Management of Salinity for Lettuce Production

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Moderate levels of salts in soil and water can degrade the quality and yield of lettuce by stunting growth, reducing head formation, and by causing necrotic lesions on the leaf margins. Growers who are using water with elevated levels of salts are challenged to minimize the detrimental effects of salinity on lettuce production. Salts from irrigation water, fertilizer, and other amendments may build up in the soil during a single season. Knowing the level at which salts in soil and water reduce production of lettuce is important for determining if cultural practices are adequate for controlling salinity.

One of the widely used thresholds for salinity tolerance of lettuce was published in the FAO irrigation and drainage paper 29 in 1985. An electrical conductivity (EC) of 0.9 dS/m in irrigation water and 1.3 dS/m in soil paste extract was found to cause yield loss in lettuce. A 10% yield loss was associated with 1.4 dS/m in irrigation water and 2.1 dS/m in soil paste extract. These thresholds are often higher than the EC of water sources and soils currently used for lettuce production in the Salinas and Pajaro Valleys. However, the response of lettuce to salinity can depend on other factors such as the weather regime, species of salts, irrigation practices, and varietal tolerance to salinity.

Salinity Field Trial

To better understand the effect of salinity on lettuce production under conditions of the Central Coast, we conducted a field experiment to measure the effect of varying levels of salinity and sodium adsorption ratios (SAR) on the quality and yield of crisphead lettuce at the USDA Spence Research Field Station during the 2003 and 2004 seasons. The soil was a well-drained Chualar loam. The trial included 2 commercial varieties (Salinas and Sniper) and 8 salinity treatments. Sniper is a variety currently commercially grown, and Salinas is an older commercial variety. Salinity treatments, listed in Table 1, were replicated 4 times and varied in level of bulk salinity (EC) and sodium adsorption ratio (SAR). Plots measured one bed in width (40 in) × 70 feet in length. The crop was planted June 30 in 2003, and June 29 in 2004, and germinated using sprinklers. After thinning and sidedressing, the crop was irrigated using surface drip. Salinity treatments were applied through the drip system during the irrigations until 2 days before harvest. The crop was harvested Sept 4 in 2003 and Sept 2 in 2004 by a commercial crew and evaluated for head size and carton yield (24's and 30's). Samples of the wrapper leaves and cores were analyzed for nutrients and salts. Soil was sampled from 6, 12, 24, and 36-inch depths for salinity analysis before, during and after completing the field trial.

Results

Soil salinity

Irrigating with moderately saline water significantly increased the salinity level in the 0 to 3 foot zone of the soil profile during the first season of the trial (Fig 1). The highest salinity levels were measured in the 0-1 ft layer. The ECe (electrical conductivity of soil paste extract) of the highest salinity treatment was less than 4.5 dS/m at the 1-foot depth in 2003 but increased to almost 5.5 dS/m by the end of the second crop (2004). Salinity levels in the subsoil also increased between the 2003 and 2004 seasons.

Yield and biomass

Elevated levels of salinity in the irrigation water reduced carton yield and biomass of both varieties during the 2003 and 2004 seasons (Figs. 2 and 3). The reduction is yield and biomass was more severe during the second year than the first, presumably because of the build-up of salt in the soil profile caused by consecutive years of irrigation with saline water. The most severe salinity treatment (ECw = 8.5 dS/m) reduced biomass yield by 32% during the first year and by 72% during the second year of the trial (Fig. 3). The relationship between salinity level and carton yield was linear during 2003; but as the salts built up in the soil and caused more severe losses in yield in 2004, the relationship between salinity and yield became curvilinear (Fig. 3). Similarly, the relationship between salinity in the soil (0-12 inches) and biomass was also was linear in 2003 and curvilinear in 2004 (Fig 4). Injecting gypsum to reduce the SAR of the irrigation water minimized the detrimental effects of salinity on carton yield of 24-size heads in 2004 but had no effect on yield in 2003 (Fig. 2).

Cultivar response to salinity

Both cultivars responded similarly to the salinity treatments in 2003, but in 2004, the Salinas variety had a higher loss in carton yield and biomass than the Sniper variety (Figs. 5 and 6). The highest salinity level reduced marketable biomass of the Salinas variety by 96% and the biomass of the Sniper variety by 38% (Fig. 5). Additionally, the low SAR treatment, obtained through the injection of gypsum, minimized the effect of salinity on carton yield of the Sniper variety more than the Salinas variety in 2004 (Fig. 6). Salt toxicity symptoms other than stunting were not observed in either variety during 2003; however, plants of both varieties were severely stunted and had necrotic areas (burning) on the leaf margins under the highest salinity treatment in 2004. The salinity treatments did not significantly reduce canopy size of either variety during the 2003 season, but the treatments did cause significant reduction in canopy size of both varieties in 2004 (data not presented). High levels of salts in the irrigation water reduced the weight of 24-size heads (data not presented) and increased the percentage of culled heads of both varieties during the 2003 and 2004 seasons (Fig. 7).

Tissue analysis of salts

Analysis of the wrapper leaves demonstrated that the level of sodium was correlated with the SAR of the soil and the level of chloride was correlated with the soil EC (data not presented). However carton yield and biomass yield were not correlated with the chloride and sodium levels of the wrapper leaf tissue. The lack of correlation with yield suggests that tissue analysis is a less accurate diagnostic tool for assessing potential salinity problems than the direct monitoring of salts in soil and water.

Salinity effects on yield potential

By conducting a regression analysis of the data presented in Fig. 2, we determined that a 10% yield loss of 24-size heads occurred when the salinity level of water was greater than 2.1 dS/m during the 2003 season and 1.1 dS/m during the 2004 season. The lower salinity threshold during the second season may be due to the effect of applying saline water to the soil during 2 consecutive years. The threshold for a 10% loss in marketable biomass for irrigation water (Fig. 3) was 3.1 dS/m in 2003 and 1.3 dS/m in 2004. However, the thresholds differed between the Salinas and Sniper varieties in 2004. The ECw threshold for a 10% loss in biomass was 0.9 dS/m for Salinas and 2.4 dS/m for Sniper in 2004, which suggests that Sniper is more tolerant to salinity than Salinas. In soil, the ECe threshold for a 10% loss of marketable biomass was 1.8 dS/m in 2003 and 1.3 dS/m in 2004 (Fig. 4). However, for Sniper alone, the ECe threshold for a 10% loss in biomass yield was 2.0 dS/m in 2004 (data not presented).

Conclusions

Considering that only the highest salinity treatment resulted in salt burn symptoms on the leaves, it is possible that growers may be experiencing some loss in yield and head size without observing salinity symptoms when using water with an ECw above 1.1 dS/m. Growers, who are using moderately saline water should monitor salinity levels in the soil profile during the season, plant salt tolerant varieties, and apply gypsum to prevent the build up sodium in the soil. Additionally, maximizing leaching of salts from rainfall, by improving drainage and soil structure, could help prevent salts from reaching levels that would cause yield loss.

Table 1. Irrigation salinity treatments used in the field trial.

Treatment	Description	Treatment Salinity	Measured Salinity	Treatment SAR	Measured SAR
		----- EC (dS/m) ----			
1	well water	0.6	0.6	3	3
2	low salinity	1.5	1.6	3	3
3	low salinity	1.5	1.7	10	8
4	medium salinity	2.5	2.7	3	3
5	medium salinity	2.5	2.9	10	12
6	high salinity	5	5.2	3	4
7	high salinity	5	5.4	10	11
8	very high salinity	8	8.5	10	12

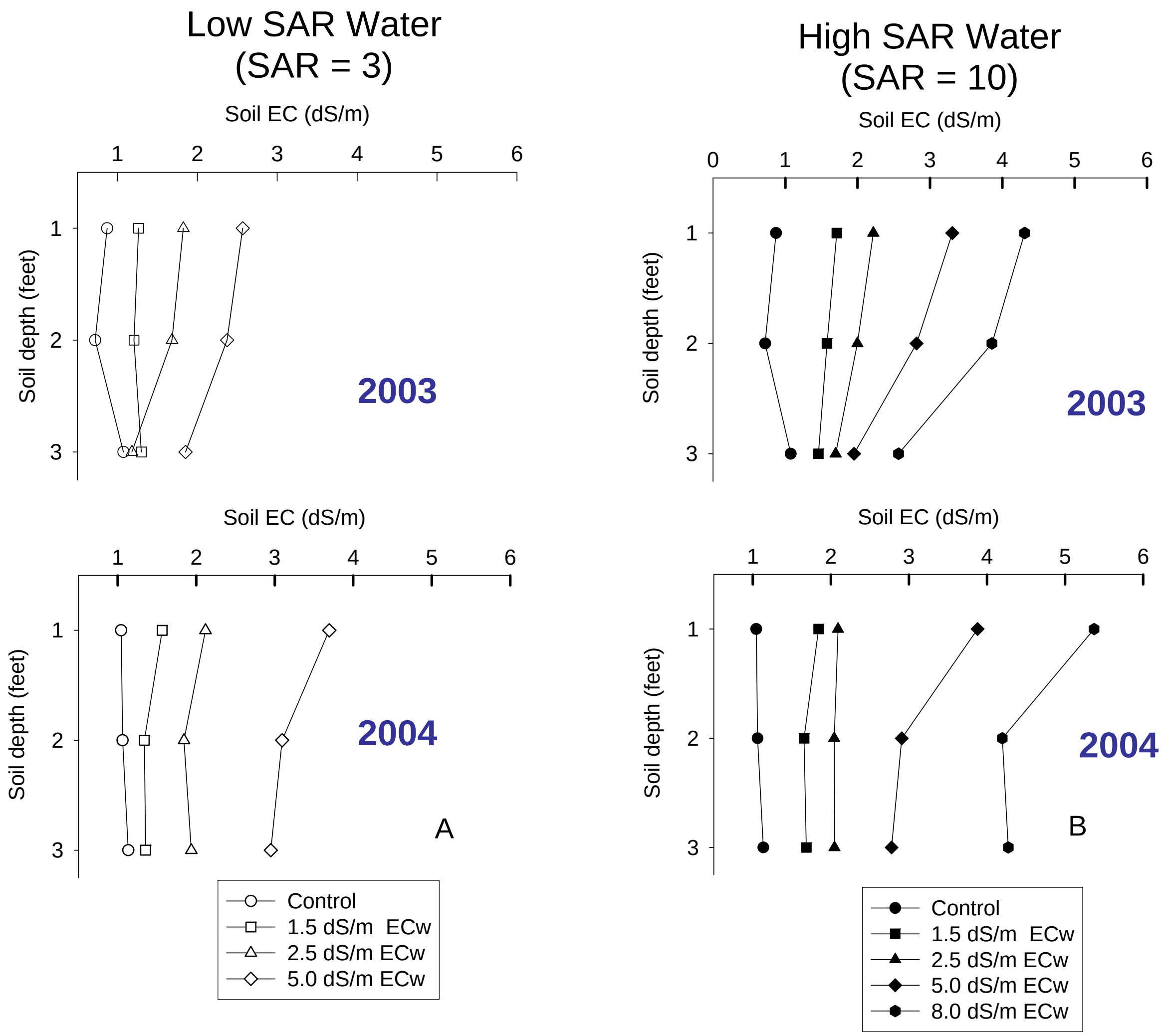

Figure 1. Salinity (ECe) distribution in the soil profile after irrigating with water of varying levels of salinity, and sodium adsorption ratios of 3 (A) and 10 (B). Samples were taken after harvest in 2003 and 2004 and are composites of the 0-1, 1-2, and 2-3 foot depths.

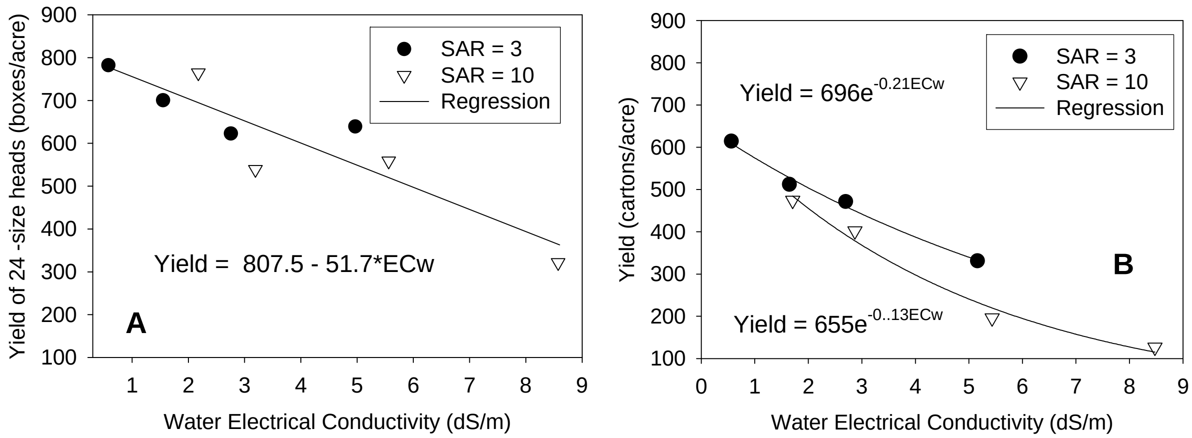

Figure 2. Effects of salinity treatments on carton yield of 24-size heads for the 2003 (A) and 2004 (B) seasons.

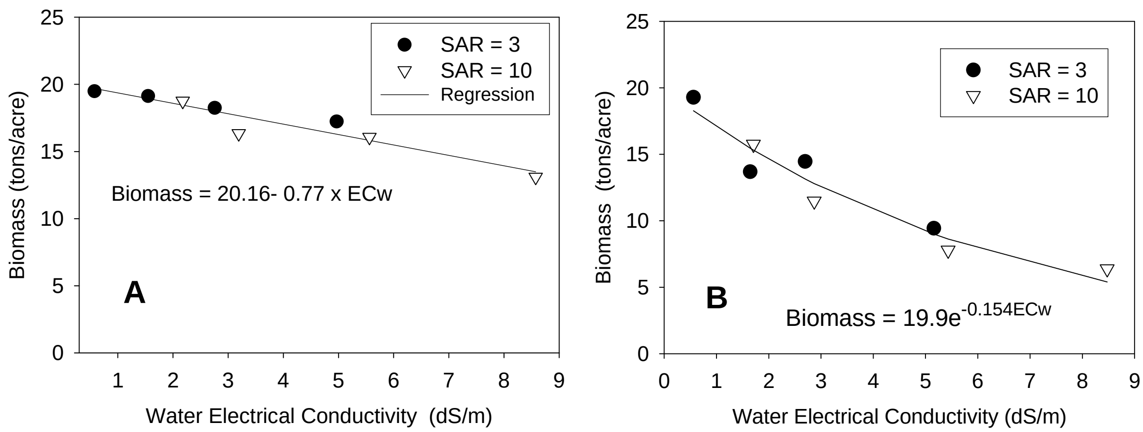

Figure 3. Effects of salinity treatments on marketable, fresh-weight biomass for the 2003 (A) and 2004 (B) seasons.

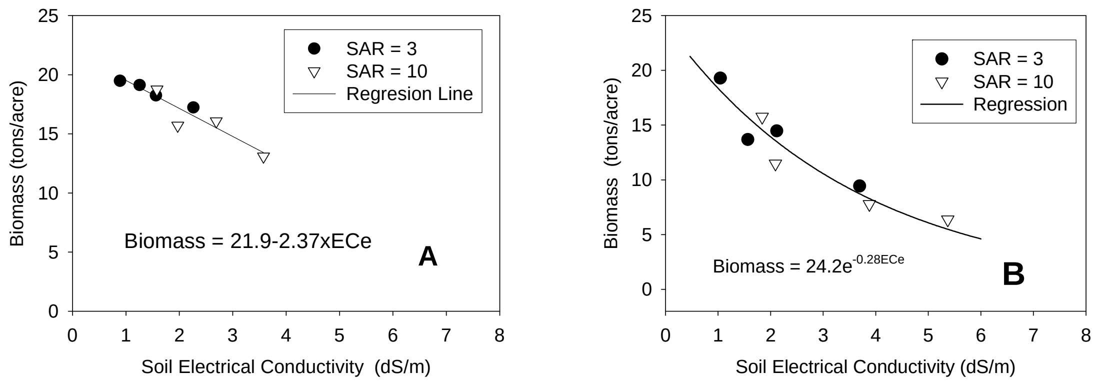

Figure 4. Relationship between soil salinity (ECe) of the 0-12 inch layer and marketable, fresh-weight biomass for the 2003 (A) and 2004 (B) seasons (average of Salinas and Sniper varieties).

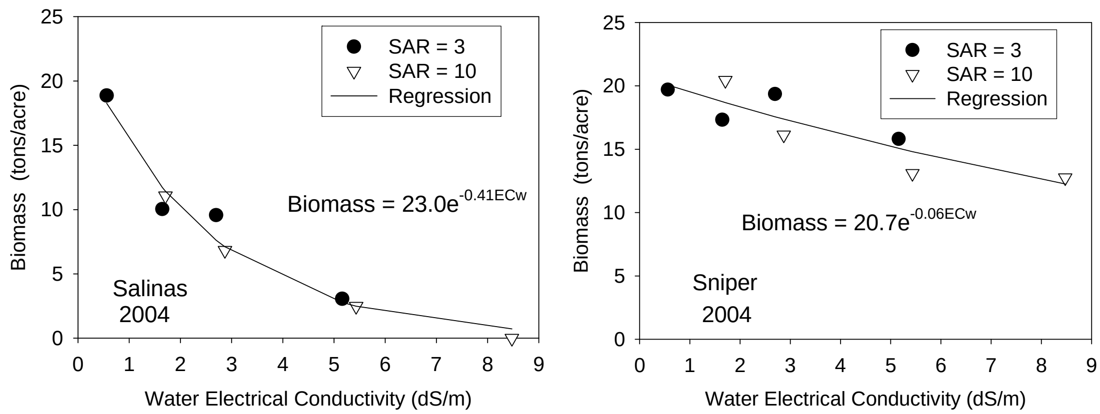

Figure 5. Effects of salinity treatments on marketable, fresh-weight biomass for Salinas and Sniper varieties during the 2004 season.

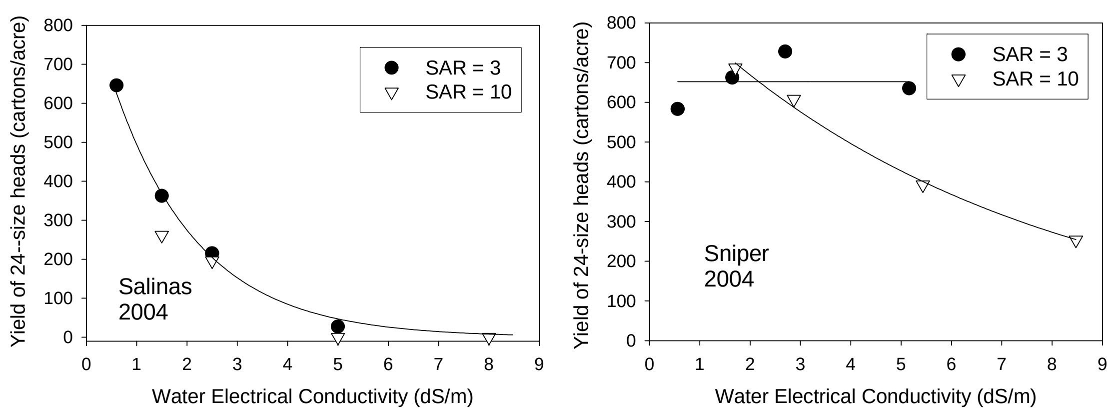

Figure 6. Effects of salinity treatments on marketable yield of 24-sized heads for Salinas and Sniper varieties during the 2004 season.

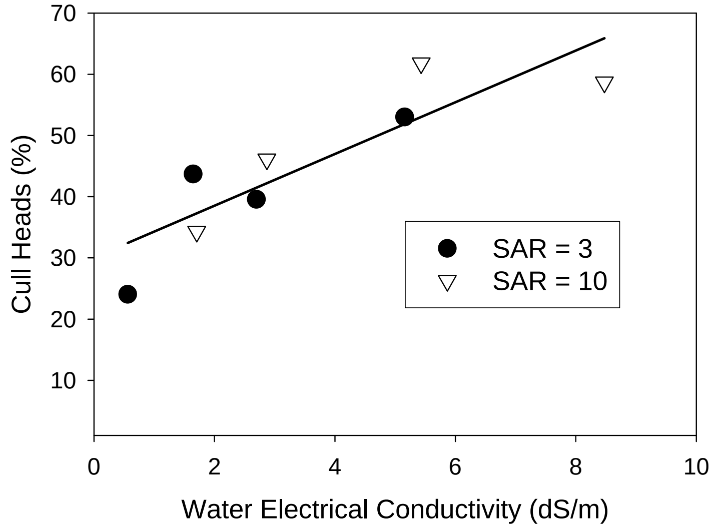

Figure 7. Relationship between the irrigation water (ECw) and percent cull heads for the 2004 season (average of Salinas and Sniper varieties).