

Effects of Salinity on Alfalfa Seedling Growth in the Imperial Valley

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Abstract The Colorado River Water Agreement of 2003, which allows for the long-term transfer of water from the Imperial Valley to the San Diego region, will have negative effects on the production of water intensive crops, particularly alfalfa. The shift in production from high water intensive to low water intensive and high labor intensive crops has angered local Imperial Valley farmers. Farmers are currently devising alternatives to return water supplies back to the Imperial Valley in order to maintain current levels of alfalfa productivity. Further acquisition of water by the Imperial Valley may lead to decreased alfalfa production because of the saline nature of the irrigation water. This study examines the effects of salinity on alfalfa seedling growth in the Imperial Valley. The experiment will determine the point at which alfalfa growth is significantly reduced by increased salinity. Four seed varieties were planted and measured against varying salinity concentrations (330, 565, 895, 1240, 1550 mg/L). Plots were irrigated with the various salt concentrations and analyzed in the field for differences in height. Growth measurements were obtained throughout the experiment's two month duration and analyzed for variance of growth. The results show that alfalfa productivity is severely hindered by the irrigation of water with a salinity ≥ 895 mg/L. Farmers will have to expand their search for alternative water supplies in order to maintain agricultural sustenance of alfalfa production.

Introduction

The signing of the Colorado River Water Agreement on October 16, 2003 marked the end of one of California's greatest water debates. The water agreement allowed for the long-term transfer of water supplies from the Colorado River to San Diego. In order to meet the water needs of the San Diego region, given the area's drought severity and alarming population growth increase, the San Diego County Water Authority (SDCWA) decided to approach the Imperial Irrigation District for purchase of water (SDCWA 2001, elect. comm.). After years of negotiation the SDCWA obtained a fourteen year water transfer agreement with the Imperial Valley in order to meet the increasing water demand of the San Diego region (SDCWA 2001, elect. comm.). Under the agreement the Imperial Valley will allocate 200,000 to 300,000 acre-feet of water annually to San Diego in exchange for an undisclosed sum of money (Martin 2003, elect. comm.).

Redirection of water to San Diego from the Colorado River will result in a decrease in water supplies to the Imperial Valley agricultural sector. Dry climatic conditions coupled with lower water supplies are bound to have a negative impact on Imperial Valley agricultural sustenance. A report issued by the California Farm Bureau Federation states that "the transfer would have a significant impact on the Valley's \$1 billion agricultural industry and the farmers who grow there" (Campbell 2003, elect. comm.).

Farmers of the Imperial Valley are currently pushing for measures to return valuable water resources, now allocated to the San Diego region, to their community in order to maintain high crop productivity. Water is the lifeblood of the Imperial Valley, one of the poorest per capita counties in California, and without it the county would be nothing but a barren desert. The transfer of water supplies from the Imperial Valley to the San Diego region will mean that farmers will now have to switch from water intensive crops, such as alfalfa, to higher value and less water intensive crops, such as wheat and corn (Martin 2003, elect. comm.). Fewer water supplies to the Imperial Valley agricultural sector will lead to a rearrangement in the agricultural crop makeup of the area. Currently, "over half of the irrigated Imperial Valley cropland is used to grow field crops such as alfalfa and other grasses" (Martin 2003, elect. comm.).

Further acquisition of water by the Imperial Valley farmers may undoubtedly lead to decreased alfalfa production because of the saline nature of the irrigation water. Soils in the Imperial Valley which have high evaporative rates, due to increased local temperatures, have a

greater chance of accumulating salt when irrigated with relatively saline water, such as the water from the Colorado River. Water from the Colorado River has an approximate salinity of 650 mg/L (Bali 2001, elect. comm.). The irrigation of soils in arid regions, such as the Imperial Valley, has been known to increase the soil salt content dramatically (Brady 2002). Increased levels of sodium chloride in the soil have been known to reduce plant growth by altering the plants osmotic potential and ability to conduct basic physiological mechanisms (Brady 2002).

The experiment that I conducted analyzed the effects of sodium chloride on alfalfa seedling growth in the Imperial Valley. Unlike other experiments, such as Kaya (2002) which examined the effects of salinity on lettuce and spinach under closed conditions in a culture, this one was unique in that it was one of few experiments to be conducted outdoors in the Imperial Valley.

Past research on the effects of salinity on plant growth has focused on plants such as sorghum, lettuce, fennel, and carrot. A study done on the effects of salinity and lettuce growth reported that lettuce was more sensitive to tip burn and growth stunting after exposure to saline water (Pascale 1995). Further studies have revealed a reduction in overall seedling and vegetative growth when spinach and lettuce were exposed to high salinity levels (Kaya 2002). The negative response of plant growth to increased salinity should be of major concern for farm owners of the Imperial Valley who rely on agriculture, particularly alfalfa, as a means of economic sustainability. "Alfalfa is the second most important revenue-producing crop in the Imperial Valley" and thus justifies my reasoning for conducting the experiment on the high valued crop (Putnam 2003, elect. comm.).

My experiment analyzed the differences in alfalfa growth with varying salinity levels in an effort to determine the point at which salinity had its greatest hindrance on alfalfa growth. My experiment looked at the effects of salinity on shoot growth of four seed types under varying salinity concentrations. Four seed types were used, two were resistant to salinity and the other two were not. My decision to use two varying seed types (resistant vs. non-resistant) was done in order to gauge the overall effectiveness of each seed type with respect to plant growth. The hypothesis is that when salinity levels reach a level of about 1500 mg/L, alfalfa growth will be most significantly reduced relative to the plot with the next lowest salt-water concentration of 1240 mg/L. My hypothesis applies to all four plots, each of which contains varying seed types. Overall I expect delineation in growth in all plots with increasing salinity, particularly between those plots with salinity application of 1240 mg/L and 1500 mg/L. The salinity concentration of

1500 mg/L was used in accordance with a similar study done on alfalfa which determined 1350 mg/L to be the point at which alfalfa growth was most significantly reduced with the addition of sodium chloride (Triplett 1960).

The research on alfalfa growth in the Imperial Valley will hopefully serve as an informational tool used by farmers. More specifically, the research will assess the point of maximum alfalfa productivity with the use of saline water for irrigation. The delineation in alfalfa growth with increasing salinity will hopefully educate Imperial Valley farmers, and others advocating for additional water resources, that bringing back additional water resources from the Colorado River will consequently lead to less alfalfa productivity, yielding additional agricultural economic losses. The use of my data combined with other studies done on alfalfa and salinity, such as Leathers (1975), which assessed the economic losses that farmers would incur if saline water was used to irrigate alfalfa, will make farmers think twice about bringing in more water to the Imperial Valley.

Methods

This experiment measured the point at which salinity had the greatest effect on alfalfa seedling growth. The experiment was conducted on a privately owned acreage in Brawley, CA. Prior to the initial planting of the seeds, which took place on June 6th, 2003; several soil factors were assessed in order to determine whether the soil was suitable for alfalfa growth. The LaMotte Soil testing kit was utilized in order to analyze the concentrations of nitrogen, potassium, and phosphorus present in the soil. Soil pH was also accounted for in the preliminary soil screening. Soil textural analysis was used to estimate the soil's water retention capacity. A high water retention capacity, typical of a predominately clay-loam soil, is important for initial alfalfa seedling growth (Benes 2003).

Prior to planting the seeds, soil bed preparation was completed. The soil was tilled to a depth of two feet to ensure nutrient mixing, homogenize soil structure, and remove rocks and large soil aggregates. The experimental design consisted of five evenly spaced plots, which measured approximately three by five feet and were spaced approximately two feet from one another. Within each of the plots four varying seed types were planted. Two (A&B) were not resistant to salt and two varieties (C&D) were resistant to high salinity. Seed Services Inc. of Fresno, CA donated all seed types. Since Seed Services Inc. "conditions alfalfa for numerous seed companies

they felt it was unfair to place the exact names of the varieties on each of the four varying seed types” (Simon 2003). It is for this reason that the seeds are labeled and referred to as salt tolerant and non salt tolerant throughout the experiment. No additional information was provided about the seed types’ physiological makeup.

In order to determine the level at which salinity most affected plant growth, varying salt concentrations were added to the water being used to irrigate the crops. The desired salinity levels were achieved by using the Primo Total Dissolved Solids meter. Water was obtained from a local water pump and placed into a four liter watering bucket. Various salt measurements (in milligrams) were placed onto a teaspoon and added to the bucket full of water, which was used to irrigate a plot. The procedure was replicated five times for each of the five plots. Plot 1 was the control and no additional salt was added to the water, used for irrigation. The level of total dissolved solids (TDS) in the control measured $330\text{-ppm} \pm 10$. The salinity of the water used throughout the experiment was consistent with the salinity of the water used by most farmers in the Imperial Valley for crop irrigation. Plots (2-5) were treated with varying salinity levels. Minute concentrations of salt were added to the experimental plots (2-5). Plots 2, 3, 4, and 5 were watered with TDS levels of approximately 565, 895, 1240, and 1550-ppm, respectively. The plots were watered twice everyday for the first two weeks. The increased moisture regime of the soil, as a result of watering the plants twice a day, facilitated seed germination given the high temperature conditions of the Imperial Valley region, which exceeded 100 degrees during the length of the experiment. After the two week period, the plots were watered once a day. Weeds and plant debris were removed from the plots once weekly.

Plots were watered everyday throughout the experiment’s two month time span. Seed germination, shoot elongation, and flower growth were assessed twice a week. Shoot growth was measured every month. Plant height data was collected on three occasions, the first on June 24, the second on July 16 and the third on August 10, 2003. This method was executed in response to a recent study that determined that “under increased salinity, root growth is almost always less affected than shoot growth (Lauchli 1990).” Height measurements were taken from the base of the plant to its apical meristem using a plastic measuring tape.

One problem that arose during the collection of data was in determining how many of the plants per row to count and use in statistical testing. Since there were approximately thirty to sixty plants per row and eighteen rows in the whole experiment it would have been nearly

impossible to account for all plant growths. Construction of additional plots, as replicates, also posed a problem given the limited space at the field site. Thus the individual plants per row were used as replicates for each of the five plots. A rectangular parameter of 0.03 meters squared was established in the center of each row. Plants which fell within the parameters were the only plants measured and assessed throughout the experiment. Plants measured under the 0.03 m parameter were the replicates for each row. The placement of the parameter in the center of the row also accounted for discrepancies that could have occurred if measurements were taken toward the end of the rows, where the possibility of salt contamination by neighboring plots was more likely. Plant height and densities were also recorded. All plants that were measured for plant height were accounted for in the plant density measurement (counting the number of plants per row).

ANOVA was used to assess whether alfalfa growth differences existed among each of the five plots. Individual plant measurements within each plot were used as the replicates for each treatment. Rather than creating three or four extra plots as replicates per plot, I decided to use the individual plant growths as the replicates. The latter would be more time consuming and labor intensive, including the watering and daily care of the plants (i.e. removing noxious weeds). Another constraint was that the field site did not allow for further experimental plot expansion. Expanded analysis was also conducted to determine whether there lay significant differences in growth among the seed types within each of the five plots (salt resistant vs. non-salt resistant). The analysis of this sort will also assume individual plant growths as the replicates. Analysis between seed types will show the effectiveness of resistant versus non-resistant seed types with varying salinity levels. The results obtained from the ANOVA testing will be used to determine the point at which salinity most affects alfalfa growth.

Tukey-Kramer HSD all pairs test, on JMP statistical analysis program, was performed on plant growth means for those seed types which exhibited an F-statistic greater than 1.0 and significance value less than 0.05. This was done in order to determine the greatest mean growth difference in plant growth with increasing salinity along the various plots.

Results

Soil textural analysis revealed the soil at the site to be a clay loam with a pH of approximately seven. Soil nutrient testing revealed the soil at the field site to contain low levels

of nitrogen, and high levels of phosphorus and potassium. Three growth measurements were taken throughout the experiment's entirety. Data was compiled and is shown below in (Tables 1-3). Each table represents the data on growth measurements of all plots during the specified date. Seeds (A, B) are the seed types which exhibit no resistance to salinity and strains (C, D) are resistant to salt. Each of the seed types were watered with varying salinity concentrations (mg/L), wherein mean plant growth, standard deviation and plant density per plot were computed using descriptive analysis computation on excel. In the graphs below, mean plant growth per plot is signified by (x) and standard deviation (σ). The number of plants which were used to calculate the plots' mean and standard deviation are signified by (#).

| Seed Type | 330 (mg/L) | 565 (mg/L) | 895 (mg/L) | 1240 (mg/L) | 1500 (mg/L) |
|---------------------------|---|--|---|--|--|
| A | x = 3.221 in. σ = 0.836 in. # = 29 | x = 2.965 in. σ = 1.26 in. # = 29 | x = 4.022 in. σ = 2.51 in. # = 19 | x = 1.221 in. σ = 1.645 in. # = 15 | No growth |
| B | x = 2.962 in. σ = 1.05 in. # = 39 | x = 3.481 in. σ = 1.63 in. # = 49 | x = 2.398 in. σ = 1.682 in. # = 16 | x = 2.981 in. σ = 1.672 in. # = 21 | No growth |
| C – salt resistant | x = 3.25 in. σ = 2.088 in. # = 30 | x = 3.074 in. σ = 0.996 in. # = 56 | x = 1.998 in. σ = 1.26 in. # = 69 | x = 3.0042 in. σ = 1.655 in. # = 35 | x = 1.296 in. σ = 1.65 in. # = 10 |
| D – salt resistant | x = 3.721 in. σ = 1.05 in. # = 33 | x = 2.451 in. σ = 0.8445 in. # = 37 | x = 1.492 in. σ = 1.033 in. # = 32 | x = 1.142 in. σ = 1.649 in. # = 24 | x = 0.875 in. σ = 1.0339 in. # = 24 |

Table 1. Final data on alfalfa seedling growth 06/24/03.

| Seed Type | 330 (mg/L) | 565 (mg/L) | 895 (mg/L) | 1240 (mg/L) | 1500 (mg/L) |
|---------------------------|---|---|---|---|---|
| A | x = 5.051 in. σ = 1.36 in. # = 31 | x = 5.44 in. σ = 2.096 in. # = 35 | x = 7.267 in. σ = 3.29 in. # = 15 | x = 3.42 in. σ = 1.97 in. # = 13 | No growth |
| B | x = 4.97 in. σ = 1.876 in. # = 45 | x = 5.23 in. σ = 1.721 in. # = 44 | x = 4.042 in. σ = 2.008 in. # = 19 | x = 4.123 in. σ = 1.648 in. # = 19 | No growth |
| C – salt resistant | x = 5.378 in. σ = 2.088 in. # = 33 | x = 5.086 in. σ = 1.939 in. # = 62 | x = 4.871 in. σ = 1.316 in. # = 77 | x = 4.709 in. σ = 1.887 in. # = 41 | x = 1.761 in. σ = 1.21 in. # = 5 |
| D – salt resistant | x = 4.976 in. σ = 1.667 in. # = 31 | x = 3.213 in. σ = 1.964 in. # = 38 | x = 3.33 in. σ = 2.039 in. # = 31 | x = 2.775 in. σ = 1.366 in. # = 24 | x = 2.349 in. σ = 1.553 in. # = 22 |

Table 2. Final data on alfalfa seedling growth 07/16/03.

| Seed Type | 330 (mg/L) | 565 (mg/L) | 895 (mg/L) | 1240 (mg/L) | 1500 (mg/L) |
|---------------------------|---|---|--|---|---|
| A | x = 5.34 in. σ = 1.235 in. # = 33 | x = 6.88 in. σ = 2.22 in. # = 39 | x = 9.46 in. σ = 3.64 in. # = 13 | x = 5.22 in. σ = 2.879 in. # = 10 | No growth |
| B | x = 5.685 in. σ = 1.726 in. # = 48 | x = 6.456 in. σ = 2.236 in. # = 48 | x = 7.07 in. σ = 2.38 in. # = 18 | x = 5.058 in. σ = 1.468 in. # = 17 | No growth |
| C – salt resistant | x = 6.42 in. σ = 2.641 in. # = 35 | x = 5.726 in. σ = 2.306 in. # = 67 | x = 5.489 in. σ = 2.63 in. # = 81 | x = 5.405 in. σ = 2.03 in. # = 37 | x = 2.21 in. σ = 0.669 in. # = 7 |
| D – salt resistant | x = 5.696 in. σ = 1.65 in. # = 27 | x = 4.674 in. σ = 1.711 in. # = 38 | x = 4.87 in. σ = 1.66 in. # = 28 | x = 4.77 in. σ = 1.591 in. # = 26 | x = 4.735 in. σ = 1.716 in. # = 16 |

Table 3. Final data on alfalfa seedling growth 08/10/03.

In depth data analysis using ANOVA testing was performed on all three of the data sets for alfalfa growth. ANOVA testing, which looks to see if there is a significant difference among the means, was performed on an excel spreadsheet. Four different ANOVA tests were performed for each of the four seed types for each data set compiled (06/24, 07/16, and 08/10). Significance values for all seed types taken on 06/24 and 07/16 were all less than 0.05 (Fig. 4-5). Likewise, the F-statistics for the first two data sets are all greater than one. Data analysis for the third data set, taken on 08/10/03, exhibits more complexity (Fig. 6). The first seed type A, which was non-resistant to salinity exhibited an F-statistic of 11.80 and significance value of 0.000. Seed type B, which was also non-resistant to salinity, had an F-statistic of 17.15 and significance of 0.007. Seeds C and D had F-statistics of 4.581, 0.6615 and significance values of 0.001 and 0.620, respectively.

| Seed Type | Source of Variation | F-Statistic | Significance |
|----------------------|---------------------|-------------|--------------|
| A | Between | 18.25 | < 0.001 |
| B | Between | 3.887 | 0.012 |
| C (resistant) | Between | 14.55 | < 0.001 |
| D (resistant) | Between | 67.63 | < 0.001 |

Figure 4. ANOVA analysis of data (06/24/03)

| Seed Type | Source of Variation | F-Statistic | Significance |
|--------------------------------|---------------------|-------------|--------------|
| A | Between | 10.08 | < 0.001 |
| B | Between | 4.016 | 0.0093 |
| C (resistant) | Between | 6.343 | < 0.001 |
| D (resistant) | Between | 30.13 | < 0.001 |

Table 5. ANOVA analysis of data (07/16/03)

| Seed Type | Source of Variation | F-Statistic | Significance |
|--------------------------------|---------------------|-------------|--------------|
| A | Between | 11.80 | 0.000 |
| B | Between | 4.286 | 0.007 |
| C (resistant) | Between | 4.581 | < 0.001 |
| D (resistant) | Between | 0.6615 | 0.620 |

Table 6: ANOVA analysis of data (08/10/03)

Seed germination in all seed types which were watered with salinity concentration ≤ 1240 mg/L occurred four to seven days after the seeds were planted. Seed germination for seed varieties (C,D) occurred one week later for the plot watered with salinity 1550 mg/L. Seeds (A,B) watered with 1550 mg/L never germinated. Shoot elongation varied with seed type and salinity levels. During the first month the greatest difference in shoot elongation for seed types A, C, and D occurred for those plants watered with salinity concentration of 895 mg/L. The mean difference in plant growths for seed types A, C, and D, between 06/24/03 and 07/16/03 at 895 mg/L plot, were 3.245, 2.873, and 1.838 inches, respectively. Seed type B exhibited the greatest mean growth shoot elongation when watered with 330 mg/L. Between the periods of 07/16/03 and 08/10/03 the greatest difference in mean shoot elongation for seed types A and B along all salinity the varying salinity gradients was experienced at 895 mg/L. Seed types C and D showed the greatest increase in mean plant growth when watered with 330 and 1240 mg/L,

respectively. Plant densities were higher with those plots watered with a salinity concentration ranging between 565 – 895 mg/L (Table 1-3). Flower growth was first noticed on 07/16/03, when the second plant growth measurements were obtained. Only those plants which were greater than 16 inches began to exhibit flower growth. Flowers were purple in color and were only noticed on two plants of which were in plots 4B and 4C (Table 2). The plant in plot 4B measured 21 inches in height compared to the plant in 4C which measured 17 inches. Flower growth at the field site increased during the last plant growth measurement (08/10/03), particularly on those plots watered with salinities 565 and 895 mg/L.

In conducting ANOVA analysis, mean plant growths as well as other descriptive analysis information were computed for each of the plots. Descriptive analysis computed for mean, 95% confidence interval mean, median, and standard deviation. All were useful in determining the variation in plant growths within each of the plots for the varying seed types. Below are graphical representations of the growth rates of each of the four seed types (A, B, C, D) with increasing salinity. It is apparent from the graphs that each seed type experienced some sort of growth delineation with increasing salinity. This is particularly evident of seed types A and B, the non-resistant seed types, which experienced no growth when irrigated with a water-salt concentration of 1500 mg/L. Although seed types C and D experienced growth in the 1550 mg/L [salt] plot, the plot density was significantly smaller than the prior plot of [salt] 1240 mg/L. Plant density for seed type C was 37 when watered with a [salt] 1240 mg/L. The decrease in plot density for seed type C was noticeable in the plot watered with [salt] 1550 mg/L, wherein the density was 7 plants per plot. There was also a decrease in plant density for seed type D, between plots watered with [salt] 1240 and 1550 mg/L (Table #3).

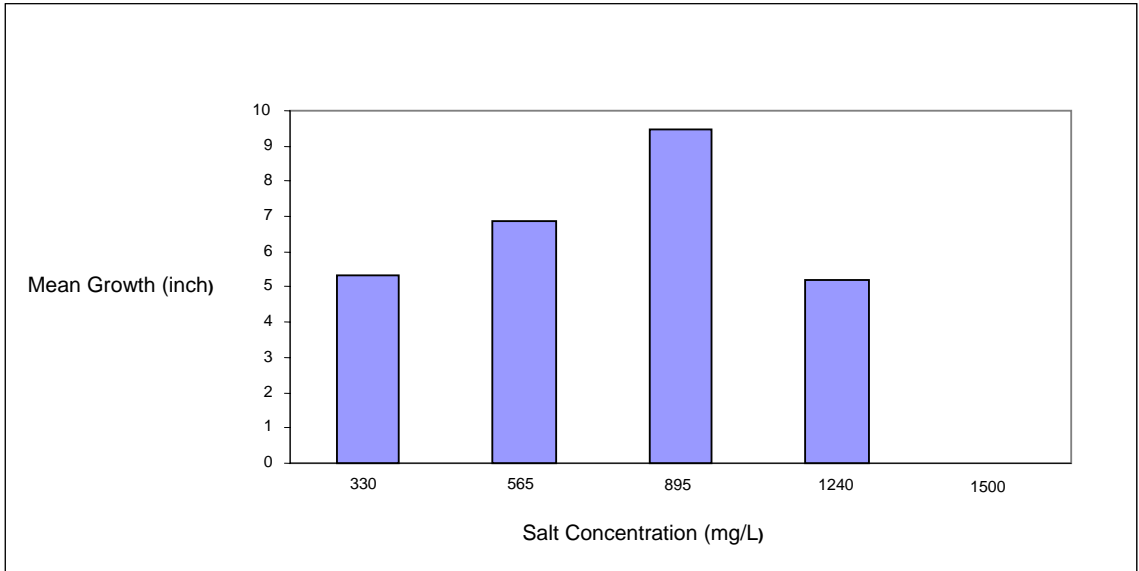


Figure 1. Mean growth comparison for Seed Type A (08/10/03).

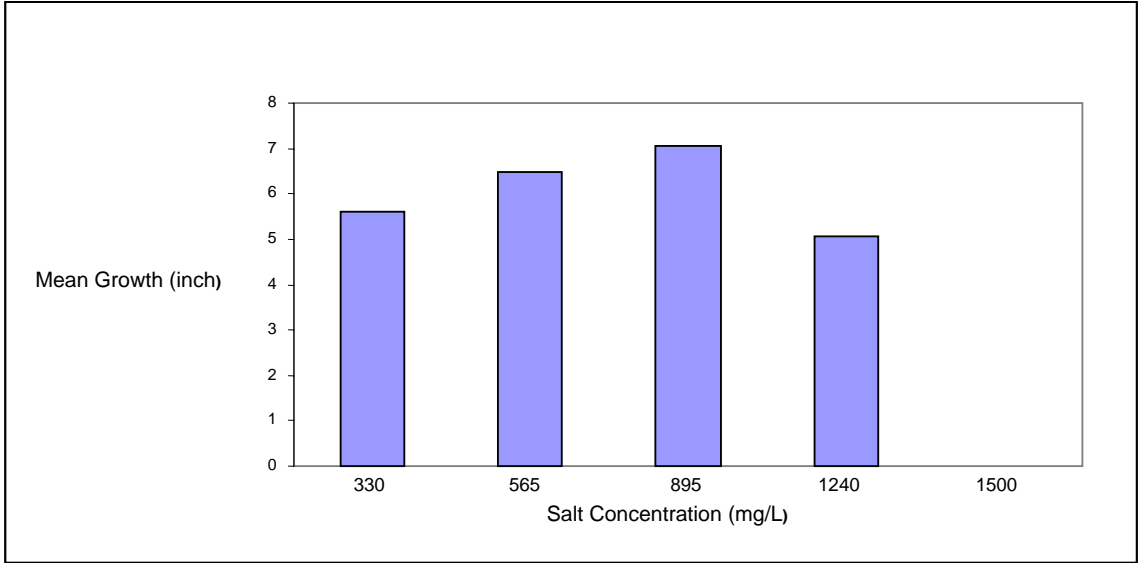


Figure 2. Mean growth comparison for Seed Type B (08/10/03).

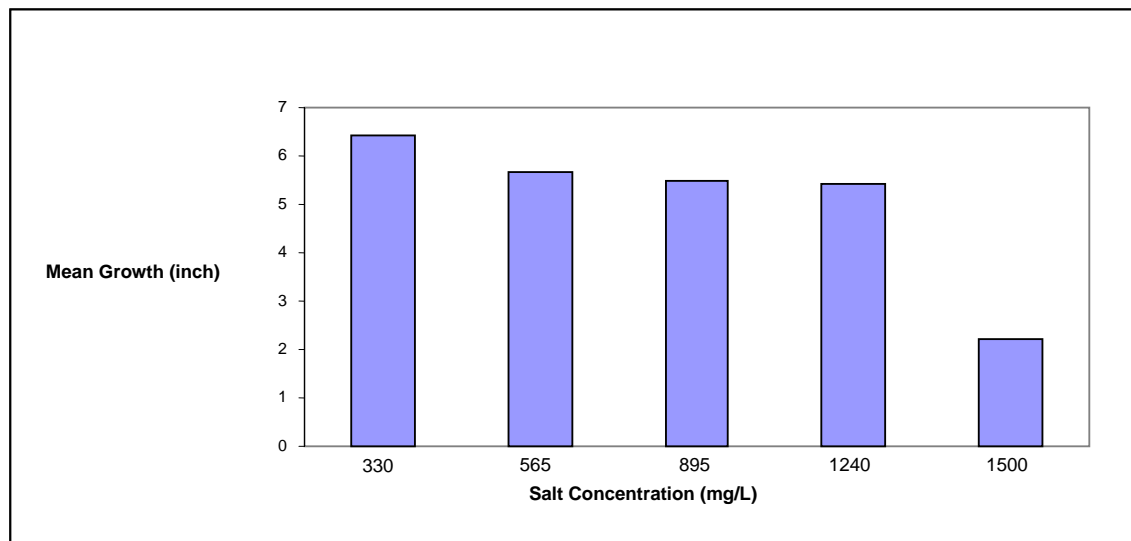


Figure 3. Mean growth comparison for Seed Type C (08/10/03).

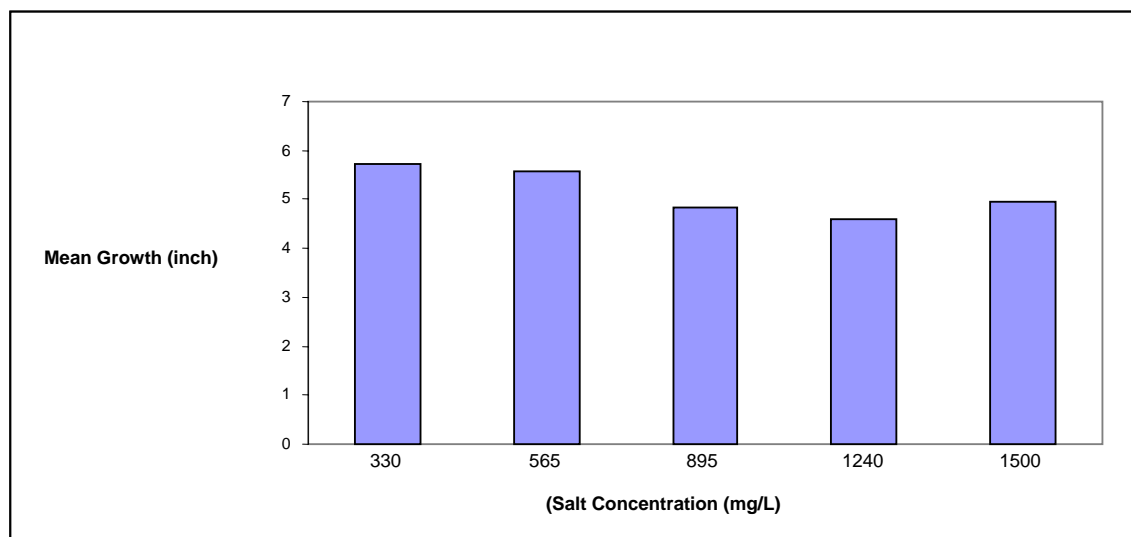


Figure 4. Mean growth comparison for Seed Type D (08/10/03).

For plants which grew and were recorded in the first data set (06/24/03), post hoc comparison of means testing showed that the greatest difference in mean plant growth for seed type A, across the varying salinity gradients, occurred between plots watered with 895 and 1240 mg/L. Seed type B showed the greatest plant growth delineation between 565 and 895 mg/L, seed type C between 1240 and 1550 mg/L, and seed type D between 330 and 565 mg/L. The same results were obtained for all seed varieties in the second data set (07/16/03). On the last data set, which was collected on (08/10/03), the greatest delineation in plant growth for seed types (A-C) occurred between plots watered with 895 and 1240 mg/L. Seed type D had the greatest plant growth difference/delineation between 330 and 565 mg/L.

Tukey-Kramer HSD test revealed that significant differences in plant growth means with increasing salinity existed for seed types (A-C) between salinity ranges (895 and 1550 mg/L) and (1240 and 1550 mg/L). The growth differences experienced between salinity ranges 895 and 1240 mg/L for all seed types were not deemed significantly different. There were no significant differences in plant growth means across all salinity applications to seed type D.

Discussion

Review of the data shows that the patterns in plant growth for seed types (A, B) and (C, D), differ with increasing salinity. The non-salt resistant seed types (A, B) illustrated a parabolic growth curve when watered with increasing salinity. Growth in these seed types gradually increased from 330 mg/L to the (565- 895 mg/L) range and decreased therein after, to the point of no growth at 1550 mg/L. This is apparent with all three data collection points. On the other hand, salt resistant seed types (C, D) demonstrated a growth curve which resembled the graph of $y = 1/X$, with increasing salinity. The ability of seeds types (C, D) to maintain consistent growth along all salinity gradients demonstrates the resiliency and true nature of salt resistant species. From the results obtained it seems as if the genetic engineering of salt resistant seeds (C, D) have allowed them to grow in more saline conditions at the expense of expanded shoot elongation as experienced by non-resistant seed types.

Post hoc comparative mean testing (Tukey-Kramer HSD) showed that the difference in mean plant growth among seed types (A-C) was most significant between plots watered with salinity concentrations (895 and 1550 mg/L) and (1240 and 1550 mg/L). This result signifies that alfalfa growth for seeds (A-C) was most stressed when watered with a salinity concentration greater than 895 mg/L. It is at 895 mg/L where alfalfa growth for seed types (A-C) experienced maximum mean plant growth before decreasing in plant height. Seed types (A-B) inability to germinate when watered with salinity 1550 mg/L signifies that the level of minimum growth for non-resistant seed types lies between the salinity range of 1240 and 1550 mg/L. Seed varieties A and B inability to demonstrate growth under the saline conditions (1550 mg/L) goes to show that the plants osmotic potential was severely hindered to the point wherein seedling growth was not possible. The excessive amount of salinity used to irrigate plots (1550 mg/L) of all seed types, particularly A and B, interfered with the seedlings ability to uptake water from the surrounding soil.

The results gathered from the ANOVA analysis and Tukey-Kramer HSD test showed that the delineation in plant growth among seed types A thru C was significant, particularly the drop in alfalfa growth between plots (895 and 1550 mg/L) and (1240 and 1550 mg/L). This is consistent with the findings made by Triplett who determined 1350 mg/L to be the point at which alfalfa growth was most significantly reduced with the addition of sodium chloride (Triplett 1960). Being that both seed types A and B demonstrated similar differences in means (comparison of significance value and F-statistic) it is reasonable to say that the null hypothesis, which stated that when salinity levels reach a level of about 1550 mg/L, alfalfa growth will be most significantly reduced relative to the prior plot with a salt-water concentration of 1240 mg/L, proved correct for seed types A and B. It is also important to note that the mean plant growth differences between salinity levels 895 and 1550 mg/L were also significantly different. The delineation in plant growth between plots watered with 895 and 1550 mg/L should be examined more closely. Further testing should focus on conducting an experiment comparing mean plant growth and salinity application ranging from 895 to 1550 mg/L. Seed types C and D, of which both were resistant to salt, were not consistent in their significance values. Further research to evaluate what differences in seed physiology caused seed type (C) results to be different from those obtained for seed (D) could not be assessed during this experiment because of Seed Services Inc. denial to provide me with the exact names of the varieties on the seed packages sent. Future studies will have to make sure and obtain seed varieties with known names and corresponding physiologies in order to explain the differences in plant mean growths experienced by different salt resistant seed types along the various salinity levels. The mixed results yielded by ANOVA analysis between the two salt resistant seed types provide inconclusive results. Thus, the null hypothesis cannot be accepted for seed types (C and D).

A bias in my experiment is that in conducting ANOVA variance of means testing, I assumed the replicates to be the individual plant heights within each of the plots. As stated earlier the creation of further replicates in my experimental design was not possible considering the limited amount of field space I had to work with in my grandmother's backyard. Additional construction of plots, which would serve as replicates, would also translate itself to added amount of time required to maintain the crops throughout the experiment's two and half month duration. My decision not to construct additional plots, to be used as replicates, could explain the wide range in variance in plant growth means among some of the plots.

From this study it can be concluded that plant growth in seed types A and B was most significantly reduced between plots with salinity application of 895 and 1550 mg/L. This observation can be verified after noting that ANOVA analysis of variance testing concluded that there were significant differences in the mean plant growth across the various salinity gradients in both seed types A and B.

Acknowledgements

I would like to thank my grandmother Dora Mendoza for letting me use her backyard in Brawley, CA to grow the alfalfa plants during the summer of 2003 and Sharon Benes for her advice on proper alfalfa seedling preparation and land tillage.

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