INTERNATİONAL JOURNAL OF AGRİCULTURE & BİOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
15–572/2016/18–2–435–440
DOI: 10.17957/IJAB/15.0109
http://www.fspublishers.org

***Full Length Article***

# Salt Accumulation in the Root Zone of Eggplant Irrigated using Partial Root Drying Technique

**Harun Kaman* and Ömer Özbek**
*University of Akdeniz, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, 07058 Campus, Antalya, Turkey*
*For correspondence: hkaman@akdeniz.edu.tr

## Abstract

In this study, the yield and possible salt accumulation around the root area of eggplant was investigated. Seven irrigation treatments were tested including a controlling irrigation (FULL). Two of these irrigation treatments had 25% and 50% less water accordingly than the treatment of FULL and water was conventionally applied to both sides of the plant roots (CDI25 and CDI50). The other two deficit irrigation treatments had 25% and 50% less water accordingly than the treatment of FULL and water was applied only one side of the roots and the other halves were left relatively dry in each irrigation. This case was replaced alternatively for every irrigation (APRD25 and APRD50). The last two deficit irrigation treatments had also 25% and 50% less water accordingly than the treatment of FULL, however throughout the season water was applied only one side of the roots and the other halves were left relatively dry in each irrigation in fixed irrigations (FPRD25 and FPRD50). The differences between the yields of the eggplant under different irrigation treatments were statically important ($p < 0.01$). The range of yields depending on irrigation treatments were between 23.37 t $ha^{-1}$ and 83.10 t $ha^{-1}$. The highest salt accumulation was recorded in treatment FPRD25 for the root area and treatment CDI50 for along the rows of plants. When compared with the values of the beginning of the season; the salinity was multiplied by 3.2 for the root area of treatment FPRD25 at the end of the season. In a similar way, the salinity was multiplied by 7.1 at the end of the season for treatment CDI50 along the rows of plants when compared with the beginning of the season. 

**Keywords:** Greenhouse; Irrigation water; Salt tolerance; Yield

## Introduction

The cut of the irrigation water in conventional irrigations reduces the growth of the green parts of the plant and accordingly limits the use of water in return (Kirda *et al.,* 1999). But this situation causes substantial decrease in product yield and quality. On the other hand, with the application of partial root drying (PRD), which has been developed in recent years; agricultural production is expected to be without a decrease in terms of fruit quality and yield. As a result of some researches; fruit yield and quality is kept while there is reduction on the green parts of the plant (Dry and Loveys, 1998; Kang *et al.,* 2000; Kang *et al.,* 2001; Mingo *et al.,* 2003; Zegbe-Dominguez *et al.,* 2003). PRD technique is basically based on reducing the applied water used for conventional irrigation in a given ratio, and wetting only half of the plant roots. With this technique, where water is limited and expensive, more efficient utilization of the available water can be ensured by applying less water similarly to the conventional deficit irrigation (Kang *et al.,* 1998). The water use efficiency is higher under PRD application when compared to the known conventional irrigation practices (Chaffey, 2001; Kirda *et al.,* 2004). Thus, with the help of PRD irrigation technique the desired irrigation efficiency can be achieved and for the benefit of other sectors the possibility of reducing the amount of irrigation water used in agriculture may be obtained.

Salinity is one of the most important of the irrigated agriculture and mostly it occurs due to the irrigation practices. Inaccuracies in the application of irrigation and more or less use of water than needed amount reduce the efficiency of water use and crop yield. Excessive irrigation causes increased groundwater and hence soil salinity (Cetin and Kirda, 2003). The amount of the lands facing salinity problem increases day by day. Salinity leads to stunting of plant growth and leads to a decrease in efficiency.

There are numerous researches about the effects of conventional deficit (CDI) and the PRD technique on yield and quality of the product (Tardieu and Davies, 1992, 1993; Kirda *et al.,* 2004; Kirda *et al.,* 2005; Kirda *et al.,* 2007; Kaman *et al.,* 2011). Higher yield and good quality products can be obtained as a result of some interactions between plant roots and leaves by increasing the water efficiency of PRD irrigation applications unlike the conventional deficit irrigation (Dry and Loveys, 1998; Kang *et al.,* 2000; Mingo

**To cite this paper:** Kaman, H. and Ö. Özbek, 2016. Salt accumulation in the root zone of eggplant irrigated using partial root drying technique. *Int. J. Agric. Biol.,* 18: 435–440

*et al.,* 2003). In the mentioned studies, while having production without a significant reduction in yield with the PRD practices, plant root zone salinity is not taken into the consideration which may occur due to irrigation scheduling methods. In addition, although the effects of the PRD techniques on yield and quality are studied and the superiority of this technique over CDI technique has been performed, not enough studies are conducted about the level of possible salt accumulation in the soil as a result of applying these methods, assessments and the sustainability of performing these methods. In this regard, the objective of this work was to assess the possible salt accumulation around the plant root zone and the relationship between salinity, yield and irrigation techniques under partial root drying (PRD) and conventional deficit irrigation (CDI) practices.

## Materials and Methods

### Experimental Site

The research was conducted at the Research and Application field of the Faculty of Agriculture, Akdeniz University, Antalya, Turkey. The study was conducted in a glass greenhouse which is widely used in our country, established in the north-south direction, with the side and roof vent. The research area is located between 30° 38' 30'' – 30° 39' 45'' east longitudes and 36° 53' 15'' – 36° 54' 15'' north latitudes. The elevation of the research from sea level is 54 m (Anonim, 1998). In the study area, where Mediterranean climate prevails, summer is hot and dry, winter is mild and rainy.

The soil of research area is from Gölbasi territory series. The soil of Gölbasi series is included in Entisols Ordo because they do not show more profile development and they are relatively young soils developed on massive travertine. Some physial and chemical specifications of the greenhouse soil of the research are given in Table 1. The soil of trial area does not have any salinity problem.

There are intensive researches conducted about the PRD technique in the last ten years when the PRD related literature is reviewed. Although some studies deal with different plant species and varieties as a material, no study has been conducted about the possible responses of eggplant under the PRD technique. Eggplant is the plant material of this research, because it has a very large production area and consumption in Antalya region and Turkey. In this context, the Phaselis eggplant type is used as plant material.

The irrigation water is supplied from the pumping system located in the Research and Application Area. The water used has a good quality and will not cause any problem in irrigation with EC (0.55 dS $m^{-1}$) and pH (7.58) values. Irrigation applications were made by drip irrigation method. In the study, seven irrigation treatments (Table 2) were placed in the greenhouse in a randomized complete block design with 3 replicates.

**Table 1:** Some physical and chemical properties of the experimental soil

| Depth (cm) | Texture | FC ($cm^3$ $cm^{-3}$) | PWP ($cm^3$ $cm^{-3}$) | BD (g $cm^{-3}$) | ECe (dS $m^{-1}$) |
|---|---|---|---|---|---|
| 0-20 | CL | 0.30 | 0.22 | 1.28 | 1.46 |
| 20-40 | CL | 0.23 | 0.16 | 1.52 | 0.65 |
| 40-60 | CL | 0.16 | 0.12 | 1.34 | 0.50 |

FC, field capacity; PWP, permanent wilting point; BD, bulk density; ECe, salinity of soil saturation extract

**Table 2:** Irrigations treatments

| Irrigation treatment | Description |
|---|---|
| FULL | Full irrigation with all roots wetted (CONTROL). |
| CDI25 | All roots were wetted but received 25% less water, compared to FULL irrigation. |
| CDI50 | All roots were wetted but received 50% less water, compared to FULL irrigation. |
| APRD25 | Compared to FULL irrigation 25% less water was applied; irrigated sides of the root zone were alternated every irrigation. |
| APRD50 | Compared to FULL irrigation 50% less water was applied; irrigated sides of the root zone were alternated every irrigation. |
| FPRD25 | Compared to FULL irrigation 25% less water was applied; irrigation was fixed to one side of the root zone, and the other side was kept drying |
| FPRD50 | Compared to FULL irrigation 50% less water was applied; irrigation was fixed to one side of the root zone, and the other side was kept drying |

The eggplant plantation process is performed with 50 cm space above the row and 100 cm space between the rows. 14 plants took place in each row and 4 lines took place for each irrigation treatment. Thus, a total of 56 plants were grown in each irrigation treatment. Once the greenhouse soil was ready, the research on seedling and planting operations were started on September 20$^{th}$, 2011 and the study was completed on June 14$^{th}$, 2012.

The water amount used for irrigation treatments is calculated based on evaporation measured by Class A evaporation pan by using the formula given below.

$$I=kp\times kc\times Ep\times A$$

In the formula: I, irrigation water (liter $plant^{-1}$); kp and kc, evaporation container and plant coefficients respectively; Ep, the evaporation taken from evaporation container Class A-Pan (mm) and A, is the area of a plant ($m^2$).

### Soil Sampling for Salinity Assessment

The soil samples were taken in two stages and repeated three times during the production season in order to determine the possible salinity values among the treatments discussed. The first phase was to determine the starting salt level of the sampling at the start of the experiment right after planting seedlings. In the second phase, sampling was performed immediately at the end of the season and after harvest. The sampling in this stage: two different ways were carried out including 20 points and approximately 30 cm depths; (1) for each treatment from the depth of root points of the plants 5, 15, 25, 35 and 50 cm and (2) throughout the plant roots and drippers in a plant row consecutively.

The samples taken from the soil of greenhouse were carried to the laboratory and they were dried by air. The samples were sieved with a 2 mm sieve after pounding the dried air soil. Sieved samples were treated in accordance with Janzen (1993) and saturation mud was prepared. Mud particles were obtained by applying vacuum to the saturation mud. Electrical conductivity (ECe, dS $m^{-1}$) measurements were conducted in the mud particles (Janzen, 1993). Salinity values were determined around the root area, along the plant row and at the points where drippers were located by using the ECe (dS $m^{-1}$) values obtained with the measurements. The data was graphed according to the salinity of the soil depth by using the statistical analysis of the data. In addition, the yields were also recorded derived from the irrigation treatments. Thus, the water-yield relationships and possible salt accumulation of eggplant are discussed under conventional irrigation and partial root drying techniques.

## Results

In the study, the irrigation application form and pruning, spraying, maintenance, etc. were applied equally to all agricultural operations excluding the amount of water in accordance with the definition of the topics discussed (Table 2). Therefore, the possible differences in the yield of plants and soil salinity were affected by only the method and level of applied irrigation water.

### Water-yield Relationship

The statistical analyses of the yields were conducted which were obtained from the research treatments and differences between treatments were significant ($p<0.01$) in terms of statistics (Fig. 1). The yields depending on irrigation issues were ranging between 23.37 t $ha^{-1}$ and 83.10 t $ha^{-1}$. The highest yield was recorded under FULL treatment. However, the difference between yields of FULL and APRD25 treatments were not significant in statistical terms and they had shown a similar attitude. The lowest yield was calculated under APRD50 treatment; however it was incuded in the same group of CDI50 and FPRD50 treatments statically. The yields of the treatments discussed in the research were from highest to lowest; FULL>APRD25>CDI25>FPRD25>CDI50>FRPD50>AP RD50. APRD25 treatment had shown a yield advantage over the other treatments which were having a 25% of irrigation cut when compared with the FULL treatment. However, with increasing water cut rate CDI50 treatments had a higher yield value than APRD50 and FPRD50 treatments.

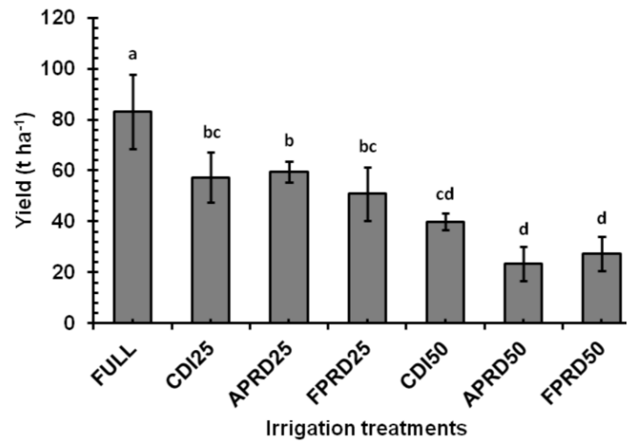


**Fig. 1:** Eggplant yield (t $ha^{-1}$). The vertical line bars show means (n=3) ± SD. Bars with different letters show significantly different data, based on LSD mean range test at $\alpha = 0.01$ rejection level

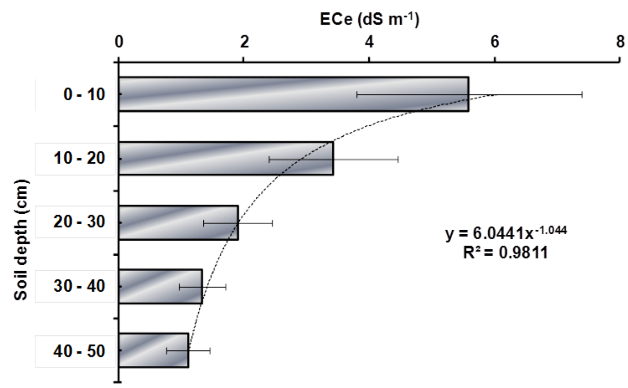


**Fig. 2:** Salt accumulation in the eggplant plant root zone at the end of season. Histograms show average soil salinities (n=105) of all treatments with bars of standard deviations

### Salinity Changes in the Root Zone of the Plant

The average salinity values of the data obtained from all treatments, within the change of the layers in the soil profile was shown in Fig. 2. Salinities in the upper layer of the soil profile were higher. The plant roots concentrate in the upper layers of the soil profile as it is known. There is a relationship between the depth from the surface and reduction of root concentration. This relationship was expressed as $R^2$=0.98.

Salinity of a total of 257 soil samples was measured at the beginning and end of the season. Some descriptive statistical information about the salinity values belonging to these measurements was given in Table 3. As expected, the lowest salinity (0.467 dS $m^{-1}$) was recorded at the beginning of the season. The lowest salinity (0.664 dS $m^{-1}$) was measured in the treatment of FPRD50 and the highest value (8.200 dS $m^{-1}$) was measured in the treatment FPRD25 from the samples taken from root zones of the plants.

**Table 3:** Descriptive statistics of soil salinity (ECe, dS m$^{-1}$) in the root zone of eggplant

| Statistics | Initial | Irrigation treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | FULL | CDI25 | APRD25 | FPRD25 | CDI50 | APRD50 | FPRD50 |
| | | Soil salinity profile of the eggplant plant root zone | | | | | | |
| Number of samples | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Mean | 1.015 | 2.641 | 3.176 | 2.715 | 3.232 | 3.141 | 1.687 | 2.448 |
| Median | 0.843 | 1.325 | 1.743 | 2.890 | 1.981 | 2.700 | 1.289 | 2.570 |
| Minimum | 0.467 | 0.973 | 0.886 | 1.594 | 0.819 | 1.255 | 0.701 | 0.664 |
| Maximum | 1.922 | 6.800 | 7.310 | 4.010 | 8.200 | 5.860 | 3.150 | 5.050 |
| Standard deviation | 0.556 | 2.211 | 2.493 | 0.889 | 2.623 | 1.780 | 0.800 | 1.556 |
| | | Soil salinity at 20 sampling points along the eggplant plant rows | | | | | | |
| Number of samples | 12 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Mean | 1.015 | 3.132 | 3.796 | 4.759 | 3.841 | 7.230 | 5.306 | 4.532 |
| Median | 0.843 | 3.200 | 3.730 | 4.455 | 3.210 | 7.195 | 5.490 | 4.720 |
| Minimum | 0.467 | 2.180 | 1.913 | 1.181 | 0.857 | 3.810 | 3.640 | 1.073 |
| Maximum | 1.922 | 4.590 | 6.050 | 8.740 | 7.450 | 12.620 | 6.740 | 9.100 |
| Standard deviation | 0.556 | 0.693 | 1.052 | 2.743 | 2.063 | 1.746 | 0.975 | 2.328 |

A comparison of the salinity increases of FULL, CDI25, APRD25, FPRD25, CDI50, APRD50 and FPRD50 treatments at the end of the season and the beginning of the season was as follows; multiplied by 2.6, 3.1, 2.7, 3.2, 3.1, 1.7 and 2.4, respectively. These values were sorted based on the treatments from highest to lowest as FPRD25>CDI25=CDI50>APRD25>FULL>FPRD50>APRD50. In this context, according to the average salinity accumulation values when compared per season; APRD50 treatments was measured as the lowest and FPRD25 treatment was measured as the highest.

Within 0–50 cm depth of the soil profile, salinity changes of the root zone of the plants compared with the beginning and end of the season can be seen in Fig. 3. The salinity accumulations of all the treatments were determined within 0–30 cm depths from the soil surface where the root concentrations were at higher values. In deeper (30–50 cm layer) areas, the salinity of all treatments showed a decreasing slope in a similar manner. The salt accumulation values were higher for FPRD25, CDI25 and CDI50 treatments when compared the beginning and end of the season (Fig. 3). The lowest salt accumulation values belong to APRD25 and APRD50 treatments.

### Salinity Change of Root and Dripper Zones throughout the Plant Row

Some descriptive statistical information of salinity values throughout the plant rows can be seen in Table 3. The highest salinity value was recorded as 12.620 dS m$^{-1}$ under CDI50 treatment in the root zone of the plant. A comparison of the salinity increase values of FULL, CDI25, APRD25, FPRD25, CDI50, APRD50 and FPRD50 treatments at the end of the season and the beginning of the season was as follows; multiplied by 3.1, 3.7, 4.7, 3.8, 7.1, 5.2 and 4.5 respectively. These values were sorted based on the treatments from highest to lowest as CDI50>APRD50>APRD25>FPRD50>FPRD25>CDI>FU

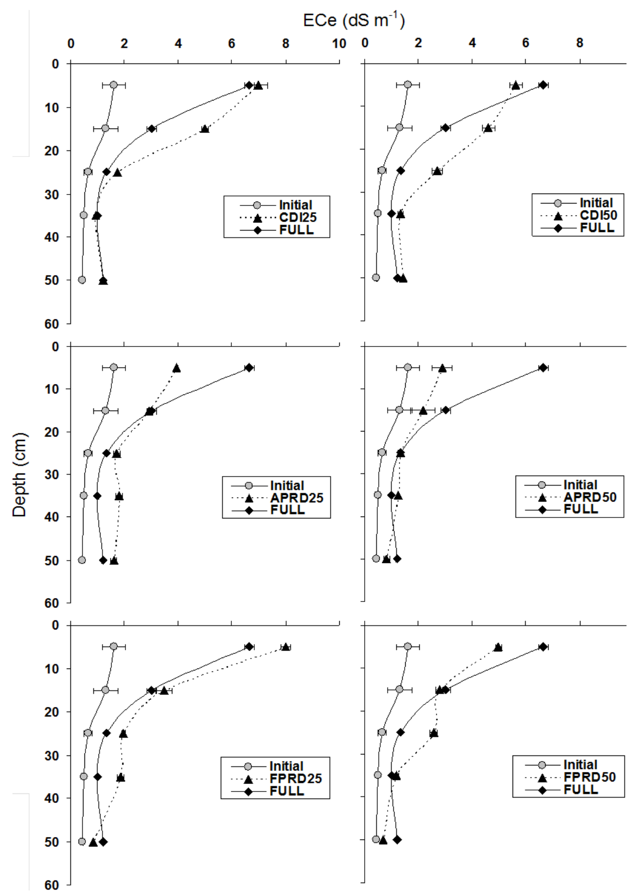


**Fig. 3:** Salinity changes in soil profile at the initial stage and at the end of season for FULL, CDI25, CDI50, APRD25, APRD50, FPRD25 and FPRD50 treatments. The horizontal line show means (n=3)±SD

LL. The salinity changes of root and dripper zones of all the treatments throughout the consecutively rows were shown in Fig. 4 and Fig. 5. As expected, the lowest salinity was recorded in FULL treatment.

## Discussion

Many researches had been conducted about the PRD technique, and water-yield relationship (Zegbe *et al.,* 2004; Dorji *et al.,* 2005; Kirda *et al.,* 2007; Kaman *et al.,* 2011). In the referred studies in general, the PRD technique had been proposed in order to save some irrigation water. In our study, especially under APRD25 treatment similar results statically were obtained with the referred researches in the same group in terms of controlling the obtain crop yields.

Öztürk (2002) had studied the possible effects of salty water on the development of eggplant and soil salinity. In the study, the used water had 5 dS $m^{-1}$ salinity. The salty water which had been applied in different development stages of eggplant effects the water consumption, the height and the weight of the plant and increased the salinity level of the soil significantly (Öztürk, 2002). The salinity tolerance of eggplant was reported as low. In addition, washing was proposed in the salty water applications with high level of salinities. In our study, APRD25 and APRD50 treatments had the lowest salinity ratios among the irrigation treatments except the FULL (Table 3 and Fig. 3). Due to the low salt tolerance of eggplant (Öztürk, 2002), APRD25 and APRD50 were more advantaged treatments in terms of salinity accumulation when compared with other deficit irrigation treatments.

Ünlükara *et al.* (2010) had examined the effects of salty water on the relationship of yield, development and water consumption of eggplant. His research differs from the research conducted by Öztürk (2002), where five different saline water treatments were taken in except the controlling one. These treatments had a salinity of 1.5, 2.5, 3.5, 5 and 7 dS $m^{-1}$. A proportional decrease was recorded in the yield due to increased salinity values. In our study, the salinity values were recorded as 3.176 dS $m^{-1}$ for CDI25 treatments; 3.232 dS $m^{-1}$ for FPRD25 treatments and 2.715 dS $m^{-1}$ for APRD25 treatment (Table 3). According to the model belongs to Ünlükara *et al.* (2010) the proportional eggplant yield decrease due to the salinity was 14% for CDI25 and FPRD25 treatments and 12% for APRD25 treatment.

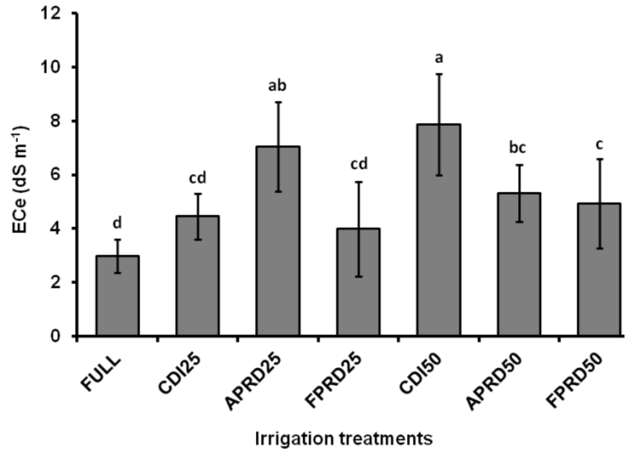


**Fig. 4:** Salinity changes at 10 sampling points (root of eggplant) along the eggplant plant rows at the end of season for FULL, CDI25, CDI50, APRD25, APRD50, FPRD25 and FPRD50 treatments. The vertical line bars show means (n=10)±SD. Bars with different letters show significantly different data, based on LSD mean range test at α = 0.01 rejection level

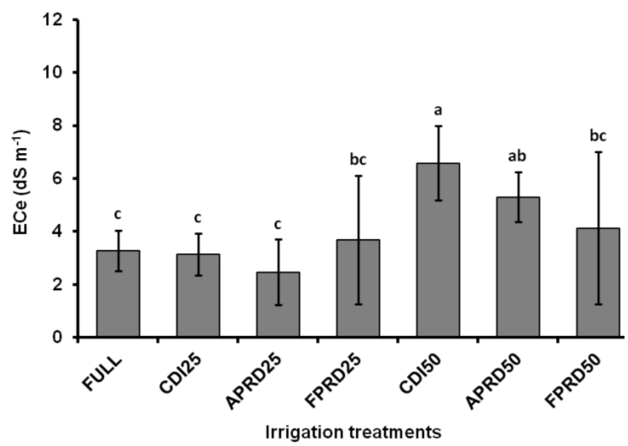


**Fig. 5:** Salinity changes at 10 sampling points (dripper) along the eggplant plant rows at the end of season for CDI25, CDI50, APRD25, APRD50, FPRD25 and FPRD50 treatments. The vertical line bars show means (n=10)±SD. Bars with different letters show significantly different data, based on LSD mean range test at α = 0.01 rejection level

## Conclusion

In this study, the PRD techniques were compared with conventional irrigation practices. The highest salinity values were recorded with FPRD25 treatment in the root zone and with CDI50 throughout the row of the plants. A 3.2 times more salinity was calculated in the root zone of FPRD25 treatment when the beginning and the end of the season were compared. In a similar manner, the salinity increase had become 7.1 times more for CDI50 treatment along with the plant row. On the other hand, the highest yield values were recorded for FULL and APRD25 treatments. Under the light of obtained data, the irrigation water could be decreased by 25% than the FULL, and APRD25 treatment could be applied where the water resources were limited and expensive. In addition, before starting a new plant to be grown in the greenhouse, washing the soil was recommended. Otherwise, the salt accumulation would have a potential of increasing in the soil of greenhouse year by year.

## Acknowledgments

The authors would like to thank the Research Fund of Akdeniz University for financial support given to this study.

## References


Anonim, 1998. *1997 Yılı Çalışma Raporu*, p: 71. (in Turkish), T.C. Tarım ve Köyişleri Bakanlığı, Tarım İl Müdürlüğü, Antalya, Turkey

Cetin, M. and C. Kirda, 2003. Spatial and temporal changes of soil salinity in a cotton field irrigated with low-quality water. *J. Hydrol*., 272: 238–249

Chaffey, N., 2001. Restricting water supply enhances crop growth. *Trends Plant Sci.*, 6: 346

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

Dry, P.R. and 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

Janzen, H.H., 1993. *"Soluble Salts" in the Soil Sampling and Methods of Analysis by Carter*, pp: 161–166. M.R. Carter (ed.), CRC Press, Boca Raton, Florida, USA

Kaman, H., C. Kirda and S. Sesveren, 2011. Genotypic differences of maize in grain yield response to deficit irrigation. *Agric. Water Manage*., 98: 801–807

Kang, S., Z. Liang, W. Hu and J. Zhang, 1998. Water use efficiency of controlled alternate irrigation on root- divided maize plants. *Agric. 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. *Agric. 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. Hortic*., 89: 257–267

Kirda, C., P. Moutonnet, C. Hera and D.R. Nielsen, 1999. *Crop Yield Response to Deficit Irrigation*. Kluwer Academic Publishers, Dordrecht, The Netherlands

Kirda, C., M. Cetin, Y. Dasgan, S. Topcu, H. Kaman, B. Ekici, M.R. Derici and A.I. Ozguven, 2004. Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation. *Agric. Water Manage.*, 69: 191–201

Kırda, C., F. Topaloğlu, S. Topçu and H. Kaman, 2007. Mandarin yield response to partial root drying and conventional deficit irrigation. *Turk. J. Agric. For.,* 31: 1–10

Kirda, C., S. Topcu, H. Kaman, A.C. Ulger, A. Yazici, M. Cetin and M.R. Derici, 2005. Grain yield response and N-Fertiliser recovery of maize under deficit irrigation. *Field Crop Res*., 93: 132–141

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

Öztürk, A., 2002. The effect of saline and normal waters applied in different stages on some properties of eggplant (Solanum melongena L.) and soil salinity. *S.Ü. Ziraat Fakültesi Dergisi*, 16: 14–20

Tardieu, F. and W.J. Davies, 1992. Stomatal response to abscisic acid is a function of current plant water status. *Plant Physiol*., 98: 540–545

Tardieu, F. and W.J. Davies, 1993. Integration of hydraulic and chemical signaling in the control of stomatal conductance and water status of droughted plants. *Plant Cell Environ*., 16: 314–349

Ünlükara, A., A. Kurunç, G.D. Kesmez, E. Yurtseven and D.L. Suarez, 2010. Effects of salinity on eggplant (Solanum melongena L.) growth and evapotranspiration. *Irrig. Drain*., 59: 203–214

Zegbe-Dominguez, J.A., M.H. Behboudian, A. Lang and B.E. Clothier, 2003. Deficit irrigation and partial root zone drying maintain fruit dry mass and enhance fruit quality in 'Petopride' processing tomato (Lycopersicon esculentum, Mill.). *Sci. Hortic*., 98: 505–510.

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


**(Received 29 May 2015; Accepted 26 October 2015)**