efficiency and performance of the various types of tricklers should be studied and compared. In some designs, the water is released in drips through a long, small tube such that the flow is laminar and the discharge is

directly proportional to the head causing flow. Other designs utilize the principle of an orifice in which the discharge varies with the square root of pressure head in the lateral. The latter type of trickler would give more uniform discharge if fluctuation of pressure in laterals exists.

Some tricklers need manual adjustment to obtain the required discharge. This adjustment or calibration could involve excessive amounts of work and expense which may reflect the economy of the system. For this reason, studies on characteristics of each type of tricklers should be conducted.

5. In most tricklers the water flows through a passage of tiny cross-section and discharges from the trickler in drop form. If the water in the system contains sediments, they may be lodged in the tiny passage and reduce the discharge. To prevent sediments and small particles from entering the system, a filtering device is usually installed in the inlet pipe of the system. There have been reports that some filtering devices are inefficient. Thus, an investigation on performance of filtering devices should be attempted.

6. The saving of water for different kinds of crops should be investigated to obtain conclusive results on the optimum amount of water required by crops when a trickle irrigation system is employed.

Considerable experience was gained by the author in conducting the research on saving of water for growing sweet corn as presented

in this thesis. In order to obtain a better result of investigation, the following suggestions should be seriously considered:

1. Selection of type of soil for the experimental plot. — Fine textured soil may store large quantities of moisture at the beginning of the growing season. If the growing period for the crops to be planted in the research is short and the crop requires relatively small amount of water, the saving of water by trickle irrigation will be hardly evident.

2. Initial water storage in the soil. — If it is practical and possible, attempts should be made to plant the crop when the initial moisture storage in the soil is minimum. This is for the same reason as stated in 1. above.

3. Kind of crops. — In order to obtain a more distinct evidence on water saving, a crop consuming large quantities of water should be used in the research.

4. Climatic conditions. — Should avoid research plots located in area having considerable rainfall. The moisture supplied by rain and storage may comprise a large proportion of the total crop requirement. Consequently, only small portions of the total requirement are supplied by trickle irrigation which makes it difficult to evaluate the water saving by this irrigation method.

5. Crop growing pattern. — If the distance between laterals or spacing of tricklers is small, for example, 1.5 feet apart, the distribution of moisture from tricklers in the soil could be fairly uniform over the entire area of the plot. But if the spacing is large, precaution should be taken that each plant is supplied with water by the same number of tricklers located at a similar location with respect to each plant. Otherwise the moisture distribution over the area of the plot may contain much less moisture than that located directly under tricklers and the non-uniform moisture distribution may affect plant growth if they are located in areas having different soil moisture.

6. Measurement of available moisture in the soil. — At least one lysimeter should be located in each plot so that the amount of water to replenish the soil moisture to its field capacity can be determined independently for each plot. This arrangement could result in a more uniform distribution of moisture in the soil for all plots.

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# APPENDICES

# Appendix A

## Location of Research Field and Soil Properties

Location of Research Field and Soil Properties #1480

SOIL MAPPING UNIT: Millville silt loam, moderately well drained, 1 to 3 percent slopes.
SURVEY AREA: Cache Area, Utah
LOCATION: One-half mile N. and 3/8 miles W. of USU Dairy Farm. 800' S. and 200' E. of the N.W. corner of the N.E. 1/4 Section 22, T12N, R1E. Photo and coordinates, 90 C-11.
PROFILE NUMBER: 107-61.
PHYSIOGRAPHY: Alluvial fan.
ELEVATION: 4,525 feet.
RELIEF: Normal, gently sloping, medium length, west exposure.
DRAINAGE: Moderately well drained.
PARENT ATERIALS: Mixed alluvium - dominantly Dolomite limestone.
VEGETATION: Irrigated cropland.
CLIMATEL: Dry sub-humid.
EROSION: None.
CLASSIFICATION: Alluvial - Orthic Rendolls (5.110).
OTHER FEATURES: Watertable - 46"
COLLECTORS: Mortensen, Carley and Stock
DATE: 5/3/61

State Profile — Millville silt loam, 1-3% slopes

$A_{11}$ 0-3" — Grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak very fine platy structure; slightly hard, very friable, slightly sticky and slightly plastic; abundant fine roots; common fine pores; strongly calcareous; mildly alkaline, pH 7.8 (paste); abrupt smooth boundary.

$A_{12}$ 3-15" — Grayish brown (10YR 5/2) silt loam, dark brown (10YR 3/3) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; plentiful fine roots; many fine and medium pores; strongly calcareous; moderately alkaline pH 8.3 (paste) gradual smooth boundary.

$C_1$ 15-26" — Light gray (10YR 7/2) silt loam, pale brown (10YR 6/3) moist; massive; hard, friable, slightly sticky and slightly plastic; common fine and medium pores; common medium faint yellowish brown (10YR 5/4) mottles; very strongly calcareous; moderately alkaline; pH 8.2 (paste); clear smooth boundary.

Location of Research Field and Soil Properties (Continued)

State Profile

| | | |
|---|---|---|
| $C_2$ | 26-36" | Light gray (2.5Y 7/2) silt loam, light brownish gray or light yellowish brown (2.5Y 6/3) moist; massive; hard, friable, slightly sticky and slightly plastic; few fine pores; common medium faint yellowish brown (10YR 5/4) mottles; moderately alkaline, very strongly calcareous; pH 8.1 (paste). |
| $C_3$ | 36-50"+ | Light gray (2.5Y 7/2) silt loam, light brownish gray or light yellowish brown (2.5Y 6/3) moist; massive; hard, friable, slightly sticky and slightly plastic; common medium faint yellowish brown (10YR 5/4) mottles; very strongly calcareous; moderately alkaline; pH 8.1 (paste). |

Remarks: Below 26 inches the soil was saturated with water.

SOIL SURVEY LABORATORY Logan, Utah January 7, 1963 #1480

SOIL TYPE Millville sil LOCATION Cache - ½ mi. N & 3/8 mi. W of USU Dairy Farm. 800' S & 200' E of the NW cor. of the NE¼ of Sec. 22, T12N, R1E

SURVEY NOS. 900-11 107-61 LAB. NOS. U6293 to U6297

Collected: 5/3/61

| DEPTH INCHES | HORIZON | PARTICLE SIZE DISTRIBUTION (in mm.) (per cent) VERY COARSE SAND 2-1 | COARSE SAND 1-0.5 | MEDIUM SAND 0.5-0.25 | FINE SAND 0.25-0.10 | VERY FINE SAND 0.10-0.05 | SILT 0.05-0.002 | CLAY < 0.002 | 0.2-0.02 | 0.02-0.002 | > 2 | TEXTURAL CLASS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-3 | $A_{11}$ | 0.1 | 0.3 | 0.6 | 3.3 | 13.1 | 59.9 | 22.7 | | | | sil |
| 3-15 | $A_{12}$ | 0 | 0.1 | 0.4 | 2.8 | 12.3 | 61.5 | 22.9 | | | | sil |
| 15-36 | $C_1$ | 0 | 0.1 | 0.4 | 3.1 | 12.5 | 58.9 | 25.0 | | | | sil |
| 36-36 | $C_2$ | 0 | 0.1 | 0.2 | 1.9 | 11.6 | 67.5 | 18.7 | | | | sil |
| 36-50+ | $C_3$ | 0 | 0.1 | 0.2 | 2.1 | 13.2 | 69.3 | 15.1 | | | | sil |

| | pH SATURATED PASTE | pH 1:5 | ORGANIC MATTER Org. Mat. % | ORGANIC CARBON % | NITROGEN % | C/N | EST% SALT (BUREAU CUP) | ELECTRICAL CONDUCTIVITY EC×10³ MILLIMHOS PER CM @25°C. | $CaCO_3$ equivalent % | GYPSUM me./100g. SOIL | MOISTURE TENSIONS 1/10 ATMOS. % | 1/3 ATMOS. % | 15 ATMOS. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.8 | 8.8 | 3.56 | 2.07 | .202 | 10.2 | .08 | 1.42 | 26.3 | | | 28.4 | 13.3 |
| 2 | 8.3 | 9.1 | 1.93 | 1.12 | .124 | 9.0 | .05 | .88 | 29.2 | | | 28.9 | 12.6 |
| 3 | 8.2 | 9.4 | .67 | .39 | - | - | .04 | .49 | 56.3 | | | 25.6 | 10.2 |
| 4 | 8.1 | 9.4 | .36 | .21 | - | - | <.03 | .41 | 64.5 | | | 24.3 | 7.3 |
| 5 | 8.1 | 9.2 | .28 | .16 | - | - | <.03 | .39 | 62.0 | | | 23.4 | 5.8 |

| | CATION EXCHANGE CAPACITY (H ) | EXTRACTABLE CATIONS Ca | Mg | H | Na | K | EXCH. Na % | SATURATION EXTRACT SOLUBLE Na | K | | | | MOISTURE AT SATURATION % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | milliequivalents per 100g. soil → | | | | | | ← milliequivalents per liter → | | | | | |
| 1 | 19.4 | | | | .29 | 1.50 | 1 | | | | | | 47 |
| 2 | 17.4 | | | | .33 | .96 | 2 | | | | | | 44 |
| 3 | 8.1 | | | | .29 | .39 | 4 | | | | | | 39 |
| 4 | 5.4 | | | | .24 | .32 | 4 | | | | | | 32 |
| 5 | 5.4 | | | | .24 | .31 | 4 | | | | | | 32 |

# Appendix B

## Neutron Meter Readings for Each Plot

Neutron Meter Readings for Each Plot

| Plot A-1 | | Plot A-2 | | Plot A-3 | | Plot A-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 56 | 6095 | 55 | 6637 | 54 | 5836 | 56 | 5699 |
| 50 | 5762 | 49 | 6963 | 48 | 6010 | 50 | 6003 |
| 44 | 6107 | 43 | 6816 | 42 | 6301 | 44 | 6262 |
| 38 | 5850 | 37 | 6707 | 36 | 6371 | 38 | 6256 |
| 32 | 6279 | 31 | 6202 | 30 | 5784 | 32 | 6051 |
| 26 | 6229 | 25 | 6481 | 24 | 5839 | 26 | 6002 |
| 20 | 6500 | 19 | 6191 | 18 | 5984 | 20 | 6568 |
| 14 | 4542 | 13 | 2664 | 12 | 4348 | 14 | 4730 |
| 8 | 242 | 7 | 84 | | | 8 | 271 |
| *rs1 = 11329<br>rs2 = 11534 | | rs1 = 11429<br>rs2 = 11418 | | rs1 = 11241<br>rs2 = 11429 | | rs1 = 11341<br>rs2 = 11193 | |

*rs1 and rs2 are the count rate in the shield before and after readings the count rate in the soil.

Neutron Meter Readings for Each Plot (Continued)

| Plot C-1 | | Plot C-2 | | Plot C-3 | | Plot C-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 51 | 5115 | 54 | 6403 | 56 | 5245 | 58 | 5022 |
| 45 | 4752 | 48 | 6652 | 50 | 4950 | 52 | 5296 |
| 39 | 4908 | 42 | 6776 | 44 | 5120 | 46 | 5655 |
| 33 | 4903 | 36 | 6531 | 38 | 4897 | 40 | 5364 |
| 27 | 4997 | 30 | 5664 | 32 | 4895 | 34 | 5301 |
| 21 | 5591 | 24 | 6018 | 26 | 5074 | 28 | 5118 |
| 15 | 5608 | 18 | 6022 | 20 | 5497 | 22 | 5742 |
| 9 | 3187 | 12 | 3713 | 14 | 4747 | 16 | 4688 |
| | | | | 8 | 519 | 10 | 391 |
| rs1 = 11503<br>rs2 = 11433 | | rs1 = 11413<br>rs2 = 11241 | | rs1 = 11246<br>rs2 = 11209 | | rs1 = 11193<br>rs2 = 11233 | |

Neutron Meter Readings for Each Plot (Continued)

| Plot D-1 | | Plot D-2 | | Plot D-3 | | Plot D-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 48 | 6095 | 58 | 4979 | 58 | 5066 | 58 | 5277 |
| 42 | 5738 | 52 | 5320 | 52 | 5051 | 52 | 5488 |
| 36 | 5185 | 46 | 5482 | 46 | 5087 | 46 | 6004 |
| 30 | 4802 | 40 | 5752 | 40 | 5023 | 40 | 5701 |
| 24 | 5331 | 34 | 5943 | 34 | 4428 | 34 | 5330 |
| 18 | 5492 | 28 | 5728 | 28 | 3972 | 28 | 4861 |
| 12 | 2877 | 22 | 6115 | 22 | 4550 | 22 | 5637 |
| | | 16 | 5468 | 16 | 4224 | 16 | 5124 |
| | | 10 | 571 | 10 | 473 | 10 | 730 |
| rs1 = 11344<br>rs2 = 11413 | | rs1 = 11079<br>rs2 = 11329 | | rs1 = 11291<br>rs2 = 11459 | | rs1 = 11249<br>rs2 = 11291 | |

Neutron Meter Readings for Each Plot (Continued)

| Plot E-1 | | Plot E-2 | | Plot E-3 | | Plot E-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 56 | 5800 | 57 | 5044 | 55 | 5071 | 54 | 4870 |
| 50 | 5400 | 51 | 4683 | 49 | 4795 | 48 | 4964 |
| 44 | 5333 | 45 | 4637 | 43 | 4377 | 42 | 4912 |
| 38 | 5346 | 39 | 4514 | 37 | 4361 | 36 | 4390 |
| 32 | 4926 | 33 | 3968 | 31 | 3871 | 30 | 3757 |
| 26 | 5231 | 27 | 4120 | 25 | 4172 | 24 | 4530 |
| 20 | 5645 | 21 | 4876 | 19 | 4268 | 18 | 4693 |
| 14 | 5293 | 15 | 4226 | 13 | 1786 | 12 | 1682 |
| 8 | 803 | 9 | 1784 | 7 | 71 | | |
| rs1 = 11441<br>rs2 = 11176 | | rs1 = 11433<br>rs2 = 11577 | | rs1 = 11418<br>rs2 = 11341 | | rs1 = 11425<br>rs2 = 11249 | |

Neutron Meter Readings for Each Plot (Continued)

| Plot B-2 | | Plot B-2 | | Plot B-3 | | Plot B-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 56 | 6193 | 57 | 6516 | 55 | 5410 | 581 | 5651 |
| 50 | 6371 | 51 | 6689 | 49 | 5929 | 52 | 5993 |
| 44 | 6471 | 45 | 6652 | 43 | 5729 | 46 | 6077 |
| 38 | 6470 | 39 | 6855 | 37 | 5669 | 40 | 6073 |
| 32 | 5832 | 33 | 6576 | 31 | 5517 | 34 | 5494 |
| 26 | 5858 | 27 | 6245 | 25 | 5755 | 28 | 5512 |
| 20 | 6024 | 21 | 6365 | 19 | 6077 | 22 | 6005 |
| 14 | 3881 | 15 | 5608 | 13 | 3694 | 14 | 5505 |
| 8 | 203 | 9 | 1115 | 7 | 170 | 8 | 1160 |
| rs1 = 11410<br>rs2 = 11604 | | rs1 = 11209<br>rs2 = 11441 | | rs1 = 11274<br>rs2 = 11402 | | rs1 = 11429<br>rs2 = 11496 | |

Neutron Meter Readings for Each Plot (Continued)

| Plot F-1 | | Plot F-2 | | Plot F-3 | | Plot F-4 | |
|---|---|---|---|---|---|---|---|
| Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil | Depth (inches) | Count Rate in the Soil |
| 53 | 4056 | 53 | 3566 | 48 | 4176 | 56 | 3454 |
| 47 | 3337 | 47 | 3029 | 42 | 3684 | 50 | 3196 |
| 41 | 3106 | 41 | 2754 | 36 | 3266 | 44 | 3065 |
| 35 | 3139 | 35 | 2862 | 30 | 3180 | 38 | 2834 |
| 29 | 3281 | 29 | 2894 | 24 | 2962 | 32 | 2649 |
| 23 | 3931 | 23 | 3474 | 18 | 2764 | 26 | 3027 |
| 12 | 3566 | 17 | 3037 | 12 | 3301 | 20 | 3859 |
| 11 | 678 | 11 | 467 | | | 14 | 3317 |
| | | | | | | 8 | 239 |
| rs1 = 11534<br>rs2 = 11429 | | rs1 = 11402<br>rs2 = 11410 | | rs1 = 11031<br>rs2 = 11425 | | rs1 = 11496<br>rs2 = 11246 | |

# Appendix C

## Climatological Data

Climatological Data - June

| Date | Temperature °F | | | | | Rainfall (inches) | Evaporation (inches) | Wind Miles/Day |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | At Observ. | Dry Bulb | Wet Bulb | | | |
| 1 | 75 | 39 | 75 | 74 | 61 | - | 0.23 | 198 |
| 2 | 82 | 43 | 81 | 77 | 63 | - | 0.26 | 215 |
| 3 | 84 | 46 | 84 | 84 | 63 | - | 0.28 | 242 |
| 4 | 85 | 40 | 84 | 82 | 63 | - | 0.51 | 378 |
| 5 | 85 | 53 | 79 | 78 | 63 | - | 0.31 | 429 |
| 6 | 81 | 49 | 74 | 74 | 65 | - | 0.25 | 457 |
| 7 | 76 | 49 | 73 | 70 | 62 | - | 0.20 | 506 |
| 8 | 77 | 49 | 71 | 69 | 61 | 0.01 | 0.17 | 535 |
| 9 | 71 | 48 | 57 | 55 | 54 | 0.74 | 0.11 | 608 |
| 10 | 64 | 43 | 59 | 58 | 56 | 0.10 | 0.12 | 635 |
| 11 | 60 | 42 | 57 | 56 | 52 | - | 0.13 | 670 |
| 12 | 65 | 44 | 60 | 59 | 57 | 0.02 | 0.12 | 707 |
| 13 | 66 | 50 | 66 | 68 | 56 | 0.41 | 0.16 | 715 |
| 14 | 68 | 46 | 66 | 68 | 60 | 0.02 | 0.17 | 830 |
| 15 | 68 | 44 | 65 | 64 | 59 | - | 0.23 | 874 |
| 16 | 72 | 43 | 72 | 70 | 61 | - | 0.10 | 912 |
| 17 | 78 | 43 | 76 | 75 | 64 | - | 0.32 | 930 |
| 18 | 78 | 52 | 76 | 75 | 66 | - | 0.18 | 969 |
| 19 | 82 | 49 | 80 | 80 | 69 | - | 0.30 | 10 |
| 20 | 86 | 50 | 85 | 86 | 71 | - | 0.23 | 30 |
| 21 | 91 | 53 | 90 | 90 | 75 | - | 0.32 | 5 |
| 22 | 90 | 55 | 77 | 75 | 65 | - | 0.27 | 80 |
| 23 | 91 | 56 | 91 | 91 | 73 | - | 0.25 | 117 |
| 24 | 93 | 57 | 90 | 90 | 72 | - | 0.22 | 132 |
| 25 | 93 | 54 | 92 | 92 | 76 | - | 0.28 | 167 |
| 26 | 96 | 57 | 95 | 96 | 76 | - | 0.33 | 183 |
| 27 | 95 | 67 | 75 | 75 | 65 | 0.08 | 0.42 | 255 |
| 28 | 85 | 48 | 85 | 82 | 70 | - | 0.21 | 301 |
| 29 | 85 | 61 | 69 | 64 | 62 | - | 0.39 | 362 |
| 30 | 69 | 39 | 66 | 65 | 60 | - | 0.20 | 415 |

Climatological Data (Continued) - July

| Date | Temperature °F | | | | | Rainfall (inches) | Evaporation (inches) | Wind Miles/Day |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | At Observ. | Dry Bulb | Wet Bulb | | | |
| 1 | 83 | 40 | 82 | 65 | 62 | - | 0.20 | 435 |
| 2 | 89 | 47 | 88 | 88 | 69 | - | 0.27 | 458 |
| 3 | 97 | 50 | 91 | 96 | 69 | - | 0.22 | 486 |
| 4 | 94 | 56 | 93 | 94 | 76 | - | 0.28 | 503 |
| 5 | 94 | 58 | 90 | 90 | 72 | - | 0.23 | 538 |
| 6 | 91 | 61 | 85 | 85 | 74 | 0.08 | 0.32 | 564 |
| 7 | 85 | 52 | 84 | 84 | 70 | 0.17 | 0.21 | 602 |
| 8 | 89 | 51 | 87 | 85 | 74 | - | 0.29 | 638 |
| 9 | 88 | 47 | 76 | 76 | 69 | - | 0.29 | 655 |
| 10 | 81 | 51 | 81 | 81 | 68 | 0.01 | 0.19 | 694 |
| 11 | 22 | 53 | 82 | 80 | 68 | 0.42 | 0.16 | 722 |
| 12 | 84 | 52 | 75 | 72 | 68 | - | 0.30 | 755 |
| 13 | 87 | 56 | 86 | 86 | 70 | - | 0.22 | 770 |
| 14 | 86 | 46 | 82 | 82 | 61 | - | 0.28 | 800 |
| 15 | 90 | 48 | 90 | 89 | 65 | - | 0.26 | 829 |
| 16 | 91 | 59 | 90 | 90 | 71 | - | 0.17 | 847 |
| 17 | 92 | 59 | 92 | 91 | 72 | - | 0.19 | 878 |
| 18 | 94 | 58 | 93 | 92 | 79 | - | 0.35 | 893 |
| 19 | 92 | 62 | 89 | 86 | 71 | - | 0.28 | 926 |
| 20 | 95 | 53 | 80 | 80 | 68 | - | 0.33 | 936 |
| 21 | 86 | 64 | 84 | 84 | 70 | 0.38 | 0.38 | 968 |
| 22 | 84 | 54 | 77 | 77 | 68 | - | 0.23 | 22 |
| 23 | 79 | 48 | 78 | 79 | 65 | 0.21 | 0.27 | 57 |
| 24 | 86 | 47 | 81 | 86 | 68 | - | 0.28 | 78 |
| 25 | 88 | 56 | 87 | 88 | 69 | - | 0.29 | 127 |
| 26 | 90 | 55 | 87 | 86 | 72 | - | 0.26 | 157 |
| 27 | 88 | 61 | 80 | 79 | 68 | 0.11 | 0.26 | 160 |
| 28 | 85 | 56 | 85 | 86 | 73 | - | 0.13 | 190 |
| 29 | 88 | 59 | 87 | 88 | 68 | 0.02 | 0.38 | 272 |
| 30 | 87 | 61 | 80 | 83 | 69 | - | 0.21 | 290 |
| 31 | 89 | 52 | 89 | 89 | 68 | - | 0.12 | 310 |

Climatological Data (Continued) - August

| Date | Temperature °F | | | | | Rainfall (inches) | Evaporation (inches) | Wind Miles/Day |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | At Observ. | Dry Bulb | Wet Bulb | | | |
| 1 | 95 | 51 | 95 | 95 | 70 | - | 0.43 | 380 |
| 2 | 95 | 57 | 91 | 91 | 69 | - | 0.35 | 361 |
| 3 | 91 | 50 | 90 | 88 | 69 | - | 0.30 | 396 |
| 4 | 91 | 63 | 67 | 67 | 65 | 0.02 | 0.22 | 425 |
| 5 | 87 | 59 | 84 | 83 | 70 | - | 0.10 | 436 |
| 6 | 89 | 62 | 88 | 87 | 72 | 0.03 | 0.23 | 464 |
| 7 | 94 | 55 | 93 | 91 | 70 | - | 0.28 | 482 |
| 8 | 93 | 60 | 85 | 86 | 85 | - | 0.58 | 522 |
| 9 | 87 | 44 | 86 | 85 | 62 | - | 0.24 | 550 |
| 10 | 91 | 45 | 90 | 88 | 61 | - | 0.18 | 565 |
| 11 | 95 | 49 | 95 | 94 | 67 | - | 0.36 | 580 |
| 12 | 95 | 61 | 94 | 94 | 61 | - | 0.23 | 611 |
| 13 | 94 | 55 | 94 | 94 | 68 | - | 0.31 | 636 |
| 14 | 94 | 56 | 88 | 88 | 66 | - | 0.37 | 662 |
| 15 | 90 | 47 | 89 | 89 | 68 | - | 0.25 | 587 |
| 16 | 93 | 50 | 91 | 90 | 68 | - | 0.37 | 701 |
| 17 | 91 | 66 | 90 | 91 | 68 | - | 0.42 | 734 |
| 18 | 90 | 57 | 89 | 90 | 67 | - | 0.29 | 763 |
| 19 | 90 | 55 | 88 | 83 | 68 | - | 0.17 | 780 |
| 20 | 88 | 60 | 87 | 82 | 70 | - | 0.34 | 802 |
| 21 | 88 | 52 | 84 | 80 | 67 | 0.04 | 0.22 | 847 |
| 22 | 89 | 50 | 89 | 85 | 56 | - | 0.23 | 850 |
| 23 | 91 | 51 | 90 | 89 | 68 | - | 0.17 | 885 |
| 24 | 93 | 52 | 92 | 91 | 68 | - | 0.31 | 895 |
| 25 | 95 | 53 | 90 | 90 | 70 | - | 0.27 | 928 |
| 26 | 91 | 63 | 88 | 85 | 68 | - | 0.14 | 950 |
| 27 | 88 | 59 | 84 | 84 | 70 | 0.08 | 0.19 | 989 |
| 28 | 85 | 64 | 84 | 85 | 68 | - | 0.20 | 14 |
| 29 | 89 | 55 | 81 | 80 | 70 | - | 0.17 | 48 |
| 30 | 90 | 62 | 89 | 89 | 71 | - | 0.23 | 51 |
| 31 | 91 | 57 | 89 | 91 | 61 | - | 0.17 | 82 |

Climatological Data (Continued) - September

| Date | Temperature °F | | | | | Rainfall (inches) | Evaporation (inches) | Wind Miles/Day |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | At Observ. | Dry Bulb | Wet Bulb | | | |
| 1 | 91 | 57 | 79 | 77 | 69 | 0.12 | 0.42 | 131 |
| 2 | 87 | 53 | 86 | 86 | 63 | - | 0.24 | 167 |
| 3 | 86 | 47 | 82 | 82 | 60 | - | 0.14 | 182 |
| 4 | 83 | 63 | 82 | 83 | 61 | - | 0.41 | 290 |
| 5 | 83 | 43 | 50 | 49 | 48 | 0.60 | 0.10 | 340 |
| 6 | 51 | 44 | 51 | 50 | 49 | 0.78 | 0.00 | 358 |
| 7 | 72 | 49 | 71 | 70 | 62 | - | 0.14 | 398 |
| 8 | 82 | 49 | 81 | 72 | 63 | - | 0.22 | 468 |
| 9 | 81 | 37 | 65 | 64 | 55 | - | 0.19 | 492 |
| 10 | 77 | 34 | 76 | 75 | 60 | - | 0.15 | 501 |
| 11 | 80 | 40 | 80 | 81 | 60 | - | 0.19 | 542 |
| 12 | 80 | 38 | 72 | 71 | 59 | - | 0.17 | 552 |
| 13 | 72 | 38 | 66 | 65 | 55 | - | 0.14 | 676 |
| 14 | 66 | 38 | 59 | 59 | 50 | - | 0.26 | 718 |
| 15 | 65 | 29 | 65 | 64 | 52 | - | 0.03 | 730 |
| 16 | 68 | 32 | 52 | 51 | 49 | - | 0.28 | 754 |
| 17 | 77 | 35 | 77 | 74 | 47 | - | 0.02 | 774 |
| 18 | 83 | 42 | 80 | 76 | 59 | - | 0.16 | 815 |
| 19 | 80 | 61 | 72 | 68 | 57 | - | 0.34 | 892 |
| 20 | 72 | 42 | 53 | 50 | 48 | 0.31 | 0.18 | 948 |
| 21 | 59 | 35 | 55 | 53 | 49 | - | 0.02 | 976 |
| 22 | 63 | 31 | 62 | 58 | 52 | - | 0.15 | 6 |
| 23 | 68 | 35 | 66 | 64 | 52 | - | 0.16 | 41 |
| 24 | 67 | 29 | 50 | 49 | 45 | - | 0.03 | 74 |
| 25 | 58 | 24 | 58 | 57 | 47 | - | 0.19 | 101 |
| 26 | 67 | 27 | 67 | 75 | 52 | - | 0.14 | 139 |
| 27 | 75 | 32 | 75 | 65 | 55 | - | 0.12 | 158 |
| 28 | 79 | 35 | 75 | 74 | 58 | - | 0.16 | 177 |
| 29 | 79 | 37 | 78 | 75 | 57 | - | 0.15 | 186 |
| 30 | 80 | 38 | 79 | 78 | 59 | - | 0.07 | 204 |

# Appendix D

## Computer Program for the Determination of Water Storage in the Soil

```
$JOB          THESIS02,KP=29,TIME=1,PAGES=15  804026,AE298,RAMIREZ
      DIMENSION SREAD(40),TETAT(40),TETAC(40),VOLSTO(40),TVOLST(40)
   50 READ(5,100)STD1,STD2,N,J,(SREAD(I),I=1,9),K
  100 FORMAT(2F5.0,2I2,9F4.0,I3)
      SAV=(STD1+STD2)/2.
      DO 10 I=1,N
      TETAT(I)=SREAD(I)/SAV
   10 CONTINUE
      DO 20 I=1,N
      TETAC(I)=TETAT(I)*0.511-0.017
      IF (TETAC(I) .LE. 0.)TETAC(I)=0.0
      VOLSTO(I)=TETAC(I)*15.
   20 CONTINUE
      TVOLST(1)=0.0
      M=N+1
      DO 30 I=2,M
      TVOLST(I)=TVOLST(I-1)+VOLSTO(I-1)
   30 CONTINUE
      IF(J .EQ. 1)GO TO 1
      IF(J .GT. 1 .AND. J .LT. 5)GO TO 2
      IF(J .EQ. 5)GO TO 3
      IF(J .GT. 5 .AND. J .LT. 9)GO TO 4
      IF(J .EQ. 9)GO TO 5
      IF(J .GT. 9 .AND. J .LT. 13)GO TO 6
      IF(J .EQ. 13)GO TO 7
      IF(J .GT. 13 .AND. J .LT. 17)GO TO 8
      IF(J .EQ. 17)GO TO 9
      IF(J .GT. 17 .AND. J .LT. 21)GO TO 11
      IF(J .EQ. 21)GO TO 12
      IF(J .GT. 21 .AND. J .LT. 25)GO TO 13
      GO TO 15
    1 WRITE(6,201)K,(TVOLST(I),I=2,M)
  201 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    2 WRITE(6,202)K,(TVOLST(I),I=2,M)
  202 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    3 WRITE(6,203)K,(TVOLST(I),I=2,M)
  203 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    4 WRITE(6,204)K,(TVOLST(I),I=2,M)
  204 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    5 WRITE(6,205)K,(TVOLST(I),I=2,M)
  205 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    6 WRITE(6,206)K,(TVOLST(I),I=2,M)
  206 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    7 WRITE(6,207)K,(TVOLST(I),I=2,M)
  207 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    8 WRITE(6,208)K,(TVOLST(I),I=2,M)
  208 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
    9 WRITE(6,209)K,(TVOLST(I),I=2,M)
  209 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
   11 WRITE(6,211)K,(TVOLST(I),I=2,M)
  211 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
   12 WRITE(6,212)K,(TVOLST(I),I=2,M)
  212 FORMAT(1H1,20X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F ',I
     12,' IN CENTIMETERS',//,(40X,F10.4))
      GO TO 50
   13 WRITE(6,213)K,(TVOLST(I),I=2,M)
  213 FORMAT(////,21X,'SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F ',
     112,' IN CENTIMETERS',//,(40X,F10.4))
      IF(J .LT. 24)GO TO 50
   15 STOP
      END

$ENTRY
```

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A 1 IN CENTIMETERS

3.8318
7.4403
11.2801
14.9477
18.9028
22.8244
26.9278
29.7183
29.7183

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A 2 IN CENTIMETERS

4.1983
8.6154
12.9338
17.1791
21.0856
25.1792
29.0783
30.6108
30.6108

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A 3 IN CENTIMETERS

3.6914
7.5005
11.5064
15.5597
19.2159
22.9094
26.7009
29.3861

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT A 4 IN CENTIMETERS

3.6221
7.4509
11.4560
15.4570
19.3185
23.1467
27.3599
30.3228
30.3228

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B 1 IN CENTIMETERS

3.8703
7.8591
11.9145
15.9693
19.5991
23.2462
27.0038
29.3340
29.3340

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B 2 IN CENTIMETERS

4.1552
8.4274
12.6746
17.0592
21.2550
25.2267
29.2797
32.8203
33.3200

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B 3 IN CENTIMETERS

3.4024
7.1557
10.7737
14.3512
17.8260
21.4616
25.3149
27.5572
27.5572

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT B 4 IN CENTIMETERS

3.5238
7.2764
11.0851
14.8911
18.3099
21.7408
25.5014
28.9276
29.4482

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C 1 IN CENTIMETERS

3.1638
6.0849
9.1103
12.1324
15.2173
18.6992
22.1925
24.0676

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C 2 IN CENTIMETERS

4.0779
8.3243
12.6547
16.8192
20.3970
24.2144
28.0345
30.2921

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C 3 IN CENTIMETERS

3.3258
6.4501
9.6905
12.7787
15.8655
19.0745
22.5723
25.5981
25.6574

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT C 4 IN CENTIMETERS

3.1779
6.5432
10.1538
13.5656
16.9342
20.1778
23.8548
26.8044
26.8166

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D 1 IN CENTIMETERS

3.8508
7.4612
10.6990
13.6788
17.0150
20.4596
22.1426

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D 2 IN CENTIMETERS

3.1513
6.5359
10.0313
13.7114
17.5222
21.1859
25.1143
28.6001
28.7358

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D 3 IN CENTIMETERS

3.1587
6.3073
9.4802
12.6099
15.3387
17.7602
20.5712
23.1625
23.2262

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT D 4 IN CENTIMETERS

3.3340
6.8115
10.6400
14.2624
17.6324
20.6835
24.2624
27.4923
27.7338

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E 1 IN CENTIMETERS

3.6763
7.1086
10.4683
13.8369
16.9208
20.2114
23.7826
27.1152
27.4045

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E 2 IN CENTIMETERS

3.1055
5.9704
8.8048
11.5571
13.9457
16.4356
19.4291
21.9896
22.9232

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E 3 IN CENTIMETERS

3.1607
6.1355
8.8288
11.5113
13.8637
16.4189
19.0387
19.9867
19.9867

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT E 4 IN CENTIMETERS

3.0376
6.1388
9.2048
11.9179
14.2031
17.0108
19.9288
20.8110

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F 1 IN CENTIMETERS

2.4528
4.4255
6.2441
8.0847
10.0200
12.3894
14.5150
14.7126

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F 2 IN CENTIMETERS

2.1414
3.9219
5.5177
7.1860
8.8758
10.9554
12.7413
12.8001

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F 3 IN CENTIMETERS

2.5958
4.8558
6.8304
8.7462
10.5133
12.1452
14.1437

SUM OF VOLUME STORAGE IN THE PROFILE OF PLOT F 4 IN CENTIMETERS

2.0733
3.9727
5.7837
7.4391
8.9697
10.7552
13.1014
15.0824
15.0824

OBJECT CODE= 4552 BYTES, ARRAY AREA= 800 BYTES, TOTAL AREA = 68536

CORE USAGE EXECUTION TIME= 10.99 SEC, WATFIV - VERSION 1 LEVEL

COMPILE TIME = 2.92 SEC 1 JANUARY 1970

# Appendix E

## Computer Program for Analysis of Data by ANOVA Method

```
      IMPLICIT REAL*4(A-H,O-Z)
      DIMENSION NOBS(100),IP(21),CONE(20),FMT(20),G(20),C(100,20),
     1R(100,20),TREE(20,20),B(20),R(20,20),ZN(100),A(21,20)
C     NI= MODEL IDENTIFICATION (ZERO  2-4PD  5-LSD
C     NT= NO. OF TREATMENTS
C     NB= NO. OF BLOCKS
C     NO= NO. OF OBS
C     NV= NO. OF VPS
C     IZ= CONTROL FOR REG. WITHIN TREATMENT
C     IN=INPUT DEVICE # OF
      DATA IP(1),IP(2),IP(3),IP,IOF/5,6,7,12,13,14/
      NI=2
      READ (IP(1),103)  NI,NT,NB,NO,NV,IZ,IN,(FMT(I),I=1,10)
      WRITE (IP(2),101)  NI,NT,NB,NO,NV,IZ,IN,(FMT(I),I=1,10)
  101 FORMAT (5I4,2I2,1A8,10A4)
  103 FORMAT (10I1,5I4,2I2,1A8,10A4)
      NVB=NV**2
      NVP=NV+1
C     IND=NVAP  IF NI=1,2
C     IND=NVAP+1  IF NI=3
      IND=NV*(NV+1)/2
      GO TO (201,204,202),NI
C     NOBS(I)= NO. OF OBSERVATIONS FOR TREATMENT I
  201 READ (IP(1),102)  (NOBS(I),I=1,NT)
      WRITE (IP(2),102)  (NOBS(I),I=1,NT)
  102 FORMAT(20I4)
  202 FORMAT(20I4)
  202 NN=NT
  204 READ  (IP(1),105)  (FMT(I),I=1,20)
      WRITE (IP(2),105)  (FMT(I),I=1,20)
  105 FORMAT(20A4)
  105 FORMAT(20A4)
C     IF(I)= NUMBER IN INPUT LIST OF VARIABLE I
      READ  (IP(1),106)  (IZ(I),I=1,IND)
      WRITE (IP(2),106)  (IZ(I),I=1,IND)
  106 FORMAT (10I 20I4)
  106 FORMAT (   20I4)
C     ZERO MATRIX AREAS
      DO 2 K=1,NVAP
      GE(K)=0.0
      DO 4 I=1,NT
      GO TO (4,4,7),NI
    7 CE(I,K)=0.0
    4 TR(I,K)=0.0
      DO 5 J=1,NT
    5 RE(J,K)=0.0
      DO 2 I=1,NVP
      AE(  J,K)=0.0
    2 AE(  J,K)=0.0
      NDF=0.0
      DO 21 I=1,NT
      GO TO (204,205,205),NI
  204 NN=NOBS(I)
  205 ZN(I)=NN
      NDF=NDF+NN
      DO 10 K=1,NP
      READ  (IN,FMT) (XE(K),K=1,IND)
      L=IZ(1)
      LF=IZ(1)
      DO 10 K=1,NVAP
      L=IZ(K)
      ZE(K)=XE(L)
      GO TO (211,212,211),NI
  211 CE(K,K)=CE(K,K)+ZE(K)
  212 RE(J,K)=RE(J,K)+ZE(K)
  211 TR(I,K)=TR(I,K)+ZE(K)
      DO 10 M=1,M
   10 AE(M,K)=AE(M,K)+ZE(K)*ZE(M)
      DO 21 K=1,NVAP
      GE(K)=GE(K)+TR(I,K)
      DO 20 M=1,NVAP
      RE(K,M)=RE(K,M)+AE(K,M)
      IF (IZ) 20,20,29
   29 AE(K,M)=AE(K,M)-TR(I,K)*TR(I,M)/ZN(I)
      AE(K,M)=AE(K,M)
   20 AE(M+1,K)=AE(M+1,K)+TR(I,M)*TR(I,K)/ZN(I)
   21 ZE(K)=DSQRT(AE(K,K))
      IF (IZ) 67,67,66
   66 GO TO (62,67,71),NI
   62 IF (NT-1) 67,67,68
   68 WRITE (IP(2),607) I
  607 FORMAT (/////30H REGRESSION ANALYSIS TREATMENT I4)
  600 FORMAT (/25H CORRELATION MATRIX FOR TREATMENT  I4)
      WRITE (IP(2),600) I
      DO 61 K=1,NVAP
      DO 65 M=K,NVAP
   65 AE(M,K)=AE(M,K)/ZE(M)/ZE(K)
   61 WRITE (IP(2),603) K,(AE(M),M=K,NVAP)
  603 FORMAT (10I 14,5E15.7/(5X,5E15.7))
      NKP=NK+1
      CALL DINVST  (A,1,NK,NKP,NVAP,DET,NE)
      WRITE (IP(2),602) I
  602 FORMAT (/25H INVERSE MATRIX FOR TREATMENT  I4)
      DO 501 K=1,NK
  501 WRITE (IP(2),603) K,(A(M),M=K,NK)
      WRITE  (IP(2),604)
  604 FORMAT  (/21H COEFFICIENTS )
      DO 502 K=NKP,NVAP
      DO 502 M=1,NK
  502 WRITE (IP(2),604) M,K,(A(M,K)
  604 FORMAT (10I 2I4,(1P,7)
      DO 550 K=NKP,NVAP
      WRITE (IP(2),606)  K
  606 FORMAT ( /24H VARIABLE I4)
      WRITE (IP(2),108)
      ZA=AE(K,K)
      ZR=0.0
      DO 530 M=1,NK
  530 ZR=ZR+AE(K,M)*A(M,K)
      ZD=ZA-ZR
      IDF=ZN(I)-1.0
      WRITE (IP(2),109)  IDF,ZD
      AK=NK
      IDF=IDF-NK
      D=IDF
      RMS=ZD/AK
      FRMS=ZD/D
      F=RMS/FRMS
      WRITE (IP(2),607)  NK,ZD,RMS,F
  607 FORMAT (3H    NK,I7,3(2X,E15.7))
  550 WRITE  (IP(2),110)  IDF,ZD,FRMS
   67 DO 69 K=1,NVAP
      DO 69 M=K,NVAP
      AE(K,M)=0.0
      AE(M,K)=0.0
   69 CONTINUE
   71 CONTINUE
  108 FORMAT(2H  SOURCE5X2HDF10X2HSS15X2HMS16X2HF)
  109 FORMAT(2H    IDF,F7.2,E15.7)
```

```
[illegible]
      CONTINUE
   60 CONTINUE
      CALL EXIT
      END
```

# Appendix F

## Statistical Analysis of Water Used Data by ANOVA Method

## TREATMENTS A, B

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.5137463D 02 | | |
| BLK | 3 | 0.1286223D 02 | | |
| TRT | 1 | 0.3273214D 02 | 0.3273214D 02 | 0.1698824D 02 |
| ERR | 3 | 0.5780257D 01 | 0.1926752D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3801950D 02 | 0.6940376D 00 |
| 2 | 0.3397400D 02 | 0.6940376D 00 |

EXP MEAN 0.35996750D 02 C.V. 0.38561123D-01

## TREATMENTS A, B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.9561087D 02 | | |
| BLK | 3 | 0.2873645D 02 | | |
| TRT | 2 | 0.5603724D 02 | 0.2801862D 02 | 0.1551251D 02 |
| ERR | 6 | 0.1083717D 02 | 0.1806195D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3801950D 02 | 0.6719738D 00 |
| 2 | 0.3397400D 02 | 0.6719738D 00 |
| 3 | 0.3304050D 02 | 0.6719738D 00 |

EXP MEAN 0.35011333D 02 C.V. 0.38386074D-01

## TREATMENTS B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.4038266D 02 | | |
| BLK | 3 | 0.3548198D 02 | | |
| TRT | 1 | 0.1742845D 01 | 0.1742845D 01 | 0.1655735D 01 |
| ERR | 3 | 0.3157832D 01 | 0.1052611D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3397400D 02 | 0.5129841D 00 |
| 2 | 0.3304050D 02 | 0.5129841D 00 |

EXP MEAN 0.33507250D 02 C.V. 0.30619291D-01

## TREATMENTS B, C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.1040895D 03 | | |
| BLK | 3 | 0.6521360D 02 | | |
| TRT | 2 | 0.2834163D 02 | 0.1417081D 02 | 0.8071287D 01 |
| ERR | 6 | 0.1053424D 02 | 0.1755707D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3397400D 02 | 0.6625154D 00 |
| 2 | 0.3304050D 02 | 0.6625154D 00 |
| 3 | 0.3034900D 02 | 0.6625154D 00 |

EXP MEAN 0.32454500D 02 C.V. 0.40827339D-01

## TREATMENTS C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.7252751D 02 | | |
| BLK | 3 | 0.5316390D 02 | | |
| TRT | 1 | 0.1448834D 02 | 0.1448834D 02 | 0.8915410D 01 |
| ERR | 3 | 0.4875270D 01 | 0.1625090D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3304050D 02 | 0.6373951D 00 |
| 2 | 0.3034900D 02 | 0.6373951D 00 |

EXP MEAN 0.31694750D 02 C.V. 0.40220864D-01

## TREATMENTS C, D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.1296499D 03 | | |
| BLK | 3 | 0.3336340D 02 | | |
| TRT | 2 | 0.3882149D 02 | 0.1941075D 02 | 0.2026702D 01 |
| ERR | 6 | 0.5746502D 02 | 0.9577504D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3304050D 02 | 0.1547377D 01 |
| 2 | 0.3034900D 02 | 0.1547377D 01 |
| 3 | 0.2867400D 02 | 0.1547377D 01 |

EXP MEAN 0.30687833D 02 C.V. 0.10084629D 00

## TREATMENTS D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.7550854D 02 | | |
| BLK | 3 | 0.2446867D 02 | | |
| TRT | 1 | 0.5611250D 01 | 0.5611250D 01 | 0.3705539D 00 |
| ERR | 3 | 0.4542862D 02 | 0.1514287D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3034900D 02 | 0.1945692D 01 |
| 2 | 0.2867400D 02 | 0.1945692D 01 |

EXP MEAN 0.29511500D 02 C.V. 0.13185993D 00

## TREATMENTS D, E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.7919797D 02 | | |
| BLK | 3 | 0.1496255D 02 | | |
| TRT | 2 | 0.6297390D 01 | 0.3148695D 01 | 0.3260755D 00 |
| ERR | 6 | 0.5793803D 02 | 0.9656339D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.3034900D 02 | 0.1553733D 01 |
| 2 | 0.2867400D 02 | 0.1553733D 01 |
| 3 | 0.2900425D 02 | 0.1553733D 01 |

EXP MEAN 0.29342417D 02 C.V. 0.10590351D 00

## TREATMENTS E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.3601068D 02 | | |
| BLK | 3 | 0.1848634D 02 | | |
| TRT | 1 | 0.2181301D 00 | 0.2181301D 00 | 0.3781246D-01 |
| ERR | 3 | 0.1730621D 02 | 0.5768737D 01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2867400D 02 | 0.1200910D 01 |
| 2 | 0.2900425D 02 | 0.1200910D 01 |

EXP MEAN 0.28839125D 02 C.V. 0.83283371D-01

# Appendix G

## Statistical Analysis of Yield Data by ANOVA Method

## TREATMENTS A, B

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.4064488D 03 | | |
| BLK | 3 | 0.3208770D 03 | | |
| TRT | 1 | 0.2701125D 02 | 0.2701125D 02 | 0.1383760D 01 |
| ERR | 3 | 0.5856055D 02 | 0.1952018D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2373750D 02 | 0.2209083D 01 |
| 2 | 0.2006250D 02 | 0.2209083D 01 |

EXP MEAN 0.21900000D 02 C.V. 0.20174270D 00

## TREATMENTS A, B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.5527383D 03 | | |
| BLK | 3 | 0.2653943D 03 | | |
| TRT | 2 | 0.1131959D 03 | 0.5659793D 02 | 0.1949992D 01 |
| ERR | 6 | 0.1741481D 03 | 0.2902469D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2373750D 02 | 0.2693728D 01 |
| 2 | 0.2006250D 02 | 0.2693728D 01 |
| 3 | 0.2758500D 02 | 0.2693728D 01 |

EXP MEAN 0.23795000D 02 C.V. 0.22641130D 00

## TREATMENTS B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.2732932D 03 | | |
| BLK | 3 | 0.1248597D 03 | | |
| TRT | 1 | 0.1131760D 03 | 0.1131760D 03 | 0.9629969D 01 |
| ERR | 3 | 0.3525744D 02 | 0.1175248D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2006250D 02 | 0.1714094D 01 |
| 2 | 0.2758500D 02 | 0.1714094D 01 |

EXP MEAN 0.23823750D 02 C.V. 0.14389795D 00

## TREATMENTS B, C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.2808966D 03 | | |
| BLK | 3 | 0.7464857D 02 | | |
| TRT | 2 | 0.1160395D 03 | 0.5801976D 02 | 0.3859044D 01 |
| ERR | 6 | 0.9020848D 02 | 0.1503475D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2006250D 02 | 0.1938733D 01 |
| 2 | 0.2758500D 02 | 0.1938733D 01 |
| 3 | 0.2278750D 02 | 0.1938733D 01 |

EXP MEAN 0.23478333D 02 C.V. 0.16515085D 00

## TREATMENTS C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.1108768D 03 | | |
| BLK | 3 | 0.2449774D 02 | | |
| TRT | 1 | 0.4603201D 02 | 0.4603201D 02 | 0.3422706D 01 |
| ERR | 3 | 0.4034704D 02 | 0.1344901D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2758500D 02 | 0.1833645D 01 |
| 2 | 0.2278750D 02 | 0.1833645D 01 |

EXP MEAN 0.25186250D 02 C.V. 0.14560681D 00

## TREATMENTS C, D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.2827278D 03 | | |
| BLK | 3 | 0.7654216D 02 | | |
| TRT | 2 | 0.4817405D 02 | 0.2408703D 02 | 0.9146299D 00 |
| ERR | 6 | 0.1580116D 03 | 0.2633527D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2758500D 02 | 0.2565895D 01 |
| 2 | 0.2278750D 02 | 0.2565895D 01 |
| 3 | 0.2429000D 02 | 0.2565895D 01 |

EXP MEAN 0.24887500D 02 C.V. 0.20619950D 00

## TREATMENTS D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.1789639D 03 | | |
| BLK | 3 | 0.8106774D 02 | | |
| TRT | 1 | 0.4515013D 01 | 0.4515013D 01 | 0.1450511D 00 |
| ERR | 3 | 0.9338114D 02 | 0.3112705D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2278750D 02 | 0.2789581D 01 |
| 2 | 0.2429000D 02 | 0.2789581D 01 |

EXP MEAN 0.23538750D 02 C.V. 0.23702031D 00

## TREATMENTS D, E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.4142396D 03 | | |
| BLK | 3 | 0.5922630D 02 | | |
| TRT | 2 | 0.1203672D 03 | 0.6018361D 02 | 0.1538921D 01 |
| ERR | 6 | 0.2346460D 03 | 0.3910767D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2278750D 02 | 0.3126806D 01 |
| 2 | 0.2429000D 02 | 0.3126806D 01 |
| 3 | 0.1694750D 02 | 0.3126806D 01 |

EXP MEAN 0.21341667D 02 C.V. 0.29302364D 00

## TREATMENTS E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.3969571D 03 | | |
| BLK | 3 | 0.7022264D 02 | | |
| TRT | 1 | 0.1078246D 03 | 0.1078246D 03 | 0.1477658D 01 |
| ERR | 3 | 0.2189098D 03 | 0.7296995D 02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.2429000D 02 | 0.4271122D 01 |
| 2 | 0.1694750D 02 | 0.4271122D 01 |

EXP MEAN 0.20618750D 02 C.V. 0.41429499D 00

# Appendix H

## Statistical Analysis of Water Used and Yield Data by ANOVA Method

## TREATMENTS A, B

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | [illegible] | | |
| BLK | 3 | [illegible] | | |
| TRT | 1 | 0.2701125D-02 | 0.2701125D-02 | 0.2189133D 00 |
| ERR | 3 | 0.3701638D-01 | 0.1233879D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | [illegible] | [illegible] |
| 2 | [illegible] | [illegible] |

EXP MEAN [illegible] C.V. [illegible]

## TREATMENTS A, B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.4710407D 00 | | |
| BLK | 3 | 0.1573807D 00 | | |
| TRT | 2 | 0.1485612D 00 | 0.7428058D-01 | 0.2699495D 01 |
| ERR | 6 | 0.1650988D 00 | 0.2751647D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.6227500D 00 | 0.8294045D-01 |
| 2 | 0.5860000D 00 | 0.8294045D-01 |
| 3 | 0.8382500D 00 | 0.8294045D-01 |

EXP MEAN 0.68233333D 00 C.V. 0.24310830D 00

## TREATMENTS B, C

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.2620469D 00 | | |
| BLK | 3 | 0.8479738D-01 | | |
| TRT | 1 | 0.1272601D 00 | 0.1272601D 00 | 0.7637230D 01 |
| ERR | 3 | 0.4998938D-01 | 0.1666313D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.5860000D 00 | 0.6454286D-01 |
| 2 | 0.8382500D 00 | 0.6454286D-01 |

EXP MEAN 0.71212500D 00 C.V. 0.18126836D 00

## TREATMENTS B, C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.3563917D 00 | | |
| BLK | 3 | 0.5720433D-01 | | |
| TRT | 2 | 0.1519002D 00 | 0.7595008D-01 | 0.3093959D 01 |
| ERR | 6 | 0.1472872D 00 | 0.2454786D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.5860000D 00 | 0.7833879D-01 |
| 2 | 0.8382500D 00 | 0.7833879D-01 |
| 3 | 0.8082500D 00 | 0.7833879D-01 |

EXP MEAN 0.74416667D 00 C.V. 0.21054097D 00

## TREATMENTS C, D

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.1370215D 00 | | |
| BLK | 3 | 0.8821750D-01 | | |
| TRT | 1 | 0.1800000D-02 | 0.1800000D-02 | 0.1148838D 00 |
| ERR | 3 | 0.4700400D-01 | 0.1566800D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.8382500D 00 | 0.6258594D-01 |
| 2 | 0.8082500D 00 | 0.6258594D-01 |

EXP MEAN 0.82325000D 00 C.V. 0.15204601D 00

## TREATMENTS C, D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.3157583D 00 | | |
| BLK | 3 | 0.2162262D 00 | | |
| TRT | 2 | 0.2976000D-02 | 0.1488000D-02 | 0.9246448D-01 |
| ERR | 6 | 0.9655600D-01 | 0.1609267D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.8382500D 00 | 0.6342844D-01 |
| 2 | 0.8082500D 00 | 0.6342844D-01 |
| 3 | 0.8442500D 00 | 0.6342844D-01 |

EXP MEAN 0.83025000D 00 C.V. 0.15279359D 00

## TREATMENTS D, E

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.2498575D 00 | | |
| BLK | 3 | 0.2300485D 00 | | |
| TRT | 1 | 0.2592000D-02 | 0.2592000D-02 | 0.4516466D 00 |
| ERR | 3 | 0.1721700D-01 | 0.5739000D-02 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.8082500D 00 | 0.3787809D-01 |
| 2 | 0.8442500D 00 | 0.3787809D-01 |

EXP MEAN 0.82625000D 00 C.V. 0.91686763D-01

## TREATMENTS D, E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 11 | 0.5483589D 00 | | |
| BLK | 3 | 0.1005036D 00 | | |
| TRT | 2 | 0.1587627D 00 | 0.7938133D-01 | 0.1647527D 01 |
| ERR | 6 | 0.2890927D 00 | 0.4818211D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.8082500D 00 | 0.1097521D 00 |
| 2 | 0.8442500D 00 | 0.1097521D 00 |
| 3 | 0.5842500D 00 | 0.1097521D 00 |

EXP MEAN 0.74558333D 00 C.V. 0.29440604D 00

## TREATMENTS E, F

ANALYSIS OF VARIANCE, VARIABLE 1

| SOURCE | DF | SS | MS | F |
|---|---|---|---|---|
| TOT | 7 | 0.4550915D 00 | | |
| BLK | 3 | 0.5366650D-01 | | |
| TRT | 1 | 0.1352000D 00 | 0.1352000D 00 | 0.1523523D 01 |
| ERR | 3 | 0.2662250D 00 | 0.8874167D-01 | |

| TRT | TRT MEANS | SE |
|---|---|---|
| 1 | 0.8442500D 00 | 0.1489477D 00 |
| 2 | 0.5842500D 00 | 0.1489477D 00 |

EXP MEAN 0.71425000D 00 C.V. 0.41707441D 00

# VITA

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Master of Science

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