THE CONJUNCTIVE USE OF SALINE IRRIGATION WATER ON DEFICIT-IRRIGATED COTTON

A Dissertation

by

JOSEPH CHARLES HENGGELER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2004

Major Subject: Biological and Agricultural Engineering

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December 2004

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ABSTRACT

The Conjunctive Use of Saline Irrigation Water

on Deficit-Irrigated Cotton. (December 2004)

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Cotton (*Gossypium hirsutum*) is able to survive relatively large levels of both water and salinity stress. The objective of this study was to evaluate cotton lint production and soil salinization under a conjunctive use strategy using saline water at deficit levels. A three-year experiment applying irrigation at deficit amounts on cotton was conducted in Pecos, Texas on a Hoban silty clay loam. Treatments were four irrigation water qualities, conjunctively applied. Initial irrigation was with water having an electrical conductivity (EC_{IW}) of 4.5 dSm-1, representing about one-third of the total amount of water applied. Thereafter, treatments were applied using water of varying EC_{IW}, e.g., 1.5, 4.5, 9.0, and 15.0 dSm^{-1} for all subsequent irrigations. Total irrigation plus rain was approximately two-thirds of full water requirements. Lint yields for the three years averaged 1050, 1008, 809, and 794 kg ha^{-1}, respectively, and treatment levels did not decline over time. However, the soil salinity levels of the three more saline treatments increased throughout the test period. Yields declined due to salinity prior to reaching the published threshold value (Maas and Hoffman, 1977) of ECe = 7.7 dSm-1. Under the deficit conditions of two-thirds of the full water requirements, the threshold level was lowered to 4.5 dSm^{-1}. The overall yield loss that resulted from limiting water by one-third was three times > than the yield loss from even the highest salinity treatment. Relative lint yield was reduced 3% for each dSm^{-1} of EC_{IW}. The pre-dawn and solar-noon leaf water potential values decreased at a rate of 0.026 and 0.042 MPa per dS m^{-1} of the EC_{IW}, respectively. Study conclusions were that yields within treatments remained stable for three years. However, the increase of salinity in the soil profile indicated that long-term viability of using highly saline water conjunctively is impractical under deficit irrigation conditions. In the short-term,

however, saline water of up to 15.0 dS m^{-1} can be used at mid-season under deficit conditions on Hoban silty clay loam soil to secure 75% of the yield level obtained by using high quality water if a pre-plant irrigation of medium quality water is first applied.

DEDICATION

This dissertation, and the Doctorate of Philosophy that is associated with it, are dedicated to my mother, the late Dorothy Merrigan Henggeler. She was aware of the importance of education. My mother assisted me at all times during the pursuit of this degree—with maternal encouragement during the tough periods along the way and at all times with untold prayers for a fruitful completion. I thank and remember her from the bottom of my heart.

ACKNOWLEDGMENTS

I would like to thank the leadership of both Texas Cooperative Extension and the Department of Biological and Agricultural Engineering of Texas A&M University for permitting me the study leave that allowed me to pursue this Ph.D. degree. Among this group, I wish especially to single out Dr. John Sweeten who was my direct supervisor when I started this project.

I would also like to thank the staff of the Texas Agricultural Experiment Station at Pecos, Texas where my research was conducted. These include Dr. Jaroy Moore, Mike Murphy, Paul Ward, Melissa Grote, Jaxie Young, Raymond Tillis, and Johnny Ramirez. The large amount of data in the appendix reflects many hours of labor. I would like to acknowledge and thank my counterparts in the plots who worked so hard collecting this—Misty, Chris, Michael, and Anthony. The Texas State Support Committee and Cotton Incorporated helped fund part of the research on this project. I wish to acknowledge and thank them for the support.

I would like to thank my doctoral committee: Dr. Bruce Lesikar, Dr. John Sweeten, Dr. Robert Lascano, and Dr. Jaroy Moore. I appreciate them working so understandingly with me. I would like to especially acknowledge Dr. Lesikar who "inherited" this work late but was willing to assist in helping me bring it to completion, and Dr. Lascano who provided great assistance in helping to make this into a professional document. I would also like to thank Dr. Don Reddell, Dr. Tom Hallmark and Dr. Juan Landivar, all who helped me earlier in the effort. In addition, I wish to acknowledge the help of Dr. Gerald Riskowski and Mrs. Sonya Stranges from the office of department head.

Lastly, I would like to acknowledge the assistance and encouragement I received from my parents, wife, children, and friends, both while I was employed by Texas A&M University and then after I moved to the University of Missouri.

NOMENCLATURE

ITEM	Units
Adjusted Basal Crop Coefficient (to local wind and minimum air RH conditions), K_{cb_adj}	
Basal Crop Coefficient (transpiration only), K_{cb}	
Basal Crop Coefficient (transpiration only - during initial growth stage), K_{cb_ini}	
Basal Crop Coefficient (transpiration only - during middle growth stage), K_{cb_mid}	
Basal Crop Coefficient (transpiration only - during end growth stage), K_{cb_end}	
Basal Crop Coefficient (transpiration only - as provided by FAO-56), K_{cb_guide}	
Crop Coefficient (evaporation & transpiration together), K_c	
Crop Coefficient (evaporation & transpiration together - during initial growth stage), K_{cb_ini}	
Crop Coefficient (evaporation & transpiration together - during middle growth stage), K_{cb_mid}	
Crop Coefficient (evaporation & transpiration together - during end growth stage), K_{cb_end}	
Crop Water Productivity (aka Water Use Efficiency)	kg m^{-3}
Crop Water Stress Index, CWSI	
Days after planting, DAP	d
Days since last irrigation, DSI	d
Evaporation, E	mm
Evaporation Coefficient (evaporation only), K_e	
Evaporation Reduction Coefficient, K_s	
Evapotranspiration (actually used by the crop), ET_c	mm
Evapotranspiration (reference), ET_o	mm
Evapotranspiration (maximum), ET_m	mm
Experimental Unit, EU	
Force, Newtons	N
Height of crop canopy, h	m
Heat Unit, HU	°C d^{-1}
Irrigation Applied, IRR	mm
Leaf water potential, LWP	MPa
Leaf water potential (pre-dawn), LWP_{PD}	MPa
Leaf water potential (solar noon), LWP_{SN}	MPa

ITEM	Units
Osmotic potential, OP	MPa
Relative Humidity, Minimum (air, average) (RH_{min})	%
Relative Yield, RY	kg ha^{-1}/kg ha^{-1}
Relative Yield (for the T1 treatment [no salt stress]), RY_{T1}	kg ha^{-1}/kg ha^{-1}
Relative Yield (as a function of drought alone), RY_D	kg ha^{-1}/kg ha^{-1}
Relative Yield (as a function of salinity alone), RY_S	kg ha^{-1}/kg ha^{-1}
Rainfall, RAIN	mm
Salt content of the leaf (dry weight)	mol kg^{-1}
Salinity of irrigation water, EC_{dw}	dS m^{-1}
Salinity of irrigation water, EC_{IW}	dS m^{-1}
Salinity (average after mixing) of irrigation water, $EC_{IW\text{-}net}$	dS m^{-1}
Salinity of soil solute solution, EC_{ss}	dS m^{-1}
Salinity of saturated paste extract, EC_e	dS m^{-1}
Salinity (estimated) of saturated paste extract, EC_e'	dS m^{-1}
Salinity of saturated paste extract (capillary method), $EC_{cap\text{-}e}$	dS m^{-1}
Salinity of filtered soil paste (water:soil at 2:1), $EC_{2:1}$.	dS m^{-1}
Sodium Absorption Ratio, SAR	
Soil permeability	cm h^{-1}
Soil water potential	MPa
Soil volumetric water content, θ_v	m^3 m^{-3}
Soil water storage (change in), Δ_{sws}	mm
Temperature (sum of daily maximum air), DMT	°C
Total dissolved solids	mg l^{-1}
Wind at 2 m, u_2	m s^{-1}
Yield response factor, K_y	
Yield (actual crop), Y_c	kg ha^{-1}
Yield (maximum), Y_m	kg ha^{-1}
Yield (mean yield of T1 replicates), Y_{T1}	kg ha^{-1}
Yield loss (relative, as a function of drought alone), YL_D	
Yield loss (relative, as a function of salinity alone), YL_S	

ITEM	Units
Yield loss (relative, as a function of drought & salinity), $YL_{D\&S}$	

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CHAPTER I

INTRODUCTION

The concept of irrigating a crop using two or more sources of water is known as *conjunctive use*. Conjunctive use of water implies that the benefit derived from the combination of waters is > the sum of the individual benefits of the water used independently. A field experiment was carried out for three growing seasons (1994-1996) to study *deficit irrigation* involving the use of mid-season irrigation waters of different salinity levels (EC_{IW}). Salinity treatments were not imposed until later portions of the growing season. During the first portion of the season, irrigation water of moderate quality was used. Cotton lint yield levels and changes in soil salinity were monitored throughout the three-year period to ascertain if such production systems were agronomically viable. *Viability* in this study involves both avoiding soil salinization and maintaining economic viability (yield level) for the farmer.

DEFINITION OF THE PROBLEM

In many parts of the world, water resources are so limited that the combination of both rainfall and irrigation do not meet the full crop water requirement, also referred to as maximum evapotranspiration for that crop (ET_m). This is true for several large irrigated regions in Texas, which practice deficit irrigation. This experiment was conducted given that the vast majority of irrigated crops are grown under deficit irrigation conditions in Texas, the second largest agricultural state in America. Texas has been referred to as a cotton-growing region having a "three-bale" potential and a "one-bale" reality. This yield shortfall is due to the lack of water resources. The Southern High Plains, one of the major cotton-growing regions in the world, applies on average 362 mm of irrigation per year, (TWDB, 1991), and its annual rainfall is less than 500 mm. The combination of both sources of water, after efficiencies are accounted for, is the actual amount available for crop evapotranspiration (ET_c), and for cotton in most regions in Texas, $ET_c < ET_m$. *Deficit irrigation* can be defined as: $ET_c < ET_m$, while the degree of deficit irrigation is: ET_c / ET_m. On the other hand, the Trans-Pecos region receives less rain but has more underground water resources. However, pumping depths in many parts of the Trans-Pecos are so deep that water application has decreased due to economic reasons.

Texas' limited water resources may be the reason why many of the popular water-

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This dissertation follows the style of the *Transactions of the ASAE.*

conserving irrigation methods, such as LEPA (low-energy precision application), surge flow, and sub-surface drip irrigation, were either developed or nurtured to popularity in the state. Conservation technologies not withstanding, many fresh water resources in Texas are being depleted. In 1999 irrigators in the state applied 12 billion m^3 of water (TSSWCB and TWDB, 2002).

There are, however, several sources of saline irrigation water available for the Trans-Pecos region, both as ground and surface sources. This experiment evaluated the use of both deficit irrigation and saline water. The Trans-Pecos irrigation water represents a salinity hazard based on two properties. One is the sodium hazard, based on water's sodium content with respect to existing amounts of calcium and magnesium. This type of water can be hazardous, because sodium, in high proportions in soil solution, can lead to degradation of the soil structure. The second hazardous aspect of irrigation water is related to the quantity of salts in the water. The sodium hazard was not part of this study.

Cotton is an ideal crop for such a study as it is both drought- and salt-tolerant, and also is Texas' largest crop. While many previous studies have been conducted on deficit irrigation and cotton (e.g., Grimes et al., 1969; Meiri et al., 1992; Bordovsky et al., 1992; Yazar et al., 2000; and, Enciso-Medina et al., 2002) and salt effects on cotton (e.g., Maas and Hoffman, 1977; Thomas, 1980; Francois, 1982; and, Nawar et al., 1995), very few studies have been conducted on cotton experiencing the simultaneous effects of drought and salinity. Examples from the literature that involved both drought and salinity include Dregne (1969), which was a modeled projection of the simultaneous impact of drought and salt stress on cotton, not a replicated study, and Russo and Bakker (1987), which was done in Israel with drip irrigation. Neither of these works involved conjunctively mixing water sources in an effort to mitigate the harmful effects of salinity.

RESEARCH OBJECTIVES

For more than 150 years, Texas has demonstrated its ability to grow cotton with limited water. The purpose of this study was to evaluate if cotton could be grown using limited water amounts, <u>if</u> part of the water supply is from a saline resource.

The objectives of this experiment were:

1) <u>Evaluate impact on soil salinization</u> from using various EC_{IW}

by collecting and analyzing soil samples for salinity of the saturated soil extract (EC_e) prior to test commencement and after three years of testing.

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2) Evaluate cotton lint yield to determine if yield decline was occurring from using various EC_{IW} through collecting cotton lint yield over the course of the experiment.

3) Examine the physiological effects on cotton from using various EC_{IW} by collecting and analyzing data on plant height, node number, leaf area, plant mass, fruiting patterns, and leaf water potential.

Since 1994, when this project began, cotton farmers in West Texas have confronted difficult times due to drought and low cotton prices. Hopefully, row-crop agriculture will increase in profitability as farmers in Texas are able to better manage their limited resources and continue adopting technologies that will make irrigation—the key to all farming in West Texas—more efficient.

CHAPTER II
LITERATURE REVIEW

SALINITY AND COTTON

Manner in Which Cotton is Affected

Salinity affects cotton lint yield through a variety of ways. During germination, the presence of salts can be instrumental in the formation of thin soil crusts through which cotton seedlings are not able to penetrate or do so at a detriment. An emerging cotton seedling exerts a force of approximately 2.8 N; soil crust strength can reach levels 10 times greater than this (Gerard, 1980).

Foliar damage can occur from sprinkler-irrigated saline water through absorption of salt into the leaf. The amount of absorption is a function of concentration and duration of sprinkling. Cotton develops injury symptoms when the salt content of the leaves is about 0.8 mol kg^{-1} dry weight. Foliar salinity decreases the amount of K^+ concentration of the leaves (Maas et al., 1982). Busch and Turner (1967) showed that leaf damage and lint yield loss on cotton would be caused by sprinkling with water having a salinity of 4.4 dSm^{-1}, while no damage occurred when it was flood-applied.

There can also be toxicity-related lint yield losses due to salts, but the most significant reason that salinity is detrimental to cotton and others crops is that salts in soil solution decrease the overall soil water potential. This additional potential is termed *osmotic potential*. Figure 1 (from Grimes et al., 1974) shows soil water potential as a function of cotton leaf water potential (LWP). Note that plant water potential values are three to 13 times lower than corresponding soil water potential values. When osmotic potential is present, it becomes additive to the soil water potential, and thus it is more difficult for a plant to uptake water. It is because of this that salt stress is sometimes viewed as drought stress.

The soil osmotic potential (OP) can be estimated (Richards, 1954) as a function of the salinity of the saturated soil extract:

$$OP = -0.036\ EC_e \qquad (1)$$

where

OP = osmotic potential (MPa)
EC_e = salinity of saturated soil extract (dS m^{-1})

For example, the threshold damage level for cotton is 7.7 dS $m^{-1}$of the saturated soil extract. At field capacity, such a soil sample has an OP of ≈ -0.6 MPa and at permanent wilting point ≈ -1.2 MPa.

TWO-WAY INTERACTION: SALINITY AND LINT YIELD

Combining salinity-yield data from various experiments in the published literature for a specific crop does not always provide a seamless yield function. Such is the case for cotton. This is probably due to the fact that experimental parameters differ among studies. Variety of species, type of salt involved, growth media differences, climatic conditions, maintained soil water content conditions, leaching fraction observed, etc., all influence final results. Part of the problem in developing a unified picture may also be that many salinity studies are inadequately documented, with not all factors reported. Ulery et al. (1998) reported that only 10% of the 3500 to 5000 published references on salt tolerance provided sufficient data to fully describe the plant yield response. Studies on cotton response to salinity, likewise, exhibit some discrepancies.

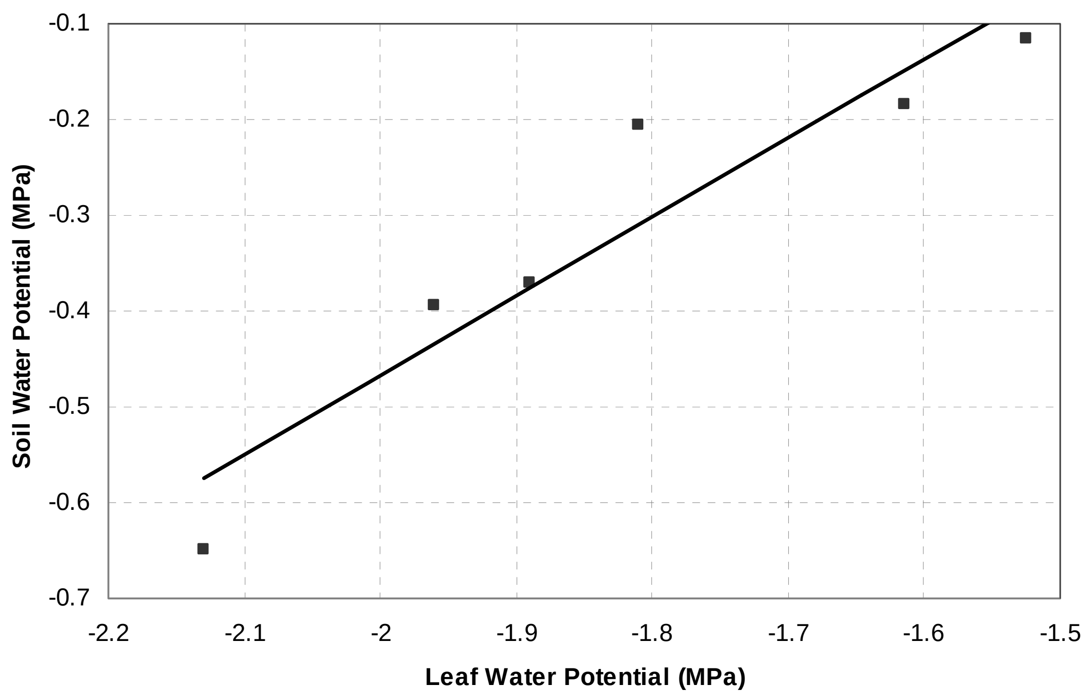

Figure 1. Leaf water potential versus soil water potential at 0.5-m depth for Coker 310 cotton (after Grimes, et al., 1974).

The concept of reporting a crop's susceptibility to salinity by using a threshold value of the saturated paste extract (EC_e) as the beginning point of yield loss in conjunction with a rate loss per additional unit of salt is referred to as the Maas-Hoffman format. Maas and Hoffman (1977) used relative yield and published coefficients for many agronomic crops, including cotton. The Mass-Hoffman values for cotton are an EC_e value of 7.7 dSm^{-1} for yield threshold with a yield reduction rate of 5.2 % for each additional dSm^{-1} above 7.7.

Procedures used in the Maas-Hoffman studies involved high leaching fractions. In cases where smaller amounts were applied and little leaching occurs, these derived coefficients would not apply (Bresler, 1987). Wichelns and Oster (1991) reported data from on-farm surveys in California. Despite the fact that the majority of soil samples were below the threshold value where any lint yield reduction should occur, a correlation was still found (10% level) between lint yield and EC_e. Farmers in this study applied a mean total of 989 mm of irrigation water on fields 800 m long. Thomas (1980), whose study likewise was on-farm, reported a lint yield loss of 50% by the time the threshold EC_e value of 7.7 dSm^{-1} was reached. His results (Fig. 2) showed larger reductions in relative lint yield from salinity levels than the Maas-Hoffman function would have predicted. Thomas felt that the discrepancies between his and the Maas-Hoffman results might be due to the fact that plants in his study were not well watered.

Alternatively, some studies can be found, such as in the case of Nawar et al. (1995), that show smaller reductions in relative lint yield loss than those predicted by Maas-Hoffman. These data are also seen in figure 2 along with Thomas' data and the Maas-Hoffman results. Despite some reported discrepancies to the Maas-Hoffman cotton-salinity function, it still remains as the definitive reference on the topic with validations from other researchers, such as Francois (1982), whose results likewise can be seen in figure 2.

Although lint yield may not be reduced until EC_e values reach nearly 8 dSm^{-1}, vegetative mass reductions begin at much lower rates. Data from Francois (1982) showed that plant height was reduced 35% at the yield threshold level of 7.7 dSm^{-1}. Salinity can also indirectly influence cotton growth by decreasing the effective rooting capacity of the plant (Russo and Bakker, 1987), which causes the plant LWP to react more quickly and decrease more for any increase in solar irradiance.

Salinity stress affects cotton green mass differently than lint. While the EC_e value must be > 7.7 $dS\ m^{-1}$ before lint yield is affected, cotton green matter is affected at much lower levels, as illustrated in figure 3 from a study by Francois (1982). Cotton differs from other crops where fruit and vegetative growth do decline at parallel rates with increasing salinity. (Fowler, 1986).

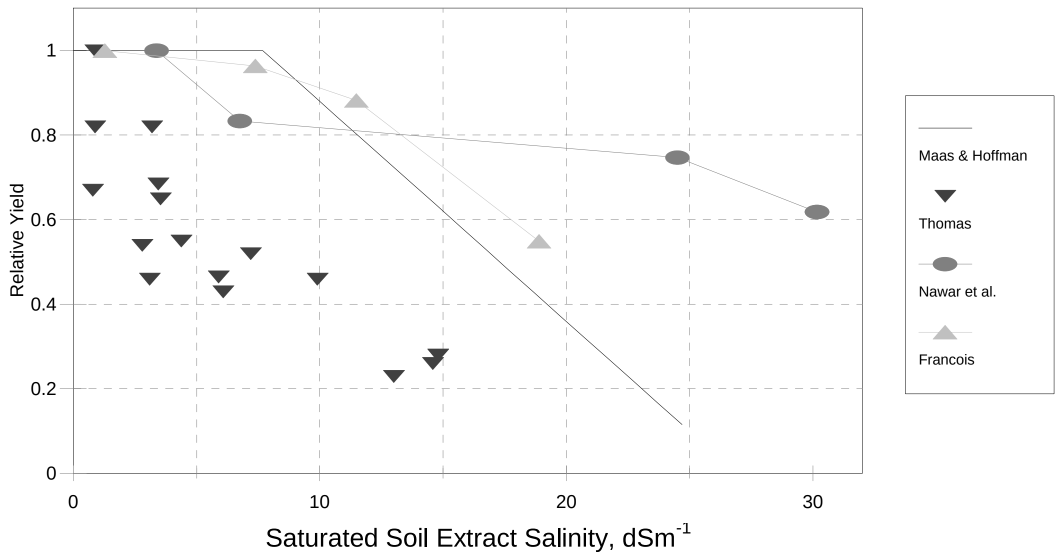

Figure 2. Relative yield of lint cotton as related to the mean salinity (EC_e) of the root zone (after Maas and Hoffman, 1977) in comparison to a study that over-predicts (Thomas, 1980) and one that under-predicts (Nawar et al., 1995) yield loss, and Francois (1982) which shows close agreement.

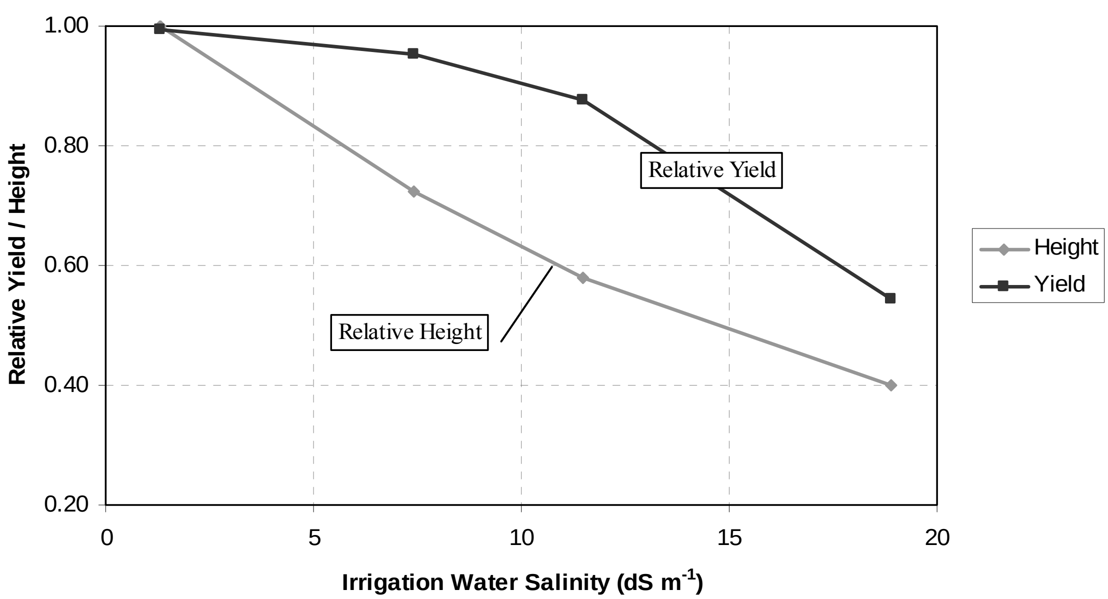

Figure 3. The difference in relative lint and relative height of cotton for various irrigation water salinities (Francois, 1982).

TWO-WAY INTERACTION: WATER AND LINT YIELD

As previously discussed, lint yield is a function of not only water *quality*, but of water *quantity*. Bordovsky et al. (1992) reported that maximum yield of lint cotton was at 0.75 of reference evapotranspiration (ET_o), and that less quantities of water produced proportionally less yield. Grimes et al. (1969) described the relative lint yield of cotton grown on two soil types as a function of evapotranspiration (ET). Indications were that no lint yield will occur if ET < 350 mm. Yield began to decline if ET > 650 mm. Meiri et al. (1992) showed a linear relationship between seed cotton yield and total water for two salinity levels (3.7 and 7.1 dS m^{-1}), two frequencies (7- and 14-day), and two irrigation methods (drip and sprinkler). Both sets of authors agreed that a 50% yield reduction in lint would occur if only 400 mm of water was available. They also seem to agree that potential lint yield occurs when around 600-700 mm of water is available for consumptive use. This value is much less than Erie et al. (1982), who reported cotton water use for Phoenix, Arizona to be > 1000 mm. Data from the former two studies are shown in figure 4.

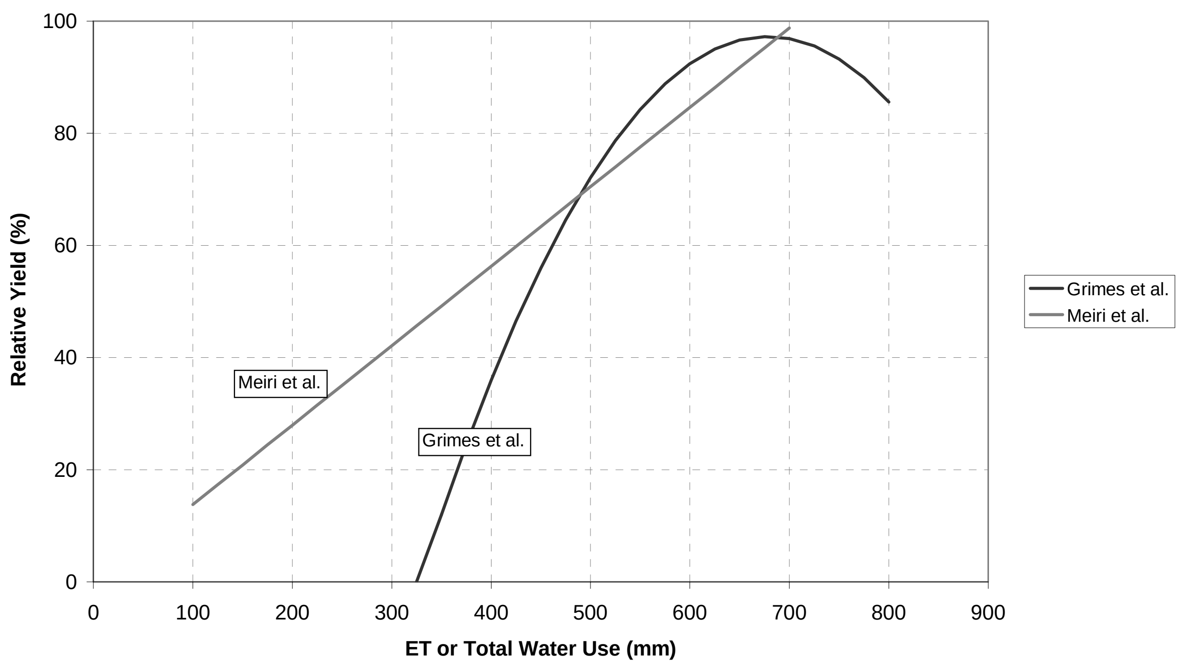

Figure 4. Relative yield versus applied water or ET from two separate studies (after Grimes et al., 1969 and Meiri et al., 1992).

Doorenbos and Kassam (1979) developed a concept of "yield response factor," termed

K_y, which is the relationship between relative yield to relative ET. In an extensive review of the literature of the period, they found a linear relationship between relative water use and relative yield for the 25 crops they evaluated. They developed K_y values to encompass the entire growing season, as well as for different growth stages. The total season K_y value for cotton is 0.85. The higher the value of K_y, the more sensitive the crop is to water stress. More recently, a reevaluation of the procedure with data from other field studies (Kassam and Smith, 2001 and Kirda, 2002) showed that the procedure of Doorenbos and Kassam (1979) remained sound to predict relative cotton lint yields, especially using the season-long yield response factor. The original relationship was expressed as:

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y\left(1 - \frac{ET_c}{ET_m}\right) \quad (2)$$

where

Y_a	=	actual crop yield (kg ha^{-1})
Y_m	=	maximum crop yield (kg ha^{-1})
ET_c	=	actual crop water use (the original work used the term "ET_a") (mm)
ET_m	=	maximum crop water requirement (mm)
K_y	=	yield response factor

Data from Yazar (2000) was used to construct a typical cotton lint yield response graph (Fig. 5). While the K_y, involves relative yield and relative water, a related concept, Crop Water Productivity (CWP), also called Water Use Efficiency, uses actual yield mass (kg) divided by applied water (m^3). The CWP is 0.41-0.95 and 0.14-0.33 kg m^{-3} for seed cotton and lint cotton, respectively (Zwart and Bastiaanssenm, 2004).

To calculate lint yield reduction due to insufficient water, equation 2 requires a value for ET_m. Additionally, water that evaporates from the soil surface (E) should not be included in ET_c. The ET_m and E change from year to year based on weather, and both ET_c and ET_m can be estimated using ET models and crop coefficients. To further enhance accuracy, the Food and Agricultural Organization (FAO), Irrigation and Drainage Paper No. 56 (Allen et al., 1998) presents methods to adjust crop coefficient values for local conditions based on wind and minimum air relative humidity (eq. 3). Furthermore, use of dual crop coefficients that separately calculate water transpired (K_{cb}) versus that which is evaporated from the soil (K_e), gives a better estimate of ET_c and ET_m. The estimate of ET_c is enhanced through the use of a water stress factor, K_s, for periods when the soil water content levels are limiting. Hunsaker (1999) concluded that this procedure gives good estimates of cotton water use in an arid environment. Smith et al. (2002) used this procedure to evaluate crop yield under deficit conditions through use of the computer program CROPWAT on several crops, including cotton.

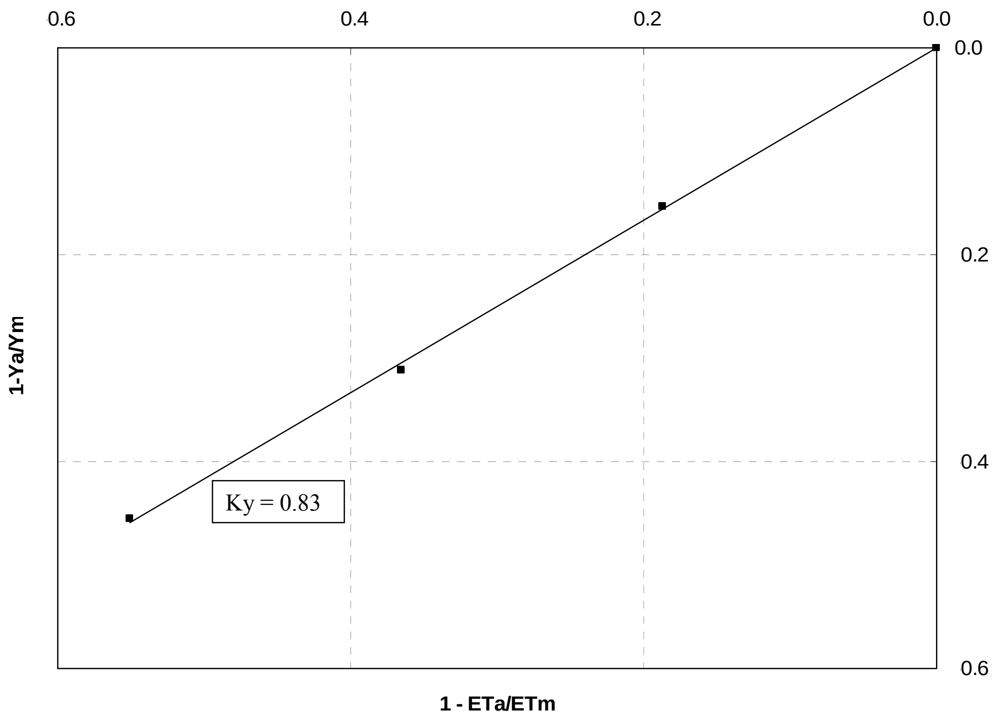

Figure 5. The yield response of LEPA-irrigated cotton in Turkey having a K_y value of 0.83 (after Yazar, 2000).

Equation 3 adjusts crop coefficient values based on measured average daily minimum air relative humidity and average daily wind speed of the period in question, and is in the form:

$$K_{cb\_adj} = K_{cb\_guide} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](\frac{h}{3})^{0.3} \quad (3)$$

where

K_{cb_adj}	=	crop coefficient value adjusted for local wind and minimum air RH
K_{cb_guide}	=	crop coefficient value as provided by FAO-56
u_2	=	local average daily wind velocity at 2 m for the period (m s^{-1})
RH_{min}	=	local average minimum air relative humidity for the period (%)
h	=	crop height for the period (m)

Since K_c incorporates both transpiration and E, and K_{cb} only involves transpiration, $K_c > K_{cb}$, and thus these values are not interchangeable. FAO-56 reports that for cotton the K_{c_ini}, K_{c_mid}, and K_{c_end} values are 0.35, 1.15-1.20, and 0.5-0.7, respectively; and the K_{cb_ini}, K_{cb_mid}, and K_{cb_end} values are 0.15, 1.10-1.15, and 0.4-0.5, respectively. Using typical lengths of time for growth periods of cotton,(Allen et al., 1998) the seasonal K_c value is 0.76, and the seasonal K_{cb} value is 0.80.

Water stress begins to affect the vegetative components of the cotton plant before lint yield is affected. Bordovsky et al. (1992) estimates that ET_m occurs at 0.75 of ET_o, which is almost exactly the FAO seasonal K_c value. Cotton green matter, however, would begin to be affected at levels above 0.75 ET_o. Also, as water quantity increases > ET_m, green matter is able to accumulate mass past this point where lint accumulation has peaked or actually begins to decline (Russo and Bakker, 1987).

While the total amount of water affects cotton lint yield, other secondary water-related factors may also affect final yield, such as plant stage when irrigations occur (Hiler and Clark, 1971; Krieg, 2000), irrigation frequency (Bordovsky et al. 1992), and plant stress history (Cutler and Rains, 1977).

THREE-WAY INTERACTION: SALINITY, WATER AND LINT YIELD

Significant amounts of research have been published on cotton lint yield, both as a function of various *levels of water* and *levels of salinity*. However, less has been published on the simultaneous effect of applying deficit amounts of water and elevated levels of salt on cotton lint yield. Solomon (1985) showed that by specifying a set amount of water and its salinity level, a distinct point balances yield, leaching fraction, ET, and soil salinity. This is termed system equilibrium.

Dregne (1969) developed a set of relations of the water-salinity production function for cotton and several other crops for the conditions of the Pecos Valley of New Mexico. His theoretical procedure was to additively combine the expected yield losses stemming from both (a) deficient water quantity and (b) salt content. Yield was reported in relative terms and is shown in figure 6. The additive procedure probably leads to overestimating yield loss. Solomon (1985) reasoned that the water-yield and the salinity-yield functions were interactive. The presence of significant amounts of salinity can have the net effect of reducing plant size. This results in less water use, thus leaving more water in the root zone to increase soil water potentials and induce higher rates of leaching. These results normally are not predicted by simple water-yield functions. Thomas and Wiegand (1970) documented a field study where the salinity-water processes affected each other, as did Russo and Bakker (1987) in a controlled study. In their work, Russo and Bakker developed a second-order equation to calculate seed cotton yield as functions of time-averaged soil water content and soil solution salinity. Allen et al. (1998) developed a model that estimated the combined effects of deficit water (Doorenbos and Kassam, 1979) and salinity stress (Ayars and Westcot, 1985 and Rhoades et al., 1992) on final lint yield. While most of these studies mathematically predicted cotton lint response as a function of water- and salinity-stress, Guo and Landivar (1993) attempted to mechanistically model cotton growth and response to variations in soil water potential, osmotic potential, osmotic adjustment, root and leaf resistance, and vapor pressure deficit.

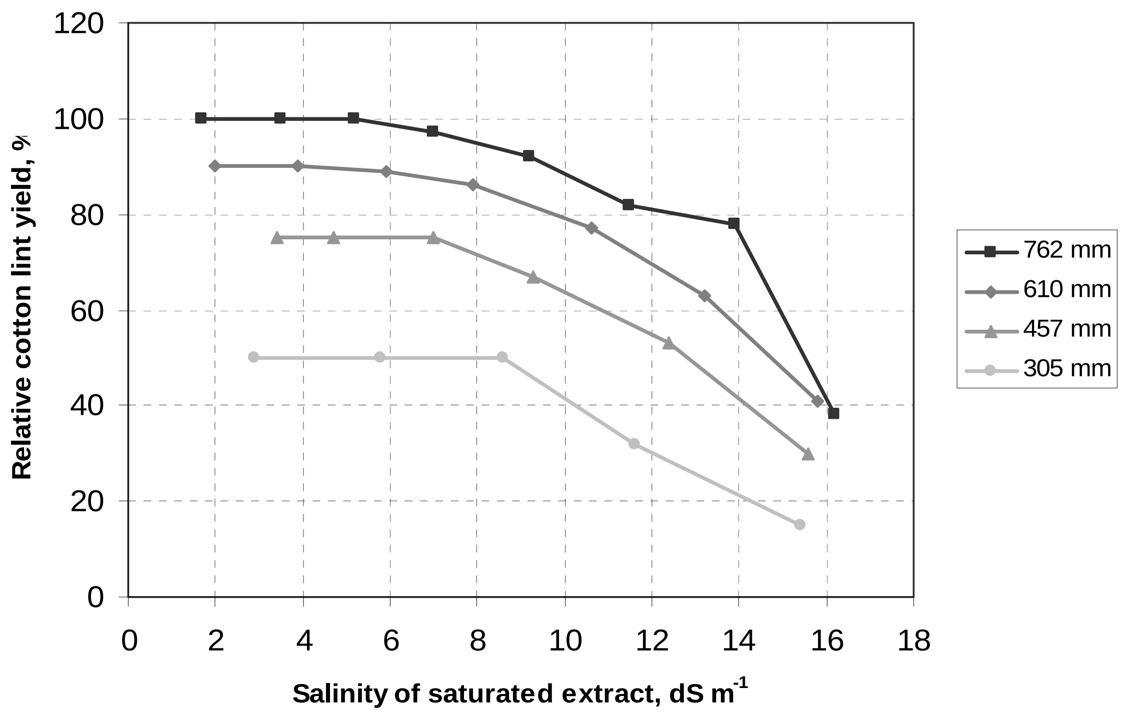

Figure 6. Theoretical relative cotton lint yield as a function of average salinity of root zone for four seasonal irrigation amounts (after Dregne, 1969).

Physiologically, a plant undergoing both water-stress and salinity-stress is affected by a variety of factors that have bearing on final yield results, such as the change in water-use efficiency. Hoffman and Phene (1971) demonstrated this in a growth chamber study where cotton that was subjected to higher salinity levels developed lower water-use efficiencies (mg net CO_2 assimilated / g H_2O transpired). It is interesting to note that kidney beans, a salt-sensitive crop, did not show this. Apart from complex interactions involved in combined salinity- and water-stress, additional interactions may occur. For example, Heald and Heilman (1971) showed that nematode injury to cotton increases with elevated levels of soil salinity. Lauter et al. (1988) and Kurth et al. (1986) indicated that the type of salt ion, notably Ca^{2+} and K^+, impact the response of cotton to salinity.

CONJUNCTIVE USE OF SALINE IRRIGATION WATER

The conjunctive use of water means that two or more water sources are used to irrigate the same field. Ideally, the benefits derived from conjunctively using two sources of water are > the sum of the benefits of using the waters individually. When one of the waters is of marginal quality, and could cause yield decline or harm soil structure, the addition of a second water source of better quality might avert or reduce the harm.

The lint yield reduction in cotton, stemming from saline irrigation waters that exceed the salinity threshold, can be diminished by using various management techniques. A summary of the literature on this subject is given by Grattan and Rhoades (1990). Management strategies can be divided into three categories: (a) maintenance of saline water tables at optimal depths, (b) blending waters, and (c) cyclically using waters of different qualities:

> **Strategy 1: Water Table Management.** Empirical studies have developed relationships between soil texture and the depth/quality of a perched water table to maximize either yield or ground water extraction for cotton and other crops.
>
> **Strategy 2: Blending Waters.** Mixing a yield-reducing saline water (in the case of cotton, water having an EC_{IW} of ≈ 4-6 dSm^{-1}) with a less saline source may mitigate, or even eliminate, yield reduction. Final results depend on the concentrations and relative amounts of water mixed.

In the 1980s, sub-surface drip irrigation (SDI) in the United States has increased yields, irrigation use efficiency, and farmer profits. A possible new use of SDI may be the disposal of feedlot and dairy farm effluent since odor and handling problems are reduced (Lamm et al., 2002). However, an inherent problem is that critical loads of N, P, and K for a crop/soil type would likely be reached before the water needs of the crop are met. Applying other sources of water through the system would allow the investment in the SDI to be fully reached. This would be an application of conjunctive use with Strategy 2. Sweeten (1976) developed guidelines to dilute holding pond water from feedlots to minimize land degradation or reduce crop yield due to salinization.

The concept of blending waters to mitigate salinity hazard may also be used to mitigate water containing sodium hazards (Ayars and Westcot, 1985). However, special care should be taken in determining the resulting Na hazard of the mixed water. Neglecting precipitation, the electrical conductivity (EC) of two waters mixed 1:1 will be close to the average of the individual EC values; whereas, the resulting Sodium Adsorption Ratio (SAR) would not necessarily be the average of the two waters' SAR values:

> **Strategy 3: Cyclic Use of Good and Poor Irrigation Water Sources.** On a long-term basis (i.e., two or more growing seasons), the rotation of salt-sensitive crops with moderately tolerant crops is possible. Yields of neither are reduced if a better quality water is used during the cultivation of the sensitive crop, while the poorer water is reserved for the tolerant crop in the rotation. The more common method of cyclical management, however, occurs within a single growing season. Good quality water is used during the initiation stage (which is generally more susceptible to salinity); later, poorer quality water is used to mature the crop. This use of two or more waters of different qualities is referred to as *conjunctive use*.

Oster and Rhodes (1983) demonstrated the cyclical use of good and poor quality water in cotton where different quality of water was used in early and later growth stages. Using saline water to mature the crop (4.9 dSm^{-1} in one case and 7.9 dSm^{-1} in another case), harvested lint yields were 0.80 and 0.81, respectively, of a non-conjunctive use check treatment that used only good water quality (0.7 dSm^{-1}) for the entire season.

Areas with poor water quality for irrigation that experience significant amounts of rain are in effect experiencing conjunctive use of water. In a laboratory test, Malladi (1994) applied three levels of salinized water interdispersed with simulated rain. There were also three rates of rain to treated water, but the total amounts were constant. There was a negative trend relating total applied salinity to shoot growth. The implication was that for a set amount of water, it is the total volume of seasonal salts, whether they accumulate steadily or in fewer, larger doses, that influences cotton growth.

Singh et al. (2002) attempted to mitigate cottonseed yield loss due to poor quality irrigation water over six seasons by either employing conjunctive mixing or chemical and natural additives. The conjunctive mixing strategies performed better than the amendments as shown in figure 7. During the six seasons, plots that received only the better canal water (GOOD) had a cottonseed yield 39% higher than plots irrigated with the inferior quality water of tube wells (BAD). Alternatively, irrigating with GOOD then BAD water increased seedcotton 18%, and applying a single pre-plant irrigation with GOOD and then BAD water for the rest of the season gave a 17% yield increase. Using only soil amendments plus BAD water only increased yields 6%.

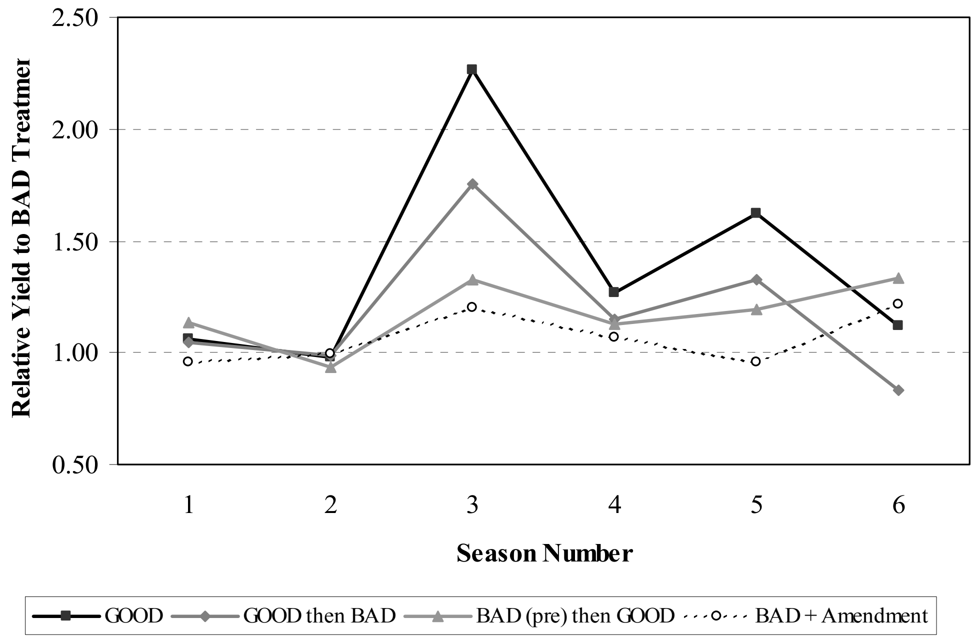

Figure 7. Relative yields of cottonseed in relation to the cottonseed obtained using poor quality tube well water (BAD) for treatments using only good quality canal water (GOOD), irrigating alternately between GOOD and BAD, using BAD for a pre-sowing irrigation and later using only GOOD, and using BAD but applying soil amendments.

Conjunctive Water Use in Texas and the Southwest

Conjunctive use occurs frequently in the cotton-growing regions of the Southwestern United States. Perched water table management (strategy one) is basically a case of conjunctive use (strategy three), because good quality water is later replaced with the poorer water of the perched table. In the western San Joaquin Valley, California, cotton is often irrigated early in the season with good quality water. As the roots lengthen and/or the water table rises, the plant begins to use the shallow ground water. Nearly 20% of California's 0.45 million ha of cotton is farmed on land that has a water table within 3.0 m of the surface (Munk and Wroble, 1995). Wallender et al. (1979) showed that 60% of the consumptive use of cotton can be supplied by perched water tables, despite high salinity levels (EC_{dw} = 6.0 dSm^{-1}). Ayars and Schoneman (1986) grew cotton for three years under a water table averaging 10 dSm^{-1} during that period; on average the water table supplied 16% of consumptive use. During one season, one of the experimental blocks was shown to have derived 37% of its consumptively used water from the perched table.

In the El Paso valley area of Texas along the Rio Grande River, good quality water is normally available during the early growing season, but in years of scarce flow, may not be available during the later part of the season. In those years, local shallow wells could supply saline water, but the fine texture of the valley soils may preclude this practice from being sustainable. Further downstream in the El Paso Valley, where return flows are reused by cotton producers, the late summer months see an increase in levels of salinity (Miyamoto, 1995). At least one water district has installed water reservoirs equipped with automatic gates and real-time water salinity sensors to allow for remote channeling of water based on quality parameters. In the Coyanosa area near Reeves County, Texas, irrigation pumping reverses the hydraulic gradient in the Cenozoic Pecos Alluvium aquifer, which causes an increase in salinity levels in those wells (TWDB, 1999).

Flynn (2003) used agronomic and economic models to determine the optimal cropping and water distribution patterns for crops grown in New Mexico where two local water sources, the Gila River (EC = 3.14 dS m^{-1}) and the Artesia aquifer (EC = 9.16 dS m^{-1}) could be conjunctively used. The poor quality of the Artesia aquifer had previously kept farmers from using it, but the models showed that using a 75:25 ratio of good:poor quality water would result in the economic optimum, and would increase total water resources by 33% and the amount of land in production by 17%.

The High Plains of Texas has experienced significant reductions in ground water levels. The 2.7-million ha service region of the High Plains Underground Water Conservation District No. 1 (HPUWCD#1) averaged a 0.66-m and a 0.58-m decline in the water table after the 1994 and 1995 seasons, respectively. The average annual decline for the previous five years was 0.37 m (High Plains Underground Water Conservation District No. 1, 1995). At the same time, specialists from Texas Cooperative Extension (TCE) reported an increase in the number of queries from local farmers regarding salinity concerns.

Most cotton-producing regions of Texas have suffered drought since the 1990s. The National Weather Service (1996), during the course of this study (May 1996), classified the Trans-Pecos area as -3.36, the High Plains as -3.61, and the Edwards Plateau as -2.96 on the Palmer Drought Stress Index (PDSI). The PDSI values between -2.0 to -3.0 are classified as "Moderate Drought", -3.0 to -4.0 as "Severe Drought", and -4.0 as "Extreme Drought." From 2000 to 2004, the PDSI during the cotton growing season ranged from “Incipient Dry Spell” to “Extreme Drought” for the Trans-Pecos area > 90% of the time (TWDB, 2004). Under such conditions, salinity levels in the irrigation water applied to cotton and other crops may increase. This is because farmers use saline ground water not generally used or, in the case of over-lying aquifers, the fresh waters aquifers are drawn down and higher percentages of the pumped water are derived from the more saline strata. The Trinity-Edwards (plateau) Aquifer, which supplies ground water to St. Lawrence, Texas (Glasscock, Upton, and Reagan Counties), undergoes a 40-m drawdown during the typical growing season (Henggeler and Harston, 1993).

In Texas, the recent upsurge of investment by farmers in new irrigation systems, notably in the High Plains and Edwards Plateau regions, may force farmers for financial reasons to continue to use saline water, if it is available, should their normal source of good water decline. Between 1993 and 1995, 2,532 new pivots were installed within the service area of the HPUWCD#1 (Pigg, 1995). Also, in the Texas High Plains, an estimated 100,000 ha of sub-surface drip (Boman, 2004) has been installed to irrigate cotton.

In 1985 and 1986, the Knott area of Texas in the Lower High Plains experienced saline seeps after heavy rains. Since this area is primarily dryland, germination and seedling establishment rely on moisture provided by rain. In parts of the area affected by the saline seeps, yields have increased to higher than normal levels, while other areas, where the water table is too close to the surface, stands cannot be maintained.

Conjunctive Water Use Under Deficit Conditions. The majority of research on the conjunctive use of poor and good quality waters to grow cotton has been conducted under well-watered conditions. However, much of Texas' irrigated cotton, especially in areas where saline water is used, is grown under deficit irrigation. The average gross irrigation amount applied for the Southern High Plains, Trans-Pecos and San Angelo areas is shown in table 1 (the average for all three regions is 423 mm). Rain, pan water evaporation and cotton lint yields are also shown. Annual pan water evaporation is twice as large as annual gross irrigation and rain combined. In contrast, a California study described 385 irrigation audits, nearly half of which were on micro-irrigation systems where the annual application depth was 700 mm (Pitts et al., 1996).

Texas cotton farmers would not have to "stretch their water" and deficit irrigate if they instead selected to reduce the planted area inversely proportional to the deficit amount of available water. However, experience has shown that it is economically better to be in a deficit position and farm more land area (Henggeler et al., 2002). The deficit nature of irrigated cotton production in Texas is illustrated by the fact that on a land-unit basis Texas has the smallest lint yield of almost all other states in the Cotton Belt—even though it produces more total bales of cotton than any other state,. This impact of conjunctive water use on cotton, grown under the compounding effect of deficit irrigation, merits investigation and is the subject of this dissertation.

Table 1. Gross average irrigation amounts applied to crops, annual rain, annual pan water evaporation, and average lint yields in 1989 for various regions in Texas (after TWDB, 1991).

	Southern High Plains	**Trans-Pecos Area**	**San Angelo Area**
Gross Irrigation Amount (mm)	362	1041	498
Annual Precipitation (mm)	452 (Lubbock)	323 (Pecos)	498 (San Angelo)
Pan Water Evaporation (mm)	1978 (Lubbock)	2712 (Ft. Stockton)	2465 (Sonora)
Cotton Lint Yields (kg ha^{-1})	517	725	663

MEASURING SOIL SALINITY

Plants are subject to changing concentrations of salt as soil water content changes throughout the growing season and responds accordingly, but measuring *in situ* salinity is normally not attempted in either field nor laboratory studies. A practical alternative used by salinity experts is to measure the salinity of the aqueous extract of the saturated paste extract

(Richards, 1954). This procedure, with its result termed as the EC of the saturated extract (EC_e), has become the standard procedure and term to quantify soil salinity. Values are reported as dSm^{-1}. The measurement procedure is to add water to air-dried soil until a saturated paste is achieved. A vacuum is applied and the filtrate is tested for salinity using an electrical bridge. It is important to note that salinity yield studies are generally reported using EC_e values.

There are inherent benefits of using the saturation paste extract method. One is that the portion of water that is mixed physically relates to the soil properties. Tests that incorporate a soil-to-water ratio (e.g., 1:2) to obtain a testable solution do not have this “natural” linkage between amount of soil volume and water volume used. One of the benefits in using the saturated paste extract is that—as a rule of thumb—a soil’s water content will have a 4:2:1 ratio between the saturated percentage, field capacity percentage, and permanent wilting point percentage, respectively. Electrical conductivity values for the solute at saturation, field capacity, and permanent wilting would share the inverse relationship. Even the osmotic potential, which for a fixed amount of salt is linearly associated with variations in water content (Richards, 1954), will have a similar ratio. Lastly, early researchers established that Sodium Adsorption Ratios (SAR) of the saturated extract were correlated to exchangeable sodium percentage values, because SAR values are much easier to obtain.

One of the problems with the saturated paste extract method was the requirement of a subjective amount of water mixed into the sample. Longenecker and Lyerly (1964) developed a procedure in which the oven-dried sample was partially submerged from the bottom and allowed to reach terminal saturation through capillary action, thus bypassing the need to manually mix the saturated paste. They referred to the apparatus as a *capillary saturation table*, and the extract as the capillary saturation extract ($EC_{cst\text{-}e}$). Results showed that EC_e and $EC_{cst\text{-}e}$ values were the same. Nowadays, extracts of soil/water ratios, such as 1:2 continue to be done in many laboratories. If values are reported in dSm^{-1}, confusion can exist among both lay and professional people, who equate results from these soil/water ratio tests as synonymous to saturated paste extracts (Ec_{e}.) values. For a 1:2 test, this type of error would drastically underestimate the salinity hazard.

LEAF WATER POTENTIAL

Grimes and Yamada (1982) showed that minimum LWP, which normally occurs around or shortly after solar noon, was related to main stem elongation during the vegetative growth stage of cotton, and it was constant across years and soil types (R^2 = -0.65). They determined that main stem elongation ceased around -2.4 to -2.5 MPa, and lint elongation ceased at -2.7 to -2.8 MPa. They also presented information of LWP as a function of days after irrigation and found that lint yields were reduced if LWP was < -1.9 MPa. Guinn and Mauney (1984) found that at a LWP of -1.9 MPa the boll retention rates began to decrease.

Howell et al. (1984) reported that LWP values were negatively correlated to crop water stress index (CWSI) values (R^2 = -0.66). Seasonal average LWP values were positively correlated to lint yield (each increase in MPa led to ≈ 180 kg ha^{-1} more lint). They summarized their own and other's results and indicated that the ideal cotton irrigation trigger point, the termination point for main stem growth, and the termination point for lint elongation occurs at CWSI values of 0.2 to 0.3, 0.7, and 1.0, respectively. Corresponding values of LWP were -1.7 to -1.8 MPa, -2.4 MPa, and -2.8 MPa, respectively. California recommendations for timing irrigations are a mid-day value of -1.6 MPa for the first one with subsequent irrigations at a -2.0 MPa threshold (Goldhammer, 1983). Steger et al. (1998) found that the first irrigation for Arizona conditions should occur when the mid-day LWP values are at –1.5 MPa.

The LWP can be measured with a pressure chamber (Scholander et al., 1965). Advantages of the measuring LWP are that the values integrate the plant, the atmosphere, the soil, and the water quality into one measurement that quantifies stress level. A disadvantage in using LWP values to interpret plant stress is that diurnal fluctuations of LWP occur. However, these fluctuations follow a pattern with pre-dawn LWP values being the largest and solar noon LWP values being the smallest of the day. Thus, either pre-dawn or solar noon LWP values are used to interpret plant stress. In areas that have afternoon cloud cover, pre-dawn values may be more appropriate since LWP responds readily to changes in solar irradiance (Namken et al., 1969 and Davis and Huck, 1978). For College Station, Texas, both Clark (1986) and Cudrak (1988) found that LWP values taken before dawn were better indicators of stress, and Clark (1986) attributed this to clouds influencing mid-afternoon LPW values. On the other hand, in arid areas without cloud cover interference, noon LWP may be more appropriate as these values are more likely to exhibit differences between treatments at an earlier stage (Howell et al., 1984 and Cudrak, 1988).

Diurnal Cycle of Leaf Water Potential

Leaf water potential in cotton is normally highest in the early morning pre-dawn hours, and under clear atmospheric conditions, it will decrease to its lowest values following solar noon. These low values are maintained for two or three hours, and then recovery (re-hydration) begins in the late afternoon. The rate of decline and recovery, as well as the pre-dawn maximum value and the solar noon minimum value, are affected by soil and atmospheric conditions. A diagram of the diurnal LWP values for water stressed and nonstressed cotton plants (after Grimes and Yamada, 1982) is given in figure 8. Longenecker (1971) had, likewise, but somewhat earlier, shown that water content (g H_2O / g green weight) in the leaves and petioles was a function of available soil water and followed a diurnal pattern.

Namken et al. (1969) measured both stem contraction and changes in LWP of cotton and found that they were related to increasing/decreasing solar energy irradiance. Davis and Huck (1978) used time-series spectral analysis to examine a previously collected database of radiation load and stem diameter measurements on well-watered and water-stressed cotton. They established a correlation and used Fourier series analysis to determine the accompanying time lag (1 to 20 minutes). Physical changes in stem diameter at any time are the sum of two rates, namely, the root water uptake and the rate of water leaving the stem. However, the level of water in the phloem acts as a capacitor on the lag/extent of stem diameter response to changes in solar irradiance. Stored water in the phloem, the authors argued, was a function of rooting area and density, and soil water potential. Cotton plants with smaller phloem reserves (i.e., stressed plants) reacted more quickly and more dramatically to changes in radiation.

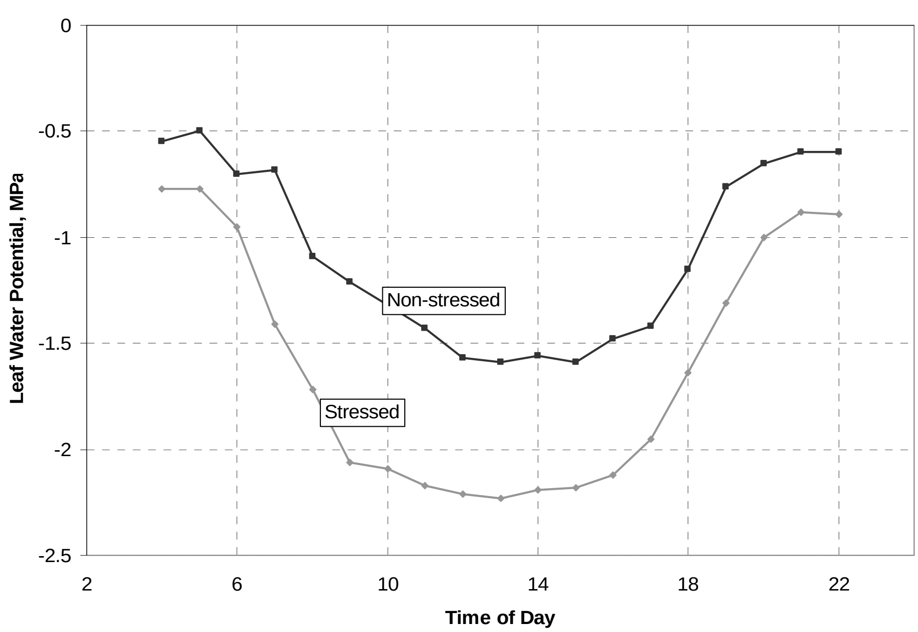

Figure 8. Diurnal leaf water potential values for stressed and non-stressed cotton (after Grimes and Yamada, 1982).

REGIONAL CONDITIONS OF THE STUDY AREA

Climate

Annual average rainfall in the Trans-Pecos region is about 240 mm and potential annual evaporation > 2,500 mm (Bedinger et al., 1989). Annual water evaporation from area Class A Pan exceeds rainfall tenfold (Bloodgood et al., 1954). The wettest month is September, and much of the rainfall occurs as afternoon thunderstorms (36 events per year on average), especially during a warm season (Jaco, 1980). Rainfall amount from these thunderstorms varies over short distances. The variation in annual average rainfall is high with a standard deviation of 100 mm (Tahal Consulting Engineers, Ltd, 1985). The number of days per year that a rainfall event ≥ 2.5 mm or more occurs is 22 (Jaco, 1980). The annual average air relative humidity at 6:00 am, noon, and 6:00 pm is 73, 42, and 36%, respectively. The mean daily maximum and minimum air temperatures are 29 °C and 9 °C, respectively (Natural Fibers Information Center, 1987). The growing season is ≈ 225 days and the frost-free period extends from 1 April to 12 November (Jaco, 1980). Wind speeds are fairly strong, especially from March to June, and can damage young crops (Natural Fibers Information Center, 1987). Hail can also occur, especially during mid-summer.

Soil

The Hoban silty clay loam, other than its surface crusting problems, is well suited for irrigation with saline water because it drains well. The NRCS suggested that if saline water was used on this soil, a leaching program should be in place and that a crop residue should be kept on the soil surface to keep salt from moving up by capillary action to the surface (Jaco, 1980). Velasco-Molina et al. (1971), as reported in Moore (1973), studied soil dispersion as a function of irrigation water SAR and salinity level. They compared Hoban silty clay loam to Nacodoches fine sand loam and Houston black clay, and found that the micaeous Hoban soil remained fairly stable compared to the other soils that contained halloysitic-kaolinitic and montmorillonitic clay minerals. Longenecker and Lyerly (1959), in a study of irrigated West Texas soils, showed that while the total salt content, gypsum and ESP had increased during 15 to 20 years of irrigation, the soil permeability and drainage had not been impaired. H.B. Jaco, the principal author of the NRCS's Reeves County Soil Survey, felt Hoban silty clay loams were capable of satisfactory yield levels when saline irrigation water was used, and, as such, should be exempt from NRCS policy of not working with growers using highly saline water (Moore, 1973). Ogilbee and Wesselman (1962) likewise reported that "although the water (of Reeves County) is of questionable standards, the water has been used with apparent success to the present time." Jaco found that EC_e on some soil tests from local farms would often be lower than the irrigation water's conductivity (EC_{IW}). Moore (1973) had a similar experience, and concluded that equilibrium between these soils and the irrigation water had not been reached. Longenecker and Lyerly (1959) indicated that the presence of gypsum and lime carbonates, which were serving as buffering agents, was precipitating out material and thus leading to $EC_e < EC_{IW}$.

While high levels of salinity in the irrigation water are not advantageous, area farmers have used saline water resources uninterrupted for many years. A local farmer from Imperial started farming shortly after returning from World War I (Johns, personal communication) and, seventy years later, despite the $EC_{IW} \approx 9$ dSm^{-1}, the land continues to be farmed.

Local Water Resources

The water resources for Reeves and Pecos Counties are described by Armstrong and McMillion, (1961), Ogilbee and Wesselman, (1962), Small and Ozuna, (1993), and Ashworthy, (1990), and Texas Water Development Board (1999).

Ground Water. Reeves County had 926 active irrigation wells in 1959, and at that time the water level had declined 60 m in the central part of the county. As irrigated land began to decrease in the 1970s, water levels began to rise, making it one of the few exceptions to an overall state decline in water tables. The estimated safe aquifer yield before water tables drop in Reeves County is about 10^9 m^3 per year (Tahal Consulting Engineers, Ltd, 1985). The Cenozoic alluvium that underlies 80% of the county is characterized by water of < 1,000 mg l^{-1} dissolved solids in the eastern and southern parts of the county, water with 2,000 to 4,000 mg/l in the central part of the county, and waters > 5,000 mg l^{-1} in the northwest. The shallow ground water associated with the Pecos River has a water quality > 10,000 mg l^{-1}.

The first irrigation wells in Reeves County were believed to have started circa 1890 when artesian wells watered gardens and small farms. At the beginning of World War II, there were only 40 irrigation wells in the county. During these early days, large amounts of ground water recharged the Pecos River, as it transverses NW to SE along the border of Reeves County.

Its flow increased 1.4 m^3s^{-1}, even during times of little or no rain. Most of this gain occurred on the Reeves County side of the river (Armstrong and McMillion, 1961).

Surface Water. The Pecos River was first used for irrigation in the Reeves/Pecos County area circa 1870. By the turn of the 20th Century, 2,500 ha were in cultivation. An umbrella water management district, the Red Bluff Water Power Control District, was formed early in the 20th Century to coordinate activities of seven constituent water districts, including constructing and managing the Red Bluff Reservoir. The largest amount of land farmed with the Pecos River water was 16,500 ha during the early 1940s. Due to decreases in river flow and the ensuing rises in salinity, irrigated cultivated land dropped to only 2000 ha in the 1980s. Annual flow quantity decreased from an average of 3.25×10^8 m^3 in the years 1938 to 1949 to 0.92×10^8 m^3 in the years from 1950 to 1987 (US Department of Interior, 1991). This decrease was associated with increased pumpage along the Pecos River in New Mexico. The ensuing salinity levels resulting from the decreased river flow in the Pecos River are shown in table 2. Note that wide differences in salinity levels up- and down-stream of Reeves County indicate that additional salt loads entered the river.

Table 2. Salinity levels (sample size, mean, maximum, minimum, and period of record) upstream and downstream of the farmland of Red Bluff Irrigation District (after US Bureau of Reclamation, 1991).

Parameters	Upstream	Downstream
No. of samples	254	164
Mean (mg/l)	8 486	13 626
Maximum (mg/l)	19 700	42 300
Minimum (mg/l)	1 190	639
Period of record	Nov. 1963 to April 1983	Oct. 1967 to Aug. 1982

Local Farming Practices

Area farmers, especially in Reeves County, have traditionally used high-input production practices. For cotton producers, this has been financially unsuccessful as attested by the decrease in cotton grown in the area. Area specialists from TCE attempted to find a more profitable middle-ground approach and introduced the ECONOCOT Program in the 1970s (Condra et al., 1978). This effort was not successful either, and irrigated area continued to decline. In Reeves County alone, cotton production area declined from 65,500 ha in 1967 to an average of 3,000 ha in 1994-1996. Furthermore, the cotton area planted since then has decreased and was only 2,600 and 2,300 ha in 2000 and 2001, respectively (US Deptartment of Agricture/NASS, 2004). Although the region has an excellent growing season, good soils, and has recorded some of the highest county-average lint yields in the state, the high cost of irrigation and insect control was forcing farmers out of production.

Fortunately, new transgenic cotton varieties have helped reduce the cost of weed and insect control and may make cotton farming more profitable today. Also, other cultural practices to mitigate salinity yield loss are being tested in Texas and other arid locales, such as ultra-narrow row cotton (Unruh and Murphy, 2001), subsurface drip irrigation (Enciso-Medina and Multer, 2002) and site-specific management (Horney et al., 2001). However, the challenge still exists. The Texas Water Development Board (1999) has projected area water demands by the year 2030 to exceed the average annual effective recharge of the Cenozoic Pecos Alluvium aquifer (8.4×10^7 m^3 [67,800 acre-feet]), resulting in less water for irrigation and higher salinity levels for the Trans-Pecos area.

SUMMARY OF LITERATURE REVIEW

Texas produces more cotton than any other state in the United States but unfortunately also experiences one of the lowest per-hectare yield rates for Cotton Belt states. This shortfall in yield is attributed to insufficient water sources. There are several saline water resources in the state that are currently not being used.

Cotton lint yield is influenced by the total amount of water that is available for transpiration. Peak yields are realized when total available water ≈ 0.75 of ET_o. Growing cotton under conditions where the quantity of total water is less than this induces yield loss. Many studies have shown that the yield response factor for cotton is ≈ 0.85. There is close agreement among authors on yield decline as a function of deficit water conditions.

There is less agreement among authors in predicting cotton lint yield loss due to salinity stress. The most widely accepted estimate for yield decline in cotton due to salinity is when EC_e

values > 7.7 dSm^{-1}, which causes a relative yield reduction rate of 5.2 % for each additional dSm^{-1} above 7.7. However, some salinity studies have shown yield reductions to occur before this level, while others have shown just the opposite. The difference in results is often explained by the fact that leaching factors and drainage conditions may have differed between the studies involved.

One method to mitigate salinity yield loss is through conjunctively using a less saline source of water with a more saline source. When two types of water are conjunctively used, the better quality one is normally applied first. Plants, including cotton, are more susceptible to salinity damage during early stages of growth.

CHAPTER III
MATERIALS AND METHODS

A field experiment was carried out for three growing seasons (1994-1996) to study the synergistic effects of salinity and deficit irrigation on cotton production. Lint yield levels and changes in soil salinity were monitored throughout the three-year period to ascertain if such production systems are viable, both in terms of maintaining production and avoiding salinization (Objectives 1 and 2). The experiment was conducted near Pecos in Reeves County, Texas, at latitude 31° 25" (North) and longitude 103° 30" (West). Reeves County is in the Pecos Valley area of West Texas located on the northern reaches of the Chihuahuan Desert.

This experiment was carried out on a Hoban silty clay loam, which had been out of production ≈ 20 years prior to the initiation of the test. Hoban silty clay loam comprises 3.4% of the soil in Reeves County (Jaco, 1980). The soil is classified as a fine-silty, mixed, thermic Ustollic Calciorthid. Organic matter in the upper 0.45 m ranges from 1.0 to 1.8% (Moore, 1973). The soil is well drained and permeability is moderate. The rooting zone can be expected to be deep and roots from plants can easily penetrate the soil profile. Irrigation tends to cause soil surface crusting (Jaco, 1980). The Natural Resource Conservation Service (NRCS) reported that the major concerns of management with this particular soil were salinization and tilth, and that a leaching program is required if salinity of the irrigation water is high. As an irrigated soil, the Hoban silty clay loam is given a Capability Class I (having only slight limitations that restrict use). Cotton lint yield levels for this soil when irrigated and managed with high levels of expertise were estimated to be 1,400 kg ha^{-1} (2½ bales ac^{-1}), which was the highest yielding level by soil category for the county. The topsoil layer (0-117 cm) was reported to have a permeability of 1.5 to 5.0 cm h^{-1} and available water holding content of 14.0 to 20.0%. The bottom soil layer (117-183 cm) had values of 1.5 to 15.0 cm h^{-1} and of 6.0 to 14.0%, respectively, for the same parameters (Jaco, 1980).

Measurement of the soil water content release curve made on a Hoban silty clay loam is shown in figure 9. Measurements include data from Moore (1973), where soil volumetric water content and water potential were measured *in situ* with a neutron probe and tensiometers, respectively, at six depths from 25 cm to 130 cm. Figure 9 also includes data from Zimmer (1987) with measurements made on disturbed soil samples using Tempe cells. Data from tests on intact soil cores used with the *GOSSYM-COMAX* computer program (US Deptartment of Agricture/Extension Service, 1990) are also shown in figure 9. The soil used by Moore (1973) was located on the southern boundary of the Hoban silty clay loam range and the other two soils from the Pecos Texas A&M University Research Station. It lies on the northern reaches of the Hoban silty clay loam range. The distance between the northern and the southern edges of the Hoban range is ≈ 10 km.

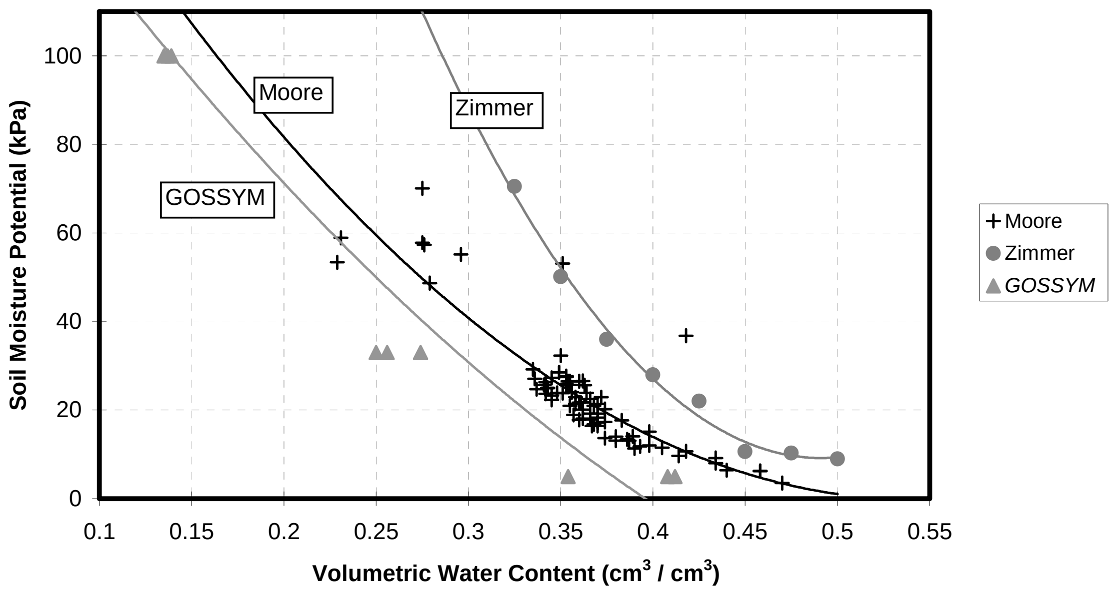

Figure 9. Soil water potential as a function of volumetric water content for Hoban silty clay loam soil from three authors (dash symbols are after Moore [1973], closed-faced circles are after Zimmer [1987], and closed-face triangles are data from the *GOSSYM-COMAX* computer program [USDA, 1990]).

EXPERIMENTAL DESIGN

The experiment was carried out on the facilities of the Texas Agricultural Experiment Station at Pecos, Texas. The test area dimensions, including guard rows, were 85 by 90 m, shown in figure 10. Within the interior of this block, 12 separate Experimental Units (EU) were laid out. The research involved four water quality treatments (EC_{IW}), each replicated three times. The same treatment was applied to the same EU each of the three years. Rows were laid out north-south with precision each year using permanent reference points (irrigation riser pipes) to assist in locating starting positions for row bedding. Thus, the plant beds and water furrows

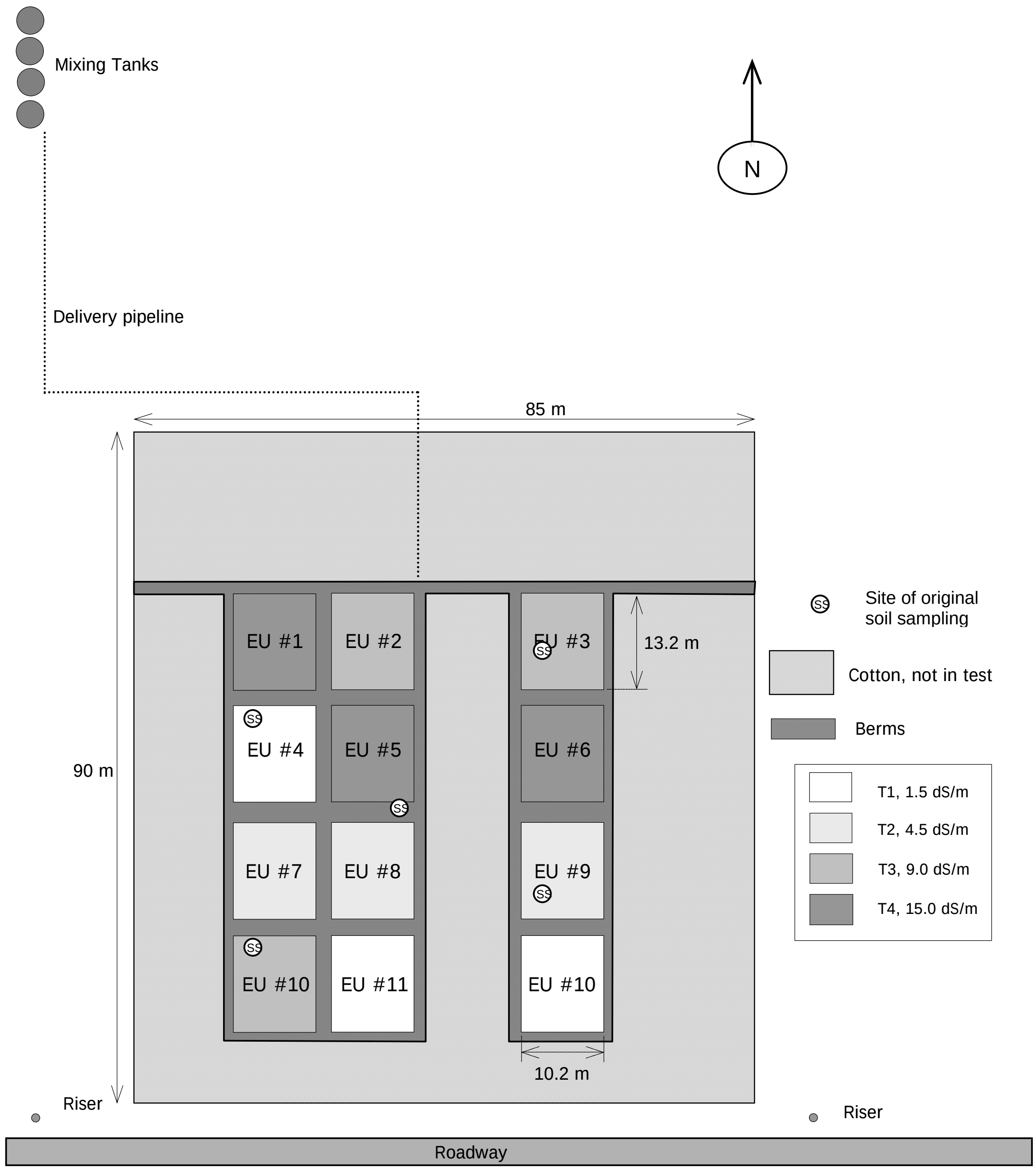

Figure 10. Diagram of experimental area showing Experimental Units (EU), tanks for mixing salts, and locations of original soil samples.

where established in the same locations each year. Each EU consisted of 10 rows of cotton (row width = 1.0 m); length was 13.2 m. A large berm with a base of about 2.0 m was constructed around each EU to preclude the occurrence of any run-off/run-on.

The same variety of cotton (Gossypium hirsutum L. cv. *Acalla 90*) was used each year of the study. After the cotton had germinated at the start of Year 1, a strip in the field going north-south was excluded from use for experimental blocks, because the cotton stand was weaker in that area. The locations of the blocks were then randomly chosen and the EUs were laid out. Guard rows were on all sides of the EUs. Treatments were randomly assigned to the EUs. Table 3 shows which EUs were assigned to the various treatments.

Table 3. Summary of the Experimental Units that comprised each treatment.

Treatment Number	Experimental Units in the Treatment
1	4, 11, 12
2	7, 8, 9
3	2, 3, 10
4	1, 5, 6

The test area was planted with a mechanized planter. The research station manager indicated that, unless a pre-plant irrigation was applied, the soils of the region remain too dry to initiate germination. He considered the date irrigation is first applied as the first date of the growing season (Murphy, personal communication, 1994). Although the field had been planted 2 or 3 d earlier into dry soil, irrigation which began germination occurred 4 May, 2 May, and 14 May for Years 1 to 3, respectively. These dates, for the sake of clarity in the study, were also considered the dates of planting. The final stand populations were 25, 15, and 17 plants per $m^2$for Years 1 to 3, respectively. Bed width was 0.9 m, and bed height above the bottom of the furrow was 14 cm. A foliar fertilizer application of 11 kg ha^{-1} of N in Year 1 and ≈ 40 kg ha^{-1} N was applied in two split applications in Year 3. All plots were hand harvested and ginned as described below.

Soil samples were taken prior to planting the first year to a depth of 1.5 m at five locations in the test area. The cores were separated into 15-cm segments and a portion of the sample was used to make a composite sample of the 5 locations. The composite samples were analyzed by the Soil Characterization Laboratory of Texas A&M University, and results are shown in table 4. The five sampling locations are shown in figure 10. The portion of the 50 samples (5 locations and 10 depths) that was retained was measured for EC using a 1:2 soil-to-water solution to determine field variability.

Table 4. Soil analysis prior to start of test showing Ca, Mg, Na, K ions (in both soluble and extractable form) and pH, Cation Exchange Capacity, and Sodium Absorption Ratio at 15-cm increments to a depth of 1.5 m.

Depth	Soluble Ions				Extractable Ions				pH	CEC	SAR
	Ca	Mg	Na	K	Ca	Mg	Na	K			
cm	mg l^{-1}									g kg^{-1}	
0-15	16	3.4	21.3	1.2	42.0	3.3	3.3	1.9	7.7	19.9	7
15-30	2.4	0.6	22.2	0.3	44.0	3.5	5.5	1.2	8.4	20.9	18
30-45	2.9	0.7	37	0.3	45.1	3.0	7.6	1.2	8.5	18.4	28
45-60	1.9	0.6	33.5	0.2	45.9	2.9	7.5	1.0	8.6	18.9	30
60-75	4.2	1.2	44.3	0.3	42.4	3.0	7.7	0.9	8.4	18.0	27
75-90	23	4.9	65.2	0.4	54.6	3.1	7.7	0.8	7.9	18.9	18
90-105	22	4.1	57.4	0.3	168.0	3.0	6.9	0.6	7.9	18.3	16
105-120	22	3.9	52.2	0.3	198.0	2.6	6.1	0.6	7.9	16.9	15
120-135	23	3.6	47.4	0.3	220.0	2.3	5.3	0.5	7.9	15.3	13
135-150	22.5	3.1	45.7	0.3	217.0	2.3	5.9	0.5	7.9	16.2	13

APPLICATION OF TREATMENTS

Salinity Treatments

The treatments involved four irrigation water qualities (EC_{IW}). The EC value for the treatments are shown in table 5. The T1 water was potable water from a local utility water company (Madera Valley) that provided drinking water for the community and the T2 water was from an on-station irrigation well, known as Well #5. Both sources were pressurized. Samples of the T1 and T2 water were taken in the winter of 1994 and sent to the Soil, Water and Forage Testing Laboratory of Texas Cooperative Extension in College Station, Texas for analysis. The corresponding water analyses and information on the tests are shown in Appendix A. The T3 and T4 waters were formulated using the T2 water as the base, to which amounts of NaCl, Ca_2Cl, and Mg_2Cl were added. The SAR value of T1 and T2 were ≈ 5. The T3 and T4 waters were constituently mixed with proportions of the three added salts to maintain a SAR value of 5. The Ca to Mg ratio was kept to ≈ 2, reflecting similar levels found in the T1 and T2 waters. Although T1 and T2 had high levels of sulfate salts, there was no effort to add sulfates to T3 and T4 water, because precipitation of gypsum might occur (Hallmark, 1994). The procedure used to calculate the quantities of NaCl, Ca_2Cl, and Mg_2Cl to formulate T3 and T4 waters is detailed in Appendix B.

Table 5. Summary of treatments used.

Treatment Number	Treatment Name	Electrical Conductivity of Irrigation Water (EC_{IW}) (dSm^{-1})
1	T1	1.5
2	T2	4.5
3	T3	9.0
4	T4	15.0

An irrigation to facilitate germination, using T2 water and hand-move sprinklers, was applied after planting. The first in-season irrigation was likewise supplied with T2 water. Application of treatment water began thereafter. The T2 was the only treatment that had similar water qualities for both early- and late-season irrigation. All of the other treatments were conjunctive in nature, using water of 4.5 dSm^{-1} (T2) early in the season, followed thereafter by use of waters having a salinity of 1.5 dSm^{-1}, 9.0 dSm^{-1}, and 15.0 dSm^{-1} for T1, T3, and T4, respectively. The average irrigation water salinity (EC_{IW-net}) applied to each treatment was calculated by weighted average of both the quantity and EC level of each source used.

The T3 and T4 treatments were mixed and dissolved in concentrate form and then poured into 1,500-gallon polyethylene tanks of T2 water. There were 4 tanks in total and they were slightly elevated with respect to the plots. The tanks were semi-transparent and had a scale on the side for measuring content, with 1 cm of height representing 37 L.

Water Applications

As previously described, the germinating-irrigation and the first in-season irrigation were applied with T2 water using sprinklers. The remaining irrigations, using the various treatment waters, were applied by flood irrigation. A 2-inch, PVC-manifold was constructed for each EU. The outlets to the ports serving the 9 water furrows in each EU were reduced to ¾-inch. The downstream ends of water furrows were left open to allow faster streams to flow back into furrows not yet out to increase the evenness of water distribution.

Figure 11 is a diagram of an EU. Special controlling outlet devices were made of ¾-inch polyvinylchloride (PVC) pipe with two sets of 45°elbows. This device could be rotated in an arc fashion to decrease/increase outlet head, thus affecting flow and allowing equivalent flow rates for all water furrows. Figure 12 is a photograph depicting the manifold and the water-control outlets.

In Year 1, the treatment water for all applications was first measured out into the large holding tanks, and then allowed to flow by gravity into each EU using networks of PVC and polyethylene pipe. Since this was time consuming and interfered with timing, a ½-inch centrifugal pump was installed in Year 2 to expedite watering the blocks. This pump was connected to the holding tanks and was used to pump T3 and T4 water to the plots. Two-inch disc water meters were installed in line for the T2, T3, and T4 plots. Applied water was measured into each replicate and recorded. The corresponding manifold for that replicate was then closed and another manifold for another replicate was opened, watered and recorded. The third replicate was watered in a similar fashion. The T1 treatment had separate 1¼-inch meters on each replicate, because these blocks might have to be watered at night to avoid dropping in-line pressure on the station headquarters' water supply.

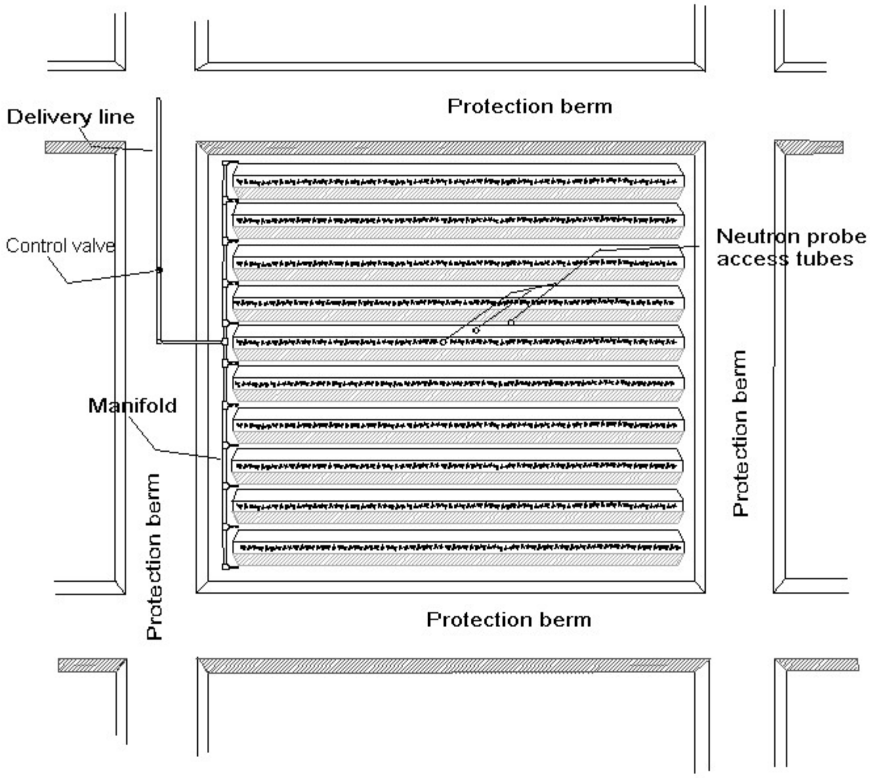

Figure 11. Plan view of EUs, showing beds, water furrows, berms and irrigation manifold.

Figure 12. Photograph of an Experimental Unit being watered with a 38-mm (1½-inch) PVC manifold with 19-mm (¾-inch) rotating arms. Outlet arms could be rotated in arc fashion to increase or decrease flow.

DATA MONITORING

A completely randomized design was used in laying out the treatments and Duncan's multiple range test was used to compare the following measured plant parameters: plant height, number of nodes, internodal length, number of green bolls, total fruit number, fruit abscission, leaf area per plant, mass of plant (leaf, stem, fruit, and total above ground), leaf water potential, (Objective 3); and, seed cotton, lint turn out, lint, and relative yield (Objective 2). During the study, data was also collected on daily weather, soil salinity (prior to commencement of study and each year after harvest - Objective 1) and volumetric soil water content.

Soil and Volumetric Soil Water Content

Composite soil samples at 15-cm increments down to 1.5 m were collected from five augured holes and analyzed by the Soil Characterization Laboratory of Texas A&M University for texture, saturated volumetric water content, and soluble and extractable ions. Soil textural analysis classified the soil profiles primarily as silty clay loams and silty loams. Textural analysis results were used to estimate permanent wilting point, field capacity, saturation content, and total available water with a tool developed by Juma (1999) using soil properties developed by Saxton et al. (1986).

In-season soil volumetric water content, θ_v ($m^3\ m^{-3}$), was measured with a CPN (Model 503DR, Campbell Pacific Nuclear, Martinez, CA) Hydroprobe neutron probe. Each EU had 3 neutron probe access tubes for a total of 36 access sites. The tubes were located in the plant drill, in the middle of the water furrow, and in a position half way between the former two, as shown previously in figure 11. Holes were bored out using a power auger. The average distance between access tubes within the EU was about 0.4 m. Tubes were inserted to a depth of 1.0 m, with several placed down to 1.5 m to monitor any deep drainage or water extraction activity that might occur. Soil volumetric water content readings were taken, starting at the 30-cm depth, down to tube depth in 15-cm depth increments. After each tube had been read, the neutron probe was placed on the access tube and a standard count was made. The average value of these standard counts (about 20 most days) was used in the θ_v calculations for that day. The calibration curve used was developed by Doak (1988), which was developed on the Pecos Station with the same neutron probe meter used in this study. The calibration equation for the neutron probe readings was:

$$\theta_v = 0.2408 \text{ Count Ratio} - 0.0784 \quad (4)$$

where

θ_v = volumetric water content ($m^3\ m^{-3}$)
Count Ratio = neutron probe reading of soil /avg. Standard Count of that day

The neutron probe was not used to measure θ_v at the 15-cm level due to inherent problems with neutron scattering technique near the soil surface. A statistical model, however, was developed in Year 3 to calculate θ_v of the 15-cm depth as a function of θ_v in the 30-cm depth and days since irrigation/rainfall. Near-surface θ_v, as well as the θ_v of the 30-cm depth, was gathered continuously with a capacitance probe (EnviroSCAN, Sentek Pty Ltd, Australia) in EU#8, a T2 block as part of a separate study. A relationship ($R^2 = 0.92$) between the two θ_v values as a function of days since rainfall/irrigation was established. Following a wetting event, the value of θ_v of the 15 cm was ≈ 0.7 to 0.8 of that of the 30-cm depth and decreased in a nonlinear fashion to 0.5 about 10 d afterwards.

Climatological Data

Climatological weather data was collected from a weather station (Station #2) maintained by the staff at the Pecos Research Station that was ≈ 400 m from the research plots. The instruments included on the weather station were a LI-200SA pyronometer (LI-COR, Inc., Lincoln, NE), a LI-190SA quantum sensor (LI-COR, Inc., Lincoln, NE), a combination air temperature and relative humidity sensor (Model 207), a model 014A Met One anemometer (Met One, Inc., Grants Pass, OR), and a Model TE525 tipping bucket rain gage (Texas Electronics, Inc., Dallas, TX). The instruments were connected to a CR-10 data logger (Campbell Scientific, Inc., Logan, UT) and read at 10 s intervals. Hourly means and daily means, highs, and lows were stored in memory and retrieved via telemetry to a dedicated computer at the Pecos Station headquarters. The sensor air temperature/relative humidity sensor was changed every winter. Data collected from another weather station located nearby were compared to those from Station #2 to see if deviations may be occurring; any inaccurate instrument was replaced. The research plots were located approximately half way between the two weather stations. Additionally, a Class A Water Evaporation Pan was located near Station #2. Weather data from Station #2, the research station's primary weather station, was used in this study.

Weather data (maximum and minimum daily air relative humidity, maximum and minimum daily air temperature, wind run, and solar irradiance) were used to calculate grass-reference evapotranspiration (ET_0) using the Penman-Monteith Equation as calibrated by the computer program *REF-ET* Ver. 2.1 (Allen, 1991) during the growing season. Climatological data from the 3 years is found in Appendix C.

The weather data were also used to calibrate the basal crop coefficient values (K_{cb}) used in estimating ET_o by the FAO-56 method (Allen et al., 1998). This procedure divides the growing season into four periods: *Initial* (prior to planting to 10% of canopy coverage), *crop development* (from 10 to 70-80% coverage, corresponding to a Leaf Area Index of 3.0), *mid-season* (70-80% cover until start of maturity when leaves begin to show aging), and *late season* (maturity to full senescence or crop harvest). The length of the four periods for the cotton crop in this study was based on Allen et al. (1998) and Hunsaker (1999).

Although the FAO-56 procedure establishes four periods, only three crop coefficient values (initial [K_{cb_ini}], mid-season [K_{cb_mid}], and end [K_{cb_end}]) are needed to construct the crop coefficient curve (Fig. 13). The original FAO-56 crop coefficient values were developed for conditions with an average daily minimum air relative humidity value of 45% and an average daily 2-m wind velocity of 2 m s^{-1}. If the region's average minimum air relative humidity was < 45%, the crop coefficients would under-predict water use. Likewise, it would also under-predict water use if the average wind velocity was > 2 m s^{-1}. For Pecos, Texas, the average minimum air relative humidity was 21 and 27% during mid-season and late-season, respectively, and for the same periods the average wind velocity was 3.2 and 2.8 m s^{-1}. Using these average minimum air relative humidity and wind speed values, the value of K_{cb_mid}, was increased to 1.23 (from 1.13) and K_{cb_end} was increased to 0.52 (from 0.45). The K_{cb_ini} value did not change and remained at 0.15.

These coefficient values were fit using a fifth-order polynomial to percentage of seasonal heat units (HUs) (fig. 13). Percentage of season was used as the independent variable in the equation, because the time spans for each growing period correlated better to seasonal percentages than to actual number of days from data analyzed from various locations in the world (Henggeler, 2004). This relationship is seen in equation 5:

$$K_{cb} = 0.1297x^5 + 11.947\,x^4 - 29.332\,x^3 + 19.372\,x^2 - 1.7486x + 0.1579 \qquad (5)$$

where

x = percentage of seasonal Heat Units (%)

Heat Units were calculated as ([daily maximum air temperature °C + daily minimum air temperature °C])/2 - 15.6 °C with no maximum or minimum limit. Daily HU values were accumulated through the season. The average seasonal Σ HU was 1844. Percentage of HU for any date was the accumulated HUs to that date divided by 1844.

An estimate of actual water use was made using ET_o, crop coefficient (K_{cb}), soil water evaporation coefficient (K_e), and the soil depletion coefficient (K_s) using equation 6. A "check-book" irrigation scheduling program, ***MO-Scheduler*** (Henggeler, 2004), was used to calculate the water balance.

$$ET_{c\_adj} = (K_s \; K_{cb} + K_e) \; ET_o \qquad (6)$$

where

ET_{c_adj} = actual water use of the crop incorporating soil water stress (mm)
K_s = soil water depletion factor
K_e = soil water evaporation coefficient

Plant Growth Parameters

Plant Mapping. Plant maps consisting of plant height and fruit set by position were made on six plants on each EU at various times throughout the growing season. Data was entered into *PMAP* Ver. 3.0 (Landivar, 1992) to summarize various parameters by EU and by treatment.

Leaf Area per Plant. The leaf area per plant was measured on the same six plants harvested for the plant mapping by removing all leaves and measuring their combined surface area using a Li- Cor 3100 (LI-COR, Inc., Lincoln, NE) leaf area meter. The leaf area index (LAI) was calculated by multiplying the average leaf surface area per plant (m^2 $plant^{-1}$) times the plant density (plants m^{-2}).

Leaf Water Potential. Leaf water potential was measured with a Model 600 pressure chamber (PMS Instrument Company, Corvallis, OR). The procedure used was to excise the third fully extended leaf from the top with petiole attached. The leaf was immediately inserted into the pressure bomb chamber, and pressure was introduced until the petiole exuded water. The pressure was recorded. If the time between removing the leaf and the pressure measurement was > 20 s, it was discarded and a new leaf was tested. Two separate LWP measurements were performed on leaves from different plants. If the results were within 10 to 20% of each other, then no other measurement was taken, and the mean of the two was accepted. If there were greater differences, then a third measurement was performed, and all three values were averaged. Normally, measurements were performed on all three replicates of each treatment. However, during times when it was desired to get rapid readings of LWP as diurnal changes occurred, only a single replicate from each of the 4 treatments was measured Figure 14 shows a technician, Michael Martinez, preparing to take leaf water potential readings.

Plant Partitioning. Harvested plants that were used to measure leaf area were partitioned into leaves, stem, and fruit, oven dried, and then weighed. Weight per plant in leaf mass, stem mass, and fruit mass was reported. This data was collected for Year 1 and Year 2.

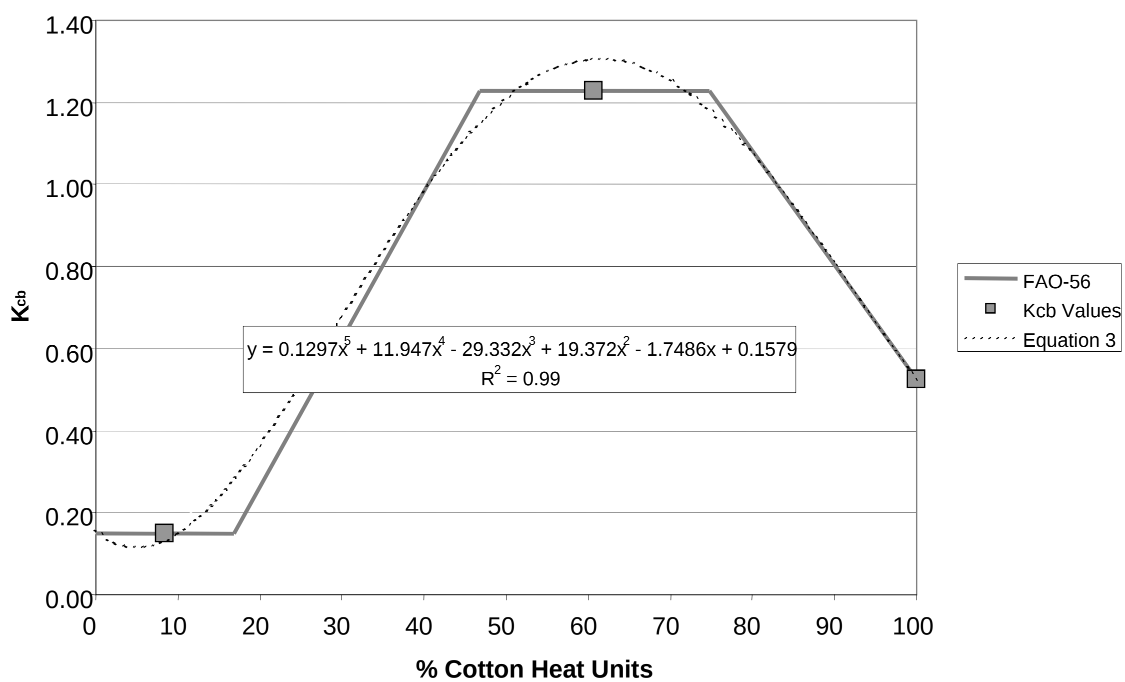

Figure 13. Basal cotton crop coefficient with adjustments based on average minimum air relative humidity and average daily wind speed for Pecos, Texas, using percentage of seasonal cotton Heat Units (after Allen et al., 1998).

Figure 14. A technician taking leaf water potential measurements on the site of the test at the Texas A&M University Research Station in Pecos, Texas.

Lint Yields

A measured amount of row distance was hand-harvested in each EU. Care was taken to not harvest areas that may have experienced other influencing factors, such as the two outside rows. Lint samples were ginned at the Texas A&M Research & Extension Center gin in Lubbock, Texas, on the reduced-scale roller gin. Lint and seed mass were measured.

Statistical analysis was made on lint yield as part of Objective 2 to determine if yield was affected by irrigation salinity levels when using deficit irrigation. Furthermore, lint yields were compared to estimated potential yields based on seasonal HUs and county average yields to determine if any decrease in relative yield (RY) occurred over time.

Changes in Soil Salinity

Soil samples were taken to determine salinity profiles (a) prior to the initiation of the tests, (b) intermittently during the three years of the test, and (c) after concluding the test (table 6). Soil profiles were taken from the plant drill and from the center of the irrigation furrow, except for the original soil sampling, which was done prior to beds being laid out. Sampling was done with both hand and powered augers.

Procedures for determining soil salinity values varied due to cost and sample size. If the sample volume was of insufficient size (<300 cm^3), then a filtered soil paste procedure of 2:1 parts was used and is thereafter referred to as $EC_{2:1}$. This is the standard procedure used by the TCE Soil and Water Testing Soil Laboratory. Soil samples of sufficient size were measured using the capillary saturation table procedure described by Longenecker and Lyerly (1964), and referred to in this document as EC_{cap-e}. A select number of soil samples were sent to the Texas A&M Soil Salinity Characterization Laboratory to have salinity measured on a saturated extract basis (EC_e). Sub-samples from these were correlated to EC_{cap-e}, and results were used to develop a relationship of (a) EC_{cap-e} to EC_e, and (b) $EC_{2:1}$ to EC_e. When a saturation extract value was estimated, rather than measured, the term EC_e**'** was used to denote this. The extracts from the EC_{cap-e} samples were measured with a Beckman solute bridge (Beckman Instruments, Fullerton, CA). Extracts from the $EC_{2:1}$ samples, which were more numerous and of smaller size, were measured primarily with a solute bridge from the local NRCS office. A calibration curve was developed for the NRCS meter using solutions of known conductivity, and readings were adjusted. The Beckman bridges were accurate as shown by measurements on samples of known conductivity and did not need calibration. The processed $EC_{2:1}$ samples yielded 19.2 ml of solute. If the solute sample was not immediately measured, it was placed in a beaker and covered with filter paper. Prior to measuring EC, the beaker was reweighed to see if any liquid had evaporated, and, if so, EC measurement was adjusted.

Table 6. Soil sampling time period, procedures (position on bed, depth sampled to, method of extraction, and sample size), and notes for the study period, 1994-1997.

Time	Location [a]	Depth Sampled (m)	Sampling Tool	Sample Size (cm^3)	General Notes
Apr 1994	[b]	1.50	Power Auger	1000	Establish baseline data
Dec 1994	D, F	0.90	Power coring machine	300	Establish salinity after 1st season
Aug 1995	D, F	1.00	Hand auger	500	Establish salinity after 2nd season
May 1996	D, F	1.50	Hand auger	300	Establish salinity after 2nd season, and following pre-irrigation leaching
Oct 1996	D, F	1.00	Hand auger	500	Establish salinity after 3rd season
Dec 1996	[c]	1.00	Back-hoe	500	Construct detailed salinity grid
Jan 1997	D, F	1.50	Power auger	800	Establish salinity after 3rd season, and following pre-irrigation leaching

[a] D = plant drill; F = middle of water furrow.
[b] Test area still in undisturbed condition with blocks and furrows not yet laid out.
[c] Complete grid on 20-cm centers, 1 m deep and 1 m wide.

QUANTIFYING RELATIVE YIELDS

Objective 2 of this three-year experiment was to "evaluate cotton lint yield to determine if decline was occurring." There are two challenges to accomplishing this task. First, normal year-to-year differences in weather, insect pressure, etc., may make this determination difficult when the period of record is only three growing seasons. Secondly, two separate variables, salt- and drought-stress, are involved, making it difficult to isolate cause between the two variables.

The concept of relative yields assists in both regards. Both the Maas-Hoffman equation (which quantifies effects due to salinity) and the yield response factor (which quantifies effects of drought) already use relative yield (Y_a/Y_m), rather than actual yield (Y_a). In this study, cotton lint yield was normalized as a relative yield value to help separate the impact of drought from that of salinity.

Relative Lint Yield, Salinity Not Affecting

Treatment yields were normalized by dividing them by potential yield (Y_m) for that year. Y_m was determined by a procedure (Henggeler, 1987) that uses the seasonal sum of daily maximum temperatures to estimate Y_m when water is not limiting. The relative yield equation is:

$$RY = \frac{Y_a}{Y_m} \tag{7}$$

where,

RY	=	relative cotton lint yield
Y_a	=	actual cotton lint yield = mean yield of treatment replicates (kg ha^{-1})
Y_m	=	estimated max. potential yield based on weather conditions (kg ha^{-1})

Because the T1 treatments had an EC_{IW} level that should not cause salinity-related yield loss, it can be assumed that all yield loss was then a function of water stress alone. Thus, the effect of drought alone, with no salinity interaction, can be estimated as:

$$RY_D \approx RY_{T1} \tag{8}$$

where

RY_D	=	relative yield of cotton lint as a function of drought alone
RY_{T1}	=	relative yield of cotton lint in T1 (as calculated in eq. 7)

Relative Lint Yield, Salinity Affecting

To quantify the lint yield loss due to salinity, the effect of drought had to be first removed. Since T1 is a function only of the imposed drought conditions, the equation quantifying the effect of salinity on the other treatments is given by:

$$RY_S \approx \frac{Y_a}{Y_{T1}} \tag{9}$$

where,

RY_S	=	relative yield of cotton lint as a function of salinity alone
Y_{T1}	=	mean yield of T1 replicates (kg ha^{-1})

and recombining equations 7 to 9 gives:

$$RY_{D\&S} = RY_D RY_S \approx \frac{Y_{T1}}{Y_m} x \frac{Y_a}{Y_{T1}} = \frac{Y_a}{Y_m} \tag{10}$$

where,

$RY_{D\&S}$ = relative yield of cotton lint as a function of drought plus salinity

Relative Lint Yield Loss

The inverse concept to relative yield is relative yield loss. The lint yield loss associated with equations 8 to 10 is given in equations 11 to 13:

$$YL_D = (1 - RY_D) \tag{11}$$

where

YL_D = Yield loss of cotton lint as a function of drought

$$YL_S = (1 - RY_S) \tag{12}$$

where

YL_S = Yield loss of cotton lint as a function of salinity

and

$$YL_{D\&S} = (1 - [1 - RY_D][1 - RY_S]) \tag{13}$$

where

$YL_{D\&S}$ = Yield loss of cotton lint as a function of drought and salinity

CHAPTER IV
RESULTS AND DISCUSSION

SOIL WATER STATUS

Evaporative Demand

Because cotton seed germination does not start until the soil is sufficiently moist, the season length for this study was calculated from the first application of irrigation water (4 May, 2 May, and 14 May for the 1994, 1995 and 1996 growing season, respectively) until the day when air temperatures dropped below 5°C (40°F). Season length was 159, 171, and 161 d, respectively. Seasonal ET_o amounts were 1368, 1361, and 1233 mm for the 1994, 1995, and 1996 crop seasons, respectively.

Peak cotton coefficient values (K_{cb_mid}) in arid regions are reported to be 1.20 to 1.25 depending on wind conditions (Doorenbos and Pruitt, 1977). The FAO-56 procedure, using measured minimum air relative humidity and wind speed values, yielded K_{cb_mid} = 1.23 for Pecos, Texas. Using the computer irrigation scheduling program, *MO-Scheduler* (Henggeler, 2004), ET_m for the three years of study was estimated to be about 1087, 1006, and 1001 mm for the 1994, 1995, and 1996 growing seasons, respectively. If the combined amounts of rainfall and irrigation minus surface evaporation from these events were less then these ET_m values, then deficit conditions are inferred.

Seasonal Precipitation. In-season annual precipitation averaged 150 mm each season and occurred in more than twenty rainfall events each season. Actual precipitation amounts were 136, 186, and 123 mm for the 1994, 1995, and 1996 growing seasons, respectively (Appendix C). The scheduling program calculated that surface water evaporation (E) from rainfall and irrigation would be 43, 40, and 81 mm for 1994, 1995, and 1996, and thus seasonal irrigation/rainfall available for the crop must be reduced by these amounts.

IRRIGATION APPLICATIONS. Total irrigation amounts applied to treatments were 596, 634, and 535 mm for 1994, 1995, and 1996, respectively. Approximately one-third of the total applied irrigation water was the "better" quality water used for establishment and early growth, which had an EC_{IW} of 4.5 dSm^{-1}. Table 7 contains information on amounts and dates of application for the three years. On average, applications were made within ± 36 hs of each other.

The number of irrigations applied each year varied from six to nine. These events were likewise subject to increased E from wetted-surface conditions, and were calculated similarly to the rain, except only 80% of the surface area was exposed to E due to the way furrows were wetted.

Deficit Conditions

Crop water use (ET_c) can be calculated using a mass balance approach as shown in equation 14:

$$ET_c = IRR + RAIN - E + \Delta_{sws} \tag{14}$$

where,

IRR	=	seasonal irrigation amount applied (mm)
RAIN	=	seasonal rainfall (mm)
E	=	evaporation from soil surface (mm)
Δ_{sws}	=	change in soil water storage volume, where positive value indicates decrease (mm)

Table 8 lists the amounts of water supplied by rain and irrigation, difference in average seasonal soil water storage, and losses due to E for each of the three years. ET_c for the three years of the study was 721, 781, and 561 mm. During the study, $ET_m > ET_c$ each year, meaning that deficit soil irrigation occurred every year. Over the three years, the mean deficit fraction of $ET_c / ET_m = 0.67$.

Using the deficit ratio of 0.67 in the yield response factor (eq. 2), the estimated Relative Yield for plots not affected by salinity (e.g., T1 and T2) would be 0.72. This estimate uses a cotton yield response factor (K_y) of 0.85 as suggested by Doorenbos and Kassam (1979).

Table 7. Irrigation amounts (both pre-treatment and treatment) and dates of application for 1994-1996.

Water Source Used	1994		1995		1996	
	Amount (mm)	Date	Amount (mm)	Date	Amount (mm)	Date
Pre-Treatment Irrigations	56	3 May	147	2 May	76	14 May
	48	14 May	32	9 May	152	14 Jun
	53	8 June	81	13 June	51	20 Jun
Treatment Irrigations	74	26 June	89	23 Jul	47	2 Jul
	91	11 July	187	11 Aug	85	21 July
	91	19 July	98	31 Aug	87	2 Aug
	91	10 Aug			37	3 Sept
	46	19 Aug				
	46	28 Aug				
TOTAL	596		634		535	

Table 8. Water amounts from rain and pre-treatment and treatment irrigation, E, Δ_{sws}, ET_c, ET_m, ET_o, ratios of ET_c/ET_o, and deficit fraction (ET_c/ET_m).

Item	1994	1995	1996	Avg.
Pre-Treatment Irrigation Amounts (mm)	157	260	279	232
Treatment Irrigation Amounts (mm)	439	374	256	356
Seasonal Precipitation (mm)	136	186	123	148
Soil Water Evaporation, E (mm)	(43)	(40)	(81)	(55)
Average change in soil water storage [a], Δ_{sws} (mm)	32	1	(16)	6
Actual crop water use, ET_c (mm)	721	781	561	688
Maximum seasonal cotton water use, ET_m (mm)	1087	1006	1001	1031
Seasonal reference evapotranspiration, ET_o (mm)	1368	1361	1233	1321
Actual seasonal crop coefficient [b]	0.53	0.57	0.46	0.52
Deficit fraction [c]	0.66	0.78	0.56	0.67

[a] Positive value indicates a decrease in soil water storage through the growing season.
[b] ET_c/ET_o.
[c] ET_c/ET_m.

Volumetric Soil Water Content

Water-Holding Properties. Table 9 shows measured soil texture and saturated water content as a function of depth in 0.15-m increments to 1.5 m. Volumetric water content (θ_v) estimated at saturation, field capacity, and permanent wilting point based on texture (Saxton, 1986) are also shown in table 9. The estimated (i.e., Saxton, 1986) and measured (i.e., Soil Characterization Laboratory of Texas A&M University) saturated θ_v values are, on average, within 2% of each other, except on the surface 0.15 m.

Based on table 9 and neutron probe readings, the soil profile to 1.0 m depth, the normal rooting depth for irrigated cotton (Allen et. al., 1998), held about 340 mm at field capacity and 180 mm at permanent wilting point. For nonstressed cotton, assuming a 50% allowable depletion, irrigation should occur after 80 mm of water has been used, or when there is ≈ 260 mm of water remaining in the top 1.0 m.

Table 9. Textural analysis and water holding characteristics of soil profile down to 1.5 m at 15-cm depth intervals showing permanent wilting point, field capacity, saturation percentage, and available water.

Depth	Laboratory Analysis [a]				Estimated Values [b]			
	Sand Content	Silt Content	Clay Content	Saturation Point	Permanent Wilting Point	Field Capacity	Saturation Point	Available Water
cm	------------- % -------------				----------------------------- $m^3\ m^{-3}$ ----------------------------			
0-15	29.0	44.0	27.0	0.42	0.15	0.30	0.49	0.15
15-30	28.0	41.8	30.2	0.46	0.17	0.32	0.50	0.15
30-45	27.2	41.5	31.3	0.49	0.17	0.32	0.50	0.15
45-60	25.8	41.0	33.2	0.51	0.18	0.34	0.51	0.15
60-75	23.4	39.7	36.9	0.51	0.21	0.36	0.51	0.15
75-90	20.1	40.0	39.9	0.54	0.22	0.38	0.52	0.15
90-105	16.7	42.7	40.6	0.53	0.23	0.39	0.53	0.16
105-120	19.7	42.8	37.5	0.51	0.21	0.37	0.52	0.16
120-135	19.8	40.4	39.8	0.53	0.22	0.38	0.52	0.16
135-150	20.1	39.9	40.0	0.53	0.22	0.38	0.52	0.15

[a] Soil Characterization Laboratory of Texas A&M University.
[b] After Saxton et al. (1986).

Neutron Probe Data. Information on the soil θ_v for depths > 30 cm was measured by neutron attenuation (Appendix D). Since neutron probe readings were not taken at the 15-cm depth, an algorithm used a correlation of (a) the ratio of 30-cm to 15-cm θ_v (both taken from EnviroSCAN sensors that was part of a separate study [Sentek PTY LTD, Australia]) and (b) days since irrigation or rain to estimate θ_v at 15 cm, based on the θ_v at 30-cm neutron probe value. Figure 15 shows the ratio between θ_v at 15 cm to θ_v at 30 cm as a function of days since wetting. The EnviroSCAN data from the 10-, 20-, and 30-cm depths on a T2 treatment block in Year 3 were used to develop equation 15 ($R^2 = 0.92$). The θ_v of the 15-cm depth was estimated as the average of the 10- and 30-cm depths. Equation (15) is:

$$R_{\frac{15-cm}{30-cm}} = \frac{\theta_{v15-cm}}{\theta_{v30-cm}} = 0.005d^2 - 0.216d + 0.7271 \qquad (15)$$

where,

$R_{15-cm/30-cm}$ = ratio between the θ_v of the 15-cm depth to θ_v of the 30-cm depth
θ_{v15-cm} = volumetric water content at 15 cm (m^3/m^3)
θ_{v30-cm} = volumetric water content at 30 cm (m^3/m^3)
d = days since irrigation or major rainfall (> 8 mm)

Rearranging equation 15 solves for the θ_v at 15 cm as seen in equation 16:

$$\theta_{v15-cm} = \frac{0.005d^2 - 0.216d + 0.7271}{\theta_{v30-cm}} \qquad (16)$$

The value from equation 16 was multiplied by the θ_v of the 30-cm depth to obtain an estimate of the 15-cm depth water content. Rainfall events less then 8 mm were ignored, because they did not register on the EnviroSCAN probes, probably because of canopy interception.

The average water content to a depth of 1.05 m during Year 1 of the study is given in figure 16. Since a soil water availability > 280 mm was needed to stay above the 50% allowable depletion level, soil water conditions were deficit through most of the season. However, neutron measurements were generally taken before irrigation was applied, so our results perhaps show drier conditions than were experienced by the crop. In the first year, cotton water extraction

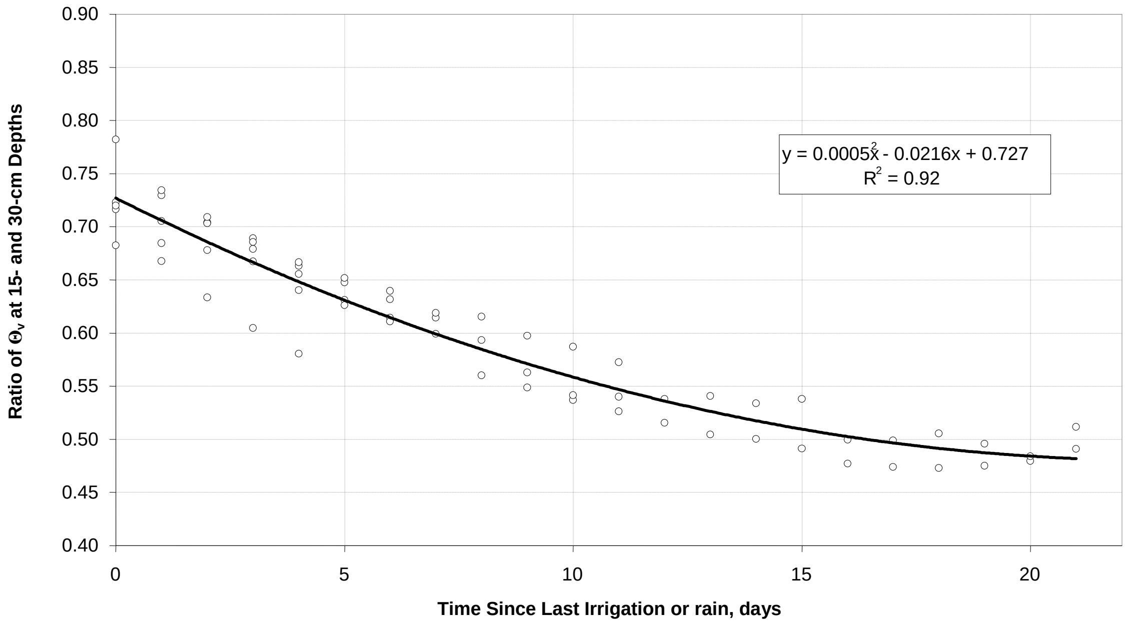

Figure 15. Ratio of the θ_v at the 15-cm depth to the 30-cm depth as taken with the EnviroSCAN system and as a function of d since irrigation or rain.

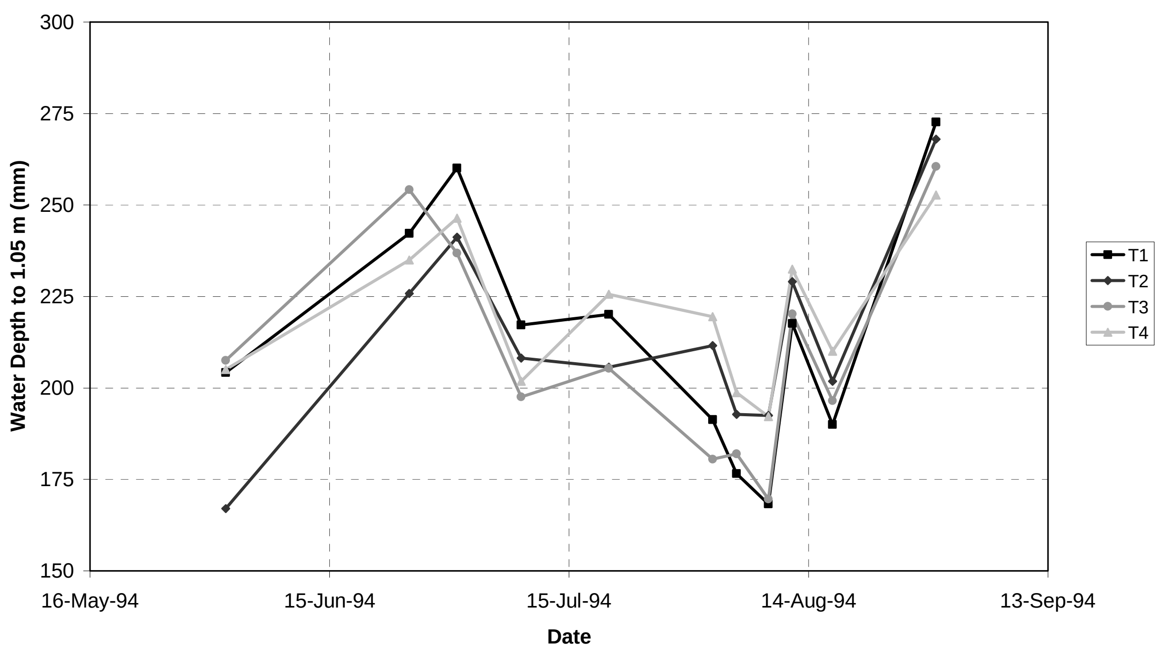

Figure 16. Soil water content to 1.05 m in Year 1 of the study as taken with the neutron probe.

rates subjected to the various levels of salinity appeared to be similar, as indicated by the similar water contents among treatments, with the exception of the T2 treatment at the first measurement period. The lower value probably stems from distribution uniformity during pre-watering where one EU was only wetted down to 60 cm. After the first applied irrigation, differences between treatments were not present.

In Year 2, deficit water content conditions were again maintained. Differences in water content among treatments were apparent in mid-August of Year 2 (Fig. 17), as they were again present in Year 3. The reason that the saltier T3 and T4 treatments had higher water contents in the profile than the T1 or T2 treatments could be due to a smaller leaf area and a decreased soil water osmotic potential, resulting in less transpired water.

In Year 3, the soil profile water content remained in a deficit condition, and similar to Year 2, the water extraction rates differed among the treatments during the season. Figure 18 shows average water content depth down to 1.05 m as measured with the neutron probe.

Evapotranspiration Estimates of Soil Volumetric Water Content

The FAO-56 methodology to estimate crop water use was incorporated in the irrigation scheduling software, ***MO-Scheduler*** (Henggeler, 2004), and used to calculate a daily water balance for all three years of the study. Figure 19 shows the estimate of ET_m, ET_c (i.e., ET_m reduced due to deficit soil water conditions), and E all in units of mm d^{-1} for Years 1 to 3. Figure 19 also shows that E was high during the first part of the season before the crop canopy was developed.

The average actual ET_c and the calculated ET_c and its error are shown in table 10. The program parameters used in ***MO-Scheduler*** were a rooting depth of 1.05 m, total available water (field capacity minus permanent wilting point) of 160 mm, and readily available water of 80 mm.

The ***MO-Scheduler*** was also used to calculate the soil water deficit in the top 1.05 m and is shown in figure 20. We assume that when the soil water deficit = 0 mm, the profile is at field capacity. The permanent wilting point and the allowable depletion level are also shown. The soil water depletion point, as measured by the neutron probe, is indicated with open circles.

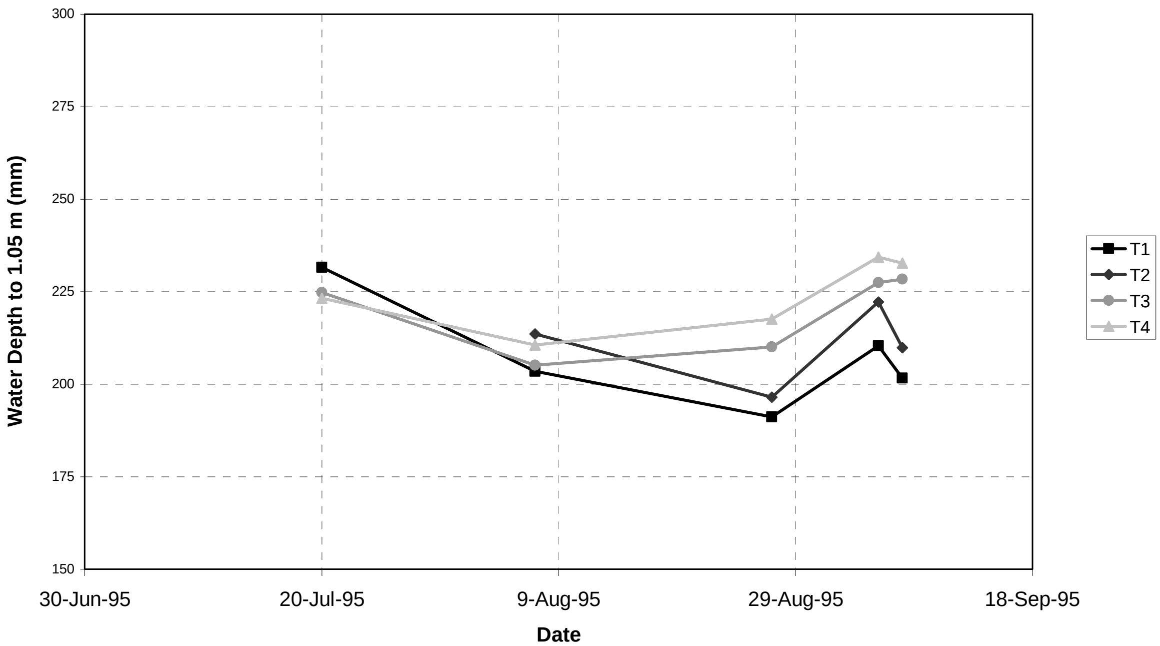

Figure 17. Soil water content down to 1.05 m in Year 2 of the study as taken with the neutron probe.

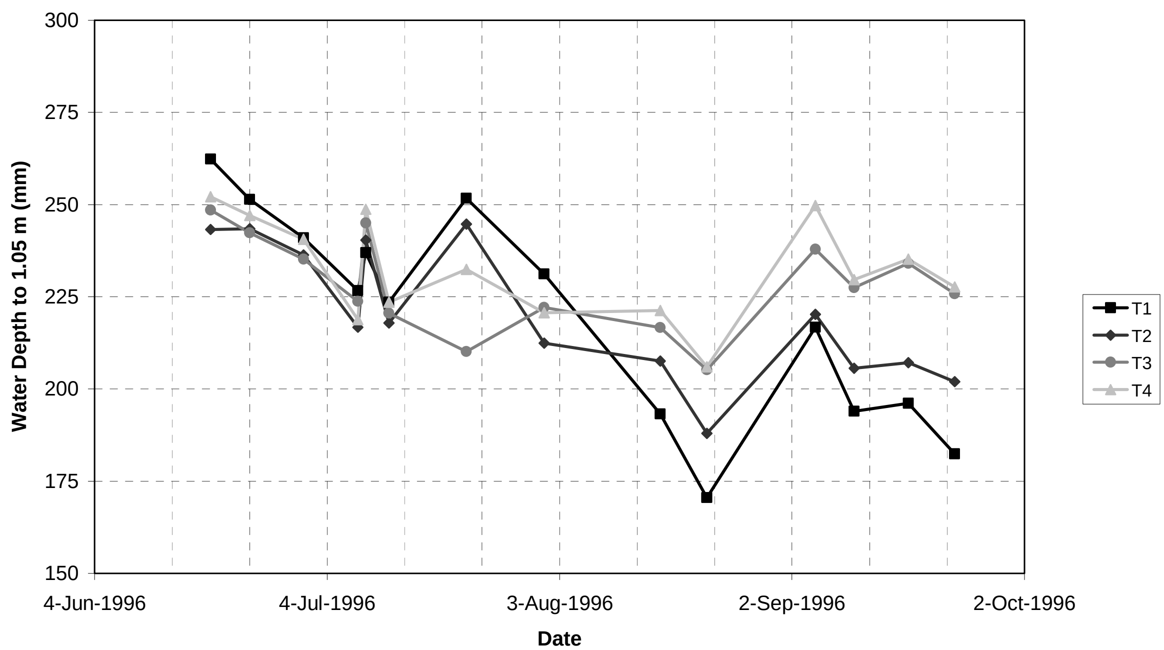

Figure 18. Soil water content down to 1.05 m in Year 3 of the study as taken with the neutron probe.

Table 10. Actual ET_c (average for all four treatments), calculated ET_c using *MO-Scheduler*, and the error of estimation using *MO-Scheduler*.

	Measured ET_c [a]	Calculated **ET_c** [b]	**Error**
	------------- mm	---------------	%
Year 1	721	606	16.0
Year 2	781	689	11.8
Year 3	561	593	- 5.7
Average	688	629	7.4

[a] Based on equation 7: $ET_c = IRR + RAIN - E + \Delta_{sws}$

[b] Calculated using the FAO-56 procedure and *MO-Scheduler*.

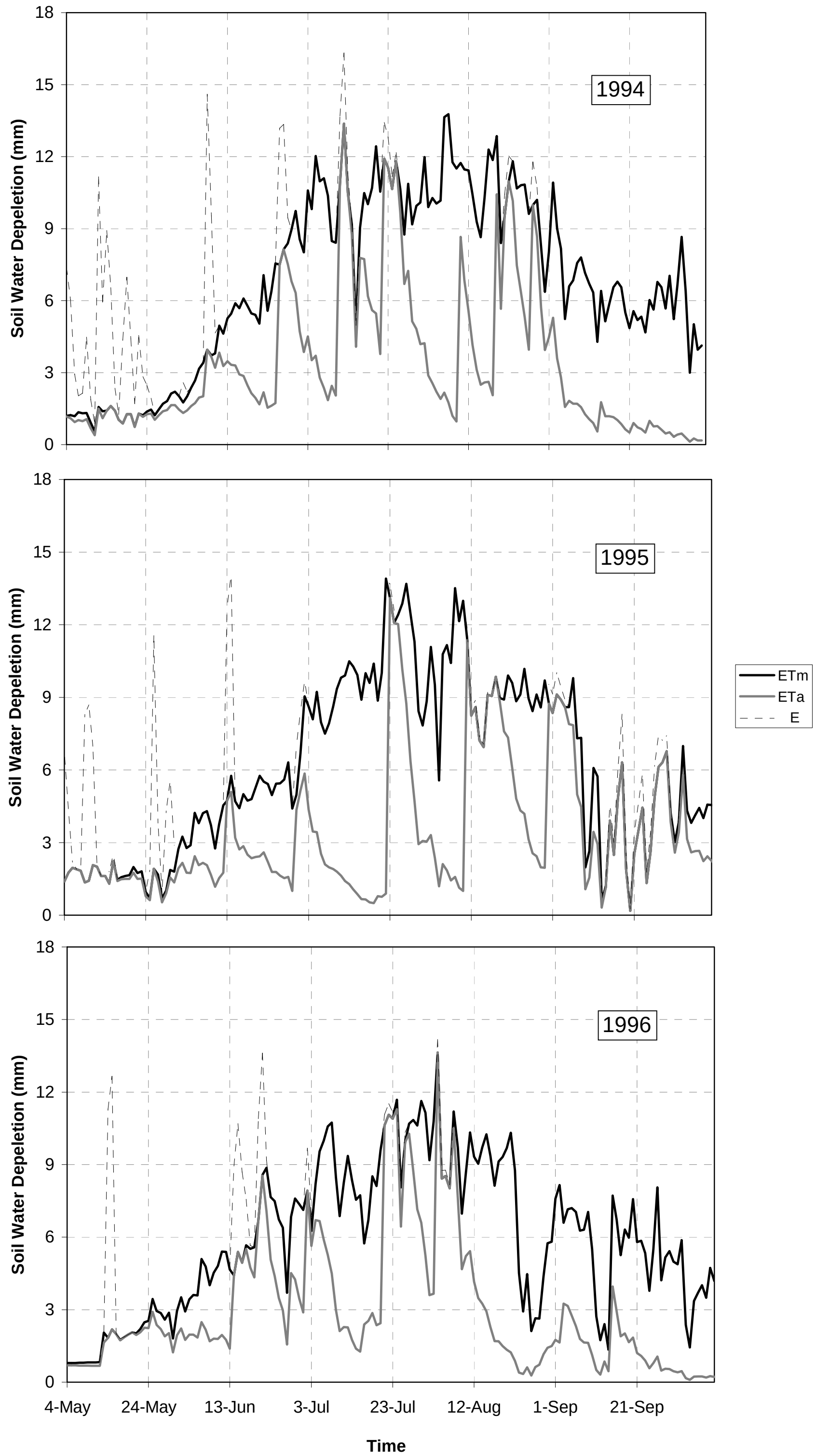

Figure 19. Calculated ET_m, ET_c, and E amounts as modeled by the irrigation program *MO-Scheduler* for Years 1 to 3.

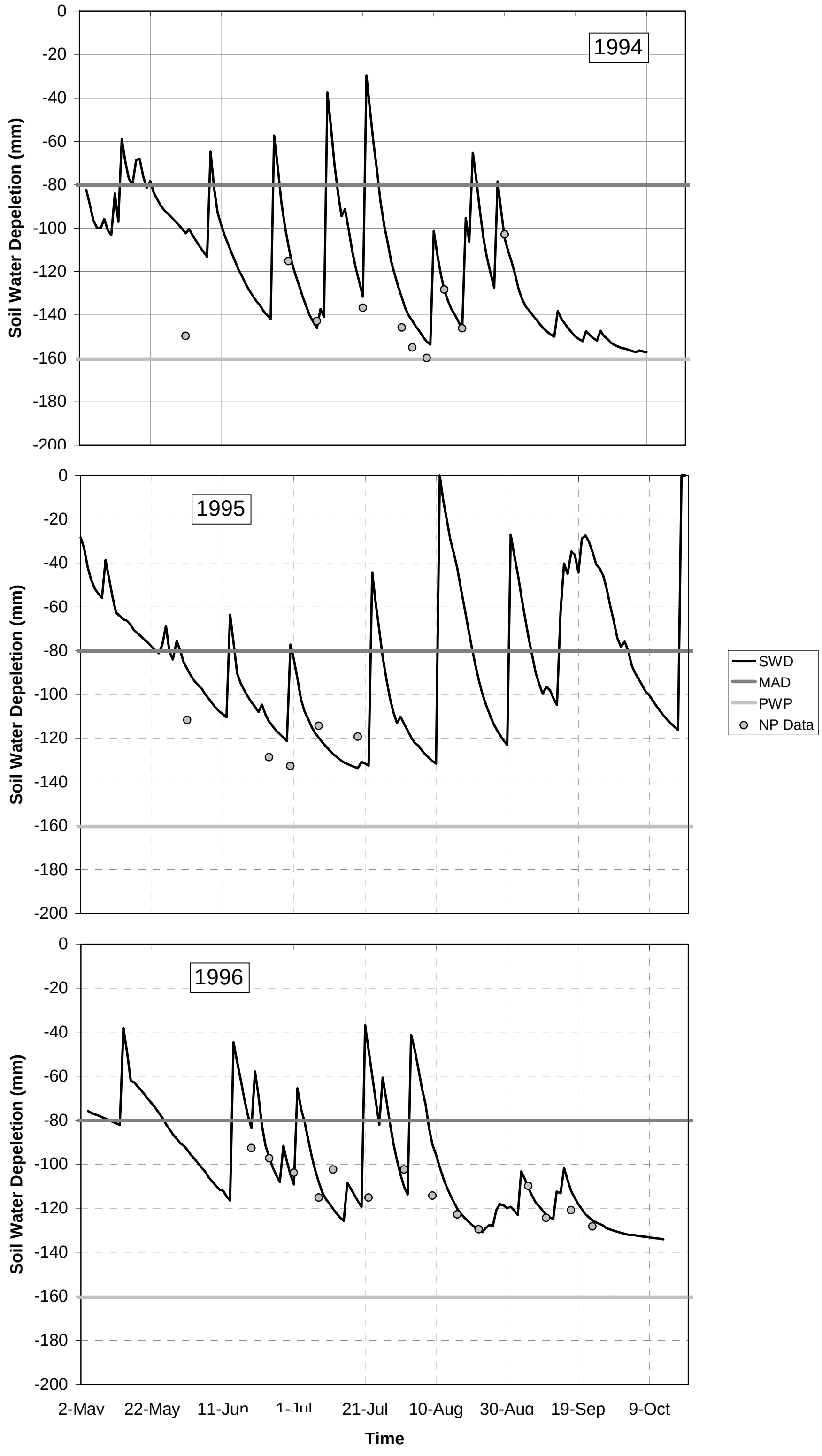

Figure 20. Calculated soil water deficit using FAO-56 procedure and the irrigation program *MO-Scheduler*, soil water deficit as measured by neutron probe, manageable allowable depletion (MAD), and permanent wilting point (PWP) for Years 1 to 3.

SOIL SALINITY

Laboratory Procedures

A set of soil samples representing each soil layer and the wide ranges of salinity used in our test were selected from two sampling periods and were analyzed for EC_e at the Texas A&M Soil Salinity Characterization Laboratory using the standard saturation paste method procedure. Furthermore, on subsets of these samples, the capillary method of Longenecker and Lyerly (1964), referred to as EC_{cap-e}, was also performed. A good agreement ($R^2 = 0.91$) for samples with < 15 dS/m was established, and when using the complete data set the linear correlation was $R^2 = 0.85$. A second order polynomial equation was fit to the complete data set and had $R^2 = 0.93$. Figure 21 shows the data. Equation 17 is the linear relationship EC_{cap-e} to EC_e for values of EC < 15 dS m^{-1}, and equation 18 is the polynomial relationship of the same variables using all data points. Longenecker and Lyerly (1964) had established their work using soils similar to Hoban silty clay loam. In our trials, as they had previously documented, the two procedures for testing EC_e give similar EC values, thus, $EC_{cap-e} \approx EC_e$. The relationship between the two is described in equation 17 as:

$$EC_e = 1.06\ EC_{cap-e} + 0.80 \qquad (17)$$

where,

EC_e = electrical conductivity of the saturated paste extract (dS m^{-1})
EC_{cap-e} = electrical conductivity of the capillarity, saturated paste extract (dS m^{-1})

and,

EC_e < 15 dS m^{-1}

and equation 18 is:

$$EC_e = -0.030\ (EC_{cap-e})^2 + 1.30\ EC_{cap-e} - 0.58 \qquad (18)$$

In a similar manner, tests were done on a variety of soil samples to relate $EC_{2:1}$ to EC_{cap-e}. Equation 19 relates the two values ($R^2 = 0.80$), and the data is shown in figure 22.

$$EC_{cap-e}. = 1.79\ EC_{2:1}. + 2.21 \qquad (19)$$

An estimate of EC $_e$ can be made from a soil sample tested using the $EC_{2:1}$ method, by combining equation 17 and equation 19 to obtain equation 20:

$$EC_e' = 1.43\ EC_{2:1} + 2.84 \qquad (20)$$

where

EC_e' = estimate of EC_e (dS m^{-1})

Since equation 20 is only an estimate of EC_e it is referred to as EC $_e$**'.** These relationships between the various EC testing methods were developed to allow all data to be jointly presented.

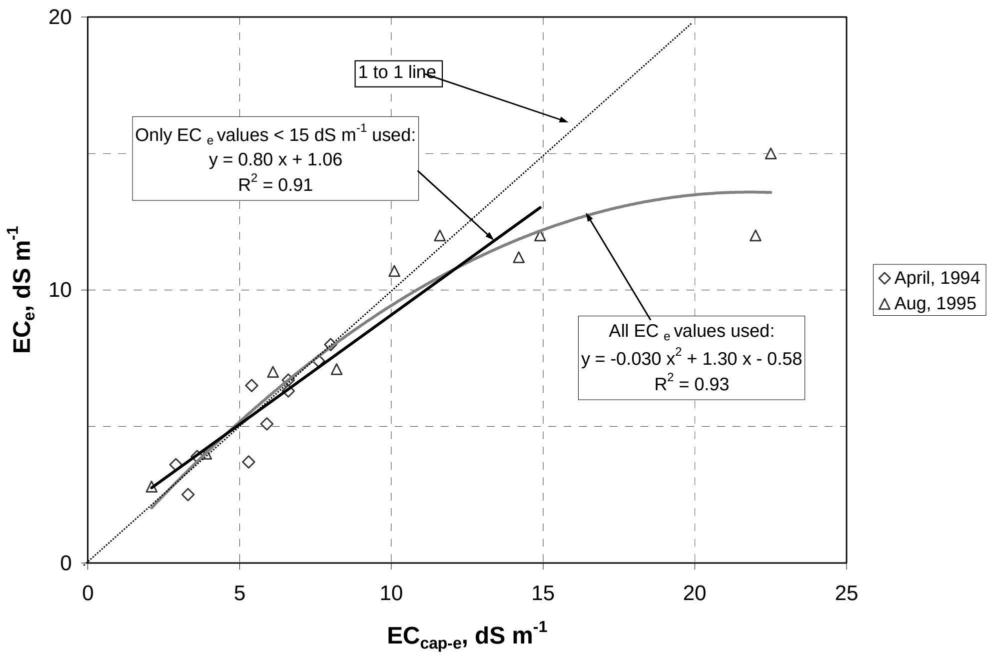

Figure 21. Relationship between EC_{cap-e} and EC_e showing linear relationship when EC values > 15 dSm^{-1} were not used, polynomial relationship where total data set was used, and one-to-one line.

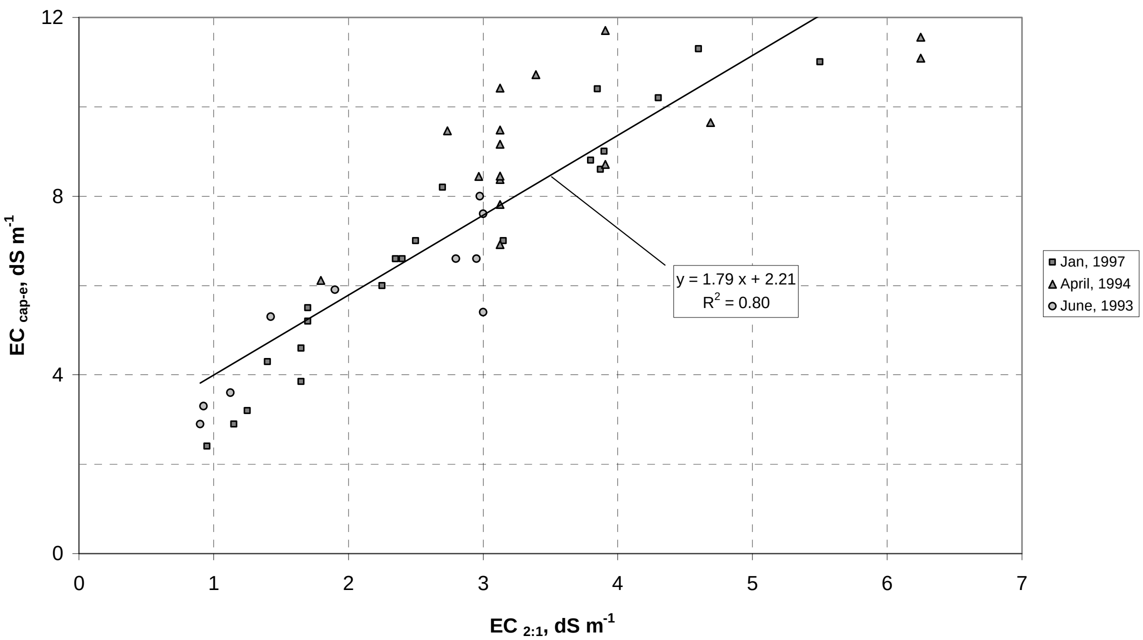

Figure 22. Relationship between $Ec_{cap\text{-}e}$ and $EC_{2:1}$.

Initial Conditions

The soil salinity profile prior to the application of treatments is given in table 11. Profile measurements were obtained from five sites that were cored down to 1.5 m depth and separated into 15-cm increments. These soil samples, tested with the 2:1 ratio method showed that variability existed in the field. The calculated EC_{e}' values are shown in figure 23 with the standard deviation of the means indicated. Composite soil samples by depth were made by combining appropriate segments from each core. These composite samples were analyzed using the saturated extract method (EC_e). The profile is also shown in figure 23. The EC_e values in the profile for the top 80 cm were at levels not harmful to cotton (Ayars and Westcot, 1985). The maximum EC_e was at 0.8-m depth and was 8.0 dSm^{-1}, which is slightly above the level when cotton lint yields may be reduced (Maas and Hoffmann, 1997).

Three observations can be made from the data of table 11 and figure 23. First, there is a large variability among the soil samples taken within 50 m of each other. Thomas (1980) observed large in-field variation in EC. Wichelns and Oster (1991) attributed variations they found in California farm fields to problems in irrigation system uniformity, specifically with gravity methods of irrigation. Secondly, relatively high levels of salinity exist in the profile, especially in light of the fact that it has been fallow for ≈ 20 years. Thirdly, the high SAR values at 30- to 60-cm soil depth should be taken into account when discussing future viability of farming this land with water as saline as T3 or T4.

Table 11. Initial electrical conductivity (EC_e') values by depth with their mean and standard deviation and saturated paste extract electrical conductivity (ECe) and SAR of a composite sample.

Depth (cm)	**Individual Sample Sites**							**Single Composite Sample**	
	Site 1	Site 2	Site 3	Site 4	Site 5	Mean of Sites 1 to 5	STD of Sites 1 to 5	EC_e	SAR
	---------- EC_e' ----------								
	---------- (dS m^{-1}) ----------							(dS m^{-1})	
0-15	3.3	5.3	3.6	5.0	3.6	4.1	0.83	3.6	7
15-30	3.6	3.7	3.8	5.1	3.8	4.0	0.57	2.5	18
30-45	3.4	3.6	6.6	3.7	5.4	4.5	1.25	3.9	28
45-60	3.7	4.0	6.8	3.7	4.6	4.6	1.19	3.7	30
60-75	4.6	3.7	7.1	4.4	5.3	5.0	1.17	5.1	27
75-90	8.4	3.6	6.8	5.0	5.8	5.9	1.65	8.0	18
90-105	7.0	4.1	8.0	4.8	6.0	6.0	1.40	7.4	16
105-120	6.3	4.1	7.3	4.3	5.7	5.5	1.20	6.7	15
120-135	6.4	4.4	7.1	4.1	7.1	5.8	1.31	6.3	13
135-150	4.8	6.7	7.6	4.3	7.4	6.2	1.35	6.5	13
Average	5.1	4.3	6.5	4.4	5.5	5.2	0.78	5.4	22

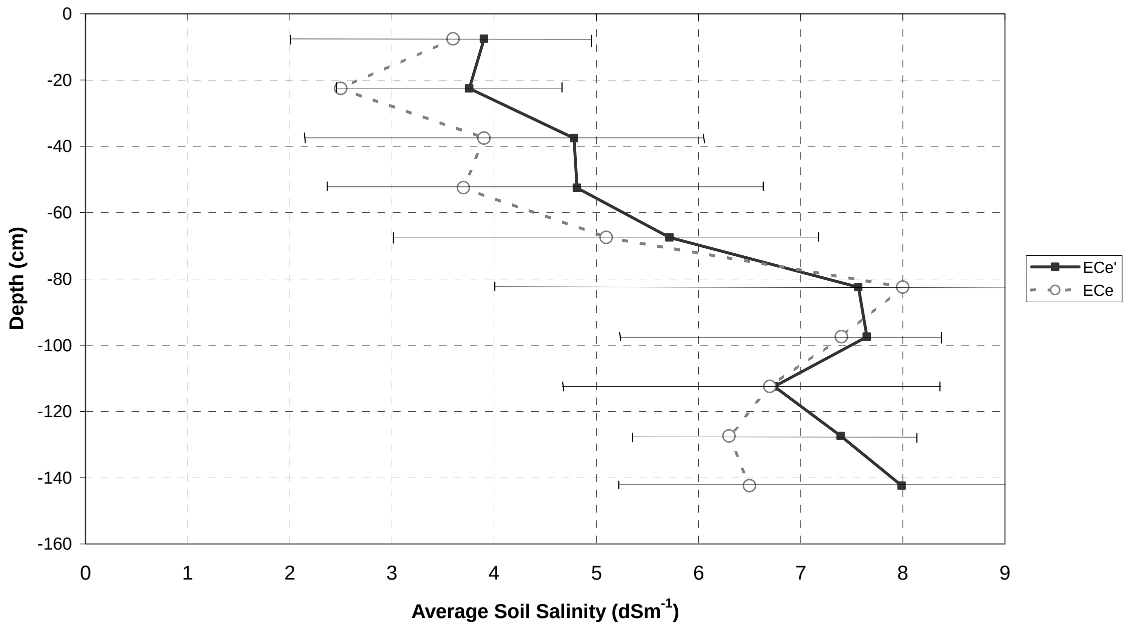

Figure 23. Initial soil salinity profile (solid line) for all plots April 1994 prior to the beginning of experiments showing the mean and standard deviations of EC_e' (EC_e' values are estimates of the electrical conductivity of the saturated paste extract [EC_e] made from EC measurements on soil pastes with a soil-to-water ratio of 1:2 [$EC_{1:2}$]) and EC_e values (dashed line).

Changing Salinity Profiles

Electrical conductivity levels shifted in each treatment during the three-year test period. For example, EC levels in T1 were reduced, in T2 slightly increased, while T3 and T4 accumulated EC in the profile in comparison to their starting points. Figures 24 to 27 show the change of EC with time for the T1, T2, T3, and T4 treatments. These figures show the initial EC measured April 1994. Soil sampling in December 1994 represents changes after one year, the August 1995 sampling two years, and the final sample in January 1997 represents the condition of the soil after three years. This final sampling was after a simulated pre-plant irrigation in the winter of 1996, and thus represents EC levels for the upcoming crop.

The EC value from each profile depth is the average EC value for the drill and the water furrow at that depth. In the majority of sampling periods, the EC of the drill > EC of the water furrow. This is probably due to the action of the wetting front, moving water from the furrows and carrying soluble salts inward towards the center of the bed.

Benefits of Pre-Plant Irrigation. In our tests, pre-plant irrigation application was essential to manage the three higher salinity treatments (T2, T3, and T4) by leaching salts to deeper soil depths. Even after the application of saline irrigation water for three years, the final simulated pre-plant irrigation (80 mm of T2 water [EC_{IW} = 4.5 dSm^{-1}]) was able to create a zone of less-saline soil in which the cotton roots could grow. This is evident in the EC_e profiles shown in figures 24 to 27 where the final soil test (Jan 1997) showed decreased EC_e in the top soil layers. However, this buffer zone, based on a threshold salinity level of 7.7 dS m^{-1} (Ayars and Westcot, 1985) was only 40 cm in the T3 treatment and 15 cm in the T4 treatment. The EC profiles prior to and following this pre-plant irrigation for T3 and T4 are shown in figure 28 and 29.

The pre-plant irrigation helps leach salts deeper into the soil profile, ideally below the root zone. Salts move with the wetting front. Thus, soluble salts that have accumulated in the top layer of soil are pushed out of this part of the profile to the depth to which the pre-plant irrigation wetted. The end result, using Ayers and Westcot's (1976) estimate of $EC_e \approx 1.5\ EC_{IW}$, is that EC_e in the top zone will be < the critical salinity threshold if pre-plant irrigation is applied with water of EC_{IW} < 5 dSm^{-1}. Wicheins and Oster (1991) found pre-irrigation depth was correlated to cotton lint yield in farms in an area in California with high salinity, as did Nightingale et al. (1986).

Another important aspect of pre-plant and/or early growth stage irrigation is that it provides the opportunity to <u>conjunctively use</u> a good- and a bad-quality water. Cotton, like many other plants, is vulnerable to salinity at early stages and then later "hardens off." Once cotton is established, it can utilize saline water sources, such as perched water tables (Wallender et al., 1979). It is, however, important that the good-quality water be employed first. The effectiveness of conjunctive use in reducing overall EC_{IW} levels, and thus salinity hazard, is shown in table 12 where data on both total quantities and EC_{IW} values of the initial and final irrigation waters are listed. After combining waters, the net time-average irrigation water salinity (EC_{IW-net}) for T3 and T4 was 7.2 and 10.8 dSm^{-1}, respectively. Thus, conjunctive use reduced T3 and T4's EC_{IW} by 20 and 30%, respectively.

Table 12. Total quantities and EC_{IW} values for the initial water (pre-emergence / early growth period irrigation) and the later treatment water, and $EC_{IW\text{-}net}$ resulting from combining them.

	Year 1				Year 2				Year 3			
Quantity of Pre-Emergence/Early Growth Period Irrigation (EC_{IW} = 4.5 dSm^{-1})	157 (mm)				260 (mm)				279 (mm)			
Quantity of Mid-season Treatment Irrigation	439 (mm)				374 (mm)				256 (mm)			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---------- dSm^{-1} ----------											
Treatment EC_{IW}	1.5	4.5	9.0	15.0	1.5	4.5	9.0	15.0	1.5	4.5	9.0	15.0
$EC_{IW\text{-}net}$ after combining both sources	2.3	4.5	7.8	12.2	2.7	4.5	7.2	10.7	3.1	4.5	6.7	9.5

However, even with using a pre-plant irrigation of moderate water quality, salinization of the soil still occurred. Data taken prior to the test and each year of the test showed that T3 and T4 increased in EC_e at a rate of 0.9 and 1.4 dS m^{-1} y^{-1}. Even the T2 treatment increased in EC_e with time (0.6 dS m^{-1} y^{-1}). The T1 treatment decreased in EC_e at a rate of -0.1 dS m^{-1} y^{-1}. The EC_e to a depth of 1.0 m for the initial, the end, and following each growing season is shown in figure 30.

The question of system equilibrium as mentioned by Solomon (1985) and Longenecker and Lyerly (1959) was important in regard to both Objective 1 and 2. If equilibrium between the plant, soil, and water had been established after the three years of this test, it could be argued that these final salinity levels, even for T3 and T4, would be acceptable based on obtained yield level, as will be discussed later. However, if equilibrium had not been reached and salinization continued at the rate of 0.8 and 1.4 dS m^{-1} y^{-1}, production levels would decrease. On the question of equilibrium, Longenecker and Lyerly (1959) felt early on in the history of irrigation in the Pecos region that chemical equilibrium was unlikely to have occurred in its soils, which at that time had been irrigated for 15 to 20 years. Thus, it is also unlikely that equilibrium had yet been reached in our study, and further salinization would probably occur. Therefore, the conclusion regarding Objective 1 is that soil salinization increases when deficit irrigation is used with saline water, even when better quality water is used early in the growing season.

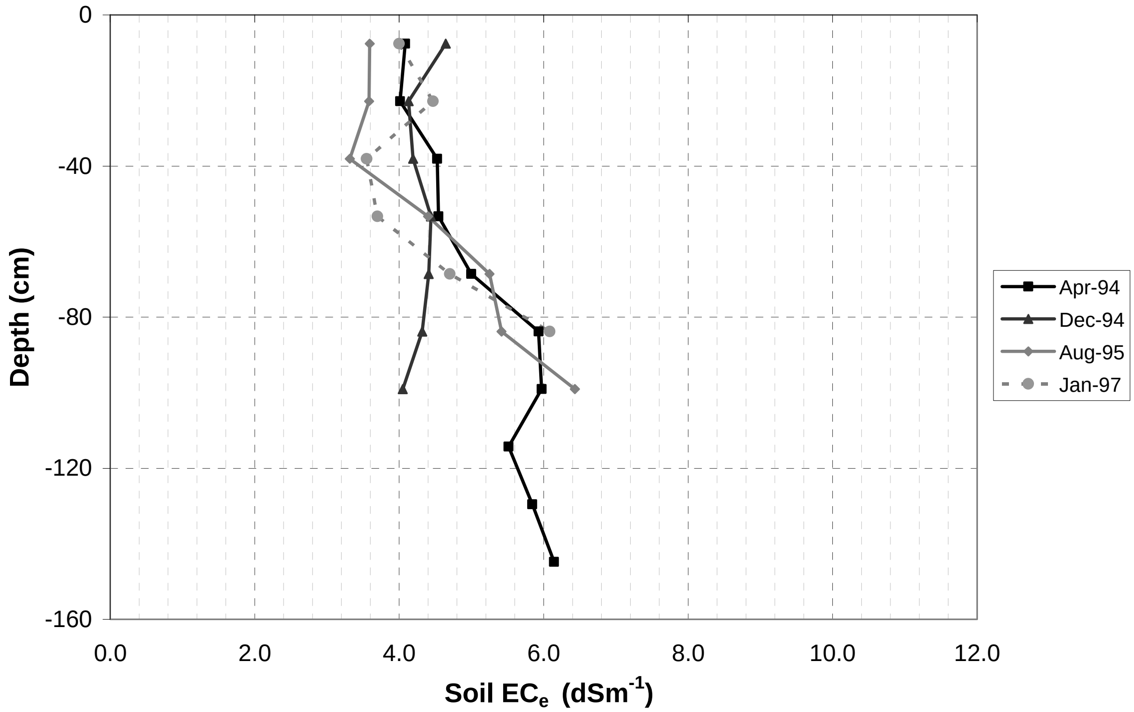

Figure 24. Soil EC$_e$ profile for the T1 treatment at beginning and end of test, and at two periods in between.

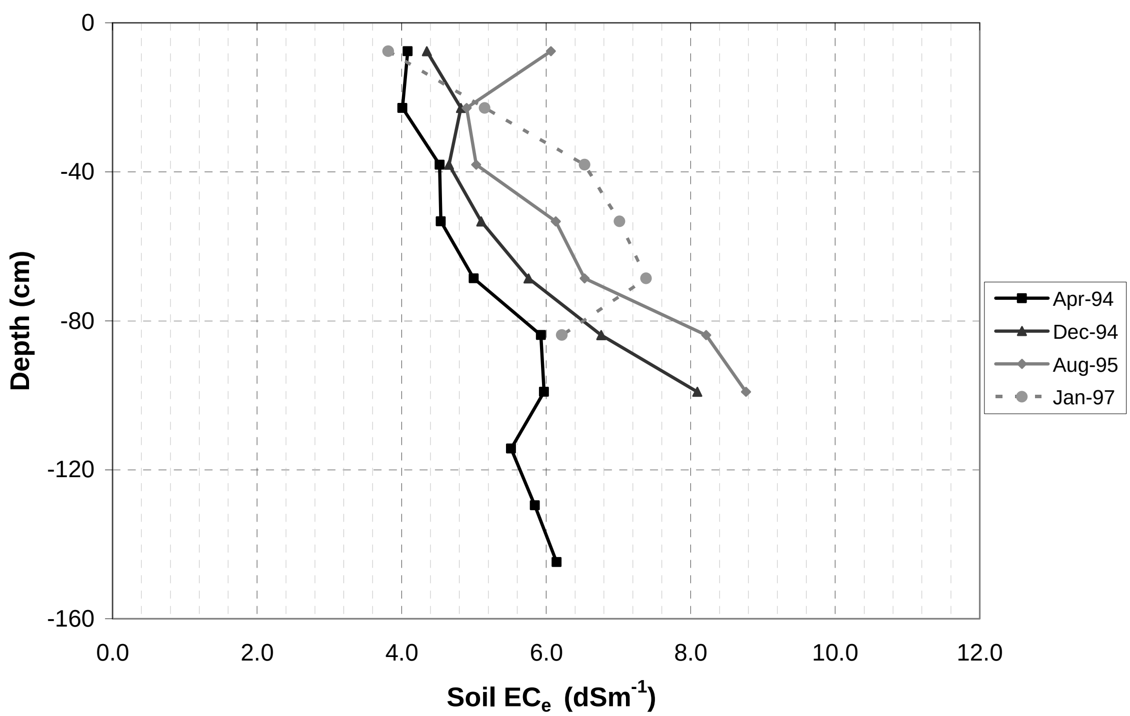

Figure 25. Soil EC$_e$ profile for the T2 treatment at beginning and end of test, and at two periods in between.

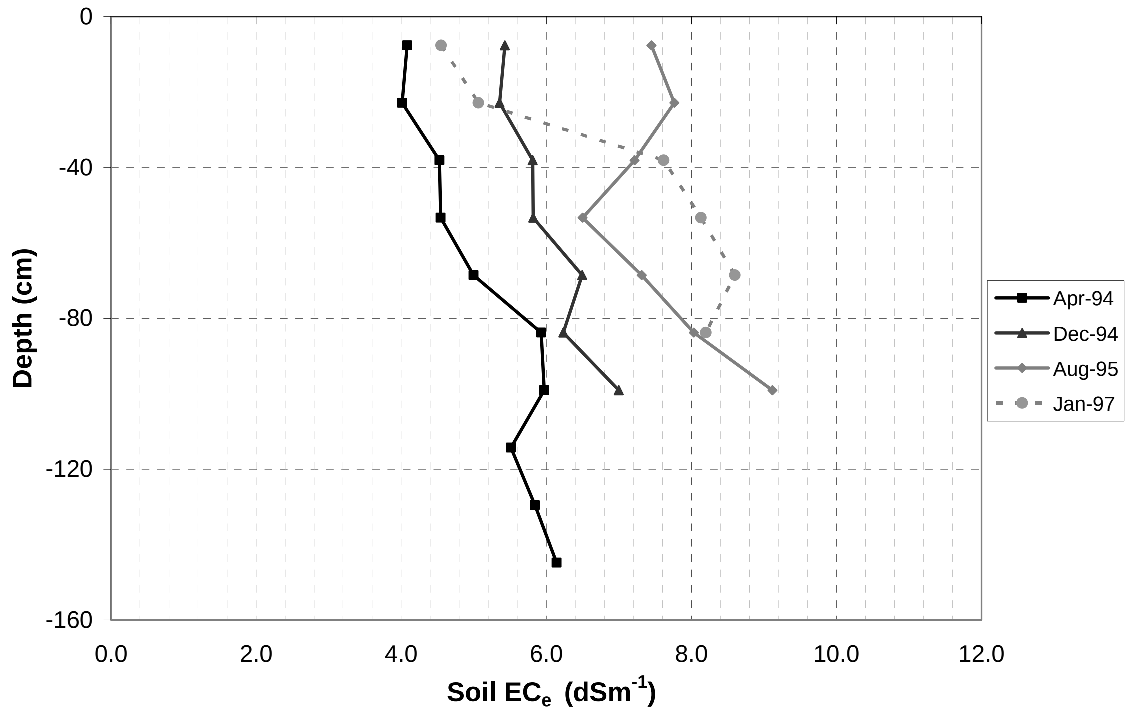

Figure 26. Soil EC$_e$ profile for the T3 treatment at beginning and end of test, and at two periods in between.

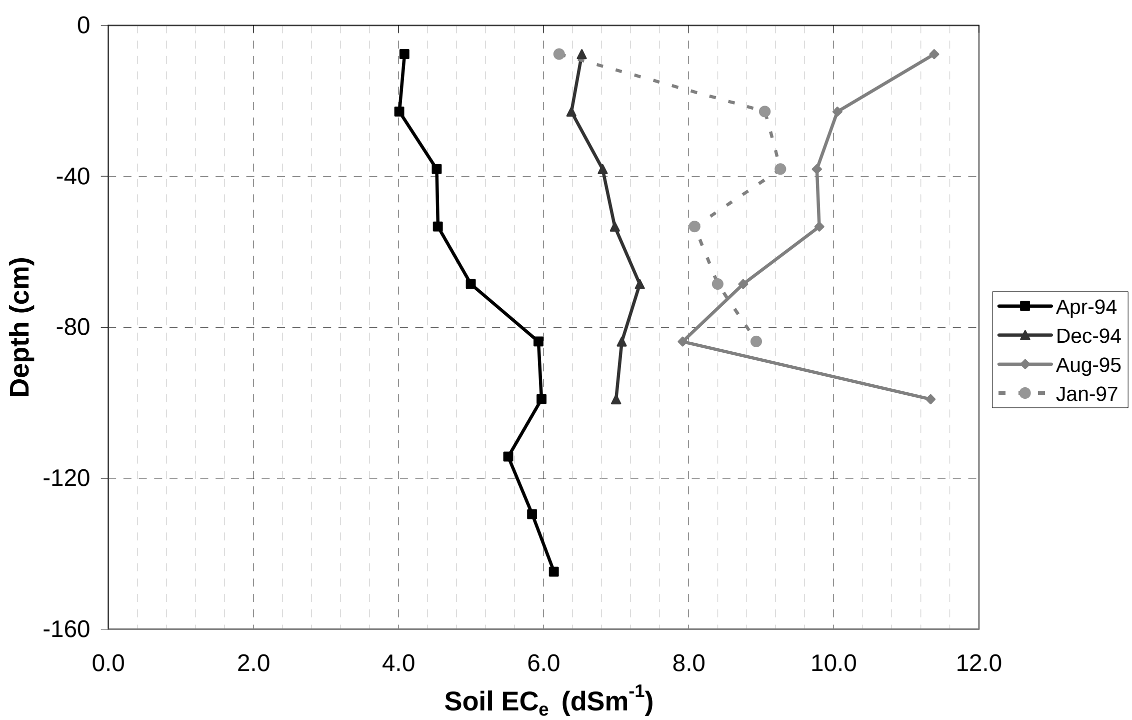

Figure 27 Soil EC$_e$ profile for the T4 treatment at beginning and end of test, and at two periods in between.

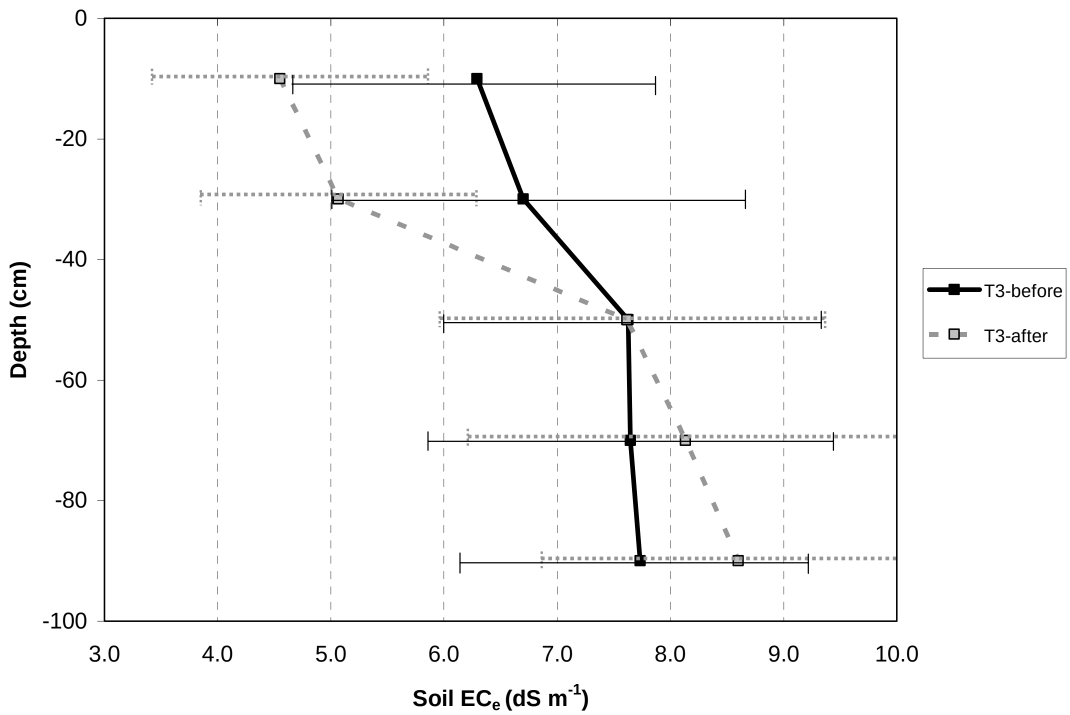

Figure 28. The soil EC_e profile with standard deviations for the T3 treatments at the end of Year 3 before and after a simulated pre-plant irrigation for the fourth season.

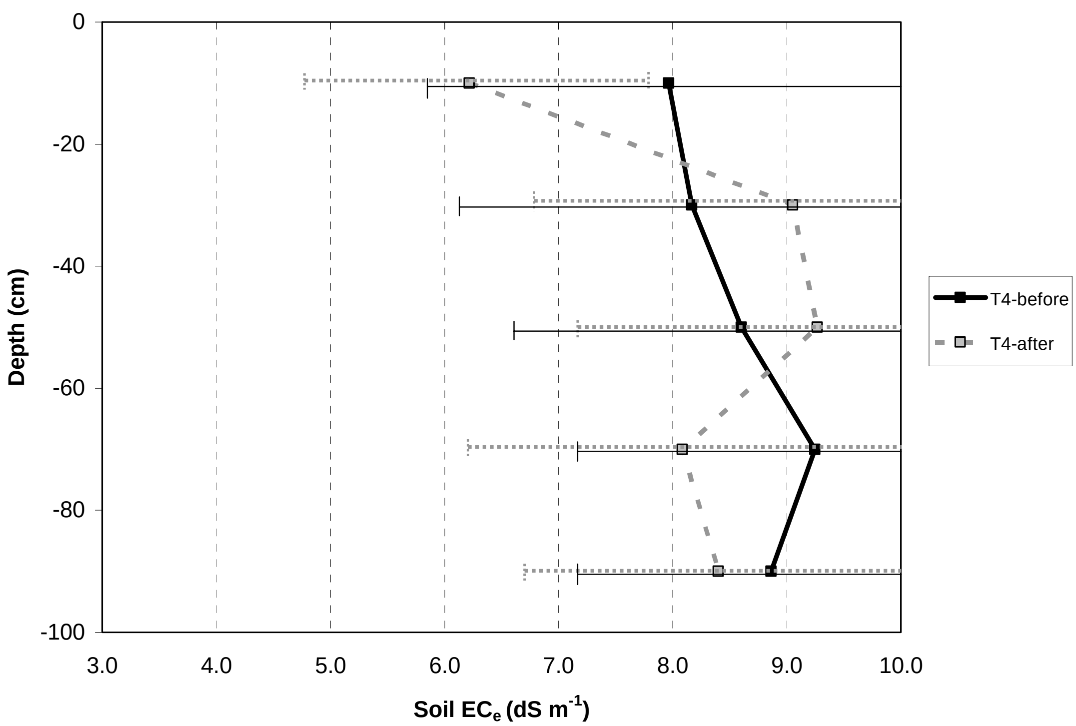

Figure 29. The soil EC_e profile with standard deviations for the T4 treatments at the end of Year 3 before and after a simulated pre-plant irrigation for the fourth season.

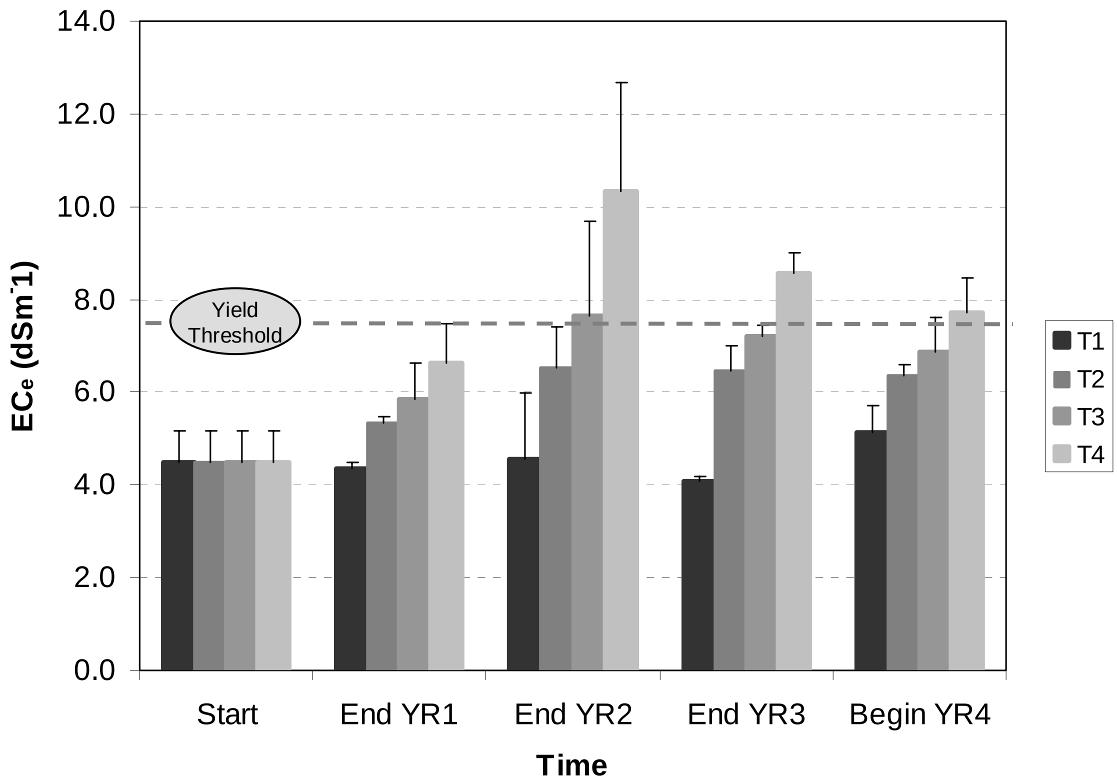

Figure 30. Change in average EC_e plus standard deviations to 1.0 m soil depth for all treatments, plus yield-decline threshold level for the beginning conditions, the end of each of the three seasons, and the beginning of what would be Year 4 when only a pre-plant irrigation has been applied.

YIELD LOSS ATTRIBUTED TO SALINITY. The average EC_e value in the top 1.0-m soil depth rarely exceeded the Maas-Hoffmann threshold of 7.7 dS m^{-1} (Fig. 30); thus, it would be expected that yield levels would be similar among all treatments. However, T3 and T4 yielded only 0.78 of what T1 and T2 did (the Maas-Hoffmann procedure estimates the relative yields based on the average seasonal EC_e to be: 1.0, 1.0, 1.0, and 0.93 for T1, T2, T3, and T4, respectively). This under-prediction in yield loss for EC_e indicated that, under <u>deficit conditions</u>, the 7.7 dS m^{-1} threshold in the Maas-Hoffmann relationship was too high.

The estimated impact salinity had on relative yield (RY_S) of treatments was previously given by equation 9.

$$RY_S \approx \frac{Y_a}{Y_{T1}} \qquad (9)$$

Table 13 lists RY_S for the 4 EC_{IW} treatments for Years 1 to 3. By using T1 yield as reference, the drought effect was isolated, leaving only the salinity effect, RY_S. RY_S are plotted against average EC_e in figure 31 (R^2 = 0.71), as is the Maas-Hoffman function, and there is an obvious difference between the two.

These data show that the threshold value for yield reduction under deficit conditions (specifically, when deficit ratio [ET_c / ET_m] = 0.67) was ≈ 4.5 dSm^{-1}, or about half the established threshold. The rate of yield decline per dSm^{-1}, however, is similar to the Maas-Hoffman relationship, i.e., 5.2% for each additional dSm^{-1} exceeding the threshold value. Using the EC_e–to-EC_{IW} guide of 1.5 (Ayers and Westcott, 1976), it is projected that yield loss in cotton lint will begin when EC_{IW} > 3 dSm^{-1} when the deficit ratio is 0.67. The T2 treatment in our test (4.5 dSm^{-1}) had 3% loss.

The reason that the study data differ from the Maas-Hoffman relationship is because deficit conditions existed during the study. When the same data are plotted alongside data from Thomas (1980), where plots were not irrigated, there is closer agreement; whereas, Francois's data (1982), where plots were irrigated frequently, are in agreement with the Maas-Hoffman relationship (figure 32). The Thomas (1982) data was from a dryland study and both the data from Francois (1982) and Maas-Hoffman were under conditions of full irrigation. Data from the current study, which was only partially irrigated, fits in the middle.

Table 13. Relative Yields with the effect of drought removed (RY_S) for all EC_{IW} treatments for Years 1 to 3 and the average of all three years.

Year	T1	T2	T3	T4
Year 1	1.00	0.99	0.84	0.85
Year 2	1.00	1.00	0.74	0.73
Year 3	1.00	0.92	0.76	0.72
Average	1.00	0.97	0.78	0.77

The negatively correlated relationship between $EC_{IW\text{-}net}$ and RY_S (Fig. 33) is of particular importance, because, like EC_e in figure 31, it relates to the expected yield level, but is based instead on irrigation water salinity, which is easier to ascertain than is EC_e. The R^2 value was -0.63. As an example, interpolating figure 33 shows that without conjunctively combining the T4 water, the expected RY would have been 63, as opposed 77%.

End of the season EC_e (average in the top 1.0 m of soil) increased with rising $EC_{IW\text{-}net}$ levels (R^2 = 0.63) and is shown in figure 34. The initial value of EC_e prior to commencing treatments is also indicated. Only T1 from each of the three years was less than the initial value.

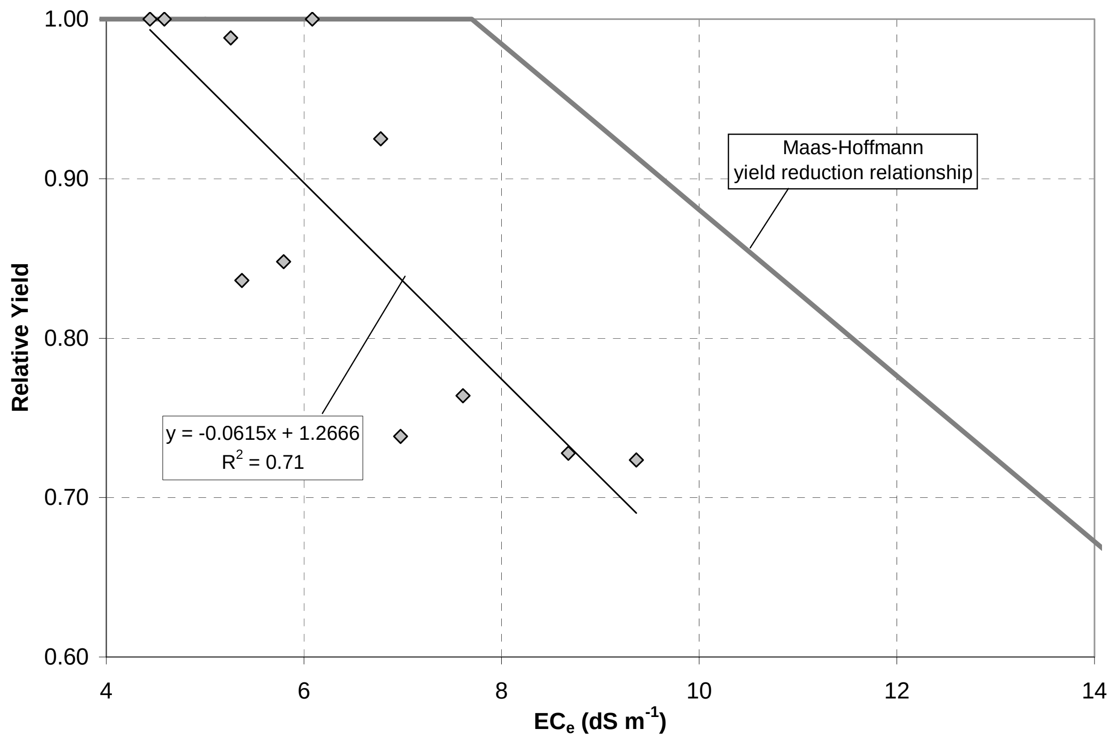

Figure 31. Relative Yield versus average EC_e to 1.0 m soil depth for all treatments for Years 1 to 3, plus the Maas-Hoffman yield threshold relationship.

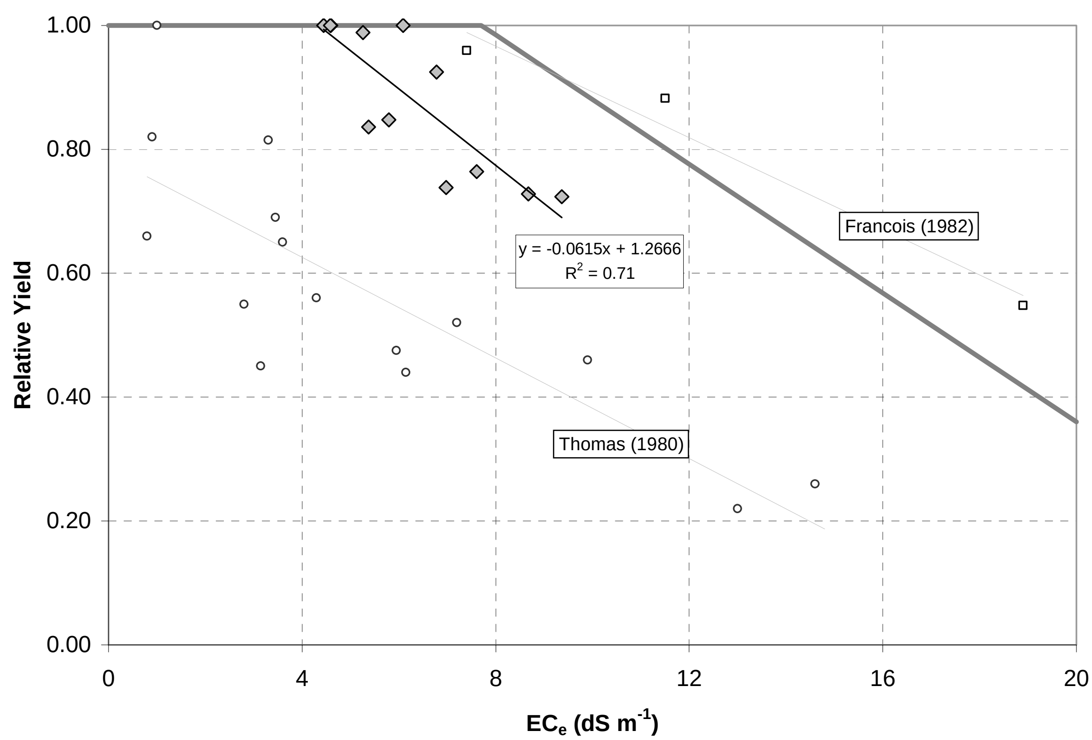

Figure 32. Data as in Fig. 31 with the addition of results from Thomas (1980) where nonirrigated conditions occurred and from Francois (1982) where frequent irrigations occurred.

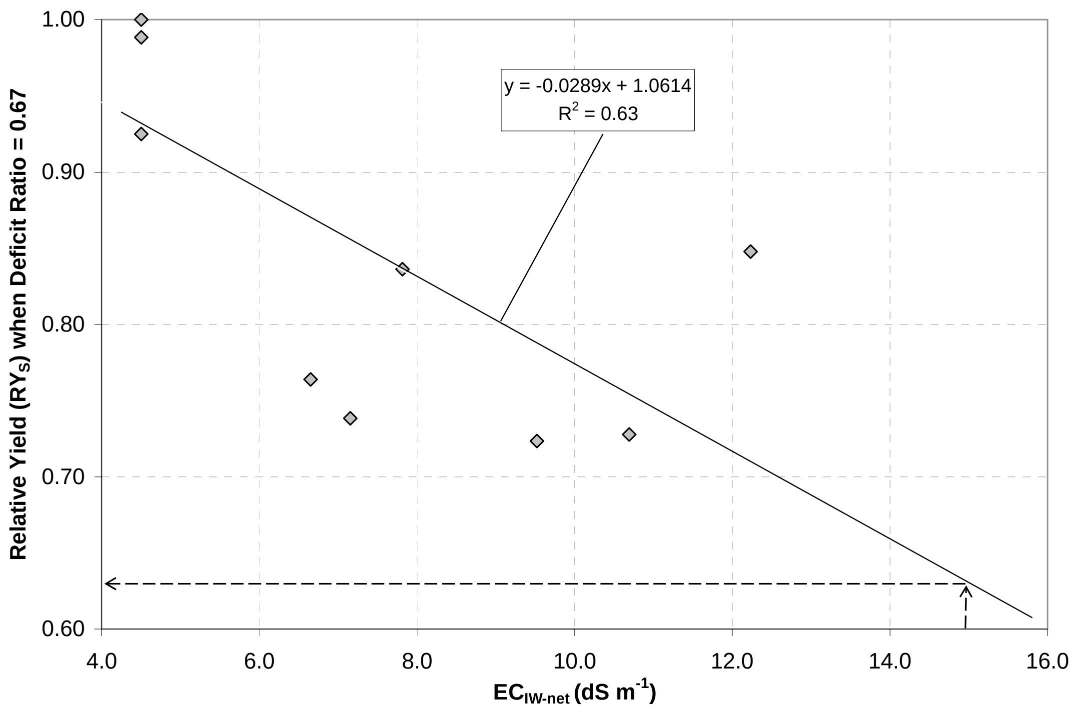

Figure 33. Average net $EC_{IW\text{-}net}$ versus RY_S for Years 1 to 3 and a projection showing that a $EC_{IW\text{-}net}$ = 15 dSm^{-1} would result in RY_S = 0.63.

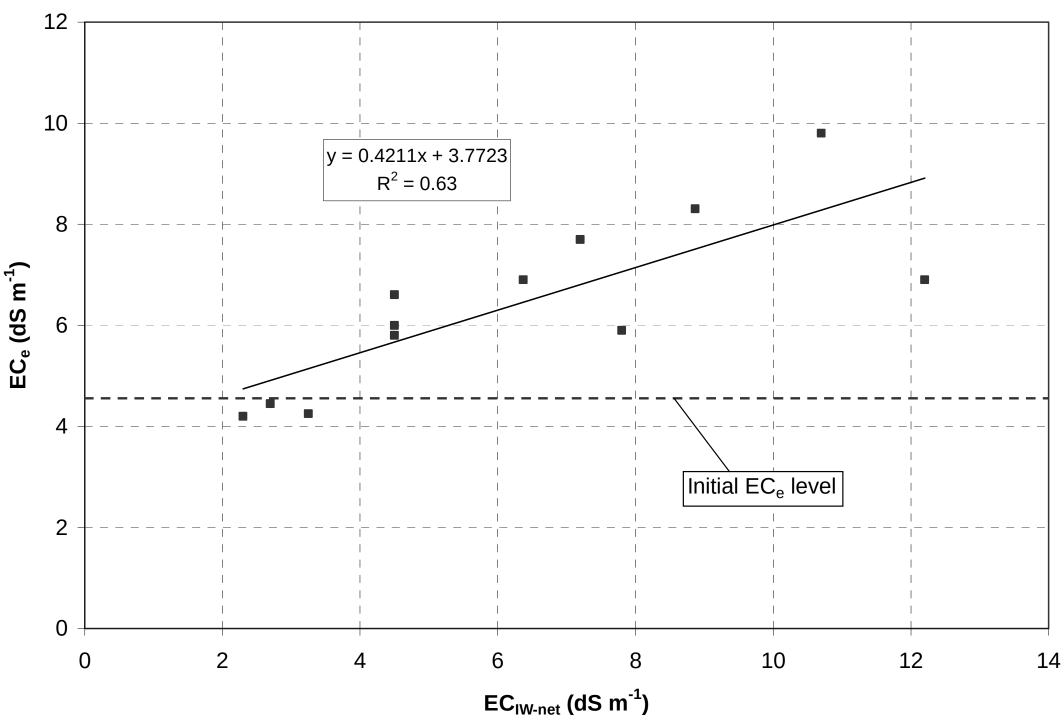

Figure 34. Relationship between $EC_{IW\text{-}net}$ and EC_e at the end of each season for all treatments and all 3 years plus initial EC_e value from April 1994.

Viability of Using Deficit Irrigation and Saline Water: Soil Salinization

Results regarding the increase in EC_e over time (shown earlier in Fig. 30) indicate that under deficit irrigation, the use of T3 and T4 water led to soil salinization. Additionally, there were indications that soil water extraction at depths > 60 cm was being limited under T3 and T4 treatments as seen in the soil θ_v data measured with the neutron probe. An example is shown in figure 35 in which the seasonal θ_v for all treatments is at 30-, 45-, and 60-cm soil depths in the last year of the study. At 30-cm soil depth, cotton in the T3 and T4 extracted water in a similar manner to that of the cotton in the T1 and T2 treatments. Soil θ_v fluctuated as irrigations occurred and cotton extracted water. However, at the 45- and 60-cm soil depths, there was a marked flattening of root water extraction in the T3 and T4 treatments, even though the soil θ_v in T3 and T4 treatments was ≈ 25% higher than in T1 and T2. This indicated a diminished ability to utilize soil water. This trend remained the same for the deeper depths.

End-of-season soil water content (a value which should be between 180 mm [permanent wilting point] and 340 mm [field capacity]) showed that the higher saline treatments retained more residual water and that the cotton crop had extracted less (table 14). After Year 1, there was no statistically significant difference in end-of-season soil water content. Following Year 2, T1 and T4 were statistically significant (5% level), and following Year 3, the T1 and T2 were both statistically significant different from T3 and T4. Meiri at al. (1992) reported similar results in which the higher saline treatments had larger end-of-season θ_v values. Figure 36 shows this change in end-of-season soil water content by treatments over the three years.

Discussion Summary Regarding Salinity and Soil

Encountered concerns in using saline water and deficit irrigation can be summarized as:

1) Soil salinization occurred on T3 and T4 at the rates of 0.9 and 1.4 $dSm^{-1}\ y^{-1}$, respectively.
2) There was diminished ability for T3 and T4 to utilize soil water at depths > 0.5 m.
3) The threshold level at which EC_{IW} becomes detrimental to lint yield decreased from being 5 dSm^{-1} with full irrigation, to become 3 dSm^{-1} under deficit irrigation.
4) RY_S decreased 3% per dSm^{-1}.

Objective 2 involved evaluating the impact of deficit irrigation with saline water on the soil, and based on the four concerns above, the conclusion is that it does negatively impact the soil.

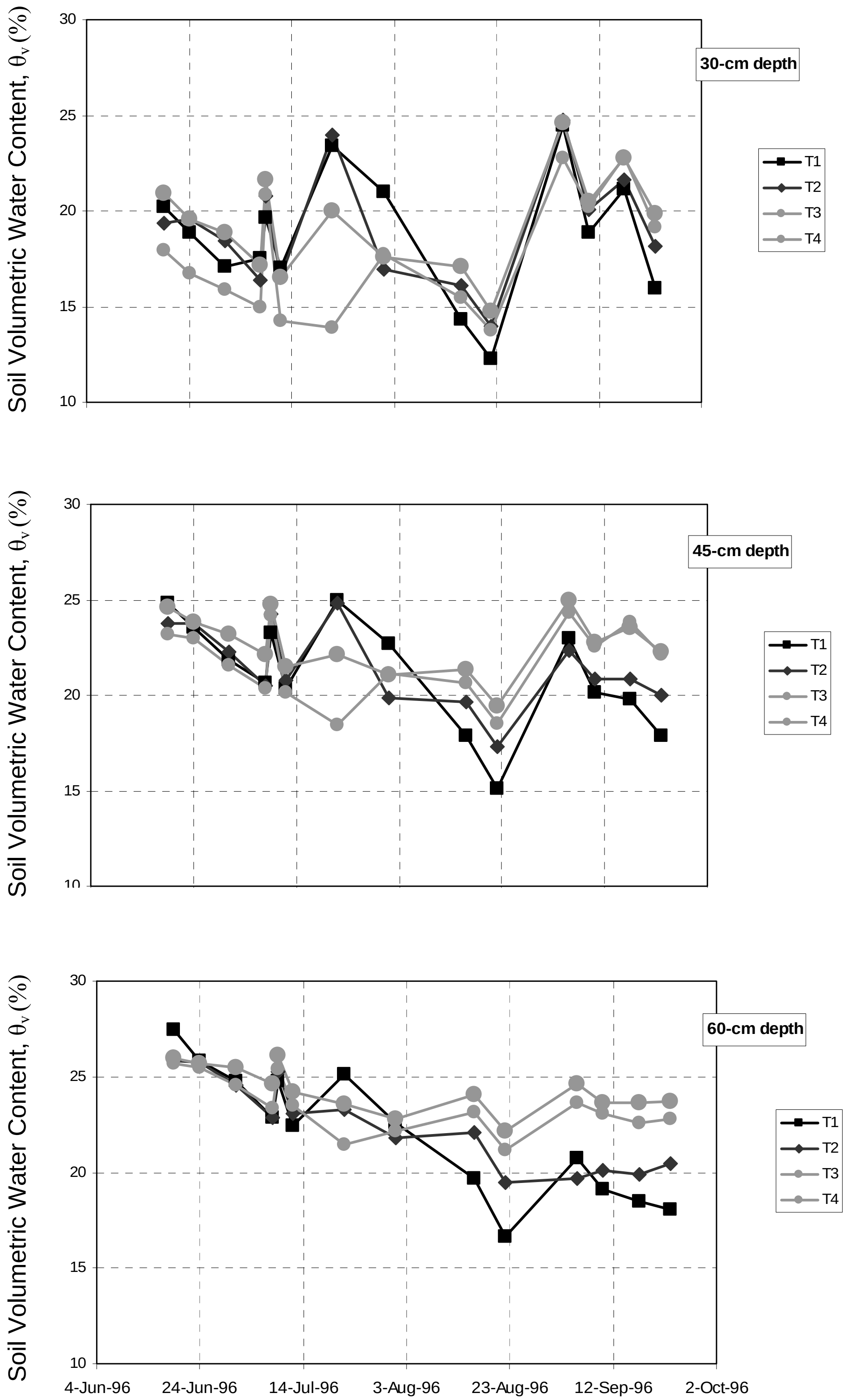

Figure 35. Seasonal soil volumetric water content (θ_v) at the 30-, 45-, and 60-cm depths, for the four treatments in Year 3.

Table 14. End-of-season soil water content [a], [b] in top 1.0 m of soil.

	End of Year 1			
	T1	T2	T3	T4
	mm			
Rep 1	259	243	244	233
Rep 2	273	269	249	259
Rep 3	258	268	272	258
Avg.	263 a	260 a	255 a	250 a
S. D.	8.4	14.8	15.1	14.7

	End of Year 2			
	T1	T2	T3	T4
	mm			
Rep 1	228	226	231	238
Rep 2	211	210	235	244
Rep 3	196	238	224	232
Avg.	211 a	225 a,b	230 a,b	238 a
S. D.	15.9	14.3	5.4	6.0

	End of Year 3			
	T1	T2	T3	T4
	mm			
Rep 1	193	222	221	232
Rep 2	170	196	220	229
Rep 3	185	188	237	221
Avg.	182 a	202 a	226 b	228 b
S. D.	11.6	17.6	9.5	5.7

[a] A value which should be between 180 mm [permanent wilting point] and 340 mm [field capacity])
[b] Within the four treatments for each year, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.

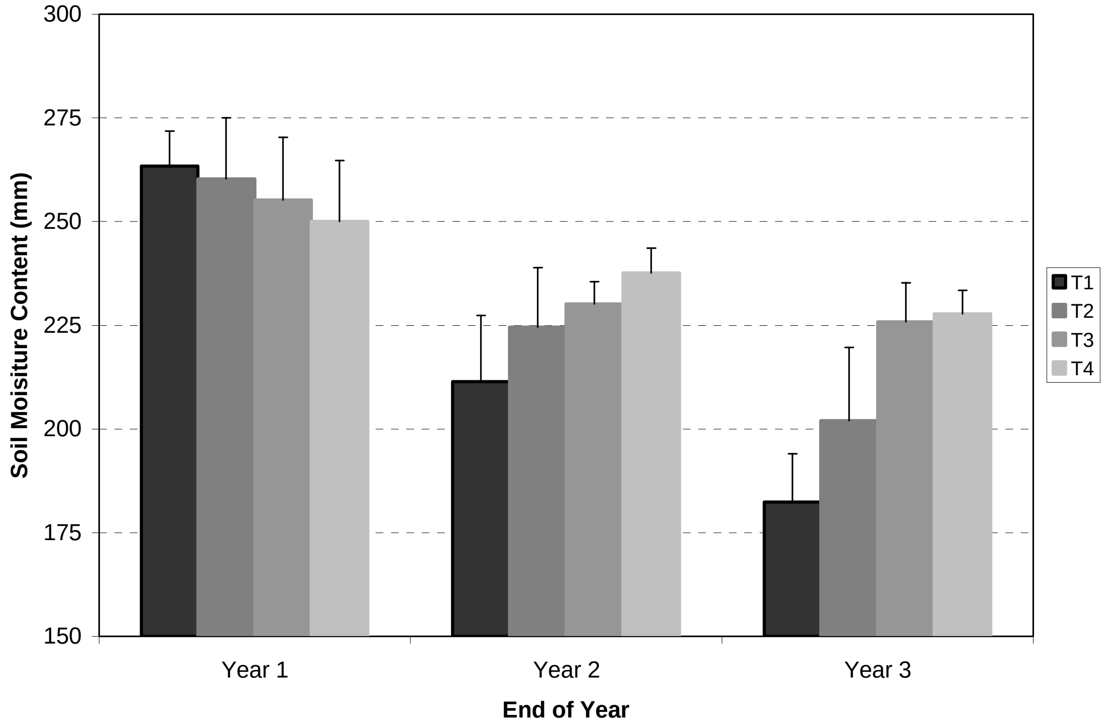

Figure 36. Soil water content in the top 1.05 m of soil at the season's end.

PLANT GROWTH

Plant Height

Average final plant height for all treatments was 41, 55, and 50 cm for the 1994, 1995, and 1996 growing seasons, respectively (table 15). The tallest plant height was in 1995 for the T1 treatment water (67 cm), while the shortest plant height occurred in 1994 on the T4 treatment (33 cm). The average final plant height for T1, T2, T3 and T4 was 59, 50, 45, and 38 cm, respectively (table 15). Two trends appeared regarding plant height. Beginning 52 d after planting (DAP) on the first year of the test and after irrigation water with different levels of EC was applied, the order of plant heights 90% of the time was T1 > T2 > T3 > T4. Salinity effects on plant height from Year 1 were carried over, and in Years 2 and 3 height differences were statistically significant even before the in-season salinity treatments were imposed. The other noticeable trend was that the T1 and T2 heights usually were paired, while the T3 and T4 heights were also paired. Height values are given in tables 16 to 18 and are graphically displayed in figure 37.

In Year 1, treatments started 52 DAP and height measurements showed a difference 11 d later. Height measurements were statistically different (5% level) 20 d after application of the treatments. Thereafter, the pattern was that T1 treatments were always statistically significantly taller then the T4 treatments during the 3-year study. The same was true for T1 versus T3, with two exceptions. The T2 did not become statistically significantly taller then the T3 and T4 treatments until later in the growing season.

Table 15. Final plant height [a],[b] for the four separate treatments, 1994-1996.

	T1	T2	T3	T4	Avg.	S.D.
	---------- cm ----------					
1994	49	44	36	33	41	7
1995	67	--- [c]	56	43	55	12
1996	61	56	42	39	50	11
Avg.	59 a	50 a,b	45 a,b	38 b	49	---
S.D.	9	8	10	5	---	---

[a] Within the four treatments, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Taken 10 days after last irrigation in Year 1 and at end of season for Years 2 and 3.
[c] Missing data

Table 16. Effect of EC of four water qualities on average plant height [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	12	11	13	11	18	20	19	20	30	26	25	25
Rep 2	11	11	11	11	23	21	21	21	31	31	26	26
Rep 3	12	13	13	12	23	26	24	19	32	31	25	25
Avg.	12 a	12 a	12 a	11 a	21 a	22 a	21 a	20 a	31 a	29 a	25 b	25 b
S. D.	0.6	0.9	0.7	0.2	2.2	2.8	2.1	0.8	0.8	2.6	0.6	0.7

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	35	36	35	32	47	42	36	35	50	42	38	37
Rep 2	40	35	32	29	46	45	35	34	54	42	39	31
Rep 3	40	39	32	28	42	41	21	31	42	48	32	31
Avg.	38 a	37 a,b	33 b,c	30 c	45 a	43 a	31 b	33 b	49 a	44 a,b	36 b,c	33 c
S. D.	2.2	1.7	1.7	1.6	2.9	1.9	7.2	1.9	4.8	2.7	3.3	2.7

[a]. Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 17. Effect of EC of four water qualities on average plant height [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	33	31	29	32	45	41	33	31	48	50	35	36
Rep 2	36	34	32	28	44	43	35	27	43	39	32	32
Rep 3	34	31	33	24	43	35	36	34	51	50	53	31
Avg.	34 a	32 a,b	31 a,b	28 b	44 a	40 a,b	35 b,c	31 c	47 a	46 a,b	40 a,b	33 b
S. D.	1.2	1.7	1.8	3.5	0.8	3.5	1.2	2.9	3.0	5.4	9.0	2.4

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	cm							
Rep 1	---	53	42	47	64	---	61	49
Rep 2	62	55	44	31	66	---	50	37
Rep 3	57	51	49	31	68	---	56	42
Avg.	59 a	53 a,b	45 b,c	37 c	67 a	---	56 b	43 c
S. D.	2.5	1.6	3.2	7.6	1.5	---	4.6	4.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 18. Effect of EC of four water qualities on average plant height [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	18	20	13	16	31	34	21	20	38	38	26	27
Rep 2	27	15	11	12	47	34	25	24	67	36	34	27
Rep 3	19	17	18	12	39	32	26	23	47	36	29	25
Avg.	21 a	18 a,b	14 b	13 b	39 a	33 a	24 b	22 b	50 a	36 a,b	30 b	26 b
S. D.	3.9	2.2	3.0	2.0	6.7	1.1	2.0	1.6	11.8	0.9	3.1	1.0

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	47	50	28	33	47	47	38	44	58	56	39	41
Rep 2	64	43	40	34	71	59	39	36	67	58	46	37
Rep 3	56	41	35	36	55	47	47	41	58	53	39	40
Avg.	56 a	45 b	34 c	34 b,c	57 a	51 a,b	41 b	41 b	61 a	56 a	42 b	39 b
S. D.	6.6	3.6	4.8	1.3	9.8	5.6	3.9	3.1	4.3	1.8	3.3	1.9

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

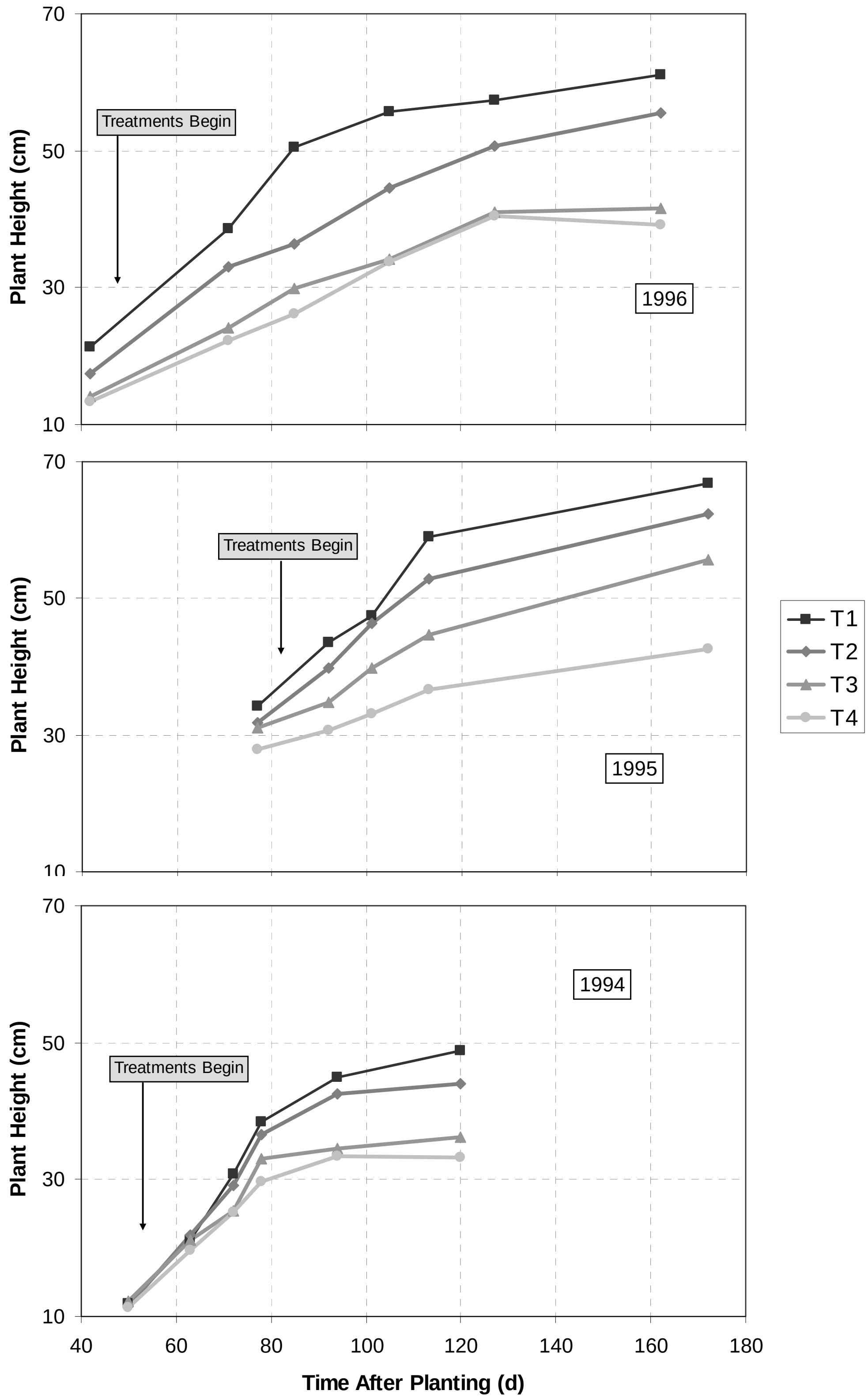

Figure 37. Mean plant height as a function of days after planting and water quality for 1994-1996.

Nodes

The production of nodes was affected by the EC level but not to the same extent as plant height. A summary showing final nodal count is given in table 19. Tables 20 to 22 show node numbers throughout the 1994, 1995, and 1996 seasons, respectively, and figure 38 shows the node production for the four treatments and for the three years of the study.

Table 19. Final average node count [a] for the four EC treatments, 1994-1996.

	T1	T2	T3	T4
1994	20.1	20.1	18.4	16.8
1995	20.7	---	18.7	14.5
1996	18.4	17.2	14.1	15.0
Avg.	19.7 [a]	18.7 [a,b]	17.1 [a,b]	15.4 [b]
S.D.	1.19	2.05	2.57	1.21

[a] Within the four treatments, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.

Approximately 90 to 110 DAP node production flattened. However, even before this, point node production, which should normally be about a node every 3 or 4 d, was slow, especially during Years 2 and 3. In Year 1, the nodal production rate was nearly at expected levels of about one every 3 or 4 d. In Year 2 and 3, the rate of node production was lower than in Year 1. The average total nodal production for all treatments was 19, 18 and 16 for Years 1, 2 and 3, respectively. In Year 2, the nodal numbers on the T3 and T4 decreased slightly between counts at DAP 101 and 113. This should not occur and probably is an artifact of identifying small nodal scars on older cotton stalks.

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Table 20. Effect of EC of four water qualities on average number of nodes [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	nodes											
Rep 1	8.3	7.5	7.3	6.8	10.0	11.7	11.2	10.2	14.5	13.5	15.0	13.5
Rep 2	7.7	7.2	8.5	7.2	13.3	11.0	13.5	10.0	15.2	14.5	14.0	13.8
Rep 3	8.2	7.7	9.2	6.7	13.0	11.3	13.0	12.1	15.3	13.7	14.5	14.5
Avg.	8.1 a	7.4 a,b,c	8.3 a,b	6.9 c	12.1 a	11.3 a	12.6 a	10.8 a	15.0 a	13.9 b,c	14.5 a,c	13.9 c
S. D.	0.3	0.2	0.8	0.2	1.5	0.3	1.0	1.0	0.4	0.4	0.4	0.4

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	nodes											
Rep 1	15.8	16.2	15.5	15.7	17.8	17.1	16.9	16.3	20.8	20.3	19.0	16.3
Rep 2	17.2	15.0	15.5	15.0	17.4	19.2	16.7	16.9	20.7	19.2	18.2	17.2
Rep 3	16.5	15.0	16.7	14.5	16.5	17.5	15.9	15.6	18.7	20.7	18.0	17.0
Avg.	16.5 a	15.4 a,b	15.9 a,b	15.1 b	17.3 a,b	17.9 b	16.5 a,b	16.3 a	20.1 a	20.1 a	18.4 b	16.8 c
S. D.	0.5	0.6	0.6	0.5	0.7	1.0	0.4	0.6	1.0	0.7	0.4	0.4

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 21. Effect of EC of four water qualities on average number of nodes [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---- nodes ----											
Rep 1	14.3	14.5	14.5	14.3	16.8	15.3	14.3	15.2	17.8	18.0	14.5	16.0
Rep 2	13.7	15.3	13.2	13.7	17.0	16.8	16.0	14.2	16.5	15.3	14.2	14.2
Rep 3	14.8	13.3	13.2	13.7	16.2	16.0	15.2	14.8	19.0	17.3	19.8	15.0
Avg.	14.3 [a]	14.4 [a]	13.6 [a]	13.9 [a]	16.7 [a]	16.1 [a,b]	15.2 [b,c]	14.7 [c]	17.8 [a]	16.9 [a]	16.2 [a]	15.1 [a]
S. D.	0.4	0.8	0.6	0.3	0.4	0.6	0.7	0.4	1.0	1.1	2.6	0.7

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	---- nodes ----							
Rep 1	---	18.2	15.7	16.7	19.7	---	19.5	18.5
Rep 2	19.0	17.8	14.2	12.5	19.0	---	18.7	15.8
Rep 3	18.0	18.4	17.5	14.8	20.7	---	18.7	14.5
Avg.	18.5 [a]	18.1 [a,b]	15.8 [a,b,c]	14.7 [c]	19.8 [a]	---	18.9 [a]	16.3 [b]
S. D.	8.7	0.2	1.4	1.7	0.7	---	0.4	1.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 22. Effect of EC of four water qualities on average number of nodes [a] and their SD as a function of days after planting (DAP) in Year 1, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	nodes											
Rep 1	8.5	9.7	8.5	9.0	12.8	14.2	10.4	10.8	16.3	16.3	14.0	15.0
Rep 2	10.3	7.7	7.2	7.7	13.8	14.6	14.2	11.8	17.0	15.3	16.4	14.0
Rep 3	8.7	9.7	8.9	7.0	14.4	13.8	12.0	14.6	15.7	14.8	13.3	13.3
Avg.	9.2 [a]	9.0 [a]	8.2 [a]	7.9 [a]	13.7 [a]	14.2 [a]	12.2 [a]	12.4 [a]	16.3 [a]	15.5 [a,b]	14.6 [a,b]	14.1 [b]
S. D.	0.8	0.9	0.7	0.8	0.7	0.3	1.6	1.6	0.5	0.6	1.3	0.7

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	nodes											
Rep 1	17.3	17.0	14.2	15.7	15.3	17.8	16.2	15.5	17.5	17.3	13.8	15.8
Rep 2	17.3	17.2	16.5	15.8	18.7	17.7	15.7	14.3	20.2	17.5	15.7	14.0
Rep 3	17.5	16.5	14.8	16.0	16.7	16.2	17.8	15.3	17.5	16.8	13.0	15.2
Avg.	17.4 [a]	16.9 [a,b]	15.2 [b,c]	15.8 [b,c]	16.9 [a]	17.2 [a]	16.6 [a]	15.1 [a]	18.4 [a]	17.2 [a]	14.1 [b]	15.0 [b]
S. D.	0.1	0.3	1.0	0.1	1.4	0.7	0.9	0.5	1.3	0.3	1.1	0.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

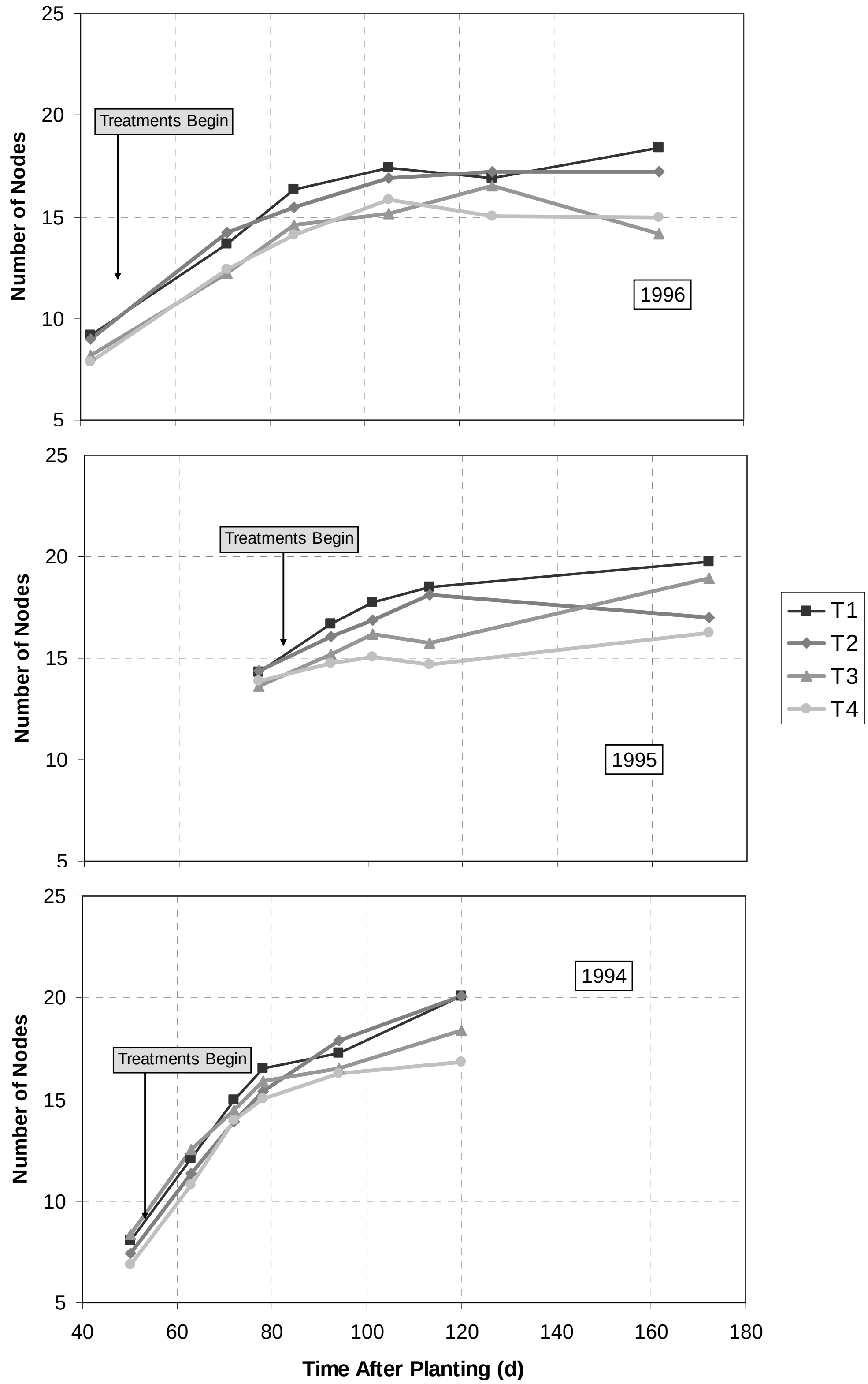

Figure 38. Mean total node number as a function of days after planting and water quality for 1994-1996.

Internode Length

Because height and node number were both affected by the EC treatments in a similar fashion (i.e., T1 > T2 > T3 > T4), the internodal length, which is a total height divided by total number of nodes, will likewise also exhibit these trends. Significant statistical differences among treatments for internodal length became apparent first on 72 DAP of Year 1, 16 days after treatments started. Hereafter, differences in the T1 versus T4 treatments was observed. Again, this occurred in Years 2 and 3 prior to the initiation of EC treatments. The T1 internodal length became statistically significantly longer then the T4 length within 16 d of the first application of salinized water. It was 6 d later that it was observed in the T1 versus T3 internodal length. Likewise, T1 and T3 internodal remained significant at the 5% level for the duration of the study.

In the three years of the study and throughout the 18 comparisons made, T2 was only statistically significantly different from the T3 treatment four times and significantly different to the T4 treatment six times. In Year 3 on the final plant mapping, T3 internodal length was statistically significantly longer than the T4 treatment. This may be partial proof that the crop-soil-water-salinity equilibrium had not yet been reached, as discussed by Solomon (1985) and Longenecker and Lyerly (1959), and that the T3 and T4 treatments would perhaps continue to show differences if this study was continued longer. Tables 23 to 25 show the average internodal length for the various treatments for the three years of the study. Healthy, nonstressed cotton should have internodal lengths between 5-8 cm (Phipps, 1982). These results show that the highest rate of measured internodal length was 3.4 cm, which occurred in the T1 treatment during Year 2 and 3. Figure 39 shows the internodal length for the four treatments during the three years of the study.

Table 23. Effect of EC of four water qualities on average internodal length [a] and their SD as a function of days after planting (DAP) in Year 1, 1994

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	1.5	1.5	1.8	1.6	1.8	1.7	1.7	1.9	2.0	1.9	1.7	1.8
Rep 2	1.4	1.5	1.3	1.5	1.7	1.9	1.6	2.1	2.0	2.2	1.9	1.9
Rep 3	1.5	1.6	1.4	1.7	1.7	2.3	1.8	1.5	2.1	2.3	1.7	1.7
Avg.	1.5 a	1.5 a	1.5 a	1.6 a	1.7 a	1.9 a	1.7 a	1.8 a	2.1 a,b	2.1 a	1.8 c	1.8 b,c
S. D.	0.0	0.1	0.2	0.1	0.0	0.3	0.1	0.2	0.0	0.2	0.1	0.1

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	2.2	2.2	2.3	2.0	2.7	2.4	2.1	2.1	2.4	2.1	2.0	2.3
Rep 2	2.3	2.3	2.0	1.9	2.6	2.3	2.1	2.0	2.6	2.2	2.2	1.8
Rep 3	2.4	2.6	1.9	1.9	2.5	2.4	1.3	2.0	2.3	2.3	1.8	1.8
Avg.	2.3 a	2.4 a,b	2.1 a,b,c	2.0 c	2.6 a	2.4 a,b	1.8 b,c	2.0 c	2.4 a	2.2 a,b	2.0 b	2.0 b
S. D.	0.1	0.2	0.1	0.0	0.1	0.1	0.4	0.1	0.1	0.1	0.2	0.2

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 24. Effect of EC of four water qualities on average internodal length [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	2.3	2.1	2.0	2.2	2.7	2.7	2.3	2.0	2.7	2.8	2.4	2.3
Rep 2	2.6	2.2	2.4	2.0	2.6	2.6	2.2	1.9	2.6	2.5	2.3	2.2
Rep 3	2.3	2.3	2.5	1.7	2.6	2.2	2.4	2.3	2.7	2.9	2.6	2.1
Avg.	2.4 a	2.2 a,b	2.3 a,b	2.0 b	2.6 a	2.5 a,b	2.3 a,b,c	2.1 c	2.7 a,b	2.7 a	2.4 b,c	2.2 c
S. D.	0.2	0.1	0.2	0.2	0.0	0.2	0.1	0.2	0.0	0.2	0.2	0.1

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	cm							
Rep 1	---	2.9	2.6	2.8	3.3	---	3.1	2.6
Rep 2	3.2	3.1	3.1	2.5	3.5	---	2.7	2.4
Rep 3	3.1	2.8	2.8	2.1	3.3	---	3.0	2.9
Avg.	3.2 a	2.9 a,b	2.8 a,b	2.5 b	3.4 a	---	2.9 b	2.6 b
S. D.	1.5	0.1	0.2	0.3	1.6	---	0.2	0.2

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 25. Effect of EC of four water qualities on average internodal length [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---------- cm ----------											
Rep 1	2.1	2.1	1.6	1.8	2.4	2.4	2.1	1.9	2.3	2.3	1.9	1.8
Rep 2	2.6	1.9	1.5	1.6	3.4	2.3	1.8	2.0	3.9	2.3	2.1	1.9
Rep 3	2.2	1.8	2.1	1.7	2.7	2.3	2.2	1.6	3.0	2.4	2.2	1.9
Avg.	2.3 [a]	1.9 [a,b]	1.7 [b]	1.7 [b]	2.8 [a]	2.3 [a,b]	2.0 [b]	1.8 [b]	3.1 [a]	2.4 [a,b]	2.1 [b]	1.9 [b]
S. D.	0.2	0.1	0.2	0.1	0.4	0.0	0.2	0.2	0.6	0.1	0.1	0.0

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---------- cm ----------											
Rep 1	2.7	2.9	2.0	2.1	3.1	2.6	2.3	2.8	3.3	3.2	2.8	2.6
Rep 2	3.7	2.5	2.4	2.1	3.8	3.3	2.5	2.5	3.3	3.3	2.9	2.6
Rep 3	3.2	2.5	2.4	2.2	3.3	2.9	2.6	2.7	3.3	3.2	3.0	2.6
Avg.	3.2 [a]	2.6 [b]	2.2 [b]	2.1 [b]	3.4 [a]	2.9 [a,b]	2.5 [b]	2.7 [b]	3.3 [a]	3.2 [a]	2.9 [b]	2.6 [c]
S. D.	0.4	0.2	0.2	0.1	0.3	0.3	0.1	0.1	0.0	0.1	0.1	0.0

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

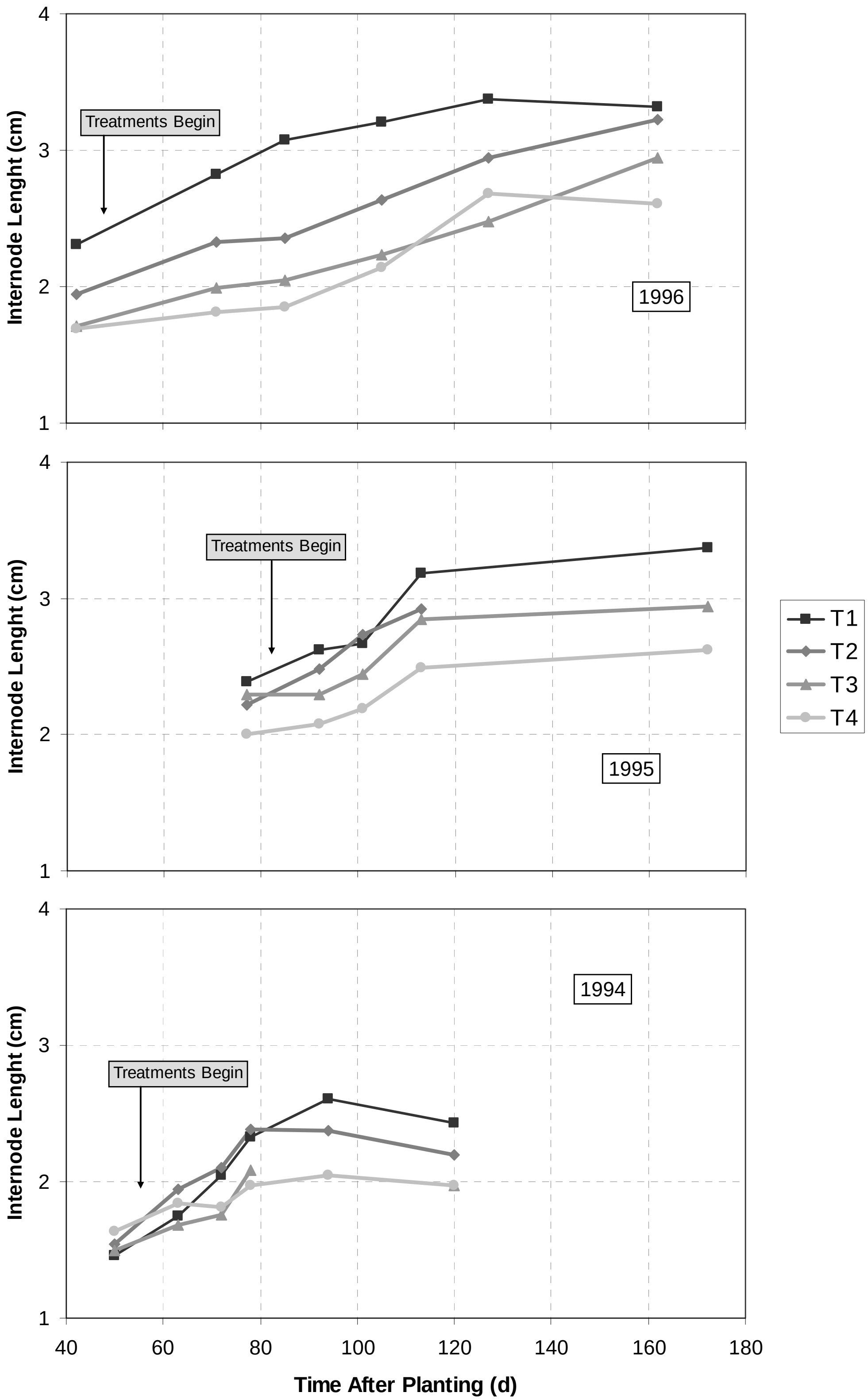

Figure 39. Mean internodal length as a function of days after planting and water quality for 1994-1996.

Fruit Production

Green boll production for Years 1, 2 and 3 is given in tables 26 to 28 and plotted in figure 40. Total fruit, which includes squares, green bolls and open bolls, for the same years are given in tables 29 to 31, and graphed in figure 41. When fruiting positions of a cotton plant are counted and divided by the total fruit count, the result yields the percent fruit set. Subtracting this number from unity gives the percentage of abscised fruit positions. Tables 32 to 34 show abscised positions for the growing season for Years 1 through 3, and the graphical representation of this data is shown in figure 42.

Increase of abscised fruiting positions during the growing season mostly likely stems from the continued deficit water conditions experienced by the cotton plants. Starting at early squaring, abscission rates were only 10 to 25%, even for the T3 and T4 treatments. However, at the end of the growing, final abscission rate was about 60 to 65%, regardless of treatments.

While the T1 and T2 treatments produced more fruit than those of the saltier treatments, which could lead to their higher lint yields, their retention rate was similar to the saltier treatments as shown in tables 32 through 34. These results indicate that when cotton is exposed to both water and salt stress, the abscission rate is no greater than when water stress acts alone. The limiting factor of cotton suffering both water and salinity stress was that fruit set was limited.

Table 26. Effect of EC of four water qualities on mean green boll number [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---- bolls ----											
Rep 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	1.0	0.8
Rep 2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.8	0.5	0.3	0.8
Rep 3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.8	1.2	1.2	0.3
Avg.	0.0 a	0.0 a	0.0 a	0.0 a	0.1 a	0.1 a	0.0 a	0.1 a	1.1 a	0.6 a	0.8 a	0.7 a
S. D.	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.6	0.4	0.4	0.2

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---- cm ----											
Rep 1	2.8	2.7	3.0	5.0	5.8	7.3	5.5	5.7	3.0	3.0	3.0	1.7
Rep 2	1.8	1.7	3.2	2.3	6.2	8.4	7.0	6.3	3.8	3.7	1.0	2.5
Rep 3	2.0	1.7	4.3	3.3	5.4	8.4	5.2	5.1	2.3	2.3	2.3	0.7
Avg.	2.2 a	2.0 a	3.5 a	3.6 a	5.8 a	8.0 b	5.9 a,c	5.7 a,c	3.1 a	3.0 a	2.1 a	1.6 a
S. D.	0.4	0.5	0.6	1.1	0.8	1.2	0.9	0.8	0.6	0.5	0.8	0.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 27. Effect of EC of four water qualities on mean green boll number [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	--- bolls ---											
Rep 1	0.5	1.3	1.2	0.2	4.7	6.3	7.3	6.2	10.0	9.0	6.7	8.2
Rep 2	0.8	0.5	1.3	0.7	5.3	6.5	8.0	2.8	8.0	6.7	5.7	6.3
Rep 3	1.3	0.2	0.3	0.7	4.0	5.3	4.0	6.8	11.0	9.0	10.8	6.5
Avg.	0.9 a	0.7 a	0.9 a	0.5 a	4.7 a	6.1 a	6.4 a	5.3 a	9.7 a	8.2 a	7.7 a	7.0 a
S. D.	0.3	0.5	0.4	0.2	0.5	0.5	1.7	1.8	1.2	1.1	2.2	0.8

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	--------------------------------------- bolls ---------------------------------------							
Rep 1	---	7.3	8.3	13.5	0.0	---	0.0	0.3
Rep 2	9.0	10.2	6.0	4.0	0.5	---	0.0	0.3
Rep 3	11.3	10.6	5.5	9.8	0.3	---	0.0	0.3
Avg.	10.2 a	9.4 a	6.6 a	9.1 a	0.3 a	---	0.0 a	0.3 a
S. D.	4.9	1.5	1.2	3.9	0.2	---	0.0	0.0

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 28 Effect of EC of four water qualities on mean green boll number [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	bolls											
Rep 1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	2.8	2.8	3.3	1.8
Rep 2	0.0	0.0	0.0	0.0	1.0	1.4	0.0	0.0	5.0	2.3	2.2	2.3
Rep 3	0.0	0.0	0.0	0.0	1.0	0.0	0.8	0.0	3.2	2.5	1.8	2.2
Avg.	0.0 a	0.0 a	0.0 a	0.0 a	0.7 a	0.6 a	0.3 a	0.1 a	3.7 a	2.6 a,b	2.4 a,b	2.1 b
S. D.	0.0	0.0	0.0	0.0	0.5	0.6	0.4	0.2	1.0	0.2	0.6	0.2

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	bolls											
Rep 1	4.0	5.8	2.5	3.5	1.7	2.0	2.7	2.8	0.0	0.0	0.0	0.0
Rep 2	4.3	4.0	4.8	4.0	2.3	2.8	2.0	2.7	0.0	0.0	0.0	0.0
Rep 3	4.8	4.5	3.7	4.5	2.2	1.0	2.3	1.8	0.0	0.0	0.0	0.0
Avg.	4.4 a	4.8 a	3.7 a	4.0 a	2.1 a	1.9 a	2.3 a	2.4 a	0.0 a	0.0 a	0.0 a	0.0 a
S. D.	0.3	0.8	1.0	0.4	0.3	0.7	0.3	0.4	0.0	0.0	0.0	0.0

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

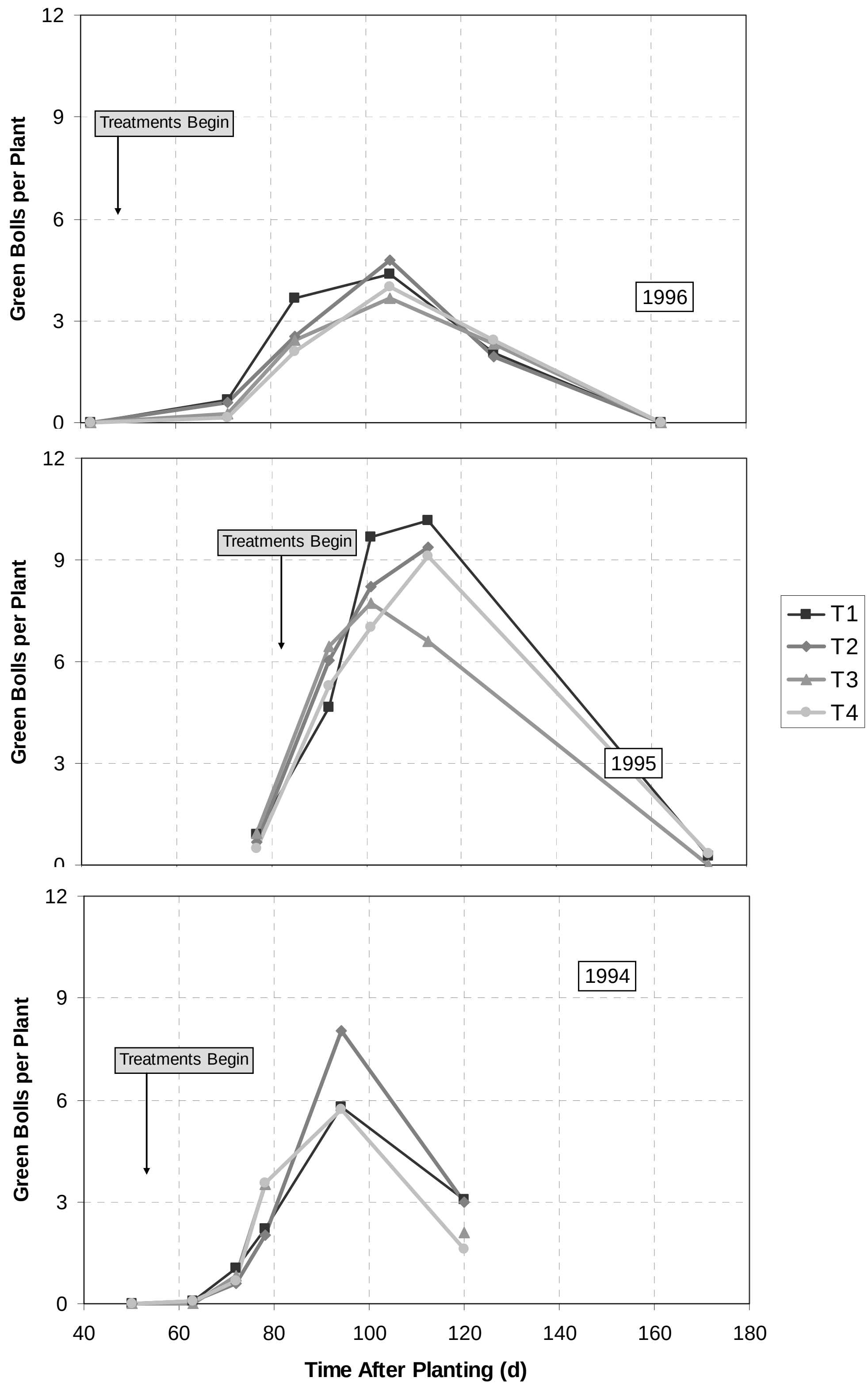

Figure 40. Mean green boll production as a function of days after planting and water quality for 1994-1996.

Table 29. Effect of EC of four water qualities on mean total fruit number [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	fruit											
Rep 1	0.0	0.0	0.0	0.0	5.3	4.0	6.5	5.0	7.5	7.7	12.8	11.0
Rep 2	0.0	0.0	0.0	0.0	7.0	4.8	8.3	4.7	9.0	9.3	9.3	9.3
Rep 3	0.0	0.0	0.0	0.0	7.5	6.0	6.2	5.1	10.5	7.8	10.0	8.0
Avg.	0.0 [a]	0.0 [a]	0.0 [a]	0.0 [a]	6.6 [a,b,c]	4.9 [a,c]	7.0 [b]	4.9 [c]	9.0 [a]	8.3 [a]	10.7 [a]	9.4 [a]
S. D.	0.0	0.0	0.0	0.0	0.9	0.8	1.0	0.2	1.2	0.8	1.5	1.2

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	fruit											
Rep 1	13.8	12.8	14.8	14.7	9.1	9.6	9.6	7.6	7.2	6.8	5.0	4.7
Rep 2	14.8	12.8	14.3	13.0	8.9	14.0	10.2	9.4	6.2	5.7	6.3	4.3
Rep 3	13.2	13.8	15.3	11.8	7.9	12.8	6.7	7.4	5.5	9.5	5.2	4.3
Avg.	13.9 [a]	13.2 [a]	14.8 [a]	13.2 [a]	8.6 [a]	12.1 [b]	8.8 [a]	8.1 [a]	6.3 [a,b]	7.3 [b]	5.5 [a,b]	4.4 [a]
S. D.	0.7	0.5	0.4	1.2	1.0	2.3	1.6	1.4	0.7	1.6	0.6	0.2

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 30. Effect of EC of four water qualities on mean total fruit number [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm											
Rep 1	9.5	12.5	9.8	10.7	15.7	15.8	10.2	12.3	11.7	13.3	8.5	9.5
Rep 2	11.5	10.3	8.2	9.2	13.7	16.0	12.0	6.8	11.8	9.0	6.0	8.2
Rep 3	10.2	8.5	8.7	8.7	13.0	15.2	10.0	10.2	16.5	11.8	16.2	8.7
Avg.	10.4 a	10.4 a	8.9 a	9.5 a	14.1 a	15.7 a	10.7 b	9.8 b	13.3 a	11.4 a	10.2 a	8.8 a
S. D.	0.8	1.6	0.7	0.8	1.1	0.4	0.9	2.3	2.2	1.8	4.3	0.5

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	fruit							
Rep 1	---	12.5	8.3	14.7	---	---	3.7	8.5
Rep 2	12.0	15.0	6.0	4.0	9.2	8.8	5.8	4.7
Rep 3	14.5	14.2	9.0	10.0	10.2	---	9.7	3.7
Avg.	13.3 a	13.9 a	7.8 a	9.6 a	9.7 a	8.8	6.4 a	5.6 a
S. D.	6.3	1.0	1.3	4.4	4.6	0.0	2.5	2.1

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 31. Effect of EC of four water qualities on mean total fruit number [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	fruit											
Rep 1	0.0	0.0	0.0	0.0	10.0	18.6	6.8	5.2	12.8	10.2	11.8	11.8
Rep 2	0.0	0.0	0.0	0.0	15.2	19.6	12.4	7.4	14.0	12.5	12.8	7.7
Rep 3	0.0	0.0	0.0	0.0	15.8	12.6	10.8	11.4	10.0	10.8	7.2	7.2
Avg.	0.0 a	0.0 a	0.0 a	0.0 a	13.7 a,b	16.9 a	10.0 b	8.0 b	12.3 a	11.2 a	10.6 a	8.9 a
S. D.	0.0	0.0	0.0	0.0	2.6	3.1	2.4	2.6	1.7	1.0	2.5	2.1

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	fruit											
Rep 1	4.5	6.7	3.2	4.0	3.3	4.8	4.2	3.8	58.2	55.6	39.1	41.1
Rep 2	4.7	4.2	5.6	4.2	3.7	4.8	3.5	3.7	67.1	57.7	46.2	36.6
Rep 3	4.8	4.8	3.8	5.2	3.5	3.3	4.7	4.0	57.7	53.3	39.4	39.6
Avg.	4.7 a	5.2 a	4.2 a	4.4 a	3.5 a	4.3 a	4.1 a	3.8 a	61.0 a	55.5 a	41.6 b	39.1 b
S. D.	0.1	1.1	1.0	0.5	0.1	0.7	0.5	0.1	4.3	1.8	3.3	1.9

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

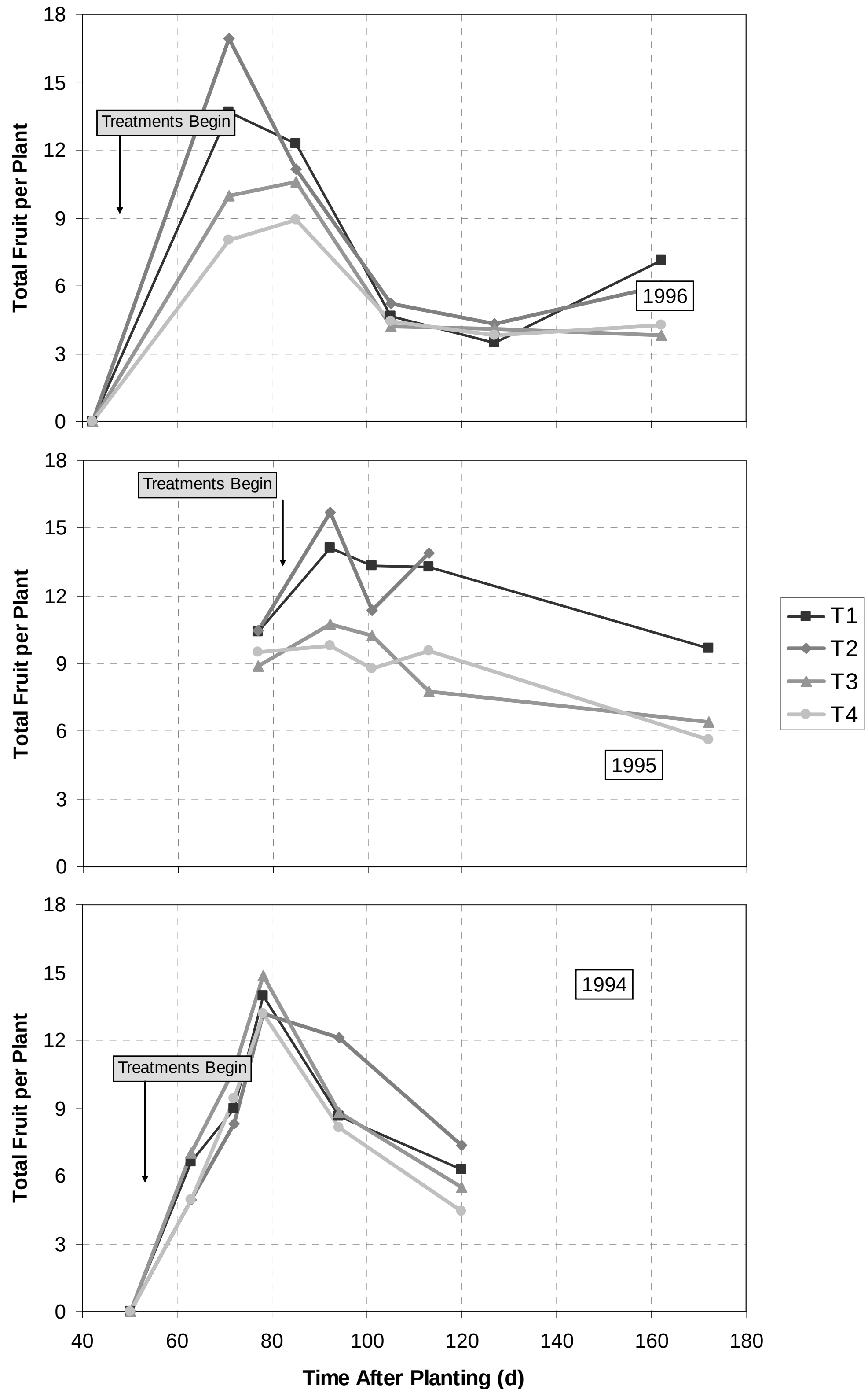

Figure 41. Mean total fruit production as a function of days after planting and water quality for 1994-1996.

Table 32. Effect of EC of four water qualities on mean fruit abscission percentage [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	%											
Rep 1	---	---	---	---	11.1	27.3	0.0	0.0	10.0	14.8	9.4	9.6
Rep 2	---	---	---	---	14.3	14.7	16.7	22.2	3.6	16.4	15.2	12.5
Rep 3	---	---	---	---	8.2	26.5	19.6	16.3	7.4	9.6	13.0	18.6
Avg.	---	---	---	---	11.2 a	22.8 a	12.1 a	12.8 a	7.0 a	13.6 a	12.5 a	13.6 a
S. D.	---	---	---	---	2.5	5.8	8.6	9.4	2.6	2.9	2.4	3.8

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	%											
Rep 1	12.6	13.5	6.3	9.3	35.2	31.2	25.8	40.5	67.2	66.9	71.2	65.0
Rep 2	16.0	11.5	9.5	7.1	35.8	28.1	34.0	35.0	67.8	67.3	63.1	71.4
Rep 3	26.2	12.6	17.9	11.3	31.4	23.2	39.0	40.8	66.0	59.6	62.7	66.7
Avg.	18.3 a	12.5 a	11.2 a	9.2 a	34.1 a,b	27.5 b	32.9 a,b	38.8 a	67.0 a	64.6 a	65.6 a	67.7 a
S. D.	5.8	0.8	4.9	1.7	3.7	4.2	5.7	5.7	0.8	3.6	3.9	2.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 33. Effect of EC of four water qualities on mean fruit abscission percentage [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	%											
Rep 1	8.1	3.9	23.4	15.8	16.8	7.8	20.8	19.6	32.0	18.4	29.2	26.0
Rep 2	5.5	15.1	21.0	14.1	18.0	7.7	16.3	24.1	21.2	19.4	35.7	19.7
Rep 3	18.7	7.3	23.5	10.3	16.1	7.1	11.8	25.6	12.4	26.8	23.6	21.2
Avg.	10.7 a,b	8.7 b	22.6 c	13.4 b	17.0 a	7.5 b	16.3 a	23.1 c	21.9 a	21.5 a	29.5 a	22.3 a
S. D.	5.7	4.7	1.2	2.3	0.8	0.3	3.7	2.6	8.0	3.8	4.9	2.7

DAP [b]	113				172			
	T1	T2	T3	T4	T1	T2	T3	T4
	%							
Rep 1	---	31.2	60.9	33.3	58.6	60.0	75.3	59.8
Rep 2	25.0	25.0	35.7	55.6	58.3	60.0	58.3	56.9
Rep 3	25.6	23.7	33.3	38.8	58.8	---	52.5	66.7
Avg.	25.3 a	26.6 a	43.3 a	42.6 a	58.6 a	60.0 a	62.0 a	61.1 a
S. D.	11.9	3.3	12.5	9.5	0.2	0.0	9.7	4.1

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 34. Effect of EC of four water qualities on mean fruit abscission percentage [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	%											
Rep 1	---	---	---	---	5.7	3.1	17.1	3.7	22.2	26.5	12.4	16.5
Rep 2	---	---	---	---	7.3	5.8	11.4	5.1	14.3	11.8	12.5	33.3
Rep 3	---	---	---	---	7.1	11.3	10.0	6.6	16.7	11.0	17.3	23.2
Avg.	---	---	---	---	6.7 a,b	6.7 b	12.8 c	5.1 b	17.7 a	16.4 a	14.1 a	24.3 a
S. D.	---	---	---	---	0.7	3.4	3.1	1.2	3.3	7.1	2.3	6.9

DAP [b]	105				127				162			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	%											
Rep 1	71.0	56.0	67.8	63.1	82.3	76.6	70.2	76.0	68.7	60.7	63.2	56.8
Rep 2	62.2	68.0	64.8	64.8	80.7	82.6	74.7	70.7	58.3	53.4	56.3	64.8
Rep 3	67.8	64.2	66.7	59.2	78.8	78.7	75.2	76.0	59.0	57.3	61.5	52.5
Avg.	67.0 a	62.7 a	66.4 a	62.4 a	80.6 a	79.3 a,b	73.4 b,c	74.2 c	62.0 a	57.1 a	60.3 a	58.0 a
S. D.	3.6	5.0	1.2	2.3	1.4	2.5	2.2	2.5	4.8	3.0	3.0	5.1

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

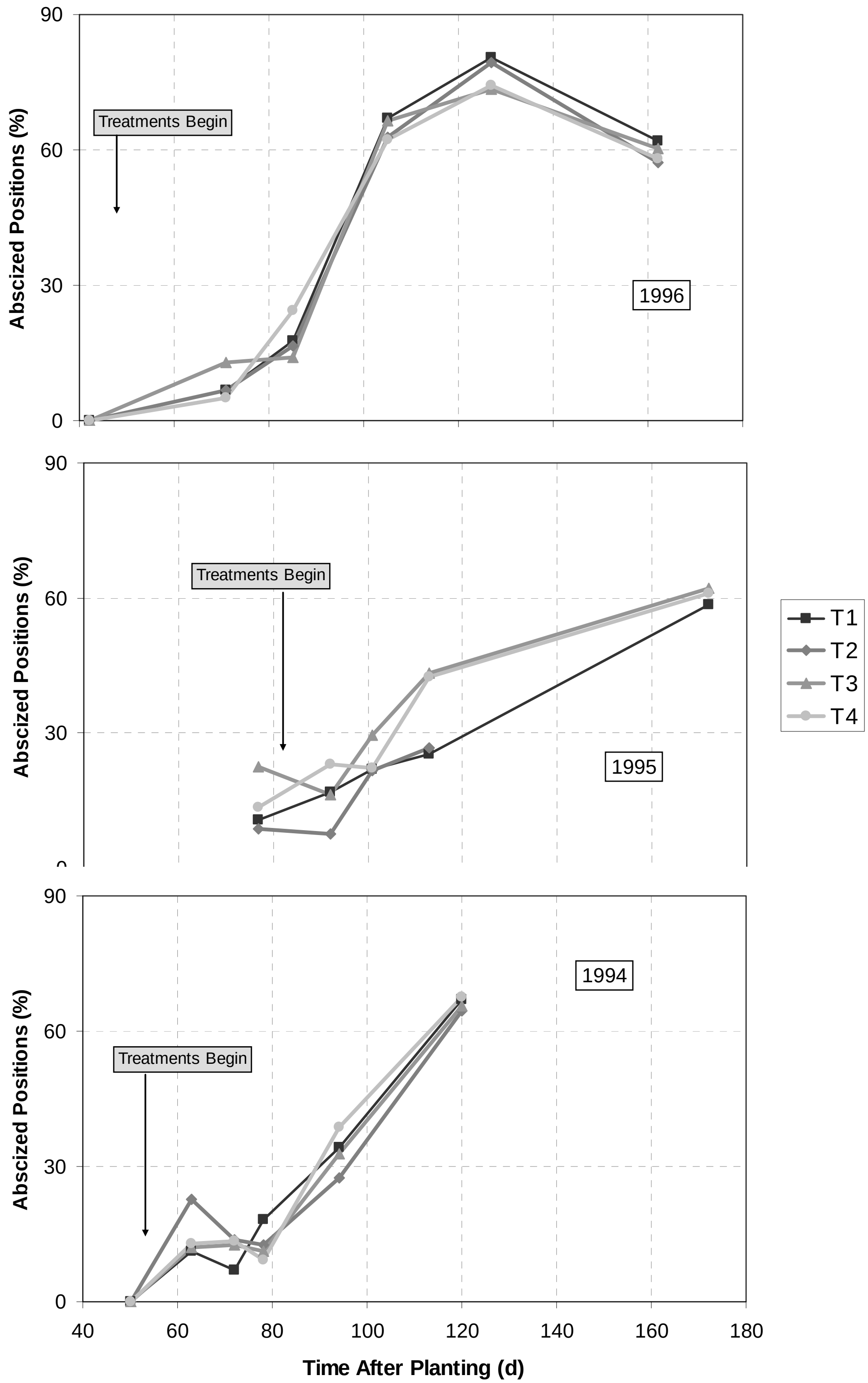

Figure 42. Fruit abscission as a function of days after planting and water quality for 1994-1996.

Leaf Area per Plant

Leaf area per plant was influenced by salinity levels. However, there was no carry over from year to year, and significant statistical differences were only found once treatment waters were applied (ca. 9 weeks after planting). This is in contrast to plant height, which showed significance statistical differences in Years 2 and 3 before salinity treatments started. Tables 35 to 37 include data on plant leaf area and results are also graphed in figure 43.

The T1 treatment consistently had the largest amount of leaf area per plant. However, even that treatment had relative small leaf areas per plant, as its LAI < 3. Under these water deficit and saline conditions it may be better to use smaller row widths and increase plant population (Unruh and Murphy, 2001). However, the traditional strategies for cotton, at least under deficit water conditions, are to increase row width or even use a skip pattern.

Mass of Various Plant Parts per Plant

Plant parts were separated into components, oven dried, and then weighed to determine mass of leaf, stems, and fruit parts per plant. These data were collected Year 1 and Year 2 of the study. It was found that leaf and stem mass were more sensitive than fruit mass. The reason for this was that the T3 and T4 treatments induced earliness that tended to set fruit earlier. Statistically significant differences in fruit mass were established only in two of 10 measurement periods for those two years. Stem mass had statistically significant differences five of 10 times, and leaf mass three of 10 times.

Leaf mass per plant for Years 1 and 2 are given in tables 38 and 39 with the data plotted in figure 44. The stem mass data is given in tables 40 and 41 and plotted in figure 45. Tables 42 and 43 include information on fruit dry mass, and are plotted in figure 46. Total above the ground dry mass per plant is shown in tables 44 and 45, and plotted in figure 47.

Table 35. Effect of EC of four water qualities on mean leaf area per plant [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm²											
Rep 1	142.2	110.7	120.2	93.3	259.3	211.9	265.0	200.5	428.8	396.8	407.3	340.2
Rep 2	118.5	101.7	144.8	103.0	235.6	287.2	338.2	289.5	507.0	509.0	439.7	378.8
Rep 3	136.8	125.7	163.5	90.7	268.8	258.5	191.6	269.2	480.7	399.4	383.0	350.3
Avg.	132.5 a,b	112.7 a,c	142.8 b	95.7 c	254.6 a	252.5 a	264.9 a	253.1 a	472.2 a	435.1 a,b	410.0 a,b	356.4 b
S. D.	10.1	9.9	17.7	5.3	14.0	31.0	59.8	38.1	32.5	52.3	23.2	16.3

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm²											
Rep 1	---	504.0	406.9	432.7	768.3	637.5	535.9	593.2	951.6	909.7	662.1	446.7
Rep 2	482.1	---	327.4	391.2	728.6	759.9	639.4	526.8	796.9	762.6	585.0	509.0
Rep 3	498.6	538.5	413.7	369.3	669.3	729.8	409.5	487.6	568.2	1008.6	487.7	431.5
Avg.	490.4 a	521.3 a	382.7 b	397.7 b	722.0 a	709.0 a	528.3 b	535.8 b	772.2 a,b	893.6 a	578.3 b,c	462.4 c
S. D.	8.3	17.3	39.2	26.3	40.7	52.1	94.0	43.6	157.5	101.1	71.4	33.5

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 36. Effect of EC of four water qualities on mean leaf area per plant [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77 [c]				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm²											
Rep 1	---	---	---	---	1168.7	750.2	523.9	667.5	1295.6	1095.3	479.5	1235.2
Rep 2	---	---	---	---	1077.8	828.2	636.2	369.3	1146.5	1104.6	626.6	426.3
Rep 3	---	---	---	---	747.8	770.0	867.6	968.8	1286.6	1507.2	1448.1	600.0
Avg.	---	---	---	---	998.1 a	782.8 a	675.9 a	668.6 a	1242.9 a	1235.7 a	851.4 a	753.8 a
S. D.	---	---	---	---	180.8	33.1	143.1	244.7	68.3	192.0	426.2	347.7

DAP [b]	113			
	T1	T2	T3	T4
	cm²			
Rep 1	1462.1	974.5	760.3	479.4
Rep 2	1404.2	1100.7	416.7	635.7
Rep 3	1618.5	1470.6	917.4	582.6
Avg.	1494.9 a	1181.9 a	698.1 b	565.9 b
S. D.	90.5	210.5	209.1	64.9

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.
[c] Missing data sheet.

Table 37. Effect of EC of four water qualities on mean leaf area per plant [a] and their SD as a function of days after planting (DAP) in Year 3, 1996.

DAP [b]	42				71				85			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	cm^2											
Rep 1	70.9	162.0	95.0	87.9	510.5	382.9	361.2	270.9	1100.5	619.7	350.6	518.7
Rep 2	222.0	37.3	64.5	35.6	1011.2	370.4	401.4	332.7	1102.9	507.7	426.4	426.0
Rep 3	108.2	142.0	127.4	40.0	584.0	358.8	284.8	392.8	1103.0	668.7	637.9	482.4
Avg.	133.7 a	113.8 a	95.6 a	54.5 a	701.9 a	370.7 b	349.1 b	332.1 b	1102.1 a	598.7 b	471.6 b	475.7 b
S. D.	64.3	54.7	25.7	23.7	220.8	9.9	48.4	49.8	1.1	67.4	121.6	38.1

DAP [b]	105				127			
	T1	T2	T3	T4	T1	T2	T3	T4
	cm^2							
Rep 1	919.3	923.6	346.9	630.8	884.9	692.9	471.3	559.3
Rep 2	1314.4	913.9	610.7	541.4	1728.5	693.6	528.5	399.3
Rep 3	1185.1	614.2	449.8	779.2	987.5	541.0	970.8	500.6
Avg.	1139.6 a	817.2 b	469.2 c	650.5 b,c	1200.3 a	642.5 b	656.9 b	486.4 b
S. D.	164.5	143.6	108.6	98.1	375.9	71.7	223.2	66.1

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

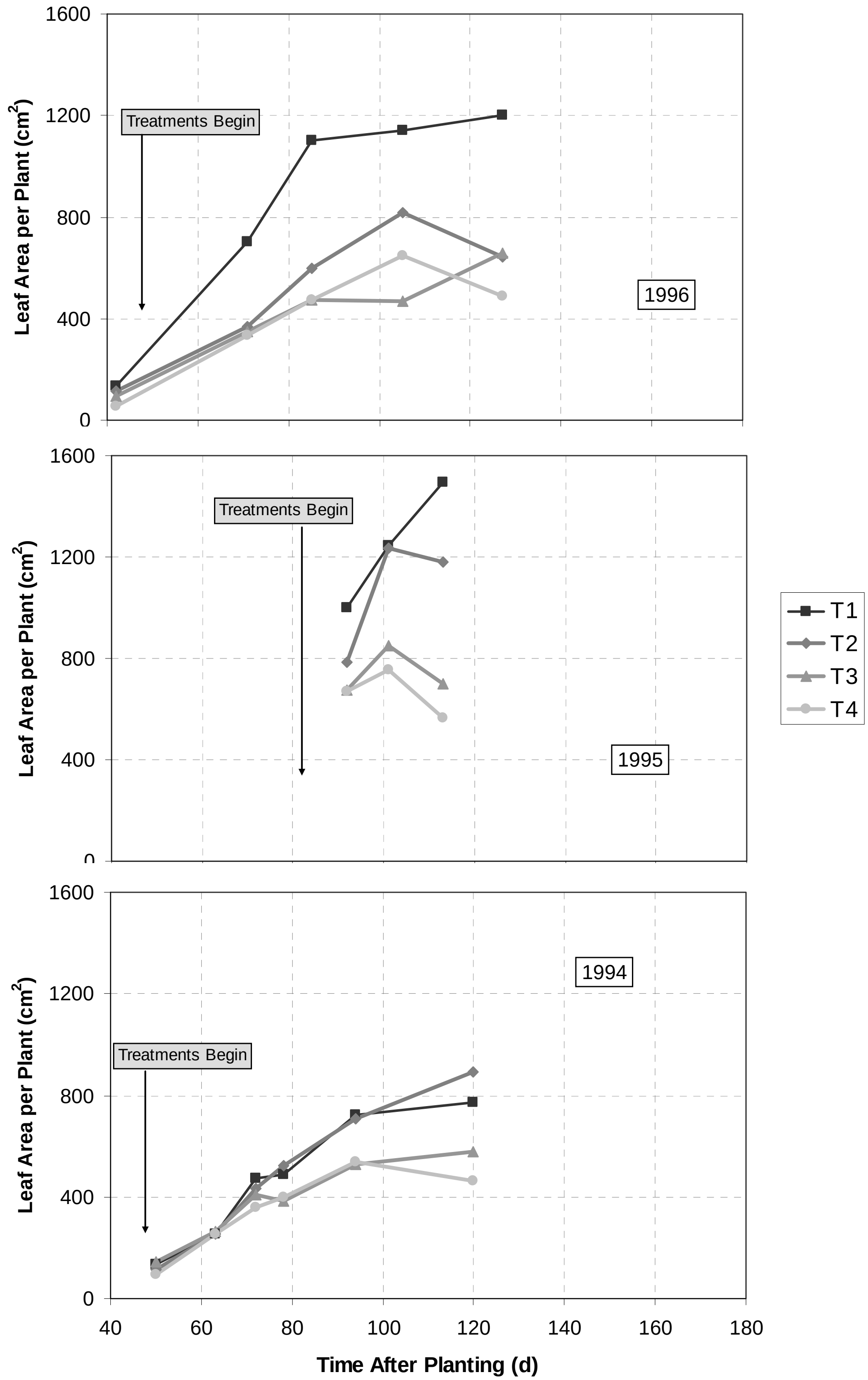

Figure 43. Leaf area per plant as a function of days after planting and water quality for 1994-1996.

LEAF WATER POTENTIAL (LWP)

More then 1100 LWP readings were taken during the three-year study (Appendix F). Tests included (1) replicated comparisons of treatments and (2) day-long evaluations of change in LWP for all four treatments (diurnal tests). The replicated comparisons had significantly different interactions 60% of the time. The diurnal evaluations indicated that solar noon LWP (LWP_{SN}) values were more likely to exhibit significance than were pre-dawn LWP values (LWP_{PD}). Leaf water potential values responded early in the growing season to the effect of salinity. Treatment water was applied the first year on 26 June and by 21 July significant differences in LWP values were measured.

Diurnal Nature

In the diurnal evaluations, LWP values of T1 were nested on top, followed by T2, T3 and then T4, as shown in figure 48. After dawn, LWP values decreased at a rate ≈ 0.01 MPa h^{-1} until about 1 h prior to solar noon. The "mid-day" LWP conditions were then in place for 2 or 3 h, and then values began to increase again. Since a diurnal pattern existed, time of day was an important factor in describing cotton LWP values. In all tests during the three-year study, the maximum in-test spread in LWP values among the four EC_{IW} treatments averaged 0.4 MPa and never exceeded 0.8 MPa. In contrast, the average fluctuation between LWP_{PD} and LWP_{SN} values (nearly always equal among all EC_{IW} treatments) was 1.5 MPa. Thus, the time-of-day response range in LWP was 4 x larger than the response range among EC_{IW} treatments. Without reference to time, EC_{IW} had little correlation to LWP (R^2 = 0.10). However, when LWP values are time-referenced (e.g., LWP_{PD} or LWP_{SN}), a strong relationship existed.

Table 38. Effect of EC of four water qualities on mean leaf mass per plant [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	1.3	---	1.0	0.0	2.2	1.6	2.3	2.0	2.7	3.3	0.0	2.6
Rep 2	0.7	---	0.9	0.8	3.0	2.2	2.7	2.3	4.2	3.9	3.4	3.3
Rep 3	0.9	1.0	0.9	0.9	2.4	2.5	2.5	2.2	4.1	3.7	4.1	2.9
Avg.	1.0 [a]	1.0	0.9 [a]	0.9 [a]	2.5 [a]	2.1 [a]	2.5 [a]	2.1 [a]	3.7 [a]	3.7 [a]	3.8 [a]	2.9 [a]
S. D.	0.3	0.0	0.0	0.0	0.3	0.4	0.2	0.1	0.7	0.3	0.3	0.3

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	3.2	3.8	3.7	3.6	6.1	5.9	4.9	5.2	50.3	42.3	37.7	37.0
Rep 2	3.9	3.1	3.5	3.2	5.6	7.5	6.0	4.9	53.7	41.8	39.3	31.2
Rep 3	3.5	4.3	3.6	3.0	5.5	7.0	4.6	4.9	42.3	47.8	31.7	31.3
Avg.	3.5 [a]	3.7 [a]	3.6 [a]	3.3 [a]	5.7 [a,b]	6.8 [a]	5.2 [b]	5.0 [b]	48.8 [a]	44.0 [a,b]	36.2 [b,c]	33.2 [c]
S. D.	0.3	0.5	0.1	0.2	0.6	0.9	0.7	0.2	4.8	2.7	3.3	2.7

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 39. Effect of EC of four water qualities on mean leaf mass per plant [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	4.8	5.6	5.2	5.0	9.2	7.1	6.6	6.8	24.5	21.8	8.4	20.9
Rep 2	5.4	4.8	5.2	4.6	9.2	8.1	6.2	3.7	23.3	18.0	11.3	6.5
Rep 3	5.1	4.0	4.3	3.4	6.4	7.3	6.9	6.8	23.1	35.4	30.7	11.4
Avg.	5.1^{a}	4.8^{a}	4.9^{a}	4.3^{a}	8.3^{a}	7.5^{a}	6.6^{a}	5.8^{a}	9.7^{a}	10.2^{a}	7.3^{a}	6.4^{a}
S. D.	0.2	0.7	0.4	0.7	1.3	0.4	0.3	1.4	0.6	7.5	9.9	6.0

DAP [b]	113			
	T1	T2	T3	T4
	g			
Rep 1	20.1	15.5	9.9	9.7
Rep 2	17.6	13.8	4.8	6.7
Rep 3	17.7	23.2	9.9	6.4
Avg.	11.2^{a}	9.7^{a}	6.0^{b}	4.8^{ba}
S. D.	1.1	4.1	2.4	1.5

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

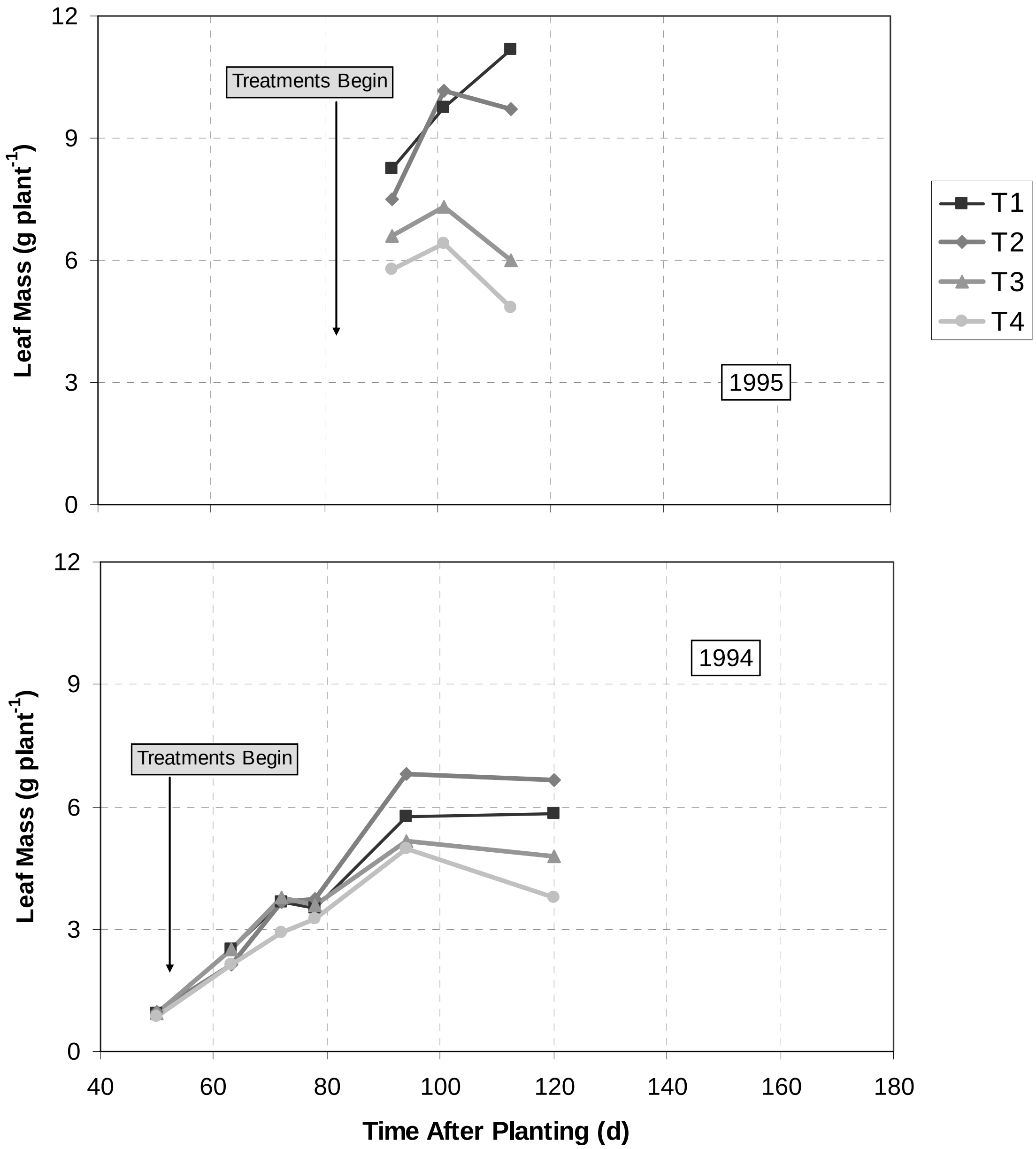

Figure 44. Leaf mass per plant as a function of days after planting and water quality for 1994 and 1995.

Table 40. Effect of EC of four water qualities on mean stem mass per plant [a] and their SD as a function of days after planting (DAP) in Year 3, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	0.6	---	0.4	0.0	1.3	1.1	1.3	1.2	2.3	2.4	2.2	2.0
Rep 2	0.4	---	0.5	0.4	2.1	1.4	1.7	1.5	3.2	3.3	2.5	2.5
Rep 3	0.5	0.5	0.3	0.5	1.8	2.1	1.9	1.3	2.9	2.8	2.8	2.2
Avg.	0.5 [a]	0.5	0.4 [a]	0.4 [a]	1.8 [a]	1.5 [a]	1.6 [a]	1.3 [a]	2.8 [a]	2.8 [a]	2.5 [a]	2.2 [a]
S. D.	0.1	0.0	0.1	0.0	0.3	0.4	0.2	0.1	0.4	0.4	0.2	0.2

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	3.4	4.4	4.3	4.4	5.7	5.3	4.0	4.1	6.2	5.1	3.5	3.1
Rep 2	3.4	3.6	3.8	3.7	5.7	6.7	5.0	4.0	6.1	4.4	4.2	2.8
Rep 3	3.4	5.2	3.7	3.7	4.7	6.2	3.6	3.8	3.5	6.0	2.6	2.4
Avg.	3.4 [a]	4.4 [b,c]	3.9 [a,c]	3.9 [a,c]	5.4 [a]	6.1 [a]	4.2 [b]	4.0 [b]	5.3 [a]	5.2 [a,b]	3.4 [a,b,c]	2.8 [c]
S. D.	0.0	0.7	0.3	0.3	0.6	0.8	0.7	0.3	1.2	0.6	0.7	0.3

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 41. Effect of EC of four water qualities on mean leaf mass per plant [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	3.7	4.9	4.6	4.6	7.9	7.1	6.7	5.4	16.5	13.8	6.4	15.5
Rep 2	4.8	4.0	4.7	3.9	7.7	7.1	5.6	3.4	16.5	17.2	8.8	5.4
Rep 3	4.5	2.9	3.6	2.6	6.2	6.0	5.5	6.2	15.2	26.5	19.2	7.9
Avg.	4.3 a	3.9 a	4.3 a	3.7 a	7.3 a	6.7 a,b	6.0 a,b	5.0 c	6.6 a	7.8 a	5.0 a	4.8 a
S. D.	0.4	0.8	0.5	0.8	0.8	0.5	0.6	1.2	0.6	5.4	5.5	4.3

DAP [b]	113			
	T1	T2	T3	T4
	g			
Rep 1	19.4	11.4	7.6	7.0
Rep 2	14.6	10.6	4.5	3.2
Rep 3	6.3	15.1	4.6	4.7
Avg.	6.6 a	6.9 a,b	4.1 b,c	3.1 c
S. D.	5.4	2.0	1.4	1.6

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

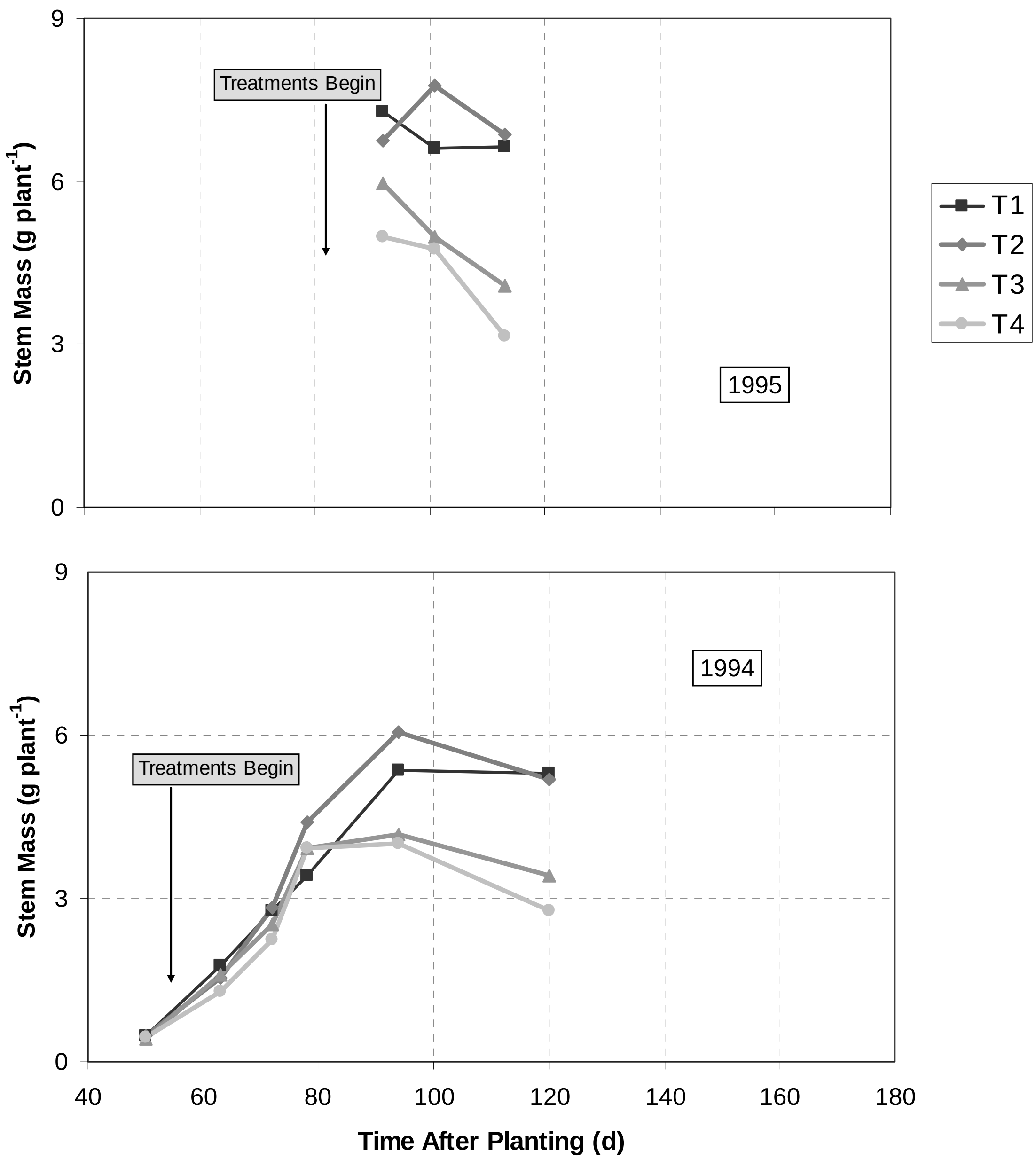

Figure 45. Stem mass per plant as a function of days after planting and water quality for 1994 and 1995

Table 42. Effect of EC of four water qualities on mean fruit mass per plant [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	0.0	---	0.0	0.0	0.3	0.2	0.3	0.2	0.5	0.7	0.6	0.6
Rep 2	0.0	---	0.0	0.0	0.5	0.3	0.3	0.4	1.1	0.9	0.8	0.8
Rep 3	0.0	0.0	0.0	0.0	0.4	0.3	0.6	0.3	1.5	1.0	1.3	0.7
Avg.	0.0	0.0	0.0	0.0	0.4 a	0.3 a	0.4 a	0.3 a	1.0 a	0.9 a	0.9 a	0.7 a
S. D.	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.4	0.1	0.3	0.1

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	1.5	1.8	1.9	2.8	18.4	16.8	12.2	18.4	13.1	18.8	13.9	11.7
Rep 2	1.1	1.0	2.2	1.5	16.0	20.1	19.1	14.8	14.8	15.2	15.7	13.0
Rep 3	1.2	1.3	2.6	2.5	17.1	21.6	13.9	13.6	9.9	18.1	10.0	9.6
Avg.	1.3 a	1.4 a	2.2 b	2.2 b	17.2 a	19.5 a	15.1 a	15.6 a	12.6 a	17.4 b	13.2 a,b,c	11.4 a,c
S. D.	0.1	0.3	0.3	0.5	2.1	2.8	3.1	2.8	2.0	1.6	2.4	1.4

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 43. Effect of EC of four water qualities on mean fruit mass per plant [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	1.0	1.3	1.7	1.0	12.6	15.9	24.4	20.7	80.1	82.5	38.4	109.6
Rep 2	1.3	1.0	2.1	0.8	18.8	18.3	31.3	11.6	83.7	59.7	47.8	24.9
Rep 3	1.0	0.8	0.7	0.7	10.2	15.5	7.9	26.3	85.1	118.7	88.8	49.7
Avg.	1.1 a	1.0 a	1.5 a	0.9 a	13.9 a	16.6 a	21.2 a	19.5 a	34.2 a	35.2 a	25.4 a	30.5 a
S. D.	0.2	0.2	0.6	0.1	3.6	1.2	9.8	6.1	2.1	24.3	21.9	35.6

DAP [b]	113			
	T1	T2	T3	T4
	g			
Rep 1	97.6	31.6	39.4	31.4
Rep 2	32.6	24.5	15.6	15.6
Rep 3	44.7	59.1	21.9	18.8
Avg.	24.5 a	21.3 a	18.7 a	13.9 a
S. D.	28.2	14.9	10.1	6.8

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

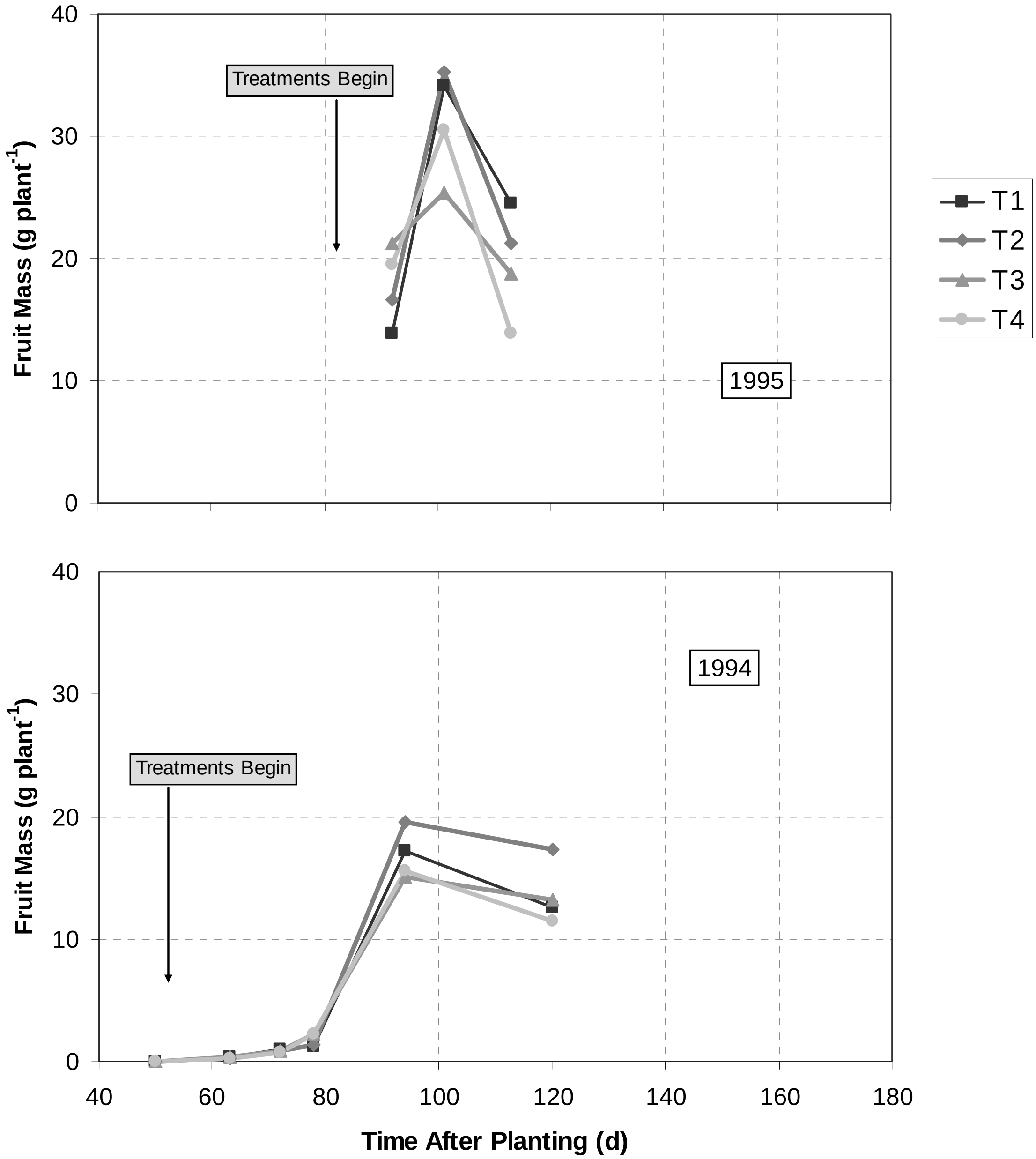

Figure 46. Fruit mass per plant as a function of days after planting and water quality for 1994 and 1995.

Table 44. Effect of EC of four water qualities on mean total mass per plant [a] and their SD as a function of days after planting (DAP) in Year 1, 1994.

DAP [b]	50				63				72			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	1.9	---	1.4	0.0	3.9	2.9	3.9	3.3	5.4	6.5	2.8	5.2
Rep 2	1.0	---	1.4	1.2	5.7	3.9	4.7	4.2	8.5	8.1	6.8	6.6
Rep 3	1.4	1.5	1.2	1.4	4.6	4.9	4.9	3.7	8.6	7.4	8.2	5.8
Avg.	1.4 a	1.5	1.3 a	0.9 a	4.7 a	3.9 a	4.5 a	3.7 a	7.5 a	7.3 a	6.0 a	5.8 a
S. D.	0.3	---	0.1	0.6	0.7	0.8	0.4	0.3	1.5	0.7	2.3	0.6

DAP [b]	78				94				120			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	g											
Rep 1	8.1	10.0	9.9	10.7	30.2	28.0	21.1	27.7	25.8	31.0	22.9	18.7
Rep 2	8.4	7.6	9.5	8.4	27.3	34.2	30.1	23.7	27.6	25.3	24.8	19.9
Rep 3	8.1	10.9	9.9	9.2	27.3	34.8	22.0	22.4	17.7	31.29	16.6	15.3
Avg.	8.2 a	9.5 a	9.8 a	9.4 a	28.3 a,b	32.4 a	24.4 b	24.6 b	23.7 a,b	29.2 b	21.4 a,b	18.0 a
S. D.	0.1	1.4	0.2	1.0	3.1	3.9	4.3	3.1	4.3	2.8	3.5	1.9

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

Table 45. Effect of EC of four water qualities on mean total mass per plant [a] and their SD as a function of days after planting (DAP) in Year 2, 1995.

DAP [b]	77				92				101			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
	---- g ----											
Rep 1	1.0	1.3	1.7	1.0	12.6	15.9	24.4	20.7	80.1	82.5	38.4	109.6
Rep 2	1.3	1.0	2.1	0.8	18.8	18.3	31.3	11.6	83.7	59.7	47.8	24.9
Rep 3	1.0	0.8	0.7	0.7	10.2	15.5	7.9	26.3	85.1	118.7	88.8	49.7
Avg.	1.1 a	1.0 a	1.5 a	0.9 a	13.9 a	16.6 a	21.2 a	19.5 a	34.2 a	35.2 a	25.4 a	30.5 a
S. D.	0.2	0.2	0.6	0.1	3.6	1.2	9.8	6.1	2.1	24.3	21.9	35.6

DAP [b]	113			
	T1	T2	T3	T4
	---- g ----			
Rep 1	97.6	31.6	39.4	31.4
Rep 2	32.6	24.5	15.6	15.6
Rep 3	44.7	59.1	21.9	18.8
Avg.	24.5 a	21.3 a	18.7 a	13.9 a
S. D.	28.2	14.9	10.1	6.8

[a] Within the four treatments for each DAP, differences are significant at the 5% level (Duncan's multiple test range) if the same letter does not appear.
[b] Days after planting.

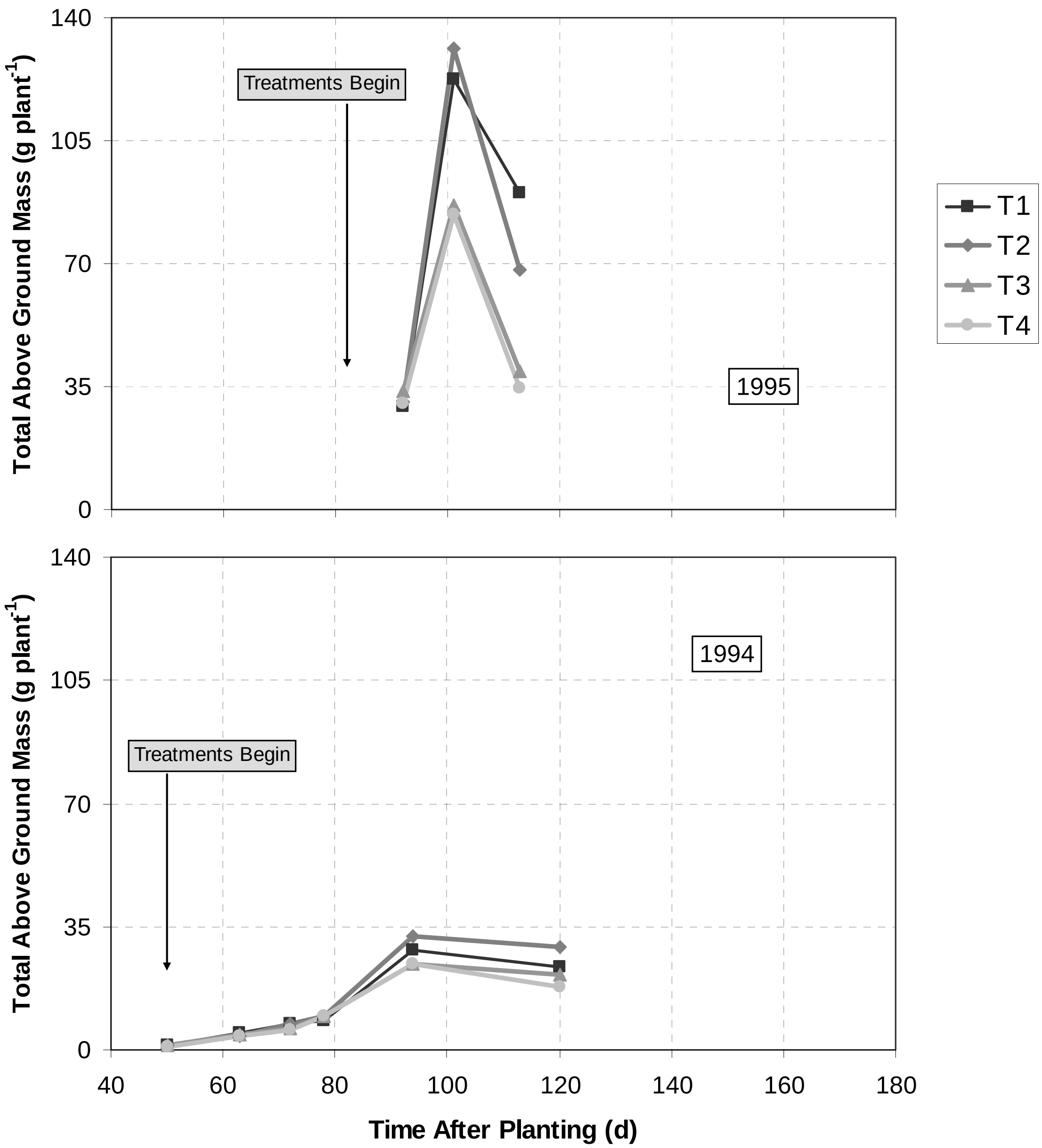

Figure 47. Mean total above ground mass per plant as a function of days after planting and water quality for 1994 and 1995.

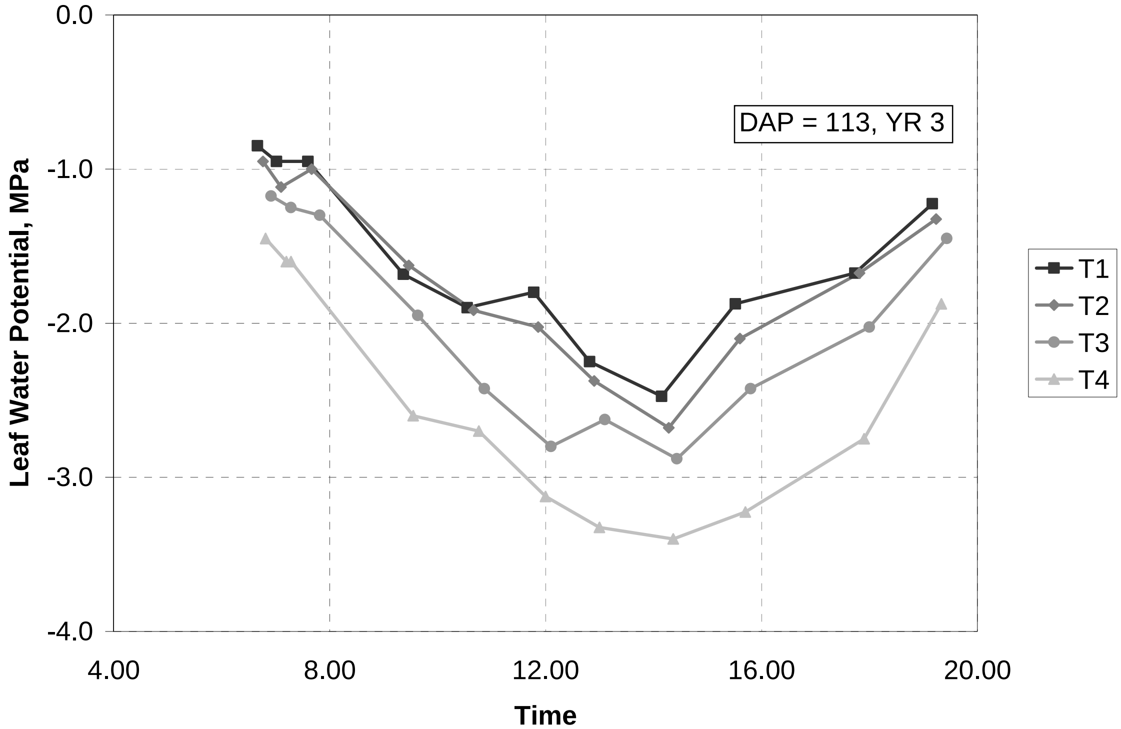

Figure 48. Diurnal LWP values for the four salinity treatments on DAP 113 in Year 3.

The average ratio of LWP_{SN} to LWP_{PD} values for all treatments was 2.6. This ratio is consistent with other studies, such as Grimes and Yamada (1982) with 3.0 to 3.2, Clark (1986) with 3.0 to 3.5, and Seymour et al. (1996) with 2.37. The cotton LWP values from the study were converted to ratios of LWP_{PD} and LWP_{SN} by dividing the value of the LWP reading by the LWP_{PD} (fig. 49) or LWP_{SN} value (fig. 50) for that same day. The figures indicate that mid-morning values of LWP had less scatter than did LWP taken later in the day.

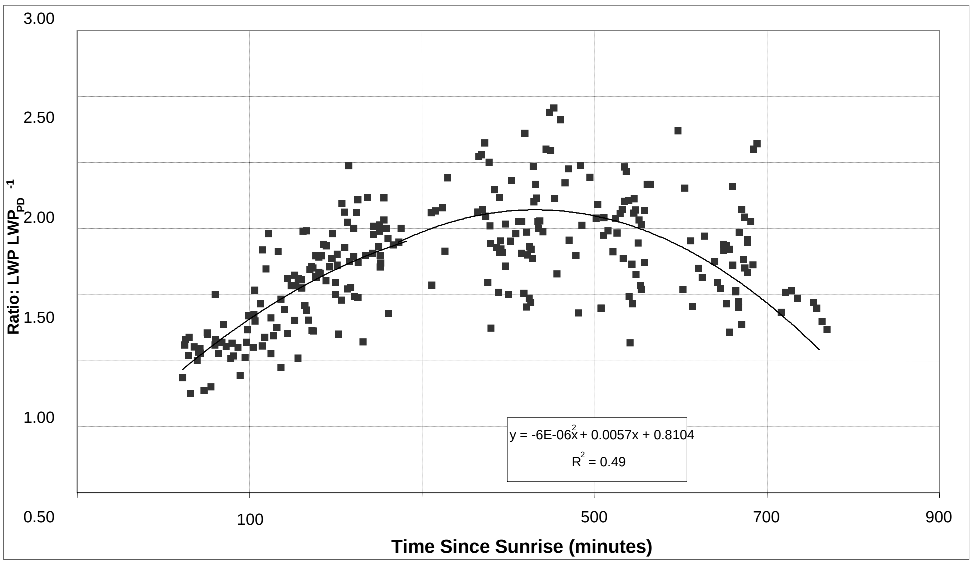

Figure 49. Ratio of LWP values to LWP_{PD} values of the same day for Treatments T1, T2, and T3 for all three years.

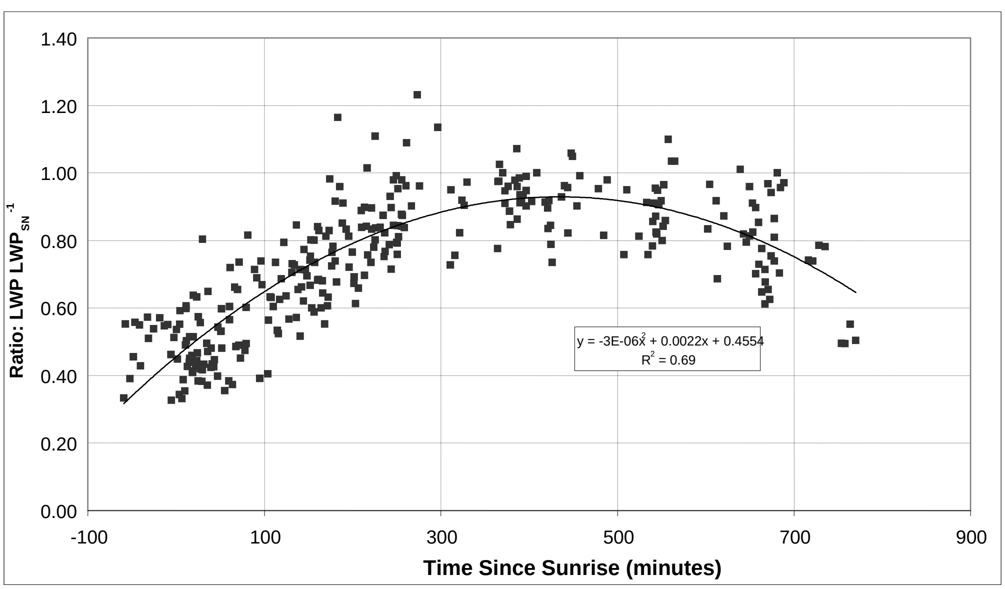

Figure 50. Ratio of LWP values to LWP_{SN} values of the same day for all treatments and for all three years.

EC_{IW} and LWP Values

When LWP values were time-based, a strong correlation for both three-year average LWP_{PD} and LWP_{SN} values to treatment EC_{IW} levels existed (R^2 = 0.92 and 0.99), as seen in figure 51. For each 1.0 dSm^{-1} in EC_{IW}, there was a decrease in LWP_{PD} and LWP_{SN} values of 0.026 and 0.042 MPa per dSm^{-1}, respectively.

The osmotic potential in the soil water, which was primarily influenced by the levels of irrigation EC, would be significant, especially for T3 and T4 waters. On the same figure 51, the calculated soil OP values for the different EC_{IW} treatments based on soil water conditions before irrigation are shown along side the LWP values. The cotton plants in the T4 treatments would experience a difficult time re-hydrating since the nighttime LWP value ≈ the OP value. Howell et al. (1984) attributed differences in LWP of cotton following irrigation when soil water matric potential would be minimal to variations in OP. He reported a relationship of 0.009 and 0.013 MPa per dSm^{-1} for LWP_{PD} and LWP_{SN} in relationship to mean root zone soil water EC.

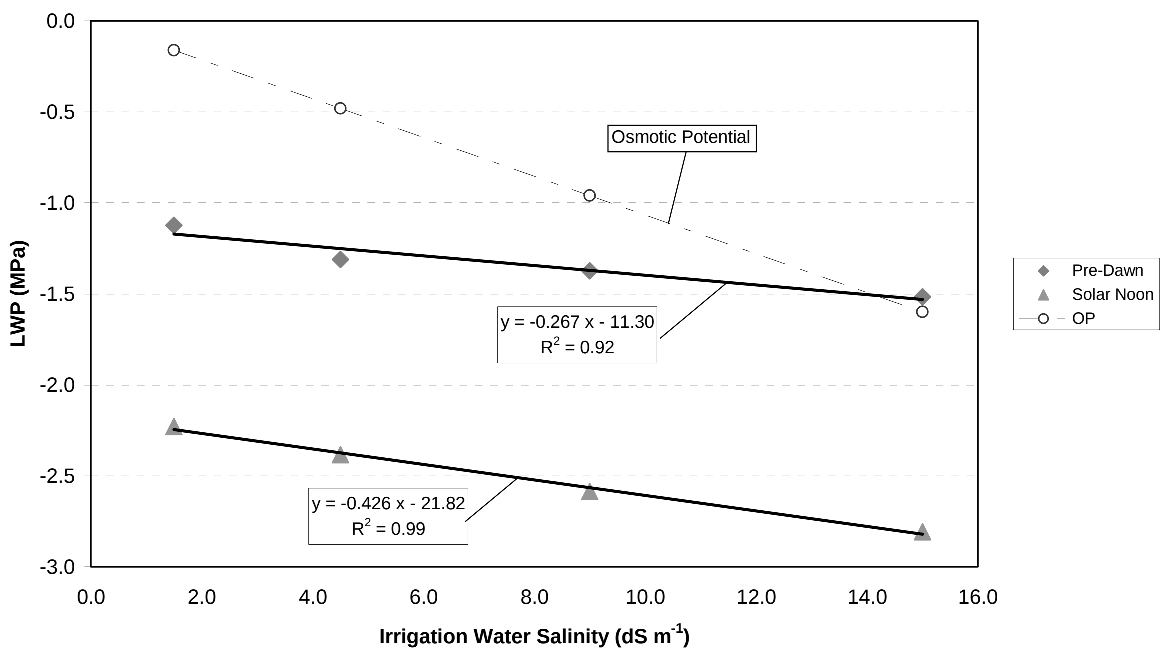

Figure 51. Average measured pre-dawn and solar noon LWP values and the estimated soil water osmotic potential prior to irrigation as a function of four irrigation water qualities.

Days since Irrigation and LWP Values

Figure 52 shows LWP_{PD} and LWP_{SN} values versus d since irrigation (DSI) for T1 and T2, and figure 53 shows the same for T3 and T4. The LWP_{PD} values were more linear to DSI than were LWP_{SN} values. DSI decreased LWP_{PD} values 0.04 MPa per day for each for the T1 and T2 treatments, while the T34 and T4 treatments declined at twice this rate.

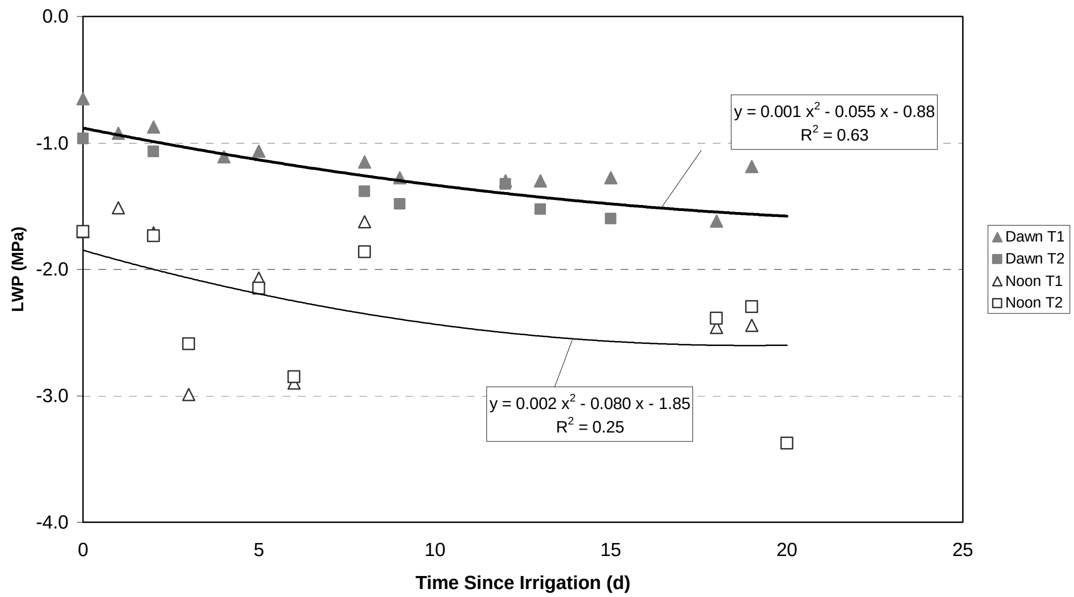

Figure 52. The study-long, average LWP values (pre-dawn and solar noon) for T1 and T2 based on days since irrigation using mean value for each period.

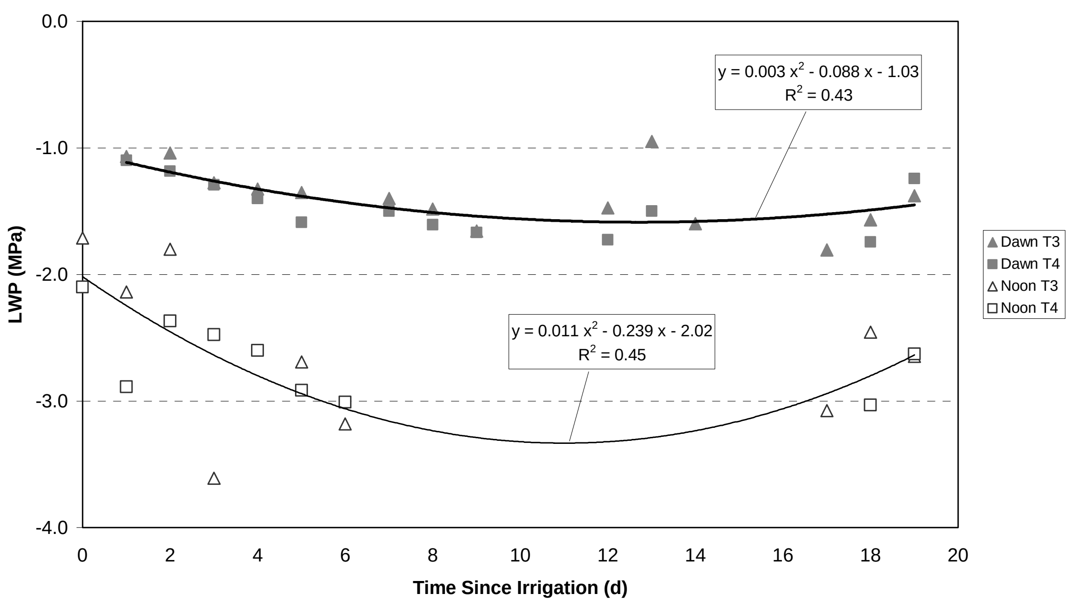

Figure 53. The study-long, average LWP values (pre-dawn and solar noon) for T3 and T4 based on days since irrigation using mean value for each period.

COTTON PLANT YIELD

Actual Yield

Seed-cotton yield for the three years of study is given in table 46, gin turnout data in table 47 and lint yield in table 48. Gin turnout was not statistically significantly different among treatments, but did differ within years. The overall lint yield in Year 3 was the highest of all, despite the fact that salinization had been taking place for three years. The cotton lint yield in Year 3 was statistically significantly > that of Year 1. Among treatments, the three-year average lint yield order was T1 > T2 > T3 >T4. The T1 and T2 were both statistically higher then T3 and T4.

Relative cotton lint yields (RY) can be calculated by dividing actual lint yields (Y_a) by the estimated maximum potential yield (Y_m). Henggeler (1987) found that maximum cotton lint yield was correlated better to the seasonal summation of daily maximum temperature (DMT) values than to various HU indexes. The accumulated DMTs were 8581°C, 9135°C, and 8553°C respectively for 1994, 1995, and 1996. The estimated maximum yields for those same years were 1467, 1657, and 14758 kg ha^{-1}.

RY for the treatments for the three years were then 0.68, 0.66, 0.53, and 0.53 for the T1, T2, T3, and T4 treatments, respectively. Data from individual years is seen in table 49. The T1 and T2 treatments were significantly statistically different from the T3 and T4 treatments. There was no significant difference in relative lint yields between the years.

The percentage of the pre-plant irrigation to total applied water varied each year and ranged from 26 to 51%. Thus, the average irrigation water salinity ($EC_{IW\text{-}net}$) fluctuated year-by-year. The T1 treatment had an average irrigation water quality of 2.3, 2.7, and 3.0 dSm^{-1} for Years 1, 2, and 3, respectively. Since T2 water constituted both the pre-irrigation and treatment waters, there was no year-to-year change from the 4.5 dSm^{-1} value. The T3 treatment had 7.8, 7.2, and 6.7 dSm^{-1} values for those same years. The T4 treatment had 12.3, 10.7, and 9.6 dSm^{-1} values. Cotton lint yield and RY data are plotted versus ($EC_{IW\text{-}net}$) in figures 54 and 55, respectively. The second order polynomial functions describing these relationships had R^2 values of 0.73 for lint yield and 0.57 for relative yield. The equations describing these two relationships are:

$$YLD = 3.297(EC_{IW-net})^2 - 77.391 \cdot EC_{IW-net} + 1239.4 \qquad (21)$$

where

Table 46. Seed cotton yield as a function of water quality treatments for all replicates and also given as yearly averages, 1994-1996 [a]

Year	Rep	T1	T2	T3	T4	Average
		kg ha^{-1}				
1994	Rep 1	2744.5	2959.6	2372.3	2389.4	2512.6 A
	Rep 2	2792.0	2474.3	2258.8	2428.7	
	Rep 3	---	2763.9	2287.0	2168.3	
	Average	2768.2 a	2732.6 a	2306.0 b	2328.8 b	
	S.D.	23.7	199.4	48.3	114.6	
1995	Rep 1	2528.5	2528.1	1820.8	1697.6	2178.3 B
	Rep 2	2009.3	2668.6	1631.6	1994.5	
	Rep 3	2821.7	2553.2	2125.6	1760.3	
	Average	2453.1 a	2583.3 a	1859.4 b	1817.5 b	
	S.D.	335.9	61.2	203.5	127.8	
1996	Rep 1	2943.6	2908.7	2226.7	2142.1	2553.6 A
	Rep 2	2747.9	2644.0	2470.4	2000.6	
	Rep 3	3163.8	2812.5	2475.4	2107.1	
	Average	2951.8 a	2788.4 a	2390.8 b	2083.3 c	
	S.D.	169.9	109.4	116.0	60.2	
Average		2724.4 A	2701.4 A	2185.4 B	2076.5 B	

[a] Within the four treatments, annual differences are significant at the 5% level (Duncan's multiple test range) if the same lower case letter does not appear. Also within the four treatments, final differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear. Year-by-year differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear.

Table 47. Lint turnout as a function of water quality treatments for all replicates and also given as yearly averages, 1994-1996 [a]

Year	Rep	T1	T2	T3	T4	Average
		%				
1994	Rep 1	34.1	33.9	36.6	38.1	34.9 B
	Rep 2	35.4	36.3	36.0	30.5	
	Rep 3	---	34.4	32.0	36.7	
	Average	34.8 a	34.9 a	34.9 a	36.7 a	
	S.D.	0.6	1.0	2.0	3.3	
1995	Rep 1	36.6	35.8	37.1	35.7	36.7 A
	Rep 2	38.3	35.8	35.6	36.4	
	Rep 3	37.9	35.4	36.9	38.6	
	Average	37.6 a	35.7 a	36.5 a	36.9 a	
	S.D.	0.7	0.2	0.7	1.2	
1996	Rep 1	39.5	36.5	36.6	38.8	37.7 A
	Rep 2	37.5	39.0	36.4	39.1	
	Rep 3	37.4	36.6	34.9	39.3	
	Average	38.1 a	36.6 a,b,c	34.9 b	39.3 a,c	
	S.D.	1.0	1.1	0.8	0.2	
Average		37.1 A	36.0 A	35.8 A	37.0 A	

[a] Within the four treatments, annual differences are significant at the 5% level (Duncan's multiple test range) if the same lower case letter does not appear. Also within the four treatments, final differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear. Year-by-year differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear.

Table 48. Lint cotton yield as a function of water quality treatments for all replicates and also given as yearly averages, 1994-1996 [a]

		T1	T2	T3	T4	Average
Year	Rep	kg ha^{-1}				
1994	Rep 1	935.9	1003.3	868.3	910.4	
	Rep 2	988.4	898.2	813.2	740.8	
	Rep 3	----	950.7	731.9	795.8	876.1 B
	Average	962.1 a,b	950.7 a	804.4 c	815.6 b,c	
	S.D.	26.2	42.9	56.0	70.7	
1995	Rep 1	1037.1	1014.3	757.1	679.3	
	Rep 2	862.4	1070.7	651.0	813.7	
	Rep 3	1198.5	1013.0	879.0	761.5	894.8 A,B
	Average	1032.7 a	1032.7 a	762.4 b	751.5 b	
	S.D.	137.2	26.9	93.2	55.3	
1996	Rep 1	1162.0	1063.0	815.9	830.6	
	Rep 2	1030.1	1030.7	900.2	782.9	
	Rep 3	1184.0	1028.7	862.9	829.1	960.0 A
	Average	1125.4 a	1040.8 a	859.7 b	814.2 b	
	S.D.	67.9	15.7	34.5	22.1	
Average		1049.8 A	1008.1 A	808.8 B	793.8 B	

[a] Within the four treatments, annual differences are significant at the 5% level (Duncan's multiple test range) if the same lower case letter does not appear. Also within the four treatments, final differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear. Year-by-year differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear.

YLD = cotton lint yield (kg ha^{-2})
EC_{IW-net} = average irrigation water salinity (dS m^{-1})

and

$$RY = 0.0023(EC_{IW-net})^2 - 0.0525 \cdot EC_{IW-net} + 0.8188 \quad (22)$$

where

RY = relative cotton lint yield

The Dregne (1969) calculation on yield reduction, when both salinity and water deficits are in play, overestimated yield levels by ≈ 40%. This result was expected, as this process additively reduced lint yield for the lack of water and presence of salt. As discussed in the literature review, this is probably an incorrect methodology.

The calculated Maas-Hoffman function, which predicts a 5.2% reduction in relative yield for each additional dSm^{-1} of salinity beyond the 7.7 dSm^{-1} threshold for EC_e, underestimated the relative yield loss for the three years. Average root zone salinity only exceeded the threshold level in the T4 treatment in two out of three years; however, there was statistically significant RY loss between treatments. The obvious reason for this result is that the Maas-Hoffman function was based on a full water supply with ample leaching. Under a 0.67 deficit fraction, the slope of function should be kept at 5.2% reduction in RY for each additional dSm^{-1} of salinity beyond the threshold and should decrease the threshold value to 4.5 dSm^{-1}.

Discussion

The cotton lint yields, relative to the amount of applied water (0.67 deficit fraction or ≈ 0.5 ET_o), were close to the average Reeves County lint yields for those years (US Deptartment of Agricture /NASS, 2004). The county average yield was only slightly higher than the T3 and T4 yields for two of the years, and it was actually less than the T3 and T4 yields in 1995 (Fig. 56). One explanation for the study levels being ≈ to local yields is that the application efficiency of irrigation water in the study was very high. The application efficiency of furrow irrigation, even with surge flow valves, is only 50 to 70%, and it is only 40 to 60% for furrows with open ditches (TWDB, 2002). Thus, even though only 600 mm of irrigation water was applied during the tests, the net amount applied was high, which may not be the case for local farms with long furrow runs. The cotton lint yields, in addition, did not decline during the three years, even for the more saline treatments.

In our study, drought had more effect than did salinity in overall yield reduction. The T3 and T4 treatments had a salinity-related yield loss of only 22 and 23%, respectively, but a drought-related yield loss of 32%. Table 50 lists the final yield loss components for the four treatments. Relative Yield was calculated with equations 8 and 9 and Relative Yield Loss with equations 11 and 12. Note that the RY (Y_a/Y_m) for non-salt stressed treatments (e.g., T1 and T2) averaged 0.68. This value was closely estimated with the yield reduction factor (e.g., K_y ($ET_a \div ET_m$) [Doorenboos and Kassam, 1979]) which gave 0.72.

One of the prime purposes of using both deficit irrigation and a secondary saline water source is to increase the amount of land being irrigated. Although deficit irrigation led to a yield level decrease (RY = 0.68), it in effect allowed 63% more land to be in production, which would have resulted in a 9% total production increase (table 51).

Additionally, yield levels in the saline T3 and T4 treatments were just 21% lower than the T1 and T2 treatments. However, more land could have been irrigated by using the T3 and T4 treatments. Because the ratio of treatment water to the 4.5 dSm^{-1} pre-plant water was 60:40, 150% more land was irrigated by conjunctive using both sources, rather than being limited to just using the 4.5 dSm^{-1} water source. When the 79% yield reduction level is offset by the 150% increase in land base from employing the secondary water sources, the end result was that there is 98% more total production.

Combining deficit irrigation and use of saline water expanded the total amount of land that could be irrigated even more. For the T3 and T4 treatments, allowing some amount of deficit-related yield loss (32%) and some amount of salinity-related yield loss (23%), the land base actually increased 300% over the situation where the land irrigated was sufficiently small enough to preclude all drought and salinity stress and overall production was twice as high (table 51).

Although the present study was conducted using a ratio of 60:40 poor water to good, more favorable blends such as 50:50, 25:75, etc., may be found to be more advantageous. Flynn (2003) used models to develop such a strategy for New Mexico conditions.

Table 49. Relative lint cotton yield, 1994-1996 based on a prediction model of Henggeler (1987)

	T1	T2	T3	T4
Year	%			
1994	0.66	0.65	0.55	0.56
1995	0.62	0.62	0.46	0.46
1996	0.77	0.71	0.59	0.57
Average	0.68 [A]	0.66 [A]	0.53 [B]	0.53 [B]

[a] Within the four treatments, annual differences are significant at the 5% level (Duncan's multiple test range) if the same lower case letter does not appear. Also within the four treatments, final differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear. Year-by-year differences are significant at the 5% level (Duncan's multiple test range) if the same upper case letter does not appear.

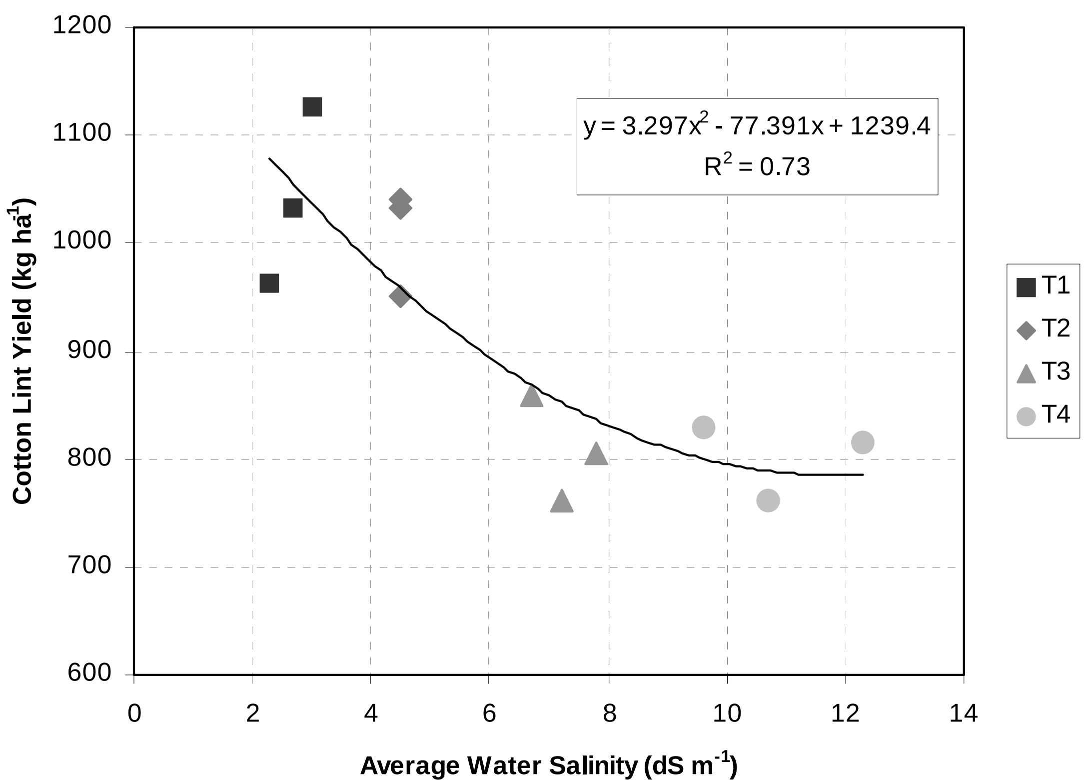

Figure 54. Cotton lint yield for the four treatments versus season-average irrigation water salinity levels ($EC_{IW\text{-}net}$) for all three years of the study.

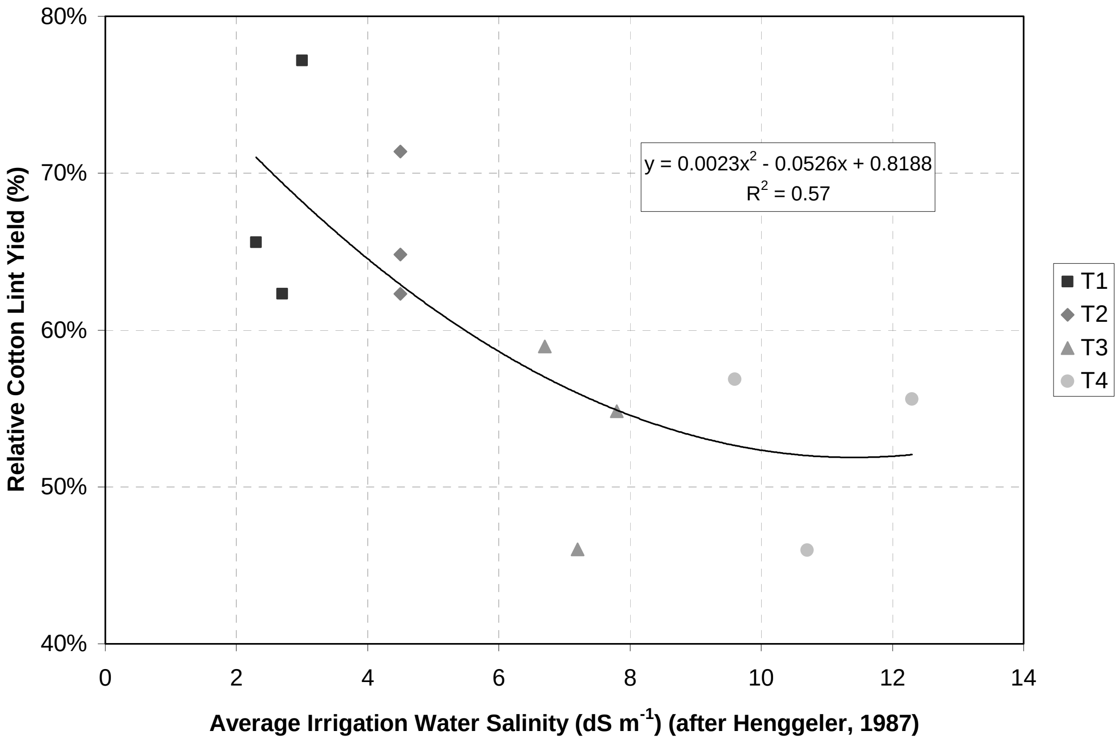

Figure 55. Relative cotton lint yield for the four treatments versus season-average irrigation water salinity levels ($EC_{IW\text{-}net}$) for all three years of the study.

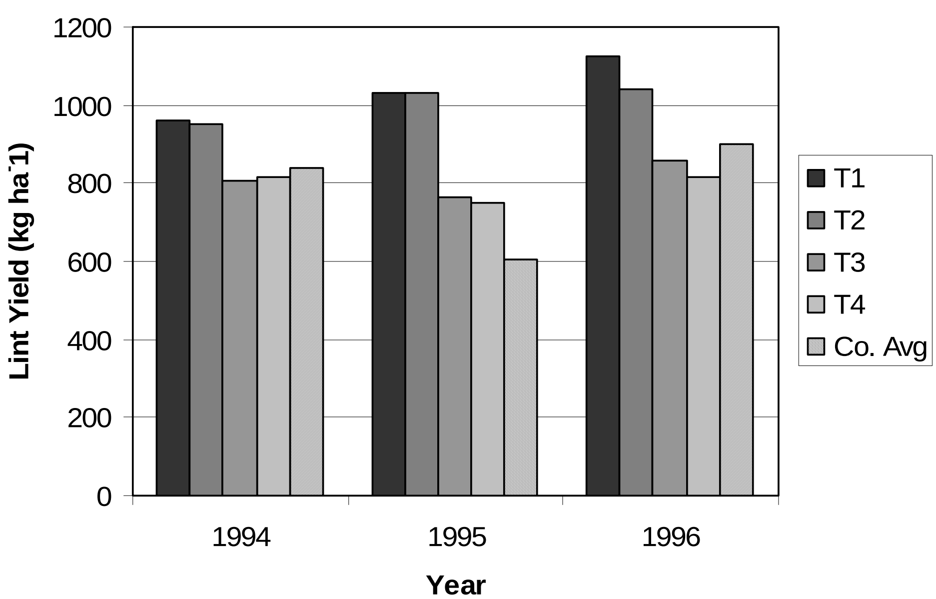

Figure 56. Reeves County, Texas, cotton lint yields for the years of the test, along with lint yields of the four treatments for Years 1 to 3.

Table 50. Relative yield loss by type of stress for all treatments, 1994–1996.

Year	Type of Stress	T1	T2	T3	T4	Average
		------------------------ (1 - actual yield / potential yield) ---------------- -----------------				
1994	Drought Stress	0.34	0.34	0.34	0.34	0.34
	Salinity Stress	0.00	0.01	0.16	0.15	0.08
1995	Drought Stress	0.38	0.38	0.38	0.38	0.38
	Salinity Stress	0.00	0.00	0.26	0.26	0.13
1996	Drought Stress	0.23	0.23	0.23	0.23	0.23
	Salinity Stress	0.00	0.08	0.24	0.26	0.14
Average	Drought Stress	0.32	0.32	0.32	0.32	0.32
	Salinity Stress	0.00	0.03	0.22	0.23	0.12

Table 51. The relative amount of land irrigated, relative yield on an area basis and relative total production under conditions of no stress, only salinity stress and both drought and salinity stress.

Condition	Relative Amount of Land Irrigated	Relative Yield on n Areas Basis	Relative Total Production
No Water Stress No Drought Stress	1.00	1.00	1.09
No Water Stress Salinity Stress Present	1.63	0.67	1.09
Water Stress Present Drought Stress Present	4.08	0.53	2.16

SUMMARY OF OVERALL RESULTS

Soil Water Status

The FAO-56 procedure for calculating crop water use and evaporation was used to estimate non-stressed cotton water use (ET_m) and resulted in average ET_m = 1,031 mm. The ET_o for this period was 1,321 mm, resulting in an actual seasonal crop coefficient value of K_{cb} = 0.78. This is in close agreement to Bordovosky et al. (1992) who found maximum yield at K_c = 0.75.

Two methods were used to determine ET_a. These were the mass balance method (average ET_a = 688) and the FAO-56 procedure/computer program (average ET_a = 629). The E component calculated by the program was used in the mass balance method. Values were similar; however, differences should be expected. With the FAO-56 procedure, the decrease in LAI due to salinity and drought are not automatically taken into account to reduce the crop coefficient values.

T3 and T4 did have higher end-of-season storage amounts, which indicates less crop water uptake and supports statement 1. The average deficit ratio (ET_a / ET_m) was 0.67 and predicts a relative yield of 0.72 when used in the yield response factor equation. Using actual yields of the T1 treatment and the temperature prediction model (Henggeler, 1987), relative yield was estimated at 0.68.

Soil Salinity

The T3 and T4 had soil salinization rates of 0.9 and 1.4 dSm^{-1} y^{-1}, respectively. Additionally, the T3 and T4 had diminished the cotton's ability to utilize soil water at soil depths > 0.5 m. The RY decreased 3% for each $dSm^{-1}$of irrigation water EC.

Plant Growth

For three years, tests were conducted on vegetative components of cotton, including: height, number of nodes, internodal length, leaf area, mass of plant parts, and leaf water potential. Over two-thirds of these evaluations were statistically significant, and it is concluded that cotton's green matter was affected by salinity.

Leaf Water Potential

For each 1.0 dSm^{-1} in EC_{IW}, there was a decrease in LWP_{PD} and LWP_{SN} values of 0.026 and 0.042 MPa per dSm^{-1}, respectively. Days since irrigation decreased LWP_{PD} values 0.04 MPa d^{-1} for the T1 and T2 treatments, while the T34 and T4 treatments declined at twice this rate.

Cotton Plant Yield

Yield was most affected by drought, which caused an average 32% cotton lint yield loss for the three years of the study. The assumption was made that all treatments had the same loss.

Salinity-related loss for the three years of the study average 0, 3, 22, and 23% for the T1, T2, T3, and T4 treatments, respectively.

CHAPTER V
CONCLUSIONS

The purpose of this study was to evaluate if deficit irrigation, already in wide-spread use in Texas because of limited water, can still be successfully used if part of the water supply was from a saline source. The wise conjunctive use of a good water source along with a poor one has the potential of extending the overall useable water supply. However, risks to both yield and soil are involved. The objectives of this study were to evaluate changes in yield level and soil salinization when combining deficit irrigation and saline water.

SUMMARY OF STUDY

Because cotton is a drought- and salt-tolerant crop, it is often grown in regions with limited or poor-quality water. This study involved cotton subjected both to deficit water amounts and poor-quality water. The amount of drought stress (equivalent to reducing full requirements by one-third) remained constant during the study; whereas, four variable rates of water quality (EC_{IW}) were used.

Two estimates on yield loss were employed in this study. Equation 2, the yield reduction function, can characterize Relative Yield (RY) due to inadequate water. For the rate of deficit irrigation used in the study, it projected a RY of 0.72. Secondly, expected RY in cotton lint as a function of salinity was based on the work of Maas and Hoffman (1977), which projects a 5.2% reduction in RY per dSm^{-1} in the EC_e beyond the threshold value of 7.7 dSm^{-1}.

This study was carried out for three years in west Texas. The objectives pertaining to the goal of determining if cotton can be grown under deficit, saline conditions involved:

- Concerns regarding soil salinization.
- Concerns regarding maintenance of yield levels.
- What the physiological effects on cotton were.

OBJECTIVES OF STUDY

Evaluate Impact on Soil Salinization

The most detrimental effect from using deficit irrigation with saline water was the salinization of the Hoban silty clay loam soil. The observed problems included:

- T3 and T4 had soil salinization rates of 0.9 and 1.4 dSm^{-1} y^{-1}, respectively.
- T3 and T4 had diminished ability to utilize soil water at soil depths > 0.5 m.
- Relative Yield decreased 3% for each $dSm^{-1}$of irrigation water EC.

Objective 1 sought to evaluate the impact of using deficit irrigation with saline water on the soil. Based on the concerns above, the conclusion is that it does negatively impact the soil.

Evaluate Impact on Yield Level

Yield levels did not decline during the course of the study for any treatment. Even in the case of the T3 and T4 treatments, the main factor in yield loss remained drought, which caused a 32% reduction in yield over all three years. T3 and T4 experienced an additional 23% yield loss on average due to salinity. Based on the fact that only two-thirds of the full water requirement was applied, yield levels, which were equivalent to county yields, do not appear to be problematic.

The Physiological Effects of Salinity on Cotton

Physiological aspects of the cotton plant were affected by salinity. In two-thirds of the replicated tests performed, there were statistically significant differences between treatments.

FINAL CONCLUSIONS

Conclusion One: Soil salinization occurred in all but the T1 treatment. T3 and T4 had soil salinization rates of 0.9 and 1.4 $dSm^{-1}\ y^{-1}$, respectively.

Conclusion Two: Reducing water requirements by one-third led to a 32% yield loss.

Conclusion Three: In addition to the 32% yield loss due to water stress, T3 and T4 experienced an additional 23% yield loss due to salinity.

Conclusion Four: Under deficit irrigation, conjunctive use of a secondary saline water source at the rate of 60:40 good water to saline water led to a 21% drop in yield. However, it would have allowed two-and-one-half times more land to be irrigated, which would have doubled total production.

Conclusion Five: Yield levels did not decline, even for the T3 and T4 treatments, which had yields similar to countywide averages.

Conclusion Six: This study was conducted on a soil with a known ability to function well when irrigated with water having high salinity levels. Additionally, the SAR of the irrigation water used was within a safe range. Thus, results from this study may not apply to all soils.

OTHER OBSERVATIONS

Salinity and Irrigation Efficiency

For this study, relatively small quantities of water produced moderate levels of yield. This was in part due to high irrigation efficiency. Wichelns and Oster (1991) stress that irrigation uniformity and efficiency are of utmost importance in managing saline soils. Longenecker and Lyerly (1959), pioneers in irrigation and salinity research in the Trans-Pecos area, were prophetic in what they observed:

> The future productivity of this area is dependent upon farm management practices that control salinity and exchangeable Na…. In the past, efficiency has been greatly lowered by excessively long irrigation runs of up to ½ mile (800 m) or more which resulted in unequal water distribution and penetration and considerable waste of water. This entire area is apparently dangerously near the point of reduced production unless utmost care is taken to control salinity….

Salinity management is not possible without excellent irrigation efficiency.

Additonal Study Findings

- EC_{IW} decreased LWP_{SN} values by 0.042 MPa per dS m^{-1} and LWP_{PD} values by 0.026 MPa per dS m^{-1}.
- In the T3 and T4 treatments, soil water extraction was reduced at soil depths > 0.5 m.
- The threshold EC_e value from the Maas-Hoffman salinity yield-loss function on cotton (7.7 dS/m $^{-1}$) at which yield decline begins is too high. The estimated value, with a deficit fraction of 0.67, is 4.5 dS/m^{-1}. The slope of the decline beyond this point, -5.2% in relative yield for each additional dS/m^{-1}, is in agreement with the study's findings.
- The days since irrigation decreased pre-dawn cotton LWP values by 0.04 MPa d^{-1}.

FUTURE RESEARCH

Although there was noted soil salinization, yields remained level. Future work should explore the possibility of using a smaller percentage of the saline waters. Nearly two-thirds of the water applied in our tests was treatment water. Reducing this ratio may allow portions of the saline water resources in the Trans-Pecos area to be safely used on the proper type of soil and with high irrigation efficiency.

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APPENDIX A

WATER ANALYSIS FOR T1 (MADERA VALLEY) AND T2 (WELL #5) WATERS

Tested by

The Soil, Water and Forage Testing Laboratory

of the

Texas Cooperative Extension in College Station, TX

on

31 January 1994

WATER ANALYSIS FOR T1 (MADERA VALLEY) AND T2 (WELL #5) WATERS

Table 52. Water analysis for T1 and T2 waters

Item	--------------- T1 Water ---------------			--------------- T2 Water ---------------		
	(meq/l)	(mg/l)	(other unit)	(meq/l)	(mg/l)	(other unit)
Calcium	5.64	113	---	20.71	415	---
Magnesium	2.63	32	---	10.03	122	---
Sodium	7.57	174	---	20.26	466	---
Potassium	0.15	6	---	0.38	15	---
Boron	---	0.2	---	---	0.4	---
Bi-Carbonate	3.60	219	---	2.75	168	---
Sulfate	5.68	273	---	22.11	1062	---
Chloride	7.11	252	---	25.04	888	---
Nitrate (N)	---	0.1	---	---	40.9	---
pH	---	---	7.3	---	---	7.1
Hardness	---	---	9.7 gn gal $^{-1}$	---	---	36 gn gal $^{-1}$
Electrical Conductivity	---	---	1.27 dSm^{-1}			4.52 dSm^{-1}
Total Cations	15.99	325	---	51.39	1018	---
Total Anions	16.40	745	---	49.91	2118	---
Total mg/l	---	1070	---	---	3136	
SAR	---	---	4	---	---	5
% Sodium (SSP)	---	---	47	---	---	39

APPENDIX B

PROCEDURE USED TO DETERMINE THE RELATIVE AMOUNTS OF SALTS ADDED

PROCEDURE USED TO DETERMINE THE RELATIVE AMOUNTS OF SALTS ADDED

Desired SAR = 5.0, so:

$$SAR = 5 = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}} = 25(Ca+Mg) = 2Na^2 \quad \text{(B.1)}$$

Desired EC:

T3 = 9.0 dSm^{-1}
T4 = 15.0 dSm^{-1}

Desired ratio of Ca to Mg = 2.0 to 1.0 (reflecting ratios of T1 and T2 water)

Salts used:
NaCl
$MgCl_2$□6 H_20
$CaCl_2$□2 H_20

Cation concentrations needed are based on Richards (1954) and are:

for EC of 9Ca + Mg + Na = 110 meq l^{-1}
for EC of 15Ca + Mg + Na = 190 meq l^{-1}

Solving the above and keeping the correct ratios of Ca to Mg gives values as shown in table A1. Since part of the salinity will be supplied by the existing salts from the water of Well #5, only the difference need be added. These values are shown in table A1 also.

Table 53. Existing cations in Well #5, plus total and additional required for T3 and T4 waters.

Cation	Existing Salts in Well #5 Water	----------- T3 Water ------------		------------ T4 Water ---------	
		Total Required	Additional Required	Total Required	Additional Required
	---------------------- meq l^{-1} ----------------------				
Na	20.3	31.4	11.1	42.9	22.6
Ca	20.7	52.4	31.7	98.1	77.4
Mg	10.0	26.2	16.1	49.0	39.0

The milliequivalent values of the cations in question (from the columns labeled “Additional Required” in table A1), when multiplied by the equivalent masses of the salts used times 1,000, gives the required amount of each salt in mg l^{-1} of Well #5 water (Table A2).

Table 54. Required amounts of various salts to be added to Well #5 water to formulate T3 and T4 treatment waters.

Salt	T3 Water	T4 Water
	------------------ mg l^{-1} -------------------	
NaCl	0.651	1.323
$CaCl_2 \cdot 2\ H_20$	2.330	5.689
$MgCl_2 \cdot 6\ H_20$	1.645	3.966

APPENDIX C

WEATHER DATA

Table 55. Maximum and minimum air daily temperature, daily global solar irradiance, average daily wind run and calculated ET_o for 1994 growing season.

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
122	2	32.7	8.8	98.2	9.7	28.6	3.0	8	8	7.7	8
123	0	30.4	15.3	91.8	15.7	26.7	4.2	10	18	8.2	16
124	0	29.6	11.4	93.6	34.7	23.5	3.3	10	28	5.7	22
125	2	32.7	13.6	97.5	37.7	27.4	4.4	9	37	6.8	28
126	6	37.1	14.9	98.0	8.4	20.9	2.3	7	44	7.0	35
127	0	31.1	20.0	55.1	13.4	16.4	2.9	10	54	6.7	42
128	0	33.0	16.4	97.9	14.8	13.0	4.0	8	62	7.7	50
129	17	30.2	15.6	96.6	36.9	27.4	4.9	3	66	7.4	57
130	0	32.1	18.2	94.9	33.1	21.1	5.3	6	72	7.5	65
131	0	29.5	18.2	92.8	52.9	21.7	4.4	9	81	5.2	70
132	0	23.8	13.8	98.0	68.5	15.9	3.2	7	88	3.1	73
133	0	31.1	12.8	97.5	15.9	29.4	4.2	7	96	8.9	82
134	0	31.4	17.9	56.7	25.4	29.0	3.8	11	106	7.9	90
135	11	31.4	14.1	84.2	14.1	30.6	2.9	9	115	8.0	98
136	5	32.5	13.2	86.6	14.9	30.4	3.9	7	122	9.1	107
137	0	34.8	17.5	90.5	25.5	25.0	4.0	9	131	8.0	115
138	0	31.7	17.5	94.3	40.6	16.4	4.9	9	140	5.9	121
139	4	29.4	16.2	95.0	48.8	18.6	4.2	6	146	5.0	126
140	0	31.8	16.7	94.4	37.3	29.1	3.8	9	155	7.2	133
141	0	32.1	16.6	89.7	32.1	26.2	3.7	10	165	7.2	140
142	0	27.5	16.2	95.1	47.8	13.7	3.5	11	176	4.2	144
143	0	33.7	15.1	96.6	26.7	28.8	2.8	9	185	7.3	152
144	0	34.3	16.8	87.8	24.8	24.0	2.8	8	193	6.9	159
145	0	35.0	17.4	92.2	12.6	24.7	2.8	11	204	7.8	166
146	0	32.0	17.9	84.7	21.6	28.0	3.6	13	218	8.3	175
147	0	30.8	16.8	86.6	33.8	27.7	3.0	14	231	6.9	182
148	0	37.7	15.6	93.7	10.6	31.0	2.2	14	245	8.2	190
149	0	40.5	17.4	73.6	8.8	30.0	2.6	12	257	9.0	199
150	3	39.3	18.9	60.3	8.3	30.1	2.7	12	269	9.0	208
151	0	37.7	20.5	69.9	11.5	29.4	3.5	10	279	10.0	218
152	0	35.7	20.0	63.8	12.6	29.7	3.6	12	291	9.8	228
153	0	35.5	19.6	95.2	24.5	25.6	3.6	14	305	8.5	236
154	0	33.6	17.4	94.5	27.6	27.7	2.2	15	320	7.1	243
155	0	37.3	17.7	90.5	14.5	30.7	2.0	16	336	7.7	251
156	1	40.6	17.5	69.2	10.0	28.3	2.5	17	353	8.6	260
157	0	42.7	19.0	65.3	6.2	29.9	2.5	15	367	9.1	269
158	0	40.5	22.5	39.6	8.4	24.1	3.7	13	381	10.1	279
159	0	42.2	22.4	62.4	6.6	25.7	3.3	14	395	10.2	289
160	0	41.9	19.1	40.2	6.2	31.9	3.3	14	410	11.2	300
161	0	38.2	19.7	63.6	19.3	22.7	4.6	13	423	10.0	310

Table 55, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
162	0	39.8	19.9	51.7	9.6	28.0	3.0	14	437	9.7	320
163	0	38.5	21.5	83.4	11.2	24.0	5.5	15	451	12.0	332
164	0	38.8	18.6	59.3	10.6	31.4	3.7	16	468	10.7	343
165	0	39.5	19.6	73.2	13.5	27.1	5.0	15	483	11.6	354
166	0	40.8	19.5	88.9	7.6	30.4	4.0	13	496	11.5	366
167	0	41.7	22.2	81.1	7.0	30.9	4.2	12	508	11.8	377
168	0	39.3	21.7	77.8	14.9	30.6	4.1	13	520	10.9	388
169	0	36.2	21.7	71.6	13.4	29.8	4.8	13	533	11.2	400
170	0	35.7	18.9	64.6	14.3	31.6	3.9	13	546	10.3	410
171	0	35.2	21.0	60.3	21.2	30.6	3.8	17	563	9.4	419
172	0	35.7	20.9	64.4	11.6	31.0	3.0	16	579	9.0	428
173	0	39.3	18.4	48.8	8.6	31.4	2.0	17	596	8.1	436
174	0	39.9	24.3	40.0	11.1	29.8	4.1	18	614	10.9	447
175	0	42.3	20.3	37.3	6.5	31.9	1.9	19	633	8.3	456
176	0	44.7	20.5	30.8	5.6	27.9	2.4	20	652	9.2	465
177	0	46.6	20.8	32.0	4.6	28.9	2.9	17	669	10.5	475
178	0	48.0	21.0	24.0	3.9	31.9	2.4	19	688	10.1	485
179	0	46.8	23.6	14.3	4.5	28.5	3.0	19	707	10.6	496
180	0	43.4	21.6	29.0	6.3	26.8	3.2	19	726	10.6	507
181	0	46.1	22.9	26.7	4.8	28.2	3.2	18	744	11.0	518
182	0	44.3	24.2	37.7	5.8	29.3	3.6	17	761	11.6	529
183	0	43.6	25.1	34.1	6.7	24.7	3.1	17	778	9.9	539
184	0	41.9	26.1	38.5	7.7	16.1	3.1	16	794	9.0	548
185	0	40.7	24.6	65.9	9.3	28.3	4.1	15	809	11.6	560
186	0	42.6	21.8	69.5	9.3	28.0	3.3	16	825	10.5	570
187	9	42.2	20.8	59.5	6.1	31.7	4.2	14	838	12.6	583
188	1	43.8	16.9	18.7	5.4	32.3	3.1	13	851	11.3	594
189	0	38.4	24.4	58.3	13.8	24.6	4.9	14	865	11.2	605
190	0	38.8	19.5	101.2	14.4	28.2	3.8	16	880	10.3	616
191	2	36.7	20.2	93.8	23.6	27.1	3.1	15	896	8.3	624
192	0	41.4	17.2	91.1	7.9	30.9	1.8	11	907	8.1	632
193	0	41.4	20.9	53.8	8.6	29.9	3.4	11	918	10.3	642
194	7	41.4	20.7	90.8	9.3	27.3	5.0	11	929	12.5	655
195	0	34.7	18.0	91.4	23.6	29.9	4.6	12	941	9.7	664
196	0	33.8	20.1	90.0	34.8	29.6	4.4	14	955	8.4	673
197	0	32.3	20.3	94.2	43.4	10.6	3.2	14	969	4.5	677
198	0	36.8	18.8	93.5	20.6	28.7	2.8	15	983	8.1	685
199	0	39.3	19.5	74.3	9.4	30.5	2.9	15	998	9.3	695
200	0	40.3	18.4	57.8	9.8	23.8	2.9	14	1012	8.8	704
201	0	41.2	19.2	53.2	8.8	29.3	2.8	14	1026	9.3	713
202	0	36.6	24.4	47.4	14.7	29.3	4.5	14	1040	10.7	724
203	0	38.7	20.0	58.3	10.8	30.4	2.6	15	1055	9.0	733

Table 55, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
204	0	38.9	20.1	45.5	9.3	30.4	3.3	16	1071	10.1	743
205	0	38.9	20.4	43.0	8.3	29.6	3.1	12	1083	9.7	752
206	0	41.6	19.8	40.9	7.0	28.7	2.5	12	1095	8.9	761
207	0	36.8	25.6	34.6	14.5	22.3	4.2	13	1107	9.8	771
208	0	33.3	21.4	61.0	23.7	27.6	3.7	9	1116	8.8	780
209	0	33.3	21.5	45.6	27.4	20.3	3.1	11	1128	7.2	787
210	0	38.2	18.5	54.1	10.5	27.8	2.8	13	1141	8.9	796
211	0	30.5	19.0	88.1	32.7	23.5	4.4	13	1154	7.5	803
212	0	35.0	18.6	93.0	24.4	28.4	3.2	12	1167	8.1	812
213	1	35.1	22.3	74.9	19.8	18.4	4.0	12	1179	8.2	820
214	0	36.0	22.1	53.8	12.2	27.5	3.9	12	1191	9.7	829
215	0	35.6	20.4	47.7	17.0	22.4	3.1	13	1204	8.0	837
216	0	36.5	19.5	77.5	15.8	28.0	2.7	16	1220	8.3	846
217	0	35.5	19.3	86.7	24.1	27.7	3.0	14	1235	8.1	854
218	0	38.8	19.0	61.9	9.9	28.8	2.3	14	1249	8.2	862
219	0	41.1	21.9	55.4	9.2	28.9	4.0	11	1260	11.0	873
220	0	38.3	21.8	53.7	11.7	28.2	4.5	12	1272	11.1	884
221	0	37.1	22.9	57.4	16.5	27.5	3.6	13	1285	9.5	894
222	0	33.5	19.7	89.4	24.6	27.3	4.5	13	1298	9.3	903
223	0	34.2	20.1	81.0	20.9	27.4	4.4	12	1310	9.5	912
224	0	37.4	19.5	73.8	13.9	28.4	3.3	13	1323	9.3	922
225	0	37.1	19.9	55.9	12.0	28.4	3.3	13	1335	9.3	931
226	0	35.8	19.1	52.3	16.6	26.7	3.1	15	1351	8.5	940
227	0	33.8	23.0	72.9	32.9	23.8	3.7	16	1367	7.6	947
228	0	37.9	19.0	56.8	14.7	26.2	1.8	16	1384	7.1	954
229	3	41.6	20.2	46.1	8.2	28.3	2.3	15	1399	8.5	963
230	41	43.4	20.6	46.3	6.1	28.2	3.1	12	1411	10.2	973
231	0	42.7	21.2	38.0	6.5	26.1	3.1	15	1425	9.9	983
232	0	36.9	24.9	86.6	13.0	24.4	4.6	15	1440	10.8	994
233	0	34.4	20.3	102.8	37.4	26.0	2.5	13	1453	7.1	1001
234	0	38.6	21.6	90.2	16.6	26.8	2.4	14	1467	8.1	1009
235	0	38.8	21.6	84.2	16.2	27.8	3.3	14	1482	9.4	1018
236	0	36.2	21.7	73.2	17.5	27.4	4.5	13	1494	10.2	1028
237	0	38.2	20.5	78.4	13.7	27.5	3.2	14	1508	9.3	1038
238	0	38.9	21.0	72.9	12.2	27.3	3.2	13	1521	9.5	1047
239	0	36.7	20.1	64.2	12.6	27.5	3.6	14	1535	9.6	1057
240	2	39.2	19.1	65.6	10.0	27.2	2.6	13	1548	8.6	1065
241	0	36.7	19.5	62.8	15.9	27.2	3.2	9	1557	9.0	1074
242	0	40.0	19.9	62.3	10.8	27.1	3.1	11	1567	9.3	1084
243	0	35.3	20.9	92.7	29.6	22.9	3.5	12	1579	7.6	1091
244	0	30.4	19.0	92.4	45.0	23.0	2.9	14	1593	5.9	1097
245	0	32.3	20.1	92.1	36.4	22.7	4.8	15	1609	7.5	1105
246	0	35.2	19.6	90.0	18.0	26.0	5.4	10	1619	10.3	1115

Table 55, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
247	0	39.5	19.9	65.4	12.5	26.0	2.9	12	1631	8.6	1124
248	0	40.2	21.8	71.5	16.5	20.5	3.0	10	1641	7.9	1132
249	0	30.6	21.2	92.3	43.9	15.6	2.7	10	1651	5.1	1137
250	0	34.4	20.4	90.2	26.3	22.9	2.2	10	1661	6.5	1143
251	0	33.0	18.0	89.7	33.5	25.0	2.8	9	1670	6.8	1150
252	0	34.1	17.7	91.5	22.6	25.8	3.0	9	1679	7.6	1158
253	0	32.9	17.5	90.7	24.5	25.1	3.8	12	1691	7.9	1165
254	11	32.3	16.9	89.8	29.6	24.9	3.8	10	1701	7.3	1173
255	0	31.7	17.9	89.5	35.3	24.0	4.0	12	1713	6.9	1180
256	0	34.8	20.7	86.9	27.8	19.9	3.1	8	1721	6.6	1186
257	0	33.9	17.3	100.2	31.7	12.9	2.1	5	1726	4.5	1191
258	0	35.6	19.4	91.7	28.4	22.3	3.0	6	1732	6.8	1198
259	0	29.6	17.1	93.2	35.8	18.1	2.9	7	1739	5.5	1203
260	0	29.9	10.8	88.3	15.6	24.7	2.0	9	1748	6.3	1209
261	0	31.8	11.9	69.0	11.8	24.7	2.6	10	1758	7.1	1216
262	5	33.6	11.9	52.9	10.4	24.1	2.8	3	1760	7.4	1224
263	0	35.8	12.7	54.6	8.6	24.2	2.5	4	1765	7.2	1231
264	0	36.4	14.1	61.8	9.0	20.2	2.0	4	1769	6.1	1237
265	0	26.2	10.2	94.6	19.7	10.9	3.2	5	1774	5.4	1243
266	5	32.8	7.0	95.4	17.5	23.4	2.1	8	1783	6.2	1249
267	0	27.3	11.6	72.0	15.3	23.5	2.3	10	1793	5.8	1255
268	0	31.1	11.0	63.5	13.8	22.8	2.4	10	1803	6.0	1261
269	0	35.3	12.8	95.3	14.3	19.2	1.9	9	1812	5.3	1266
270	0	37.0	14.6	77.0	7.9	23.5	2.4	8	1821	6.9	1273
271	0	38.3	13.2	44.4	7.5	23.5	1.9	8	1829	6.5	1279
272	0	36.1	13.5	38.9	8.5	23.1	2.9	13	1841	7.9	1287
273	0	36.1	11.4	51.5	8.6	23.2	2.6	10	1852	7.7	1295
274	0	35.3	12.2	90.1	9.9	20.3	2.3	11	1863	6.7	1302
275	0	35.3	20.9	38.4	9.7	21.8	3.7	12	1874	8.4	1310
276	0	34.5	16.9	40.5	10.6	15.1	2.5	10	1884	6.3	1316
277	1	33.5	19.7	77.5	29.7	19.9	5.6	4	1889	8.1	1324
278	0	38.1	16.3	81.0	8.7	19.9	4.9	1	1890	10.6	1335
279	0	34.9	16.4	61.7	9.2	21.3	3.2	0	1890	7.9	1343
280	0	25.3	14.3	93.4	38.6	5.8	3.0	0	1890	3.7	1347
281	0	24.1	9.7	94.6	16.0	21.0	3.2	0	1890	6.2	1353
282	2	24.0	5.6	53.7	14.7	21.5	1.9	8	1890	4.9	1358
283	0	25.3	3.5	48.7	12.6	22.1	2.1	10	1890	5.1	1363
284	0	29.0	2.2	40.5	10.8	22.0	1.8	10	1890	5.1	1368

Table 56. Maximum and minimum air daily temperature, daily global solar irradiance, average daily wind run and calculated ET_o for 1995 growing season.

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	$\sum$	Daily	$\sum$
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
123	0	33.4	10.6	78.5	9.3	31.5	4.8	6	6	9.9	10
124	0	29.5	13.6	78.3	14.7	24.1	4.1	6	12	8.1	18
125	1	32.6	17.5	90.4	26.5	21.8	4.8	9	22	7.9	26
126	0	35.2	13.8	91.1	9.0	30.9	3.8	9	31	10.0	36
127	0	29.7	16.1	54.8	10.9	27.9	6.7	7	38	11.1	47
128	0	26.9	10.8	25.5	12.6	29.9	8.2	3	41	10.8	58
129	0	31.3	13.3	22.6	10.6	31.6	5.1	7	48	10.4	68
130	0	28.5	11.8	44.4	16.4	30.8	3.0	5	53	7.7	76
131	0	34.7	14.2	73.3	11.1	28.0	2.9	9	62	8.1	84
132	0	37.0	11.2	96.6	8.3	29.8	5.0	9	70	11.7	96
133	0	36.4	18.6	21.2	8.5	32.0	4.6	12	82	11.4	107
134	0	38.2	16.6	28.6	8.2	29.9	2.8	12	94	9.2	116
135	1	38.2	21.3	74.0	22.9	24.6	4.3	14	108	9.2	126
136	0	34.9	22.2	68.7	15.1	16.5	2.9	13	121	7.4	133
137	0	28.8	19.3	51.9	12.3	32.0	8.1	9	130	12.7	146
138	0	29.0	13.0	40.6	17.3	31.7	3.0	5	135	8.3	154
139	0	35.6	11.1	41.6	9.7	27.4	3.1	8	143	8.9	163
140	0	38.1	15.3	43.9	11.3	27.7	3.3	11	154	9.2	172
141	0	36.6	15.1	38.3	10.2	28.0	3.5	10	164	9.4	181
142	0	40.4	14.0	57.0	6.7	32.6	3.6	12	176	11.3	193
143	0	36.6	20.6	70.2	12.1	14.5	5.1	13	189	9.9	203
144	0	33.3	15.8	66.7	14.1	31.1	4.5	9	198	10.3	213
145	5	28.9	18.1	92.1	51.5	18.2	5.2	8	206	5.3	218
146	10	26.8	16.9	103.5	60.3	15.2	3.9	6	212	3.8	222
147	0	32.6	13.3	98.4	10.9	32.4	4.2	7	220	10.0	232
148	0	32.8	14.9	76.1	21.2	27.6	4.1	8	228	8.4	240
149	9	23.8	16.7	98.6	68.6	16.7	4.4	5	233	3.4	244
150	0	27.5	15.6	97.9	49.4	21.4	3.1	6	239	4.8	249
151	0	35.8	15.6	98.1	9.3	31.0	2.7	10	249	8.5	257
152	0	37.0	15.2	98.1	12.8	29.7	2.3	11	259	7.7	265
153	0	40.7	19.7	94.5	15.5	30.1	4.4	15	274	10.9	276
154	0	39.0	19.8	60.8	7.4	32.7	4.6	14	288	12.2	288
155	0	38.1	19.3	89.2	7.9	31.5	3.1	13	301	9.9	298
156	0	39.1	16.0	96.8	7.5	32.3	2.6	12	313	9.7	308
157	0	39.8	17.2	41.1	7.1	32.5	5.2	13	326	13.3	321
158	0	38.9	21.2	60.4	8.1	31.7	4.1	15	340	11.3	332
159	0	39.5	19.6	75.7	8.0	31.9	4.2	14	354	11.8	344
160	0	38.6	19.6	69.0	7.7	32.3	3.9	14	368	11.4	355
161	0	39.1	19.1	81.6	19.5	27.9	3.5	14	381	9.4	365
162	0	28.2	16.1	82.1	34.7	21.9	4.2	7	388	6.8	372
163	0	33.9	14.5	82.2	14.7	31.7	3.2	9	397	9.0	381
164	0	36.2	14.6	62.2	9.2	32.6	3.9	10	406	10.5	391

Table 56, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ETo	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
165	0	38.4	13.4	50.2	8.0	32.5	3.6	10	417	10.5	402
166	0	37.6	15.0	65.8	9.5	31.6	5.4	11	427	12.2	414
167	0	33.3	20.7	69.8	33.8	26.3	8.0	11	439	9.6	423
168	0	31.0	20.0	69.0	38.8	25.8	8.5	10	449	8.7	432
169	0	33.3	21.1	58.4	33.6	28.9	6.8	12	460	9.5	442
170	0	33.8	19.9	77.3	32.0	30.0	4.8	11	472	8.7	450
171	0	35.2	19.8	79.2	29.3	30.0	4.0	12	484	8.5	459
172	0	36.7	19.8	69.4	21.6	30.5	3.5	13	496	9.0	468
173	6	39.2	19.1	97.8	15.5	27.5	3.5	14	510	9.5	477
174	0	37.7	17.3	94.7	11.8	26.2	2.9	12	522	8.8	486
175	0	33.2	17.8	77.1	33.4	30.7	4.4	10	532	8.4	494
176	0	32.4	19.6	76.3	30.1	23.1	4.0	10	542	7.5	502
177	0	34.4	17.7	85.3	30.3	29.1	3.7	10	553	8.0	510
178	0	35.8	17.8	86.5	23.3	28.1	2.9	11	564	7.8	518
179	0	37.5	16.9	90.3	16.3	24.9	2.7	12	576	7.8	526
180	0	35.5	17.8	71.2	24.8	30.6	3.5	11	587	8.6	534
181	27	28.1	15.6	103.5	38.6	19.5	3.7	6	593	5.9	540
182	0	31.4	19.3	95.6	43.4	28.2	3.2	10	603	6.5	547
183	0	38.7	21.0	90.5	17.2	27.4	3.2	14	617	8.5	555
184	0	37.6	17.9	92.2	10.5	28.8	4.8	12	629	11.2	566
185	0	38.1	20.8	39.0	7.6	32.5	3.5	14	643	10.4	577
186	0	38.7	19.1	40.1	13.3	30.9	3.1	13	657	9.5	586
187	0	36.5	21.2	67.8	13.3	31.5	4.2	13	670	10.6	597
188	0	34.0	19.9	89.0	29.7	31.0	4.4	11	681	9.0	606
189	0	36.3	17.2	85.8	20.8	31.3	2.6	11	692	8.3	614
190	0	36.2	18.7	76.1	14.9	31.6	2.6	12	704	8.6	623
191	0	37.3	18.2	56.3	10.8	31.6	2.9	12	717	9.2	632
192	0	37.3	16.9	51.5	9.2	32.0	3.2	12	728	9.8	642
193	0	37.1	17.9	51.5	10.8	31.4	3.6	12	740	10.1	652
194	0	37.0	20.3	47.5	12.5	31.2	3.7	13	753	10.0	662
195	0	37.8	21.8	58.4	15.6	30.3	4.2	14	767	10.4	672
196	0	36.7	20.9	66.6	18.4	30.6	4.0	13	781	10.0	682
197	0	35.9	24.6	53.3	22.6	25.9	4.4	15	795	9.5	692
198	0	36.7	22.8	61.8	21.3	25.9	3.2	14	809	8.4	700
199	0	37.1	20.9	66.6	14.8	29.7	3.2	13	823	9.3	709
200	0	39.2	20.4	54.5	11.7	30.7	2.5	14	837	8.8	718
201	3	39.9	22.3	87.4	11.7	30.6	2.9	16	853	9.4	728
202	0	38.6	20.9	83.2	23.3	26.8	2.5	14	867	7.9	735
203	0	40.5	24.5	61.7	15.6	26.8	2.9	17	884	8.8	744
204	0	42.4	24.0	42.9	6.6	31.3	4.1	18	901	12.1	756
205	0	42.7	18.7	23.3	6.0	31.8	3.3	15	917	11.3	768
206	0	44.1	18.9	39.8	5.5	31.4	2.6	16	932	10.3	778
207	0	44.6	20.8	45.1	5.5	30.2	3.0	17	950	10.5	788

Table 56, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
208	0	46.6	19.1	42.3	4.6	31.4	2.7	17	967	10.8	799
209	0	40.0	19.7	40.6	7.6	31.1	3.7	14	981	11.4	811
210	0	42.5	21.9	23.9	6.4	29.4	3.1	17	998	10.3	821
211	0	34.8	24.2	56.1	24.0	27.1	4.0	14	1012	9.3	830
212	6	35.6	21.5	100.7	28.9	20.4	2.7	13	1025	6.9	837
213	0	30.9	20.4	92.4	38.4	18.0	3.8	10	1035	6.4	843
214	0	35.5	19.1	85.1	27.8	27.5	2.3	12	1047	7.2	851
215	0	37.8	19.4	81.8	12.1	30.3	2.9	13	1060	9.0	860
216	0	35.8	22.4	83.8	33.6	24.9	3.9	14	1073	7.7	867
217	0	32.2	21.8	90.9	43.4	13.3	2.4	11	1085	4.5	872
218	0	36.6	18.3	79.4	22.3	29.0	3.4	12	1096	8.7	881
219	0	36.2	19.8	66.2	22.0	25.6	4.1	12	1109	9.0	890
220	0	38.3	23.6	66.6	22.3	24.2	3.5	15	1124	8.4	898
221	0	37.8	22.7	49.3	15.1	29.4	4.5	15	1139	10.9	909
222	0	36.6	20.3	65.1	21.8	29.0	4.2	13	1152	9.8	919
223	0	37.4	21.4	74.2	11.5	29.5	3.9	14	1166	10.5	929
224	0	35.1	21.7	74.7	30.8	28.6	4.7	13	1179	9.2	938
225	0	36.5	24.3	74.0	32.1	14.4	3.8	15	1193	6.7	945
226	0	38.8	22.9	75.5	24.3	20.5	2.6	15	1209	7.0	952
227	1	35.2	21.7	94.9	41.1	19.4	2.7	13	1222	5.9	958
228	0	34.4	22.2	92.3	39.7	18.6	2.4	13	1234	5.7	964
229	0	36.5	20.9	90.5	31.7	26.1	2.8	13	1248	7.5	971
230	0	36.7	19.1	88.2	27.3	27.3	2.5	12	1260	7.5	979
231	1	34.1	20.9	95.3	28.8	22.0	4.5	12	1272	8.2	987
232	0	34.5	21.3	92.5	27.5	25.4	3.0	12	1284	7.5	994
233	0	37.2	20.7	71.1	19.7	27.0	2.3	13	1298	7.5	1002
234	0	37.0	22.7	67.0	19.9	27.3	3.0	14	1312	8.4	1010
235	0	35.6	21.8	61.3	21.0	27.4	2.9	13	1325	8.2	1019
236	0	36.1	21.6	63.4	15.8	25.1	2.4	13	1338	7.6	1026
237	0	37.1	17.6	66.9	12.9	27.6	2.2	12	1350	7.9	1034
238	0	37.1	21.2	69.1	16.9	26.1	3.4	14	1364	8.9	1043
239	0	35.7	21.6	72.0	25.0	24.2	3.3	13	1377	7.9	1051
240	0	36.8	20.5	58.1	19.7	24.2	2.6	13	1390	7.5	1058
241	0	38.0	20.3	61.3	16.6	26.3	2.7	14	1403	8.2	1067
242	0	38.1	20.2	63.6	14.0	26.2	2.3	14	1417	7.8	1074
243	0	36.7	21.9	60.7	19.3	25.4	3.6	14	1431	8.9	1083
244	0	33.4	20.3	80.8	25.0	25.7	3.5	11	1442	8.1	1091
245	0	34.5	18.0	64.6	22.3	26.0	2.9	11	1453	7.8	1099
246	0	36.2	17.2	49.3	10.8	26.3	3.0	11	1464	8.6	1108
247	0	37.3	18.0	45.1	10.2	26.0	2.9	12	1476	8.5	1116
248	0	39.7	18.3	49.3	8.3	26.3	2.5	13	1490	8.3	1125
249	0	41.2	17.8	50.2	7.5	26.8	2.3	14	1503	8.4	1133

Table 56, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
250	0	39.2	19.0	46.9	10.5	25.3	3.6	14	1517	9.7	1143
251	0	30.8	18.4	93.6	39.1	23.6	4.9	9	1526	7.3	1150
252	0	32.8	20.0	84.7	32.8	22.0	4.2	11	1537	7.4	1157
253	4	24.4	18.4	96.0	79.5	8.7	3.2	6	1543	2.0	1159
254	0	28.4	19.5	95.0	53.6	9.8	1.6	8	1551	2.7	1162
255	0	36.7	17.0	94.6	17.6	23.9	2.0	11	1562	6.3	1168
256	0	32.3	18.5	91.3	35.4	19.8	3.4	10	1572	6.0	1174
257	43	24.1	18.9	101.9	88.7	3.6	3.0	6	1578	0.7	1175
258	23	25.9	20.9	97.0	87.9	6.4	1.9	8	1586	1.2	1176
259	0	34.5	19.0	94.1	39.9	23.0	0.4	11	1597	4.2	1180
260	13	30.1	21.0	99.3	55.7	12.3	1.2	10	1607	2.7	1183
261	4	34.0	21.3	94.4	43.5	21.8	2.2	12	1619	5.3	1188
262	0	31.8	20.7	91.0	35.4	23.3	3.9	11	1630	7.0	1195
263	18	25.7	18.2	96.3	72.7	7.5	2.7	6	1636	2.1	1198
264	2	23.6	7.6	96.8	81.7	7.2	4.3	0	1636	0.2	1198
265	1	14.9	6.8	96.9	59.3	14.0	2.7	0	1636	2.8	1201
266	0	30.3	8.1	96.8	40.6	22.0	1.6	4	1640	3.9	1204
267	0	35.2	13.1	96.0	24.1	22.3	2.0	9	1649	5.0	1209
268	0	21.6	14.7	95.2	72.6	7.7	2.7	3	1651	1.5	1211
269	0	28.7	13.0	96.4	52.0	14.5	1.8	5	1656	3.0	1214
270	0	37.3	15.7	95.4	14.6	21.5	1.8	11	1667	5.6	1220
271	0	37.2	17.0	92.1	12.8	21.5	2.8	12	1679	7.1	1227
272	0	35.3	16.4	95.7	14.3	23.0	2.9	10	1689	7.4	1234
273	0	31.5	17.9	57.0	14.3	23.5	3.6	9	1698	8.0	1242
274	0	29.1	13.9	82.4	38.4	19.8	2.4	6	1704	5.0	1247
275	5	27.6	14.9	95.4	49.4	13.9	2.3	6	1710	3.6	1251
276	0	26.5	11.9	96.9	35.7	22.3	1.8	4	1714	4.6	1255
277	0	34.1	11.3	96.9	9.6	23.0	3.8	7	1721	8.4	1264
278	0	25.7	10.3	60.2	15.6	22.7	1.9	2	1723	5.2	1269
279	0	23.2	9.0	71.5	23.1	22.2	1.8	0	1724	4.6	1273
280	0	31.3	7.1	90.0	17.7	21.5	1.8	4	1727	5.0	1278
281	0	34.6	11.4	88.5	9.9	20.5	2.0	7	1735	5.4	1284
282	1	28.2	12.9	82.4	19.4	13.3	2.7	5	1740	4.9	1289
283	0	32.9	10.9	90.6	10.8	21.4	2.0	6	1746	5.6	1294
284	0	30.6	9.6	55.6	16.7	21.3	2.0	5	1751	5.7	1300
285	0	31.9	8.3	70.3	11.0	21.5	2.0	5	1755	5.1	1305
286	0	32.5	9.2	61.6	10.8	20.9	3.4	5	1760	6.4	1312
287	0	26.2	7.3	70.8	15.4	20.9	1.8	1	1762	5.9	1317
288	0	32.1	7.2	66.6	14.3	20.8	1.6	4	1766	6.5	1324
289	0	32.8	7.6	75.5	10.7	20.8	1.9	5	1770	6.3	1330
290	0	35.0	7.8	53.1	9.2	20.7	1.7	6	1776	4.9	1335
291	0	33.9	8.4	61.7	9.4	20.5	2.1	6	1782	7	1342
292	0	32.2	10.5	53.3	10.4	19.9	3.3	6	1788	7.8	1350

Table 56, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
293	0	23.1	4.4	57.5	13.1	20.1	2.1	0	1788	5.9	1356
294	0	31.6	3.7	58.0	10.4	20.2	3.1	2	1790	5.5	1361

Table 57. Maximum and minimum air daily temperature, daily global solar irradiance, average daily wind run and calculated ET_o for 1996 growing season.

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
135	0	41.3	16.4	51.9	7.5	24.2	4.6	13	13	11.7	12
136	0	38.4	22.5	45.6	9.2	14.8	4.9	15	28	10.4	22
137	0	39.9	16.4	63.5	7.0	32.1	4.3	13	41	12.4	35
138	0	40.8	15.4	23.3	6.8	31.6	3.4	13	53	11.3	46
139	0	41.4	18.5	42.2	6.7	30.1	2.8	14	68	9.9	56
140	0	42.5	16.3	44.6	6.1	30.1	3.1	14	82	10.6	66
141	0	41.9	16.7	51.2	6.4	26.6	3.7	14	95	11.2	78
142	0	40.7	16.6	18.8	6.7	31.3	3.8	13	108	11.7	89
143	0	39.4	18.6	15.5	8.0	32.3	3.3	13	122	10.8	100
144	0	42.4	16.7	29.8	6.1	31.9	3.2	14	136	11.2	111
145	0	39.2	19.1	36.4	7.4	32.4	4.2	14	149	11.9	123
146	0	38.5	19.4	47.4	8.5	29.3	4.4	13	163	11.5	135
147	0	39.8	22.5	69.2	7.2	31.0	6.5	16	178	14.6	149
148	0	32.2	19.0	53.8	9.7	32.4	5.4	10	188	11.8	161
149	0	35.4	14.1	20.6	8.6	32.9	4.1	9	198	11.1	172
150	0	37.7	15.4	16.3	8.1	30.1	3.1	11	209	9.6	182
151	0	37.9	15.7	48.9	12.5	30.1	3.8	11	220	10.2	192
152	0	35.3	20.8	85.3	40.1	17.6	4.1	12	232	6.1	198
153	0	35.1	20.6	87.2	21.2	23.6	4.8	12	245	9.4	207
154	0	38.8	16.4	71.1	8.0	32.4	3.5	12	257	10.8	218
155	0	36.1	21.2	85.0	30.4	24.8	4.6	13	270	8.5	227
156	0	34.7	19.2	71.6	20.9	28.1	4.4	11	281	9.5	236
157	0	39.7	18.8	68.9	11.7	31.0	3.0	14	295	9.6	246
158	0	43.6	17.9	60.5	5.8	31.9	2.2	15	310	9.1	255
159	0	44.0	19.1	59.4	5.6	31.5	3.9	16	326	12.3	267
160	0	35.2	20.2	59.5	10.4	26.6	4.8	12	338	11.0	278
161	0	36.4	16.4	54.2	18.5	29.3	3.1	11	349	8.9	287
162	0	41.6	17.9	46.2	9.2	29.1	2.9	14	363	9.7	297
163	1	41.0	22.5	66.7	8.1	29.8	3.1	16	379	9.8	307
164	0	39.3	22.0	39.1	12.3	29.8	3.8	15	395	10.5	317
165	0	38.6	23.1	58.4	19.5	24.6	4.4	15	410	10.0	327
166	0	36.5	22.6	54.2	26.4	22.8	3.7	14	424	8.3	335
167	0	35.4	20.6	84.2	33.9	22.6	3.9	12	436	7.6	343
168	2	37.2	19.2	98.9	24.1	26.4	3.9	13	449	9.0	352
169	0	37.3	17.8	84.3	19.7	27.8	2.5	12	461	8.0	360
170	0	39.3	18.6	92.3	19.8	31.3	2.8	13	474	8.9	369
171	0	40.1	19.0	83.9	12.2	31.9	2.1	14	488	8.4	377
172	0	43.8	21.1	43.4	7.0	27.5	2.2	17	505	8.2	386
173	0	45.2	20.6	37.8	5.7	27.8	2.6	17	523	9.5	395
174	0	43.0	22.4	40.1	7.3	32.4	3.7	17	540	11.8	407
175	0	39.0	23.3	51.5	15.6	31.7	4.7	16	555	11.8	419
176	1	40.5	21.7	91.3	17.3	29.6	3.3	16	571	9.9	429

Table 57, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
177	0	40.0	22.7	55.9	16.1	29.9	2.9	16	587	9.4	438
178	0	37.6	23.3	75.6	32.1	23.9	4.0	15	601	8.2	446
179	0	34.0	22.1	87.9	41.5	25.0	4.5	13	614	7.6	454
180	18	37.4	22.0	113.4	53.2	12.0	4.4	14	628	4.3	458
181	0	35.8	19.6	94.7	35.9	30.3	3.1	12	640	7.8	466
182	0	35.5	20.5	86.5	32.0	29.5	4.0	12	653	8.5	474
183	0	34.9	20.0	80.1	26.4	28.3	3.2	12	665	8.1	482
184	0	37.2	20.0	76.2	26.1	30.0	2.4	13	678	7.7	490
185	0	38.6	21.3	64.4	19.5	31.3	2.5	14	692	8.4	499
186	1	33.1	21.7	85.0	39.0	21.4	3.2	12	704	6.5	505
187	0	39.8	22.4	68.6	20.5	30.0	2.6	16	719	8.4	513
188	0	37.9	19.8	55.8	13.3	31.8	3.1	13	733	9.6	523
189	0	39.4	19.0	48.6	9.9	32.1	3.0	14	746	9.9	533
190	0	39.1	22.2	53.2	15.0	31.5	3.7	15	761	10.3	543
191	0	39.8	21.3	50.1	11.0	30.9	3.5	15	776	10.3	554
192	0	37.8	21.6	57.1	24.9	26.0	2.9	14	791	8.0	562
193	0	34.7	23.2	78.9	36.2	16.2	3.6	13	804	6.4	568
194	0	37.8	22.1	80.5	30.9	27.0	2.8	14	818	7.6	576
195	0	36.5	22.1	75.8	33.5	28.2	4.1	14	832	8.5	584
196	0	35.9	24.7	69.8	35.0	24.2	3.4	15	847	7.5	592
197	0	35.8	24.0	69.9	35.4	17.5	3.5	14	861	6.7	598
198	19	35.5	21.8	112.9	36.9	22.1	3.2	13	874	6.8	605
199	0	33.5	21.6	92.9	49.7	18.5	2.5	12	886	5.0	610
200	0	37.4	20.0	94.6	35.2	20.7	2.0	13	899	5.8	616
201	0	39.2	21.2	93.1	26.3	29.1	2.0	15	914	7.3	623
202	0	40.3	22.1	83.0	26.8	25.2	2.1	16	930	6.9	630
203	0	41.3	21.0	84.7	14.8	29.6	2.1	16	945	8.1	638
204	0	41.4	23.4	64.9	16.3	30.6	2.5	17	962	8.9	647
205	0	40.2	22.4	54.0	13.3	30.8	2.6	16	978	9.2	656
206	0	38.6	23.1	52.8	19.9	29.8	2.9	15	993	9.0	665
207	0	35.5	22.4	56.8	20.2	27.3	4.0	13	1006	9.6	675
208	28	34.7	18.4	107.2	36.9	24.9	2.5	11	1017	6.6	681
209	0	38.4	19.4	88.3	15.2	30.7	2.1	13	1031	8.1	690
210	0	37.3	21.0	70.0	23.6	29.7	3.2	14	1044	8.7	698
211	0	36.7	22.0	63.8	24.1	28.1	3.6	14	1058	8.8	707
212	0	40.3	21.6	59.5	15.7	30.1	2.4	15	1074	8.6	716
213	0	40.6	25.1	44.8	15.0	28.0	3.1	17	1091	9.4	725
214	0	38.8	24.2	48.6	19.7	28.1	3.1	16	1107	9.0	734
215	0	39.2	21.9	47.0	15.7	20.4	2.3	15	1122	7.4	741
216	0	39.8	20.3	49.5	11.4	27.5	2.5	14	1136	8.7	750
217	7	39.8	22.7	103.8	16.9	28.6	4.5	16	1152	11.0	761
218	0	35.6	23.0	104.0	34.2	16.0	3.8	14	1166	6.8	768
219	0	37.1	23.9	74.6	29.3	16.8	3.2	15	1181	6.9	775

Table 57, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET_o	
		Mx	Mn	Mx	Mn			Daily	∑	Daily	∑
	(mm)	----- (°C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			(mm d^{-1})	(mm)
220	1	37.0	21.2	78.1	29.9	20.8	2.4	14	1194	6.5	781
221	0	36.6	21.5	82.5	26.9	29.2	3.8	14	1208	9.1	790
222	0	35.0	20.6	81.3	33.8	26.2	3.8	12	1220	7.9	798
223	0	32.4	21.0	86.2	43.4	19.5	2.8	11	1231	5.7	804
224	0	37.2	19.8	91.5	24.4	28.4	1.9	13	1244	7.1	811
225	0	35.5	22.0	85.8	22.5	28.8	3.2	13	1257	8.5	820
226	0	37.4	19.0	73.4	14.7	29.2	2.1	13	1270	7.7	827
227	0	38.4	19.6	66.9	15.2	28.5	1.9	13	1283	7.5	835
228	0	37.4	19.5	64.8	14.5	28.7	2.3	13	1296	8.1	843
229	0	38.6	17.9	53.5	11.7	28.6	2.6	13	1309	8.6	852
230	0	38.4	20.6	61.2	15.0	24.8	2.5	14	1323	7.9	859
231	0	33.8	20.4	78.7	31.4	20.9	3.3	12	1334	6.9	866
232	0	38.2	19.1	65.4	16.4	27.6	2.3	13	1347	7.8	874
233	0	37.7	19.3	62.4	21.8	26.4	2.7	13	1360	8.0	882
234	0	34.7	23.2	67.0	29.6	26.0	3.9	13	1374	8.4	891
235	0	35.8	19.7	72.1	17.0	26.9	3.5	12	1386	9.0	900
236	0	33.9	20.0	68.7	29.0	24.8	3.5	11	1397	7.7	907
237	2	27.6	20.7	93.8	53.4	13.0	2.5	9	1406	4.0	911
238	2	25.7	20.0	94.5	78.4	12.6	4.2	7	1413	2.6	914
239	0	29.1	19.6	94.7	57.8	15.7	3.6	9	1422	4.0	918
240	8	27.6	20.5	100.5	75.0	9.0	2.0	9	1431	1.9	920
241	3	27.6	20.6	94.0	74.4	12.2	1.9	9	1439	2.4	922
242	0	26.2	20.1	94.3	71.2	10.6	2.1	8	1447	2.4	925
243	0	29.2	20.3	93.8	61.4	19.0	2.5	9	1456	4.0	929
244	2	30.9	20.6	94.3	47.7	23.1	2.6	10	1466	5.3	934
245	0	32.5	19.3	94.3	35.5	20.5	2.3	10	1476	5.4	939
246	0	35.9	18.7	93.5	31.4	26.1	2.9	12	1488	7.1	946
247	0	36.9	20.2	90.4	25.9	22.9	3.5	13	1501	7.7	954
248	1	34.7	21.0	81.1	31.3	18.3	3.0	12	1513	6.3	960
249	0	33.2	20.0	92.1	34.2	24.0	3.2	11	1525	6.9	967
250	0	33.0	17.6	93.9	34.9	25.5	3.2	10	1534	7.0	974
251	0	34.4	17.7	93.2	33.1	25.2	2.9	10	1545	6.9	981
252	1	34.4	18.7	92.0	35.4	22.7	2.7	11	1556	6.2	987
253	0	34.4	17.8	93.9	32.3	24.8	2.3	11	1566	6.3	994
254	0	33.9	18.2	90.5	25.3	25.1	2.7	10	1577	7.1	1001
255	0	31.4	18.5	88.6	41.7	17.3	3.7	9	1586	5.6	1006
256	0	27.3	20.1	92.0	64.5	9.3	3.3	8	1594	2.8	1009
257	15	24.4	17.5	95.8	77.3	8.0	2.8	5	1600	1.8	1011
258	1	25.8	17.5	95.3	63.9	10.5	1.7	6	1606	2.5	1013
259	15	25.3	18.0	106.3	77.2	7.5	1.3	6	1612	1.4	1015
260	0	29.6	17.0	94.6	27.3	25.5	5.5	8	1620	8.1	1023
261	0	32.8	15.1	83.7	23.5	25.5	3.1	8	1628	7.1	1030
262	0	36.3	15.4	94.6	29.6	22.7	2.0	10	1638	5.6	1036

Table 57, continued

Day of Year	Rain	Air Temperature		Air Relative Humidity		Global Irradiance	Wind Speed	Heat Unit		ET$_o$	
		Mx	Mn	Mx	Mn			Daily	∑	**Daily**	∑
	(mm)	----- (□C) -----		----- (%) -----		(MJ m^{-2})	(m s^{-1})			**(mm d^{-1})**	**(mm)**
263	0	34.0	18.5	90.5	24.2	24.9	2.5	11	1649	**6.8**	**1042**
264	0	32.1	17.0	62.1	24.6	24.9	2.3	9	1658	**6.5**	**1049**
265	0	33.0	16.9	68.3	16.4	24.3	3.7	9	1667	**8.3**	**1057**
266	0	34.7	14.0	66.9	14.7	24.6	1.8	9	1676	**6.4**	**1064**
267	0	37.5	14.0	85.3	11.0	24.6	1.8	10	1686	**6.5**	**1070**
268	0	37.5	17.6	81.9	10.1	24.0	1.6	12	1698	**6.0**	**1076**
269	0	25.4	19.5	90.1	40.6	8.3	3.2	7	1705	**4.3**	**1080**
270	0	34.7	17.4	92.7	28.6	23.0	2.5	11	1716	**6.3**	**1087**
271	0	33.0	20.1	60.7	16.7	23.5	4.9	11	1727	**9.3**	**1096**
272	0	22.5	12.0	84.2	37.6	17.3	3.4	2	1728	**4.9**	**1101**
273	0	24.4	6.3	92.8	14.9	24.0	2.5	0	1728	**6.0**	**1107**
274	0	28.1	5.4	73.1	13.1	24.0	2.6	1	1730	**6.3**	**1113**
275	0	29.5	7.2	78.3	15.6	23.5	2.5	3	1732	**5.8**	**1119**
276	0	34.6	9.6	79.3	13.4	22.9	2.0	7	1739	**5.7**	**1125**
277	0	33.3	11.6	79.2	14.0	22.7	3.0	7	1746	**6.9**	**1132**
278	0	22.6	13.8	95.6	55.5	9.6	3.0	3	1748	**2.8**	**1134**
279	0	21.7	14.7	94.3	67.8	5.8	2.6	3	1751	**1.7**	**1136**
280	0	26.3	15.6	93.6	46.1	18.3	2.7	5	1756	**4.0**	**1140**
281	0	30.1	10.7	95.0	33.0	21.7	1.8	5	1761	**4.4**	**1145**
282	0	32.8	12.2	92.4	22.5	21.2	1.7	7	1768	**4.8**	**1149**
283	0	27.2	15.0	84.5	40.4	16.7	2.6	6	1774	**4.2**	**1154**
284	0	35.8	10.1	93.5	12.9	21.4	1.8	7	1781	**5.7**	**1159**
285	0	31.9	13.6	67.2	27.7	20.8	2.1	7	1788	**5.1**	**1164**
286	0	36.8	11.3	84.5	8.9	20.9	2.2	8	1797	**6.4**	**1171**
287	0	35.9	13.1	74.8	9.6	19.4	2.1	9	1806	**5.9**	**1177**
288	0	35.3	12.7	89.3	10.1	20.6	2.4	8	1814	**6.5**	**1183**
289	0	33.7	11.9	94.1	13.2	20.4	2.4	7	1821	**6.3**	**1189**
290	0	30.7	12.8	86.4	23.2	8.4	2.9	6	1828	**4.9**	**1194**
291	0	32.4	11.6	81.4	14.5	19.9	3.3	6	1834	**7.0**	**1201**
292	0	33.3	13.8	47.6	10.8	20.5	3.7	8	1842	**7.8**	**1209**
293	0	21.8	6.7	41.3	16.2	20.2	3.6	0	1842	**5.9**	**1215**
294	0	31.5	8.5	39.6	12.8	14.2	2.6	4	1846	**5.5**	**1221**
295	0	31.1	11.7	58.1	12.5	18.3	4.0	6	1852	**7.2**	**1228**
296	0	23.4	5.6	83.1	28.7	14.5	5.1	0	1852	**5.0**	**1233**

APPENDIX D

NEUTRON PROBE DATA

Instrument:

CPN (Model 503DR, Campbell Pacific Nuclear, Martinez, CA)

Calibration equation:

$$\theta_v = 0.2408 \text{ Count Ratio} - 0.0784$$

where,

θ_v	=	volumetric soil water content x 100 ($m^3\ m^{-3}$)
Count Ratio	=	neutron probe reading at site ÷ Standard Count

Table 58. Neutron probe data for 2 June 1994.

EU	15-cm	Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------------------------- Volumetric soil water content (%) ---------------------------------								
1-D										
1-M										
1-F										
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D										
4-M	18	11.2	22.4	27.9	28.3	30.0	27.6	18.7	19.7	22.6
4-F	18	11.6	23.1	27.5	26.1	24.2	18.3	13.2	19.4	21.5
5-D										
5-M	18	10.6	21.1	26.6	27.7	28.2	27.1	21.2	11.9	15.4
5-F	18	12.8	25.5	27.5	28.7	29.0	23.8	18.2	21.3	22.5
6-D										
6-M	18	10.6	21.2	25.1	23.6	15.4	10.0	9.2	10.1	10.3
6-F	18	12.9	25.9	22.7	13.5	8.6	9.2	11.1	12.2	13.0
7-D										
7-M	18	10.8	21.7	27.4	24.8	17.5	11.4	12.3	18.5	22.5
7-F	18	12.1	24.2	26.1	22.0	13.0	10.8	15.7	20.8	21.7
8-D										
8-M	18	11.3	22.6	27.3	24.0	17.2	11.2	11.7	14.3	14.8
8-F	18	12.8	25.7	24.7	16.3	11.4	12.3	14.5	18.4	19.8
9-D										
9-M	18	11.1	22.1	20.5	10.1	7.6	8.0	9.5	12.6	19.3
9-F	18	11.1	22.3	16.3	8.2	7.2	8.1	13.3	18.7	19.0
10-D										
10-M	18	10.9	21.9	26.4	24.7	24.2	20.0	12.0	14.4	19.9
10-F	18	12.8	25.7	27.8	25.2	19.0	11.6	14.5	20.4	21.9
11-D										
11-M										
11-F	18	13.2	26.3	27.3	25.4	20.4	12.6	12.3	15.9	20.7
12-D										
12-M	18	11.8	23.6	26.5	20.6	28.0	10.0	11.3	10.7	11.8
12-F	18	12.7	25.3	20.5	11.9	8.5	10.2	11.2	12.0	14.5

Table 59. Neutron probe data for 25 June 1994.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------------------------- Volumetric soil water content (%) ---------------------------------								
1-D	16	9.9	19.5	23.0	23.9	25.3	21.2	16.0	18.5	
1-M										
1-F	16	10.4	20.3	25.1	24.3	26.0	22.3	12.9	13.3	19.9
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D	18	8.1	16.1	20.7	23.1	26.3	30.3	30.1	29.5	29.8
4-M	18	8.8	17.5	25.6	27.4	30.9	31.2	29.4	31.8	31.4
4-F	18	10.4	20.8	27.0	27.9	29.1	30.0	29.0	31.0	28.9
5-D										
5-M	16	8.9	17.5	25.6	27.7	29.3	30.1	29.7	25.9	25.7
5-F	16	11.8	23.3	28.1	30.7	32.6	32.4	29.9	27.0	23.5
6-D										
6-M	19	8.3	16.8	22.8	24.9	24.5	24.0	23.4	17.3	11.1
6-F	19	12.3	24.8	25.6	25.0	23.3	24.3	22.4	15.1	13.8
7-D	14	8.1	15.6	24.1	27.5	29.5	11.7	26.1	21.9	22.5
7-M	14	9.9	18.9	27.7	28.9	28.1	27.3	21.6	20.3	22.4
7-F	14	12.0	22.9	27.9	29.3	31.2	28.5	30.7	32.9	30.7
8-D	14	10.4	19.9	25.4	27.4	27.5	19.5	13.3	14.9	14.9
8-M	14	10.6	20.4	27.0	26.6	26.0	21.2	14.3	14.8	15.2
8-F	14	13.8	26.3	28.0	29.1	28.3	23.7	17.7	18.6	19.9
9-D	14	9.4	17.9	25.8	27.4	27.5	26.2	20.9	16.7	18.0
9-M	14	11.7	22.4	25.8	23.2	20.6	13.7	9.9	13.0	25.0
9-F	14	12.8	24.5	24.1	22.5	18.7	11.7	13.2	18.5	19.1
10-D	15	10.1	19.7	24.6	26.6	30.2	30.2			
10-M	15	9.5	18.4	26.7	27.0	28.5	29.2	25.6	21.9	21.5
10-F	15	12.2	23.6	29.3	29.8	30.8	27.2	25.0	25.8	23.1
11-D	18	6.7	13.3	20.4	24.8	26.6	28.0	30.6		
11-M										
11-F	18	12.3	24.5	27.8	27.7	27.9	29.8	27.6	23.0	21.8
12-D										
12-M	18	9.3	18.5	25.2	24.3	23.2	22.8	16.7	10.9	12.2
12-F	18	11.7	23.4	26.2	25.0	27.4	27.9	26.1	22.8	16.3

Table 60. Neutron probe data for 1 July 1994.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	Volumetric soil water content (%)								
1-D	8	10.7	18.3	20.3	22.3	24.3	21.0	16.1	18.1	18.1
1-M										
1-F	8	13.4	22.9	25.0	24.2	26.0	23.0	13.5	13.7	18.6
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D	6	11.2	18.2	21.3	22.3	25.6	29.0	29.5	28.6	30.1
4-M	6	13.2	21.5	26.6	26.6	29.6	30.9	28.7	31.2	30.9
4-F	6	14.6	23.8	26.6	26.7	27.7	29.6	28.1	30.1	28.7
5-D										
5-M	8	11.1	18.9	24.6	28.1	29.2	30.2	30.1	26.1	26.1
5-F	8	14.8	25.2	27.8	31.0	32.9	32.7	28.9	27.9	24.1
6-D										
6-M	5	14.1	22.3	26.1	27.3	26.6	26.6	25.4	19.3	11.5
6-F	5	17.8	28.1	27.0	25.1	24.7	24.9	22.7	15.6	13.7
7-D										
7-M	10	8.9	15.9	25.3	26.4	27.4	26.6	22.6	21.3	22.5
7-F	10	11.2	19.9	26.4	28.8	30.2	27.7	29.5	32.3	30.8
8-D	10	11.9	21.3	25.3	27.1	27.4	23.0	14.6	14.5	14.5
8-M	10	11.0	19.6	25.8	26.3	27.6	24.4	16.5	14.7	15.2
8-F	10	14.5	25.8	29.0	30.5	30.2	26.1	17.5	18.6	19.7
9-D	10	10.6	18.9	25.5	28.0	27.0	26.2	22.7	18.8	18.7
9-M	10	11.9	21.2	25.7	26.4	25.1	23.1	15.0	13.5	19.3
9-F	10	13.9	24.8	26.8	26.8	27.0	28.3	26.9	23.1	19.1
10-D	9	11.5	20.1	21.4	24.1	28.4	28.4			
10-M	9	13.3	23.2	24.9	23.0	22.8	22.5	16.8	11.5	11.8
10-F	9	15.2	26.5	26.1	24.2	26.2	27.0	25.4	22.0	16.4
11-D	6	12.6	20.5	25.5	27.1	28.2	28.9	31.1		
11-M										
11-F	6	17.0	27.6	28.5	27.9	28.8	29.6	27.5	23.2	21.4
12-D										
12-M	6	11.1	18.1	25.5	25.3	26.9	28.7	25.2	22.6	21.4
12-F	6	14.0	22.8	27.5	29.1	30.6	28.3	25.6	26.1	22.6

Table 61. Neutron probe data for 9 July 1994.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	---------- Volumetric soil water content (%) ----------								
1-D	16	8.1	15.9	17.5	19.4	22.9	20.8	16.8	18.5	18.5
1-M										
1-F	16	8.5	16.7	17.9	18.1	22.5	21.9	13.8	14.1	19.3
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D	13	8.5	15.9	19.4	18.1	20.7	25.5	28.3	28.5	29.7
4-M	13	7.6	14.4	20.6	20.6	25.9	29.2	27.9	30.1	30.9
4-F	13	8.6	16.1	19.0	20.8	24.2	27.9	27.2	29.8	28.0
5-D										
5-M	16	6.7	13.2	20.1	20.4	23.3	26.2	27.5	24.6	25.3
5-F	16	9.5	18.7	20.8	24.9	29.9	31.4	28.7	27.3	25.1
6-D										
6-M	13	8.1	15.3	19.0	19.9	20.0	22.1	23.4	20.8	12.8
6-F	13	10.5	19.7	19.3	20.4	21.2	23.4	22.6	16.1	13.4
7-D										
7-M	17	6.4	12.8	21.2	21.8	23.3	24.4	22.2	22.2	23.1
7-F	17	7.8	15.5	19.2	21.4	24.7	25.1	28.1	30.6	30.1
8-D	17	9.3	18.4	21.3	24.5	26.2	22.4	15.1	14.7	14.7
8-M	17	7.5	14.8	20.7	21.6	23.9	24.0	17.3	14.9	15.4
8-F	17	9.6	19.0	22.7	26.5	28.4	25.2	17.8	19.0	19.9
9-D	17	7.3	14.5	22.3	24.5	24.6	25.6	22.6	20.3	18.6
9-M	17	8.4	16.7	21.2	21.4	21.7	22.4	17.0	13.7	19.7
9-F	17	9.9	19.6	22.1	22.8	24.4	26.1	26.2	24.1	20.0
10-D	17	8.8	17.5	18.6	19.8	24.4	24.4			
10-M	17	6.2	12.3	17.6	16.9	20.9	24.2	23.8	22.2	21.8
10-F	17	8.9	17.6	18.8	22.1	24.9	24.7	24.3	26.2	23.3
11-D	14	8.1	15.5	22.0	24.0	24.2	26.3	29.0		
11-M										
11-F	14	10.5	20.1	22.4	24.1	25.9	28.0	27.5	24.0	21.8
12-D										
12-M	14	8.6	16.5	20.5	18.5	20.3	22.0	17.6	11.8	12.3
12-F	14	12.4	23.7	21.0	21.1	24.0	25.9	25.0	21.5	16.7

Table 62. Neutron probe data for 20 July 1994.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------								
1-D	11	11.3	20.6	21.6	22.2	24.2	22.0	18.3	19.1	19.1
1-M	11	9.9	18.1	19.8	17.2	18.2	18.7	14.3	11.4	13.1
1-F	11	11.8	21.5	23.3	22.1	24.8	24.0	16.2	14.4	19.8
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D	12	10.4	19.2	22.0	22.4	23.5	27.0	28.7	28.1	29.8
4-M	12	9.8	18.2	23.0	22.3	26.7	29.5	28.6	31.9	31.6
4-F	12	10.3	19.2	21.5	21.6	22.9	26.1	26.9	29.8	28.9
5-D										
5-M	8	11.7	19.9	24.2	23.7	25.9	26.5	27.0	24.0	25.7
5-F	8	14.1	24.0	24.1	25.6	28.2	30.7	28.4	27.5	26.9
6-D										
6-M	8	12.3	21.0	23.5	24.0	22.4	21.9	23.6	20.8	13.8
6-F	8	15.1	25.8	23.8	21.7	21.5	22.6	22.3	16.7	14.1
7-D										
7-M	12	8.5	15.7	21.0	20.0	19.4	21.6	21.6	23.3	23.6
7-F	12	9.9	18.3	18.7	18.0	18.1	18.1	23.1	28.6	29.3
8-D	12	10.9	20.3	22.8	25.8	27.3	24.9	18.2	15.6	15.6
8-M	12	9.7	17.9	21.7	19.9	21.7	23.4	22.1	16.8	15.6
8-F	12	11.7	21.7	21.6	22.8	25.1	24.3	18.6	19.0	20.1
9-D	12	10.0	18.6	23.9	24.6	24.3	24.9	22.4	20.8	19.6
9-M	12	10.7	19.9	20.1	18.4	20.3	21.5	18.1	15.6	19.8
9-F	12	11.4	21.2	20.4	20.5	22.1	24.8	25.5	25.4	21.2
10-D	7	13.7	22.8	20.2	21.9	25.1	25.0	23.4	26.3	28.1
10-M	7	10.2	17.0	18.7	15.1	16.0	20.1	22.3	22.0	22.0
10-F	7	12.8	21.3	19.3	18.0	21.4	22.9	23.7	26.2	23.7
11-D	11	10.0	18.1	23.4	25.9	25.6	26.4	28.5		
11-M	11	12.1	22.0	23.3	24.0	24.9	26.8	27.1		
11-F	11	11.9	21.7	22.0	21.2	22.7	25.3	26.0	24.1	23.2
12-D										
12-M	11	10.3	18.8	21.0	16.8	18.5	21.9	18.7	13.1	13.0
12-F	11	11.1	20.1	19.0	17.6	20.6	23.4	23.4	20.9	16.6

Table 63. Neutron probe data for 2 August 1994.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	Volumetric soil water content (%)							
1-D	8	12.9	22.0	22.4	22.2	23.1	21.6	17.7	18.5	18.5
1-M	8	10.9	18.5	22.2	21.1	20.3	20.8	18.8	11.8	13.8
1-F	8	12.5	21.4	23.0	20.9	19.6	19.0	15.4	14.2	19.2
2-D										
2-M										
2-F										
3-D										
3-M										
3-F										
4-D	13	7.8	14.7	18.7	20.6	22.7	25.6	27.4	27.1	28.6
4-M	13	7.7	14.5	20.0	19.6	23.3	26.6	26.4	30.6	30.5
4-F	13	8.5	16.0	19.8	20.5	21.1	23.1	23.4	27.9	28.8
5-D										
5-M	9	10.2	17.8	22.3	23.6	25.2	26.8	26.2	22.5	24.4
5-F	9	13.1	22.8	23.9	24.3	25.7	27.5	27.1	26.7	26.2
6-D										
6-M	8	11.0	18.7	22.5	23.6	23.2	23.0	24.4	21.5	15.0
6-F	8	14.4	24.6	23.4	20.9	23.3	18.4	19.6	15.8	13.9
7-D	9	10.6	18.6	23.4	21.8	19.7	22.5	22.6	21.9	25.3
7-M	9	10.2	17.8	25.0	24.9	24.1	24.0	21.7	23.3	23.2
7-F	9	11.6	20.3	22.2	18.5	15.0	14.3	20.1	26.9	28.2
8-D	9	11.3	19.7	22.2	24.0	25.6	22.9	17.6	15.2	17.3
8-M	9	10.2	17.8	22.8	20.0	16.9	22.0	20.3	16.9	15.1
8-F	9	12.8	22.3	23.4	23.1	23.3	22.7	17.9	18.3	20.1
9-D	9	11.1	19.4	24.3	24.7	23.8	23.1	21.4	20.7	20.2
9-M	9	12.1	21.1	24.0	22.2	23.0	23.9	21.4	17.1	19.6
9-F	9	12.2	21.4	21.5	22.1	22.6	23.3	23.8	24.6	20.8
10-D	12	10.2	19.0	18.4	20.7	23.3	23.7	22.7	24.7	27.0
10-M	12	6.8	12.6	17.3	14.4	13.9	16.8	19.7	20.7	22.0
10-F	12	9.5	17.6	18.3	16.7	18.4	19.5	21.7	25.4	23.4
11-D	13	8.2	15.5	21.1	22.3	22.4	24.0	25.9	26.9	27.2
11-M	13	9.4	17.8	20.1	21.3	22.0	23.7	24.9	24.4	27.6
11-F	13	9.9	18.7	19.5	18.5	18.2	20.5	22.8	22.9	22.3
12-D										
12-M	13	8.8	16.6	19.2	14.9	15.5	20.2	21.1	15.6	12.4
12-F	13	9.3	17.5	16.7	14.0	14.1	15.8	18.8	19.2	16.0

Table 64. Neutron probe data for 5 August 1994.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------ Volumetric soil water content (%) ------								
1-D	11	11.0	19.9	20.4	20.9	22.7	21.2	17.9	18.1	22.4
1-M	11	9.2	16.6	19.8	18.1	19.1	20.0	17.9	11.3	13.7
1-F	11	10.4	19.0	20.7	19.1	19.1	18.6	14.9	13.7	19.1
2-D	15	7.5	14.5	17.0	19.0	20.0	21.5	24.7	27.0	
2-M	15	6.6	12.7	18.9	20.4	20.3	23.6	25.9		
2-F	15	8.1	15.7	19.2	19.5	20.7	23.5	25.0		
3-D	12	9.2	17.0	19.5	21.1	21.9	24.2	24.1	20.5	20.1
3-M	12	7.6	14.0	19.0	19.8	19.3	17.9	15.9	18.6	20.2
3-F	12	8.5	15.8	19.6	18.4	16.0	18.0	21.0	20.0	19.9
4-D	16	6.6	13.0	17.2	18.2	20.6	23.2	25.6	26.9	28.3
4-M	16	6.4	12.6	18.6	17.2	20.3	23.3	24.2	29.4	30.6
4-F	16	7.3	14.3	17.7	17.2	18.2	20.0	20.9	27.0	28.3
5-D	12	8.1	15.0	19.7	21.1	20.5	21.2	23.6	21.3	21.6
5-M	12	8.5	15.7	20.5	21.2	23.3	24.5	24.3	21.5	24.0
5-F	12	11.3	20.9	21.9	22.5	23.8	27.3	26.9	26.8	26.3
6-D	11	10.1	18.4	22.5	21.6	20.4	20.2	19.4	15.9	11.4
6-M	11	9.1	16.5	20.8	21.2	20.6	21.0	22.9	21.3	14.9
6-F	11	12.5	22.7	21.5	19.1	16.9	17.2	19.0	16.0	13.8
7-D	12	8.7	16.0	21.3	19.7	18.9	21.9	22.4	16.3	25.0
7-M	12	8.0	14.8	22.9	22.5	21.7	21.2	21.5	22.7	23.1
7-F	12	9.4	17.5	19.5	17.0	14.6	14.4	19.6	26.0	28.4
8-D	12	9.2	17.0	19.5	21.5	24.7	22.9	18.1	15.3	17.7
8-M	12	8.5	15.7	20.0	17.5	17.6	20.6	20.4	16.1	15.3
8-F	12	10.7	19.7	21.0	20.8	22.0	21.2	17.7	18.5	19.4
9-D	12	9.1	16.9	22.3	22.7	22.5	22.5	21.0	20.3	19.9
9-M	12	10.0	18.5	20.4	19.0	20.5	22.2	20.6	17.5	20.0
9-F	12	10.4	19.2	18.6	18.8	19.2	20.7	22.1	24.5	20.7
10-D	15	9.3	18.0	17.4	19.8	22.3	23.1	22.0	25.1	26.9
10-M	15	5.9	11.5	16.4	13.5	12.8	15.9	19.3	20.5	22.1
10-F	15	8.2	15.9	17.0	15.2	16.7	19.0	21.0	25.0	23.3
11-D	16	7.1	14.0	19.2	20.2	20.4	22.0	24.0	25.5	26.4
11-M	16	8.3	16.4	18.6	19.0	19.9	22.4	24.0	24.4	27.4
11-F	16	8.8	17.3	17.3	16.2	16.3	18.0	20.9	22.7	22.4
12-D	16	7.7	15.1	17.3	17.2	19.7	22.7	20.9	18.9	19.7
12-M	16	7.7	15.0	18.5	13.6	13.8	18.2	20.6	15.3	12.5
12-F	16	8.5	16.6	15.3	12.8	12.4	14.6	18.2	18.5	16.9

Table 65. Neutron probe data for 9 August 1994.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	15	8.9	17.2	18.3	19.1	22.2	21.0	18.3	18.8	22.3
1-M	15	7.3	14.2	16.9	15.9	16.7	18.6	17.1	11.2	14.6
1-F	15	8.1	15.7	18.3	16.9	16.9	16.8	14.6	13.9	20.0
2-D	19	6.3	12.6	14.9	16.8	17.3	18.7	21.7	24.5	
2-M	19	5.2	10.5	16.2	17.7	17.4	20.8	24.4		
2-F	19	7.0	14.0	16.9	17.3	18.1	21.1	23.6		
3-D	16	7.9	15.6	18.1	19.4	20.5	22.6	23.5	20.3	20.1
3-M	16	6.0	11.8	17.5	18.0	16.8	16.3	15.6	18.1	20.4
3-F	16	7.3	14.4	17.2	16.5	15.4	17.7	20.7	20.2	20.2
4-D	23	5.3	10.8	14.6	15.7	17.8	20.1	23.3	25.5	27.7
4-M	23	5.4	10.8	15.8	14.4	16.8	20.0	21.3	28.4	29.6
4-F	23	6.3	12.7	15.7	14.7	15.2	16.9	18.8	26.1	28.5
5-D	16	7.7	15.0	19.7	21.2	20.6	21.2	23.6	21.4	21.6
5-M	16	8.0	15.8	20.5	21.2	23.4	24.6	24.4	21.5	24.0
5-F	16	10.7	20.9	21.9	22.5	23.9	27.4	27.0	26.9	26.4
6-D	15	9.5	18.4	22.5	21.7	20.4	20.2	19.4	15.9	11.4
6-M	15	8.6	16.6	20.9	21.2	20.6	21.1	23.0	21.4	14.9
6-F	15	11.7	22.8	21.6	19.2	17.0	17.3	19.1	16.1	13.9
7-D	16	8.2	16.1	21.3	19.8	18.9	21.9	22.4	16.3	25.0
7-M	16	7.5	14.8	23.0	22.6	21.8	21.3	21.6	22.7	23.1
7-F	16	8.9	17.5	19.5	17.1	14.6	14.4	19.7	26.0	28.5
8-D	16	8.7	17.0	19.5	21.5	24.8	23.0	18.2	15.4	17.7
8-M	16	8.0	15.8	20.1	17.5	17.7	20.7	20.4	16.2	15.3
8-F	16	10.1	19.8	21.1	20.9	22.1	21.3	17.7	18.5	19.4
9-D	16	8.6	16.9	22.4	22.7	22.5	22.5	21.0	20.3	20.0
9-M	16	9.5	18.6	20.4	19.0	20.5	22.2	20.7	17.6	20.1
9-F	16	9.8	19.3	18.6	18.8	19.2	20.7	22.2	24.6	20.8
10-D	19	9.0	18.1	17.4	19.8	22.3	23.1	22.0	25.2	27.0
10-M	19	5.7	11.5	16.4	13.5	12.9	16.0	19.3	20.5	22.1
10-F	19	7.9	16.0	17.1	15.2	16.8	19.1	21.0	25.0	23.3
11-D	20	6.9	14.0	19.2	20.3	20.4	22.1	24.0	25.6	26.5
11-M	20	8.1	16.4	18.6	19.1	19.9	22.5	24.1	24.5	27.4
11-F	20	8.6	17.3	17.3	16.2	16.3	18.0	21.0	22.7	22.5
12-D	20	7.5	15.2	17.4	17.2	19.7	22.7	20.9	18.9	19.7
12-M	20	7.5	15.1	18.5	13.7	13.9	18.2	20.6	15.3	12.5
12-F	20	8.2	16.6	15.3	12.9	12.4	14.7	18.3	18.5	16.9

Table 66. Neutron probe data for 12 August 1994.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------ Volumetric soil water content (%) ------							
1-D	2	14.9	21.8	18.9	19.1	21.4	20.6	18.2	18.0	22.7
1-M	2	15.8	23.0	24.6	21.4	20.1	21.0	17.4	11.0	14.7
1-F	2	17.3	25.2	24.1	18.2	16.6	16.9	14.3	14.1	19.3
2-D	2	15.4	22.5	24.8	26.1	24.0	20.9	21.5	24.8	
2-M	2	16.2	23.6	27.3	27.0	24.6	24.2	25.8		
2-F	2	18.7	27.3	26.7	24.4	21.5	21.6	24.1		
3-D	2	16.0	23.3	24.7	22.0	20.5	21.9	23.2	20.9	
3-M	2	15.6	22.7	23.5	18.3	16.7	15.9	15.4	18.3	19.9
3-F	2	17.3	25.3	22.8	22.5	25.3	25.0	24.6	25.6	24.2
4-D	3	16.9	25.3	28.2	25.1	20.4	20.0	23.6	25.2	27.4
4-M	3	18.0	27.0	29.8	27.8	26.3	22.9	22.3	28.0	29.7
4-F	3	19.4	29.1	28.0	20.6	17.9	16.8	18.5	26.0	27.4
5-D	2	14.8	21.6	25.2	25.8	24.0	21.6	21.7	20.1	20.0
5-M	2	15.9	23.2	27.2	27.9	29.5	28.6	26.3	21.8	24.0
5-F	2	18.7	27.3	27.9	26.5	24.8	25.3	26.2	26.5	26.1
6-D	2	16.7	24.3	26.8	24.1	21.5	19.0	18.7	15.9	11.5
6-M	2	16.2	23.7	26.7	27.6	27.7	27.6	27.7	23.8	15.6
6-F	2	19.7	28.7	26.3	21.7	16.3	15.4	17.4	15.8	14.1
7-D	3	16.6	24.9	28.3	27.5	24.5	22.1	22.5	21.8	
7-M	3	16.4	24.6	28.7	27.5	24.0	19.8	19.9	22.7	22.6
7-F	3	18.3	27.4	28.1	23.0	15.5	13.8	18.7	25.3	27.1
8-D	3	15.6	23.5	21.7	19.2	22.7	21.8	17.8	15.0	17.7
8-M	3	17.0	25.6	26.1	19.2	15.1	18.4	19.6	16.2	15.4
8-F	3	18.7	28.1	24.2	18.3	19.1	20.3	17.2	18.9	20.9
9-D	3	16.0	24.0	27.9	24.1	20.7	21.1	20.2	20.2	19.5
9-M	3	17.4	26.1	27.5	26.4	26.2	24.8	20.9	17.5	19.7
9-F	3	17.9	26.8	25.8	23.6	18.9	16.9	20.0	23.5	20.8
10-D	2	13.2	19.2	16.4	17.9	21.7	22.4	21.6	24.9	27.0
10-M	2	17.2	25.1	24.6	15.3	12.1	14.1	18.1	19.6	21.6
10-F	2	18.3	26.7	21.3	14.0	14.9	16.7	20.2	24.6	23.1
11-D	3	15.6	23.4	27.6	25.1	24.5	22.4	21.8	23.1	19.2
11-M	3	17.5	26.3	25.9	21.2	18.6	20.3	23.0	23.3	26.9
11-F	3	17.9	26.9	21.6	16.6	15.2	15.9	18.6	21.4	22.6
12-D	3	17.0	25.6	20.2	15.6	17.5	20.7	19.7	18.3	19.7
12-M	3	16.5	24.7	20.2	17.3	16.2	16.6	19.0	14.4	12.4
12-F	3	16.7	25.0	15.7	11.4	11.6	13.3	16.0	17.5	16.5

Table 67. Neutron probe data for 17 August 1994.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	7	12.0	20.0	19.0	19.3	21.8	21.0	17.9	18.4	22.8
1-M	7	11.2	18.7	21.0	19.0	18.1	19.5	17.0	11.2	14.7
1-F	7	12.5	20.8	21.8	18.3	16.9	16.4	14.3	14.4	19.5
2-D	7	10.9	18.2	20.7	22.3	21.4	20.7	21.2	24.0	
2-M	7	9.6	15.9	21.9	22.4	22.2	22.8	25.3		
2-F	7	12.9	21.6	22.7	21.8	21.2	21.4	23.8		
3-D	7	11.7	19.4	21.2	21.0	20.5	22.4	23.0	21.1	20.5
3-M	7	9.9	16.4	20.1	18.5	16.3	15.9	15.8	18.2	20.3
3-F	7	12.0	20.1	21.5	20.2	20.2	22.2	24.0	24.9	23.4
4-D	8	10.5	17.9	21.8	21.4	20.7	20.6	23.5	25.5	27.8
4-M	8	11.3	19.2	24.4	22.9	23.9	22.5	21.4	27.9	29.9
4-F	8	13.6	23.2	23.8	19.3	16.6	16.8	18.0	26.1	28.0
5-D	7	10.2	17.0	22.2	23.0	22.7	22.3	22.2	20.0	20.7
5-M	7	10.5	17.5	22.7	24.4	25.7	26.3	24.8	20.9	23.4
5-F	7	13.9	23.1	25.4	25.8	26.1	26.3	26.1	26.8	26.2
6-D	7	12.3	20.5	25.0	23.8	21.2	20.1	19.2	16.0	11.5
6-M	7	10.9	18.1	22.8	23.7	23.7	23.5	25.1	23.2	16.7
6-F	7	14.7	24.4	23.7	21.2	18.3	15.9	17.5	15.7	13.7
7-D	8	10.8	18.4	24.1	23.9	24.1	23.5	22.1	21.6	25.2
7-M	8	10.4	17.7	24.7	24.2	23.2	21.6	20.4	23.0	22.8
7-F	8	12.6	21.4	23.3	21.4	15.9	13.9	18.8	26.1	27.2
8-D	8	11.1	19.0	19.6	19.0	22.8	21.3	17.4	15.6	18.0
8-M	8	11.0	18.8	21.9	17.4	15.1	18.4	19.2	16.3	15.4
8-F	8	13.6	23.2	21.9	18.2	18.5	19.5	17.4	18.8	21.2
9-D	8	11.0	18.8	23.7	22.8	21.2	21.7	20.4	20.1	20.0
9-M	8	11.7	20.0	21.9	20.6	21.6	23.0	21.0	18.0	20.3
9-F	8	12.2	20.8	20.6	20.5	19.2	17.9	19.7	23.3	21.0
10-D	7	11.4	19.0	16.1	17.8	20.6	22.3	21.9	24.4	27.0
10-M	7	11.4	19.1	22.3	16.0	12.4	14.3	17.7	20.1	21.5
10-F	7	13.8	22.9	20.9	14.8	15.2	16.6	19.7	24.1	23.2
11-D	8	9.5	16.2	21.0	21.4	20.5	20.8	21.5	22.9	24.6
11-M	8	11.5	19.6	22.3	19.6	18.2	19.5	22.8	23.1	26.6
11-F	8	12.6	21.5	19.3	16.3	14.4	15.3	17.9	20.7	22.6
12-D	8	11.4	19.4	18.8	15.8	17.5	20.3	20.0	18.2	20.2
12-M	8	12.5	21.4	20.0	15.6	14.2	17.1	18.3	14.2	12.6
12-F	8	12.8	21.8	16.1	11.3	11.9	13.3	15.4	16.7	16.3

Table 68. Neutron probe data for 30 August 1994.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) ---------------------------------								
1-D	4	16.1	24.8	24.9	24.5	25.2	21.8	18.0	18.2	23.8
1-M	4	16.8	25.9	27.2	23.7	20.3	18.0	16.9	11.8	13.6
1-F	4	17.2	26.5	26.8	24.3	24.0	18.2	14.0	14.6	19.6
2-D	4	14.2	21.9	24.4	25.7	24.9	24.7	25.1	24.0	
2-M	4	13.4	20.7	26.2	26.3	23.9	24.5	26.7		
2-F	4	15.3	23.6	26.6	25.2	25.3	24.6	24.9		
3-D	4	15.6	24.1	26.0	26.7	26.7	28.4	28.8	27.3	24.8
3-M	4	14.9	22.9	25.6	25.5	23.1	21.1	16.9	18.3	20.3
3-F	4	15.6	24.1	26.0	26.7	26.7	28.4	28.8	27.3	24.8
4-D	4	18.9	29.1	28.2	27.4	28.7	26.5	24.8	26.5	29.3
4-M	4	17.7	27.2	30.6	29.5	29.7	28.4	22.5	27.1	29.1
4-F	4	19.1	29.5	29.8	27.0	22.8	17.8	18.4	25.1	26.6
5-D	4	14.2	21.9	25.0	26.0	25.8	25.4	24.9	20.5	20.2
5-M	4	15.1	23.3	27.4	28.4	29.6	29.5	27.1	22.7	23.7
5-F	4	18.0	27.7	28.2	29.3	29.5	30.0	26.6	26.5	25.9
6-D	4	15.9	24.6	26.8	26.4	25.4	25.6	24.4	21.7	17.2
6-M	4	15.8	24.4	27.5	28.5	27.7	28.0	29.1	27.9	25.0
6-F	4	18.5	28.5	27.5	25.2	25.5	26.5	26.4	22.8	15.0
7-D	4	15.6	24.1	27.6	27.6	26.8	25.8	22.5	21.3	25.0
7-M	4	15.1	23.3	28.2	28.0	26.4	24.0	20.3	22.4	23.2
7-F	4	16.5	25.4	27.4	26.1	20.7	14.4	19.2	25.3	27.3
8-D	4	15.9	24.5	29.4	30.3	31.4	30.2	27.8	26.7	25.0
8-M	4	15.6	24.1	28.0	28.7	30.8	29.9	26.2	18.2	15.2
8-F	4	18.6	28.6	30.5	31.5	31.0	28.4	21.0	19.1	22.8
9-D	4	16.3	25.2	29.3	29.6	29.2	28.1	24.9	26.1	26.8
9-M	4	17.8	27.4	28.0	28.1	28.3	29.0	28.4	30.9	32.4
9-F	4	18.0	27.7	27.9	27.9	28.5	29.5	31.3	34.7	34.1
10-D	4	18.2	28.1	30.3	30.7	30.9	29.8	29.2	33.6	35.4
10-M	4	15.1	23.4	27.6	28.0	29.6	30.2	28.1	29.4	33.0
10-F	4	17.7	27.2	30.1	30.9	31.0	26.5	29.2	31.8	30.4
11-D	4	17.7	27.3	29.8	29.5	28.7	30.3	30.1	29.7	29.2
11-M	4	18.7	28.8	29.4	29.9	29.3	30.0	28.8	27.2	29.0
11-F	4	19.0	29.2	29.3	28.6	28.4	27.5	23.8	20.9	22.1
12-D	4	19.6	30.3	30.2	29.3	29.8	28.0	25.1	11.8	21.8
12-M	4	18.5	28.6	30.0	27.8	27.5	28.0	23.3	15.3	13.2
12-F	4	19.5	30.0	28.5	24.0	20.3	15.1	15.2	16.3	16.7

Table 69. Neutron probe data for 20 July 1995.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	---- Volumetric soil water content (%) ----								
1-D	5	9.6	15.2	20.6	21.9	25.7	27.7	29.9		
1-M	5	8.3	13.2	18.1	22.2	28.4	32.4	32.6		
1-F	5	11.8	18.6	21.6	27.3	30.8	31.1	30.8	34.8	36.6
2-D	5	8.1	12.9	17.3	19.2	22.0	25.4	29.8		
2-M	5	10.3	16.3	16.9	16.6	23.3	29.7	31.8		
2-F	5	10.8	17.1	16.0	16.9	23.8	30.5	30.6		
3-D	5	5.6	8.8	15.3	18.5	19.0	22.4	27.1		
3-M	5	10.1	16.0	16.2	16.2	22.3	29.7	31.7		
3-F	5	10.3	16.2	16.1	16.1	23.3	30.4	31.9	32.1	30.0
4-D	5	9.1	14.4	16.2	17.6	18.5				
4-M	5	17.7	28.0	27.2	25.6	24.5	29.9	31.1		
4-F	5	16.7	26.5	24.8	26.8	29.5	32.0	30.7	33.4	35.9
5-D	5	7.0	11.1	18.5	23.0	25.4	27.8	30.0		
5-M	5	6.7	10.6	15.2	16.6	23.8	31.2	33.8		
5-F	5	9.0	14.2	15.9	18.0	25.7	31.2	33.6	33.6	33.1
6-D	5	8.5	13.5	18.4	19.9	21.4	23.0	24.8		
6-M	5	9.4	14.9	16.8	18.0	20.7	24.7	28.9		
6-F	5	8.7	13.7	14.9	17.0	20.0	26.1	30.5	27.5	26.9
7-D										
7-M										
7-F										
8-D										
8-M										
8-F										
9-D										
9-M										
9-F										
10-D	5	11.6	18.4	20.6	23.5	26.6	29.7			
10-M	5	12.6	19.9	21.4	25.6	29.8	32.5	33.4		
10-F	5	10.3	16.3	18.9	22.5	28.8	30.7	31.5	32.1	34.8
11-D	5	8.5	13.5	17.4	18.7	20.3	23.3	26.6		
11-M	5	11.3	17.9	22.3	23.5	26.4	28.5	31.9		
11-F	5	12.4	19.6	21.6	23.8	26.8	31.2	32.0	33.8	
12-D	5	11.4	18.1	18.4	21.4	26.2				
12-M	5	10.8	17.0	19.1	19.4	23.0	28.4	30.3		
12-F	5	11.1	17.5	18.7	19.8	25.1	29.1	27.3	29.1	34.8

Table 70. Neutron probe data for 7 August 1995.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------ Volumetric soil water content (%) ------------							
1-D	5	8.4	13.2	17.4	18.4	22.5	25.2	28.1	
1-M	5	9.1	14.4	16.7	19.5	25.5	29.7	31.0	
1-F	5	10.0	15.9	20.4	22.9	27.3	29.3	29.8	31.2	34.0
2-D	5	7.4	11.7	16.1	17.2	18.8	23.7	27.5	
2-M	5	10.3	16.3	16.8	15.9	20.3	25.9	29.7	
2-F	5	8.8	13.9	17.4	14.5	15.8	21.5	27.1	
3-D	5	5.6	8.8	14.5	17.1	17.3	19.2	24.8	
3-M	5	10.2	16.1	15.4	15.5	18.5	22.8	27.9	
3-F	5	9.3	14.7	17.0	15.6	16.5	20.4	27.0	31.1	30.1
4-D	5	8.5	13.5	15.6	15.8	16.6			
4-M	5	8.9	14.1	16.3	14.6	16.8	22.4	26.7	
4-F	5	9.4	14.9	15.7	14.9	18.5	24.5	27.2	31.0	34.1
5-D	5	9.0	14.3	18.5	18.5	18.4	19.2	21.2	
5-M	5	10.1	15.9	15.8	15.9	16.6	19.1	23.7	
5-F	5	9.1	14.4	14.3	14.8	15.5	19.5	25.2	25.1	25.5
6-D	5	6.8	10.7	15.7	18.9	22.1	25.0	28.0	
6-M	5	8.2	13.0	15.9	15.6	20.5	27.6	31.1	
6-F	5	9.3	14.7	16.5	15.9	19.6	25.9	30.3	32.4	31.6
7-D	5	7.5	11.9	16.8	17.7				
7-M	5	10.2	16.1	17.3	16.2	18.5	25.8	27.8	
7-F	5	11.1	17.6	18.0	16.4	22.1	28.0	30.1	34.9	34.4
8-D	5	11.3	17.9	18.2	19.4	20.4			
8-M	5	10.3	16.4	19.5	17.6	19.1	25.5	29.4	
8-F	5	11.2	17.8	18.0	17.8	22.7	28.0	29.0	31.5	
9-D	5	10.4	16.4	19.8	19.1	19.9	22.2		
9-M	5	12.8	20.3	20.6	21.0	24.0	27.8	30.0	
9-F	5	10.5	16.6	18.5	18.2	19.9	23.1	26.8	28.2	23.8
10-D	5	10.4	16.5	16.9	17.1	19.1	21.7		
10-M	5	11.0	17.4	17.4	18.1	21.8	25.9	28.7	
10-F	5	9.5	15.1	16.5	17.7	21.9	24.1	26.3	27.6	31.3
11-D	5	8.2	13.0	15.5	16.8	16.8	17.9	20.9	
11-M	5	10.9	17.3	20.4	18.5	18.8	20.7	25.2	
11-F	5	11.8	18.7	18.4	17.5	19.3	23.4	26.4	29.9	
12-D	5	11.4	18.0	18.2	19.2	22.0			
12-M	5	10.3	16.4	18.1	18.0	20.6	24.1	24.8	
12-F	5	10.8	17.1	17.8	16.8	20.1	22.8	22.1	23.8	32.8

Table 71. Neutron probe data for 27 August 1995.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	5	8.8	14.0	16.9	18.1	22.4	24.4	29.9	
1-M	5	9.9	15.7	18.5	20.6	25.9	28.9	30.0	
1-F	5	10.7	16.9	21.0	23.2	27.1	29.6	29.9	31.7	34.3
2-D	5	8.3	13.2	17.2	18.3	20.0	23.5	27.9	
2-M	5	10.5	16.6	19.0	19.2	22.8	26.6	30.3	
2-F	5	9.2	14.6	17.8	17.1	18.1	23.0	26.2	
3-D	5	6.0	9.6	16.1	19.7	19.1	19.2	24.2	
3-M	5	12.0	18.9	18.3	16.6	18.9	22.3	27.0	
3-F	5	9.2	14.5	18.4	17.2	17.1	26.4	30.9	29.1	28.8
4-D	5	7.2	11.5	14.2	14.8	16.4			
4-M	5	8.2	13.0	15.7	15.1	16.4	19.6	23.2	
4-F	5	6.0	9.5	16.1	16.8	19.0	21.5	22.0	26.2	31.7
5-D	5	8.0	12.6	17.5	20.6	23.7	26.0	28.3	
5-M	5	9.6	15.2	18.7	19.5	21.8	27.1	32.2	
5-F	5	10.7	16.9	18.8	19.1	19.7	26.1	28.7	32.5	30.9
6-D	5	9.6	15.2	19.8	19.1	17.4	18.0	18.5	
6-M	5	11.2	17.8	18.5	17.5	17.8	28.6	23.6	
6-F	5	10.4	16.5	17.1	15.0	19.7	25.3	24.4	24.4	28.3
7-D	5	8.2	13.0	14.6	16.0				
7-M	5	9.2	14.6	16.5	15.1	17.1	22.7	23.7	
7-F	5	9.8	15.6	16.3	14.2	12.5	21.9	27.8	32.5	34.1
8-D	5	9.8	15.6	15.9	15.9	18.7			
8-M	5	9.1	14.5	16.7	15.6	15.0	20.5	23.5	
8-F	5	9.8	15.5	16.6	15.1	17.3	21.4	26.7	32.0	
9-D	5	9.1	14.4	18.1	15.8	17.2	19.4	23.5	
9-M	5	9.9	15.7	18.3	17.4	18.8	21.6	25.0	21.6	25.0
9-F	5	10.3	16.2	15.9	17.0	16.6	18.5	19.8	23.1	21.6
10-D	5	10.9	17.3	17.1	17.1	17.9	21.5		
10-M	5	12.5	19.7	19.0	22.3	25.1	26.6	27.0	
10-F	5	11.6	18.4	17.7	16.3	15.5	18.0	20.8	20.9	28.7
11-D	5	6.6	10.5	13.8	15.5	15.3	16.0	18.3	
11-M	5	10.2	16.1	18.8	16.7	16.9	18.3	21.0	
11-F	5	8.8	13.9	17.7	16.3	15.5	18.0	20.8	20.9	28.7
12-D	5	10.8	17.2	18.3	17.5	19.5	22.5		
12-M	5	9.3	14.8	16.5	16.4	18.5	11.1	22.3	
12-F	5	9.5	15.1	15.6	15.8	18.2	21.8	19.1	18.9	24.9

Table 72. Neutron probe data for 5 August 1995.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------- Volumetric soil water content (%) -------								
1-D	5	9.6	15.1	17.4	17.7	22.1	25.2	27.2		
1-M	5	14.0	22.2	19.2	20.5	25.0	28.7	29.9		
1-F	5	17.5	27.7	22.7	23.4	27.1	28.2	29.6	30.6	33.8
2-D	5	14.1	22.3	20.6	17.9	19.1	22.9	27.5		
2-M	5	15.8	25.1	19.4	18.8	22.5	26.4	28.7		
2-F	5	17.0	27.0	24.2	16.5	16.3	22.2	26.1		
3-D	5	17.3	27.4	28.8	21.3	18.9	18.3	23.4		
3-M	5	17.6	27.9	22.6	17.6	18.0	22.5	26.7		
3-F	5	18.6	29.4	24.0	17.1	17.5	19.8	26.4	29.9	28.0
4-D	5	12.4	19.6	18.1	14.8	16.5				
4-M	5	18.8	29.8	24.8	16.8	17.5	20.7	21.9		
4-F	5	18.3	29.0	30.8	25.1	20.5	21.3	22.4	25.4	30.0
5-D	5	7.9	12.5	16.6	18.1	20.7	23.1	27.0		
5-M	5	13.6	21.6	26.0	27.3	27.9	28.0	26.2		
5-F	5	16.7	26.5	29.6	29.5	29.8	29.5	28.5	29.9	32.0
6-D	5	17.6	27.9	25.2	21.1	17.8	19.7	20.5		
6-M	5	18.7	29.7	26.7	19.7	17.8	19.7	22.8		
6-F	5	15.8	25.0	20.1	17.0	18.1	23.9	26.3	25.6	23.6
7-D	6	12.6	20.4	23.7						
7-M	6	17.6	28.6	21.8	14.5	16.7	22.1	24.0		
7-F	6	17.8	29.0	20.9	15.2	18.2	24.1	27.9	31.9	31.8
8-D	7	8.4	14.0	13.9	17.6	20.1				
8-M	7	13.5	22.6	15.2	16.3	21.5	21.7	26.5		
8-F	7	10.1	16.9	16.1	20.3	21.2	27.8	28.2	33.6	
9-D	7	16.1	26.9	25.8	19.8	19.0	20.9	22.3		
9-M	7	15.8	26.4	27.5	24.6	20.9	22.2	23.6		
9-F	7	17.0	28.4	26.5	24.3	20.7	21.9	21.3	23.6	22.4
10-D	5	10.6	16.8	16.6	17.0	17.5	20.7			
10-M	5	16.6	26.3	19.1	18.7	21.3	24.7	26.4		
10-F	5	19.5	30.9	19.5	19.4	21.7	22.5	24.0	25.0	29.8
11-D	5	11.1	17.5	22.3	23.1	19.9	17.5	18.4		
11-M	5	11.9	18.8	16.1	16.6	17.8	21.0	20.3		
11-F	5	17.6	27.8	20.2	17.4	16.1	17.5	20.0	20.6	27.2
12-D	5	15.3	24.2	20.7	18.2	20.3	21.9			
12-M	5	17.6	27.9	20.5	17.0	17.1	21.4	22.3		
12-F	5	17.3	27.4	24.5	22.3	20.9	19.6	17.4	19.2	23.1

Table 73. Neutron probe data for 8 September 1995.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	---------- Volumetric soil water content (%) ----------								
1-D	8	10.1	17.3	18.7	18.5	22.1	24.8	27.3		
1-M	8	11.5	19.6	20.9	21.8	25.8	28.7	30.7		
1-F	8	12.9	21.9	24.2	24.7	28.4	29.4	29.5	31.1	33.1
2-D	8	12.7	21.7	24.7	24.6	25.0	26.5	28.9		
2-M	8	14.0	23.9	24.8	23.0	23.7	27.0	29.8		
2-F	8	12.8	21.9	24.5	21.8	20.5	22.0	27.2		
3-D	8	10.8	18.4	23.3	23.8	20.2	19.1	24.0		
3-M	8	13.8	23.6	22.2	17.1	18.0	22.8	27.4		
3-F	8	13.0	22.2	23.5	21.3	20.0	22.2	27.0	30.2	28.8
4-D	8	9.0	15.3	15.8	15.3	16.2				
4-M	8	10.9	18.6	20.9	18.0	18.0	21.4	25.3		
4-F	8	13.5	23.1	22.6	22.9	24.5	25.4	27.7	28.5	31.3
5-D	8	10.9	18.5	23.2	24.3	25.0	26.7	28.6		
5-M	8	12.4	21.2	24.7	23.5	22.8	26.8	30.4		
5-F	8	13.3	22.7	24.4	21.5	20.5	25.1	30.0	31.4	31.4
6-D	8	13.0	22.2	23.4	20.1	18.2	18.3	20.5		
6-M	8	13.3	22.7	23.3	19.9	17.2	18.9	24.3		
6-F	8	12.4	21.2	21.2	16.0	15.8	19.9	25.0	24.5	24.8
7-D	9	8.1	14.1	17.6						
7-M	9	9.1	15.9	18.0	15.8	17.7	24.4	26.6		
7-F	9	10.1	17.6	17.7	16.2	20.7	26.4	28.5	33.8	32.5
8-D	10	11.0	19.5	20.5	21.3	23.4				
8-M	10	10.3	18.3	20.7	17.0	17.8	23.5	27.5		
8-F	10	11.0	19.7	20.7	18.9	21.8	25.8	26.9	29.6	
9-D	10									
9-M	10									
9-F	10									
10-D	8	11.6	19.8	17.4	16.7	18.5	21.1			
10-M	8	14.5	24.7	21.9	21.3	23.3	25.7	28.0		
10-F	8	14.1	24.1	23.9	23.0	22.8	23.4	25.0	26.3	31.1
11-D	8									
11-M	8									
11-F	8									
12-D	8									
12-M	8									
12-F	8									

Table 74. Neutron probe data for 16 June 1996.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	Volumetric soil water content (%)								
1-D	5	8.9	14.1	20.8	23.9	26.1	28.6			
1-M										
1-F	5	15.5	24.5	26.6	26.8	29.8	29.1	29.9	33.8	
2-D										
2-M										
2-F										
3-D	5	8.9	14.1	19.8	25.0	25.9	30.7	30.6		
3-M										
3-F	5	14.8	23.5	26.7	24.2	27.5	30.4	32.3		
4-D	5	11.0	17.4	21.8	26.0	27.1	29.1	29.1	27.7	27.0
4-M										
4-F	5	14.4	22.8	26.3	26.6	26.7	28.8	27.4	26.4	
5-D	5	12.6	20.0	24.5	24.3	26.4	27.7	29.9		
5-M										
5-F	5	13.9	22.0	26.2	30.2	31.8	31.1	30.0	28.7	
6-D	5	12.3	19.5	22.8	24.5	24.4	25.2	26.9	29.4	
6-M										
6-F	5	16.1	25.4	26.9	25.8	26.0	26.8	29.9	29.6	
7-D										
7-M										
7-F	5	15.5	24.5	26.9	27.2	28.0	27.0	31.7	32.3	
8-D	5	8.5	13.5	21.1	25.5	27.9	28.7	29.2		
8-M										
8-F	5	15.5	24.5	26.7	27.2	28.2	28.2	27.8	29.3	30.4
9-D	5	9.5	15.1	21.3	24.6	24.3	23.5	25.0		
9-M										
9-F	5	15.2	24.1	25.5	25.3	24.4	24.4	28.4	32.1	
10-D	5	7.1	11.3	19.5	24.3	27.5	28.8	28.8		
10-M										
10-F	5	14.4	22.8	26.7	29.3	29.9	29.5	28.5	29.0	
11-D	5	9.4	14.9	23.1	27.7	29.2	31.8	33.6		
11-M										
11-F	5	16.1	25.5	27.7	28.9	30.7	31.5	31.0	34.8	
12-D										
12-M										
12-F	5	15.4	24.4	27.5	28.5	31.6	31.6	28.8	27.8	

Table 75. Neutron probe data for 24 June 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	4	7.3	11.2	18.9	22.9	26.1	28.5		
1-M									
1-F	4	15.5	23.8	26.0	26.7	29.0	29.0	29.3	33.2
2-D	4	10.1	15.5	22.1	24.8	26.0	28.1	32.3	
2-M									
2-F	4	12.3	19.0	26.1	26.3	24.2	28.0	30.0	31.3	31.3
3-D	4	8.2	12.7	18.3	23.5	25.9	26.6	31.0	
3-M									
3-F	4	15.2	23.4	26.0	25.6	26.8	30.0	32.7	
4-D	4	10.4	16.1	20.6	25.4	27.0	29.3	29.1	27.9	26.9
4-M									
4-F	4	14.3	22.0	26.2	26.1	26.5	28.6	27.5	27.1	29.9
5-D	4	11.5	17.7	23.1	24.8	25.9	28.3	29.5	
5-M									
5-F	4	13.8	21.3	25.8	29.5	31.9	31.2	30.0	29.8
6-D	4	12.5	19.2	23.1	24.2	24.2	25.6	27.6	30.4
6-M									
6-F	4	15.8	24.3	26.2	26.1	25.5	26.9	29.3	29.4
7-D	4	13.7	21.2	24.8	26.6	27.6	27.5	27.4	
7-M									
7-F	4	15.4	23.7	26.3	27.2	27.6	27.3	27.3	31.6	31.9
8-D	4	7.7	11.8	19.7	25.4	27.1	29.2	28.6	
8-M									
8-F	4	15.1	23.3	26.6	26.9	27.8	28.2	27.6	29.3	30.6
9-D	4	9.1	14.0	20.1	23.6	24.1	23.5	24.9	
9-M									
9-F	4	15.2	23.5	25.0	24.9	24.7	24.7	28.1	31.7
10-D	4	6.2	9.6	19.0	23.6	26.8	28.3	28.7	
10-M									
10-F	4	13.2	20.3	26.5	29.3	29.4	29.6	28.3	28.9
11-D	4	8.5	13.1	21.5	25.1	26.1	31.3	33.6	
11-M									
11-F	4	15.9	24.5	27.3	27.9	30.0	31.7	30.6	34.0
12-D	4	9.2	14.1	18.5	22.3	23.9	27.8	30.2	
12-M									
12-F	4	15.1	23.3	27.1	27.9	30.2	31.3	28.4	27.7	27.9

Table 76. Neutron probe data for 1 July 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	---------- Volumetric soil water content (%) ----------							
1-D	1	9.4	13.3	18.1	21.9	25.4	28.2		
1-M	1	15.7	22.2	24.9	26.1				
1-F	1	17.0	24.1	26.3	28.8	28.8	29.0	29.7	33.4
2-D	1	11.5	16.3	21.3	24.8	25.8	28.0	31.1	
2-M	1	11.6	16.5	22.1	24.4	25.7	27.8	32.1	
2-F	1	13.6	19.3	25.5	25.8	24.4	28.4	31.1	32.0	32.2
3-D	1	8.9	12.6	17.0	22.1	24.7	26.2	30.5	
3-M	1	9.2	13.0	19.9	23.7	25.0	27.0	29.4	
3-F	1	15.9	22.5	25.9	25.2	26.6	29.2	32.5	
4-D	1	11.1	15.8	19.5	24.0	26.2	28.1	28.5	27.4	27.1
4-M	1	14.1	20.0	24.2	26.2	27.0	28.9	27.8	
4-F	1	8.2	11.6	21.9	25.9	25.9	26.3	29.4	27.6	28.6
5-D	1	12.9	18.2	22.6	23.9	26.0	27.7	29.6	
5-M	1	11.2	15.8	22.0	26.1	29.0	30.1	31.0	
5-F	1	14.6	20.7	25.3	29.5	31.8	31.2	29.9	
6-D	1	12.9	18.2	22.8	23.8	23.9	25.1	27.7	29.7
6-M	1	10.4	14.7	20.7	23.8	23.5			
6-F	1	16.1	22.9	25.8	25.3	26.4	29.5	29.4	
7-D	1	13.4	19.0	23.0	25.2	27.6	27.2	26.5	
7-M	1	12.4	17.6	22.6	24.0	26.2	27.0	26.7	
7-F	1	17.1	24.2	26.5	26.7	27.4	27.5	28.5	33.8	34.9
8-D	1	10.3	14.6	19.7	24.3	26.8	28.9	29.2	
8-M	1	10.3	14.6	19.6	24.0	25.6	26.6	27.8	
8-F	1	15.3	21.7	24.7	26.6	28.2	28.0	28.6	31.8	33.7
9-D	1	11.0	15.5	19.5	22.5	23.2	23.6	25.0	
9-M	1	10.9	15.4	20.1	22.5	22.5	23.5	24.5	
9-F	1	16.5	23.4	25.0	24.9	24.5	24.3	28.4	32.2
10-D	1	8.4	11.9	18.5	22.5	26.6	28.4	27.7	
10-M	1	8.7	12.3	19.6	23.5	27.0	28.8		
10-F	1	13.0	18.4	24.6	28.9	30.0	29.4	28.8	29.1
11-D	1	9.7	13.8	20.1	22.4	23.4	28.4	32.6	
11-M	1	10.1	14.3	20.8	24.3	25.9	30.5	31.9	
11-F	1	16.1	22.8	24.5	26.4	29.2	30.9	30.0	33.7
12-D	1	10.4	14.7	18.3	21.4	23.1	27.2	30.0	
12-M	1	13.4	19.0	22.3	25.4	29.6	30.6		
12-F	1	15.6	22.1	25.2	26.8	29.9	30.7	28.1	27.8

Table 77. Neutron probe data for 8 July 1996.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	Volumetric soil water content (%)								
1-D										
1-M	8	10.5	17.9	22.9	24.5	26.0				
1-F										
2-D										
2-M	8	10.0	17.1	21.9	24.3	25.1	27.0	31.2		
2-F										
3-D										
3-M	8	8.0	13.7	19.0	22.5	23.7	25.7	29.1		
3-F										
4-D										
4-M	8	10.1	17.3	20.4	22.8	25.5	26.8	27.9	26.9	
4-F										
5-D										
5-M	8	9.7	16.6	22.1	25.6	27.6	30.1	30.3		
5-F										
6-D										
6-M	8	10.0	17.1	21.3	23.8	22.8				
6-F										
7-D										
7-M	8	11.2	19.0	22.9	24.0	25.6	27.2	26.3		
7-F										
8-D										
8-M	8	8.4	14.3	18.6	22.7	24.3	25.9	26.7	26.6	
8-F										
9-D										
9-M	8	9.2	15.7	19.9	21.9	22.3	23.4	23.8		
9-F										
10-D										
10-M	8	8.3	14.1	20.1	23.3	26.7	27.9	28.7		
10-F										
11-D										
11-M	8	9.8	16.7	20.6	21.8	22.9	26.9	30.1	31.5	
11-F										
12-D										
12-M	8	10.8	18.4	21.0	23.9	28.8	28.9			

Table 78. Neutron probe data for 9 July 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	9	11.4	19.8	22.8	25.1	26.8	29.0		
1-M	9	11.6	20.3	24.1	26.7	27.1			
1-F	9	14.0	24.3	28.2	29.5	30.6	30.3	30.4	32.6
2-D	9	12.2	21.4	23.5	23.6	26.0	30.6		
2-M	9	12.3	21.5	24.5	24.7	24.8	26.2	30.3	
2-F	9	11.6	20.3	24.8	25.4	24.3	27.2	30.2	31.1	30.7
3-D	9	11.7	20.4	22.5	25.0	24.9	24.5	29.3	
3-M	9	10.9	19.0	22.6	24.6	23.1	23.8	28.1	
3-F	9	12.9	22.4	23.7	22.5	23.0	26.6	30.5	
4-D	9	11.7	20.4	23.0	26.5	27.6	28.9	28.6	
4-M	9	10.1	17.6	22.8	26.5	28.1	28.2	29.0	
4-F	9	12.9	22.6	26.6	28.0	27.9	29.3	28.4	28.0
5-D	9	13.0	22.7	24.8	24.1	24.8	28.5		
5-M	9	11.1	19.4	24.0	26.5	28.1	29.6	30.0	
5-F	9	12.1	21.1	24.5	28.0	29.5	30.3	28.8	
6-D	9	12.6	22.0	24.6	24.5	24.5	25.5	27.5	
6-M	9	11.7	20.4	23.8	25.4	24.1	23.7	24.8	
6-F	9	14.1	24.7	25.9	25.4	26.5	28.9	29.1	
7-D	9	14.1	24.5	26.7	27.2	27.9	27.6		
7-M	9	13.6	23.8	27.6	27.6	29.3	29.4		
7-F	9	13.8	24.0	27.4	28.2	29.4	29.0	30.3	34.9	34.6
8-D	9	9.8	17.1	20.9	22.6	23.5	25.6	26.8	
8-M	9	9.4	16.5	20.8	24.1	23.5	24.6	26.0	
8-F	9	12.8	22.4	25.9	26.4	27.5	27.5	27.6	29.4
9-D	9	10.8	18.8	22.2	23.2	23.0	23.0	24.2	
9-M	9	10.2	17.7	22.1	23.8	22.7	22.9	23.9	
9-F	9	12.7	22.2	24.6	24.7	24.6	23.9	28.4	32.6	32.6
10-D	9	11.2	19.5	23.6	25.2	27.0	28.1	27.7	
10-M	9	11.5	20.1	24.2	26.7	28.1	29.0		
10-F	9	13.2	23.1	27.9	30.7	30.5	30.0	28.9	29.1
11-D	9	10.4	18.2	23.3	23.5	21.3	22.5	25.4	
11-M	9	9.3	16.3	21.7	23.8	23.2	24.3	25.8	
11-F	9	12.7	22.2	23.1	21.3	22.7	23.8	25.0	30.4
12-D	9	9.6	16.8	20.6	23.2	22.1	25.5	27.5	
12-M	9	11.9	20.8	23.6	24.2	27.9	28.8		
12-F	9	12.5	21.7	24.8	26.3	29.4	30.2	27.6	27.4

Table 79. Neutron probe data for 12 July 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	12	6.2	11.4	17.4	21.7	24.7	27.5		
1-M	12	8.4	15.6	21.8	24.3	25.8			
1-F	12	11.8	21.8	25.7	27.1	29.1	28.5	29.3	33.1
2-D	12	8.6	16.0	21.2	24.4	25.2	27.5	31.8	32.6
2-M	12	8.8	16.3	21.2	24.2	24.9	27.1	30.9	
2-F	12	7.7	14.3	21.6	23.5	24.4	28.3	30.6	31.7	31.1
3-D	12	6.5	12.0	17.0	21.5	24.0	25.0	29.6	
3-M	12	6.5	12.0	18.2	21.6	22.8	25.6	29.4	
3-F	12	10.2	18.8	22.7	23.9	25.1	28.5	31.5	
4-D	12	9.0	16.6	20.8	23.8	27.1	28.5	28.3	26.7
4-M	12	8.2	15.3	18.9	22.0	24.9	26.2	27.7	27.2
4-F	12	12.3	22.7	26.8	28.2	28.1	29.5	28.6	28.2
5-D	12	9.0	16.7	22.0	23.2	25.7	26.9	29.1	
5-M	12	7.5	14.0	20.0	24.5	28.2	29.3	30.3	
5-F	12	8.7	16.1	21.1	27.7	31.0	30.8	29.6	28.8
6-D	12	9.3	17.2	21.5	23.0	23.2	24.9	26.7	29.6
6-M	12	8.0	14.8	20.3	22.8	22.1	22.9		
6-F	12	11.5	21.3	23.7	23.9	24.2	26.1	28.9	29.0
7-D	12	9.9	18.4	21.9	24.3	26.7	26.8	26.1	
7-M	12	10.1	18.7	22.6	24.0	25.8	27.1		
7-F	12	10.2	18.8	23.3	25.2	26.7	26.3	28.0	33.0	34.6
8-D	12	6.6	12.2	18.2	22.6	24.6	27.6	28.1	
8-M	12	7.2	13.3	18.0	21.7	23.3	25.4	26.9	
8-F	12	9.5	17.5	21.5	24.4	26.5	27.8	27.4	30.0	32.6
9-D	12	8.1	14.9	19.4	22.2	22.5	22.6	24.5	
9-M	12	7.7	14.3	18.9	20.6	21.7	22.5	23.5	
9-F	12	11.0	20.5	23.0	22.8	23.3	23.2	27.6	31.5
10-D	12	5.6	10.3	18.2	22.0	25.3	27.8	27.6	
10-M	12	6.9	12.9	19.6	23.3	26.8	27.8		
10-F	12	8.4	15.6	21.6	27.1	28.9	29.2	28.3	28.9
11-D	12	7.2	13.3	18.2	19.8	20.2	23.8	28.2	
11-M	12	7.6	14.2	19.1	20.7	21.9	25.5	29.1	
11-F	12	10.5	19.4	19.2	19.8	24.3	28.3	29.2	33.5	34.2
12-D	12	8.6	15.9	18.9	21.3	22.3	26.1	28.6	
12-M	12	9.9	18.3	20.4	23.4	27.8	29.5		
12-F	12	9.6	17.8	20.8	23.1	27.8	29.3	27.3	27.4

Table 80. Neutron probe data for 22 July 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------ Volumetric soil water content (%) ------------							
1-D	6	9.9	16.1	19.6	21.6	24.5	27.3		
1-M	6	13.7	22.2	25.7	25.7	25.8			
1-F	6	16.5	26.8	28.3	28.9	29.6	29.3	29.7	33.3
2-D	6	10.0	16.3	21.2	24.0	24.2	26.6		
2-M	6	9.7	15.8	19.4	22.6	24.1	26.7	31.3	
2-F	6	8.6	14.0	18.7	21.4	22.4	26.6	30.5	31.7	31.4
3-D	6	7.5	12.2	16.4	20.1	22.0	24.1	27.8	
3-M	6	7.3	11.8	16.4	19.1	20.1	23.6	27.9	
3-F	6	10.0	16.2	17.8	18.7	23.3	27.9	31.8	
4-D	6	10.4	16.9	18.2	21.5	23.7	26.5	28.0	27.2	26.3
4-M	6	12.2	19.9	21.9	21.2	23.3	25.5	26.8	
4-F	6	12.9	21.0	18.9	19.3	23.1	27.6	27.4	27.7	31.4
5-D	6	10.4	16.9	21.0	22.3	24.6	26.6	28.8	
5-M	6	11.9	19.3	21.9	23.0	26.2	29.1		
5-F	6	12.8	20.8	20.1	24.1	29.2	30.1	28.9	
6-D	6	10.4	16.9	20.1	21.4	22.4	24.1	26.9	
6-M	6	10.3	16.7	19.6	22.2	21.9	22.7		
6-F	6	14.9	24.2	23.2	22.8	23.6	25.7	28.9	28.8
7-D	6	16.3	26.5	25.9	26.5	26.6			
7-M	6	15.9	25.9	27.1	25.6	26.4	27.5		
7-F	6	16.8	27.3	28.7	28.9	28.8	27.5	27.8	32.8	34.5
8-D	6	12.3	19.9	20.6	22.5	24.3	26.9	27.7	
8-M	6	12.9	21.0	21.7	21.4	22.4	24.4	26.8	
8-F	6	14.9	24.2	24.3	24.1	26.0	27.0	27.4	30.2	32.3
9-D	6	14.0	22.8	24.8	24.2	22.5	22.1	24.2	
9-M	6	14.2	23.1	24.0	22.3	21.7	22.6	23.8	
9-F	6	15.6	25.4	26.0	14.3	25.2	24.3	28.8	34.0
10-D	6	7.0	11.4	17.4	20.3	23.1	25.6	26.2	
10-M	6	7.6	12.3	18.7	22.0	25.2	27.0	27.5	
10-F	6	9.4	15.2	20.1	24.9	28.0	27.6	28.1	29.2
11-D	6	14.0	22.8	27.4	25.9	22.0	22.6	26.0	
11-M	6	13.8	22.5	26.9	28.3	27.8	27.9	27.9	
11-F	6	17.7	28.8	28.7	28.3	28.7	28.3	28.6	32.0
12-D	6	14.9	24.2	25.5	25.1	23.1	26.2	28.3	
12-M	6	16.6	27.0	27.4	26.6	29.1			
12-F	6	17.0	27.6	29.8	30.1	31.4	30.3	27.7	26.3

Table 81. Neutron probe data for 1 August 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	6	9.3	15.1	19.0	21.8	24.1	27.4		
1-M	6	13.9	22.6	24.9	25.5				
1-F	6	8.1	13.2	22.2	25.9	27.7	29.8	28.9	29.2	32.4
2-D	6	11.5	18.7	22.2	23.9	23.6	26.6		
2-M	6	11.4	18.6	20.7	22.2	23.5	25.7	30.6	
2-F	6	10.0	16.3	21.7	21.9	22.0	26.3	29.4	30.9	31.1
3-D	6	10.5	17.0	20.5	22.9	23.2	23.8	28.4	
3-M	6	9.4	15.3	18.7	19.1	19.4	22.6	27.4	
3-F	6	12.0	19.5	19.6	18.2	20.9	26.3	30.6	
4-D	6	18.3	29.8	29.8	29.5	27.0	25.7	26.3	26.2	25.9
4-M	6	17.8	28.9	27.9	23.3	20.7	22.7	25.2	25.9	26.0
4-F	6	17.9	29.0	23.3	17.7	20.1	26.3	26.7	25.5	31.2
5-D	6	10.8	17.5	21.0	22.0	23.9	26.2	28.5	
5-M	6	9.5	15.4	20.1	22.1	25.3	28.2		
5-F	6	11.2	18.1	19.1	22.3	27.5	29.1	28.7	
6-D	6	10.9	17.7	20.1	21.3	22.3	24.1	26.7	
6-M	6	10.2	16.6	20.2	22.0	21.7	22.4		
6-F	6	13.6	22.0	22.8	22.4	23.2	25.3	28.3	28.3
7-D	6	12.5	20.2	23.1	24.5	26.2			
7-M	6	12.5	20.3	23.4	23.8	25.4	27.0		
7-F	6	11.4	18.6	21.1	23.5	26.3	26.4	27.6	32.7	33.8
8-D	6	8.7	14.2	18.4	21.2	23.5	25.4	27.0	
8-M	6	8.4	13.6	17.6	20.1	21.1	23.3	25.7	
8-F	6	10.9	17.7	19.5	21.7	24.3	26.6	26.6	29.7	32.1
9-D	6	8.9	14.5	18.4	20.7	21.3	22.0	23.9	
9-M	6	9.4	15.3	18.8	20.1	20.1	21.7	22.7	
9-F	6	11.1	18.0	18.6	20.5	22.5	23.4	28.5	33.1
10-D	6	9.9	16.1	20.6	21.2	22.3	25.0	25.2	
10-M	6	10.8	17.6	22.0	23.1	24.5	26.4	27.4	
10-F	6	12.5	20.3	24.2	27.0	28.0	27.9	27.3	28.4
11-D	6	9.1	14.8	20.4	22.6	21.4	22.5	26.1	
11-M	6	8.6	14.0	19.9	22.2	22.8	24.4	26.2	
11-F	6	12.0	19.5	19.8	19.9	22.9	24.8	25.4	30.7	32.6
12-D	6	9.0	14.6	19.2	21.7	22.0	25.8	27.7	
12-M	6	12.1	19.7	22.3	23.5	27.7	28.7		
12-F	6	11.5	18.6	21.7	22.8	27.1	29.0	26.6	27.0

Table 82. Neutron probe data for 16 August 1996.

EU		15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) ---------------------------------								
1-D	22	6.8	13.8	18.9	22.3	25.3	27.2			
1-M	22	7.0	14.2	20.6	24.9	25.9				
1-F	22	10.1	20.5	24.3	27.1	29.2	29.6	29.7	32.7	
2-D	22	8.0	16.1	21.0	23.3	23.3	25.8			
2-M	22	8.0	16.2	20.7	23.0	24.4	26.5	30.6		
2-F	22	7.2	14.6	21.0	22.2	23.0	26.6	29.7	30.9	30.4
3-D	22	6.9	13.9	18.7	22.1	23.3	23.6	28.3		
3-M	22	6.7	13.6	18.7	21.3	21.3	23.0	26.5		
3-F	22	8.7	17.6	19.8	19.1	21.2	25.9	30.4		
4-D	22	6.8	13.8	17.2	19.5	22.4	25.6	27.4		
4-M	22	5.7	11.6	17.4	19.9	21.7	24.4	26.9		
4-F	22	8.6	17.4	21.4	22.4	24.1	28.0	27.7	27.8	
5-D	22	8.5	17.1	21.9	22.8	24.3	26.6	28.5		
5-M	22	7.2	14.7	19.5	23.4	26.1	28.5			
5-F	22	8.4	17.1	20.6	25.2	28.2	29.5	28.5		
6-D	22	9.1	18.5	21.6	23.2	23.8	24.6	27.4		
6-M	22	7.8	15.9	20.5	23.8	23.1	23.5	24.7		
6-F	22	10.9	22.1	23.8	23.9	24.2	26.1	29.0	28.7	
7-D	22	10.1	20.5	23.7	25.6	26.6				
7-M	22	9.8	19.9	23.6	24.6	27.0	28.1			
7-F	22	8.9	18.0	20.3	23.0	25.4	26.6	28.8	34.1	34.7
8-D	22	6.1	12.3	17.7	20.8	22.5	25.1	26.9		
8-M	22	6.1	12.3	16.8	20.3	21.2	22.9	25.1		
8-F	22	8.7	17.6	19.8	23.0	25.4	26.9	26.9	29.4	
9-D	22	6.6	13.4	17.7	20.7	20.9	21.3	23.4		
9-M	22	6.5	13.1	18.3	20.1	20.8	21.7	22.7		
9-F	22	8.6	17.5	18.7	20.6	21.8	23.1	28.5	32.6	
10-D	22	6.9	14.0	20.3	23.4	26.2	27.2	27.5		
10-M	22	7.3	14.8	21.7	25.3	27.7	28.1			
10-F	22	9.1	18.4	23.8	28.4	29.9	29.5	28.1	28.9	
11-D	22	5.8	11.7	17.8	19.7	19.3	21.3			
11-M	22	6.0	12.1	17.5	19.5	20.1	22.7	23.4		
11-F	22	8.6	17.5	17.4	18.0	19.7	21.2	21.2	28.7	
12-D	22	6.4	12.9	16.3	19.1	19.5	23.5	25.8		
12-M	22	7.9	16.0	19.0	20.3	25.6	27.8			
12-F	22	7.8	15.8	16.8	18.8	23.7	25.8	24.8	25.5	

Table 83. Neutron probe data for 22 August 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	-------------------------------- Volumetric soil water content (%) --------------------------------							
1-D	28	5.7	11.2	16.4	20.9	23.3	26.4		
1-M	28	6.1	11.9	18.8	23.5	24.6			
1-F	28	9.0	17.4	22.2	24.4	27.7	28.8	29.6	32.8
2-D	28	7.2	14.0	18.9	21.3	22.5	25.7		
2-M	28	7.1	13.7	18.5	20.7	22.8	25.5	30.0	
2-F	28	9.7	18.8	20.7	21.5	26.4	29.3	30.1	30.7
3-D	28	5.8	11.3	15.6	20.0	21.9	23.0	27.8	
3-M	28	5.6	10.9	16.3	18.7	19.1	21.2	26.5	
3-F	28	7.8	15.2	17.1	16.7	18.9	25.3	29.6	
4-D	28	6.0	11.6	14.3	15.8	18.3	22.6	25.6	
4-M	28	4.9	9.5	14.8	16.5	18.2	21.2	24.3	
4-F	28	7.5	14.6	17.1	17.7	20.6	26.1	26.9	27.6	31.3
5-D	28	7.6	14.7	20.3	21.1	23.7	25.8	28.2	
5-M	28	6.0	11.7	17.4	20.5	24.9	27.4		
5-F	28	7.8	15.2	18.5	23.0	26.4	28.3	28.4	
6-D	28	8.6	16.7	20.1	21.1	21.9	24.3	26.7	
6-M	28	7.3	14.1	18.8	22.2	21.8	22.5	24.1	
6-F	28	10.1	19.7	22.2	22.9	23.5	25.4	28.6	28.5
7-D	28	9.4	18.3	22.0	23.2	25.3			
7-M	28	8.8	17.2	19.8	21.5	24.3	26.0		
7-F	28	7.9	15.4	16.8	19.3	22.7	24.9	28.0	32.9	33.9
8-D	28	5.3	10.2	16.1	20.0	21.2	23.6	25.4	
8-M	28	5.5	10.8	15.4	17.9	18.9	21.0	23.6	
8-F	28	7.8	15.1	16.8	20.0	23.3	25.3	26.0	29.2	31.0
9-D	28	5.9	11.6	15.9	17.8	18.9	19.6	22.0	
9-M	28	5.8	11.3	16.2	17.4	18.1	19.4	21.6	
9-F	28	8.2	16.0	16.6	17.9	20.1	22.0	26.9	31.5
10-D	28	6.0	11.6	18.1	22.0	24.7	26.4	26.6	
10-M	28	6.5	12.6	19.7	23.6	26.3	27.3	27.5	
10-F	28	8.2	15.9	21.5	26.0	27.8	28.3	27.7	28.7
11-D	28	4.6	9.0	14.6	17.2	16.8	19.1	21.5	
11-M	28	5.3	10.3	15.6	17.0	18.1	20.0	20.6	
11-F	28	8.1	15.8	14.6	15.2	17.5	19.1	19.1	27.3
12-D	28	5.8	11.2	14.6	17.0	17.6	21.8	24.3	
12-M	28	7.7	14.9	15.9	17.9	22.2	25.2		
12-F	28	7.0	13.7	14.5	15.5	19.6	22.9	23.1	23.9

Table 84. Neutron probe data for 5 September 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------- Volumetric soil water content (%) -------							
1-D	7	14.4	23.9	25.0	24.1	24.6	26.2		
1-M	7	14.9	24.9	26.7	28.1	28.8			
1-F	7	17.2	28.6	28.4	28.4	29.4	28.5	28.5	31.6
2-D	7	12.2	20.3	18.9	20.0	21.4	24.2		
2-M	7	13.5	22.5	19.3	19.8	21.7	24.2	29.1	
2-F	7	15.8	26.3	25.0	21.0	20.7	24.9	28.4	29.9	30.0
3-D	7	7.1	11.7	25.7	26.2	22.7	22.1	26.5	
3-M	7	14.2	23.7	24.3	23.5	21.4	20.8	25.3	
3-F	7	16.7	27.8	27.6	25.2	23.1	25.9	29.6	
4-D	7	12.2	20.4	18.7	15.4	16.5	20.2	23.4	
4-M	7	16.0	26.7	27.1	22.4	18.3	19.5	22.8	
4-F	7	16.6	27.7	25.1	28.4	19.2	24.4	25.5	26.7	30.3
5-D	7	15.8	26.3	26.7	25.5	26.2	27.1	27.3	
5-M	7	14.0	23.4	24.3	23.7	25.1	27.4	28.7	
5-F	7	14.3	23.8	24.0	24.7	26.6	27.6	27.7	
6-D	7	12.9	21.5	22.0	21.5	21.6	23.5	26.0	
6-M	7	13.8	22.9	23.4	23.3	22.2	22.3	23.8	
6-F	7	15.5	25.8	24.4	22.7	23.3	25.0	27.8	28.4
7-D	7	15.4	25.7	22.9	22.0	24.1	25.0		
7-M	7	15.0	24.9	19.4	19.1	22.5	25.5		
7-F	7	17.0	28.4	27.8	23.3	22.5	24.2	26.9	31.9	33.0
8-D	7	9.7	16.1	17.0	18.2	19.5	21.9	23.8	
8-M	7	14.7	24.5	21.7	18.0	17.8	20.2	22.6	
8-F	7	16.6	27.6	25.6	21.5	22.6	23.8	24.9	28.4
9-D	7	14.3	23.8	21.9	17.9	16.8	17.7	20.8	
9-M	7	15.1	25.1	22.7	17.9	17.1	18.3	19.9	
9-F	7	15.9	26.5	21.8	19.0	19.2	20.8	25.6	29.8
10-D	7	12.3	20.4	22.8	22.7	23.1	25.2	25.4	
10-M	7	14.5	24.2	25.5	24.5	25.1	26.1	26.9	
10-F	7	16.9	28.2	29.5	30.3	29.3	28.0	27.0	27.9
11-D	7	14.0	23.2	28.2	27.3	23.6	22.2		
11-M	7	14.0	23.4	21.7	17.5	16.4	18.7	19.7	
11-F	7	16.3	27.1	17.4	14.1	15.6	17.8	18.7	27.2
12-D	7	12.6	20.9	24.3	24.7	21.1	21.1	22.7	
12-M	7	13.2	22.0	17.3	16.8	21.1	23.8		
12-F	7	17.2	28.7	27.3	20.1	18.4	20.8	20.9	22.4

Table 85. Neutron probe data for 10 September 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	Volumetric soil water content (%)							
1-D	12	10.7	19.8	22.1	23.3	25.4	27.3		
1-M	12	10.8	20.1	23.8	26.3	27.6			
1-F	12	12.7	23.6	26.2	27.3	28.8	29.1	29.4	32.2
2-D	12	10.6	19.7	19.6	19.9	21.0	24.4		
2-M	12	10.4	19.3	19.9	20.1	21.6	24.5	29.4	
2-F	12	11.3	21.0	23.1	21.1	20.2	24.9	28.8	29.9	29.8
3-D	12	10.3	19.2	22.4	24.0	22.8	22.5	26.7	
3-M	12	10.5	19.5	22.1	23.2	21.8	22.1	25.8	
3-F	12	12.4	23.0	24.8	22.7	22.8	25.5	29.7	
4-D	12	9.5	17.6	18.1	16.2	16.9	20.6	23.6	
4-M	12	10.3	19.1	21.7	21.2	19.2	22.8		
4-F	12	11.4	21.0	21.8	20.2	19.7	25.0	25.3	26.4
5-D	12	11.9	22.0	24.4	23.9	25.7	27.1	27.6	
5-M	12	10.0	18.5	21.4	23.0	25.3	27.8		
5-F	12	10.8	20.1	22.2	24.9	26.9	28.1	27.6	
6-D	12	10.9	20.2	22.0	22.1	21.7	24.0	25.7	
6-M	12	10.4	19.3	21.8	22.7	22.4	22.8	23.9	
6-F	12	11.2	20.8	21.0	19.1	19.5	21.0	25.7	30.1
7-D	12	12.2	22.7	22.9	22.9	24.5	24.9		
7-M	12	11.3	20.9	20.5	19.9	23.2	24.9		
7-F	12	12.2	22.7	23.6	23.2	23.0	24.2	26.7	31.5	32.5
8-D	12	8.2	15.2	17.3	18.9	19.8	22.2	23.6	
8-M	12	9.4	17.5	19.0	18.2	17.8	20.1	22.8	
8-F	12	11.6	21.4	22.6	21.4	22.5	23.9	25.0	28.4
9-D	12	11.2	20.7	21.0	18.5	17.0	17.5	20.1	
9-M	12	10.2	18.8	20.0	18.5	17.1	18.0	20.0	
9-F	12	11.2	20.8	21.0	19.1	19.5	21.0	25.7	30.1
10-D	12	9.9	18.3	21.8	23.3	24.1	26.1	25.9	
10-M	12	10.3	19.2	22.9	24.3	25.6	26.3	27.4	
10-F	12	12.3	22.8	26.3	29.0	29.0	27.8	28.5	
11-D	12	9.2	17.0	22.6	24.0	22.5	21.8		
11-M	12	8.9	16.4	19.5	17.7	15.8	18.7	19.6	
11-F	12	11.2	20.7	17.2	14.6	16.1	17.9	19.2	27.1
12-D	12	9.9	18.3	20.6	21.7	19.9	20.7	22.7	
12-M	12	10.3	19.1	17.3	16.5	20.3	23.4		
12-F	12	11.1	20.5	22.6	19.9	18.6	21.1	21.0	22.4

Table 86. Neutron probe data for 17 September 1996.

EU	15-cm Estimate *		30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	--------------------------------- Volumetric soil water content (%) ---------------------------------								
1-D	19	11.1	22.4	23.4	23.8	24.9	27.3			
1-M	19	11.2	22.5	24.7	25.3	25.9				
1-F	19	12.6	25.4	25.5	26.7	28.5	28.7	28.9	31.5	
2-D	19	11.1	22.4	27.8	19.7	20.6	23.8	28.6		
2-M	19	11.5	23.1	20.3	19.6	21.1	24.7	29.4		
2-F	19	11.6	23.4	23.0	20.8	20.3	25.1	28.5	29.9	29.8
3-D	19	10.9	21.9	23.5	24.1	22.7	22.6	26.3		
3-M	19	11.1	22.3	23.5	22.7	21.3	21.9	26.2		
3-F	19	12.1	24.3	23.5	21.9	21.7	25.3	29.6		
4-D	19	10.4	21.0	18.4	16.2	17.0	20.4	23.4		
4-M	19	11.1	22.3	21.7	20.4	19.3	20.0	22.8		
4-F	19	11.1	22.3	21.0	20.0	20.5	24.6	25.2	26.4	
5-D	19	12.1	24.3	24.8	23.5	25.0	26.5	27.1		
5-M	19	11.0	22.1	23.4	22.7	25.3	27.3			
5-F	19	10.5	21.0	21.5	23.8	26.2	27.7	27.6		
6-D	19	10.5	21.1	21.8	21.3	21.7	23.3	26.4		
6-M	19	10.9	22.0	22.9	22.8	21.7	22.2	24.5		
6-F	19	12.0	24.1	23.4	22.8	23.0	24.7	27.6	28.2	
7-D	19	11.0	22.1	22.5	22.7	24.3	25.5			
7-M	19	10.7	21.6	20.3	20.2	23.4	24.8			
7-F	19	10.9	21.9	22.2	21.9	23.6	24.1	25.7	31.2	32.1
8-D	19	9.7	19.5	18.5	18.4	19.5	21.9	23.4		
8-M	19	10.3	20.6	19.3	18.0	17.8	19.8	22.8		
8-F	19	11.2	22.6	21.4	21.4	22.5	23.9	24.8	28.4	
9-D	19	11.2	22.5	22.1	18.8	17.6	17.9	20.0		
9-M	19	10.7	21.5	21.0	18.6	17.5	18.1	19.8		
9-F	19	11.0	22.2	20.3	18.9	19.3	20.5	25.4	29.6	
10-D	19	10.7	21.5	23.4	23.0	24.5	25.9	26.2		
10-M	19	11.3	22.7	24.3	23.7	25.6	26.4	27.0		
10-F	19	12.0	24.2	25.2	27.9	28.2	27.8	27.1	27.8	
11-D	19	10.1	20.3	21.7	21.6	21.2	21.4	22.6		
11-M	19	10.2	20.6	19.5	17.2	16.2	17.9	19.3		
11-F	19	10.6	21.3	16.8	14.5	15.9	17.6	19.2	27.1	
12-D	19	10.7	21.6	20.7	20.7	19.4	20.7	20.6		
12-M	19	9.3	18.8	17.3	17.0	20.7	23.2			
12-F	19	11.1	22.3	20.9	18.9	18.9	20.8	20.3	22.2	

Table 87. Neutron probe data for 23 September 1996.

EU	15-cm Estimate *	30-cm	45-cm	60-cm	75-cm	90-cm	105-cm	120-cm	135-cm
	Days Since Irr	------------------------------- Volumetric soil water content (%)							--------------------------------
1-D	25	9.5	19.0	21.9	22.9	25.3	27.7		
1-M	25	9.1	18.3	22.7	25.5	26.8			
1-F	25	11.6	23.2	25.4	27.0	28.9	28.6	29.4	31.8
2-D	25	10.1	20.3	20.9	20.6	21.3	24.4	29.6	
2-M	25	10.0	19.9	20.8	20.6	21.5	25.1	29.3	
2-F	25	9.2	18.4	22.3	21.7	21.2	25.0	28.9	30.3	30.2
3-D	25	9.0	17.9	21.7	23.4	23.3	23.0	26.9	
3-M	25	8.9	17.9	21.8	22.5	21.7	22.2	26.2	
3-F	25	10.4	20.9	22.7	21.9	22.2	25.6	30.0	
4-D	25	8.5	17.1	17.1	16.9	19.5	23.1	24.4	
4-M	25	7.0	14.1	18.5	19.6	19.6	20.8	23.2	
4-F	25	8.5	17.1	19.6	19.3	20.8	25.0	25.9	26.7
5-D	25	10.7	21.5	23.2	23.8	25.6	26.8	27.8	
5-M	25	8.2	16.4	20.2	23.3	25.6	27.7		
5-F	25	9.6	19.1	21.3	24.2	26.8	28.3	28.2	
6-D	25	10.0	20.1	21.3	21.3	22.0	23.9	26.8	
6-M	25	9.4	18.8	21.5	22.7	22.1	22.3	25.1	
6-F	25	11.2	22.5	22.7	22.6	23.1	25.3	28.0	28.0
7-D	25	10.4	20.9	22.1	23.2	24.9	25.3		
7-M	25	9.9	19.8	20.6	20.9	23.5	25.7		
7-F	25	9.6	19.2	21.0	23.4	24.5	26.4	31.3	32.5	32.7
8-D	25	8.1	16.2	17.9	19.6	19.8	22.5	23.9	
8-M	25	7.5	15.0	17.7	18.0	18.6	20.5	23.0	
8-F	25	9.4	18.9	21.3	21.5	23.2	24.2	25.1	27.9
9-D	25	9.1	18.2	20.3	19.1	17.9	18.0	19.9	
9-M	25	7.9	15.8	19.4	18.7	17.8	18.5	20.5	
9-F	25	9.7	19.4	20.0	19.6	20.2	20.8	25.7	30.5
10-D	25	9.0	18.1	22.0	23.3	24.9	26.5	26.3	
10-M	25	9.4	18.8	22.7	23.8	25.9	26.9	28.4	
10-F	25	10.2	20.4	24.5	27.6	29.0	28.4	27.4	28.2
11-D	25	7.3	14.7	18.7	19.6	19.7	21.1		
11-M	25	6.8	13.5	17.5	17.1	16.6	18.5	20.2	
11-F	25	8.9	17.8	15.9	14.9	16.2	18.2	19.8	26.8
12-D	25	7.9	15.8	18.1	19.7	19.3	20.9	22.7	
12-M	25	8.4	16.7	17.1	17.3	20.8	23.7		
12-F	25	8.4	16.8	18.6	18.4	18.8	21.1	21.2	21.7

APPENDIX E

SOIL SALINITY PROFILE DATA

Table 88. Soil salinity measurements using EC $_{2:1}$ procedure for T1 Treatment pulled in December 1995.

	Seed Drill Location						Water Furrow Location					
Depth	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining ‡	Corrected EC $_{2:1}$ §	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]
(cm)		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})
Rep 1: Experimental Unit 4												
0-15	4d1	1.5	b	1.5		1.5	4f1	4.8	N	3.7	5.39	1.0
15-30	4d2	5.9	N	4.6	5.92	1.4	4f2	2.9	N	2.3	7.29	0.9
30-45	4d3	14.7	N	11.2	1.81	1.1	4f3	3.8	N	3.0	6.63	1.0
45-60	4d4	6.9	N	5.3	3.43	0.9	4f4	7.3	N	5.6	5.57	1.6
60-75	4d5	0.75	b	0.8		0.8	4f5	8	N	6.1	4.1	1.3
75-90	4d6	4.3	N	3.4	5.65	1.0	4f6	5.2	N	4.0	4.62	1.0
90-105							4f7	9.5	N	7.3	2.24	0.8
Rep 2: Experimental Unit 11												
0-15	11d1	0.9	b	0.9		0.9	11f1	0.9	b	0.9		0.9
15-30	11d2	0.65	b	0.7		0.7	11f2	0.5	b	0.5		0.5
30-45	11d3	0.85	b	0.9		0.9	11f3	0.65	b	0.7		0.7
45-60	11d4	1	b	1.0		1.0	11f4	0.75	b	0.8		0.8
60-75	11d5	1.6	b	1.6		1.6	11f5	0.85	b	0.9		0.9
75-90	11d6	1	b	1.0		1.0	11f6	1.15	b	1.2		1.2
Rep 3: Experimental Unit 12												
0-15	12d1	0.9	b	0.9		0.9	12f1	2.3	b	2.3		2.3
15-30	12d2	0.8	b	0.8		0.8	12f2	0.7	b	0.7		0.7
30-45	12d3	0.85	b	0.9		0.9	12f3	1.05	b	1.1		1.1
45-60	12d4	1	b	1.0		1.0	12f4	1.05	b	1.1		1.1
60-75	12d5	1.1	b	1.1		1.1	12f5	1.1	b	1.1		1.1
75-90	12d6	1.1	b	1.1		1.1						

[a] "b": Beckman meter; "N": NRSC meter
[b] NRCS meter value adjusted based on calibration curve.
[c] Refers to the amount of sample remaining after evaporation took place.
[d] EC value corrected for any loss evaporation of sample.

Table 89. Soil salinity measurements using EC $_{2:1}$ procedure for T2 Treatment pulled in December 1995.

	Seed Drill Location						Water Furrow Location					
Depth	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]
(cm)		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})
Rep 1: Experimental Unit 7												
0-15	7d1	5.6	N	4.3	5.96	1.3	7f1	4.2	N	3.3	5.48	0.9
15-30	7d2	6.9	N	5.3	6.61	1.8	7f2	3.9	N	3.1	7.15	1.1
30-45	7d3	8.9	N	6.8	4.78	1.7	7f3	5.1	N	4.0	5.04	1.0
45-60	7d4	12.0	N	9.1	4.79	2.3	7f4	4.8	N	3.7	5.22	1.0
60-75	7d5	14.0	N	10.6	5.79	3.2	7f5	5.6	N	4.3	4.71	1.1
75-90	7d6	14.7	N	11.2	6.17	3.6	7f6	6.2	N	4.8	4.99	1.2
Rep 2: Experimental Unit 8												
0-15	8d1	2.0	N	1.6	9.82	0.8	8f1	1.6	N	1.3	13.15	0.9
15-30	8d2	---					8f2	2.3	N	1.9	12.25	1.2
30-45	8d3	6.9	N	5.3	3.84	1.1	8f3	2.2	N	2.2	9.45	1.1
45-60	8d4	3.5	N	2.8	10.12	1.5	8f4	2.5	N	2.5	11.09	1.4
60-75	8d5	4.6	N	4.6	11.12	2.7	8f5	3.6	N	3.6	11.79	2.2
75-90	8d6	16.6	N	12.6	5.69	3.7	8f6	3.8	N	3.8	11.51	2.3
90-105	8d7	8.2	N	6.3	14.34	4.7						
Rep 3: Experimental Unit 9												
0-15	9d1	---					9f1	2.0	N	1.6	12.88	1.1
15-30	9d2	---					9f2	---				
30-45	9d3	---					9f3	---				
45-60	9d4	---					9f4	---				
60-75	9d5	---					9f5	3.8	N	3.0	9.24	1.4
75-90	9d6	---					9f6	4.6	N	4.6	13.08	3.1
							9f7	4.2	N	4.2	12.09	2.6

[a] "b": Beckman meter; "N": NRSC meter
[b] NRCS meter value adjusted based on calibration curve.
[c] Refers to the amount of sample remaining after evaporation took place.
[d] EC value corrected for any loss evaporation of sample.

Table 90. Soil salinity measurements using EC $_{2:1}$ procedure for T3 Treatment pulled in December 1995.

	Seed Drill Location						Water Furrow Location					
Depth	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]
(cm)		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})
Rep 1: Experimental Unit 2												
0-15	2d1	2.4	b	2.4		2.4	2f1	1.9	b	1.9		1.9
15-30	2d2	1.7	b	1.7		1.7	2f2	2.3	b	2.3		2.3
30-45	2d3	2.7	b	2.7		2.7	2f3	2.8	b	2.8		2.8
45-60	2d4	3.7	b	3.7		3.7	2f4	1.9	b	1.9		1.9
60-75	2d5	4.3	b	4.3		4.3	2f5	3.9	b	3.9		3.9
75-90	2d6	3.2	b	3.2		3.2						
Rep 2: Experimental Unit 3												
0-15	3d1	2.0	b	2.0		2.0	3f1	1.9	b	1.9		1.9
15-30	3d2	2.3	b	2.3		2.3	3f2	2.2	b	2.2		2.2
30-45	3d3	2.2	b	2.2		2.2	3f3	2.2	b	2.2		2.2
45-60	3d4	2.1	b	2.1		2.1	3f4	1.8	b	1.8		1.8
60-75	3d5	2.0	b	2.0		2.0	3f5	2.2	b	2.2		2.2
75-90	3d6	2.2	b	2.2		2.2	3f6	1.7	b	1.7		1.7
Rep 3: Experimental Unit 10												
0-15	10d1	1.2	N	1.0	13.05	0.7	10f1	3.2	N	2.5	15.20	2.0
15-30	10d2	1.2	N	1.2	6.40	0.4	10f2	2.4	b	2.4	13.43	1.7
30-45	10d3	1.9	N	1.6	11.32	0.9	10f3	1.7	b	1.7		1.7
45-60	10d4	3.3	N	2.6	12.21	1.7	10f4	2.2	b	2.2	12.24	1.4
60-75	10d5	2.7	N	2.2	11.47	1.3	10f5	2.9	b	2.9	11.75	1.7
75-90	10d6	3.4	N	2.7	9.29	1.3	10f6	2.7	b	2.7		2.7

[a] "b": Beckman meter; "N": NRSC meter
[b] NRCS meter value adjusted based on calibration curve.
[c] Refers to the amount of sample remaining after evaporation took place.
[d] EC value corrected for any loss evaporation of sample.

Table 91. Soil salinity measurements using EC $_{2:1}$ procedure for T4 Treatment pulled in December 1995.

	Seed Drill Location						Water Furrow Location					
Depth	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]	Sample Name	Measured EC $_{2:1}$	Meter Used [a]	Adj EC $_{2:1}$ [b]	Solution Remaining [c]	Corrected EC $_{2:1}$ [d]
(cm)		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})		(dSm^{-1})		(dSm^{-1})	(ml)	(dSm^{-1})
Rep 1: Experimental Unit 1												
0-15	1d1	3.0	b	3.0		3.0	1f1	3.0	b	3.0		3.0
15-30	1d2	2.8	b	2.8		2.8	1f2	3.1	b	3.1		3.1
30-45	1d3	3.8	b	3.8		3.8	1f3	3.2	b	3.2		3.2
45-60	1d4	3.4	b	3.4		3.4	1f4	3.2	b	3.2		3.2
60-75	1d5	4.0	b	4.0		4.0	1f5	3.4	b	3.4		3.4
75-90	1d6	3.5	b	3.5		3.5	1f6	3.6	b	3.6		3.6
90-105							1f7	4.5	b	4.5		4.5
Rep 2: Experimental Unit 5												
0-15	5d1	10.4	N	7.9	7.19	3.0	5f1	8.2	N	6.3	7.38	2.4
15-30	5 d2	10.4	N	7.9	5.83	2.4	5f2	10.1	N	7.7	6.07	2.4
30-45	5d3	10.3	N	7.9	5.79	2.4	5f3	11.4	N	8.7	6.06	2.7
45-60	5d4	12.0	N	9.1	5.84	2.8	5f4	14.8	N	11.2	5.22	3.1
60-75	5d5	12.6	N	9.6	5.52	2.8	5f5	14.9	N	11.3	5.16	3.0
75-90	5d6	12.9	N	9.8	6.14	3.1	5f6	12.4	N	9.4	5.11	2.5
Rep 3: Experimental Unit 6												
0-15	6d1	5.8	N	4.5	6.78	1.6	6f1	6.6	N	5.1	6.96	1.8
15-30	6d2	5.4	N	4.2	6.52	1.4	6f2	6.5	N	5.0	6.71	1.8
30-45	6d3	8.5	N	6.5	3.70	1.3	6f3	7.85	N	6.0	6.30	2.0
45-60	6d4	6.2	N	4.8	6.86	1.7	6f4	9.75	N	7.4	6.28	2.4
60-75	6d5	9.9	N	7.6	5.33	2.1	6f5	9.8	N	7.5	6.14	2.4
75-90	6d6	10.7	N	8.2	5.76	2.5	6f6	11.0	N	8.4	3.20	1.4
90-105	7d7	12.7	N	9.7	4.85	2.4						

[a] "b": Beckman meter; "N": NRSC meter
[b] NRCS meter value adjusted based on calibration curve.
[c] Refers to the amount of sample remaining after evaporation took place.
[d] EC value corrected for any loss evaporation of sample.

APPENDIX F

LEAF WATER POTENTIAL DATA

Table 92. Leaf water potential measurements showing date, days after planting (DAP), day of year (DOY), time, experimental unit, days since last irrigation or significant precipitation, solar time, and minutes since sunrise plots in 1994.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars	----------------		MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
21-Jul	77	202	12	35	-290	-300	-315	-20.8	11	1.5	18	12.58	11.58	387.9
21-Jul	77	202	12	42	-345	-300	-325	-22.3	12	1.5	18	12.70	11.70	394.9
21-Jul	77	202	12	48	-400	-420	-420	-28.5	1	15	18	12.80	11.80	400.9
21-Jul	77	202	12	54	-320	-330	-350	-23.0	2	9	18	12.90	11.90	406.9
21-Jul	77	202	13	0	-370	-360	-390	-25.7	3	9	18	13.00	12.00	412.9
21-Jul	77	202	13	6	-320	---	---	-22.1	4	1.5	18	13.10	12.10	418.9
21-Jul	77	202	13	12	-360	-370	-360	-25.1	5	15	18	13.20	12.20	424.9
21-Jul	77	202	13	18	-420	-410	-430	-29.0	6	15	18	13.30	12.30	430.9
21-Jul	77	202	13	24	-390	-390	-405	-27.2	7	4.5	18	13.40	12.40	436.9
21-Jul	77	202	13	30	-320	-330	-310	-22.1	8	4.5	18	13.50	12.50	442.9
21-Jul	77	202	13	36	-320	-350	-350	-23.4	9	4.5	18	13.60	12.60	448.9
21-Jul	77	202	13	42	-355	-355	-355	-24.5	10	9	18	13.70	12.70	454.9
4-Aug	91	216	12	0	-450	-500	-480	-32.9	1	15	18	12.00	11.00	343.8
4-Aug	91	216	12	6	-500	-500	-450	-33.3	2	9	6	12.10	11.10	349.8
4-Aug	91	216	12	12	-500	-570	-500	-36.1	3	9	3	12.20	11.20	355.8
4-Aug	91	216	12	18	-380	-480	-400	-29.0	4	1.5	6	12.30	11.30	361.8
4-Aug	91	216	12	24	-450	-450	-470	-31.5	5	15	3	12.40	11.40	367.8
4-Aug	91	216	12	30	-420	-450	-440	-30.1	6	15	6	12.50	11.50	373.8
4-Aug	91	216	12	36	-460	-360	-440	-29.0	7	4.5	3	12.60	11.60	379.8
4-Aug	91	216	12	42	-380	-420	-440	-28.5	8	4.5	6	12.70	11.70	385.8
4-Aug	91	216	12	48	-450	-400	-420	-29.2	9	4.5	3	12.80	11.80	391.8
4-Aug	91	216	12	54	-400	-450	-480	-30.6	10	9	6	12.90	11.90	397.8

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars -----------------			MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
4-Aug	91	216	13						11	1.5	3	13.00	12.00	403.8
4-Aug	91	216	13	6	-460	-500	-540	-34.5	12	1.5	19	13.10	12.10	409.8
11-Aug	98	223	12	0	-350	-370	-330	-24.1	1	15	19	12.00	11.02	339.2
11-Aug	98	223	12	6	-420	-400	-380	-27.6	2	9	19	12.10	11.12	345.2
11-Aug	98	223	12	12	-490	-380	-450	-30.3	3	9	19	12.20	11.22	351.2
11-Aug	98	223	12	18	-450	-390	-470	-30.1	4	1.5	19	12.30	11.32	357.2
11-Aug	98	223	12	24	-520	-520	-450	-34.3	5	15	19	12.40	11.42	363.2
11-Aug	98	223	12	30	-370	-340	-340	-24.1	6	15	19	12.50	11.52	369.2
11-Aug	98	223	12	36	-410	-400	-420	-28.3	7	4.5	19	12.60	11.62	375.2
11-Aug	98	223	12	42	-330	-400	-350	-24.8	8	4.5	19	12.70	11.72	381.2
					------------------------- MPa---------------------									
30-Aug	119	242	7	45	-14.5	---	---	-14.5	1	15	1	7.75	6.85	71.9
30-Aug	119	242	7	49	-11	---	---	-11.0	2	9	1	7.82	6.92	75.9
30-Aug	119	242	7	53	-11	---	---	-11.0	3	9	1	7.88	6.98	79.9
30-Aug	119	242	7	57	-7.5	---	---	-7.5	4	1.5	1	7.95	7.05	83.9
30-Aug	119	242	8	1	-13.5	---	---	-13.5	5	15	1	8.02	7.12	87.9
30-Aug	119	242	8	5	-10.5	---	---	-10.5	6	15	19	8.08	7.18	91.9
30-Aug	119	242	8	9	-9	---	---	-9.0	7	4.5	1	8.15	7.25	95.9
30-Aug	119	242	8	13	-9	---	---	-9.0	8	4.5	19	8.22	7.32	99.9
30-Aug	119	242	8	17	-9.5	---	---	-9.5	9	4.5	1	8.28	7.38	103.9
30-Aug	119	242	8	21	-8.5	---	---	-8.5	10	9	19	8.35	7.45	107.9
30-Aug	119	242	8	25	-9	---	---	-9.0	11	1.5	19	8.42	7.52	111.9
30-Aug	119	242	8	29	-6	---	---	-6.0	12	1.5	1	8.48	7.58	115.9

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars -----------------			MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
30-Aug	119	242	9	50	-21	-20	---	-20.5	1	15	1	9.83	8.93	196.9
30-Aug	119	242	9	54	-16.5	-14	---	-15.3	2	9	1	9.90	9.00	200.9
30-Aug	119	242	9	58	-14.5	-12	---	-13.3	3	9	1	9.97	9.07	204.9
30-Aug	119	242	10	2	-13	-11	---	-11.8	4	1.5	3	10.03	9.13	208.9
30-Aug	119	242	10	6	-18	-19	---	-18.3	5	15	1	10.10	9.20	212.9
30-Aug	119	242	10	10	-14	-15	---	-14.3	6	15	3	10.17	9.27	216.9
30-Aug	119	242	10	14	-15	-14	---	-14.5	7	4.5	1	10.23	9.33	220.9
30-Aug	119	242	10	18	-13	-13	---	-12.8	8	4.5	1	10.30	9.40	224.9
30-Aug	119	242	10	22	-12	-12	---	-11.8	9	4.5	3	10.37	9.47	228.9
30-Aug	119	242	10	26	-14.5	-13	---	-13.5	10	9	0	10.43	9.53	232.9
30-Aug	119	242	10	30	-12.5	-12	---	-12.3	11	1.5	1	10.50	9.60	236.9
30-Aug	119	242	10	34	-12	-13	---	-12.5	12	1.5	1	10.57	9.67	240.9
30-Aug	119	242	14	0	-26	-26	---	-26.0	1	15	4	14.00	13.10	446.9
30-Aug	119	242	14	4	-18.5	-22	---	-20.0	2	9	2	14.06	13.16	450.4
30-Aug	119	242	14	7	-20	-20	---	-20.0	3	9	2	14.12	13.22	453.9
30-Aug	119	242	14	11	-15.5	-15	---	-15.3	4	1.5	0	14.18	13.28	457.4
30-Aug	119	242	14	11	-25	-23	---	-24.0	5	15	1	14.18	13.28	457.4
30-Aug	119	242	14	14	-20	-22	---	-21.0	6	15	0	14.23	13.33	460.9
30-Aug	119	242	14	18	-21.5	-21	---	-21.3	7	4.5	2	14.29	13.39	464.4
30-Aug	119	242	14	35	-18	-18	---	-17.8	8	4.5	2	14.58	13.68	481.9
30-Aug	119	242	14	39	-16.5	-17	---	-16.8	9	4.5	1	14.64	13.74	485.4
30-Aug	119	242	14	42	-19	-20	---	-19.5	10	9	1	14.70	13.80	488.9
30-Aug	119	242	14	46	-17	-18	---	-17.5	11	1.5	2	14.76	13.86	492.4

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars -----------------			MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
30-Aug	119	242	14	49	-15	-15	---	-15.0	12	1.5	0	14.82	13.92	495.9
30-Aug	119	242	16	20	-26	-29	---	-27.5	1	15	3	16.33	15.43	586.9
30-Aug	119	242	16	24	-22.5	-24	---	-23.3	2	9	4	16.39	15.49	590.4
30-Aug	119	242	16	27	-20.5	-19	---	-19.5	3	9	4	16.45	15.55	593.9
30-Aug	119	242	16	31	-18.5	-18	---	-18.3	4	1.5	1	16.51	15.61	597.4
30-Aug	119	242	16	34	-19	-23	---	-20.8	5	15	0	16.57	15.67	600.9
30-Aug	119	242	16	38	-20.5	-20	---	-20.0	6	15	4	16.63	15.73	604.4
30-Aug	119	242	16	41	-20	-19	---	-19.3	7	4.5	4	16.68	15.78	607.9
30-Aug	119	242	16	45	-17	-17	---	-17.0	8	4.5	1	16.74	15.84	611.4
30-Aug	119	242	16	48	-17.5	-19	---	-18.3	9	4.5	2	16.80	15.90	614.9
30-Aug	119	242	16	52	-26	-21	---	-23.5	10	9	0	16.86	15.96	618.4
30-Aug	119	242	16	55	-17	-18	---	-17.5	11	1.5	4	16.92	16.02	621.9
30-Aug	119	242	16	59	-19	-16	---	-17.5	12	1.5	1	16.98	16.08	625.4
30-Aug	119	242	18	13	-21	-28	---	-24.5	1	15	5	18.22	17.32	699.9
30-Aug	119	242	18	17	-19	-16	---	-17.5	2	9	3	18.28	17.38	703.4
30-Aug	119	242	18	20	-17	-17	---	-17.0	3	9	2	18.33	17.43	706.9
30-Aug	119	242	18	24	-13	-15	---	-13.8	4	1.5	1	18.39	17.49	710.4
30-Aug	119	242	18	27	-20	-20	---	-20.0	5	15	3	18.45	17.55	713.9
30-Aug	119	242	18	31	-16	-18	---	-17.0	6	15	2	18.51	17.61	717.4
30-Aug	119	242	18	34	-17	-14	---	-15.5	7	4.5	3	18.57	17.67	720.9
30-Aug	119	242	18	38	-13.5	-14	---	-13.8	8	4.5	3	18.63	17.73	724.4
30-Aug	119	242	18	41	-13	-13	---	-13.0	9	4.5	1	18.68	17.78	727.9
30-Aug	119	242	18	45	-14	-14	---	-14.0	10	9	1	18.74	17.84	731.4

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars -----------------			MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
30-Aug	119	242	18	48	-11	-15	---	-12.8	11	1.5	3	18.80	17.90	734.9
30-Aug	119	242	18	52	-13	-12	---	-12.5	12	1.5	2	18.86	17.96	738.4
31-Aug	120	243	7	25	-14	-13	---	-13.5	1	15	2	7.42	6.52	51.3
31-Aug	120	243	7	29	-9	-9	---	-9.0	2	9	5	7.48	6.58	54.8
31-Aug	120	243	7	32	-10	-10	---	-10.0	3	9	2	7.53	6.64	58.3
31-Aug	120	243	7	36	-6.5	-6	---	-6.3	4	1.5	4	7.59	6.70	61.8
31-Aug	120	243	7	39	-12	-17	---	-14.5	5	15	5	7.65	6.76	65.3
31-Aug	120	243	7	43	-9	-10	---	-9.5	6	15	2	7.71	6.81	68.8
31-Aug	120	243	7	46	-9.5	-10	---	-9.8	7	4.5	2	7.77	6.87	72.3
31-Aug	120	243	7	50	-9	-8	---	-8.5	8	4.5	2	7.83	6.93	75.8
31-Aug	120	243	7	53	-8.5	-7.5	---	-8.0	9	4.5	2	7.88	6.99	79.3
31-Aug	120	243	7	57	-8	-8.5	---	-8.3	10	9	2	7.94	7.05	82.8
31-Aug	120	243	8	0	-7	-7.5	---	-7.3	11	1.5	2	8.00	7.11	86.3
31-Aug	120	243	8	4	-7	-6	---	-6.5	12	1.5	0	8.06	7.16	89.8
31-Aug	120	243	10	40	-26	-21	---	-23.5	1	15	2	10.67	9.77	246.3
31-Aug	120	243	10	44	-17.5	-18	---	-17.8	2	9	2	10.73	9.83	249.8
31-Aug	120	243	10	47	-15.5	-17	---	-16.3	3	9	2	10.78	9.89	253.3
31-Aug	120	243	10	51	-12.5	-12	---	-12.3	4	1.5	2	10.84	9.95	256.8
31-Aug	120	243	10	54	-20	-18	---	-18.8	5	15	0	10.90	10.01	260.3
31-Aug	120	243	10	58	-15.5	-15	---	-15.0	6	15	2	10.96	10.06	263.8
31-Aug	120	243	11	1	-15.5	-10	---	-12.8	7	4.5	2	11.02	10.12	267.3
31-Aug	120	243	11	5	-16.5	-16	---	-16.3	8	4.5	0	11.08	10.18	270.8
31-Aug	120	243	11	8	-13.5	-14	---	-13.5	9	4.5	2	11.13	10.24	274.3

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars -----------------			MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
31-Aug	120	243	11	12	-15	-15	---	-14.8	10	9	2	11.19	10.30	277.8
31-Aug	120	243	11	15	-11.5	-14	---	-12.5	11	1.5	2	11.25	10.36	281.3
31-Aug	120	243	11	19	-13	-14	---	-13.3	12	1.5	0	11.31	10.41	284.8
31-Aug	120	243	14	23	-26	-23	---	-24.5	1	15	0	14.38	13.49	469.3
31-Aug	120	243	14	27	-19	-20	---	-19.5	2	9	2	14.44	13.55	472.8
31-Aug	120	243	14	30	-19	-20	---	-19.5	3	9	3	14.50	13.61	476.3
31-Aug	120	243	14	34	-16.5	-18	---	-17.0	4	1.5	2	14.56	13.66	479.8
31-Aug	120	243	14	37	-23	-22	---	-22.5	5	15	2	14.62	13.72	483.3
31-Aug	120	243	14	41	-18	-18	---	-18.0	6	15	3	14.68	13.78	486.8
31-Aug	120	243	14	44	-19.5	-19	---	-19.3	7	4.5	8	14.73	13.84	490.3
31-Aug	120	243	14	48	-20	-19	---	-19.5	8	4.5	0	14.79	13.90	493.8
31-Aug	120	243	14	51	-18	-18	---	-18.0	9	4.5	3	14.85	13.96	497.3
31-Aug	120	243	14	55	-20	-18	---	-18.8	10	9	8	14.91	14.01	500.8
31-Aug	120	243	14	58	-15.5	-17	---	-16.3	11	1.5	8	14.97	14.07	504.3
31-Aug	120	243	15	2	-18	-18	---	-18.0	12	1.5	2	15.03	14.14	508.3
31-Aug	120	243	18	24	-22	-25	---	-23.5	1	15	3	18.40	17.51	710.3
31-Aug	120	243	18	28	-17.5	-18	---	-17.8	2	9	3	18.46	17.56	713.8
31-Aug	120	243	18	31	-18	-17	---	-17.5	3	9	8	18.52	17.62	717.3
31-Aug	120	243	18	35	-15	-14	---	-14.5	4	1.5	8	18.58	17.68	720.8
31-Aug	120	243	18	38	-19	-19	---	-19.0	5	15	2	18.63	17.74	724.3
31-Aug	120	243	18	42	-16.5	-19	---	-17.5	6	15	8	18.69	17.80	727.8
31-Aug	120	243	18	45	-19	-19	---	-18.8	7	4.5	2	18.75	17.86	731.3
31-Aug	120	243	18	49	-19.5	-17	---	-18.3	8	4.5	8	18.81	17.91	734.8

Table 92, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- bars	-----------------		MPa		dS m^{-1}	days	dec. hr.	dec. hr.	mins
31-Aug	120	243	18	52	-17	-17	---	-16.8	9	4.5	8	18.87	17.97	738.3
31-Aug	120	243	18	56	-21	-18	---	-19.5	10	9	3	18.93	18.03	741.8
31-Aug	120	243	18	59	-16	-17	---	-16.3	11	1.5	2	18.98	18.09	745.3
31-Aug	120	243	19	3	-17	-16	---	-16.5	12	1.5	8	19.05	18.16	749.3
5-Sep	125	248	9	0	-19	-16	---	-17.5	1	15	19	9.00	8.14	143.2
5-Sep	125	248	9	5	-16.5	-13	---	-14.8	2	9	19	9.08	8.22	148.2
5-Sep	125	248	9	9	-16.5	-15	---	-15.5	3	9	19	9.15	8.29	152.2
5-Sep	125	248	9	14	-11.5	-9.5	---	-10.5	4	1.5	19	9.23	8.37	157.2
5-Sep	125	248	9	18	-18.5	-18	---	-18.3	5	15	19	9.30	8.44	161.2
5-Sep	125	248	9	22	-16	-17	---	-16.3	6	15	19	9.37	8.50	165.2
5-Sep	125	248	9	27	-15	-13	---	-14.0	7	4.5	19	9.45	8.59	170.2
5-Sep	125	248	9	31	-12	-13	---	-12.3	8	4.5	19	9.52	8.65	174.2
5-Sep	125	248	9	36	-11	-11	---	-11.0	9	4.5	19	9.60	8.74	179.2
5-Sep	125	248	9	40	-13	-12	---	-12.5	10	9	19	9.67	8.80	183.2
5-Sep	125	248	9	45	-9.5	-11	---	-10.0	11	1.5	19	9.75	8.89	188.2
5-Sep	125	248	9	50	-11.5	-12	---	-11.8	12	1.5	19	9.83	8.97	193.2

Table 93. Leaf water potential measurements showing date, days after planting (DAP), day of year (DOY), time, experimental unit, days since last irrigation or significant precipitation, solar time, and minutes since sunup for plots in 1995.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa	----------------				$dS\ m^{-1}$	days	dec. hr.	dec. hr.	mins.
18-Jul	76	199	8	10	-15.0			-15.0		9	18	7.17	6.17	64.7
18-Jul	76	199	8	25	-10.5	-15.5	-11.5	-12.5	1	15	18	7.42	6.42	79.7
18-Jul	76	199	8	27	-15.0	-16.0		-15.5	2	9	18	7.45	6.45	81.7
18-Jul	76	199	8	32	-17.0	-16.0		-16.5	3	9	18	7.53	6.54	86.7
18-Jul	76	199	8	38	-11.5	-12.5		-12.0	4	1.5	18	7.63	6.64	92.7
18-Jul	76	199	8	44	-15.0	-18.5		-16.8	5	15	18	7.73	6.74	98.7
18-Jul	76	199	8	50	-14.5	-13.0		-13.8	6	15	18	7.83	6.84	104.7
18-Jul	76	199	8	56	-12.5	-15.0		-13.8	7	4.5	18	7.93	6.94	110.7
18-Jul	76	199	9	2	-13.5	-12.5		-13.0	8	4.5	18	8.03	7.04	116.7
18-Jul	76	199	9	7	-14.0	-15.5		-14.8	9	4.5	18	8.12	7.12	121.7
18-Jul	76	199	9	10	-16.5	-15.0		-15.8	10	9	18	8.17	7.17	124.7
18-Jul	76	199	9	13	-14.0	-14.5		-14.3	11	1.5	18	8.22	7.22	127.7
18-Jul	76	199	9	17	-14.5	-15.5		-15.0	12	1.5	18	8.28	7.29	131.7
19-Jul	77	200	8	50	-15.0	-11.0	-5.0	-10.3	1	15	19	7.83	6.83	104.1
19-Jul	77	200	8	54	-20.0	-7.0	-20.0	-15.7	2	9	19	7.90	6.90	108.1
19-Jul	77	200	8	56	-15.0	-15.0		-15.0	3	9	19	7.93	6.93	110.1
19-Jul	77	200	9	2	-5.0	-12.0	-15.0	-10.7	4	1.5	19	8.03	7.03	116.1
19-Jul	77	200	9	5	-17.5	-17.5		-17.5	5	15	19	8.08	7.08	119.1
19-Jul	77	200	9	8	-19.0	-21.5		-20.3	6	15	19	8.13	7.13	122.1
19-Jul	77	200	9	14	-7.0	-14.0	-17.0	-12.7	7	4.5	19	8.23	7.23	128.1
19-Jul	77	200	9	17	-16.5	-15.0		-15.8	8	4.5	19	8.28	7.28	131.1
19-Jul	77	200	9	20	-15.5	-17.0		-16.3	9	4.5	19	8.33	7.33	134.1
19-Jul	77	200	9	24	-15.5	-17.0		-16.3	10	9	19	8.40	7.40	138.1
19-Jul	77	200	9	28	-12.0	-15.0		-13.5	11	1.5	19	8.47	7.47	142.1
19-Jul	77	200	9	31	-16.0	-15.5		-15.8	12	1.5	19	8.52	7.52	145.1
19-Jul	77	200	9	38	-17.0			-17.0	1	15	19	8.63	7.63	152.1
19-Jul	77	200	14	15	-23.0	-28.0		-25.5	1	15	19	11.25	10.25	429.1
19-Jul	77	200	14	20	-28.0	-25.0		-26.5	2	9	19	13.33	12.33	434.1
19-Jul	77	200	14	25	-27.0	-27.0		-27.0	3	9	19	13.42	12.42	439.1

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa	----------------				$dS\ m^{-1}$	days	dec. hr.	dec. hr.	mins.
19-Jul	77	200	14	30	-21.5	-12.0		-16.8	4	1.5	19	13.50	12.50	444.1
19-Jul	77	200	14	35	-25.5	-28.0		-26.8	5	15	19	13.58	12.58	449.1
19-Jul	77	200	14	40	-20.5	-25.5		-23.0	6	15	19	13.67	12.67	454.1
19-Jul	77	200	14	44	-22.0	-21.0		-21.5	7	4.5	19	13.73	12.73	458.1
19-Jul	77	200	14	48	-23.5	-25.5		-24.5	8	4.5	19	13.80	12.80	462.1
19-Jul	77	200	14	52	-21.0	-21.0		-21.0	9	4.5	19	13.87	12.87	466.1
19-Jul	77	200	14	56	-22.0	-20.0		-21.0	10	9	19	13.93	12.93	470.1
19-Jul	77	200	15	1	-19.5	-22.0		-20.8	11	1.5	19	14.02	13.02	475.1
19-Jul	77	200	15	6	-19.5	-20.5		-20.0	12	1.5	19	14.10	13.10	480.1
22-Jul	80	203	7	7	-5.0	-4.0		-4.5	1	15	1	6.12	5.12	-0.8
22-Jul	80	203	7	12	-10.5	-10.0		-10.3	2	9	1	6.20	5.20	4.2
22-Jul	80	203	7	17	-9.0	-9.0		-9.0	3	9	1	6.28	5.28	9.2
22-Jul	80	203	7	22	-10.5	-10.5		-10.5	4	1.5	1	6.37	5.37	14.2
22-Jul	80	203	7	27	-8.0	-8.0		-8.0	5	15	1	6.45	5.45	19.2
22-Jul	80	203	7	33	-11.0	-10.0		-10.5	6	15	1	6.55	5.55	25.2
22-Jul	80	203	7	38	-10.0	-10.5		-10.3	7	4.5	1	6.63	5.63	30.2
22-Jul	80	203	7	43	-9.5	-10.0		-9.8	8	4.5	1	6.72	5.72	35.2
22-Jul	80	203	7	48	-11.0	-10.0		-10.5	9	4.5	1	6.80	5.80	40.2
22-Jul	80	203	7	54	-10.5	-10.0		-10.3	10	9	1	6.90	5.90	46.2
22-Jul	80	203	8	0	-10.0	-8.5		-9.3	11	1.5	1	7.00	6.00	52.2
22-Jul	80	203	8	6	-12.0	-11.0		-11.5	12	1.5	1	7.10	6.10	58.2
22-Jul	80	203	8	8	-12.5	-10.5		-11.5	1	15	1	7.13	6.13	60.2
25-Jul	83	206	6	14	-13.0	-11.5		-12.3	1	15	3	5.23	4.23	-55.6
25-Jul	83	206	6	24	-12.0	-13.0		-12.5	2	9	3	5.40	4.40	-45.6
25-Jul	83	206	6	35	-12.5	-12.0		-12.3	3	9	3	5.58	4.58	-34.6
25-Jul	83	206	6	47	-10.5	-9.5		-10.0	4	1.5	4	5.78	4.78	-22.6
25-Jul	83	206	6	58	-15.0	-12.5		-13.8	5	15	2	5.97	4.96	-11.6
25-Jul	83	206	7	11	-11.5	-12.0		-11.8	6	15	2	6.18	5.18	1.4
25-Jul	83	206	7	19	-10.5	-9.0		-9.8	7	4.5	2	6.32	5.31	9.4

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa	----------------				dS m^{-1}	days	dec. hr.	dec. hr.	mins.
25-Jul	83	206	7	24	-11.0	-10.5		-10.8	8	4.5	2	6.40	5.40	14.4
25-Jul	83	206	7	39	-14.5	-14.0		-14.3	9	4.5	2	6.65	5.65	29.4
25-Jul	83	206	7	48	-12.5	-14.5		-13.5	10	9	3	6.80	5.80	38.4
25-Jul	83	206	7	58	-10.5	-11.5		-11.0	11	1.5	4	6.97	5.96	48.4
25-Jul	83	206	8	8	-12.0	-12.5		-12.3	12	1.5	4	7.13	6.13	58.4
27-Jul	85	208	6	15	-15.0	-14.0		-14.5	1	15	4	5.25	4.25	-55.9
27-Jul	85	208	6	21	-13.0	-14.5		-13.8	2	9	4	5.35	4.35	-49.9
27-Jul	85	208	6	28	-13.0	-14.0		-13.5	3	9	4	5.47	4.46	-42.9
27-Jul	85	208	6	36	-11.0	-10.5		-10.8	4	1.5	5	5.60	4.60	-34.9
27-Jul	85	208	6	42	-15.0	-13.0		-14.0	5	15	3	5.70	4.70	-28.9
27-Jul	85	208	6	48	-13.0	-12.0		-12.5	6	15	3	5.80	4.80	-22.9
27-Jul	85	208	6	59	-15.0	-14.0		-14.5	7	4.5	3	5.98	4.98	-11.9
27-Jul	85	208	7	12	-12.0	-15.0		-13.5	8	4.5	3	6.20	5.20	1.1
27-Jul	85	208	7	20	-11.0	-14.0		-12.5	9	4.5	3	6.33	5.33	9.1
27-Jul	85	208	7	26	-13.0	-12.0		-12.5	10	9	4	6.43	5.43	15.1
27-Jul	85	208	7	34	-13.5	-11.0		-12.3	11	1.5	5	6.57	5.56	23.1
27-Jul	85	208	7	41	-10.5	-10.0		-10.3	12	1.5	5	6.68	5.68	30.1
2-Aug	91	214	6	30	-14.5	-12.0		-13.3	1	15	2	5.50	4.50	-44.9
2-Aug	91	214	6	38	-14.0	-13.5		-13.8	2	9	2	5.63	4.63	-36.9
2-Aug	91	214	6	44	-12.5	-12.5		-12.5	3	9	2	5.73	4.73	-30.9
2-Aug	91	214	6	51	-7.5	-8.5		-8.0	4	1.5	2	5.85	4.85	-23.9
2-Aug	91	214	6	57	-12.0	-13.5		-12.8	5	15	2	5.95	4.95	-17.9
2-Aug	91	214	7	3	-10.0	-10.0		-10.0	6	15	2	6.05	5.05	-11.9
2-Aug	91	214	7	13	-10.5	-12.0		-11.3	7	4.5	2	6.22	5.22	-1.9
2-Aug	91	214	7	22	-10.0	-12.0		-11.0	8	4.5	2	6.37	5.37	7.1
2-Aug	91	214	7	29	-10.0	-11.0		-10.5	9	4.5	2	6.48	5.48	14.1
2-Aug	91	214	7	35	-7.5	-9.5		-8.5	10	9	2	6.58	5.58	20.1
2-Aug	91	214	7	42	-9.5	-9.0		-9.3	11	1.5	2	6.70	5.70	27.1
2-Aug	91	214	7	47	-9.0	-8.5		-8.8	12	1.5	2	6.78	5.78	32.1

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
8-Aug	97	220	6	20	-14.5	-15.0		-14.8	1	15	8	5.33	4.34	-58.8
8-Aug	97	220	6	28	-15.0	-17.0		-16.0	2	9	8	5.47	4.48	-50.8
8-Aug	97	220	6	35	-18.0	-18.5		-18.3	3	9	8	5.58	4.59	-43.8
8-Aug	97	220	6	41	-8.5	-11.0		-9.8	4	1.5	8	5.68	4.69	-37.8
8-Aug	97	220	6	47	-18.0	-18.5		-18.3	5	15	8	5.78	4.79	-31.8
8-Aug	97	220	6	55	-15.0	-15.5		-15.3	6	15	8	5.92	4.93	-23.8
8-Aug	97	220	7	5	-15.0	-16.5		-15.8	7	4.5	8	6.08	5.09	-13.8
8-Aug	97	220	7	13	-8.0	-10.0		-9.0	8	4.5	8	6.22	5.23	-5.8
8-Aug	97	220	7	20	-16.0	-13.5		-14.8	9	4.5	8	6.33	5.34	1.2
8-Aug	97	220	7	30	-9.5	-11.0		-10.3	10	9	8	6.50	5.51	11.2
8-Aug	97	220	7	40	-11.5	-9.5		-10.5	11	1.5	8	6.67	5.68	21.2
8-Aug	97	220	7	50	-12.0	-10.0		-11.0	12	1.5	8	6.83	5.84	31.2
9-Aug	98	221	6	20	-16.0	-15.0		-15.5	1	15	9	5.33	4.35	-59.5
9-Aug	98	221	6	26	-17.5	-17.0		-17.3	2	9	9	5.43	4.45	-53.5
9-Aug	98	221	6	35	-20.0	-19.0		-19.5	3	9	9	5.58	4.60	-44.5
9-Aug	98	221	6	43	-11.5	-10.5		-11.0	4	1.5	9	5.72	4.73	-36.5
9-Aug	98	221	6	50	-20.0	-18.0		-19.0	5	15	9	5.83	4.85	-29.5
9-Aug	98	221	7	5	-15.0	-16.0		-15.5	6	15	9	6.08	5.10	-14.5
9-Aug	98	221	7	15	-15.0	-16.5		-15.8	7	4.5	9	6.25	5.26	-4.5
9-Aug	98	221	7	23	-14.5	-15.0		-14.8	8	4.5	9	6.38	5.40	3.5
9-Aug	98	221	7	30	-13.0	-15.0		-14.0	9	4.5	9	6.50	5.51	10.5
9-Aug	98	221	7	35	-12.5	-13.5		-13.0	10	9	9	6.58	5.60	15.5
9-Aug	98	221	7	40	-13.0	-13.5		-13.3	11	1.5	9	6.67	5.68	20.5
9-Aug	98	221	7	46	-14.5	-13.5		-14.0	12	1.5	9	6.77	5.78	26.5
24-Aug	113	236	7	0	-15.0	-15.0		-15.0	1	15	13	6.00	5.07	-29.3
24-Aug	113	236	7	8	-13.0	-13.0		-13.0	4	1.5	12	6.13	5.20	-21.3
24-Aug	113	236	7	13	-13.0	-13.5		-13.3	7	4.5	12	6.22	5.28	-16.3
24-Aug	113	236	7	20	-9.0	-10.0		-9.5	10	9	13	6.33	5.40	-9.3
24-Aug	113	236	7	28	-14.0	-15.5		-14.8	2	9	12	6.47	5.53	-1.3
24-Aug	113	236	7	34	-18.0	-20.0		-19.0	5	15	12	6.57	5.63	4.7

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa	----------------		----------------		dS m^{-1}	days	dec. hr.	dec. hr.	mins.
24-Aug	113	236	7	38	-15.5	-16.5		-16.0	8	4.5	15	6.63	5.70	8.7
24-Aug	113	236	7	42	-13.5	-12.0		-12.8	11	1.5	15	6.70	5.77	12.7
24-Aug	113	236	7	50	-16.5	-15.5		-16.0	3	9	14	6.83	5.90	20.7
24-Aug	113	236	8	2	-15.5	-15.5		-15.5	6	15	12	7.03	6.10	32.7
24-Aug	113	236	8	14	-15.5	-15.0		-15.3	9	4.5	13	7.23	6.30	44.7
24-Aug	113	236	8	26	-12.0	-14.0		-13.0	12	1.5	13	7.43	6.50	56.7
24-Aug	113	236	9	12	-23.0			-23.0	1	15	13	8.20	7.27	102.7
29-Aug	118	241	6	35	-19.0			-19.0	7	4.5	20	5.58	4.67	-57.4
29-Aug	118	241	6	40	-12.5			-12.5	10	9	17	5.67	4.76	-52.4
29-Aug	118	241	6	46	-18.5			-18.5	4	1.5	18	5.77	4.86	-46.4
29-Aug	118	241	6	51	-19.5	-22.0		-20.8	1	15	18	5.85	4.94	-41.4
29-Aug	118	241	7	0	-17.5	-20.5		-19.0	4	1.5	18	6.00	5.09	-32.4
29-Aug	118	241	7	7	-19.0	-18.0		-18.5	7	4.5	20	6.12	5.21	-25.4
29-Aug	118	241	7	14	-18.0	-18.5		-18.3	10	9	17	6.23	5.32	-18.4
29-Aug	118	241	7	33	-22.0	-18.5		-20.3	1	15	18	6.55	5.64	0.6
29-Aug	118	241	7	39	-10.0	-12.0		-11.0	4	1.5	18	6.65	5.74	6.6
29-Aug	118	241	7	48	-15.5	-15.5		-15.5	7	4.5	20	6.80	5.89	15.6
29-Aug	118	241	7	56	-20.5	-20.0		-20.3	10	9	17	6.93	6.02	23.6
29-Aug	118	241	8	20	-19.5	-21.5		-20.5	1	15	18	7.33	6.42	47.6
29-Aug	118	241	8	33	-18.5	-19.0		-18.8	4	1.5	18	7.55	6.64	60.6
29-Aug	118	241	8	42	-22.0	-23.0		-22.5	7	4.5	20	7.70	6.79	69.6
29-Aug	118	241	8	52	-18.5	-20.0		-19.3	10	9	17	7.87	6.96	79.6
29-Aug	118	241	9	10	-26.0	-24.5		-25.3	1	15	18	8.17	7.26	97.6
29-Aug	118	241	9	19	-21.0	-21.0		-21.0	4	1.5	18	8.32	7.41	106.6
29-Aug	118	241	9	25	-24.0	-26.5		-25.3	7	4.5	20	8.42	7.51	112.6
29-Aug	118	241	9	30	-19.5	-20.5		-20.0	10	9	17	8.50	7.59	117.6
29-Aug	118	241	10	13	-30.5	-33.0		-31.8	1	15	18	9.22	8.31	160.6
29-Aug	118	241	10	26	-27.0	-28.0		-27.5	4	1.5	18	9.43	8.52	173.6
29-Aug	118	241	10	33	-33.0	-30.0		-31.5	7	4.5	20	9.55	8.64	180.6

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
29-Aug	118	241	10	41	-29.5	-25.0		-27.3	10	9	17	9.68	8.77	188.6
29-Aug	118	241	11	18	-29.5	-31.0		-30.3	1	15	18	10.30	9.39	225.6
29-Aug	118	241	11	27	-28.0	-30.0		-29.0	4	1.5	18	10.45	9.54	234.6
29-Aug	118	241	11	35	-31.5	-32.5		-32.0	7	4.5	20	10.58	9.67	242.6
29-Aug	118	241	11	44	-27.5	-31.5	-32.5	-30.5	10	9	17	10.73	9.82	251.6
29-Aug	118	241	14	39	-36.0	-35.5		-35.8	1	15	18	13.65	12.74	426.6
29-Aug	118	241	14	47	-36.5	-31.5	-31.5	-33.2	4	1.5	18	13.78	12.87	434.6
29-Aug	118	241	15	23	-34.5	-33.0		-33.8	7	4.5	20	14.38	13.47	470.6
29-Aug	118	241	15	31	-31.0	-30.0		-30.5	10	9	17	14.52	13.61	478.6
29-Aug	118	241	16	0	-32.0	-27.0	-27.0	-28.7	1	15	18	15.00	14.09	507.6
29-Aug	118	241	16	3	-31.5	-31.5		-31.5	4	1.5	18	15.05	14.14	510.6
29-Aug	118	241	16	8	-35.5	-34.5		-35.0	7	4.5	20	15.13	14.22	515.6
29-Aug	118	241	16	14	-32.5	-29.5		-31.0	10	9	17	15.23	14.32	521.6
29-Aug	118	241	17	35	-29.0	-34.0		-31.5	1	15	18	16.58	15.67	602.6
29-Aug	118	241	17	46	-18.5	-27.0		-22.8	4	1.5	18	16.77	15.86	613.6
29-Aug	118	241	17	53	-30.0			-30.0	7	4.5	20	16.88	15.97	620.6
29-Aug	118	241	18	0	-33.0			-33.0	10	9	17	17.00	16.09	627.6
29-Aug	118	241	19	29	-28.0			-28.0	1	15	18	18.48	17.57	716.6
29-Aug	118	241	19	34	-24.5			-24.5	4	1.5	18	18.57	17.66	721.6
29-Aug	118	241	19	41	-27.0			-27.0	7	4.5	20	18.68	17.77	728.6
29-Aug	118	241	19	48	-25.0			-25.0	10	9	17	18.80	17.89	735.6
1-Sep	121	244	6	35	-10.0	-9.5		-9.8	1	15	1	5.58	4.69	-59.3
1-Sep	121	244	6	46	-14.5	-10.0		-12.3	4	1.5	2	5.77	4.87	-48.3
1-Sep	121	244	6	54	-10.0	-11.0		-10.5	7	4.5	2	5.90	5.01	-40.3
1-Sep	121	244	7	3	-13.5	-13.0		-13.3	10	9	1	6.05	5.16	-31.3
1-Sep	121	244	7	21	-16.0	-16.0		-16.0	1	15	1	6.35	5.46	-13.3
1-Sep	121	244	7	29	-7.5	-9.0		-8.3	4	1.5	2	6.48	5.59	-5.3
1-Sep	121	244	7	36	-11.5	-10.5		-11.0	7	4.5	2	6.60	5.71	1.7
1-Sep	121	244	7	45	-13.0	-12.5		-12.8	10	9	1	6.75	5.86	10.7
1-Sep	121	244	8	9	-15.0	-15.0		-15.0	1	15	1	7.15	6.26	34.7
1-Sep	121	244	8	17	-12.5	-9.0		-10.8	4	1.5	2	7.28	6.39	42.7

Table 93, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise
			hr	min	---------------- KPa ----------------					$dS\ m^{-1}$	days	dec. hr.	dec. hr.	mins.
1-Sep	121	244	8	25	-13.0	-13.0		-13.0	7	4.5	2	7.42	6.52	50.7
1-Sep	121	244	10	50	-23.0	-24.5		-23.8	1	15	1	9.83	8.94	195.7
1-Sep	121	244	10	56	-18.0	-16.0		-17.0	4	1.5	2	9.93	9.04	201.7
1-Sep	121	244	11	8	-23.0	-21.0		-22.0	7	4.5	2	10.13	9.24	213.7
1-Sep	121	244	11	20	-23.5	-33.0		-28.3	10	9	1	10.33	9.44	225.7
1-Sep	121	244	11	38	-26.0	-26.5		-26.3	1	15	1	10.63	9.74	243.7
1-Sep	121	244	11	45	-21.5	-18.5		-20.0	4	1.5	2	10.75	9.86	250.7
1-Sep	121	244	11	50	-24.0	-24.0		-24.0	7	4.5	2	10.83	9.94	255.7
1-Sep	121	244	11	55	-26.0	-24.0		-25.0	10	9	1	10.92	10.02	260.7
1-Sep	121	244	13	39	-28.0	-29.0		-28.5	1	15	1	12.65	11.76	364.7
1-Sep	121	244	13	43	-22.0	-28.5		-25.3	4	1.5	2	12.72	11.82	368.7
1-Sep	121	244	13	48	-21.0	-24.0		-22.5	7	4.5	2	12.80	11.91	373.7
1-Sep	121	244	13	54	-23.0	-26.0		-24.5	10	9	1	12.90	12.01	379.7
1-Sep	121	244	15	58	-29.0	-29.5		-29.3	1	15	1	14.97	14.07	503.7
1-Sep	121	244	16	19	-21.0	-20.0		-20.5	4	1.5	2	15.32	14.42	524.7
1-Sep	121	244	16	29	-27.5	-25.5		-26.5	7	4.5	2	15.48	14.59	534.7
1-Sep	121	244	16	40	-29.0	-26.0		-27.5	10	9	1	15.67	14.77	545.7
7-Sep	127	250	7	20	-14.0	-16.0		-15.0	1	15	7	6.33	5.47	-18.0
7-Sep	127	250	7	29	-9.0	-9.5		-9.3	4	1.5	8	6.48	5.62	-9.0
7-Sep	127	250	7	38	-11.0	-10.0		-10.5	7	4.5	8	6.63	5.77	0.0
7-Sep	127	250	7	46	-14.0	-14.0		-14.0	10	9	7	6.77	5.91	8.0
7-Sep	127	250	9	24	-20.5	-25.5		-23.0	1	15	7	8.40	7.54	106.0
7-Sep	127	250	9	33	-17.0	-17.0		-17.0	4	1.5	8	8.55	7.69	115.0
7-Sep	127	250	9	51	-22.5	-18.0	-17.0	-19.2	7	4.5	8	8.85	7.99	133.0
7-Sep	127	250	10	2	-26.0	-20.0	-22.0	-22.7	10	9	7	9.03	8.17	144.0
7-Sep	127	250	10	58	-25.0	-21.0		-23.0	1	15	7	9.97	9.11	200.0
7-Sep	127	250	11	5	-20.0	-20.5		-20.3	4	1.5	8	10.08	9.22	207.0
7-Sep	127	250	11	13	-27.0	-25.0		-26.0	7	4.5	8	10.22	9.36	215.0
7-Sep	127	250	11	19	-24.0	-26.0		-25.0	10	9	7	10.32	9.46	221.0

Table 94. Leaf water potential measurements showing date, days after planting (DAP), day of year (DOY), time, experimental unit, days since last irrigation or significant precipitation, solar time, and minutes since sunup for plots in 1996.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Minutes Since Sunrise e
			Hr	min	---------------- KPa	----------------				dS m^{-1}	days	dec. hr.	dec. hr.	mins.
11-Jul	58	192	16	55	-20.5	-19.0	---	-19.8	2	9	14	15.92	14.93	594
11-Jul	58	192	17	7	-13.5	---	---	-13.5	11	1.5	14	16.12	15.13	606
11-Jul	58	192	17	8	-18.0	---	---	-18.0	8	4.5	14	16.13	15.15	607
11-Jul	58	192	17	10	-22.0	---	---	-22.0	2	9	14	16.17	15.18	609
11-Jul	58	192	17	12	-23.0	---	---	-23.0	5	15	14	16.20	15.22	611
10-Aug	88	222	7	36	-12.0	-11.0	---	-11.5	11	1.5	8	6.60	5.61	16
10-Aug	88	222	7	48	-11.5	-13.0	---	-12.3	8	4.5	8	6.80	5.81	28
10-Aug	88	222	8	0	-16.5	-15.5	---	-16.0	5	15	8	7.00	6.01	40
10-Aug	88	222	8	12	-17.0	-14.0	---	-15.5	2	9	8	7.20	6.21	52
10-Aug	88	222	8	55	-12.0	-11.5	---	-11.8	11	1.5	8	7.92	6.93	95
10-Aug	88	222	9	5	-16.5	-16.5	---	-16.5	8	4.5	8	8.08	7.10	105
10-Aug	88	222	9	15	-18.0	-17.5	---	-17.8	5	15	8	8.25	7.26	115
10-Aug	88	222	9	25	-17.0	-24.0	---	-20.5	2	9	8	8.42	7.43	125
10-Aug	88	222	9	54	-17.5	-18.5	---	-18.0	11	1.5	8	8.90	7.91	154
10-Aug	88	222	10	2	-24.5	-24.0	---	-24.3	8	4.5	8	9.03	8.05	162
10-Aug	88	222	10	10	-26.5	-27.5	---	-27.0	5	15	8	9.17	8.18	170
10-Aug	88	222	10	18	-26.0	-24.5	---	-25.3	2	9	8	9.30	8.31	178
10-Aug	88	222	10	42	-20.0	-21.5	---	-20.8	11	1.5	8	9.70	8.71	202
10-Aug	88	222	10	50	-24.0	-28.0	---	-26.0	8	4.5	8	9.83	8.85	210
10-Aug	88	222	10	56	-29.0	-27.0	---	-28.0	5	15	8	9.93	8.95	216
10-Aug	88	222	11	6	-28.0	-26.0	---	-27.0	2	9	8	10.10	9.11	226
10-Aug	88	222	11	31	-24.0	-21.5	---	-22.8	11	1.5	8	10.52	9.53	251
10-Aug	88	222	11	39	-25.0	-24.0	---	-24.5	8	4.5	8	10.65	9.66	259
10-Aug	88	222	11	47	-30.0	-30.0	---	-30.0	5	15	8	10.78	9.80	267
10-Aug	88	222	11	56	-31.0	-31.0	---	-31.0	2	9	8	10.93	9.95	276
10-Aug	88	222	13	26	-29.0	-29.5	---	-29.3	11	1.5	8	12.43	11.45	366
10-Aug	88	222	13	39	-24.5	-25.0	---	-24.8	8	4.5	8	12.65	11.66	379

Table 94, continued.

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa ----------------					$dS\ m^{-1}$	days	dec. hr.	dec. hr.	mins.
10-Aug	88	222	13	51	-29.0	-32.0	---	-30.5	5	15	8	12.85	11.86	391
10-Aug	88	222	14	3	-29.5	-29.5	---	-29.5	2	9	8	13.05	12.06	403
10-Aug	88	222	15	24	-28.0	-29.0	---	-28.5	11	1.5	8	14.40	13.41	484
10-Aug	88	222	15	35	-28.0	-30.5	---	-29.3	8	4.5	8	14.58	13.60	495
10-Aug	88	222	15	42	-33.0	-33.5	---	-33.3	5	15	8	14.70	13.71	502
10-Aug	88	222	15	51	-32.0	-32.5	---	-32.3	2	9	8	14.85	13.86	511
10-Aug	88	222	17	17	-29.0	-34.0	---	-31.5	11	1.5	8	16.28	15.30	597
10-Aug	88	222	17	25	-27.5	-29.0	---	-28.3	8	4.5	8	16.42	15.43	605
10-Aug	88	222	17	32	-29.0	-32.0	---	-30.5	5	15	8	16.53	15.55	612
10-Aug	88	222	17	45	-27.0	-23.5	---	-25.3	2	9	8	16.75	15.76	625
20-Aug	98	232	7	31	-13.0	-11.0	---	-12.0	11	1.5	18	6.52	5.56	4
20-Aug	98	232	7	38	-15.5	-16.0	---	-15.8	8	4.5	18	6.63	5.68	11
20-Aug	98	232	7	46	-19.0	-18.0	---	-18.5	5	15	18	6.77	5.81	19
20-Aug	98	232	7	52	-17.0	-18.0	---	-17.5	2	9	18	6.87	5.91	25
20-Aug	98	232	14	22	-21.5	-22.0	---	-21.8	11	1.5	18	13.37	12.41	415
20-Aug	98	232	14	25	-21.5	-26.0	---	-23.8	8	4.5	18	13.42	12.46	418
20-Aug	98	232	14	28	-25.0	-27.0	---	-26.0	5	15	18	13.47	12.51	421
20-Aug	98	232	14	31	-24.0	-27.5	---	-25.8	2	9	18	13.52	12.56	424
20-Aug	98	232	16	30	-19.0	-21.5	---	-20.3	11	1.5	18	15.50	14.55	543
20-Aug	98	232	16	35	-26.5	-25.5	---	-26.0	8	4.5	18	15.58	14.63	548
20-Aug	98	232	16	40	-30.0	-28.0	---	-29.0	5	15	18	15.67	14.71	553
20-Aug	98	232	16	45	-28.0	-33.0	---	-30.5	2	9	18	15.75	14.80	558
4-Sep	113	247	7	40	-8.5	-8.5	---	-8.5	11	1.5	1	6.67	5.79	4
4-Sep	113	247	7	46	-9.0	-10.0	---	-9.5	8	4.5	1	6.77	5.89	10
4-Sep	113	247	7	49	-15.0	-14.0	---	-14.5	5	15	1	6.82	5.94	13
4-Sep	113	247	7	55	-12.0	-11.5	---	-11.8	2	9	1	6.92	6.04	19
4-Sep	113	247	8	1	-9.0	-10.0	---	-9.5	11	1.5	1	7.02	6.14	25
4-Sep	113	247	8	6	-10.5	-12.0	-11.0	-11.2	8	4.5	1	7.10	6.22	30
4-Sep	113	247	8	12	-16.0	-16.0	---	-16.0	5	15	1	7.20	6.32	36

Table 94, continued

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
4-Sep	113	247	8	17	-13.0	-12.0	---	-12.5	2	9	1	7.28	6.41	41
4-Sep	113	247	8	36	-9.0	-10.0	---	-9.5	11	1.5	1	7.60	6.72	60
4-Sep	113	247	8	40	-9.0	-11.0	---	-10.0	8	4.5	1	7.67	6.79	64
4-Sep	113	247	8	44	-17.0	-16.0	---	-16.5	5	15	1	7.73	6.86	68
4-Sep	113	247	8	49	-13.0	-13.0	---	-13.0	2	9	1	7.82	6.94	73
4-Sep	113	247	10	22	-13.5	-17.0	-20.0	-16.8	11	1.5	1	9.37	8.49	166
4-Sep	113	247	10	28	-16.0	-16.5	---	-16.3	8	4.5	1	9.47	8.59	172
4-Sep	113	247	10	33	-26.0	-26.0	---	-26.0	5	15	1	9.55	8.67	177
4-Sep	113	247	10	38	-20.0	-19.0	---	-19.5	2	9	1	9.63	8.76	182
4-Sep	113	247	11	33	-18.0	-20.0	---	-19.0	11	1.5	1	10.55	9.67	237
4-Sep	113	247	11	40	-16.5	-23.0	-18.0	-19.2	8	4.5	1	10.67	9.79	244
4-Sep	113	247	11	46	-28.0	-26.0	---	-27.0	5	15	1	10.77	9.89	250
4-Sep	113	247	11	52	-25.0	-23.5	---	-24.3	2	9	1	10.87	9.99	256
4-Sep	113	247	12	47	-19.0	-17.0	---	-18.0	11	1.5	1	11.78	10.91	311
4-Sep	113	247	12	52	-20.0	-20.5	---	-20.3	8	4.5	1	11.87	10.99	316
4-Sep	113	247	13	0	-31.5	-31.0	---	-31.3	5	15	1	12.00	11.12	324
4-Sep	113	247	13	6	-27.0	-29.0	---	-28.0	2	9	1	12.10	11.22	330
4-Sep	113	247	13	49	-22.0	-23.0	---	-22.5	11	1.5	1	12.82	11.94	373
4-Sep	113	247	13	54	-24.5	-23.0	---	-23.8	8	4.5	1	12.90	12.02	378
4-Sep	113	247	14	0	-34.0	-32.5	---	-33.3	5	15	1	13.00	12.12	384
4-Sep	113	247	14	6	-24.5	-28.0	---	-26.3	2	9	1	13.10	12.22	390
4-Sep	113	247	15	9	-26.5	-23.0	---	-24.8	11	1.5	1	14.15	13.27	453
4-Sep	113	247	15	17	-20.5	-22.0	-38.0	-26.8	8	4.5	1	14.28	13.41	461
4-Sep	113	247	15	22	-35.0	-33.0	---	-34.0	5	15	1	14.37	13.49	466
4-Sep	113	247	15	26	-28.0	-29.5	---	-28.8	2	9	1	14.43	13.56	470
4-Sep	113	247	16	31	-20.0	-17.5	---	-18.8	11	1.5	1	15.52	14.64	535
4-Sep	113	247	16	36	-17.0	-25.0	---	-21.0	8	4.5	1	15.60	14.72	540
4-Sep	113	247	16	42	-33.5	-31.0	---	-32.3	5	15	1	15.70	14.82	546
4-Sep	113	247	16	48	-23.0	-25.5	---	-24.3	2	9	1	15.80	14.92	552

Table 94, continued

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
4-Sep	113	247	18	44	-17.0	-16.5	---	-16.8	11	1.5	1	17.73	16.86	668
4-Sep	113	247	18	49	-16.5	-17.0	---	-16.8	8	4.5	1	17.82	16.94	673
4-Sep	113	247	18	54	-27.0	-28.0	---	-27.5	5	15	1	17.90	17.02	678
4-Sep	113	247	19	0	-18.5	-22.0	---	-20.3	2	9	1	18.00	17.12	684
4-Sep	113	247	20	10	-12.0	-12.5	---	-12.3	11	1.5	1	19.17	18.29	754
4-Sep	113	247	20	14	-13.5	-13.0	---	-13.3	8	4.5	1	19.23	18.36	758
4-Sep	113	247	20	20	-18.5	-19.0	---	-18.8	5	15	1	19.33	18.46	764
4-Sep	113	247	20	26	-14.0	-15.0	---	-14.5	2	9	1	19.43	18.56	770
6-Sep	115	249	9	58	-11.5	-13.0	---	-12.3	11	1.5	3	8.97	8.10	141
6-Sep	115	249	10	4	-16.0	-17.5	---	-16.8	8	4.5	3	9.07	8.20	147
6-Sep	115	249	10	10	-23.5	-25.0	---	-24.3	5	15	3	9.17	8.30	153
6-Sep	115	249	10	19	-18.0	-21.0	---	-19.5	2	9	3	9.32	8.45	162
6-Sep	115	249	11	33	-15.0	-21.0	-17.5	-17.8	11	1.5	3	10.55	9.69	236
6-Sep	115	249	11	39	-18.5	-18.5	---	-18.5	8	4.5	3	10.65	9.79	242
6-Sep	115	249	11	47	-30.0	-30.0	---	-30.0	5	15	3	10.78	9.92	250
6-Sep	115	249	11	53	-23.0	-27.0	---	-25.0	2	9	3	10.88	10.02	256
6-Sep	115	249	13	43	-21.0	-25.0	-26.5	-24.2	11	1.5	3	12.72	11.85	366
6-Sep	115	249	13	50	-21.5	-23.0	---	-22.3	8	4.5	3	12.83	11.97	373
6-Sep	115	249	14	4	-27.5	-30.5	---	-29.0	5	15	3	13.07	12.20	387
6-Sep	115	249	14	14	-27.0	-27.0	---	-27.0	2	9	3	13.23	12.37	397
6-Sep	115	249	14	59	-23.0	-23.5	---	-23.3	11	1.5	3	13.98	13.12	442
6-Sep	115	249	15	5	-24.0	-23.0	---	-23.5	8	4.5	3	14.08	13.22	448
6-Sep	115	249	15	10	-28.5	-30.0	---	-29.3	5	15	3	14.17	13.30	453
6-Sep	115	249	15	15	-27.5	-29.0	---	-28.3	2	9	3	14.25	13.39	458
6-Sep	115	249	15	42	-15.0	-19.0	-24.0	-19.3	11	1.5	3	14.70	13.84	485
6-Sep	115	249	15	46	-24.0	-22.0	---	-23.0	8	4.5	3	14.77	13.90	489
6-Sep	115	249	15	49	-30.0	-32.5	---	-31.3	5	15	3	14.82	13.95	492
6-Sep	115	249	15	51	-28.0	-29.0	---	-28.5	2	9	3	14.85	13.99	494
6-Sep	115	249	16	41	-17.5	-21.0	-23.5	-20.7	11	1.5	3	15.68	14.82	544

Table 94, continued

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
6-Sep	115	249	16	42	-18.0	-20.5	---	-19.3	8	4.5	3	15.70	14.84	545
6-Sep	115	249	16	47	-26.5	-29.0	---	-27.8	5	15	3	15.78	14.92	550
6-Sep	115	249	16	50	-27.0	-28.0	---	-27.5	2	9	3	15.83	14.97	553
10-Sep	119	253	7	58	-12.0	-10.5	---	-11.3	11	1.5	7	6.97	6.13	18
10-Sep	119	253	8	4	-10.0	-11.0	---	-10.5	8	4.5	7	7.07	6.23	24
10-Sep	119	253	8	10	-20.0	-25.0	---	-22.5	5	15	7	7.17	6.33	30
10-Sep	119	253	8	16	-16.0	-13.0	---	-14.5	2	9	7	7.27	6.43	36
10-Sep	119	253	8	51	-10.0	-15.0	-11.0	-12.0	11	1.5	7	7.85	7.01	71
10-Sep	119	253	8	58	-10.0	-11.0	-11.0	-10.7	8	4.5	7	7.97	7.13	78
10-Sep	119	253	9	9	-18.0	-22.0	---	-20.0	5	15	7	8.15	7.31	89
10-Sep	119	253	9	16	-17.0	-16.0	---	-16.5	2	9	7	8.27	7.43	96
10-Sep	119	253	10	17	-18.5	-17.5	---	-18.0	11	1.5	7	9.28	8.44	157
10-Sep	119	253	10	26	-14.0	-15.0	---	-14.5	8	4.5	7	9.43	8.59	166
10-Sep	119	253	10	34	-27.5	-27.5	---	-27.5	5	15	7	9.57	8.73	174
10-Sep	119	253	10	43	-25.0	-27.0	---	-26.0	2	9	7	9.72	8.88	183
10-Sep	119	253	11	46	-30.5	-20.0	-21.5	-24.0	11	1.5	7	10.77	9.93	246
10-Sep	119	253	11	52	-17.5	-19.0	---	-18.3	8	4.5	7	10.87	10.03	252
10-Sep	119	253	12	1	-31.0	-30.0	---	-30.5	5	15	7	11.02	10.18	261
10-Sep	119	253	12	13	-29.0	-26.0	---	-27.5	2	9	7	11.22	10.38	273
10-Sep	119	253	13	44	-19.0	-19.0	---	-19.0	11	1.5	7	12.73	11.89	364
10-Sep	119	253	13	50	-22.0	-23.0	---	-22.5	8	4.5	7	12.83	11.99	370
10-Sep	119	253	14	0	-31.0	-25.0	---	-28.0	5	15	7	13.00	12.16	380
10-Sep	119	253	14	9	-24.0	-20.0	---	-22.0	2	9	7	13.15	12.31	389
10-Sep	119	253	16	26	-22.5	-26.5	---	-24.5	11	1.5	7	15.43	14.59	526
10-Sep	119	253	16	32	-22.0	-23.0	---	-22.5	8	4.5	7	15.53	14.69	532
10-Sep	119	253	16	41	-25.0	-26.0	---	-25.5	5	15	7	15.68	14.84	541
10-Sep	119	253	16	54	-20.0	-21.0	-26.0	-22.3	2	9	7	15.90	15.06	554
16-Sep	125	259	8	35	-7.0	-12.0	-11.0	-10.0	11	1.5	13	7.58	6.78	51
16-Sep	125	259	8	44	-14.5	-13.5	---	-14.0	8	4.5	13	7.73	6.93	60

Table 94, continued

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa	----------------				dS m^{-1}	days	dec. hr.	dec. hr.	mins.
16-Sep	125	259	8	50	-21.0	-20.0	---	-20.5	5	15	13	7.83	7.03	66
16-Sep	125	259	9	3	-17.0	-12.0	---	-14.5	2	9	13	8.05	7.25	79
16-Sep	125	259	9	55	-12.5	-12.0	---	-12.3	11	1.5	13	8.92	8.11	131
16-Sep	125	259	10	0	-13.0	-13.5	---	-13.3	8	4.5	13	9.00	8.20	136
16-Sep	125	259	10	15	-24.0	-22.0	---	-23.0	5	15	13	9.25	8.45	151
16-Sep	125	259	10	20	-25.0	-22.0	---	-23.5	2	9	13	9.33	8.53	156
16-Sep	125	259	11	20	-16.5	-17.5	---	-17.0	11	1.5	13	10.33	9.53	216
16-Sep	125	259	11	25	-20.0	-21.5	---	-20.8	8	4.5	13	10.42	9.61	221
16-Sep	125	259	11	40	-28.0	-25.0	-23.5	-25.5	5	15	13	10.67	9.86	236
16-Sep	125	259	11	55	-24.0	-25.5	---	-24.8	2	9	13	10.92	10.11	251
16-Sep	125	259	12	40	-18.0	-20.0	---	-19.0	11	1.5	13	11.67	10.86	296
16-Sep	125	259	12	55	-24.5	-20.0	-21.5	-22.0	8	4.5	13	11.92	11.11	311
16-Sep	125	259	13	5	-24.0	-27.0	---	-25.5	5	15	13	12.08	11.28	321
16-Sep	125	259	13	10	-27.0	-26.0	---	-26.5	2	9	13	12.17	11.36	326
16-Sep	125	259	13	50	-13.5	-19.0	-19.0	-17.2	11	1.5	13	12.83	12.03	366
16-Sep	125	259	14	0	-22.5	-22.0	---	-22.3	8	4.5	13	13.00	12.20	376
16-Sep	125	259	14	10	-27.0	-26.5	---	-26.8	5	15	13	13.17	12.36	386
16-Sep	125	259	14	15	-27.0	-26.5	---	-26.8	2	9	13	13.25	12.45	391
16-Sep	125	259	15	10	-16.0	-17.5	---	-16.8	11	1.5	13	14.17	13.36	446
16-Sep	125	259	15	20	-26.0	-21.0	-22.5	-23.2	8	4.5	13	14.33	13.53	456
16-Sep	125	259	15	35	-31.0	-31.0	---	-31.0	5	15	13	14.58	13.78	471
16-Sep	125	259	15	49	-31.0	-28.0	-29.0	-29.3	2	9	13	14.82	14.01	485
24-Sep	133	267	8	50	-11.0	-15.0	-15.0	-13.7	11	1.5	12	7.83	7.08	61
24-Sep	133	267	9	0	-18.5	-15.0	-14.5	-16.0	8	4.5	12	8.00	7.25	71
24-Sep	133	267	9	10	-20.5	-21.5	---	-21.0	5	15	12	8.17	7.41	81
24-Sep	133	267	9	20	-17.0	-18.5	---	-17.8	2	9	12	8.33	7.58	91
24-Sep	133	267	11	30	-13.0	-17.0	-17.5	-15.8	11	1.5	12	10.50	9.75	221
24-Sep	133	267	11	40	-18.5	-18.0	---	-18.3	8	4.5	12	10.67	9.91	231
24-Sep	133	267	11	55	-22.0	-21.5	---	-21.8	5	15	12	10.92	10.16	246

Table 94, continued

Date	DAP	DOY	Central Daylight SavingsTime		1st Pressure Reading	2nd Pressure Reading	3rd Pressure Reading	Average Pressure Reading	Exp Unit	Irrigation Water Salinity	Days Since Last Irr./Ppt.	Time	Solar Time	Date
			hr	min	---------------- KPa ----------------					dS m^{-1}	days	dec. hr.	dec. hr.	mins.
24-Sep	133	267	12	5	-22.0	-23.0	---	-22.5	2	9	12	11.08	10.33	256
24-Sep	133	267	15	40	-16.0	-18.0	-23.0	-19.0	11	1.5	12	14.67	13.91	471
24-Sep	133	267	15	50	-21.0	-22.5	---	-21.8	8	4.5	12	14.83	14.08	481
24-Sep	133	267	16	0	-27.0	-24.5	---	-25.8	5	15	12	15.00	14.25	491
24-Sep	133	267	16	10	-25.0	-26.5	---	-25.8	2	9	12	15.17	14.41	501

APPENDIX G

HARVEST DATA

Table 95. Harvested length and weight of harvested samples for yield data, 1994-1996

Experi-mental Unit #	-------- 1994 -------		------- 1995 -------		------- 1996 -------	
	Length (m)	Weight (gm)	Length (m)	Weight (gm)	Length (m)	Weight (kg)
1	22.4	5442.9	21.9	4241.4	11.9	2586.6
2	22.2	5343.5	21.9	4549.3	11.9	2688.8
3	18.8	4319.5	21.9	4076.5	11.9	2983.0
4	22.3	6204.3	21.9	631.2	11.9	3554.5
5	18.7	4619.2	21.9	4983.2	11.9	2415.8
6	18.6	4095.4	21.9	4398.0	11.9	2544.4
7	15.3	4582.6	21.9	6316.4	11.9	3512.3
8	18.8	4731.6	21.9	6667.3	11.9	3192.7
9	15.2	4279.6	21.9	6379.1	11.9	3396.2
10	15.2	3541.2	21.9	5310.6	11.9	2989.0
11	18.6	5281.4	21.9	5020.0	11.9	3318.2
12	7.6	1616.7	21.9	7049.8	11.9	3820.4

VITA

Joseph Charles Henggeler was born 28 May 1949 in Montgomery, Alabama. He is the son of Col. (Ret.) F. J. Henggeler and the late Dorothy Merrigan Henggeler. As a child, he traveled with his parents and three brothers (including his identical twin brother, John) to various locations where his father was assigned to in the Air Force, including three years in Japan. He attended Catholic grade and high schools.

He attended Immaculate Conception Seminary, where he was a classmate of Supreme Court Justice Clarence Thomas. After graduating with a B.A. degree in *Behavioral Science*, he joined the Peace Corps and served three years in Sierra Leone, West Africa as an extension agent working with Mende rice growers. This experience led to his interest in irrigation. After returning to the United States, he had the opportunity to study art for three semesters at Northwest Missouri State University and then enrolled at Utah State University to study irrigation. He obtained an M.S. degree in *Irrigation Science* from USU in 1982. He was employed as an irrigation specialist by Texas A&M University from 1982-1997 and was stationed in west Texas. There he worked on drip irrigation, surge flow irrigation, and irrigation economics. In Texas his work involved irrigation in an arid environment with limited water supplies.

In 1997 he was hired by the University of Missouri and was stationed in southeast Missouri at the MU Delta Research Center. This career change allowed him the opportunity to work in irrigation under a new set of conditions, sub-humid ones, which expanded his appreciation that irrigation, in all cases, must meet the needs of the local users and their environment. He found that the manner of irrigation in humid areas, where water is plentiful, is quite different from that practiced in arid areas. His position there has statewide responsibilities, and he works in irrigation scheduling, fertigation, and system evaluation.

Joe is married to Norma Sanchez Henggeler. They have four children and reside at 126 Autumn Drive in Sikeston, Missouri.