YUMA CENTER OF EXCELLENCE FOR DESERT AGRICULTURE
FINAL PROJECT REPORT

Granting Agency	Arizona Iceberg Lettuce Research Council
Project Title & number	**Water and Salt Balance for Lettuce Thinning Irrigation (17-06)**
Start Date	September 1, 2016 — **End Date** August 30, 2017
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Lead Researcher(s)	Dr. Charles Sanchez Soil, Water, and Environmental Sciences University of Arizona

Abstract

Studies were conducted in the 2016-2017 iceberg lettuce season to evaluate water and salt balance during the lettuce thinning irrigation event. The data are discussed in the context of total water and salt balance during the entire lettuce production season in the context of management implications. These studies show that the summer pre-irrigation event, prior to lettuce planting, redistributed salts below the rooting zone. According to results we reported to the AILRC in 2015-2016, stand establishment irrigation by sprinklers was a net salt loading event in the planting windows evaluated. The data presented in this study shows that the thinning irrigation was generally effective in moving salts out of the rooting zone because the amounts of water applied were large relative to evapotranspiration (ET). However, because of high irrigation efficiencies for the remainder of the production season, there was net salt loading over the entire lettuce production cycle. Expanding our data base for lettuce ET, our focus for the 2017-2018 season, is needed to verify the generality of these findings.

Introduction

Water and salt management are of paramount importance to agricultural sustainability in the lower Colorado River region near Yuma. Because the irrigation water has salts, and because the shallow ground water in the valleys that fluxes up through the fine textured soil by capillarity has salts, some level of excess irrigation (beyond crop consumptive use) must be applied to leach salts below the crop root zone. Effective leaching is especially important in this region because many of the crops produced are sensitive to salinity.

Crop production systems and rotations in the lower Colorado River region of Yuma utilize a number of irrigation application methods over the cropping season. The systems utilized and the management of these systems can have a profound impact on water delivered, leaching achieved, and resulting salt distribution.

In a previous Arizona Iceberg Lettuce Research Council project we evaluated water and salt balance during the stand establishment sprinkler irrigation. Results showed that the water used was essential for climate modification and successful stand establishment, but high evaporation and wind drift water losses during sprinkler irrigation for early season stand establishment meant that there was no effective leaching fraction, so there was salt accumulation in all early season sites. Sustainability would require this leaching be achieved in another irrigation event. The objective of this project was to extend the salt and water balance findings into the thinning irrigation management phase following stand establishment. The data are discussed in the context of total season salt balance for management implications.

Materials and Methods

These studies were conducted at two sites used for lettuce production. One was in the Yuma Irrigation District (YID or South Gila) and one in the Yuma County Water Users Association (YCWUA or Yuma Valley). Pre-irrigation occurred August 13, 2016, at the YID site, and August 30, 2016, at the YCWUA site. The wet date was September 28 at the YID site, and Oct. 6 at the YCWUA site. The dates for the thinning water irrigation were Oct. 12 and Oct. 21 for the YID and YCWUA sites, respectively. The YID site had three more irrigations after cultivation on dates of Oct. 27, November 8, and November 18. The YCWUA site had four more irrigations after cultivation on Nov. 5, Nov. 18, Dec. 1 and Dec. 14. The YID site was harvested November 21, and the YCWUA site December 15.

Estimating crop water used by lettuce was accomplished by measuring evapotranspiration (ET) with an instrument system known as Eddy Covariance (ECV). ECV obtains ET by measuring incoming and outgoing energy fluxes over the cropped landscape. The ECV measures four energy flux components- net radiation (Rn), ground heat flux (G), sensible heat flux (H), and latent heat flux (LE). Rn represents absorbed solar and infrared radiation, G is heat transported into the soil, H is turbulent heat above the crop due to air temperature gradients, and LE is latent heat energy due to ET. While ET can be estimated from just the LE component, accurate estimates require collecting all four components. ECV data values are reported in energy flux units (W/m^2), with water-specific quantities also reported as depths over time (e.g. mm/day).

Each in-field ECV system requires sensors, one or more data loggers, power supplies, and mechanical supports. Sensors measure air temperature, humidity, wind speed, wind direction, water vapor concentration, CO2 concentration, soil temperatures, soil moisture, and solar and infrared radiation -- all at sample rates up to 20 Hz. Data loggers collect, analyze, and store analog and digital signals from the sensors; in some cases they are connected to a cellphone modem for transmitting synopses of data and system health information to one of our home offices. Power supplies consist of 12V batteries, voltage regulators, grounding rods, and solar panels. The mechanical supports include tripods, masts, lightning rods, anchors, and guy wires to ensure the sensors, loggers, and power supplies remain accurately aligned in all weather conditions.

Although this 2016-2017 AILRC project was focused on the iceberg lettuce thinning irrigation, we utilized other funding sources to track water and salt balance in other segments of the lettuce production cycle. The ECV systems were initially placed in the field before pre-irrigation in August. They were removed for land preparation and re-installed in the field after lettuce planting but before sprinkler irrigation for stand establishment. They were disconnected briefly (a few hours), during cultivation, and reconnected after cultivation and side-dress fertilizer operations were complete.

Along with atmospheric water measurements we tracked water applied. For sprinkler irrigation systems we used in-line meter (i.e. ESSFIFLO Ultrasonic Flowmeter) and pressure data logging instruments (i.e. Pollardwater Pres/Temp logger). For surface irrigation we used flumes with depth sensors and data loggers to measure in-flow hydrographs and water depth sensors (Troll 100 water depth sensor and logger) to measure water depth profiles in transects along the irrigation run (inlet to downstream border). Data were downloaded and processed after each irrigation event.

Each field was surveyed using a Geonics Dual-dipole EM38 meter mounted on a mobilized assessment platform with an integrated (sub-meter accuracy) GPS system, with all survey and GPS position data logged into an on-board portable computer. In the baseline survey, EM38 signal data was collected once every two seconds within transects spaced 10 to 20 meters apart, typically generating from 1000 to 5000 survey positions per field (transect spacing and the total number of survey positions depended on the field size). These data were analyzed using the ESAP software package (https://www.ars.usda.gov/pacific-west-area/riverside-ca/us-salinity-laboratory/docs/esap-model/) and the spatial response surface sampling algorithm in the ESAP-RSSD program. At each sampling location, a single 1.2 m soil core was extracted using automated soil auguring equipment and split into four depth-specific 30 cm samples. The soil samples collected from each core were bagged, labeled, and subsequently used for the chemical and physical analyses.

One-dimensional (basin or sprinkler) or two dimensional (furrow) water and salt distributions were tracked during each irrigation event, and during the intervals between irrigation events, using Decagon data loggers and GS3 moisture/temperature/conductance probes. The readings from these sensors were periodically ground-trothed using soil sampling.

Subsets of all soil samples were oven-dried to determine soil moisture contents. The remainder of the soil samples were air-dried prior to laboratory analysis. After obtaining saturated paste extracts from all soil samples, we determined electrical conductivity (EC), and cation/anion quantities for Ca^{+2}, Mg^{+2}, Na^{+}, Mn^{+2}, Cl^{-}, $SO4^{-2}$, $NO3^{-}$ and bicarbonate by ion chromatography.

Results

Calculated evaporation during pre-irrigation was about 55 mm (2 inches) as shown, for example, at the YCWUA site in Figure 1. Calculated ET for the YID site from the time sprinkler irrigation for stand establishment was terminated through thinning water irrigation was 33 mm (1.3 inches) and total season ET was 232 mm (9.1 inches) as shown in Figure 2. Calculated ET for the YCWUA site from the time sprinkler irrigation for stand establishment was terminated through thinning water irrigation was 39 mm (1.5 inches) and total season ET was 224 mm (8.8 inches) as shown in Figure 3. Thus, the amount of ET from after stand establishment though thinning was small relative to total season water use. The diurnal variations in flux at the YCWU site for five days after the thinning irrigation show nearly the same peak transpiration values except for an ~10% decrease on the fifth day, as shown in Figure 4.

Interestingly, the total-season ET values measured by ECV in these studies were slightly less than that we measured in previous AILRC-funded work in 2011 using weighing lysimeters. The focus of research funded by the AILRC during 2017-2018 will be aimed at expanding the data base for ECV-estimated ET for lettuce.

Pre-irrigation did transport salts from the soil surface into lower soil depths for the YID site (Figure 5a). For the YCWUA site, there was a small reduction in the surface with a more pronounced reduction at deeper depths (Figure 5b). It should be noted that the site selected in the YCWUA was very coarse textured and would be considered an outlier compared to the median textures of soils used for lettuce production. The lower depths are exceptionally sandy for the YCWUA site. Interestingly, there seemed to be a preferential leaching of Na and Cl, as reflected by the lower measured SAR and soil solution Cl values (Figures 6a and 6b).

In previous studies funded by AILRC in 2015-2016 we have shown that stand establishment irrigation by sprinklers is generally a net salt loading event prior to late October. Results obtained in the 2016-2017 studies are similar to those obtained in previous studies and will not be discussed in detail in this report (data not shown).

Thinning irrigation is generally assumed to provide some leaching since the crops at this seedling stage require minimal water and furrows have not yet been packed into trapezoidal furrows with bolas. This irrigation is primarily used to moisten the soil surface to facilitate the thinning operation. As shown in Figures 7 and 8, this irrigation event does appear to provide a leaching fraction from the bed, although it seemed to accumulate in the furrow. Although there was some salt increase in the immediate surface for the YCWUA site, the net effect from the bed was leaching.

Overall, in-season irrigation application efficiencies after thinning are high, often exceeding 90%. Because lettuce irrigated with Colorado River water has a required leaching of 20% to avoid salt accumulation above plant tolerance levels, we would not expect net leaching during the lettuce crop cycle. This was definitely the case for the YID site (Figure 9). For the YCWUA site, there was leaching during in-season irrigation within the sandy subsurface (Figure 10).

One interesting and previously un-noticed observation with respect to soil solution cation and anion concentrations is that near the surface, soil was supersaturated with respect to some Ca and Mg carbonate minerals (Table 1). This may mean that facilitating mineral precipitation could be an important mechanism for salt mitigation.

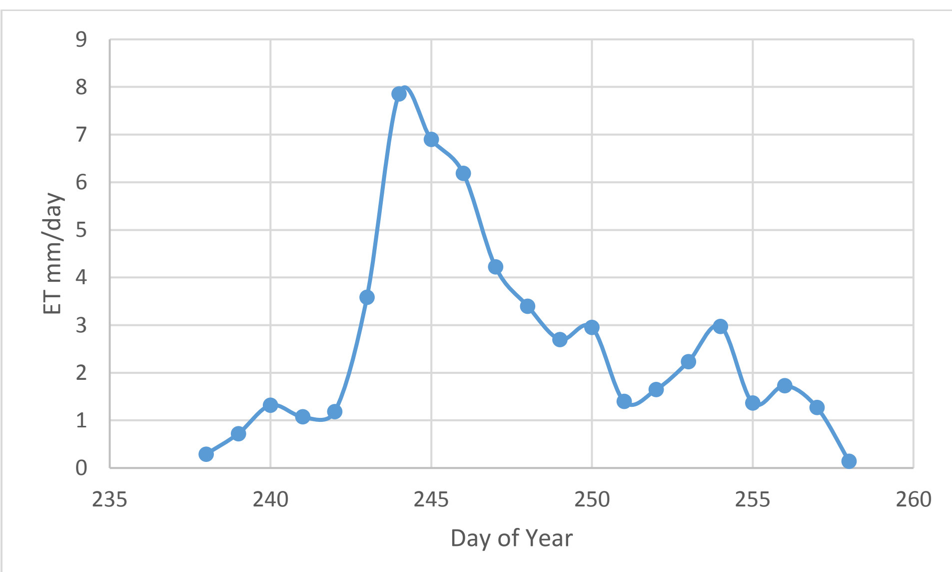


Figure 1. Evaporation (YCWUA site) before, during, and after pre-irrigation event.

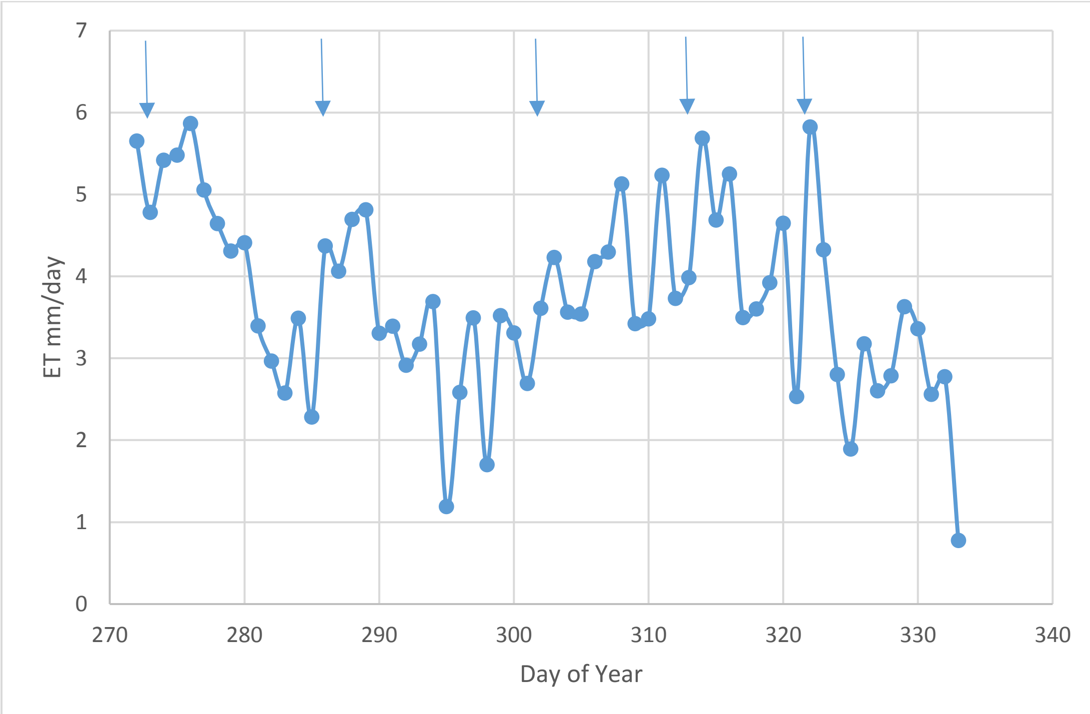


Figure 2. Daily ET over lettuce season (YID site). Arrows indicate irrigation events.

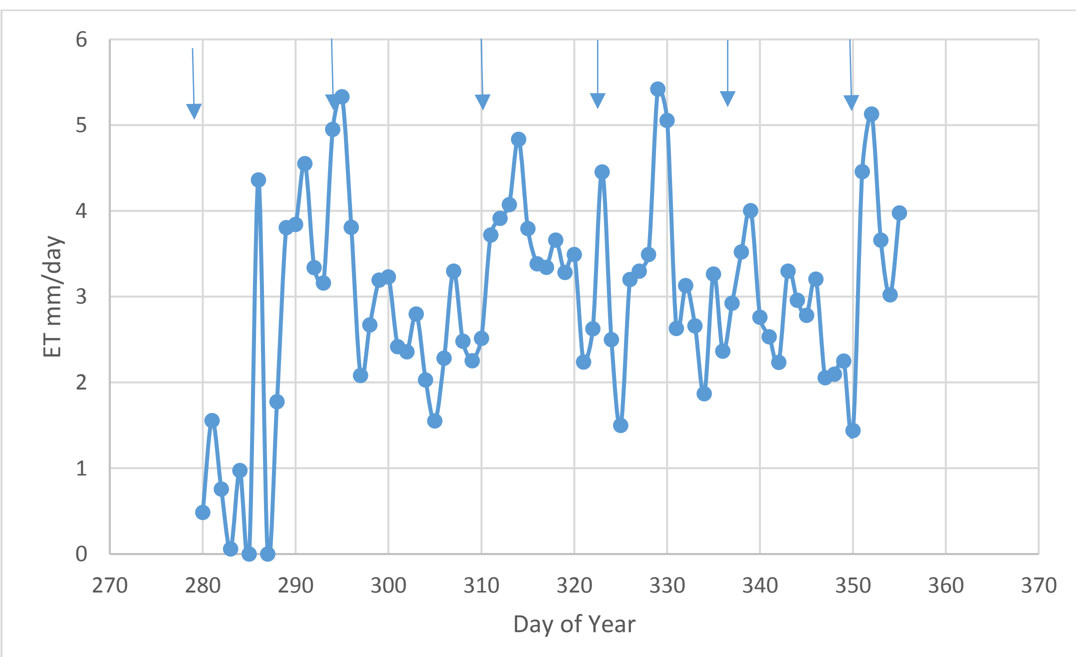


Figure 3. Daily ET over lettuce season (YCWUA site). Arrows indicate irrigation events.

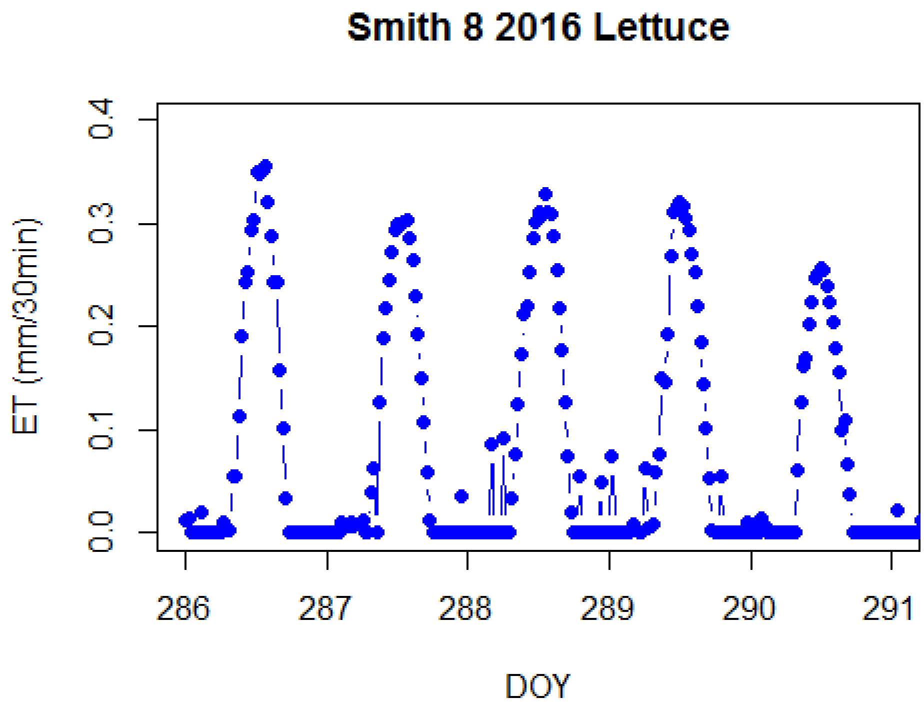
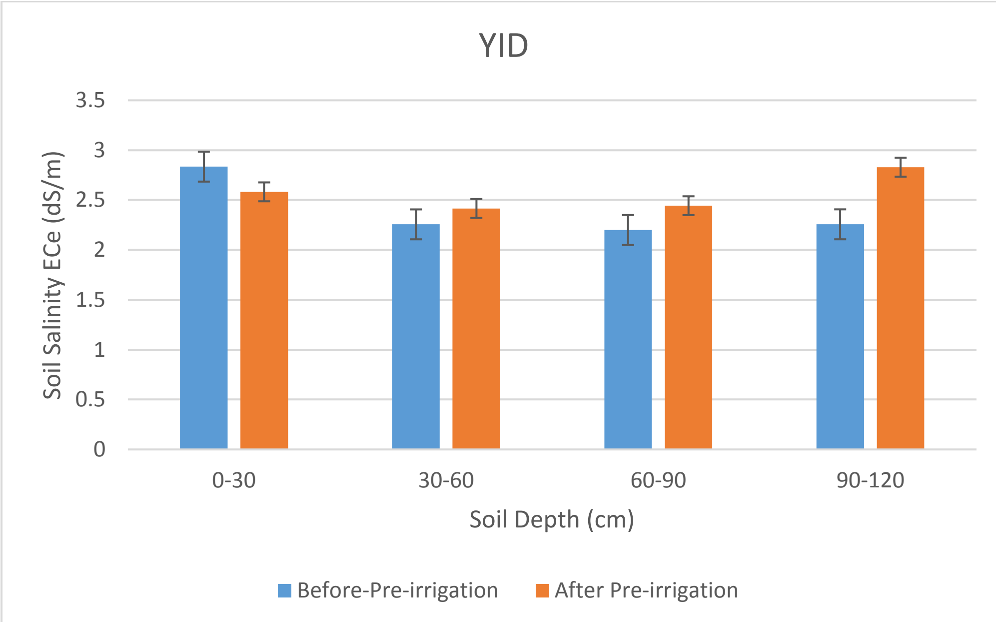


Figure 4. Diurnal changes in ET for five days after thinning irrigation (YID site)



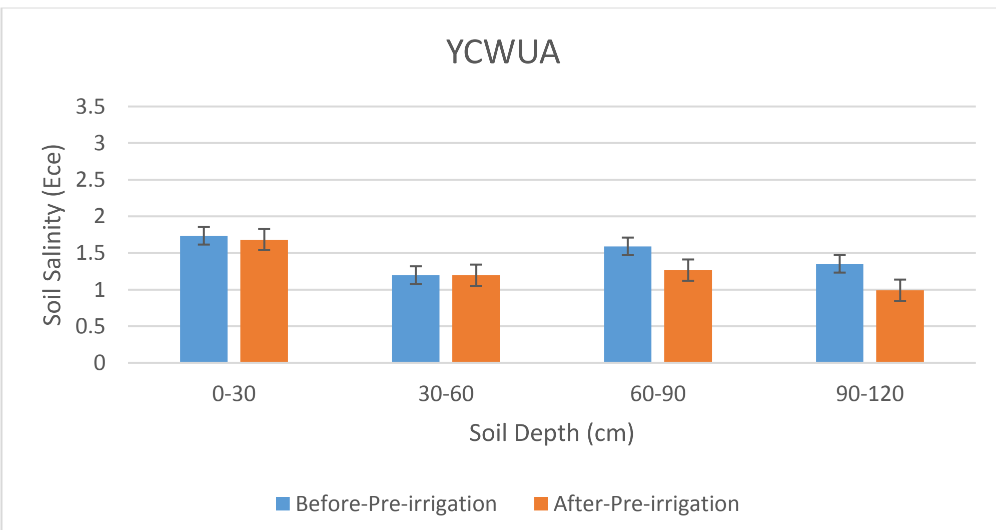
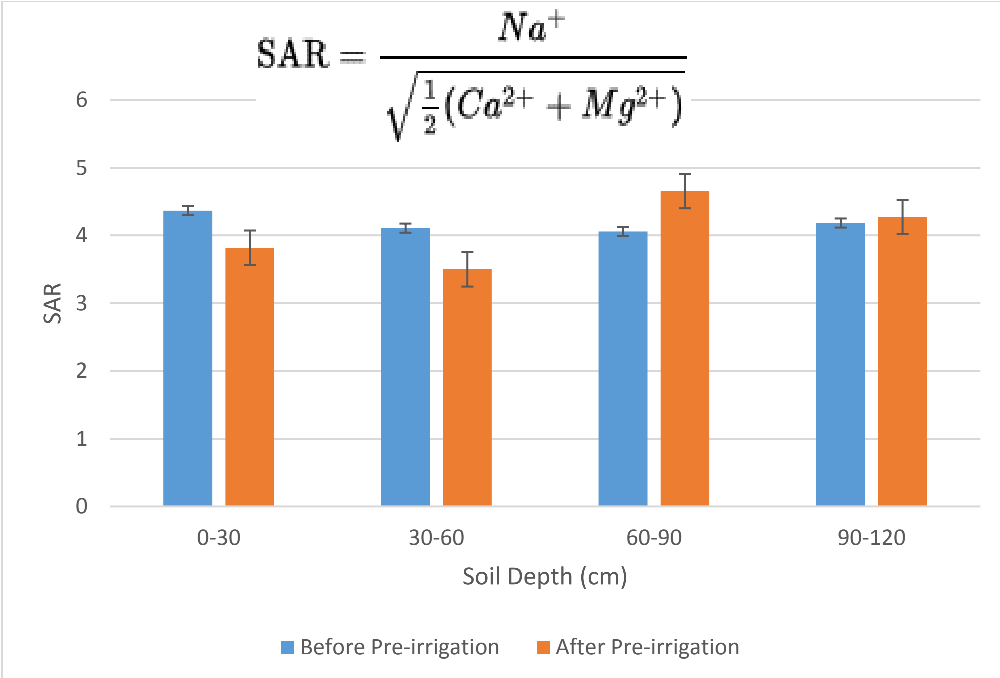


Figure 5. Changes in soil salinity to pre-irrigation in (a) YID site and (b) YCWUA site



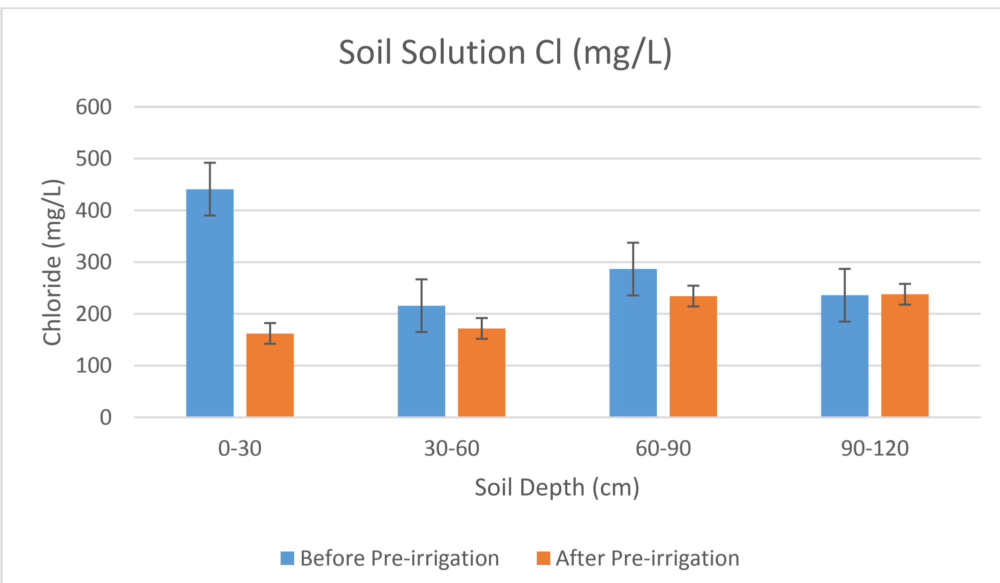


Figure 6. Changes in SAR and soil solution chloride due to pre-irrigation (YID site)

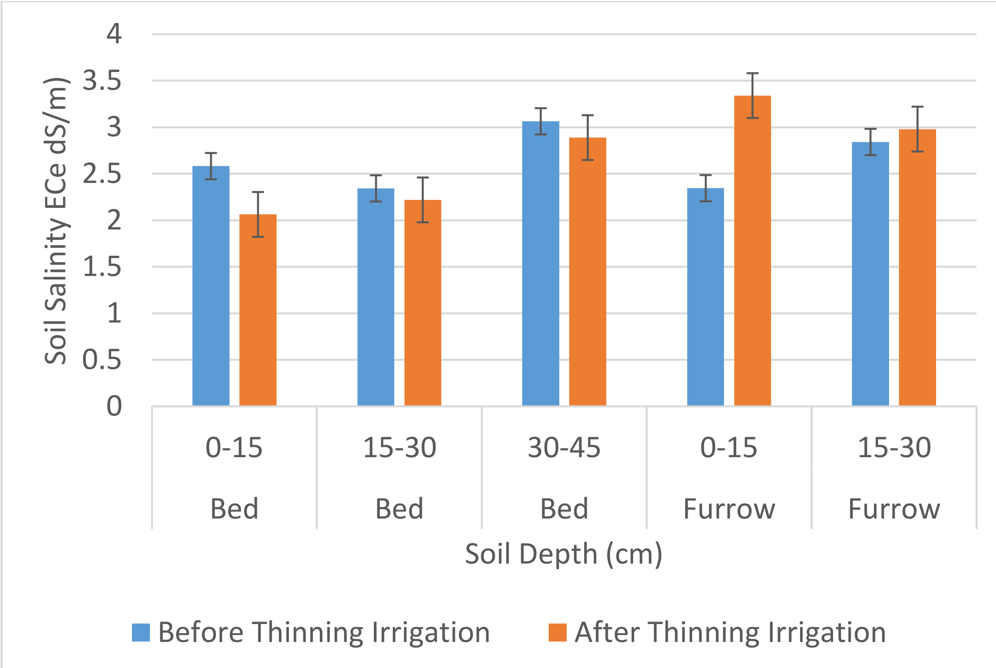


Figure 7. Soil salinity before and after thinning irrigation (YID site)

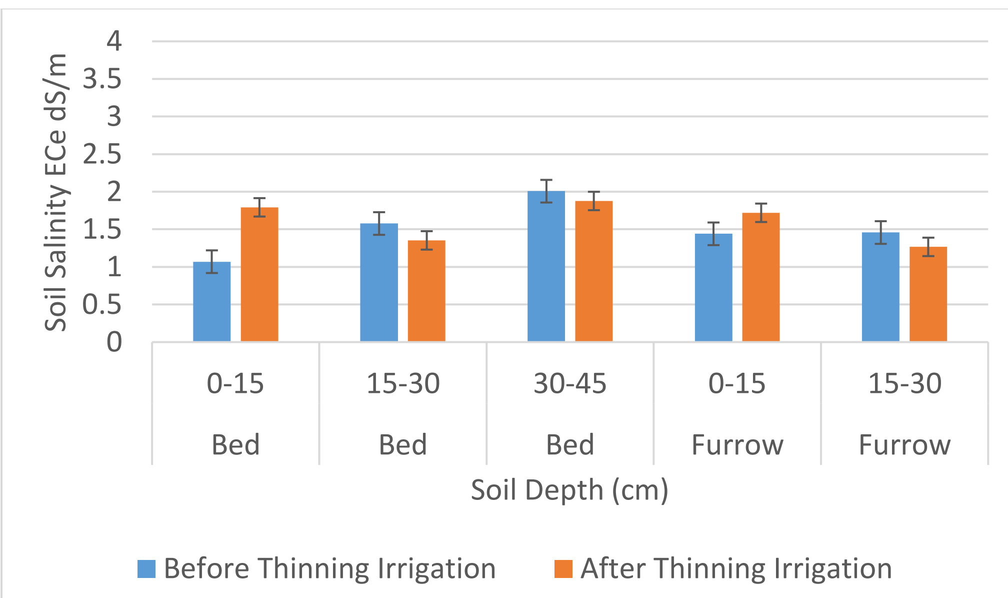


Figure 8. Soil salinity before and after thinning irrigation (YCWUA site)

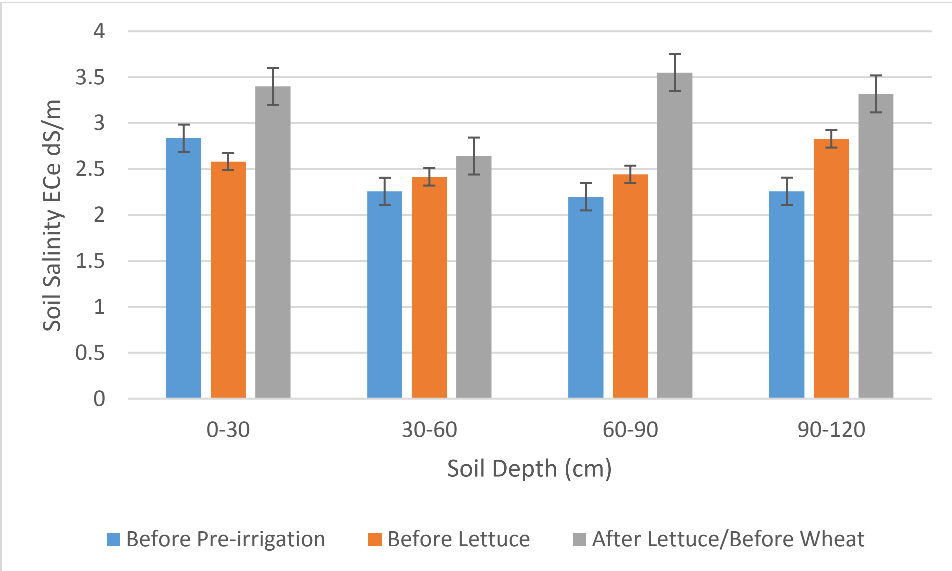


Figure 9. Changes in soil salinity at four soil depths over lettuce production season (YID site)

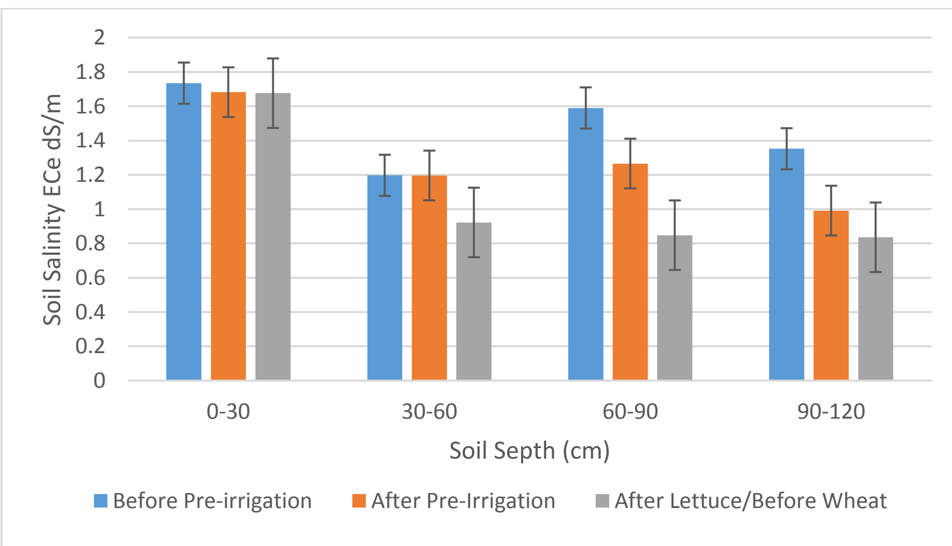


Figure 10. Changes in soil salinity at four soil depths over lettuce production season (YCWUA site)

Table 1. Saturation Indices for selected mineral species in soil solutions.

Mineral	Log IAP –Log Ks
Aragonite	0.733
Calcite	0.877
Dolomite (disordered)	0.889
Dolomite (ordered)	1.439
Gypsum	-0.826
Vaterite	0.310
KCl	-6.392