International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p:235-243

# Soil Salinity in a Drip and Furrow Irrigated Cotton Field under Influence of Different Deficit Irrigation Techniques

**Harun Kaman[1,*], Mahmut Çetin[2], Cevat Kirda[2]**

[1] Akdeniz University, Faculty of Agriculture, Dept. of Agricultural Structures and Irrigation 07058 Antalya– Turkey

[2] Çukurova University, Faculty of Agriculture, Dept. of Agricultural Structures and Irrigation 01330 Adana–Turkey

E-mail, hkaman@akdeniz.edu.tr; Fax, +90 242 227 4564; Tel., +90 242 310 2468

**ABSTRACT**

We investigated the influence of conventional deficit irrigation (CDI) and partial root zone irrigation (PRI) on soil salinity in a drip- and furrow-irrigated cotton field. Under PRI, one half of the rooting zone is wetted while the other half is maintained partially dry, and thus reduced amount of water is applied. The wetted half of the root zone is alternately changed either every or every other subsequent irrigations. Effects of time length during which one side of the root zone stays wet or partially dry on soil salinity were investigated for only furrow irrigated cotton. We had compared proportional soil salinity developed under CDI and PRI under drip irrigation. Thus we had two field experiments consisting separately drip- and furrow-irrigated cotton. The treatments under furrow irrigated cotton were (1) FULL, control treatment where rooting zone soil water content was increased to field capacity at each irrigation; (2) 1PRI and (3) 2PRI, 50% deficit irrigation compared to FULL treatment was applied while interchanging wetted and partially dry sides every and every other irrigations, respectively. The drip-irrigated cotton had similarly three treatments: (1) FULL, the control treatment where full amount of irrigation water (100% Class-A pan evaporation) was applied to both sides of the plant rows; (2) 1PRI and (3) CDI, where the both treatments had 50% deficit irrigation compared to FULL treatment. Under CDI treatment, the deficit amount of water was uniformly applied to both sides of the cotton rows. Soil salinity was assessed utilizing root zone soil salinity profiles developed at planting and following harvest. Additionally we had iso-salinity maps constructed with grid soil sampling of plant root zone at harvest. The results showed that soil salinity increase was significant ($P<0.05$) only within soil surface layer of 0-20 cm. The highest increase in soil salinity was noted under the treatment of 2PRI with furrow irrigation. The drip irrigated cotton data showed that the salinity increase under PRI was in the same range as the FULL treatment whereas the increase under CDI was the highest. However, any likely soil salinity increase, resulting from deficit irrigation either with CDI or PRI practices, was at levels which could easily be leached with winter rains.

**Keywords:** Water use efficiency, PRI, salinity profile, water quality, salinity map, cotton.

## INTRODUCTION

Fertile agricultural areas decrease as a result of uncontrolled soil salinity. Over 23% of world's agricultural lands are under the effects of salinity problem experienced by more than 100 countries (Szabolcs, 1989). Annually, $4\times10^4$ ha of agricultural lands is left out of cultivation due to salinity (Lamsal et al., 1999). Salinity problem existing in our country is nearly 20% of all irrigated areas (Konak et al., 1999). High soil salinity hinders plant growth and development and thus may reduce crop yields. Katerji et al. (1998) showed that the salinity reduces stomatal conductance and leaf area. Thus the crop water consumption was decreased. The decreasing water consumption led to significant yield loss. In another study, leaf area, plant height, plant dry matter and some other plant development parameters were all hindered with increased soil salinity in addition to decrease of crop water consumption (Romero-Aranda et al., 2001). It is known that increase of salinity both in soil and irrigation water adversely influence plant development and yield.Excess irrigation may cause rising of ground water table which may carry salts from subsurface to surface layers through capillary rise and evaporation (Turhan and Baser, 2001). Irrigation practice should be in such a way that soil salts could adequately be leached while no standing water left at surface following irrigation. To this effect, studies on new irrigation technologies aiming at both increasing water use efficiency and crop yields are receiving high priority. Conventional deficit irrigation (CDI) may adversely reduce leaf area and plant development although significant savings of irrigation water may be achieved (Kirda et al., 1999). However, there may be significant decrease of yield as well as quality of crops. It was documented that if partial root zone irrigation (PRI), an alternative to CDI, is used, the saving of irrigation water can be achieved without significant reduction of yields (Kang et al., 2000; Chaffey, 2001; Stikic et al., 2003; Nakajima et al., 2004). Half of the root zone is wetted with reduced amount of irrigation water under if the PRI technique is in use. Similar to CDI, available water resources are used effectively and most efficiently with PRI practice (Kang et al., 1998; Zegbe et al., 2004). Although vegetative growth was reduced, the yield and crop quality were not affected and maintained at nearly the same levels under PRI, compared to full irrigation with no deficit (Dry and Loveys, 1998; Kang et al., 2000, 2001; Mingo et al., 2003; Zegbe-Dominguez et al., 2003).

Water resources allotted to irrigated agriculture is to be reduced because of increase demand by municipal and industrial use of water. Therefore new innovations in irrigation techniques aiming at improving effective use of limited irrigation water resources are needed. The PRI is promoted as a new technique which was known to reduce significantly irrigation water requirement. The work under taken here evaluates soil salinity developed under furrow and drip irrigation with PRI practice.

## MATERIALS and METHODS

The experimental work was carried out at Research Fields of Cukurova University, Faculty of Agriculture (36º 59' N, 35º 18' E, 20 m above see level), Adana, Turkey. The area has typical Mediterranean climate, with cool and rainy winters, hot and dry summers. Long term annual average rainfall in the area is 646.5 mm. During summer, humidity increases with starting of irrigation season. The humidity decreases during winter.

Soils at the site belong to Mutlu series with medium lime content of dark reddish brown color. Soil profile has high clay content of 2:1 type with swelling and cracking characteristics upon wetting and drying. Some physical and chemical properties of soils at the experimental site are given in Table 1. The site had no salinity problem. Salinity and other chemical analysis of irrigation water diverted from the irrigation channel were carried out using the methods described by USSL (1954). Irrigation water quality was rated as $C_2S_1$.

The field experiments testing 4 irrigation treatments (FULL, 1PRI, 2PRI and CDI) with 3 replicates were conducted for two seasons using randomized complete block design. The FULL treatment received full amount of irrigation water with no deficit. The 1PRI had 50% deficit irrigation compared to FULL irrigation and the irrigated half of the rooting zone was alternated every irrigation. The treatment 2PRI had also similar level of deficit as 1PRI with however alternation of the wetting side was done every second irrigation. The treatment CDI also had 50% deficit irrigation, compared to FULL irrigation, but water was applied uniformly to wet complete rooting zone as done under FULL treatment. During the first year of work, the treatments FULL, 1PRI and 2PRI were implemented with furrow irrigation. During the second year the treatments FULL, 1PRI and CDI were tested using drip irrigation.

Table 1. Some physical and chemical properties of the experimental soil

| Depth, cm | FC, $cm^3\ cm^{-3}$ | PWP, $cm^3\ cm^{-3}$ | BD, $g\ cm^{-3}$ | OC, % | pH |
|---|---|---|---|---|---|
| 0-30 | 0.40 | 0.26 | 1.19 | 0.80 | 7.8 |
| 30-60 | 0.40 | 0.26 | 1.19 | 0.55 | 7.7 |
| 60-90 | 0.41 | 0.28 | 1.16 | 0.30 | 7.7 |
| 90-120 | 0.41 | 0.28 | 1.25 | 0.06 | 8.0 |

The experimental plots with 8 rows of plants were 40 m long and 6.4 m width. A cotton (*Gossypim hirsutum* L., cv. Çukurova-1518) cultivar, widely used in the area, was planted. The fertilizers rates used were similar to farmers' practice in the area as 160, 50 and 50 kg $ha^{-1}$ of N, P and K applied, respectively. The seeds were planted to 3-4 cm depth along 80 cm row spacing at 5-6 kg $da^{-1}$ rate. Irrigation was initiated when 40% of plant available soil water storage was depleted under furrow irrigation. Irrigation water applied was that amount which increased soil water content to field capacity under the FULL treatment. Under drip irrigation, irrigations were done weekly with irrigation water requirement estimated using Class-A pan data. Laterals of drip lines with drippers at 20 cm separation were laid along both sides at 40 cm distance from the plant rows. The drippers used were of 4 L $h^{-1}$ discharge rate.

Experimental data collected included soil water status, irrigation water use efficiency (IWUE), soil salinity and the like. The salinity data, which were collected at early season at planting and immediately after harvest, were used to assess change of soil salinity profiles during irrigation season. The data was also used to construct iso-salinity maps of the plant root-zone. Soil samples for salinity measurements were collected in 3 replicates from soil depths of 5, 15, 45, 75 and 105 cm. The second sampling, following the harvest, was done following a grid system so that iso-salinity maps for salinity characterization of plant rooting zone can be made. For this purpose, 3 sites consisting a line perpendicular to the plant row: (1) immediately below an individual plant, (2) and (3) at 20 cm equal distance to the plant root, on the left and right of the plant row were sampled at the same depths as initial sampling. Soil saturation extracts were used for measurement of salinity as electrical conductivity (ECe, dS $m^{-1}$). The salinity data, used either as salinity profiles or iso-salinity maps, facilitated to assess salt accumulation under the tested irrigation treatments FULL, 1PRI, 2PRI and CDI.

## RESULTS and DISCUSSION

### Yield

Total of 5 irrigations were used for the furrow irrigated cotton. Although the treatments 1PRI and 2PRI received 50% reduced amount of irrigation water compared to the FULL treatment, the yield reduction was only marginal and not significant; however, IWUE was nearly doubled (Table 2). Similar results were earlier reported for maize by Kang et al. (2000). The FULL treatment produced the highest yield in the second year under drip irrigation; however the yield reduction under 1PRI was only marginal and non significant (P>0.05) compared to FULL treatment (Table 2). The CDI produced the lowest yield. The deficit irrigation treatments (i.e., PRI and CDI) had the highest IWUE (Table 2). Irrespective of the irrigation method used, furrow or the drip, the yield reduction with 1PRI, compared to FULL treatment, was only marginal in spite of as high as 50% reduced irrigation water application. Our results confirmed the earlier findings by Chaffey (2001) who reported that high amount of irrigation water can be saved without significant yield reduction with deficit irrigation. Wahbi et al. (2005) showed that 50% savings of irrigation water achieved with PRI for 15-20% yield reduction should have significant implications toward in easing of irrigation water shortage. There are numerous other work (e.g., Zegbe-Domiguez et al., 2003; Dorji et al., 2005; Gençoğlan et al., 2006) published recently which all confirmed similar findings that the PRI technique can achieve significant savings in irrigation water requirement with only marginal yield reduction.

Table 2. Cotton seed yield and irrigation water use efficiency (IWUE)[a]

| Irrigation treatments | | Y, t $ha^{-1}$ | IWUE, kg $(ha\ mm)^{-1}$ |
|---|---|---|---|
| Furrow | FULL | 3.38 | 5.7 b |
| | 1PRI | 3.28 | 11.1 a |
| | 2PRI | 3.17 | 10.7 a |
| | Tukey's CV | NS | 2.6 |
| | P | | 0.01 |
| Drip | FULL | 1.82 a | 8.2 b |
| | 1PRI | 1.51 ab | 13.6 a |
| | CDI | 1.37 b | 12.3 a |
| | Tukey's CV | 0.42 | 3.98 |
| | P | 0.05 | 0.05 |

[a] Data in columns followed with different letters are significantly different based on Tukey's mean range test for indicated critical value for comparison (CV).

**Salinity**

Increase of soil salinity within soil depths of 40 cm or below was about 0.2 dS $m^{-1}$ under furrow irrigation. The largest increase was within the surface layer of 40 cm (Figure 1). As expected, the lowest increase was noted under the FULL treatment because of proportionally high leaching occurred. It was interesting to note that surface soil salinity was somewhat higher under 2PRI compared with that of 1PRI (Figure 1). The highest salinity was observed within the surface layer of 20 cm under 2PRI.

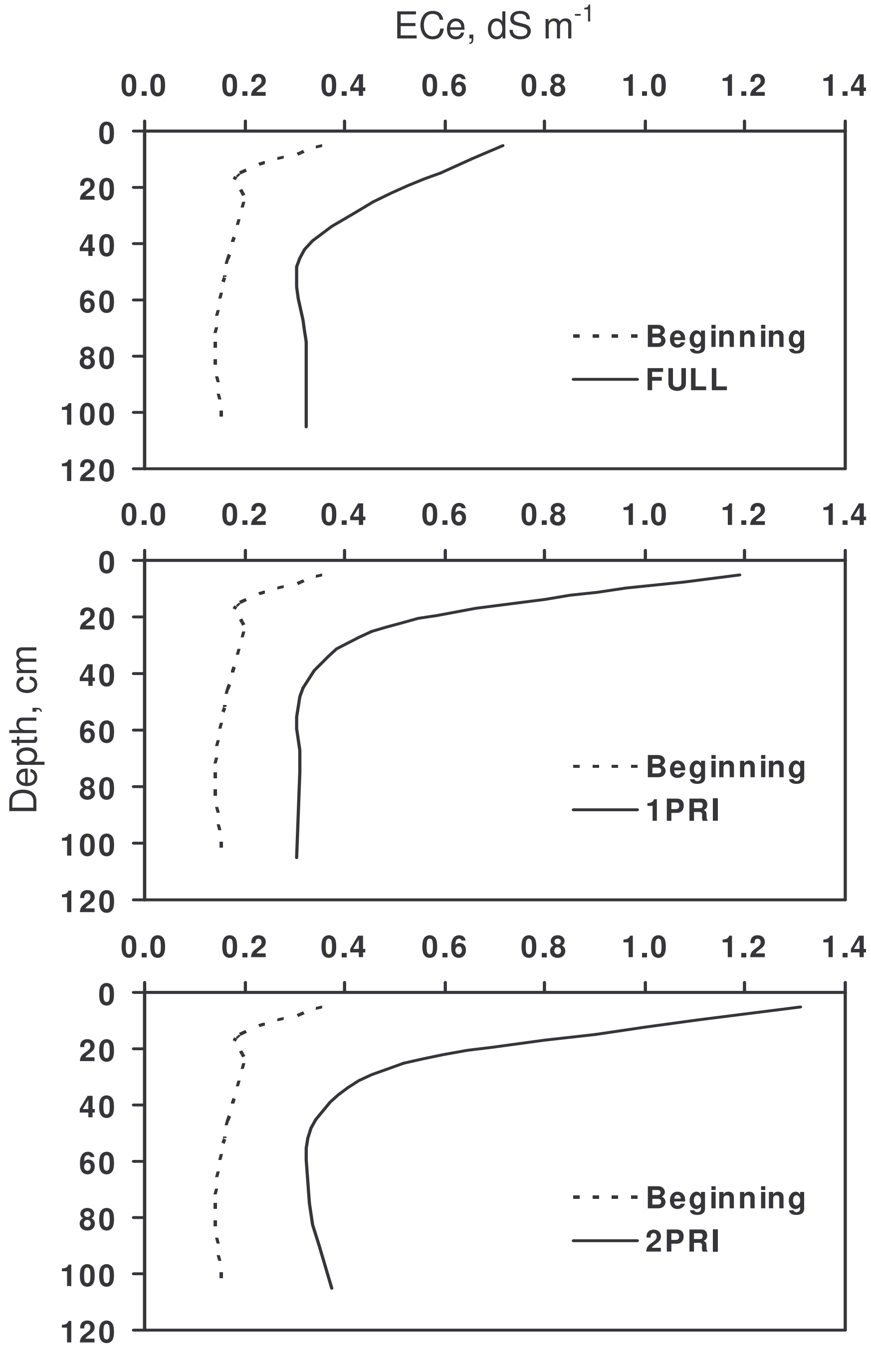


Figure 1. Salinity changing of the root zone under FULL, 1PRI and 2PRI treatments for furrow irrigated cotton at the beginning and at harvest (solid line)

The lowest salinity was observed under 1PRI treatment with drip irrigation (Figure 2). The salt accumulation was the highest under CDI. Similar to furrow irrigation, salinity was proportionally higher near soil surface. Iso-salinity maps at harvest (Figure 3) showed that the surface layer of ≈30 cm depth had the highest salinity which gradually decreased at deeper zones irrespective of the treatment. Salt accumulation essentially occurred at wetting front between the drippers and the plant root (Figure 3). This behavior was the most apparent under the CDI. Similar to furrow irrigation, salinity below 40 cm depth proportionally was lower compared to surface layers. Although salt accumulation was highest right over the plant rows under furrow irrigation (Kaman et al., 2006), the area of accumulation was shifted toward the center between the rows and the drip line under drip irrigation. The results obtained therefore suggested that the drip irrigation should be preferred if low quality irrigation water is to be used.

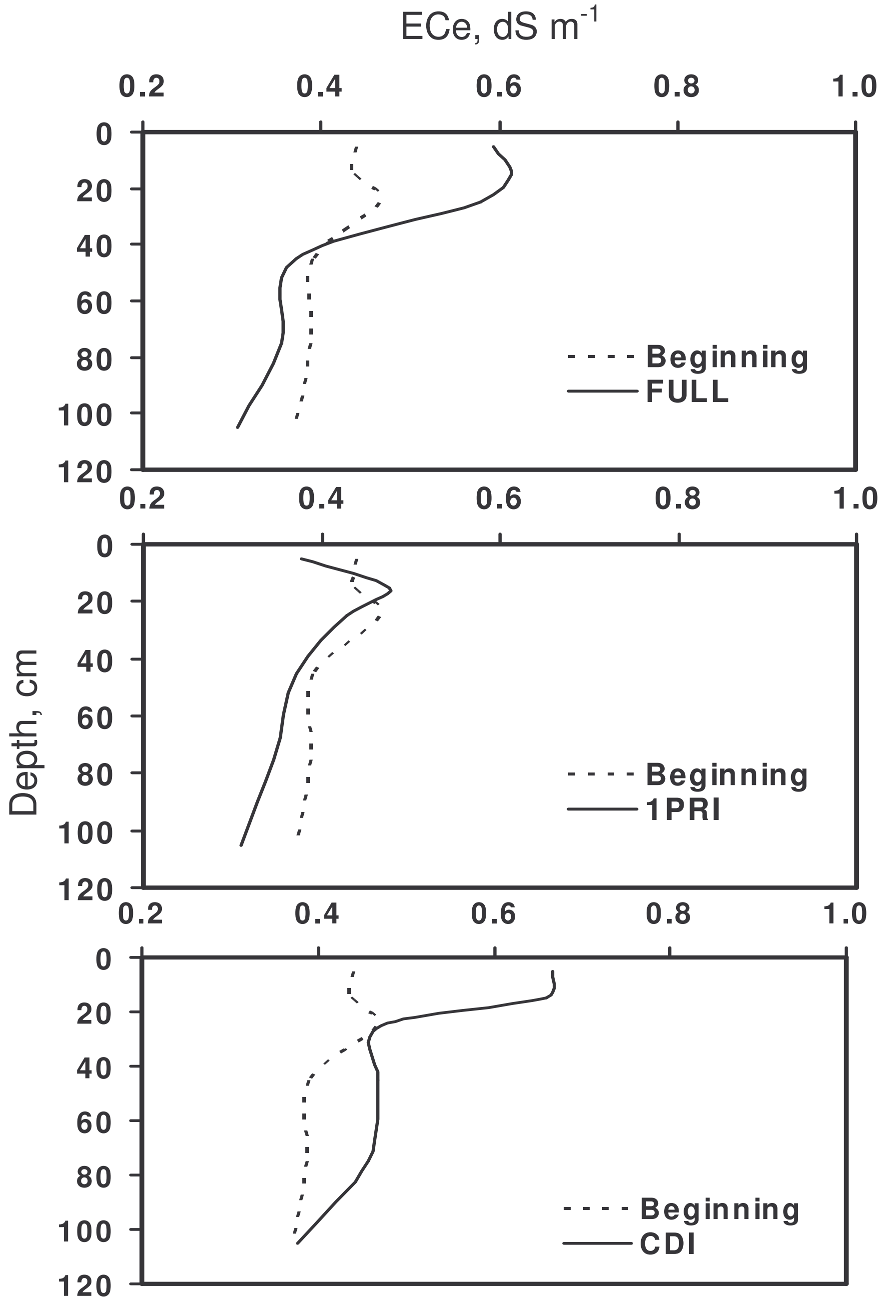

Figure 2. Salinity changing of the root zone under FULL, 1PRI and CDI treatments for drip irrigated cotton at the beginning and at harvest (solid line)

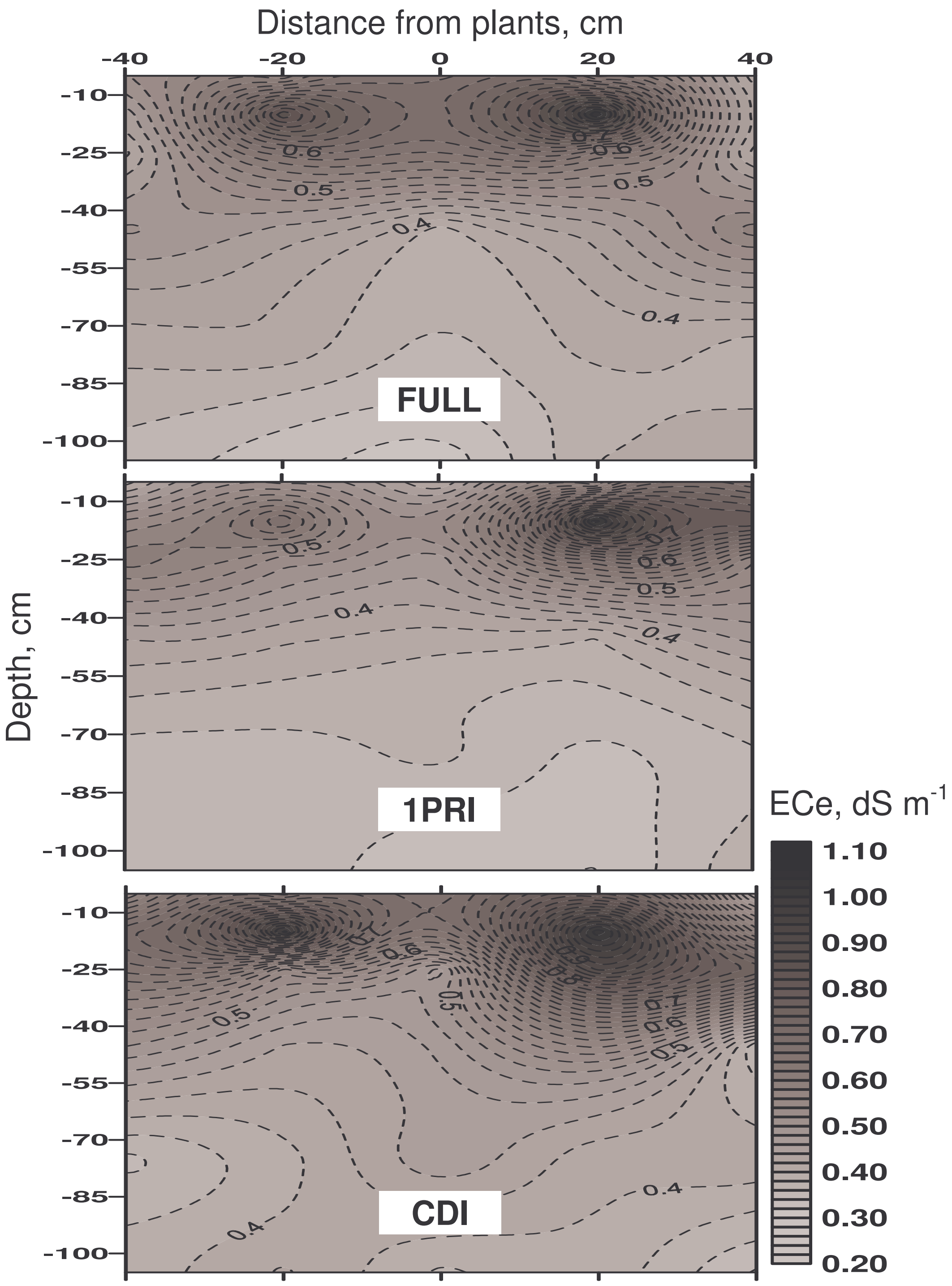


Figure 3. Map of the salt accumulation under FULL, 1PRI and CDI treatments in the root zone of drip irrigated cotton at harvest

The salt accumulation observed in the root zone was at maximum 1.3 dS m$^{-1}$ over one year of irrigation because of the fact that irrigation water quality was good with EC of below 0.4 dS m$^{-1}$. However, it should be noted that in salt affected soils of $EC_e$>4 dS m$^{-1}$, the yield reduction may be likely depending on irrigation water quality. Nevertheless, our results showed that risks of salt accumulation under the deficit treatment PRI would not be much different than under FULL irrigation. Therefore in areas of limited irrigation water, the deficit irrigation practice of PRI should be preferred over FULL irrigation.

**ACKNOWLEDGEMENT**

Authors gratefully acknowledge that this work was funded by European Union, through INCO-MED RTD Project (ICA3-CT-1999-00008).

**REFERENCES**

Chaffey, N. 2001. Restricting water supply enhances crop growth. Trends Plant Sci. 6(8): pp. 346.

Dorji, K., M.H. Behboudian and J.A. Zegbe-Domínguez. 2005. Water relations, growth, yield, and fruit quality of hot pepper under deficit irrigation and partial rootzone drying. Sci. Hor. 104: 137-149.

Dry, P.R., B.R. Loveys. 1998. Factors influencing grapevine vigour and the potential for control with partial rootzone drying. Aust. J. Grape Wine Res. 4: 140-148.

Gencoglan, C., H. Altunbey and S. Gencoglan. 2006. Response of green bean (P. Vulgaris L.) to subsurface drip irrigation and partial rootzone-drying irrigation. Agr. Water Manage. 84(3): 274-280.

Kaman, H., C. Kirda, M. Cetin and S. Topcu. 2006. Salt accumulation in the root zones of tomato and cotton irrigated with partial root-drying technique. Irrig. and Drain., 55: 533–544.

Kang, S., Z. Liang, W. Hu and J. Zhang. 1998. Water use efficiency of controlled alternate irrigation on root-divided maize plants. Agr. Water Manage. 38: 69-76.

Kang, S., Z. Liang, Y. Pan, P. Shi and J. Zhang. 2000. Alternate furrow irrigation for maize production in an arid area. Agr. Water Manage. 45: 267-274.

Kang, S., L. Zhang, X. Hu, Z. Li and P. Jerie. 2001. An improved water use efficiency for hot pepper grown under controlled alternate drip irrigation on partial roots. Sci. Hort. 89: 257-267.

Katerji, N., J.W. van Hoorn, A. Hamdy and M. Mastrorilli. 1998. Response of tomatoes, a crop of indeterminate growth, to soil salinity. Agr. Water Manage. 38: 59-68.

Kirda, C., P. Moutonnet, C. Hera and D.R. Nielsen. 1999. Crop yield response to deficit irrigation. Kluwer Aca. Pub., Dordrecht, The Netherlands, pp. 258.

Konak, C., R. Yılmaz and O. Arabacı. 1999. Salt tolerance in Eagean Region's wheats. (in Turkish with English abstract) Turk. J. Agric. For. 23(5): 1223-1229.

Lamsal, K., G.N. Paudyal and M. Saeed. 1999. Model for assessing impact of salinity on soil water availability and crop yield. Agr. Water Manage. 41: 57-70.

Mingo, D.M., M.A. Bacon and W.J. Davies. 2003. Non-hydraulic regulation of fruit growth in tomato plants (Lycoperssicon Esculentum cv. Solairo) growing in drying soil. J. Exp. Bot. 54: 1205-1212.

Nakajima, H., M.H. Behboudian, M. Greven and J.A. Zegbe-Dominguez. 2004. Mineral contents of grape, olive, apple, and tomato under reduced irrigation. Short Communication. J. Plant Nutr. Soil Sci., 167: 91-92.

Romero-Aranda, R., T. Soria and J. Cuartero. 2001. Tomato plant-water uptake and plant-water relationships under saline growth conditions. Plant Sci. 160: 265-272.

Stikic, R., S. Popovic, M. Srdic, D. Savic, Z. Jovanovic, L. Prokic and J. Zdravkovic. 2003. Partial root drying (PRD): A new technique for growing plants that saves water and improves the quality of fruit. Bulg. J. Plant Physiol., Special Issue, 164-171.

Szabolcs, I. 1989. Salt-affected soils. CRC Press, Inc. Boca Raton, Fla., 274 p.

Turhan, H. and İ. Başer. 2001. Salinity and plant growth. (in Turkish with English abstract) Akd. Ü. Zir. Fak. Der., 14(1): 171-179.

USSL, 1954. Diagnosis and improvement of saline and alkali soils. Agr. Handbook. USA, 60: pp. 160.

Wahbi, S., R. Wakrim, B. Aganchich, H. Tahi and R. Serraj. 2005. Effects of partial rootzone drying (PRD) on adult olive tree (Olea europaea) in field conditions under arid climate I. physiological and agronomic response. Agr. Ecosyst. Environ. 106: 289-301.

Zegbe, J.A., M.H. Behboudian and B.E. Clothier. 2004. Partial rootzone drying is a feasible option for irrigation processing tomatoes. Agr. Water Manage. 68: 195-206.

Zegbe-Dominguez, J.A., M.H. Behboudian, A. Lang and B.E. Clothier. 2003. Deficit irrigation and partial rootzone drying maintain fruit dry mass and enhance fruit quality in ‘petopride’ processing tomato (*Lycopersicon Esculentum,* Mill.). Sci. Hor. 98: 505-510.