PROJECT NO. RP-8

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 1998 - December 31, 1998

PROJECT TITLE: Salinity Studies in Rice

PROJECT LEADERS:

Stephen R. Grattan, Extension Plant-water Relations Specialist, Department of Land Air and Water Resources, University of California, Davis.

Steven C. Scardaci, Farm Advisor (Colusa/Yolo/Glenn), University of California Cooperative Extension (UCCE).

PRINCIPLE UC INVESTIGATORS:

Stacey R. Roberts, Post Graduate Researcher, UCCE.

James E. Hill, Extension Agronomist and Chair, Department of Agronomy and Range Science, University of California, Davis.

William K. Thomas, Post Graduate Researcher, UCCE.

COOPERATORS:

Mike and Ken Keller, Colusa County

LEVEL OF FUNDING: $14,500

OBJECTIVES AND EXPERIMENTS CONDUCTED TO ACCOMPLISH OBJECTIVES:

I. Identify and verify soil and water salinity levels where yields and economic returns are reduced.

II. Quantify and verify rice grain yield, shoot biomass and plant density as it relates to soil and water salinity in a replicated trial conducted in the Sacramento Valley under commercial field conditions.

IMPORTANCE OF RESEARCH TO INDUSTRY:

Salinity is reducing rice yields in several locations in Colusa and Glenn counties (Rhoades, 1995, personal communication; Scardaci et al., 1995 and 1996). In a survey of 27 fields, these investigators found that rice yields decreased in a linear fashion as the electrical conductivity

(EC) of the soil water increased. The electrical conductivity of the water is an indicator of the salinity hazard and increases in direct proportion to the salt concentration in the water. The investigators of the salinity survey found that although the salinity of the water in top basins was about the same as the irrigation water source, the salinity of lower basins was substantially higher. They also showed that soil EC increased from top to bottom basins. These differences indicate that salt concentrations in the lower basins are increasing by evapoconcentration and are consistent with the fact that water inflows and outflows were lower in the lower basins.

Perhaps of greater importance was the rapid decrease in seedling density (number of plants per area) with relatively small increases in salinity. Rice is extremely sensitive to salinity during the seedling and early-development stage (Maas, 1990). Therefore yields are being reduced by reductions in plant growth and its subsequent affect on the various yield components as well as by reductions in stand establishment.

In response to the recent survey conducted by Scardaci et al. (1995 and 1996), we have conducted field experiments over the past three years to quantify the relationship between salinity, seedling survival, crop growth and yield. The current salinity guidelines for rice are based on limited research and indicate that rice is relatively sensitive to salinity (Maas, 1990). However the guidelines indicate that crop yields are reduced 12% for every unit increase in EC above 3.0 dS/m. The preliminary data collected by Scardaci et al. (1995 and 1996) indicate that reduced yields were correlated with soil salinity in excess of only 2.0 dS/m and seedling establishment was adversely affected at even lower levels. Since climate and environmental factors are known to affect salt tolerance (Maas, 1990), it was important to conduct field salinity experiments in the Sacramento Valley to modify the guidelines for this area. Furthermore, most salinity studies have been conducted where salinity is imposed after the crops have been well established, bypassing the salt-sensitive seedling stage, which may inflate their apparent tolerance to salinity. Therefore, we have now completed the third and final year of field research to quantify salinity's effect on stand establishment, growth, and yield and determine whether Sacramento Valley-grown rice is more sensitive to salinity than the existing guidelines indicate.

SUMMARY OF 1998 RESEARCH:

Methods

The 1998 field salinity trial was conducted at the same site where the study was conduced the previous two years. The site was located west of Hwy. 45, just south of Tule Road. In 1996, the field was planted to a very early variety of rice, M-103, while in 1997 and 1998 it was planted to the early variety, M-202.

Saline irrigation water was prepared as it was the previous two years and stored in large (1000 gal) tanks. Small plots within rings were flooded using irrigation waters that vary in salinity (i.e. targeted EC values of 0.4 (grower water), 1, 2, 4, 6, 8 and 10 dS/m). Saline irrigation water was prepared by adding known quantities of salt of various types in proportions that produced water close to the same ionic composition to that in rice growing areas currently affected by salinity. NaCl, $CaCl_2$, $MgSO_4$ and Na_2SO_4 were added in a molar ratio of 10:1:2:1. These 7 salinity treatments were replicated 4 times in a randomized block design and plots were monitored 2-3 times weekly for EC and water depth. Treatment water or non-saline water was added to the plots to maintain water levels and EC values as close to the targeted level as possible. The data are presented based on average measured EC in the rings rather than the targeted EC.

We used the same rings we had used the previous year. These were made by cutting a 5-ft diameter culvert pipe into 2-ft sections. These rings were sturdy and before the field was flooded, we manually installed each ring in the field to a depth of 6-8 inches using shovels and a sledge hammer to drive the ring into the plow pan to prevent leaks. This proved effective at preventing field water from entering the ring thereby diluting the treatment water. Similar to last year, we plumbed each of the rings so that each would have its assigned water-treatment source as well as a non-saline source. This allowed us to control both the water level and salinity within each of the rings.

We pre-salinized plots prior to seeding as we did in 1997. All plots were flooded with their respective treatment water before seeds were sown in order to determine salinity's affect on stand establishment. To ensure uniform seeding density, we aligned our plots with the flight path of the plane dropping the seed in a similar manner as we did in 1997. Initial seed density counts in the rings confirmed that this alteration was effective at obtaining uniform seed density.

Small-plot studies are accepted as ideal methodology in salinity research carried out in the field. Small plots are necessary not only because salinity plots require numerous measurements and intense management but also the amount of salt needed to establish and maintain large scale plots is prohibitive. Carefully maintained small plots under field conditions along with extensive measurements of stand density, shoot growth, ion accumulation, yield, and yield components as they relate to soil and water salinity allow us to carefully study the response of rice to salinity. We found that this "culvert ring" method was an effective experimental method. It allowed us to study the response of field-grown rice to salinity and to test the appropriateness of the current salinity tolerance guidelines for rice grown in the Sacramento Valley. In light of the success of these culvert rings, two other rice studies conducted by other UC investigators are currently underway using these types of rings.

OBJECTIVES I AND II

The time-weighted average salinity levels (ECw) ranged from 0.3 to 9.5 dS/m. This was a suitable range of salinity treatments because a number of treatments fell both above and below the published salinity-threshold guideline for rice (i.e. 3.0 dS/m) (Ayers and Westcot, 1985). The salinity threshold is the maximum level of salinity beyond which yields decline. Soil samples were also collected at several times throughout the season but data from the analytical laboratory are still pending. The data presented in this report are in relation to the time-average EC of the standing water in each ring. Presentation of data in relation to EC of the standing water, mud or soil all produced high correlation coefficients with plant variables (Shannon et al., unpublished data) where standing water in relation to biomass gave the highest correlation (r= -0.86).

This year's unusual weather had an enormous influence on stand establishment, growth, and how salinity affected rice performance. For example, several days after the pre-salinized plots were seeded (May 19th) and only 1-2 days after the field and rings were drained, rain occurred leaving standing water in the plots 2-4 inches deep. This not only diluted the salinity in the plots but the increased water level caused many of the germinated seedlings to float to the surface reducing the stand density. Some rings were affected substantially more than others but effects were inconsistent with treatment. This introduced a substantial amount of early-season variability among treatments. This variability carried out for the remainder of the season and was reflected in the measurements of the various plant parameters.

This year's weather was also unusual in that the air temperatures was unseasonably cool during the early season and unseasonably warm during the later part of the summer. For example in May, average maximum air temperature was about 70 degrees F whereas in 1997, it was above 85 degrees F. The same trend was found for average minimum temperatures but the difference between years was not as great as it was with maximum temperatures. On the other hand, there were over 20 days throughout the entire growing season where the maximum temperature exceeded 100 degrees F, whereas last year there were only 7 days.

At 28 days after seeding (DAS), visual observations showed that severely salt-stressed seedlings were smaller and had shorter, thinner, and often chlorotic leaves compared to non-stressed plants. However only in a few rings at the highest salinity levels was this observed. Visual effects from salinity were not as apparent as they were in the previous years.

Unlike last year, this year's data indicate that salinity did not have a profound influence on either the number of tillers per plant ($r^2 = 0.18$) or on plant and tiller density (i.e. number/area) (Figure 1). High early-season variability is at least partially responsible for this behavior, induced by heavy rains just after seeding.

Salinity delayed heading and this effect is consistent with that found the previous two years. We found a relatively good second-order relationship ($r^2 = 0.79$) between salinity and days after seeding to 50% heading (Figure 2). At 8 dS/m salinity, it took plants roughly 11 additional days to reach 50% heading compared to those in non-saline controls. Last year, 8 dS/m delayed 50% heading by only 4 days indicating the salinity had a more pronounced effect at delaying heading this year as compared to last. Initial analyses using "degree days" has not been effective at explaining differences among years.

Biomass data collected 62 DAS indicated that salinity reduced shoot and root growth (Figure 3) but only at the higher salinity levels (i.e. EC's > 6 dS/m). There was a substantial amount of variability in shoot and root biomass in rings where the average seasonal EC was less than 6 dS/m suggesting that not much confidence be placed on the regression functions. This is reflected in the rather poor r^2 values (0.50-0.54). In addition to high variability in growth within rings, cooler early-season temperatures during this more salt-sensitive growth period, may have attenuated salinity's detrimental effect. Since rice is much more sensitive to salinity during early season (Maas, 1990) and salt-tolerance is often increased under cooler climates, it is understandable that the salt-tolerance during this unusual year was higher than that in previous years. Interestingly however the harvest index (the fraction of the total shoot biomass comprised of grain), decreased ($r^2 = 0.63$) with increasing salinity. This effect was also observed the first year, but not the second.

The yield components are examined to obtain a better understanding how salinity is affecting rice growth and yield. This year salinity did not affect the number of panicles per unit area ($r^2 = 0.05$). Salinity also did not enhance sterility ($r^2 = 0.09$) as it did the first year. In 1996, salinity increased the percentage of sterile florets in a given panicle such that % sterility increased with increasing salinity. It is known that salinity increases sterility in rice but little is known of the underlying cause (Khatun and Flowers, 1995). This effect on sterility was not observed during the later two years. Therefore this year, factors other than "unfilled spiklets" were responsible for the reduced harvest index.

Salinity did however reduce the individual grain weight as it did the previous years (Figure 4). The correlation of this parameter with increasing salinity has previously been the highest of all yield components. In the previous years it was clear that the individual grain weight was reduced below the "salinity threshold" guideline of 3.0 dS/m. Due to the high variability this year, reductions in 1000-seed weight were not observed below an EC of 3.0 dS/m.

The grain yield data for this year are presented in Figure 5. The correlation between yield and average seasonal salinity is not as good as is was the previous years again due to high variability. In addition, it is likely that cooler early-season temperatures may have played an important role in increasing rice's tolerance to salinity this year. Data presented in Figure 5 indicate that the salinity level that causes a 50% reduction in yield is an EC of 9 dS/m. Data from the previous two years indicate that an EC of 7 dS/m caused yield to be reduced 50% and was consistent with the current salinity guidelines for rice (Ayers and Westcot, 1995). Comparing C50 values (i.e. the salinity or EC where a 50% reduction in yield occurs) is a valuable assessment exercise by researchers to compare data sets and does not imply or suggest that these salinity levels would ever be reached under a grower's field.

In order to determine whether the existing salt-tolerance guidelines for rice are appropriate for rice grown in the Sacramento Valley, grain yield must be converted to a relative basis, combined with previous years studies and then plotted in relation to the seasonal average salinity. We did this for 1996 and 1997 (see last years report) and also for all three years. The NLIN (non-linear) procedure in SAS (1985) was used to fit the Maas and Hoffman Piecewise Linear response model. The NLIN procedure fits non-linear regression models by least squares. The NLIN procedure in this case is used in a segmented linear model combination. When 1996 and 1997 data were combined we found that a threshold of 1.9 dS/m and slope of 9.1% best fit our combined data set. When all three years were combined, the salinity threshold of 1.9 again best fit the data but the slope decreased to 8.1 due to the higher tolerance observed in this abnormal year. In light of the high variability within this year's data, along with abnormal weather patterns that the experiment was subjected to, we are inclined to place most emphasis on the results obtained during the first two years of the study when the Spring/Summer weather patterns were more typical for the Sacramento Valley.

Acknowledgment:

The investigators of this project would like to express their appreciation for the valuable work by James A. Poss, Soil Scientist, USDA/ARS Salinity Laboratory in Riverside for running the statistical program on our data.

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PUBLICATIONS AND REPORTS: None to date.

GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

Irrigation management practices in rice that have improved water quality in receiving rivers in relation to pesticides may be creating a different problem. In a salinity survey conducted in Colusa and Glenn counties between 1993 and 1995, researchers at the University of California and the USDA/ARS Salinity Lab have gathered strong evidence that suggests that salinity is reducing rice yields in several locations within the Sacramento Valley. Apparently these new water management practices while decreasing the pesticide concentration of the receiving river may increase the potential for field salinization by allowing salts to evapo-concentrate in lower basins.

Rice is known to be very sensitive to salinity. The current salinity guidelines for rice are based on limited research and indicate that crop yields are reduced 12% for every increase in unit of electrical conductivity (EC) above 3.0 dS/m. The EC of the water is an indicator of the salinity hazard and increases in direct proportion to the salt concentration in the water. The preliminary data collected in 1993-1995 indicate that yields were affected by soil salinity in excess of only 2.0 dS/m and seedling establishment was adversely affected at even lower levels. Since climate and environmental factors are known to affect salt tolerance it was necessary to conduct field salinity experiments in the Sacramento Valley to modify the guidelines for this area.

We conducted a salinity experiment for a third year at the same site in Colusa county. Our experimental methods were the same as last year. We used 5-ft diameter rings to establish 28 salinity plots, arranged in four randomized blocks, where the time-averaged seasonal EC varied from 0.3 (growers field) to 9.5 dS/m. EC stands for electrical conductance and is an indicator of the salinity hazard. Over the salinity range in our field study, the EC increases in direct proportion to the salt content in the field water. Small plots are necessary not only because salinity plots require numerous measurements and intense management but also the amount of salt needed to establish and maintain large scale plots is prohibitive.

Unlike results obtained the previous years, this year's data indicate that salinity did not have a profound influence on either the number of tillers per plant or on the number of plants and tillers in a given area. Salinity's affect on grain yield was not as great as it was the previous years. High early-season variability is at least partially responsible for this behavior, induced by heavy rains just after seeding.

In addition to reducing biomass and yield, salinity was consistent each year by delaying tillering and by reducing the individual grain weight.

We converted actual grain yield to a relative basis for each of the three years, combined the data for 1996 and 1997 as well as all three years and plotted them as a function of average seasonal EC of the standing water. This allowed us to use a statistical method to best fit the data and determine a new salinity threshold and % slope. In each case a salinity threshold of 1.9 dS/m best fit the data. By combining the data for the first two years a slope of 9.1% best fit the data. When all three years were combined, a slope of 8.1 best fit the data. The important difference between our values and those reported by Maas (1990) is a lower salinity threshold. The "salinity threshold" based on our 1996 and 1997 data are consistent with the results from the salinity surveys conducted in 1993 and 1995 as well as greenhouse data collected by colleagues at the US Salinity Laboratory (Shannon, personal communication).

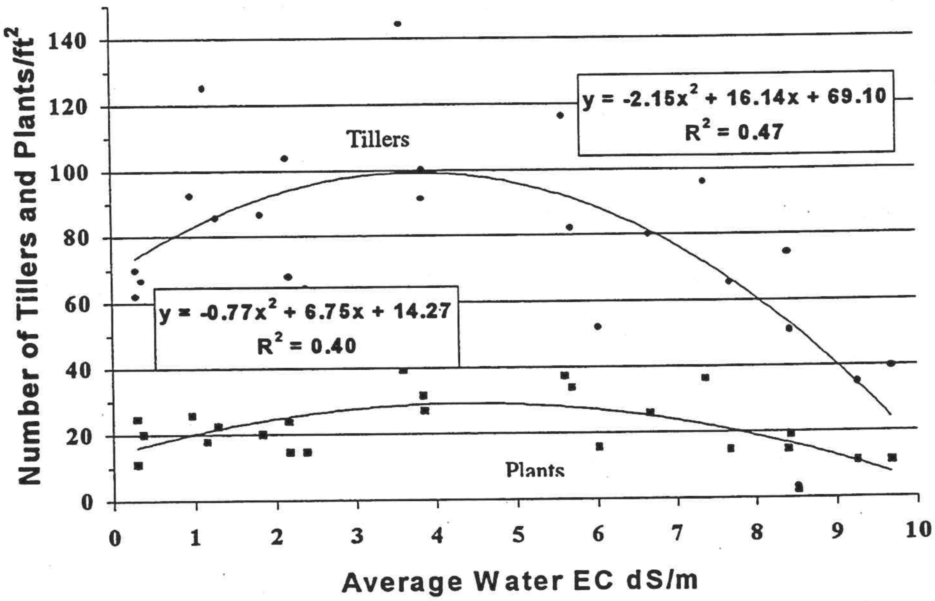

Figure 1. The number of plants or tillers per square foot in relation to the average salinity (EC) of the standing water. Counts taken 62 days after seeding (DAS).

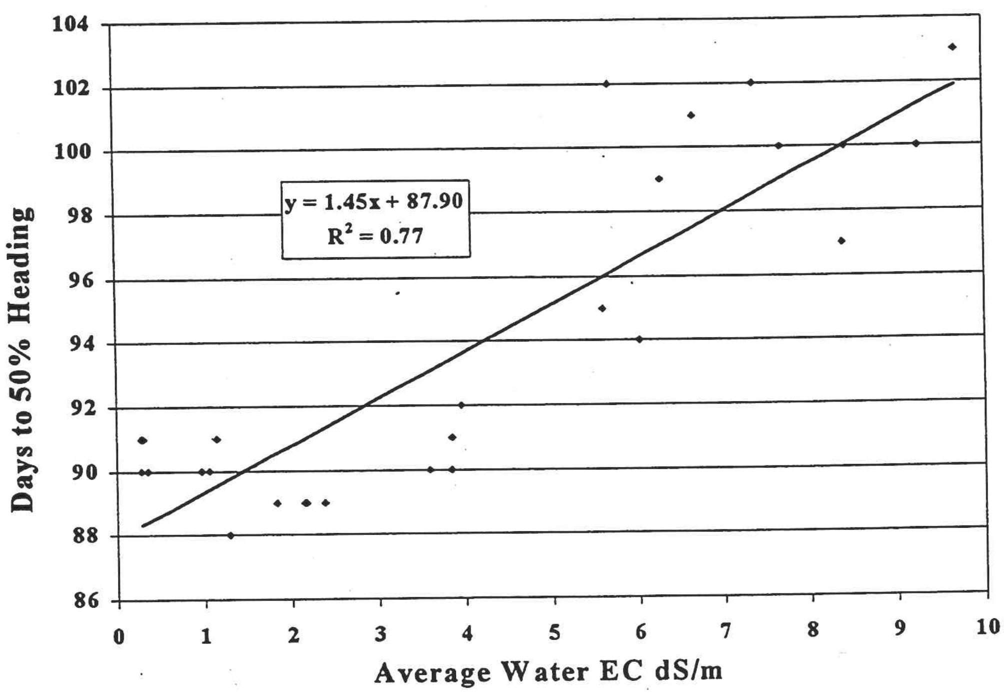

Figure 2. Days after seeding to 50% heading in relation to the average salinity (EC) in the standing water.

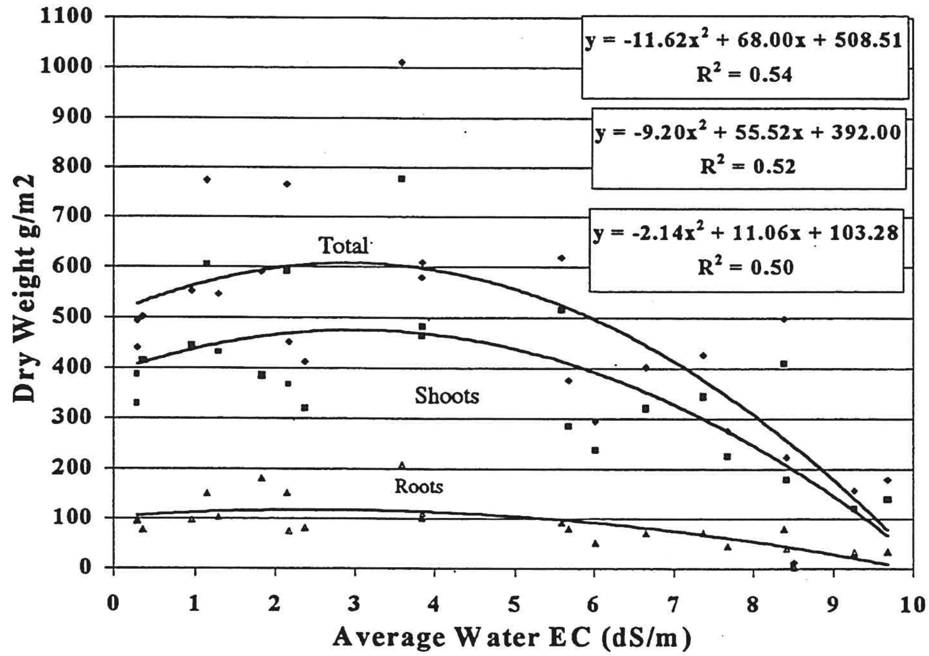

Figure 3. Dry weights of the roots, shoots and total plants per square meter in relation to the average salinity (EC) of the standing water. Biomass samples were collected 62 days after seeding (DAS).

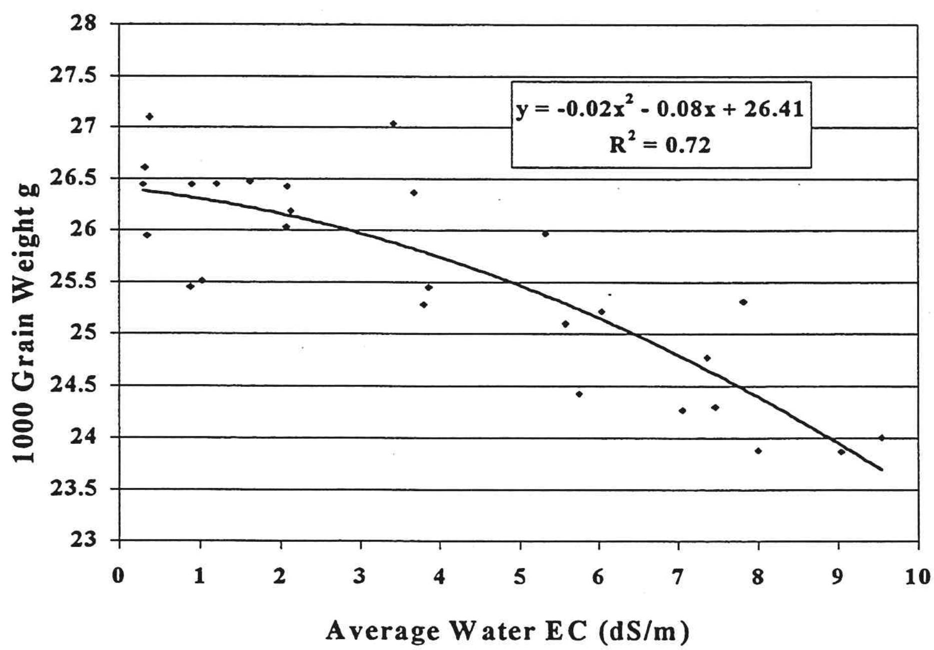

Figure 4. Individual grain weight, expressed as weight per 1000 seeds, in relation to the average seasonal salinity (EC) of the standing water.

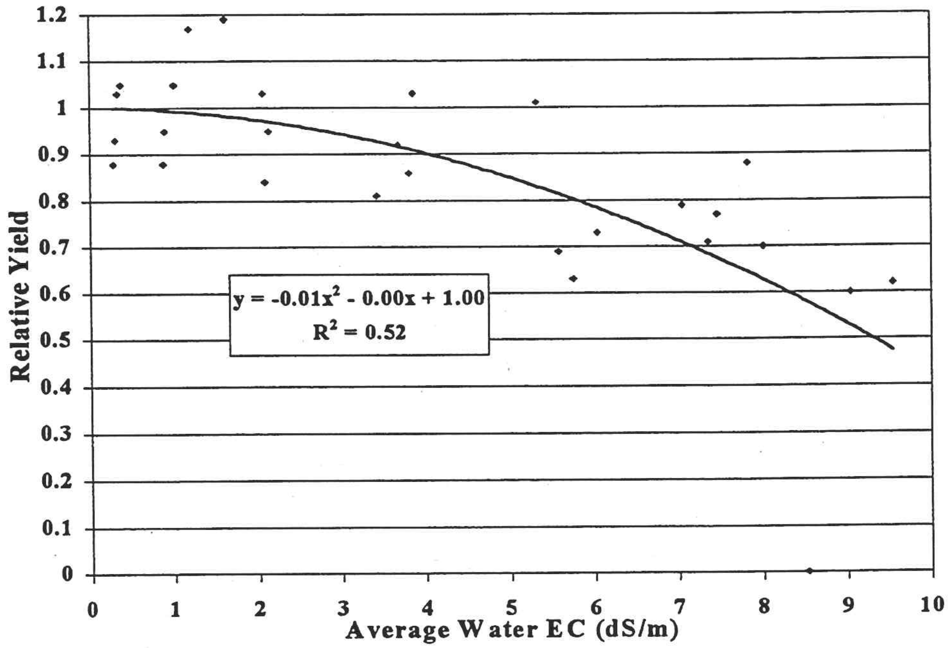

Figure 5. Dry grain yield (lbs/acre) in relation to the average seasonal salinity (EC) in the standing water.