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Determining a Crop Production Function for Corn as Influenced by Irrigation and Salinity Levels

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DETERMINING A CROP PRODUCTION FUNCTION FOR CORN AS INFLUENCED BY IRRIGATION AND SALINITY LEVELS

by

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of

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Timothy E. Sullivan

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by

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Utah State University, 1975

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Production functions were generated for dry matter and grain yields of corn. A continuous variable plot design replicated four times was established in the spring of 1974 in Vernal, Utah. Each replication included ten salt treatments and twenty irrigation levels. The salt treatments resulted in an average root zone salinity ranging from 2.7 to 14.9 mmhos/cm. Irrigation levels ranged from 4.2 to 45.0cm of water applied. Dry matter (Kg/ha) yield showed an 83 percent reduction over the range of salt applied and a 52 percent reduction over the range of water applied. Grain yield declined 96 and 64 percent over the range of salt and water applied, respectively. Salinity sensors produced results corresponding closely to measurements taken from the saturation extract of soil samples. Thermocouple psychrometers and a four probe resistivity meter produced results inconsistant with those of the soil samples.

(82 pages)

INTRODUCTION

The increasing salinity of the Colorado River and its impact on crop production has received much attention in recent years (U. S. Bureau of Reclamation, 1974, King and Hanks, 1973). Salinity affects not only the farmers of the United States and Mexico but all people of the lower basin states and Mexico that use the water for industry, energy production, recreation, and culinary needs. It has been said that the high salinity adversly affects nearly 10,000,000 people and about 1,000,000 acres of fertile, irrigated farmland. The Bureau of Reclamation in recent studies has shown annual economic losses ranging from $194,000 to $395,000 per mg/l increase in salinity at the Imperial Dam, the last major U. S. diversion point before the water reaches Mexico. In 1973 damages attributed to salinity in the Colorado River System totaled about 53 million dollars (U. S. Bureau of Reclamation, 1974).

In response to the salinity problem of the Colorado River this project has been initiated to determine the affect of salinity and irrigation on crop production. From the resulting data crop production functions were determined for use as prediction equations. Production functions have been found reliable in describing crop responses to several controlled factors within the limits of the controlled factors (Heady and Dillon, 1961).

Objectives

The objectives of this research are as follows:

(1) to determine crop production functions for corn as related to irrigation and salinity.

(2) to evaluate methods of monitoring salt movement and distribution.

LITERATURE REVIEW

Soil water and crop growth

Soil water and its availability for plant growth has been the subject of much research. Jamison (1956) in a summary article concluded that the available water depends not only on the soil factors but also to a great extent on the plant and climatic factors. Some of the climatic factors include matric potential, water content, osmotic potential, ions in the soil solution, soil water conductivity, depth of wetting, and soil temperature. Kramer (1963) pointed out that plant growth is controlled directly by plant water stress and only indirectly by soil water potential. He said it was not safe to assume that the two were always equal as plant water stress depends on the relative rates of water absorption and water loss rather than on the soil water supply alone. Thus a complicated interaction must exist between soil, plant and climatic factors.

Soil water in the available range between field capacity and the permanent wilting point has been of particular interest. One group of authors report that the water is readily available throughout the entire range (Veihmeyer and Hendrickson, 1950; Letey and Peters, 1957) while others report that water becomes less available as the water content decreases to the permanent wilting point (Lucey and Tesar, 1965). Denmead and Shaw (1960) have shown that these two views can both be supported by field data depending on climatic conditions. See Taylor and Ashchroft (1972) for a summary on this subject.

Howe and Rhodes (1955) have shown that corn production as indicated by height, dry matter production, ear development and yield of grain was materially influenced by irrigation. They concluded that it was essential to maintain a low soil water suction throughout the growing season to obtain maximum yield.

Yield of corn has been closely related to the reserve moisture condition at the beginning of the growing season and to the soil moisture stress that the plant experiences during the growing season (Letey and Peters, 1957). Moisture depletion to the wilting percentage at certain physiologic growth stages markedly depressed grain yields (Robins and Domingo, 1953; Howe and Rhodes, 1955)

Salinity and crop growth

Salinity and its detrimental effect on the growth and yield of agricultural crops is of concern in irrigated agriculture. Decreases in yield resulting from increasing salinities are well documented (Meiri and Shalhevet, 1973). Salt in the soil solution (salinity) affects the plants in two ways; first a decreased osmotic potential tends to reduce the entry of water into the plant making it less available: and second, specific ions can exert a specific toxic action on the activity of the plant cells (Wadleigh, Gauch and Strong, 1947). Magistad et al., (1943) found the osmotic component to be a greater factor in determining the amount of growth reduction than specific ions. Bernstein and Hayward (1958) have suggested that some toxicities are actually nutritional disturbances. Luken (1962) working on saline soils in Canada found that fertility and structural factors as well as water conservation all influenced yield. Lunin and Gallatin (1965), also found that bean yield on a saline soil is affected by soil fertility.

Some interesting work has been completed in the zonal salinization of various root systems to relate water uptake to plant growth. Bingham and Garber (1970) reported that sweet corn was able to withstand substantial salinization of the root zone provided that a portion of the root zone remained free from excessive salinization. Lunin and Gallatin (1965) working with tomatoes showed that with one-third of the root zone salinized yield was unaffected. With two-thirds of the root zone salinized, water uptake was reduced significantly and yield slightly reduced. Shalhevet and Bernstein (1968) concluded that the relative water uptake depends on the relative salinity of the root zone rather than on the absolute salinity. Both of the above authors showed that salinity induced yield decreases were highly correlated with transpiration decreases.

Production functions and design

The production function is a concept relatively new to the physical and biological sciences. It was developed and has been used mainly by economists. A detailed description of the types of production functions and of their use are offered by Heady and Dillon (1966). Briefly the production function is a tool of management and decision making i.e. it is useful in describing plant response to several variables. Box and Hunter (as cited in Bauder, 1974) have indicated that the production function approach of describing crop responses is used for two reasons: (1) to find the conditions of the variables under consideration, which give the best yield, and (2) to determine the characteristic of the response surface in the neighborhood of the optimum operating conditions to indicate how operations should be modified if conditions change in order to best control crop production.

A production function of two independent variables can be represented by a second degree quadratic equation of the general form

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon$$

where:

$\hat{Y}$ = dependent variable, yield

$X_1 X_2 . .$ = independent variables

ε = error due to the fact that the postulated independent variables do not completely explain Y

β_i = population regression coefficients.

An equation of this form has been used successfully in describing the response of corn to soil moisture and nitrogen fertilizer (as cited in Bauder, 1974) and will be used in this project's analysis.

The continuous variable experimental design as described by Fox (1973) and Bauder (1974) has been useful in producing data from which production functions were derived. These production functions are statistically interpolated and are thus very difficult to extrapolate beyond the situation where the data were collected. The number of treatments generated in a continuous variable design is much greater than those generated from the more commonly use used statistically replicated field plot designs. The size of each individual plot is much smaller in a continuous variable design. Bauder (1974) found that increasing the size of his fertilizer treatments from 1.2 to 3.6m (3.9 to 12.8 feet) and decreasing the number of treatments from 21 to 7 seemed to be a good compromise between large plots with few treatments and small plots with many treatments. The main advantage of a continuous variable design is the use of a relatively small amount of land area since no border areas are used between treatments.

Some question as to the reliability of the statistical analysis of data collected from the continuous variable design has been raised because of the lack of randomization of the treatments. In conventional designs, randomization is assumed to minimize the bias due to treatment interaction of natural field variation. The continuous variable design by its nature is completely non-randominized maintaining the same arrangement of treatments throughout the design. It assumes that the increment between treatments is small enough to minimize the influence of one treatment on its neighbor, thus minimizing the bias due to treatment interaction. Bauder (1974), to test the assumptions of the continuous variable, compared it to a conventional randomized block design. Production functions generated for both designs did not significantly differ in their predicted yields (Bauder, Hanks and James, 1975).

An example of a continuous variable irrigation system is the line source sprinkler system described by Hanks, Keller, and Bauder (1974). This system has been shown effective in establishing a water application pattern which is uniform along the length of the plot and continuously but uniformly variable across the plot. This system is more manageable than the tedious trickler irrigation scheme used by Bauder (1974). The small change occuring across the treatments makes the system useful for the continuous variable design.

EXPERIMENTAL PROCEEDURE

Design

The field work was conducted on the Hullinger experimental farm near Vernal, Utah. The farm has been described in detail by King and Hanks (1973). A continuous variable plot design (Figure 1) replicated four times was established early in the spring of 1974 on a Mesa sandy clay loam soil. Each replication measured 50 X 100 feet (15.2 X 30.84m) and included 10 salt treatments 10 feet (3.1m) wide by 50 feet (15.24m) long and 20 water treatments each 2.5 feet (0.76m) wide by 100 feet (30.48m) long. A single row of corn constituted a plot for a water treatment. Irrigation was accomplished approximatly every 10 days through the line source sprinkler system described by Hanks, Keller and Bauder (1974).

Corn (Utah hybrid 330) was first planted on May 22, but because of poor germination was replanted on June 13, 1974. The second planting, oriented about 6 inches (15cm) to the side of the first, helped to increase the stand. After two plantings the corn was thinned to about 53,800 plants/ha (21,800 plants/acre).

Salt treatment

$CaCl_2$ salt was applied with a 10 foot (3.0m) wide fertilizer spreader pulled behind a tractor. The quantity of salt applied was determined by the osmotic potential desired for each treatment (Table 1). The spreader was

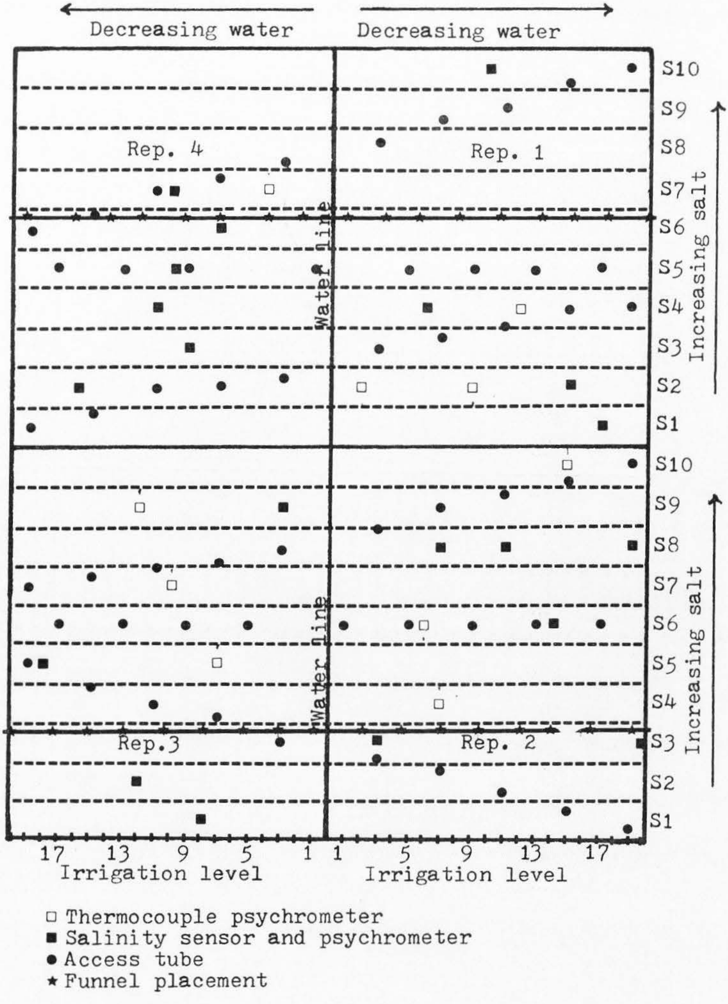

Figure 1. Plot layout and instrumentation

Table 1. Osmotic potential of the soil solution as a function of salt level, desired and obtained, (Soil samples taken 6-11-74)

Salt level	Desired (bars)	Obtained (bars)					
		Depth-inches					
		0-6	6-12	12-18	18-24	24-36	36-48
1	0.0	- 0.8	- 0.9	- 0.8	- 0.6	- 1.1	- 1.3
2	- 0.5	- 0.8	- 1.0	- 1.5	- 1.7	- 1.2	- 1.2
3	- 1.0	- 1.3	- 2.9	- 2.1	- 1.5	- 1.5	- 1.6
4	- 1.5	- 1.4	- 2.8	- 2.7	- 1.4	- 1.3	- 1.3
5	- 2.0	- 1.1	- 2.5	- 3.5	- 1.9	- 1.7	- 1.5
6	- 2.5	- 1.4	- 3.3	- 4.2	- 2.2	- 1.4	- 2.3
7	- 3.0	- 1.9	- 3.2	- 5.0	- 2.0	- 1.4	- 1.2
8	- 5.0	- 4.8	- 6.0	- 4.5	- 2.1	- 1.1	- 1.2
9	- 7.0	- 6.3	- 5.6	- 7.5	- 2.8	- 1.5	- 1.4
10	- 9.0	-11.8	-12.8	- 5.2	- 2.4	- 1.7	- 1.6

calibrated to apply 3.4 lbs/A (3.9 Kg/ha) of salt, the amount required to obtain the osmotic potential of the first salt treatment (S2). Each salt level thereafter required only additional passes by the tractor and spreader to obtain the desired salt application.

Initial intentions were to apply the salt in four applications and to disc the ground and irrigate to wet the soil to field capacity to a depth of six inches (15.2cm). This proceedure was designed to produce a uniform salinity in the top two feet (0.6m) of soil. After the first application of water, it became obvious that it was impractical to add more water and still get the tractor across the plots without getting stuck and still complete the salt application in the time allowed. The following day the wet soil was disced and a second application of salt applied. The soil was then disced again and with the spreader recalibrated the remaining salt was applied. Only after all the salt had been applied was the remaining water applied.

<u>Water application</u>

The water variable was obtained using Rain Bird #30 sprinkler heads with a three-sixteenths inch (.48cm) front nozzle and a three-thirtysecond inch (.24cm) rear nozzle with a 7 percent slit. Two parallel irrigation lines consisted of 30 foot (12.2m) sections of 3 inch (7.6cm) aluminum irrigation pipe that were placed to position a sprinkler every 15 feet (6.1m). The high water treatment next to the water line was designed to receive about 1.5 times evapotranspiration (Et). Et was measured with two lysimeters located near the plot area and planted to alfalfa.

To determine the quantity of water being applied, a series of nine funnels mounted every 6 feet (1.8m) on 3 inch (7.6cm) aluminum irrigation pipe were used. A 4 inch (0.2cm) diameter aluminum funnel was fitted snuggly into a nine-sixteenth inch (1.4cm) hole drilled into the pipe. To each funnel was connected a section of polyethylene tubing one-fourth inch (0.6cm) inside diameter that ran through the length of the irrigation pipe and out of the plot area. The end of the tubing was then connected to a 500 ml glass jar for collecting the water from each individual funnel. A number 11 rubber stopper with two 3 inch (7.6cm) pieces of copper tubing mounted through it provided for the connection of the tubing to the jar. A slight slope on the funnel line allowed most of the collected water to drain into the jars. It was necessary to use a hand vacuum system to extract all the water from the tubing for final measurement. The funnel line was fastened to four lengths of three-quarter inch (1.9cm) steel pipe driven vertically into the ground. This arrangement allowed the funnel precipitation collection line to be raised as the corn grew. The tops of the funnels were kept at the height of the corn. The funnel system allowed an accurate measure of the water being applied without entering the plot area. After an initial priming essentially all of the sprinkler water entering the funnel collection system could be extracted with the hand vacuum system.

RESULTS AND DISCUSSION

Irrigation

The funnel sampling system demonstrated the line source sprinkler system to be effective in establishing the continuous but uniformly variable water treatments (Figure 2). Total amounts of water applied (Table 2) ranged from 45.0cm (17.7 inches) at water level one (W1) to 4.2cm (1.7inches) at W20. The odd number rows corresponding to grain yield and the even number rows to dry matter yield. Wind proved to be a major problem associated with the irrigation system. As a result, irrigation was conducted only in the early mornings and some late afternoons when wind speed was low. This schedule resulted in less water being applied than had been desired, but it maintained the continuous variable water treatment.

Soil moisture

A neutron probe was used to measure soil water content and results presented in table 12 of the appendix show that soil moisture decreased very little on any treatment. Neither irrigation treatment nor salt levels had any appreciable effect on the volumetric water content of the soil (Figures 3 and 4). Readings taken as late as September 18, 1974 showed high water contents in all the treatments. Upward flow from a water table at about 7 feet (2.13m) was the only possible source of the water that caused the water contents to stay high since total natural precipitation was

Table 2. Average root zone salinity and irrigation applied for the levels studied

Salt level	Average root zone salinity* (mmhos/cm)	Grain		Dry matter	
		Irrigation level	Water applied (cm)	Irrigation level	Water applied (cm)
S 1	2.7	1	45.0	2	42.7
S 2	3.4	3	41.2	4	39.6
S 3	4.9	5	39.0	6	37.8
S 4	6.1	7	37.0	8	33.5
S 5	6.0	9	32.0	10	30.0
S 6	6.3	11	29.0	12	27.9
S 7	8.7	13	25.0	14	22.9
S 8	10.3	15	20.0	16	17.0
S 9	12.9	17	13.0	18	9.9
S 10	14.9	19	7.0	20	4.2

*Average salinity per salt treatment for the growing season 0-3 feet (0-90 cm), in the soil at the beginning of the season (May 15, 1974).

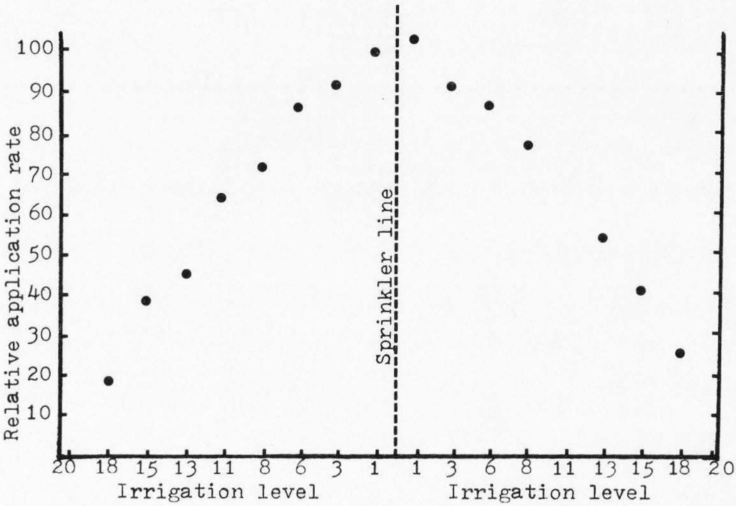

Figure 2. Relative sprinkler application rate as a function of distance from the sprinkler line

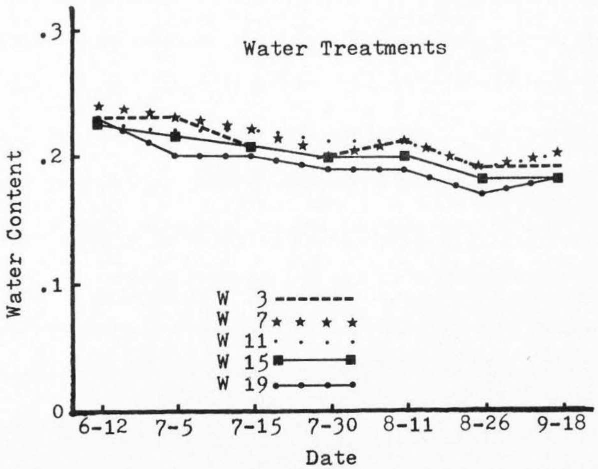

Figure 3. Average volumetric water content in the 1 - 3 feet (0.3 - 0.9m) zone during the growing season, 1974

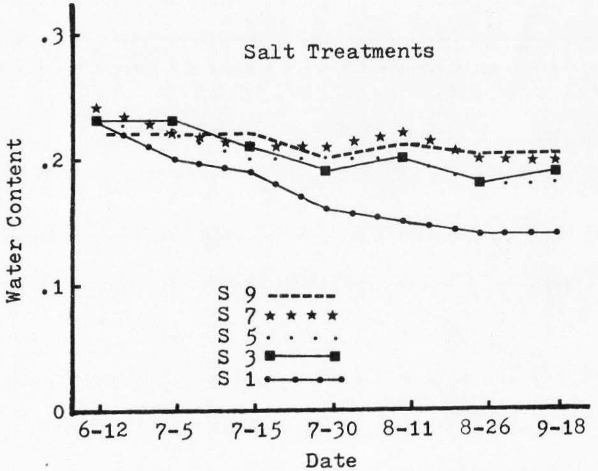

Figure 4. Average volumetric water content in the 1 - 3 feet (0.3 - 0.9m) zone during the growing season, 1974

only 0.5 inches (1.27cm) for the entire growing season. Past piezometer data collected near the plot area indicated that there was a water table between 7 and 9 feet. This plot was originally chosen because the water table was deeper than at any other place on the Vernal farm, but apparently the water movement upward from the water table was still very large.

Salinity

Intentions were to evenly distribute the salt in the top 2 feet (60cm) of soil. Achieving this would have resulted in the approximate desired osmotic potential of each treatment (Table 1). However, soil samples taken before the first irrigation (Table 13 in the appendix) showed the salt to be unevenly distributed in the top 18 inches (46cm) of soil. This concentration of salt was one of the factors that may have made a second planting necessary although seedling emergence in the whole agricultural area was generally poor.

The tractor and fertilizer spreader proved to be a relatively easy method of applying the salt but may have caused a serious soil compaction problem. Since higher salt application required more trips across the plots with the tractor and drill, the compaction problem in turn caused an infiltration problem that may have affected germination. There was noticeable difficulty getting the irrigation water into the soil without runoff. It was necessary to irrigate for a shorter duration more frequently.

The salt became more evenly distributed in the soil profile with time. Electrical conductivities of the soil samples (Table 14 in the appendix) taken just before harvest showed the salt to be relatively uniformly distributed down to 3 feet (0.9m). The higher water application levels leached the salt slightly deeper and distributed it somewhat more evenly.

Yield

The detailed yield data and their resulting graphs are presented in tables 15, 16, 17 and figures 12, 13 and 14 of the appendix. Oven dry matter has been expressed both as Kg/ha and grams/plant to isolate the compaction effect.

Figure 5 shows the average grain and dry matter yield (Metric tons/ha) plotted as a function of salt and irrigation levels. A regression line fitted to the dry matter data showed a linear relationship between yield and salt levels. Regression lines fitted to the average water application level data for dry matter and both the averaged salt and water application level data for grain production resulted in a curvilinear fit. Similar curves were found for corn height as a function of salt and water levels (Figure 6).

Plotting dry matter yield in grams/plant as a function of individual water and salt levels resulted in curves with a variety of slopes (Figure 7). Similar curves were produced for dry matter and grain yield expressed as metric ton/ha. Averaging the first five (W2, 4, 6, 8 and 10) and

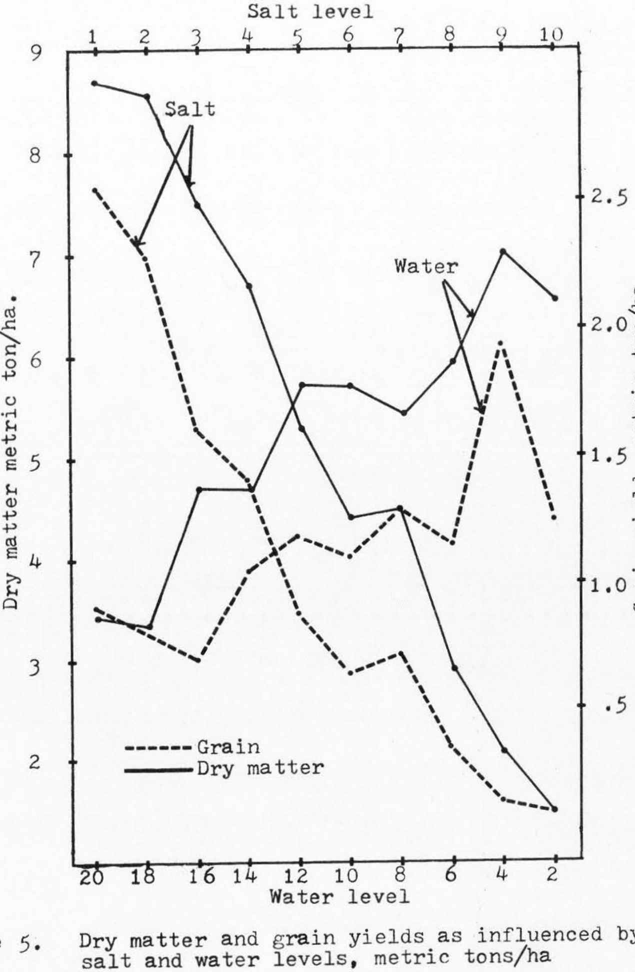

Figure 5. Dry matter and grain yields as influenced by salt and water levels, metric tons/ha

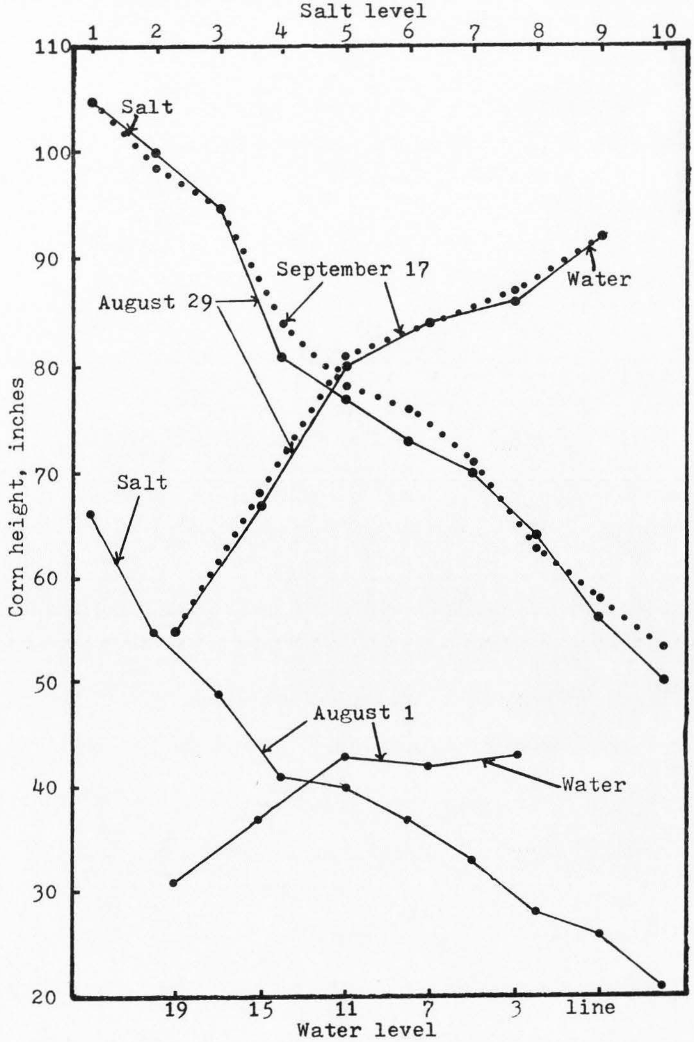

Figure 6. Average corn height as a function water and salt level

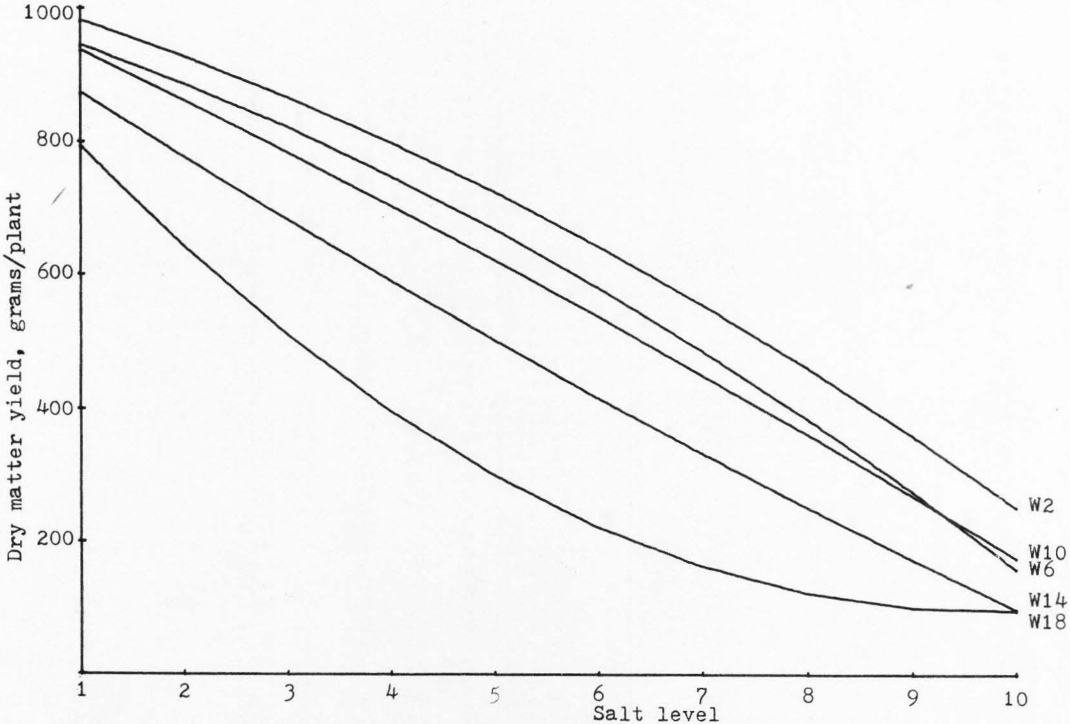

Figure 7. Dry matter yield as a function of salt and irrigation level, grams/plant

second five (W12, 14, 16, 18 and 20) water levels resulted in curves of different shapes (Figure 8). These differences in slope indicates a complex interrelationship of salinity and irrigation levels complicated further by compaction.

Dry matter (Kg/ha) yield showed an 83 percent reduction over the range of salt applied and showed 52 percent reduction over the range of irrigation levels. Expressed as grams/plant, dry matter declined 67 percent in response to salt and 56 percent in response to water application level. Grain production declined 96 percent over the range of salt applied. A 64 percent grain yield reduction was found over the range of water treatments.

The effect of compaction on yield is seen in figure (9). The yield expressed as grams/plant has been equated to that of Kg/ha by a correction factor. The difference in slope of the lines is due to decreased dry matter production of plants growing in the compacted area and a fewer number of plants in the heaviest salt treatments (Table 3). Although the average number of plants did not significantly decrease in the first seven salt levels, the dry matter produced per plant within the compacted area showed a steady decrease starting about S3. There were no plants growing in the compacted area of S10.

Because soil moisture was never limiting below about a foot (3.0cm) for the entire growing season, the effect of irrigation was realized in the early part of the growing

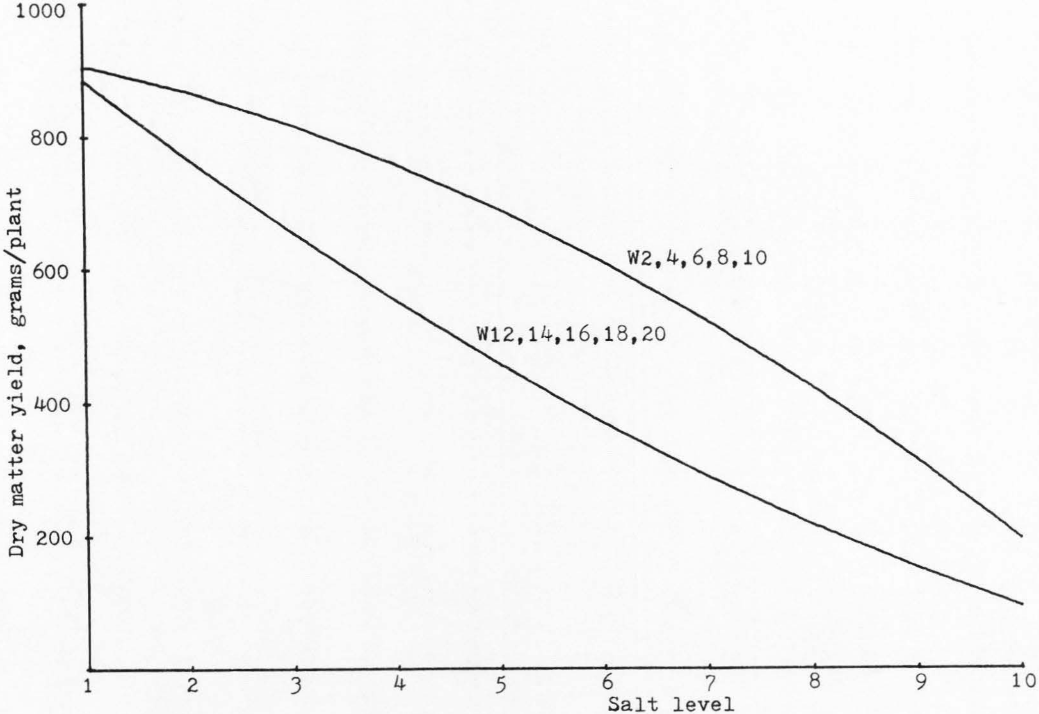

Figure 8. Dry matter yield as a function of salt and irrigation level, grams/plant

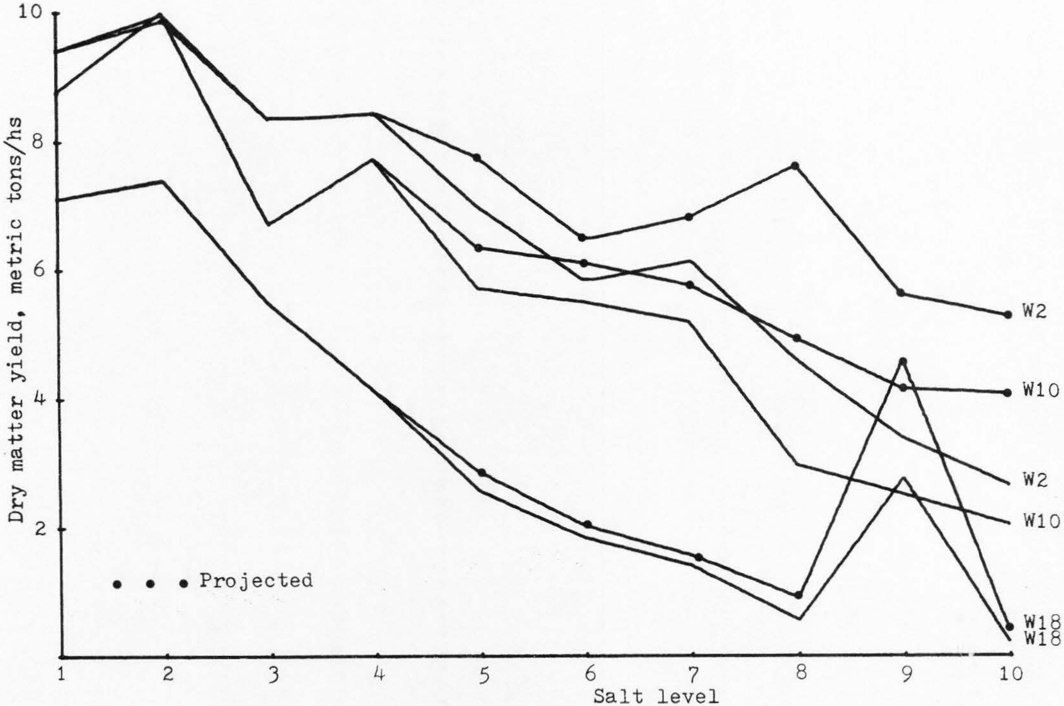

Figure 9. Projected and actual dry matter yields as a function of salt and irrigation levels, metric tons/ha

Table 3. Average number of plants as a function of salt and irrigation treatments

Salt level	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Average number of plants	10	9	10	10	9	9	9	5	6	4

Water level	W1	W3	W5	W7	W9	W11	W13	W15	W17	W19
Average number of plants	9	9	8	9	9	8	8	7	7	7

season before the plants had developed an adequate root system. Corn growing in the compacted area was stressed the most because of poor infiltration.

The moisture percentage of the grain (Table 18 in the appendix) did not appear to correlate to salinity or irrigation treatments. The protein percentage (Table 19 in the appendix) increased slightly with increasing salinity.

The analysis of variance computed for all yield data showed salinity and irrigation treatments and their interaction to be significant at the 99 percent level (Tables 4, 5 and 6). A word of caution must be included here regarding significance of the data. The error associated with the lack of randomization within the field design has been assumed insignificant through arguements previously mentioned.

A test of significance of the treatment means is presented in table 20 of the appendix. Generally all the salt treatment means proved to be significantly different from their neighbors. S6 and S7 were the only treatments which

Table 4. Analysis of variance for oven dry matter, Kg/ha

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Replication	3	.50327E+08	.16776E+08	
Salinity	9	.24506E+10	.27229E+09	69.33*
Error (A)	27	.10604E+09	.39274E+07	
Irrigation	9	.53078E+09	.58975E+08	21.83*
Error (B)	27	.72929E+08	.27011E+07	
Interaction	81	.16167E+09	.19959E+07	1.28*
Error (C)	243	.37887E+09	.15591E+07	
Total	399	.37512E+10	.94016E+07	

*Significant at the 95 percent level

Table 5. Analysis of variance for oven dry matter, grams/plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Replication	3	.60077E+06	.20026E+06	
Salinity	9	.11533E+08	.12814E+07	28.66*
Error (A)	27	.12074E+07	.44719E+05	
Irrigation	9	.65823E+07	.73136E+06	26.88*
Error (B)	27	.73462E+06	.27208E+05	
Interaction	81	.20871E+07	.25766E+05	1.56*
Error (C)	243	.40038E+07	.16477E+05	
Total	399	.26749E+08	.67040E+05	

*Significant at the 95 percent level

Table 6. Analysis of variance for grain, Kg/ha @ 15.5 percent moisture

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Replication	3	.43286E+07	.14429E+07	
Salinity	9	.27290E+09	.30323E+08	53.17*
Error (A)	27	.15396E+08	.57021E+06	
Irrigation	9	.14306E+08	.15896E+06	3.87*
Error (B)	27	.11075R+08	.41019E+06	
Interaction	81	.31873E+08	.39350E+06	1.37*
Error (C)	243	.69715E+08	.28689E+06	
Total	399	.41960E+09	.10516E+07	

*Significant at the 95 percent level

were nonsignificant between their means for all yield data. Irrigation treatments showed sporadic nonsignificance in the heavier water levels while the lighter application levels tended to show adjacent treatments to be nonsignificant.

Production functions

A second degree quadratic (Equation 1) was used to generate the production functions. The statistical analysis and production functions were generated on a Burroughs B6700 computer system. Programs from the Statistical Program Package (STATPAC: Hurst, 1973) included the Multivariate Data Collection (MDCR), Stepwise Multiple Regression (SMRR). Stepwise Multiple Regression Upward (SMRU), Multiple Regression (MREGT), and a two way Split Plot Analysis of Variance (FCTCUR).

The production functions for dry matter expressed as Kg/ha and grams/plant, and grain expressed as Kg/ha are seen in equations 2, 3 and 4 respectively. The salt variable, S, is expressed as the average root zone salinity in mmhos/cm @ 25°C while the irrigation level, W, is expressed as total centimeters of water applied (Table 2). The resulting response curves are presented in figures 10, 11 and 12.

$$\hat{Y} = 9896 - 1274S + 84W + 37S^2 + .03W^2 + .53SW \qquad (2)$$

$$R^2 = 0.74$$

$$\hat{Y} = 873 - 107S + 4.7W + 2.8S^2 + .01W^2 + .61SW \qquad (3)$$

$$R^2 = 0.64$$

$$\hat{Y} = 3676 - 604S + 6.1W + 23S^2 + .13W^2 + .008SW \qquad (4)$$

$$R^2 = 0.63$$

A regression analysis of variance (Tables 7, 8 and 9) was run on the general form of the second degree quadratic equation to determine the significance of the individual terms.

The sign associated with the first degree terms of equations 2, 3 and 4 distinguishes between a positive and negative response of yield to changing levels of salt and water. Here, the negative coefficient of the first degree salinity variable (S) indicates the negative response of increasing salinity on yield. The positive W indicates an increase in yield with an increase in water applied. The second degree terms show a nonlinear relationship of salt and irrigation levels to yield. W^2 proved to be

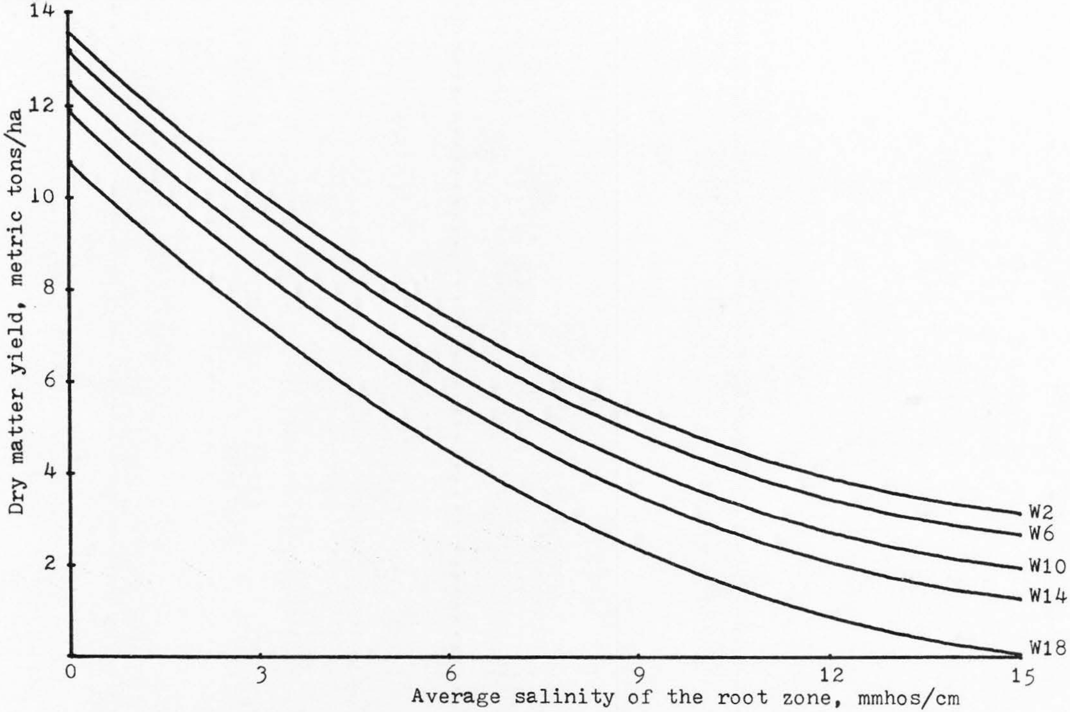

Figure 10. Predicted dry matter yield, metric tons/ha

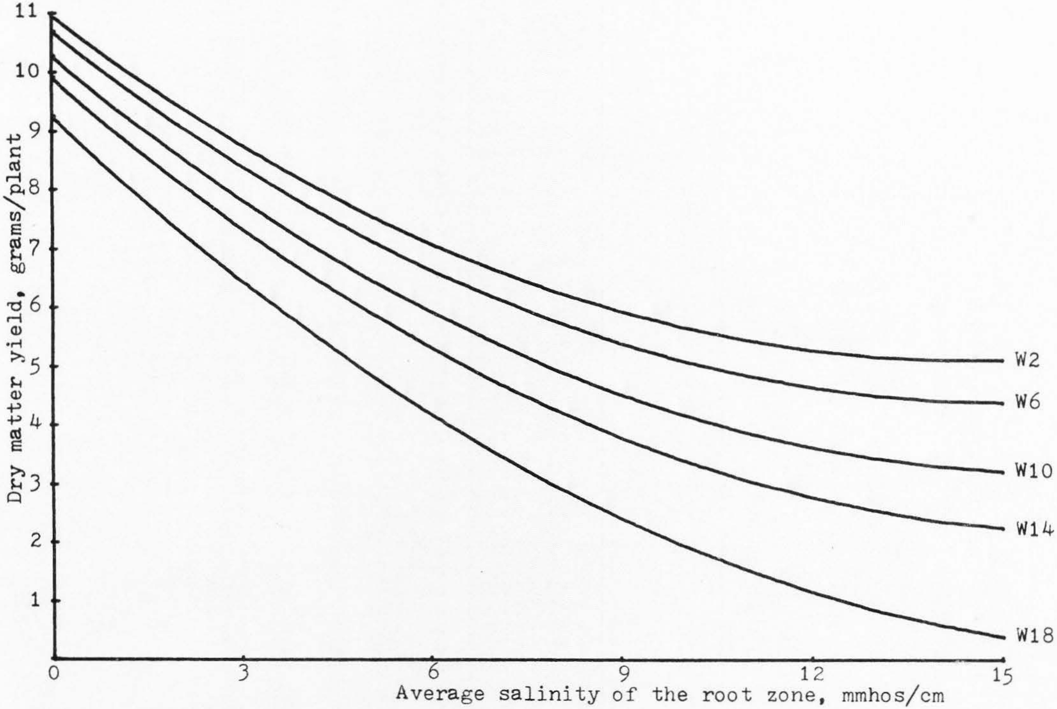

Figure 11. Predicted dry matter yield, grams/plant

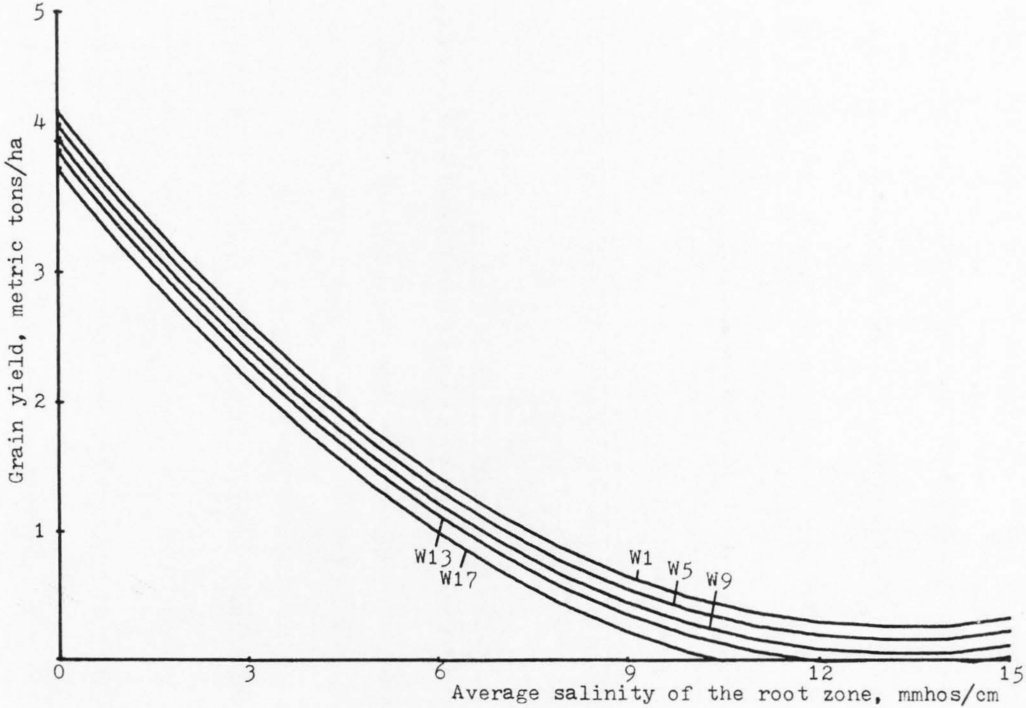

Figure 12. Predicted grain yields, metric tons/ha

Table 7. Regression analysis of variance for oven dry matter Kg/ha

Source of variation	Degrees of freedom	Mean sum of square	F-ratio
Salinity	1	.3036E+09	123.72*
Irrigation	1	.1774E+08	7.23*
Second order salinity	1	.9506E+08	38.74*
Second order irrigation	1	.8335E+04	0.003
Irrigation X salinity	1	.2471E+06	0.10
Model	5	.5569E+09	2.27
Error	394	.2454E+07	

*Significant at the 95 percent level

Table 8. Regression analysis of variance for oven dry matter grams/plant

Source of variation	Degrees of freedom	Mean sum of square	F-ratio
Salinity	1	2134426.0	86.91*
Irrigation	1	55352.0	2.25*
Second order salinity	1	545867.0	22.23*
Second order irrigation	1	1485.0	0.06
Irrigation X salinity	1	329835.0	13.43*
Model	5	3414541.0	
Error	394	24559.0	

*Significant at the 95 percent level

Table 9. Regression analysis of variance for grain, Kg/ha @ 15.5 percent moisture

Source of variation	Degrees of freedom	Mean sum of square	F-ratio
Salinity	1	.6566E+08	167.35*
Irrigation	1	.7402E+05	0.19
Second order salinity	1	.3859E+08	98.34*
Second order irrigation	1	.1192E+06	0.30
Irrigation X salinity	1	.5200E+02	0.00013
Model	5	.5300E+08	
Error	394	.3924E+06	

* Significant at the 95 percent level

insignificant for all equations. The sign of the second degree term determines the rate of increase or decrease. In the equations presented here all second degree coefficients are positive indicating the effect of salt and water to be greatest in the first four salt treatments. The interaction term in all three equations was small and in only one case (Equation 3) was it significant. The results presented here are typical for a sensitive crop and are consistent with other field data (Meiri and Shalhevet, 1973; Howe and Rhodes, 1955).

The multiple correlation coefficient (R^2) represents the degree to which the function fits the data. The Equation for dry matter expressed as Kg/ha showed the best fit with an R^2 of .74. The equation for dry matter in grams/ plant was slightly better fitted than the equation for grain with R^2's of .64 and .63 respectively.

Monitoring devises

Limited success was achieved with the monitoring insturments. EC_e was the only data to give the salinity status of the total soil profile for the course of the growing season.

Salinity sensors. The salinity sensor results were useful in differentiating between the salt and water treatments (Table 10). The salt levels are identified by the magnitude in the readings and the irrigation treatments by the range in the readings over time. The sensors in the high water treatments picked up the movement of the applied salt very early. The lowest water application levels required the entire summer to leach the salt down to one foot (30cm). Because the salinity sensors were all located at 12 inches they were insensitive in describing the salinity status of the total soil profile. Their cost prohibited using them in any quantity.

Thermocouple psychrometers. The thermocouple psychrometer data (Table 11) proved to be of little value. The main problem was obtaining a reliable low value calibration reading at the wet end of the calibration curves. A consistent low reading from the dew point microvolt meter could not be obtained. This made it very difficult to obtain a reliable water potential reading. This eliminated the usefulness of the psychrometers as most of the readings taken in field were in lower range. Since the water content did not decrease much during the season the psychrometer

Table 10. Electrical conductivity of the soil solution as a function of time and site, salinity sensor result in mmhos/cm @ 25°C

Block	Salt level	Water level	Sampling date 7-15	7-30	8-11	8-24	9-18
1	1	17	2.4	1.5	1.4	1.2	1.4
	2	15	1.7	7.9	6.0	6.3	5.8
	4	6	7.7	1.4	1.1	0.3	1.6
	0	10	3.7	15.8	13.9	17.0	19.0
2	3	3	5.5	1.0	0.3	0.3	0.3
	3	20	1.2	1.2	1.9	1.6	1.9
	6	14	5.9	4.3	1.7	1.4	2.2
	8	7	3.0	1.1	0.7	0.6	0.3
	8	11	11.7	7.2	7.4		9.2
	8	19	18.0	9.4	9.5	13.5	15.8
3	1	8	1.1	0.5	1.0	0.7	0.3
	2	12	1.9	0.3	0.3	0.3	0.3
	5	18	13.0	13.6	13.2	14.5	12.1
	9	3	4.5	3.5	2.2	3.5	9.8
4	2	16	7.7	7.0		7.7	6.9
	3	9	3.0	1.7	3.0	1.2	1.7
	4	12	10.6	7.7	10.1	10.9	10.4
	5	10	7.7	9.8	11.1	9.9	11.1
	6	7	2.3	4.5	6.4	7.7	
	7	10	12.1	9.7	12.5	9.6	9.6

reading would have been changed mostly by salt. Lack of operating experience may have been a contributing factor.

Resistivity meter. The 4-probe resistivity method (described in Gupta and Hanks, 1972) was used to monitor salt movement and distribution in the profile. The data is presented in table 21 of the appendix. Problems related to variable soil water content minimized by taking the readings just before each irrigation. The water content of the soil at this time changed very little over the course of the growing season (Figures 3 and 4).

treatments probably reduced the effectiveness of the instur-ment.

Ceramic soulution samplers. The ceramic samplers worked well as a means of obtaining soil solutions as long as the units were intact and the soil water content was high. The electrical conductivity of the water samples (Table 22 in the appendix) are useful in supporting the assumption of the effectiveness of the line source sprinkler in creating the continuous water treatments. Salt was leached more rapidly and to a greater depth in the high water treatments. The sample taken from the lowest water application levels indicate that it took the entire field season to get the salt leached to 4 feet.

SUMMARY AND CONCLUSIONS

The objectives of this research were:

(1) to determine crop production functions for corn under field conditions as related to irrigation and salinity treatments, and

(2) to evaluate methods of monitoring salt movement and distribution.

Salinity and irrigation both had a significant effect on grain and dry matter production of corn. Salinity of the root zone varied from 2.7 to 14.9 mmhos/cm and irrigation treatments were confounded somewhat because of an unknown amount of water moving upward into the root zone from the water table. Averaged dry matter (Kg/ha) yield was reduced 83 percent over the range of salt treatments and 52 percent over the range of irrigation treatments. Expressed as grams/plant, dry matter declined over the range salt and water treatments by 67 and 56 percent respectively. Grain production declined in response to salt and water treatments by 94 and 64 percent respectively.

The production functions for dry matter expressed as Kg/ha and grams/plant, and grain expressed as Kg/ha are shows as equations 2, 3 and 4 respectively.

$$\hat{Y} = 9896 - 1274S + 84W + 37S^2 + .03W^2 + .53SW \qquad (2)$$

$$R^2 = 0.74$$

$$\hat{Y} = 873 - 107S + 4.7W + 2.8S^2 + .01W^2 + 61SW \qquad (3)$$

$$R^2 = 0.64$$

$$\hat{Y} = 3676 - 604S + 6.1W + 23S^2 + .13W^2 + .008SW \qquad (4)$$

$$R^2 = 0.63$$

S is the average salinity of the root zone in mmhos/cm and W is the total centimeter of water applied.

EC_e (conductivity of the saturation extract), while the most involved proceedure for estimating soil salinity, was the only satisfactory method used to describe the soil profile salinity throughout the root zone.

The salinity sensors and ceramic extraction samples produced reasonable results but were restricted to a given position in the soil. The 4-probe resistivity meter gave a gross picture of the soil salinity. It may be more suited to a conventional type of design with larger treatments.

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APPENDIX

Table 12. Volumetric water content of the soil as a function of time and sampling site

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
2	1	19	0-6	.13	.04	.04	.06	.03	.03	.06
			6-12	.23	.17	.16	.14	.12	.12	.13
			12-18	.22	.17	.17	.14	.13	.13	.13
			18-24	.22	.21	.20	.16	.13	.14	.14
			24-36	.17	.18	.19	.13	.09	.09	.09
			36-48		.12	.13	.11	.08	.08	.08
2	1	15	0-6	.14	.06	.06	.15	.05	.03	.08
			6-12	.23	.20	.18	.19	.18	.15	.15
			12-18	.25	.22	.21	.20	.19	.16	.16
			18-24	.23	.22	.22	.21	.18	.16	.15
			24-36	.23	.22	.23	.22	.19	.15	.13
			36-48		.18	.18	.18	.16	.13	.11
2	2	11	0-6	.15	.05	.04	.06	.05	.04	.08
			6-12	.23	.21	.19	.20	.19	.17	.20
			12-18	.24	.22	.21	.24	.21	.21	.20
			18-24	.24	.22	.22	.25	.22	.21	.20
			24-36	.23	.20	.21	.22	.20	.18	.19
			36-48		.20	.22	.23	.20		.20
2	2	7	0-6	.23	.06	.04	.05	.05	.04	.09
			6-12	.30	.22	.20	.17	.18	.16	.19
			12-18	.30	.25	.24	.21	.21	.20	.22
			18-24	.31	.25	.25	.23	.23	.23	.22
			24-36	.28	.22	.22	.20	.19	.18	.17
			36-48		.22		.21	.20		
2	3	3	0-6	.11	.05	.03	.04	.06	.02	.06
			6-12	.21	.21	.17	.15	.18	.14	.16
			12-18	.22	.24	.23	.21	.22	.20	.21
			18-24	.23	.24	.23	.23	.23	.22	.23
			24-36	.24	.25	.24	.23	.22	.22	.22
			36-48		.25	.24	.23	.23		.22
3	3	3	0-6	.13	.05	.03	.03	.05	.02	.07
			6-12	.22	.20	.17	.13	.16	.12	.12
			12-18	.24	.24	.22	.19	.21	.17	.20
			18-24	.24	.25	.24	.23	.24	.22	.20
			24-36	.22	.22	.22	.21	.22	.21	.18
			36-48	.24	.22	.22	.21	.22	.20	.18

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
3	4	7	0-6	.11	.06	.05	.04	.06	.02	.09
			6-12	.22	.20	.20	.17	.19	.13	.18
			12-18	.24	.23	.26	.22	.23	.20	.23
			18-24	.25	.24	.25	.23	.24	.20	.25
			24-36	.23	.22	.24	.22	.22	.21	.21
			36-48	.24	.23	.26	.23	.24	.23	.23
3	4	11	0-6	.13	.06	.04	.05	.04	.03	.10
			6-12	.23	.20	.21	.17	.16	.15	.19
			12-18	.23	.23	.25	.23	.20	.20	.21
			18-24	.23	.23	.26	.24	.22	.21	.22
			24-36	.23	.23	.25	.23	.22	.21	.20
			36-48	.24	.23	.26	.24	.23	.22	.21
3	4	15	0-6	.12	.04	.04	.04	.05	.03	.10
			6-12	.22	.18	.19	.17	.16	.14	.19
			12-18	.25	.22	.25	.22	.21	.20	.21
			18-24	.25	.23	.27	.24	.22	.22	.21
			24-36	.23	.22	.25	.24	.22	.21	.20
			36-48	.23	.21	.24	.22	.21		.20
3	5	19	0-6	.11	.02	.02	.03	.03	.02	.08
			6-12	.21	.15	.14	.14	.14	.12	.16
			12-18	.25	.21	.21	.20	.20	.18	.23
			18-24	.25	.25	.25	.23	.23	.21	.25
			24-36	.23	.23	.23	.21	.22	.20	.20
			36-48		.23		.21	.21	.19	
3	6	17	0-6	.11	.06	.04	.05	.06	.03	.11
			6-12	.21	.20	.17	.17	.14	.14	.19
			12-18	.23	.24	.22	.22	.23	.20	.22
			18-24	.24	.26	.24	.23	.24	.21	.23
			24-36	.21	.24	.21	.20	.21	.18	.19
			36-48		.27	.24	.23	.24	.21	.22
3	6	13	0-6	.10	.02	.02	.02	.03	.01	.05
			6-12	.21	.17	.14	.14	.13	.11	.13
			12-18	.24	.23	.22	.21	.21	.18	.20
			18-24	.25	.25	.25	.25	.23	.22	.22
			24-36	.24	.24	.24	.24	.23	.21	.22
			36-48	.24	.25	.24	.24	.23	.21	

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
3	6	9	0-6	.12	.07	.04	.04	.05	.03	.06
			6-12	.22	.21	.18	.14	.15	.11	.13
			12-18	.24	.24	.25	.22	.22	.18	.19
			18-24	.24	.24	.25	.24	.24	.21	.21
			24-36	.23	.24	.26	.23	.23	.21	.19
			36-48	.23	.22	.24	.23	.23	.20	.20
3	6	5	0-6	.14	.07	.05	.05	.05	.02	.07
			6-12	.22	.21	.20	.17	.16	.12	.15
			12-18	.23	.23	.24	.21	.22	.18	.20
			18-24	.25	.24	.25	.24	.24	.22	.22
			24-36	.22	.23	.24	.23	.22	.21	.20
			36-48		.22			.20		
3	6	1	0-6	.14	.10	.04	.03	.04	.03	.06
			6-12	.21	.21	.20	.15	.16	.12	.14
			12-18	.23	.23	.23	.21	.22	.18	.18
			18-24	.24	.23	.23	.23	.23	.21	.20
			24-36	.22	.21	.22	.21	.21	.20	.18
			36-48		.21	.27	.20	.20	.19	.07
2	6	5	0-6	.13	.07	.05	.04	.04	.02	.05
			6-12	.22	.21	.20	.17	.16	.11	.13
			12-18	.23	.22	.24	.23	.21	.18	.20
			18-24	.24	.23	.25	.23	.23	.21	.21
			24-36	.22	.22	.24	.22	.21	.21	.20
			36-48		.20	.22	.21	.19	.18	.18
2	6	9	0-6	.12	.05	.03	.05	.05	.02	.06
			6-12	.20	.19	.18	.17	.17	.11	.15
			12-18	.21	.21	.22	.21	.21	.18	.19
			18-24	.23	.22	.23	.22	.22	.20	.20
			24-36	.20	.21	.22	.21	.20	.19	.18
			36-48		.20		.20	.20		
2	6	13	0-6	.14	.05	.04	.05	.05	.03	.07
			6-12	.22	.22	.20	.18	.18	.13	.15
			12-18	.25	.24	.24	.24	.22	.20	.20
			18-24	.25	.24	.25	.25	.24	.23	.21
			24-36	.21	.21	.21	.21	.19	.20	.16
			36-48		.20	.20	.21	.19	.18	.17

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
2	6	17	0-6	.13	.08	.04	.04	.04	.03	.04
			6-12	.21	.19	.20	.14	.15	.12	.12
			12-18	.21	.20	.23	.21	.19	.16	.15
			18-24	.23	.23	.25	.24	.22	.19	.18
			24-36	.18	.19	.21	.18	.18	.17	.13
			36-48	.17	.15	.18	.16	.15	.13	.13
2	10	19	0-6	.10	.03	.04	.05	.07	.04	.12
			6-12	.19	.16	.18	.17	.17	.17	.18
			12-18	.22	.19	.21	.19	.19	.19	.20
			18-24	.25	.22	.24	.21	.22	.21	.22
			24-36	.21	.20	.23	.19	.20	.20	.19
			36-48		.19		.19	.19	.18	
2	10	15	0-6	.10	.05	.04	.07	.07	.04	.11
			6-12	.18	.19	.17	.18	.18	.17	.18
			12-18	.22	.21	.19	.19	.18	.18	.18
			18-24	.26	.25	.23	.23	.22	.21	.21
			24-36	.24	.25	.22	.22	.21	.21	.19
			36-48	.25	.26	.23	.24	.23	.23	.21
2	9	11	0-6	.10	.04	.05	.08	.08	.04	.11
			6-12	.21	.20	.19	.18	.19	.17	.18
			12-18	.23	.20	.21	.20	.21	.19	.20
			18-24	.23	.25	.24	.23	.22	.21	.21
			24-36	.24	.23	.22	.22	.21	.21	.19
			36-48		.23	.22	.21	.21		
2	9	7	0-6	.12	.06	.06	.05	.06	.03	.11
			6-12	.21	.20	.20	.18	.18	.17	.18
			12-18	.25	.23	.23	.22	.21	.20	.21
			18-24	.23	.24	.24	.22	.21	.22	.21
			24-36	.19	.20	.19	.18	.17	.18	.16
			36-48	.21	.22	.21	.19	.18	.19	.17
2	8-9	3	0-6	.08	.03	.02	.04	.05	.02	.07
			6-12	.20	.20	.19	.18	.19	.15	.17
			12-18	.21	.23	.23	.22	.19	.21	.22
			18-24	.24	.22	.23	.24	.23	.23	.23
			24-36	.22	.22	.21	.20	.19	.20	.19
			36-48	.23	.24	.23	.22	.21	.21	.21

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
3	8	3	0-6	.13	.06	.04	.04	.03	.01	.06
			6-12	.23	.22	.19	.17	.17	.12	.16
			12-18	.24	.24	.22	.21	.22	.19	.20
			18-24	.26	.25	.24	.24	.24	.22	.24
			24-36	.23	.22	.22	.21	.21	.20	.19
			36-48	.24	.23	.22	.22	.21		.19
3	8	7	0-6	.11	.06	.04	.06	.10	.04	.10
			6-12	.21	.19	.18	.19	.20	.16	.17
			12-18	.24	.22	.21	.21	.23	.19	.19
			18-24	.26	.25	.24	.25	.26	.23	.24
			24-36	.26	.24	.24	.25	.26	.23	.23
			36-48	.23	.22	.21	.22	.22	.19	.19
3	7	11	0-6	.11	.06	.05	.06	.07	.04	.09
			6-12	.21	.20	.17	.17	.18	.15	.16
			12-18	.24	.24	.21	.22	.22	.20	.21
			18-24	.27	.26	.23	.25	.26	.24	.24
			24-36	.27	.26	.24	.25	.26	.24	.24
			36-48	.26	.27	.24	.25	.27	.26	.24
3	7	15	0-6	.13	.05	.03	.04	.05	.02	.07
			6-12	.21	.19	.15	.15	.15	.13	.16
			12-18	.23	.22	.20	.18	.18	.18	.18
			18-24	.25	.25	.23	.23	.24	.22	.24
			24-36	.25	.27	.25	.24	.24	.24	.23
			36-48	.24	.25	.23	.23	.23	.22	.22
3	7	19	0-6	.11	.02	.02	.03	.03	.02	.05
			6-12	.23	.14	.14	.14	.15	.15	.16
			12-18	.25	.20	.20	.20	.20	.19	.20
			18-24	.26	.24	.23	.23	.24	.23	.24
			24-36	.26	.24	.24	.24	.23	.23	.23
			36-48	.27	.24	.25	.24	.25	.24	
4	1	19	0-6	.10	.03	.03	.03	.03	.02	.05
			6-12	.20	.14	.13	.10	.11	.09	.10
			12-18	.21	.17	.16	.11	.11	.10	.11
			18-24	.24	.21	.20	.14	.15	.13	.16
			24-36	.26	.25	.27	.23	.24	.22	.22
			36-48		.26	.27	.24	.26	.25	.24

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
4	1	15	0-6	.14	.04	.03	.04	.04	.03	.06
			6-12	.20	.18	.15	.11	.12	.11	.11
			12-18	.20	.18	.15	.11	.11	.11	.11
			18-24	.24	.20	.18	.14	.14	.13	.14
			24-36	.25	.24	.23	.22	.20	.20	.21
			36-48	.26	.25	.24	.23	.25	.23	.22
4	2	11	0-6	.12	.06	.03	.04	.05	.03	.08
			6-12	.20	.20	.16	.15	.15	.14	.15
			12-18	.20	.20	.18	.16	.15	.15	.15
			18-24	.22	.21	.19	.18	.18	.17	.17
			24-36	.26	.27	.26	.24	.24	.23	.24
			36-48			.26	.25	.24	.24	
4	2	7	0-6	.10	.06	.02	.03	.05	.03	.06
			6-12	.20	.20	.14	.13	.15	.13	.13
			12-18	.25	.23	.20	.18	.20	.19	.19
			18-24	.23	.26	.24	.22	.23	.23	.22
			24-36	.24	.24	.22	.20	.22	.21	.19
			36-48		.25	.23	.23	.24	.24	.21
4	2	3	0-6	.12	.05	.03	.06	.05	.03	.08
			6-12	.24	.21	.18	.16	.19	.15	.16
			12-18	.25	.25	.23	.21	.24	.20	.19
			18-24	.23	.24	.22	.21	.22	.21	.18
			24-36	.23	.23	.21	.20	.21	.19	.19
			36-48		.23	.21	.21	.23	.20	
1	3	3	0-6	.09	.05	.03	.03	.05	.03	.06
			6-12	.21	.20	.15	.11	.14	.11	.12
			12-18	.22	.22	.19	.15	.19	.15	.16
			18-24	.23	.23	.20	.19	.12	.18	.19
			24-36	.21	.22	.20	.19	.21	.19	.19
			36-48	.24	.24	.22	.20	.23	.20	.20
1	3	7	0-6	.11	.05	.02	.02	.03	.04	.07
			6-12	.22	.20	.14	.12	.16	.15	.15
			12-18	.24	.24	.22	.18	.22	.19	.19
			18-24	.24	.24	.22	.21	.23	.21	.20
			24-36	.23	.23	.22	.21	.23	.21	.21
			36-48	.23	.23	.22	.21	.22	.21	

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
1	3	11	0-6	.11	.06	.05	.05	.06	.03	.07
			6-12	.22	.23	.20	.15	.17	.13	.14
			12-18	.23	.24	.23	.19	.21	.17	.18
			18-24	.24	.24	.23	.22	.23	.20	.20
			24-36	.26	.26	.25	.24	.25	.23	.22
			36-48		.26	.24	.23	.25	.22	
1	4	15	0-6	.11	.05	.04	.04	.05	.03	.07
			6-12	.23	.21	.17	.18	.19	.15	.16
			12-18	.25	.26	.23	.23	.25	.21	.21
			18-24	.24	.25	.22	.21	.24	.20	.20
			24-36	.26	.26	.23	.23	.25	.22	.22
			36-48		.26	.25	.23	.26	.22	
1	4	19	0-6	.10	.02	.03	.04	.07	.03	.08
			6-12	.22	.19	.18	.18	.18	.14	.15
			12-18	.26	.26	.25	.24	.24	.20	.21
			18-24	.25	.25	.24	.22	.23	.20	.19
			24-36	.23	.23	.21	.20	.23	.19	.20
			36-48		.25	.24	.23	.24	.22	
1	5	17	0-6	.11	.05	.02	.02	.04	.02	.07
			6-12	.20	.16	.14	.15	.16	.13	.15
			12-18	.23	.20	.20	.20	.22	.18	.20
			18-24	.23	.23	.23	.22	.24	.21	.20
			24-36	.22	.21	.21	.20	.23	.19	.19
			36-48	.22	.21	.20	.20	.22	.19	.18
1	5	13	0-6	.11	.04	.03	.04	.04	.02	.06
			6-12	.20	.19	.16	.15	.14	.11	.12
			12-18	.23	.21	.19	.19	.19	.14	.17
			18-24	.25	.25	.24	.25	.23	.21	.21
			24-36	.22	.21	.21	.21	.21		.18
			36-48		.22	.22	.22	.21	.20	
1	5	9	0-6	.11	.05	.04	.03	.06	.03	.05
			6-12	.20	.19	.16	.12	.12	.10	.11
			12-18	.23	.22	.20	.18	.19	.15	.18
			18-24	.25	.23	.23	.22	.21	.20	.20
			24-36	.23	.21	.21	.20	.20	.19	.19
			36-48		.22	.21	.21	.21	.20	

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
1	5	5	0-6	.13	.06	.05	.04	.07	.05	.11
			6-12	.22	.21	.19	.19	.20	.18	.18
			12-18	.25	.25	.23	.23	.19	.22	.21
			18-24	.25	.24	.24	.24	.19	.23	.21
			24-36	.25	.24	.23	.23	.19	.21	.21
			36-48		.22	.21	.21	.20	.18	.18
1	5	1	0-6	.13	.03	.02	.03	.03	.02	.05
			6-12	.20	.19	.14	.13	.14	.12	.12
			12-18	.23	.23	.21	.18	.19	.17	.16
			18-24	.24	.24	.24	.23	.24	.22	.21
			24-36	.22	.22	.21	.21	.21	.20	.19
			36-48		.21	.20	.20	.20	.20	.18
4	5	5	0-6	.14	.05	.03	.03	.05	.03	.06
			6-12	.22	.20	.17	.16	.17	.13	.14
			12-18	.24	.24	.21	.22	.22	.20	.20
			18-24	.23	.23	.21	.23	.23	.22	.21
			24-36	.23	.23	.22	.22	.22	.22	.21
			36-48		.24	.22	.23	.23	.23	.21
4	5	9	0-6	.14	.05	.03	.04	.06	.02	.06
			6-12	.22	.20	.16	.14	.15	.11	.12
			12-18	.23	.23	.22	.20	.21	.15	.16
			18-24	.22	.23	.22	.21	.19	.18	.18
			24-36	.21	.22	.20	.20	.22	.17	.18
			36-48	.22	.22	.20	.20	.22	.18	
4	5	13	0-6	.13	.02	.02	.02	.03	.01	.05
			6-12	.22	.18	.17	.14	.15	.18	.14
			12-18	.24	.23	.24	.21	.21	.18	.19
			18-24	.23	.24	.26	.24	.23	.21	.20
			24-36	.20	.19	.22	.20	.19	.17	.15
			36-48		.19	.21	.20	.18	.16	
4	5	17	0-6	.15	.04	.03	.04	.05	.03	.08
			6-12	.21	.17	.15	.15	.16	.15	.15
			12-18	.24	.21	.20	.20	.20	.19	.19
			18-24	.25	.24	.22	.22	.23	.22	.19
			24-36	.20	.21	.20	.20	.20	.18	.14
			36-48		.17	.15	.15	.20	.15	

Table 12. Continued.

Block	Salt level	Water level	Depth inches	6-12	7-9	7-15	7-30	8-11	8-26	9-18
				Sampling dates						
4	6	19	0-6	.14	.02	.02	.01	.05	.03	.07
			6-12	.21	.14	.13	.11	.18	.14	.15
			12-18	.21	.19	.18	.17	.21	.18	.18
			18-24	.24	.22	.22	.21	.25	.23	.22
			24-36	.23	.24	.24	.24	.21	.23	.22
			36-48		.23		.23	.25		
4	6	15	0-6	.15	.03	.05	.07	.06	.04	.09
			6-12	.20	.19	.19	.18	.19	.16	.16
			12-18	.23	.20	.21	.20	.21	.18	.18
			18-24	.24	.23	.23	.23	.23	.22	.22
			24-36	.24	.24	.24	.23	.23	.23	.22
			36-48		.25	.25	.24	.25	.24	
4	7	11	0-6	.16	.03	.06	.05	.07	.03	.08
			6-12	.20	.20	.18	.17	.17	.14	.15
			12-18	.22	.22	.20	.18	.18	.16	.16
			18-24	.24	.23	.23	.22	.23	.21	.21
			24-36	.22	.23	.22	.22	.22	.22	.20
			36-48		.24	.24	.23	.23	.22	.22
4	7	7	0-6	.17	.05	.04	.05	.06	.03	.09
			6-12	.20	.20	.17	.16	.17	.15	.15
			12-18	.23	.22	.19	.19	.19	.17	.17
			18-24	.26	.25	.23	.23	.24	.23	.24
			24-36	.24	.24	.21	.22	.22	.22	.21
			36-48		.24	.22	.23	.23	.22	.21
4	8	3	0-6	.13	.06	.06	.06	.07	.04	.07
			6-12	.19	.20	.18	.16	.18	.14	.14
			12-18	.20	.21	.19	.19	.21	.16	.17
			18-24	.25	.25	.23	.23	.25	.23	.23
			24-36	.22	.23	.21	.20	.22	.20	.21
			36-48	.23	.22	.21	.21	.22	.21	.20
1	8	3	0-6	.15	.04	.05	.04	.06	.04	.10
			6-12	.19	.19	.16	.16	.18	.16	.15
			12-18	.21	.20	.18	.17	.18	.17	.17
			18-24	.25	.22	.20	.19	.20	.20	.21
			24-36	.25	.25	.23	.22	.23	.22	.23
			36-48		.22	.21	.21	.21	.21	

Table 12. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-9	7-15	7-30	8-11	8-26	9-18
1	9	7	0-6	.16	.07	.06	.07	.08	.04	.09
			6-12	.20	.20	.18	.17	.20	.15	.15
			12-18	.22	.21	.20	.19	.22	.19	.19
			18-24	.24	.24	.24	.23	.25	.23	.22
			24-36	.22	.23	.23	.22	.24	.23	.22
			36-48		.23	.23	.22	.24	.22	
1	9	11	0-6	.16	.07	.06	.06	.05	.04	.09
			6-12	.17	.19	.18	.16	.16	.15	.15
			12-18	.19	.20	.19	.19	.20	.18	.19
			18-24	.23	.23	.22	.22	.22	.21	.21
			24-36	.23	.24	.24	.24	.24	.23	.22
			36-48		.23	.23	.22	.23	.22	.22
1	2	15	0-6	.13	.04	.05	.09	.07	.05	.13
			6-12	.19	.18	.18	.19	.18	.18	.17
			12-18	.20	.17	.18	.19	.18	.17	.16
			18-24	.23	.20	.20	.22	.20	.20	.20
			24-36	.24	.23	.24	.24	.23	.23	.22
			36-48		.23	.24	.25	.24	.24	.23
1	10	10	0-6	.14	.04	.04	.07	.06	.04	.10
			6-12	.17	.15	.14	.16	.16	.15	.15
			12-18	.20	.16	.16	.17	.17	.16	.18
			18-24	.23	.21	.20	.23	.20	.20	.21
			24-36	.24	.24	.24	.26	.23	.24	.24
			36-48		.23	.24	.25	.24	.23	.24

Table 13. Electrical conductivities (ECe) of the soil solution, initial (I) soil samples

Block	Salt level	Water level	Sample taken	Depth - inches				
				0-6	6-12	12-18	18-24	24-36
2	1	19	I	2.0	2.5	1.6	1.6	2.0
2	1	15	I	3.6	2.3	2.0		4.1
2	2	11	I	5.1	2.8	3.5	4.4	4.8
2	2	7	I	1.7	3.0	5.5	5.9	
2	3	3	I	8.2	8.2	5.2	3.9	3.9
3	3	3	I	4.2	7.4	4.8	1.9	1.9
3	4	7	I	4.4	8.5		3.7	3.1
3	4	11	I	3.9	4.6	6.0	6.4	2.7
3	4	15	I		5.8	5.8	1.8	
3	5	19	I	2.0	5.7	10.5	2.1	3.0
3	6	17	I	2.6	6.8		5.6	2.1
3	6	13	I	1.7	2.7	6.5	11.1	7.3
3	6	9	I	3.2	4.4	9.3	6.4	5.2
3	6	5	I	3.1	11.1	18.0	4.8	
3	6	1	I	3.9	18.0	12.6	9.8	6.1
2	6	5	I	3.1	13.7	9.4	7.2	3.5
2	6	9	I	5.3	11.5	19.5		1.9
2	6	13	I	6.5	10.0	6.4	3.5	2.9
2	6	17	I	5.1	12.1	15.6	7.0	
2	10	19	I			15.0	4.6	
2	10	15	I	35.0	45.9	15.0	4.0	6.0
2	9	11	I	25.5	5.8		4.6	4.5
2	9	7	I	36.0	20.4	6.6	3.0	3.7
2	8-9	3	I	7.5		25.0	24.6	3.2
3	8	3	I		10.5		8.4	2.2
3	8	7	I	11.8	16.5	12.1	2.8	
3	7	11	I	7.9	27.6	35.0	8.1	3.5
3	7	15	I	1.8	3.3	4.1	4.4	3.3
3	7	19	I	1.7	5.9	13.5	5.2	3.8
4	1	19	I	1.7	3.0	2.8	10.0	3.7
4	1	15	I	2.4	2.4	2.5	1.9	2.9
4	2	11	I	1.7	4.0		4.2	2.9
4	2	7	I	1.1	1.6	4.8	5.0	2.9
4	2	3	I	1.4	2.8	3.3	4.2	3.2
1	3	3	I	2.1	10.5	9.4	4.8	4.4
1	3	7	I	1.6	8.6	3.6	6.3	6.2
1	3	11	I	2.0	6.5	6.8	4.1	4.8
1	4	15	I	2.6	10.4	12.0	4.8	4.2
1	4	19	I	4.7	10.5	6.5	3.9	
1	5	17	I	2.8	3.4	7.2	8.0	4.2
1	5	13	I	2.4	5.0		3.9	4.2
1	5	9	I	7.8	15.0	9.0	4.2	4.1
1	5	5	I	1.9	2.6	11.0	10.0	4.2
1	5	1	I	3.2	12.5	13.2		4.7

Table 13. Continued

Block	Salt level	Water level	Sample taken	Depth - inches 0-6	6-12	12-18	18-24	24-36
4	5	5	I	3.5	6.7	8.3		6.5
4	5	9	I	1.7	3.2	7.5	12.0	8.2
4	5	13	I		4.7		9.2	6.0
4	5	17	I	1.8	10.2	11.5	1.9	1.9
4	6	19	I	2.0	5.4	20.7	5.7	4.4
4	6	15	I	7.2	7.3	2.8	2.8	3.6
4	7	11	I	10.9	2.3	12.0	7.5	5.6
4	7	7	I	4.1	6.0	4.9	2.9	3.2
4	8	3	I	15.0	25.8	18.0	8.0	3.0
1	8	3	I		14.0	7.2	4.6	4.3
1	9	7	I	4.3	3.7	9.0	3.6	4.3
1	9	11	I	3.6	2.9	47.0	20.0	4.5
1	10	15	I	30.6	20.4	2.0	3.1	3.7
1	10	19	I		40.0	26.0	15.2	4.4

Table 14. Electrical conductivities (ECe) of the soil solution, final (F) soil samples

Block	Salt level	Water level	Sample taken	Depth - inches 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36
2	1	19	F	3.2	2.2	2.2	1.7	1.9	2.8	2.0	3.2	3.4	3.8	3.4	3.4
2	1	15	F	2.2	2.8		2.0	2.1	2.0	2.5	3.4	3.8	3.6	3.6	3.6
2	2	11	F	1.2	1.2	1.7	2.4	4.3	5.6	5.5	5.2	4.8	4.8	4.4	4.3
2	2	7	F	1.1	1.3	1.6	2.7	2.9	4.5	4.5	5.2	4.4	4.0	4.5	4.2
2	3	3	F	1.2	1.5	2.5	3.0			5.5	6.0	7.0	7.1	5.9	5.7
3	3	3	F	1.8	2.1	2.4	3.9	5.2	6.0	7.0	7.3		6.5		3.6
3	4	7	F	2.4	4.3	5.2	6.2	5.4	5.0	5.0	3.5	5.0	4.2	3.8	3.6
3	4	11	F	0.9		3.5	4.1	5.4	8.0		6.8	6.5	4.8	4.0	2.9
3	4	15	F	3.2	8.0	8.0	8.5	8.6	6.2	6.9	4.2	3.3	2.1	2.2	3.0
3	5	19	F	7.3	13.8	11.5	11.0	8.0	6.8	4.4	3.7	2.7	2.8	3.2	2.3
3	6	17	F	10.4				12.2		7.3	5.1		3.0	2.4	2.7
3	6	13	F			16.2	9.4	12.8					4.5	4.5	3.9
3	6	9	F	1.4		3.0	3.1	4.6	6.3	7.7					7.0
3	6	5	F	1.3	2.0	2.9		10.9	10.7				9.2		

Table 14. Continued

Block	Salt level	Water level	Sample taken	Depth - inches											
				0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36
3	6	1	F	1.1	1.6	1.4	1.1		1.4	2.4	3.7				
2	6	5	F				4.0	5.4	8.5		8.2	5.4	7.8	6.0	5.5
2	6	9	F	1.2	1.6	2.8	5.2		8.0	9.3	10.2		8.3	5.7	5.3
2	6	13	F			7.6		5.8		5.6				4.1	4.0
2	6	17	F	1.3	1.6	2.1	2.0	1.8		3.6		7.1	8.4	3.1	7.0
2	10	19	F		14.1			21.6	30.0	14.0	10.5	6.1	5.2		4.9
2	10	15	F	7.4	12.2			14.4	23.0		8.3		4.8	3.9	
2	9	11	F	14.4	14.9		24.0	22.5		24.9		19.5	19.8	19.5	18.3
2	9	7	F		15.3			16.5	15.6	12.1		13.2	10.8	8.5	5.4
2	8-9	3	F	3.6		28.2	18.0	12.0	9.8		14.0	12.0	12.4		14.2
3	8	3	F	13.0	10.5	15.6			15.3	16.8	13.9	13.5		9.9	
3	8	7	F	4.1	7.5	12.0	13.5	11.0	13.0	14.0	12.0	10.5		2.8	9.3
3	7	11	F	6.8	11.0	14.0	9.2	12.5	13.5	16.2	13.2	7.7	5.1	3.8	2.6
3	7	15	F	11.0	11.0	11.3	6.5	6.7	5.3	3.9	3.0	2.9	3.8	3.6	3.4

Table 14. Continued

Block	Salt level	Water level	Sample taken	Depth - inches 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36
3	7	19	F	8.5	14.3	13.2	12.0	11.6	7.0	5.7	4.0	3.8	3.4	3.6	3.9
4	1	19	F	1.5	1.1	2.4	1.7	2.1	2.0	2.2	2.1	1.9	3.2	3.2	3.0
4	1	15	F	1.4	2.3	2.6	1.7	1.8	2.5	2.4	2.9	3.0	3.2	3.4	3.7
4	2	11	F	2.1	2.0	2.8	2.7	3.4	3.4	3.2	3.6	3.6	3.4	3.6	2.4
4	2	7	F	2.7	1.0	1.8	2.0	3.8	3.0	4.6	3.6	3.6	3.9	2.4	2.6
4	2	3	F	1.0	1.1	1.3	1.8	2.2	2.4	2.6	2.7	2.6		3.4	3.4
1	3	3	F	1.3	1.5	2.8	3.9	4.5	5.6	4.2	5.6	6.9	6.1	4.9	5.0
1	3	7	F	0.1	1.7	3.6	4.7	5.5	7.2	7.6	6.7	6.5	5.3	5.0	5.0
1	3	11	F	1.1	1.1	2.3	3.0	4.5	5.3	7.1	7.7	7.5	6.8	6.0	5.1
1	4	15	F	9.4	8.3	8.5	5.5	6.8	7.0	6.1	6.1	4.9	3.9	3.9	3.8
1	4	19	F	12.7	9.0	7.7	6.5	5.1	7.1	5.6	3.9	4.6	4.4	4.4	5.6
1	5	17	F	6.3	8.0	9.0	9.0	8.2	8.8	9.7	7.5	6.3	6.0	5.4	5.1
1	5	13	F	1.7		5.0	7.4	7.2	7.3	7.6	7.4	6.0	5.2	4.8	4.9
1	5	9	F	2.0	6.4	5.5	10.0	7.9	9.0	8.5	7.8	8.4	6.8	6.1	4.8

Table 14. Continued

Block	Salt level	Water level	Sample taken	Depth - inches 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36
1	5	5	F	3.5	5.4		6.6	6.0	6.2	5.9	5.5	4.9	4.5	4.4	4.3
1	5	1	F	1.6	3.6	3.7	4.3	3.8	5.7	3.9	4.9	5.3	5.0	5.5	5.7
4	5	5	F	2.3	4.8	5.5		6.5	6.8	9.0	8.2	5.6	6.2	5.8	5.5
4	5	9	F	1.3	1.5	3.0	3.4	3.4	5.4	4.9	5.5	6.4	5.5	5.6	8.0
4	5	13	F	2.7	6.4	8.0	9.0	8.6	10.0	6.5	7.6	8.4	6.6	5.3	4.1
4	5	17	F	6.0	9.7	7.8	7.5	7.8	9.3	5.9	4.8	3.9	2.5	2.6	2.3
4	6	19	F	11.9	11.1	11.2	10.0	8.7	5.7	5.6	4.9	4.3	4.3	3.7	4.4
4	6	15	F	3.2	6.1	6.4	5.6	5.2	5.9	5.4	3.4	2.9	3.4	3.4	3.4
4	7	11	F	1.1	1.4	2.5	4.8	7.5	8.0	9.7	10.5	8.0	8.2	7.4	5.8
4	7	7	F	7.8	9.5	8.9	9.1	10.9	11.0	9.6	8.3	7.2	6.7	6.3	7.0
4	8	3	F	3.6	7.0	6.6	8.1	7.2	8.2	8.7	8.0	8.5	7.3	6.4	7.0
1	8	3	F	7.4	8.5	11.0	8.2	9.2	11.0	11.5	12.0	13.6	11.5	8.0	5.7
1	9	7	F	8.8	13.2	12.0	10.2	11.8	14.0	16.5	13.5	11.2	9.0	6.3	6.1
1	9	11	F	6.8	17.0	18.0	30.9	20.0	22.6	19.3	13.8	17.5	11.2	5.6	5.1

Table 14. Continued

Block	Salt level	Water level	Sample taken	Depth - inches											
				0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24	24-27	27-30	30-33	33-36
1	10	15	F	33.0	13.9	14.0	10.0	8.7	13.8	24.0	12.0	7.1	10.2	4.4	3.8
1	10	19	F	43.8	19.6	21.3	26.4	21.0	23.4	22.2	16.8	11.9		9.0	7.8

Table 15. Oven dry matter yield, metric ton dry matter/ha

Salt level	Irrigation level									
	2	4	6	8	10	12	14	16	18	20
					Block 1					
1	8.0	11.5	10.8	6.8	8.7	12.2	9.4	7.3	8.3	9.8
2	11.8	11.2	7.9	6.6	13.9	11.3	8.4	11.3	8.4	8.7
3	7.1	9.5	7.2	9.1	6.2	6.4	6.7	5.3	6.3	8.0
4	6.8	10.8	8.3	4.3	9.6	6.8	5.5	4.2	3.6	4.4
5	8.2	6.8	8.4	4.3	5.0	5.1	4.4	2.3	1.5	3.2
6	6.0	7.3	4.2	6.6	6.1	4.4	3.3	2.7	0.6	1.2
7	7.4	7.4	5.7	5.8	4.5	4.0	2.0	2.1	0.3	1.9
8	4.0	3.6	3.7	3.0	1.3	2.6	1.7	0.9	t	0.1
9	2.6	2.7	1.1	2.0	1.7	0.5	0.4	1.1	0.2	0.0
10	3.3	2.5	1.0	0.9	0.8	2.3	1.4	t	0.0	0.0
					Block 2					
1	10.3	7.6	9.1	8.8	7.9	6.8	8.1	8.7	5.5	6.7
2	7.7	11.9	8.9	6.5	7.8	7.2	5.6	8.5	4.1	3.5
3	7.9	6.3	8.3	7.6	7.8	7.5	7.9	7.3	5.5	4.7
4	7.8	8.4	5.5	7.3	8.1	6.8	5.7	4.6	1.9	5.0
5	6.2	6.2	5.5	5.3	6.2	6.0	5.8	3.9	2.1	4.2
6	6.7	5.5	6.7	2.9	4.2	3.0	2.6	2.6	1.7	2.5
7	6.6	6.8	6.8	5.1	7.1	5.2	3.4	3.4	3.4	2.5
8	4.6	3.8	3.4	3.8	3.6	3.1	1.7	1.3	1.1	1.2
9	4.9	4.4	2.8	2.7	4.0	3.6	1.6	1.0	0.1	0.0
10	2.7	2.1	1.6	1.5	2.1	1.7	0.1	0.4	0.0	0.0
					Block 3					
1	10.4	8.5	10.5	7.8	8.0	9.2	9.1	8.9	4.8	5.6
2	9.9	5.9	10.9	9.4	6.0	8.7	5.1	7.6	8.0	5.6
3	10.6	10.3	7.7	11.4	3.7	8.2	8.9	6.7	4.3	7.6
4	9.5	6.5	7.2	8.3	6.0	5.5	8.4	7.5	3.9	3.0
5	5.9	6.6	4.9	5.8	4.9	2.3	3.9	5.5	2.0	3.8
6	7.0	6.2	5.1	4.8	5.4	5.5	3.5	3.2	3.1	1.8
7	5.9	8.2	5.4	4.6	4.0	4.1	3.3	3.3	0.8	3.4
8	4.8	4.8	3.6	4.3	3.0	4.5	4.2	3.1	0.7	0.6
9	2.5	4.3	3.1	3.0	1.7	2.4	2.6	1.1	4.2	0.6
10	2.6	3.0	1.7	0.6	2.8	2.5	1.6	1.1	0.4	0.0

Table 15. Continued

Salt level	Irrigation level 2	4	6	8	10	12	14	16	18	20
					Block 4					
1	9.0	10.3	7.6	9.4	10.4	8.5	9.2	9.3	9.7	10.3
2	10.4	10.6	8.4	6.7	12.2	10.3	6.4	11.9	9.1	8.5
3	7.8	9.7	8.9	7.4	9.2	9.0	8.2	9.5	5.7	5.4
4	9.6	10.5	8.5	7.3	7.1	7.8	7.5	8.4	6.9	4.7
5	7.4	7.8	6.6	7.2	6.6	10.2	4.6	6.4	4.5	4.3
6	3.5	8.3	5.7	6.0	6.2	6.8	4.7	5.1	1.8	1.6
7	4.6	7.4	6.2	3.0	5.0	6.2	4.6	4.9	0.9	2.0
8	4.8	6.1	4.5	4.2	3.8	4.2	2.8	2.0	0.2	0.3
9	3.4	3.3	1.6	2.2	2.5	2.0	0.3	1.2	6.5	0.0
10	1.8	4.0	2.5	3.0	2.3	2.7	2.4	0.6	0.3	0.0

Table 16. Oven dry matter yield, grams dry matter/plant

Salt level	Irrigation level 2	4	6	8	10	12	14	16	18	20
					Block 1					
1	714	1028	962	609	776	1142	842	654	743	875
2	1049	999	706	586	1242	1007	751	1010	751	778
3	631	846	641	815	552	571	598	475	565	715
4	611	966	740	388	854	607	489	371	320	389
5	816	679	835	431	495	504	440	229	147	321
6	596	725	413	651	605	440	330	266	55	119
7	734	736	569	573	450	396	202	211	28	188
8	596	534	550	440	193	381	248	132	3	14
9	385	409	162	296	252	69	56	14	33	0
10	598	447	183	162	150	225	75	2	0	0
					Block 2					
1	916	677	809	784	702	611	726	780	495	603
2	685	1065	792	578	693	644	503	759	363	314
3	702	561	743	677	693	669	702	652	487	421
4	693	751	495	652	726	611	512	413	173	446
5	619	615	545	525	614	596	570	383	204	420
6	665	546	666	286	415	293	259	258	172	246
7	651	679	671	504	703	516	341	481	340	246
8	688	571	512	416	537	468	252	195	165	179
9	722	660	413	406	592	537	234	144	21	1
10	479	383	281	264	371	297	16	74	0	0
					Block 3					
1	924	759	941	693	718	817	809	792	429	503
2	866	528	974	842	537	776	454	677	718	503
3	949	916	685	1015	330	735	792	594	380	677
4	850	578	644	743	537	491	751	669	347	264
5	587	651	486	578	486	229	385	541	202	376
6	697	614	504	477	532	550	349	321	303	183
7	587	816	532	459	394	404	330	330	83	339
8	715	715	537	647	440	674	619	468	110	83
9	371	647	468	440	254	358	385	165	619	96
10	462	528	301	107	502	446	294	191	78	0

Table 16. Continued

Salt level	Irrigation level 2	4	6	8	10	12	14	16	18	20
					Block 4					
1	801	916	677	842	933	759	825	834	867	916
2	925	949	751	603	1090	916	570	1065	809	759
3	693	867	792	660	817	801	735	850	512	479
4	858	941	759	652	636	693	669	751	619	421
5	734	770	651	715	651	1009	459	633	449	377
6	349	825	569	596	614	679	468	504	183	156
7	459	734	619	293	495	614	459	486	92	202
8	715	908	674	619	571	619	413	299	30	37
9	509	498	234	326	371	296	41	180	963	5
10	330	710	446	537	416	479	426	108	54	0

Table 17. Grain yield, Kg/ha

Salt level	Irrigation level 1	3	5	7	9	11	13	15	17	19
					Block 1					
1	2303	1748	4223	3187	1503	2066	2122	3584	1712	3954
2	1735	1727	1817	1791	5868	1960	2278	1922	1914	3546
3	2836	967	2101	1935	2704	1881	1330	1626	1561	1125
4	1368	2030	1020	2330	2569	981	1254	2075	1857	890
5	319	1606	517	430	776	844	312	264	490	146
6	1016	739	527	575	501	1504	785	46	81	25
7	407	297	943	1255	518	1649	94	885	495	238
8	132	20	559	542	25	199	121	55	0	0
9	11	21	26	14	36	0	0	0	0	0
10	51	141	210	118	101	0	0	0	0	0
					Block 2					
1	2884	2451	2127	2564	3358	1837	2359	1525	3241	3168
2	1372	2666	1094	2650	1734	2941	763	1239	2307	2682
3	763	1191	1934	1934	1084	1191	485	1293	659	1198
4	1292	913	1534	1515	774	1514	1580	1107	210	122
5	1007	1360	1454	740	754	387	765	164	157	158
6	1241	453	440	767	496	305	336	547	246	35
7	300	629	626	1065	1482	561	1766	238	270	174
8	574	76	741	310	706	659	102	0	80	150
9	108	242	406	287	534	358	29	0	0	0
10	106	435	548	232	213	116	29	0	0	0
					Block 3					
1	3165	3733	3147	3358	2295	2534	2984	1761	2874	3679
2	2691	1747	2332	1916	1988	2599	2326	1544	1626	2535
3	2301	2385	2301	2567	878	2452	2177	656	1241	1182
4	1410	1799	1633	1007	805	1447	1859	1541	799	269
5	1584	1370	1015	1149	871	1600	708	646	142	89
6	1474	846	823	426	947	1427	695	30	311	202
7	477	1292	1272	2279	893	904	286	11	587	269
8	334	544	592	252	895	856	320	193	0	9
9	550	407	312	527	703	11	31	9	52	749
10	86	527	5	229	81	160	107	0	0	0

Table 17. Continued

Salt level	Irrigation level 1	3	5	7	9	11	13	15	17	19
					Block 4					
1	1275	2744	2352	2678	1156	1842	2307	1505	1779	3838
2	3867	3431	2019	2497	1510	2616	5118	676	4052	1532
3	3712	1832	1371	798	1549	1221	2357	498	1563	2233
4	2817	2073	1491	2845	1218	1770	2088	1386	1316	803
5	2144	1323	754	1855	1359	1793	1767	1176	634	1326
6	1537	908	1715	951	440	2149	881	90	255	148
7	1592	1170	538	1611	765	1082	80	102	465	183
8	411	510	407	1273	858	704	159	326	435	22
9	42	125	0	91	0	144	0	149	0	0
10	132	333	220	57	104	10	0	0	0	0

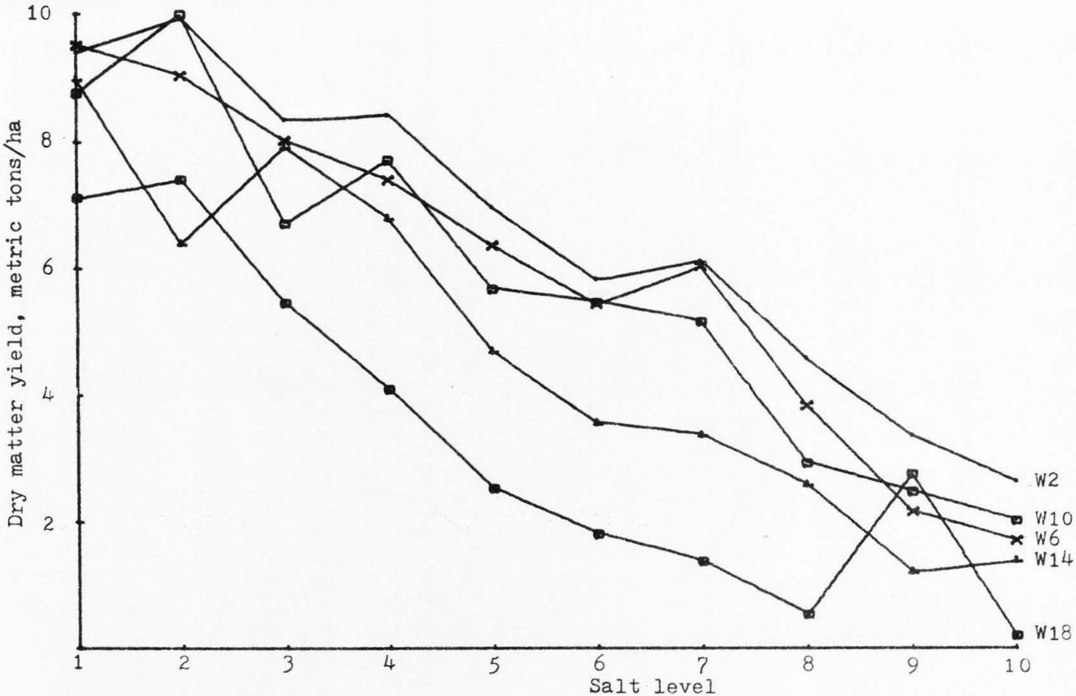

Figure 13. Dry matter yields as influenced by salt and irrigation levels, metric tons/ha

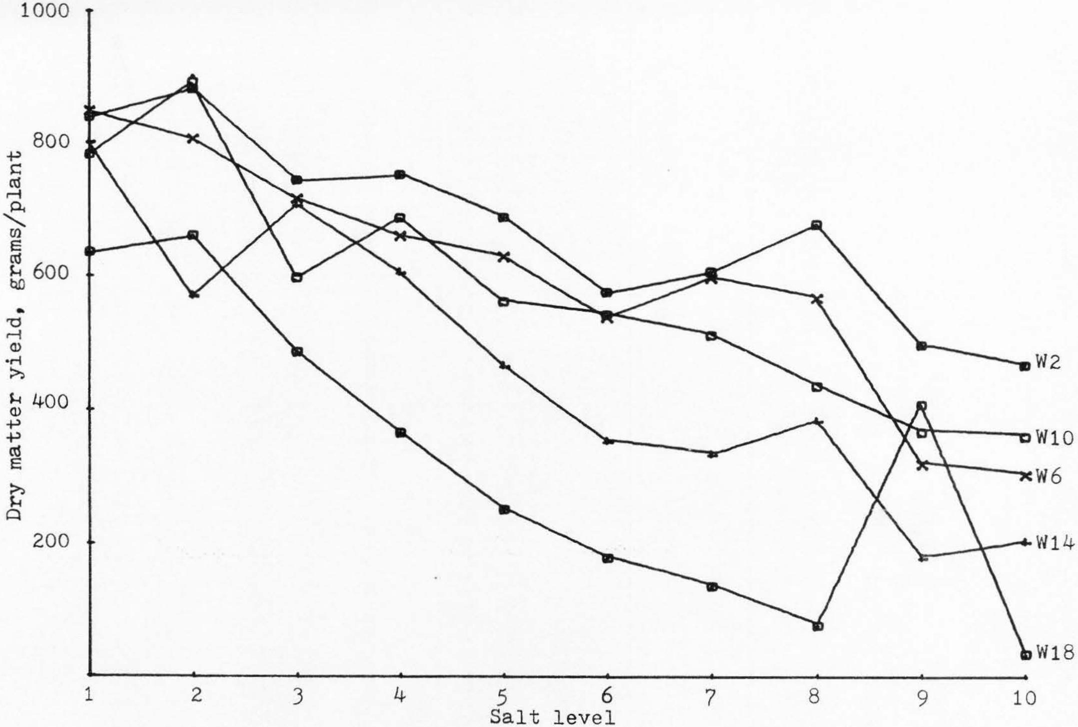

Figure 14. Dry matter yields in grams/plant as influenced by salinity and irrigation levels

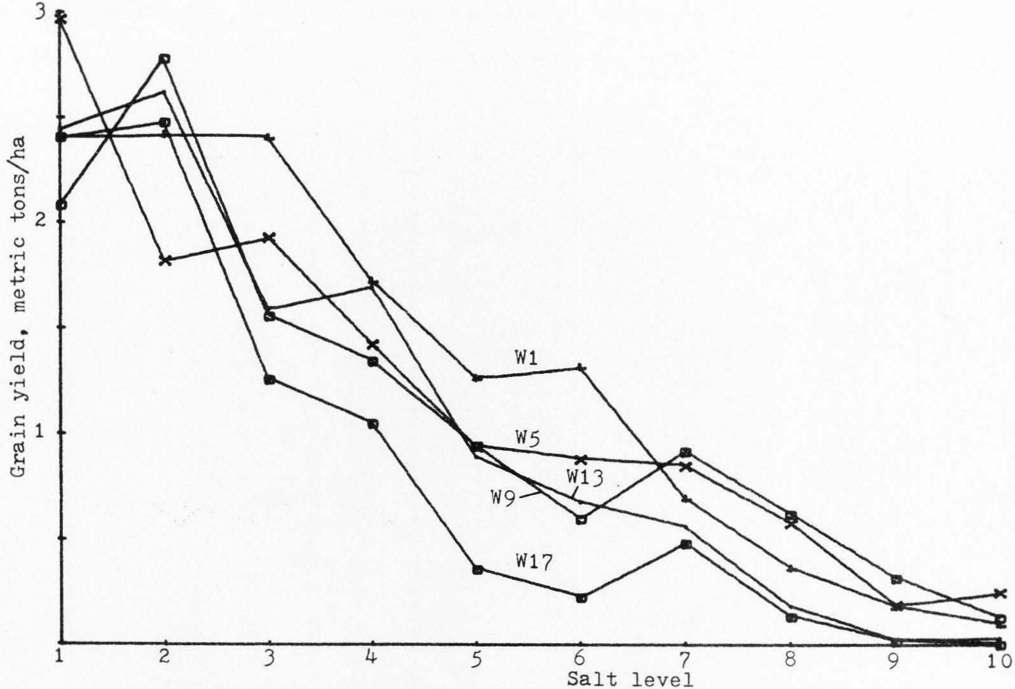

Figure 15. Grain yields metric tons/ha as influenced by salinity and water levels

Table 18. Moisture percentage by weight of the grain, corrected to 15.5 percent moisture

Salt level	Irrigation level 1	3	5	7	9	11	13	15	17	19
					Block 1					
1	1.49	6.20	3.56	0.86	1.15	1.10	3.70	1.27	0.92	1.55
2	1.61	0.45	1.67	1.88	1.39	0.86	0.45	0.40	0.40	8.50
3	0.86	0.20	6.57	1.49	0.92	3.51	0.92	0.20	0.51	0.92
4	2.92	0.92	0.25	0.40	0.63	0.80	0.86	1.33	0.51	0.31
5		3.30			0.25					
6	0.31	0.86				1.55				
7			0.25	0.37		0.51		0.51		
8										
9										
10										
					Block 2					
1	2.30	3.70	7.00	2.15	1.44	0.44	1.16	4.86	2.08	
2	2.21	0.53	1.82	0.75	0.31		0.98	3.44	1.21	3.07
3		0.52	0.31	4.89		0.63		1.44	0.31	
4	2.54	0.31	2.06	0.51		7.12	1.39			
5		1.10	0.57							
6										
7			2.38		1.39					
8					1.05					
9										
10										
					Block 3					
1	1.55	1.55		3.87	1.55	8.96	2.60	1.21		1.82
2		0.10	0.86	0.92	0.51		1.88	0.20	1.44	2.60
3	0.20	2.10	0.20	0.86	0.20	1.88	1.49	0.57		1.21
4	0.37	0.86	0.31	0.25	0.31	0.31	1.27	0.92		
5	0.92	0.57	1.27	3.50	0.80	1.05	1.33	0.37		
6	0.92	0.37	0.31		2.54	0.86	0.51	0.37	0.50	
7		1.27	1.21	4.90		1.94				
8					0.43					
9					0.25					
10										

Table 18. Continued

Salt level	Irrigation level 1	3	5	7	9	11	13	15	17	19
					Block 4					
1	2.15	1.21	0.92	4.06	0.20	7.96	1.21	3.81	0.41	4.42
2	4.21	0.80	0.75	0.63	1.55	2.86	1.33	6.14	3.56	
3	3.18	0.20	1.21	0.31	0.86	2.54	0.86		2.54	1.27
4	1.55	0.70	0.92	1.05	0.51	0.20	1.21	0.86	1.27	0.37
5	5.92	1.21	0.57	1.21	1.49	1.39	13.00	1.44	0.31	1.21
6	0.45	0.92	1.55	0.98		0.86				
7	2.15	0.40		3.70	0.57					
8				3.81	0.92	7.77				
9										
10										

Table 19. Protein percentage by weight of the grain

Salt level	Replication 1	2	3	4
1	12.43	11.46	11.17	11.40
2	11.97	11.29	11.74	12.14
3	11.97	12.60	12.26	11.51
4	11.86	12.48	13.22	11.97
5	13.22	12.83	11.69	11.63
6	12.71	13.79	11.63	11.41
7	13.34	13.62	10.72	12.31
8	13.22	13.74	12.03	11.57
9	15.16	14.31	12.20	13.85
10	19.27	12.77	11.46	15.22

Table 20. Grain and dry matter production as influenced by salt and irrigation treatments, Duncan's Multiple Range Test

Dry matter-Kg/ha		Dry matter-grams/plant		Grain-Kg/ha	
Salt	Irrigation	Salt	Irrigation	Salt	Irrigation
1a*	2a	1a	2a	1a	1ab
2a	4b	2b	4b	2b	3c
3b	6cd	3c	6c	3c	5de
4c	8ef	4d	8d	4d	7a
5d	10dfg	5e	10e	5e	9efg
6e	12ceg	6fg	12e	6f	11bdf
7e	14h	7f	14f	7f	13g
8f	16h	8g	16f	8g	15h
9g	18i	9h	18g	9h	17i
10h	20i	10i	20g	10h	19i

* Treatments with matching letters are not significant at the 0.05 level

Table 21. Electrical conductivity of the soil solution as a function of time and site, 4-probe results in mmhos/cm @ 25°C

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
2	1	19	0-6	0.84	0.42	0.31	0.21
			6-12	0.37	0.21	0.10	0.05
			12-18	0.38	0.14	0.10	0.10
			18-24	0.23	0.18	0.10	0.03
			24-36	0.06	0.06	0.06	0.04
			36-48	0.09	0.10	0.03	0.02
2	1	15	0-6	0.84	0.52	0.42	0.10
			6-12	0.47	0.37	0.21	0.26
			12-18	0.10	0.28	0.21	0.03
			18-24	0.18	0.21	0.16	0.08
			24-36	0.13	0.08	0.15	0.06
			36-48	0.09	0.12	0.05	0.05
2	2	11	0-6	1.98	1.15	0.42	0.31
			6-12	0.16	0.63	0.42	0.31
			12-18	0.38	0.38	0.31	0.21
			18-24	0.29	0.21	0.23	0.21
			24-36	0.23	0.06	0.23	0.08
			36-48	0.12	0.17	0.09	0.10
2	2	7	0-6	1.46	0.84	0.52	0.42
			6-12	0.47	0.37	0.31	0.26
			12-18	0.31	0.77	0.38	0.35
			18-24	0.29	0.08	0.31	0.31
			24-36	0.15	0.21	0.04	0.31
			36-48	0.07	0.05	0.31	0.17
2	3	3	0-6	1.78	0.63	0.42	0.21
			6-12	0.42	0.99	0.52	0.26
			12-18	0.31	0.21	0.14	0.42
			18-24	0.18	0.37	0.31	0.26
			24-36	0.29	0.38	0.44	0.23
			36-48	0.02	0.23	0.28	0.07
3	3	3	0-6	1.25	0.73	0.63	0.21
			6-12	0.52	0.42	0.26	0.31
			12-18	0.35	0.52	0.35	0.29
			18-24	0.29	0.47	0.21	0.26
			24-36	0.21	0.02	0.37	0.27
			36-48	0.03	0.21	0.16	0.14

Table 21. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
3	4	7	0-6	1.57	0.84	0.21	0.21
			6-12	0.94	0.84	0.42	0.57
			12-18	0.24	0.31	0.59	0.47
			18-24	0.26	0.37	0.23	0.16
			24-36	0.33	0.13	0.17	0.15
			36-48	0.02	0.23	0.31	0.19
3	4	11	0-6	1.36	0.63	0.42	0.21
			6-12	1.20	0.57	0.37	0.37
			12-18	0.56	0.42	0.38	0.49
			18-24	0.03	0.26	0.47	0.47
			24-36	0.73	0.23	0.23	0.10
			36-48		0.24		0.19
3	4	15	0-6	1.15	0.94	0.21	0.42
			6-12	0.84	0.99	0.68	0.52
			12-18	0.66	0.21	0.63	0.24
			18-24	0.23	0.52	0.18	0.21
			24-36	0.19	0.06	0.27	0.13
			36-48	0.17	0.05	0.17	0.12
3	5	19	0-6	1.04	1.46	0.94	0.63
			6-12	1.36	0.52	0.47	0.73
			12-18	0.17	0.45	0.52	0.31
			18-24	0.21	0.31	0.18	0.39
			24-36	0.21	0.04	0.04	0.39
			36-48		0.17	0.12	0.00
2	10	19	0-6	4.70	3.13	3.03	2.30
			6-12	1.10	1.98	1.36	1.78
			12-18	0.91	0.59	0.66	0.77
			18-24	0.05	0.26	0.26	0.08
			24-36	0.04	0.21	0.21	
			36-48		0.00	0.00	0.84
2	10	15	0-6	3.97	2.51	2.72	1.78
			6-12	1.20	2.66	0.99	1.88
			12-18	0.31	1.22	1.36	0.38
			18-24	0.21	0.91	0.05	0.29
			24-36	0.29	0.00	0.02	0.27
			36-48	0.05	0.00	0.00	

Table 21. Continued

Block	Salt level	Water level	Depth inches	6-12	7-15	8-10	9-18
				Sampling dates			
2	9	11	0-6	5.22	2.82	2.61	2.19
			6-12	0.84	2.14	0.26	0.52
			12-18	0.80	1.08	1.57	1.25
			18-24		0.99	0.13	0.08
			24-36	0.68	0.00	0.94	0.44
			36-48	0.14	0.00	0.00	
2	9	7	0-6	5.22	1.36	2.09	0.21
			6-12	0.63	2.72	1.04	0.78
			12-18	0.77	1.14	1.39	0.66
			18-24	0.18	1.25	0.13	0.16
			24-36	0.50	0.00	0.94	0.19
			36-48		0.00	0.00	0.19
2	8-9	3	0-6	5.64	0.52	0.21	0.94
			6-12	0.21	0.42	0.47	0.21
			12-18	0.94	2.16	1.36	0.97
			18-24	0.44	1.17	2.09	0.08
			24-36	0.06	0.00	0.00	0.86
			36-48	0.03	0.00	0.00	0.00
3	8	3	0-6	1.15	0.84	0.21	0.21
			6-12	1.46	1.51	0.42	0.47
			12-18	1.08	1.01	0.70	0.59
			18-24	0.13	0.75	0.37	0.16
			24-36	0.13	1.19	0.65	0.17
			36-48	0.31	0.00	0.00	0.17
3	8	7	0-6	1.46	0.84	0.21	0.10
			6-12	1.51	1.88	0.47	0.47
			12-18	0.97	0.35	1.46	1.01
			18-24	0.08	0.63	0.03	0.26
			24-36	0.21	0.92	0.88	0.06
			36-48	0.17	0.00	0.00	0.40
3	7	11	0-6	1.25	0.63	0.31	0.21
			6-12	1.20	1.10	0.63	0.37
			12-18	0.97	0.77	0.52	1.32
			18-24	0.23	0.44	0.57	0.03
			24-36	0.23	1.02	0.50	0.08
			36-48	0.10	0.00	0.16	0.45

Table 21. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
3	7	15	0-6	1.46	0.73	0.84	0.10
			6-12	1.20	1.15	1.41	1.62
			12-18	0.45	0.70	0.24	0.24
			18-24	0.47	0.55	0.55	0.13
			24-36	0.19	0.00	0.33	0.29
			36-48	0.16	0.00	0.14	0.07
3	7	19	0-6	2.82	1.36	1.36	1.15
			6-12	0.78	1.20	0.68	1.20
			12-18	0.49	1.36	0.59	0.17
			18-24	0.23	1.01	0.21	0.34
			24-36	0.13	0.00	0.56	0.17
			36-48	0.09	0.00	0.02	0.16
4	1	19	0.6	0.63	0.42	0.21	0.10
			6-12	0.21	0.31	0.16	0.10
			12-18	0.35	0.10	0.17	0.17
			18-24	0.26	0.31	0.16	0.21
			24-36	0.13	0.21	0.13	0.19
			36-48	0.12	0.09	0.09	0.21
4	1	15	0-6	0.73	0.42	0.21	0.21
			6-12	0.26	0.26	0.16	0.16
			12-18	0.38	0.28	0.17	0.28
			18-24	0.21	0.21	0.08	0.10
			24-36	0.15	0.31	0.21	0.17
			36-48	0.10	0.00	0.12	0.16
4	2	11	0-6	0.52	0.42	0.21	0.21
			6-12	0.37	0.26	0.26	0.21
			12-18	0.14	0.28	0.17	0.21
			18-24	0.21	0.13	0.10	0.16
			24-36	0.17	0.27	0.21	0.08
			36-48	0.09	0.00	0.09	0.19
4	2	7	0-6	0.94	0.31	0.21	0.10
			6-12	0.37	0.31	0.21	0.26
			12-18	0.28	0.24	0.24	0.14
			18-24	0.29	0.29	0.23	0.26
			24-36	0.92	0.33	0.36	0.08
			36-48	0.16	0.07	0.00	0.16

Table 21. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
4	2	3	0-6	0.73	0.42	0.21	0.21
			6-12	0.42	0.42	0.26	0.21
			12-18	0.17	0.28	0.17	0.28
			18-24	0.29	0.39	0.03	0.16
			24-36	0.10	0.04	0.21	0.06
			36-48	0.10	0.07	0.12	0.33
1	3	3	0-6	0.63	0.31	0.21	0.10
			6-12	0.52	0.52	0.16	0.10
			12-18	0.24	0.35	0.28	0.17
			18-24	0.23	0.29	0.18	0.21
			24-36	0.29	0.21	0.17	0.27
			36-48	0.03	0.12	0.31	0.12
1	3	7	0-6	0.63	0.31	0.21	0.10
			6-12	0.42	0.36	0.26	0.21
			12-18	0.45	0.63	0.38	0.31
			18-24	0.42	0.23	0.31	0.39
			24-36	0.15	0.02	0.23	0.29
			36-48	0.12	0.00	0.23	0.16
1	3	11	0-6	1.46	0.73	0.42	0.21
			6-12	0.37	0.89	0.37	0.38
			12-18	0.45	0.42	0.49	0.56
			18-24	0.29	0.63	0.16	0.29
			24-36	0.19	0.02	0.23	0.23
			36-48	0.16	0.09	0.28	0.00
1	4	15	0-6	2.30	0.94	1.04	0.73
			6-12	0.57	1.31	0.52	0.16
			12-18	0.59	0.38	0.80	0.87
			18-24	0.23	0.37	0.00	0.05
			24-36	0.13	0.17	0.00	0.21
			36-48	0.03	0.00	0.00	0.00
1	4	19	0-6	1.98	1.25	0.94	0.63
			6-12	0.57	0.73	0.42	0.26
			12-18	0.66	0.45	0.49	0.38
			18-24	0.21	0.29	0.13	0.16
			24-36	0.17	0.21	0.19	0.17
			36-48	0.00	0.00	0.03	0.07

Table 21. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
4	6	19	0-6	1.36	1.25	0.94	0.10
			6-12	0.57	0.63	0.57	1.25
			12-18	0.52	0.49	0.80	0.49
			18-24		0.08	0.00	0.10
			24-36	0.63	0.21	0.00	0.23
			36-48	0.12	0.00	0.00	0.12
4	6	15	0-6	2.40	0.84	1.25	0.73
			6-12	0.31	1.04	0.42	0.31
			12-18	0.91	0.24	0.87	0.73
			18-24	0.34	1.28	0.78	0.00
			24-36	0.00		0.00	0.44
			36-48	0.21		0.00	
4	7	11	0-6	1.36	0.42	1.67	0.42
			6-12	0.63	0.94	0.37	0.21
			12-18	0.84	0.31	1.08	0.59
			18-24	0.21	0.70	0.10	0.29
			24-36	0.56		0.00	0.59
			36-48		0.57	0.00	
4	7	7	0-6	1.57	0.31	1.36	0.10
			6-12	0.26	0.68	0.16	0.26
			12-18	1.04	0.45	0.73	0.31
			18-24	0.31	0.76	0.26	0.21
			24-36	0.31	0.00	0.06	0.33
			36-48		0.10	0.00	0.03
4	8	3	0-6	1.67	0.63	0.94	0.31
			6-12	1.41	0.99	0.78	0.42
			12-18	1.11	0.49	0.10	0.49
			18-24	0.13	1.31	0.26	0.18
			24-36	0.40		0.90	0.71
			36-48	0.00		0.52	0.00
1	8	3	0-6	3.34	0.94	2.09	0.21
			6-12	1.10	1.41	0.52	0.21
			12-18	0.56	0.52	0.00	0.38
			18-24	0.23	0.68	0.52	0.26
			24-36	0.13	0.13	0.71	0.36
			36-48	0.04	0.12	0.00	0.05

Table 21. Continued

Block	Salt level	Water level	Depth inches	Sampling dates 6-12	7-15	8-10	9-18
1	9	7	0-6	5.74	3.34	1.15	0.94
			6-12	0.63	1.25	1.46	0.68
			12-18	0.73	0.49	1.81	0.97
			18-24	0.39	0.89	0.00	0.29
			24-36	0.10	0.29	0.00	0.61
			36-48	0.21	0.12	0.00	0.26
1	9	11	0-6	8.56	2.61	2.51	0.21
			6-12		2.19	2.25	2.25
			12-18	0.26	0.59	0.00	1.50
			18-24	0.37	0.26	0.00	0.47
			24-36	0.19	0.23	0.00	0.40
			36-48	0.52	0.70	0.00	0.00
1	10	15	0-6	5.64	4.07	3.55	0.21
			6-12	0.84	1.98	0.99	2.51
			12-18	0.59	0.00	1.43	0.35
			18-24		0.13	0.00	0.34
			24-36	0.83	0.04	0.00	0.44
			36-48		0.17	0.00	0.10
1	10	10	0-6	4.28	2.82	2.82	2.51
			6-12	0.89	1.72	2.77	1.20
			12-18	0.80	0.17	0.00	0.56
			18-24	0.21	0.39	0.00	0.18
			24-36	0.46	0.08	0.00	0.42
			36-48		0.19	0.00	0.00

Table 22. Electrical conductivity of water samples extracted from ceramic cups, mmhos/cm @ 25°C

Block	Salt level	Water level	Sampling dates						
			6-13	7-9	7-17	8-1	8-12	8-27	9-18
2	1	19		5.3	5.8	5.6			
	1	15			5.2	5.2	5.8		
	2	11		4.8	2.7		5.3	7.0	7.6
	2	7	5.5	4.8	5.5	5.7	5.9	7.5	7.3
	3	3	4.7						
3	3	3	4.4	3.8					
	4	7	7.3	3.4	2.6	3.6			
	4	11		3.8			4.2		
	4	15	5.2		6.8	5.19	4.8		
	6	17	3.4	3.7	3.6	3.6	3.3	4.8	3.7
	6	13	6.8	4.2	4.2		4.2	4.3	
	6	9	4.4	4.8	3.3		4.9	5.8	
	6	5	4.9	2.2	2.8	3.4	3.8	4.3	5.1
	6	1	4.3		5.5	13.2	15.2	8.2	15.6
2	6	5	4.3	3.2	3.4		4.6	5.3	6.3
	6	9		4.3	4.6				
	6	13							
	6	17	3.7	3.4	4.4	5.0	6.7	7.8	
	10	19	16.7	8.4	4.2	6.0	6.1		19.2
	10	15	10.9	12.3			7.8		7.1
	9	11	14.6	24.6	7.7		7.7		8.2
	9	7		2.6					
	8-9	3	3.7	4.6			10.3		12.3
3	8	3	3.6	3.6	3.5	3.7	4.1	4.8	6.6
	8	7	4.6	4.1			4.2	4.3	4.2
	7	11	5.9	5.2			4.7		4.5
	7	15	5.2	5.3	5.2	6.6	6.4		6.4
	7	19	5.5	5.0	5.0	5.0	5.0	4.9	8.0
4	1	19	4.4	4.3	4.3	4.3	4.7		8.8
	1	15		3.8	3.8	3.8	4.1		5.0
	2	11	4.0	3.7		4.2	3.7	3.8	4.3
	2	7	3.4	2.3	3.7		3.2	4.0	4.9
	2	3							
1	3	3		5.3	3.2	4.8	5.6	5.8	7.5
	3	7	6.3		4.7	5.6	5.7	4.2	5.1
	3	11	5.2	5.1	4.4	5.2	5.6	7.1	7.7
	4	15		6.0			5.1		5.7
	4	19		5.3		6.4	5.7	7.0	5.8
	5	17			5.6	5.6	6.6	5.5	5.8
	5	13	6.1	5.2		5.4	5.7	7.1	9.7
	5	9	5.2	4.4	5.1	5.6	5.9	8.7	12.7
	5	5	4.9		1.8	6.8	10.3	9.9	9.8
	5	1	5.1	4.8	3.9	6.1	8.1	10.7	11.3
4	5	5	5.4	4.2	5.0	6.4	7.5	8.6	

Table 22. Continued

Block	Salt level	Water level	Sampling dates 6-13	7-9	7-17	8-1	8-12	8-27	9-18
4	5	9	5.7	2.6	2.8	2.3	2.9	3.8	6.4
	5	13	5.8	6.6		8.7	7.7	8.3	
	5	17	3.2	3.7		3.3	3.5	3.4	3.2
	6	19		5.7	6.2	5.1	5.0	4.9	
	6	15	5.4			4.3			
	7	11	6.4	3.5	4.2	3.8	4.3	4.4	4.8
	7	7							15.5
	8	3	6.3	4.7		5.2	7.4	11.0	7.7
1	8	3	5.9		2.6	4.2	4.7	6.4	
	9	7							
	9	11	6.3					5.3	5.6
	10	15	6.7	21.0		10.4	9.4	7.8	6.3
	10	19							

VITA

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Master of Science

Thesis: Determining a Crop Production Function for Corn as Influenced by Irrigation and Salinity Levels

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