Final Report for the Project "Validation of iceberg lettuce stand establishment irrigation"

Abstract

On-farm and regional irrigation efficiency is often assessed by an expression of crop evapotranspiration (ETc) relative to the total water diverted or delivered to farms or districts. However, there are beneficial uses of water that would not be included into this expression of efficiency. One of these beneficial uses is water used for microclimate modification during stand establishment. For example, thermodormancy inhibits germination of lettuce and other vegetable crops. Appreciable amounts of water are often used during stand establishment to moisten seed beds and reduce near surface air and soil temperatures in an effort to combat thermodormancy. This water used for stand establishment would reduce water use efficiency relative to ETc, but is required for successful stand establishment. The objective of this project is to validate or perhaps modify this stand establishment beneficial use of water for lettuce in Yuma area irrigation districts. Results show the water used was essential for climate modification and successful stand establishment. Estimates show high evaporation and wind drift water losses during sprinkler irrigation. For early season stand establishment there was no effective leaching fractions and there was salt accumulation in all early season sites. Sustainability would require this leaching be achieved in another irrigation event. For latter season stand establishment, there was effective leaching and salts in the rooting zone were reduced.

Introduction

The use of sprinklers has been a major factor contributing to improved irrigation efficiency. Two decades ago, vegetable crops were principally established by "subbing". This practice involved running water in furrows until crop emergence, which typically took 7 to 10 days. Given that typical valley soils have a water intake rate of 3 to 5 inches per day estimates for the amount of water used for "subbing" range from 18 to 37 inches. Conversely, sprinklers used for crop establishment are typically run for 36 hours continuously, and thereafter, 4 to 6 hours per day as needed to keep the soil surface moist. The typical solid set sprinkler system used in the region delivers about 0.125 inches of water per hour. Given that a typical sprinkler system is operated for about 68 hours during crop establishment, the water required for crop establishment is reduced to less than 9 inches of water.

Consumptive use of water by lettuce is approximately 12 inches. However, seasonal water use may approach 20 inches because of water required for climate modification during stand establishment. Application efficiencies for furrow irrigation of lettuce in-season typically exceed 90% due to high inflows (>20 gallons/furrow/minute), rapid advance due to the reduced friction of trapezoidal furrows, and short irrigation runs (<600 ft). Using these practices water application rates in a given irrigation typically approximate 1.5 inches, approximately what a lettuce crops used in between irrigations. However, when seasonal water application efficiency is calculated based on consumptive use relative to total water applied, efficiencies of 60% are often reported due to the water used for stand establishment. This water would be considered a beneficial use since it is required for successful stand establishment. However, competition for water has created an urgent need to justify all water utilized in agriculture. The objective of this project is to quantitate and validate the water used for stand establishment by sprinklers.

Methods

All studies were performed in grower fields. Prior to initiation of sprinkler irrigation for stand establishment, fields were set up with rain gauges (catch cans) to record water application depth, and data loggers to record air and soil temperature, soil moisture, and bulk soil salinity (ECa). Probes calibrated to measure these variables were installed in selected soil increments to a depth of 30 or 45 cm (lettuce root zone). Data loggers were set up to record measurements on all these variables every 15 minutes. We used these data to record changes throughout the soil profile seeded to lettuce during stand establishment. In addition to the measurements collected with sensors and data loggers, soil samples were collected before and after stand establishment. On these soil samples we determined soil moisture, soil salinity (ECe), and estimated texture by saturation percentage. Salinity was also measured on the water samples collected to estimate evaporation losses during sprinkler irrigation.

Weather data were collected at each site. These data were used to estimate evaporation/wind drift losses using the method of Trimmer (1987).

Results

We will report results for six sites established at the beginning of the season and two sites established mid-season after the weather cooled significantly. The study date, soil moisture deficit at each site, run time, and water received at each site is shown in Table 1. The larger soil moisture deficits at imitation are associated with fields have a finer soil texture.

As anticipated, sprinkler did effectively reduce air and soil temperature as shown for the YID#1 site (Figures 1 and 2). The other sites in the early season were similar (data not shown). Climate modification, in addition to irrigation, is one of the reasons sprinklers system are used. Upon irrigation, the various soil depths fill with moisture approximately sequentially over the first 36 to 48 hour irrigation run as shown for the YID#1 site (Figure 3). The other sites in the early season were similar (data not shown).

Evaporation as estimated from salinity concentration of water in the catch cans and the combined evaporation wind drift losses as calculated from Trimmer 1987 are shown in Table 2. During the early season evaporation and calculated wind drift losses are high. While we are confident in the evaporation estimates obtained by salt concentration increase of the water we are not certain of estimates calculated with the Trimmer equation. Future work using Eddy Covariance methods is planned to gain better estimates of evaporation and wind drift losses during sprinkler irrigation.

Measured bulk salinity (ECa) over the irrigation event is shown in Figure 4 for the YID#1 site. Overall, bulk salinity does not change dramatically and there is upward flux depending on irrigation run time and the diurnal solar cycle. Results for other sites in the early season are similar.

The measured soil salinity (ECe) at selected soil depths before and after sprinkler stand establishment are shown in Figures 5 and 6 for sites YID#1 and Bard#1. Although, there is some redistribution, and some variation among sites, for all sites there is a net salt accumulation in the top 45 cm soil depth during sprinkler stand establishment in the early season. The salt balance for all early season sites are shown in Table 3. For all sites, over 1 metric tons of salt was added with the sprinkler water and there is net salt accumulation in the surface 45 cm of all sites. Many of the cool season vegetables produced in Yuma are sensitive to soil salinity and sustainable production would require this leaching occur in a subsequent irrigation event.

Measured soil temperature and soil moisture latter in the season for site YCWU#1 is shown in Figures 7 and 8. As with the early season sites, soil layers fill with moisture approximately sequentially during the irrigation event but there is change due to irrigation event and solar cycle. Bulk soil salinity (ECa) during the irrigation event for YCWU#1 is shown in Figure 9. As with the early season sites, salts flux with irrigation event and diurnal cycle but there seems to be a gradual decline suggesting increased efficacy of leaching. This is not surprising being that the vapor pressure deficit is lower. The measured soil salinity before and after sprinkler stand establishment for YCWU#1 and #1 are shown in Figures 10 and 11. The salt balance for the late season sties is shown in Table 4. In contrast to the early season sites, there is a reduction in soil salinity in the top 45 cm soil depth indicating salt leaching was achieved. The higher leaching is likely associated with a lower vapor pressure deficit and less evaporation losses, the cooler temperatures delaying germination, and a resulting need for more irrigations to keep the seed near the soil surface wet.

Overall, it seems the water applied during the stand establishment operation is nearly optimal. During the early season salt accumulation occurs due to the large vapor pressure deficits but the required leaching must occur in subsequent irrigations since sprinklers will not be an efficient means of leaching due to the high evaporation. After the weather cools, there appears to be some leaching with sprinkler stand establishment and this is required leaching that will not have to be implemented in subsequent irrigation events.

Literature Cited

Trimmer, W.L., 1987. Sprinkler evaporation loss equation. J. Irrig. Drain. Eng., ASCE 113 (4), 616–620.

Table. 1. Experimental period, initial soil moisture deficit, total run time, and total water received for eight experimental sites in fall 2015.

Site	Wet date	Soil Deficit (cm)	Last Run date	Sprinkler Events	Total Run Time (hours)	Water Received (cm)
YID1	Sept. 11	-8.6	Sept. 15	4	64	12.8
YID2	Sept. 12	-8.9	Sept. 16	4	60	12.2
WMID1	Sept. 11	-8.7	Sept. 16	5	54	11.1
WMID2	Sept. 12	-7.9	Sept. 18	6	54	13.1
WMID3	Sept. 13	-7.8	Sept. 18	5	44	10.8
BARD1	Sept. 12	-10.3	Sept. 20	6	56	8.9
YCWUA1	Nov. 5	-12.9	Nov. 12	8	66	17.4
YCWUA2	Nov. 6	-13.0	Nov. 15	9	65	17.0

YID=Yuma Irrigation District, WMID=Wellton Mohawk Irrigation District, Bard=Bard Irrigation District, YCWUA=Yuma County Water Users Association.

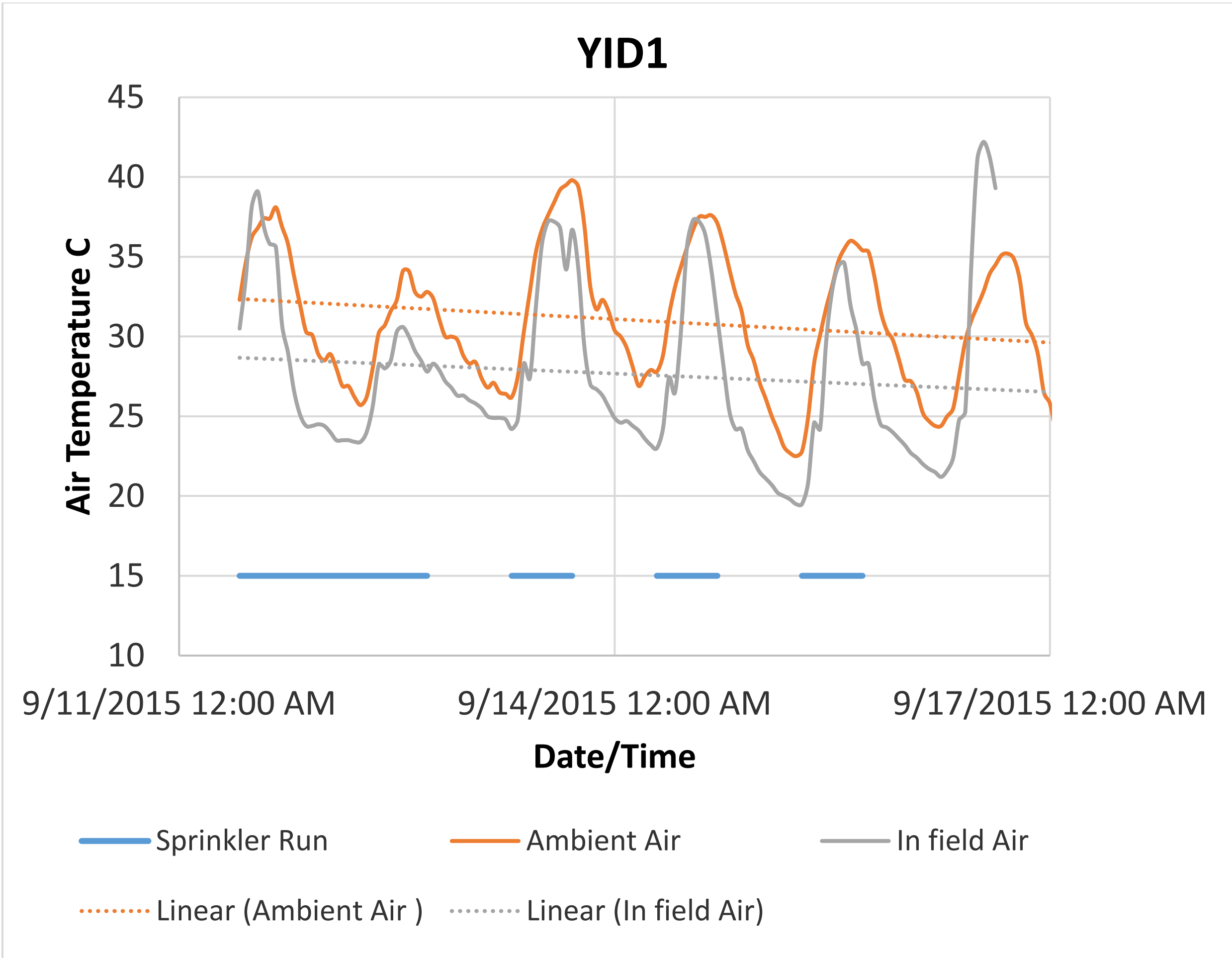

Figure 1. In field and outside ambient (no sprinklers) air temperature during sprinkler stand establishment irrigation.

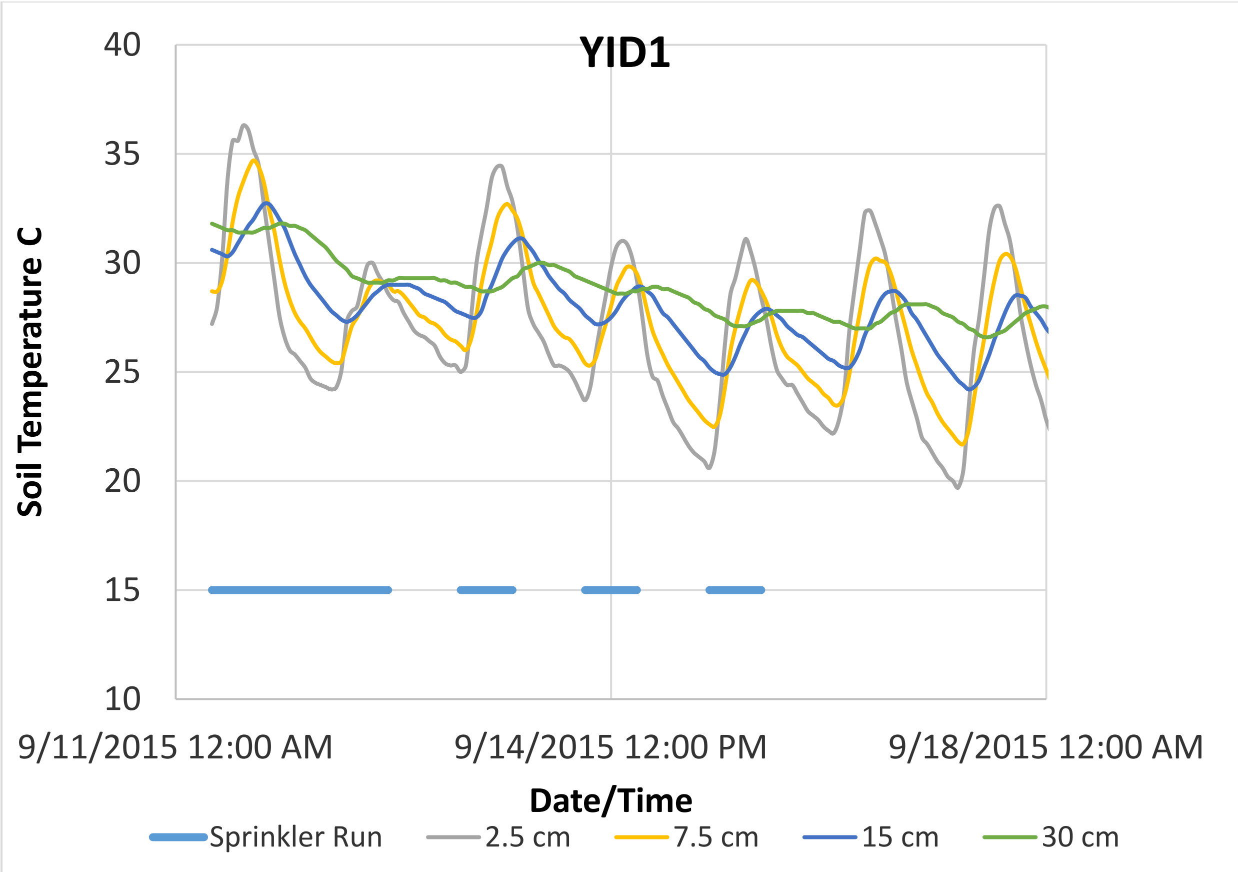

Figure 2. Soil temperatures at several soil depth during sprinkler stand establishment irrigation.

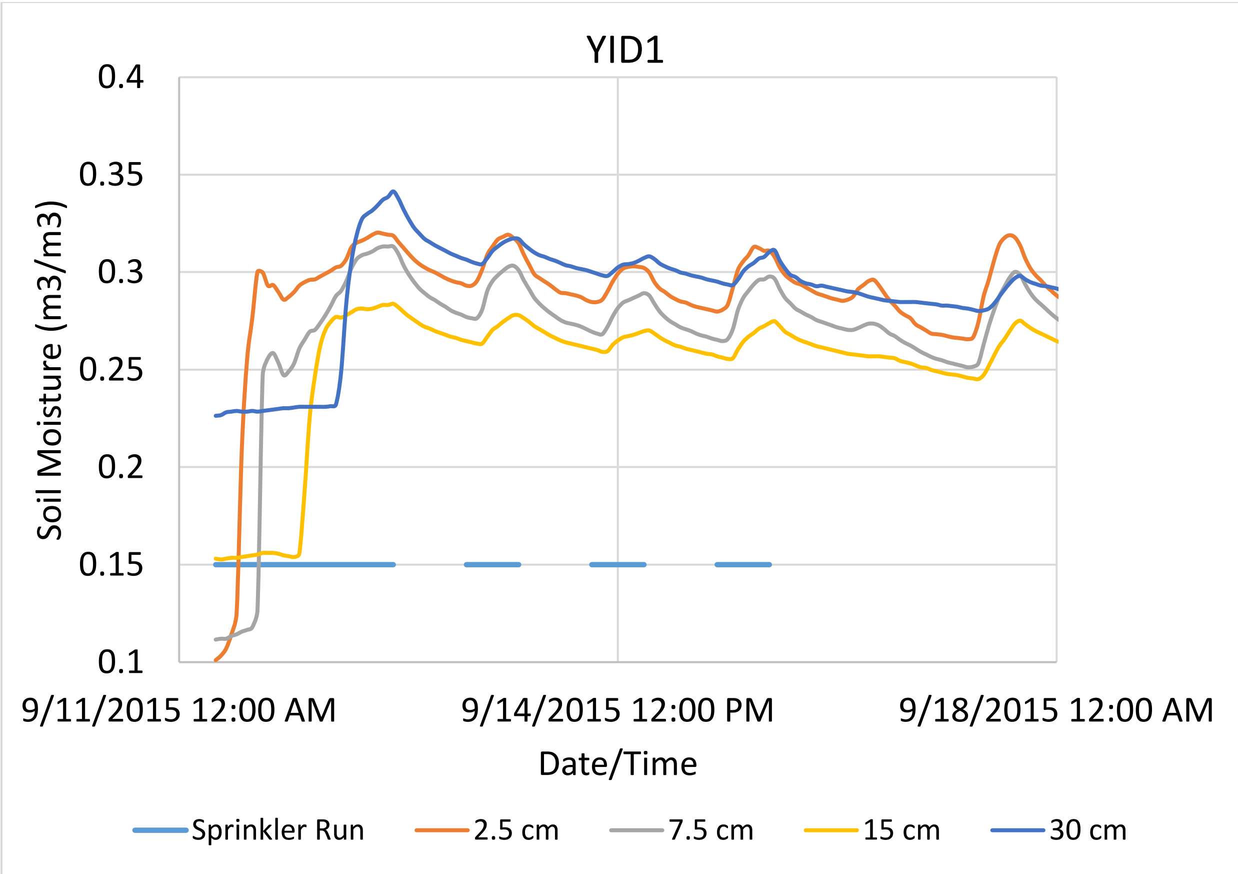

Figure 3. Soil moisture at several soil depth during sprinkler stand establishment irrigation.

Table 2. Vapor pressure deficit, wind speed, evaporation losses, and calculated evaporation/wind drift losses during sprinkler stand establishment eight experimental sites.

Site	Vapor Pressure Deficit	Wind Speed (m/s)	Evaporation (%)	Evaporation/Wind Drift (%)
YID1	2.9	2.7	22	38
YID2	2.9	2.9	25	38
WMID1	2.5	2.5	26	32
WMID2	2.7	2.3	28	33
WMID3	2.9	2.4	21	28
BARD1	3.1	3.4	24	41
YCWUA1	1.6	3.6	10	32
YCWUA2	1.6	2.7	19	28

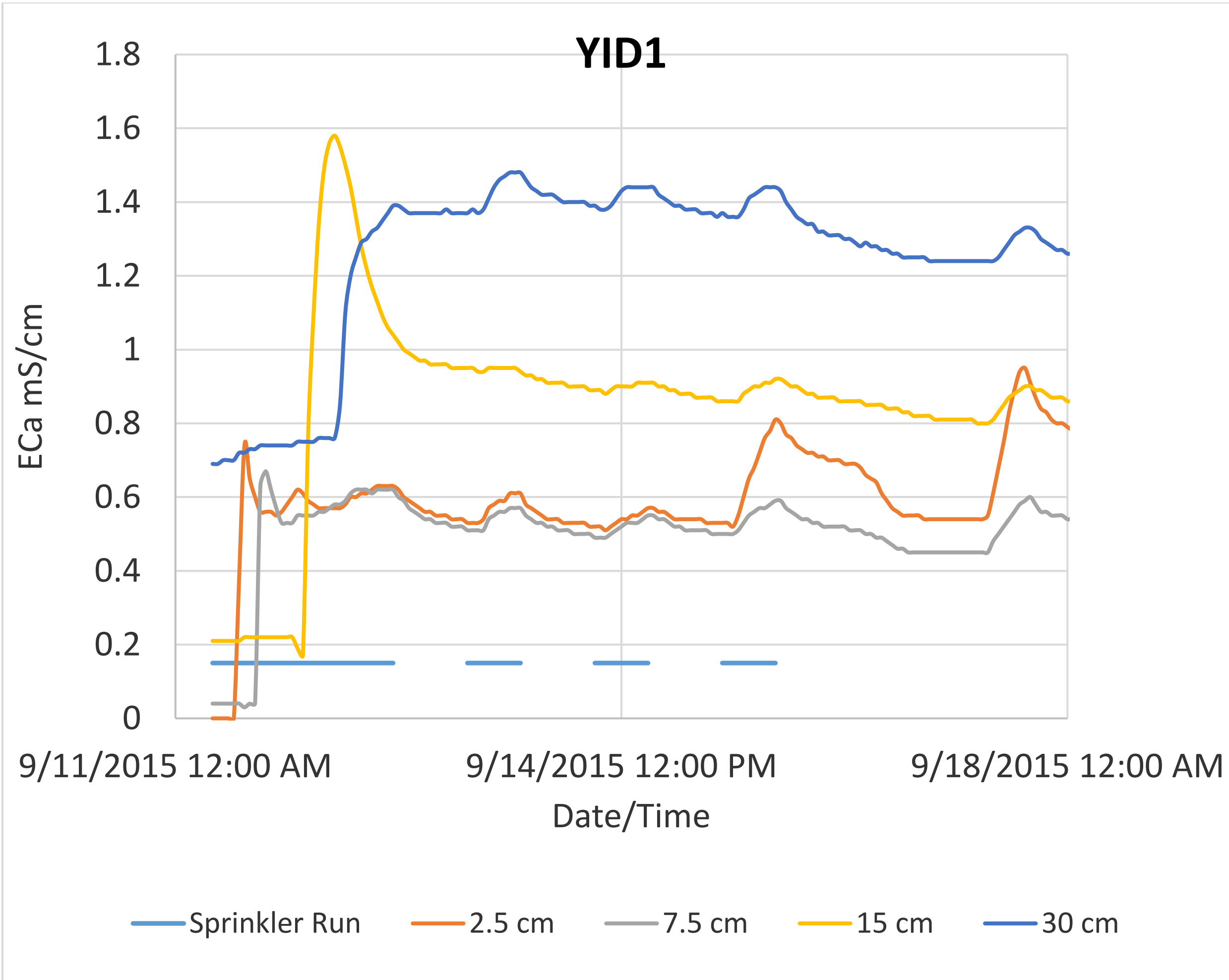

Figure 4. Bulk salinity at selected soil depths during sprinkler stand establishment.

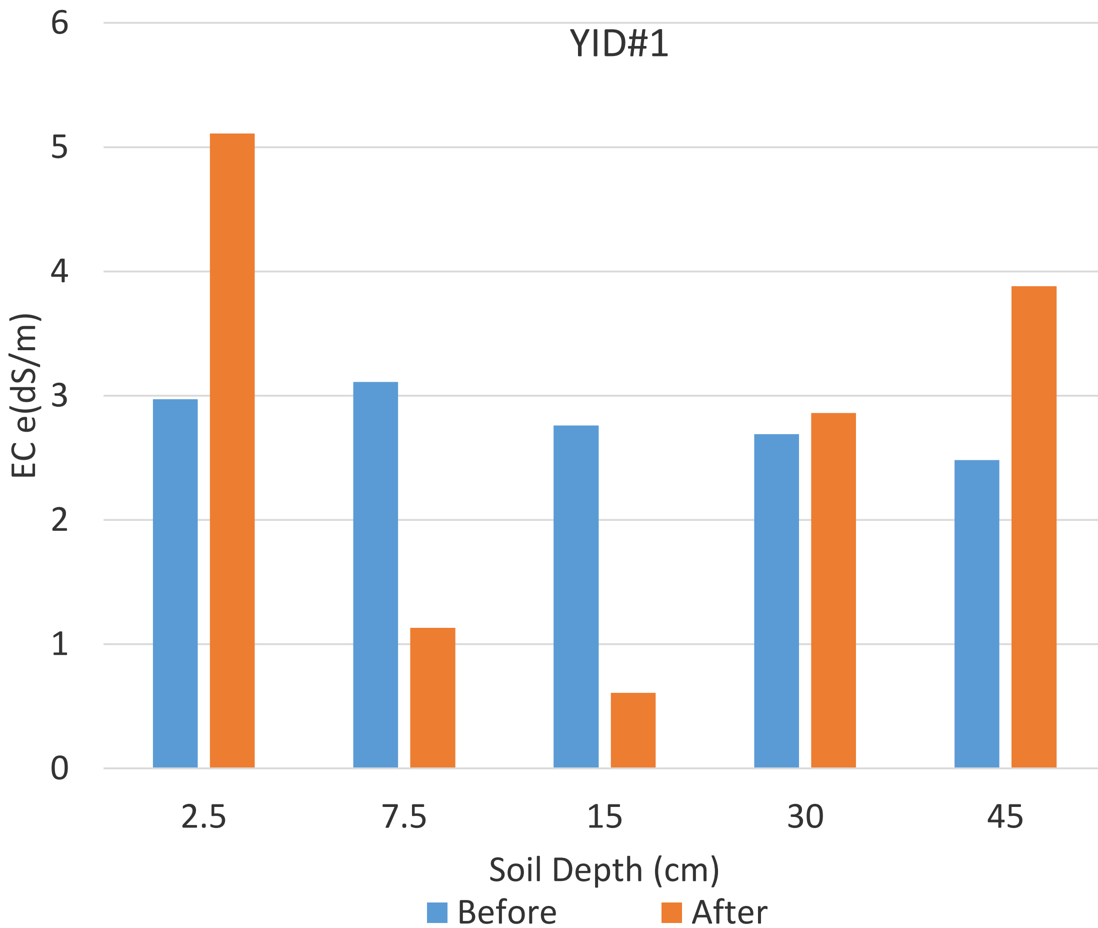

Figure 5. Soil salinity (ECe) at selected soil depth before and after stand establishment irrigation for site YID#1

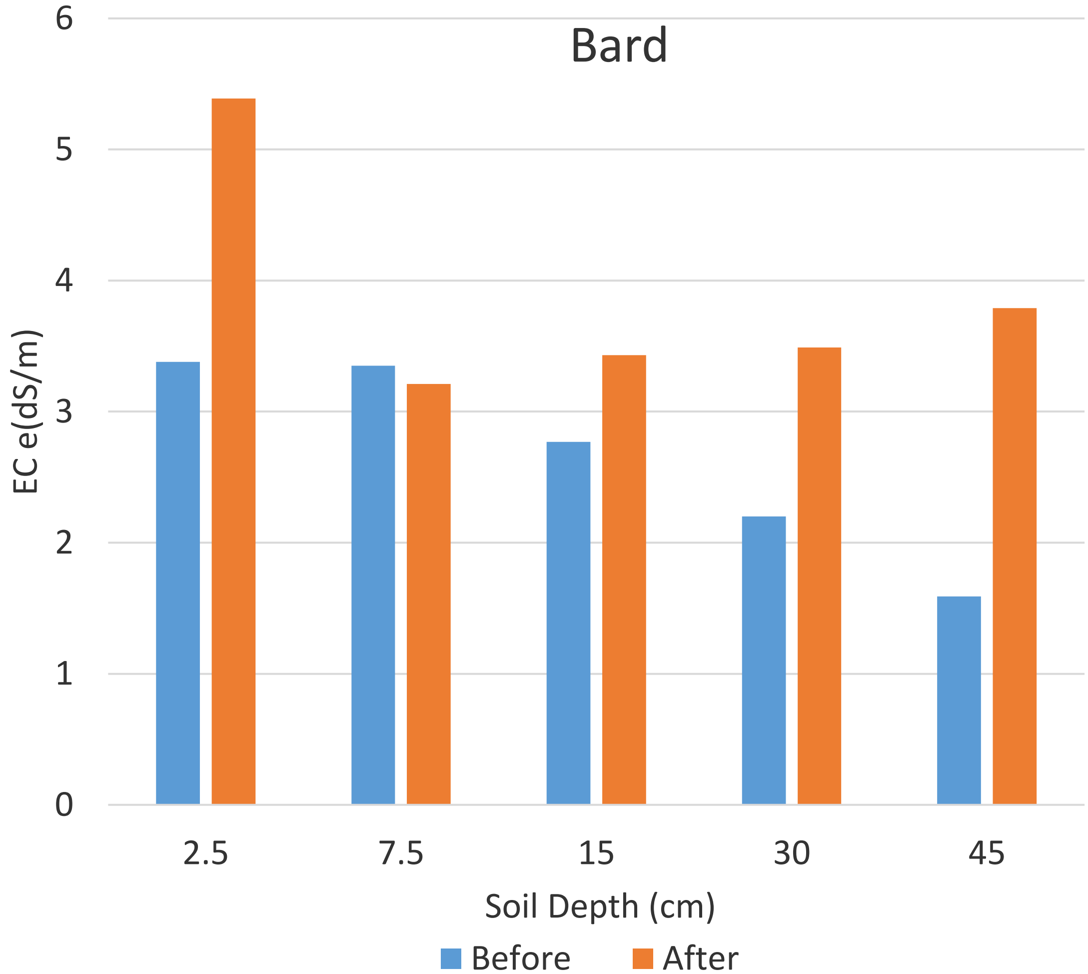

Figure 6. Soil salinity at selected soil depths during sprinkler stand establishment for site Bard#1.

Table 3. Salt balance during sprinkler irrigation stand establishment for early season sites.

Site	LF	LR	Water Salt Load (MT/ha)	Soil Water Salt (30 cm) MT/ha		Soil Water Salt (45 cm) MT/ha	
				Before	After	Before	After
YID1	0.30	0.31	1.2	2.7	2.3	3.8	4.4
YID2	0.24	0.31	1.2	2.7	2.9	4.5	4.8
WMID1	0.05	0.33	1.1	2.7	2.7	3.3	4.0
WMID2	0.27	0.34	1.4	2.1	2.5	3.1	4.0
WMID3	0.13	0.30	1.0	2.2	2.6	3.2	5.6
BARD1	0	0.27	1.1	2.8	3.6	3.6	5.3

LF=Leaching fraction achieved, LR=Leaching required.

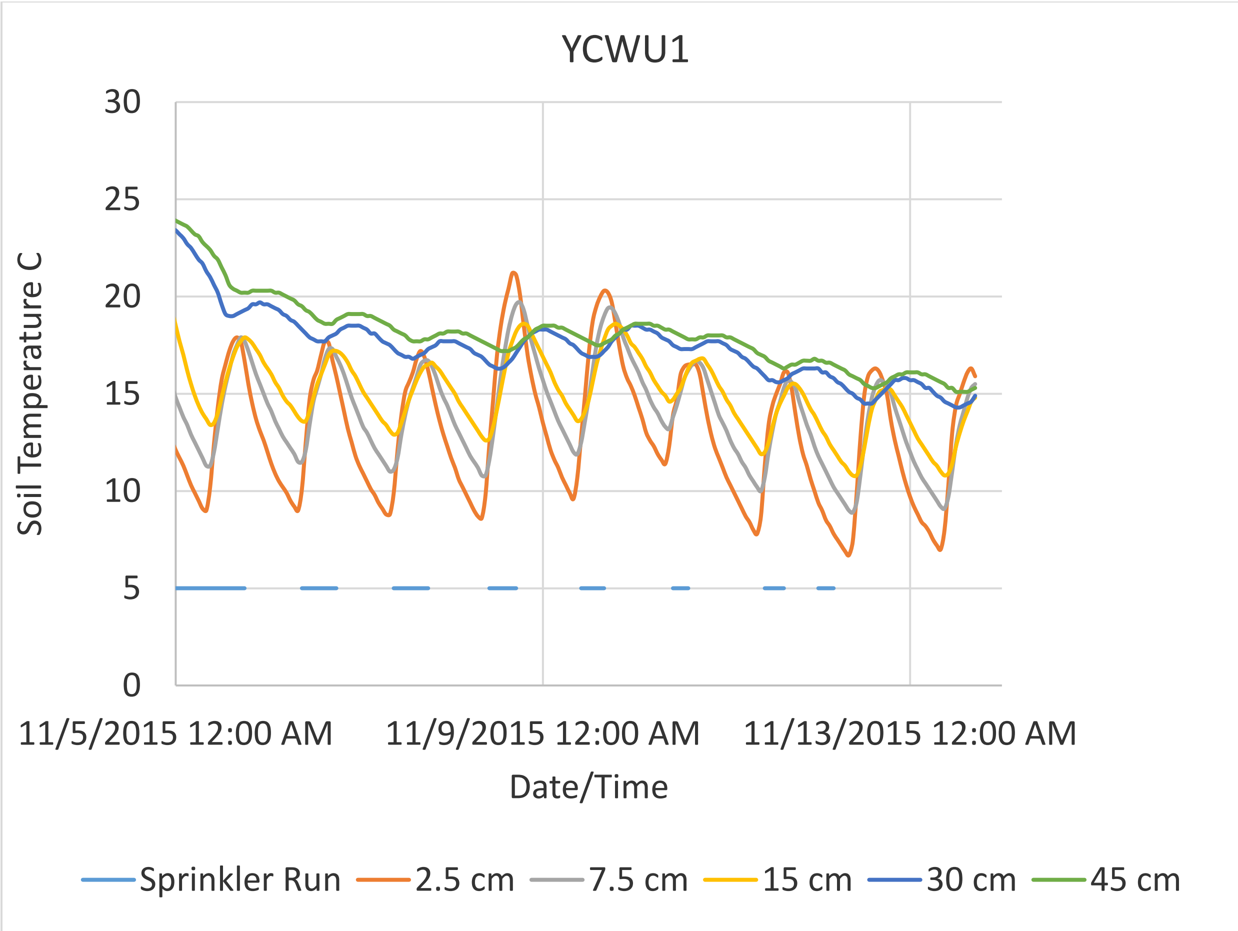

Figure 7. Soil temperature at selected soil depth for stand establishment irrigation for YCWU#1 (a latter season site).

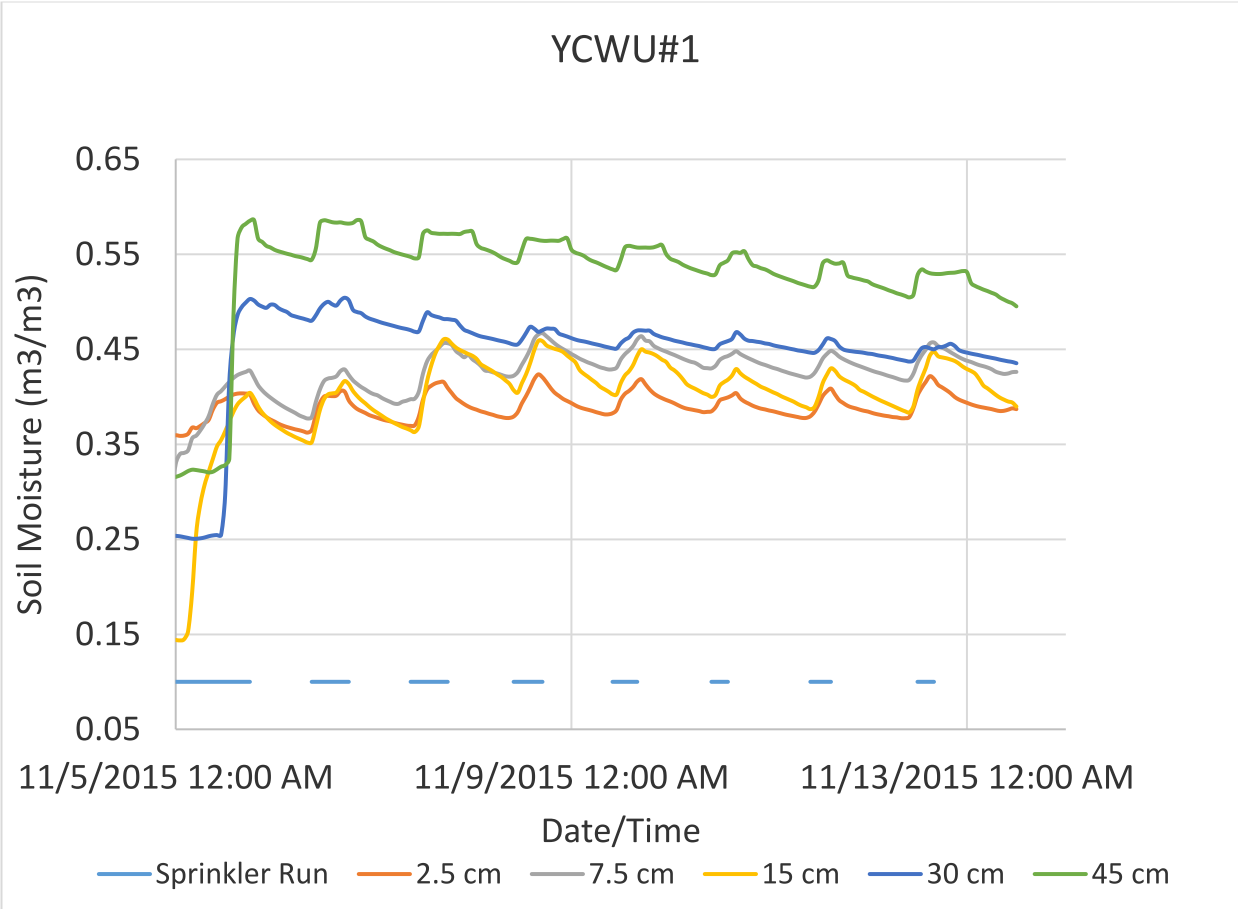

Figure 8. Soil moisture at selected soil depths during sprinkler stand establishment for YCWU#1.

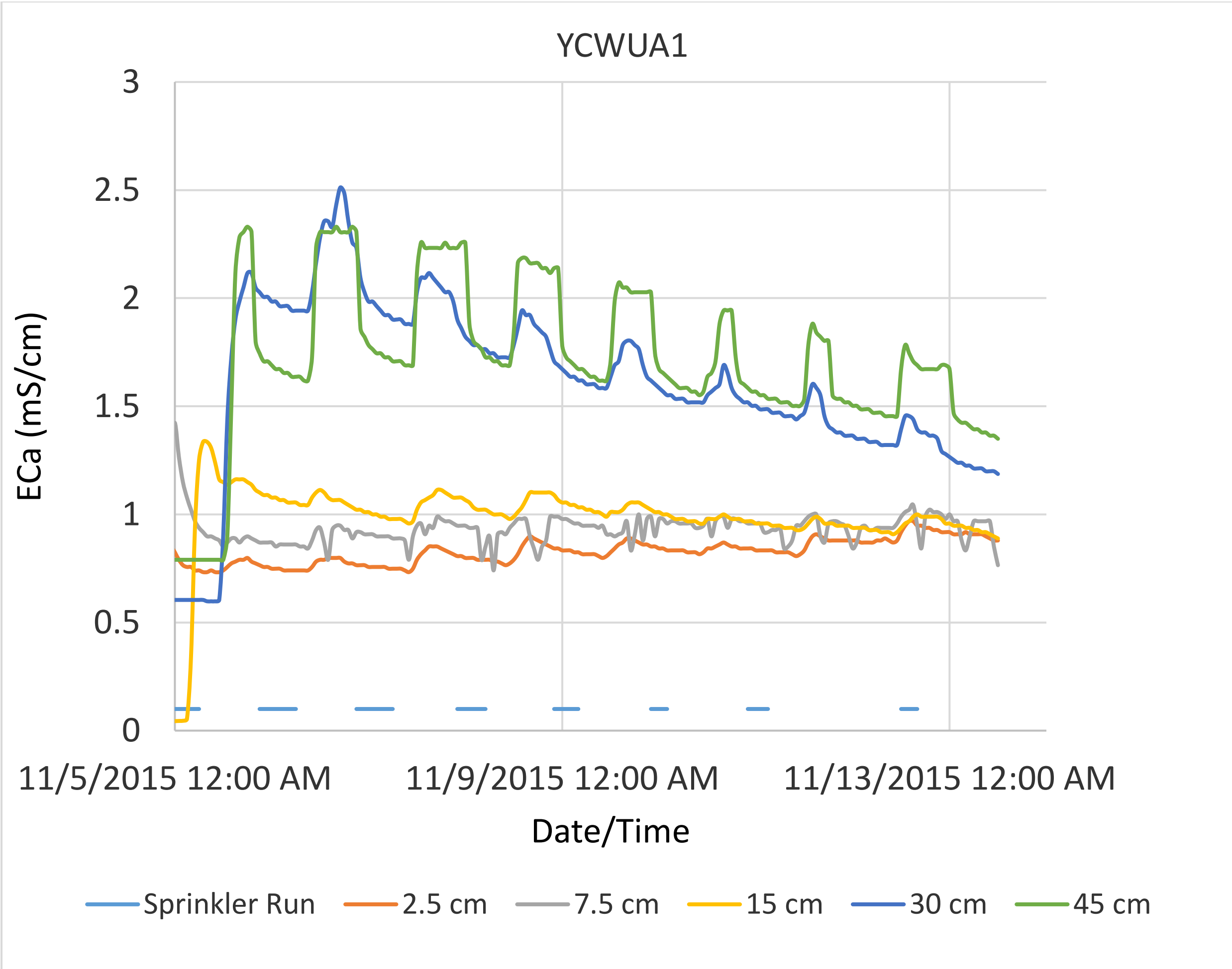

Figure 9. Bulk soil salinity (ECa) at selected soil depths during sprinkler stand establishment for YCWU#1.

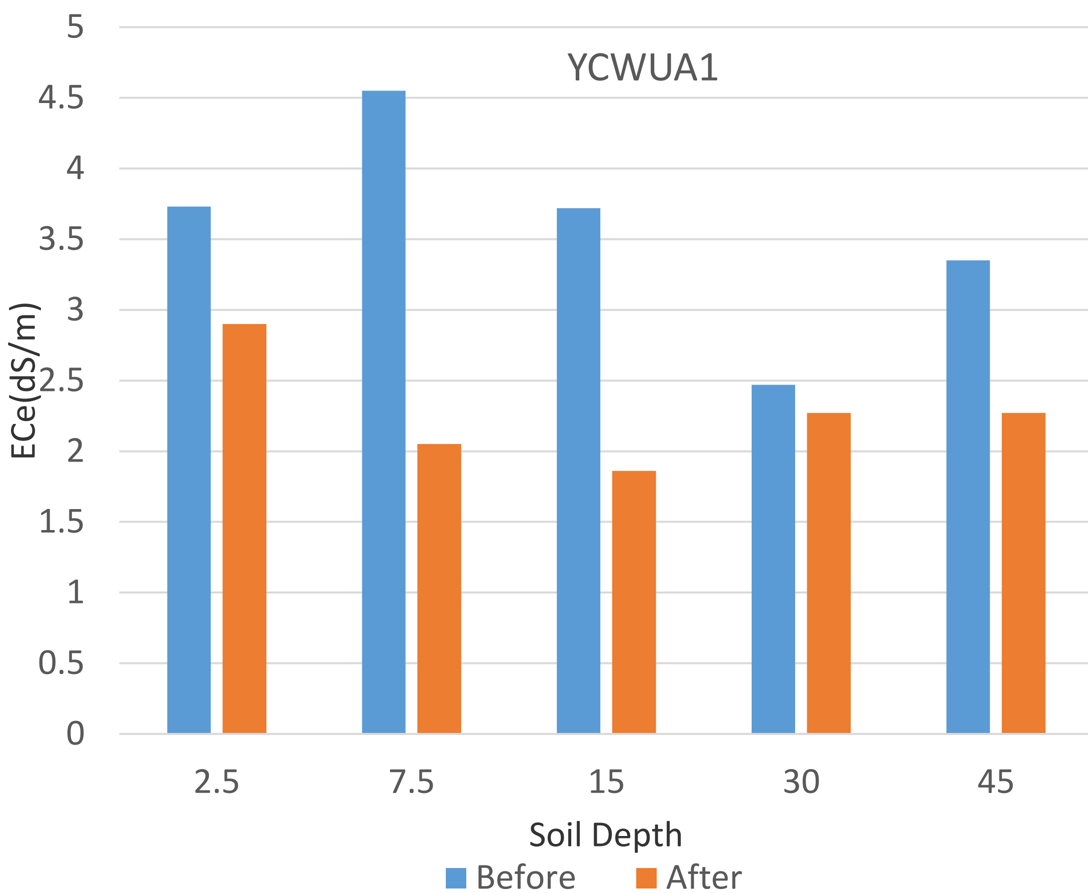

Figure 10. Soil salinity (ECe) at selected soil depths before and after sprinkler irrigation stand establishment for YCWUA#1.

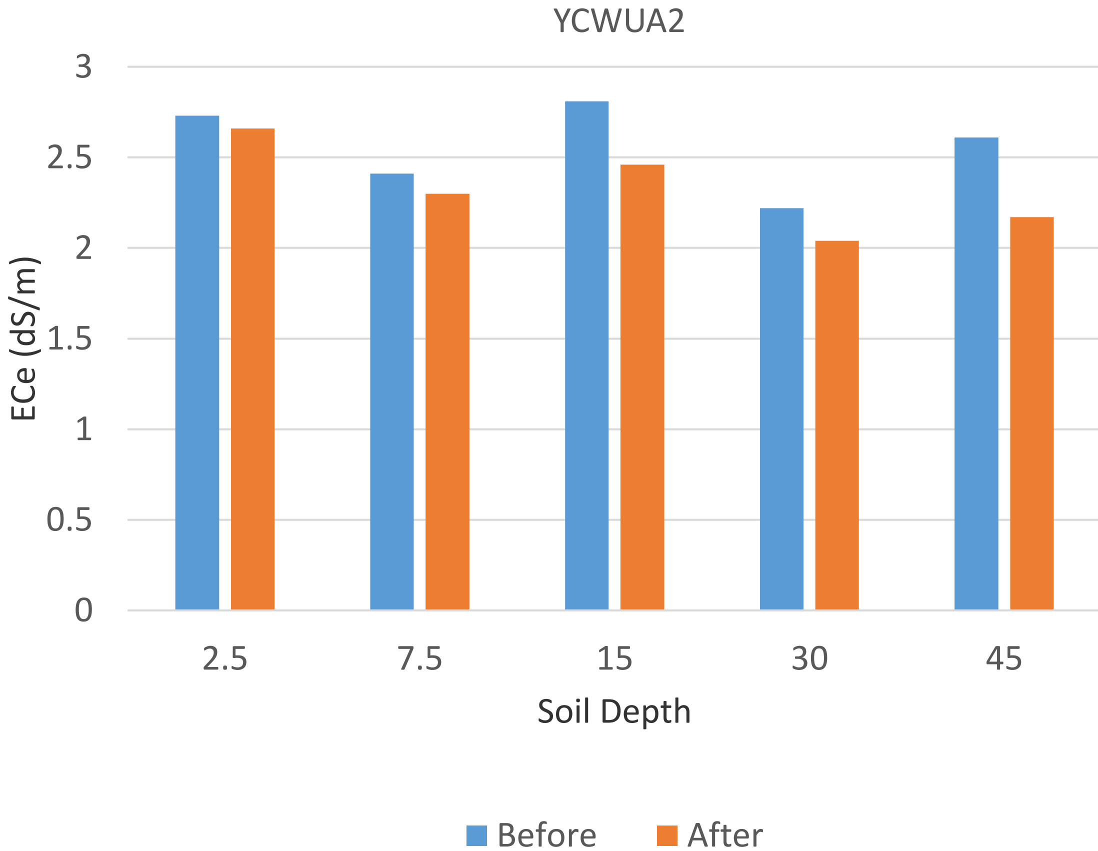

Figure 11. Soil salinity (ECe) at selected soil depths before and after sprinkler irrigation stand establishment for YCWUA#2.

Table 4. Salt balance during sprinkler irrigation stand establishment for latter season sites.

Site	LF	LR	Water Salt Load (MT/ha)	Soil Water Salt (30 cm) MT/ha		Soil Water Salt (45 cm) MT/ha	
				Before	After	Before	After
YCWUA1	0.20	0.26	1.5	3.8	2.3	7.4	4.7
YCWUA2	0.15	0.30	1.4	3.1	2.9	6.3	5.8