# Irrigation techniques and plant growth strategies in salt-affected soils

Bilal ACAR, Ahmet Melih YILMAZ

Department of Farm Building and Irrigation, Faculty of Agriculture, University of Selcuk, Konya-Turkey
(*Corresponding Author:* *biacar@selcuk.edu.tr*)

## Abstract

There is relationship between soil salinity level and crop yield. Salinization is one of the most important problems limiting agro-production especially in dry environments. White color on soil surface, postpone in germination, changes in leaf color, deformation of plant leaves, dying of plants and permanent water table in plant root zone depth are some common indicators of soil salinity. There are various sources resulting soil salinization such as water table or groundwater having high salts. Leaching is golden process for improvement of salinity soils. Leaching efficiency depends on irrigation techniques, and quality of leaching program. In salinity management, strong coordination should be established between experienced scientists, farm advisors and farmers. In order to meet food demand of the world sustainably, soils having infertile at present such as saline soils should be added to the current good quality soils after careful irrigation water and soil management especially in dry regions.

**Keywords:** Water quality, crop yield, salinity, leaching, irrigation methods.

## Introduction

In dry or hot environments, scant fresh water resources has forced to farmers to use saline water in irrigation. (Bhatti *et al.* 2015). Almost all irrigation water resources contain dissolved salts. In irrigation studies, salinity is main irrigation water quality indicator among the others. High concentrations of salts may cause physiological drought for plants. In other world, although sufficient amount water is available within root zone, crops cannot uptake such water and even they may not able to survive if that situation continues. There is a direct relationship between irrigation water quality and soil salinity content. There are number of reasons contributing salinization such as rises up or application of saltier groundwater on the soils.

In general, magnesium, sodium, calcium, chloride, sulphate, bicarbonate or carbonate ions are responsible for salinity. Concentration of whole soluble salts in water or in soil is named as salinity Anonymous, 2012).

Soil salinity is possibly one of the most important and common problems facing in arid climates. Surface white cover, delay or reduction in germination as well as low crop yield, deformation in leaf color, damages in leaves, dying of plants and permanent water table close to the soil surface are well known indicators of soil salinity. Soil salinity can be determined by measuring electrical conductivity, EC, in saturated extraction which is suggested as gold standard (Henry, 2012). The unit of EC for soil salinity is mS / cm or dS/m.

Table 1. Plant response to soil salinity (Henry, 2012).

| Salinity Level in Soils (dS / m) | Characteristics of Soils | Response of Crops |
|---|---|---|
| **0-2** | None-Saline | About none crops are damaged |
| **2-4** | Marginally Saline | Highly sensitive crops are damaged |
| **4-8** | Mid - Saline | Most crops are damaged |
| **8-16** | High Saline | Only tolerant plans are alive |
| **> 16** | Very high Saline | None crop is alive |

Leaching defining as more water application than crop requirement is only process for overcoming soil salinity. In practice leaching is done at no vegetation cover season by sprinkler or surface irrigation methods. Leaching in the crop growth period is called as ‘maintenance leaching’ but is not practical due to causing root rot and removing fertilizer to the lower parts of the root zone due to the over water application. In general, maintenance leaching is highly preferable by drip irrigation system. In row crops, trickle irrigation has some advantages in salinity management. Salts are accumulated towards to outer edge of wetted bulb in such irrigation technique and in general roots are intensive in wetted volume of soil so crops are not exposed to toxicity resulting from accumulated salts (Aegerter, 2016). The types of salts are also very important role to play in leeching processes. Solubility of salts is very important for leaching away salts from root zone depth.

Table 2. Solubility of salts (Henry, 2012)

| Dissolving Level | Salts | Solubility (g/L) |
|---|---|---|
| **Great** | $CaCI_2$ | 427 |
| | $MgCI_2$ | 353 |
| | $MgSO_4$ | 300 |
| | NaCI | 264 |
| | $Na_2SO_4$ | 160 |
| **Marginal** | $CaSO_4$ (Gypsum) | 2 |
| **Insoluble** | $CaCO_3$ (Lime) | 0.01 |

In general, salinity hazard depends on plant species, growth stages of crop, climatic factors and types of the salts within root zone. No perfect definition referring to saline soils has been developed so far (Yadav *et al.* 2011). Therefore, research relevant to salinity affects on plant yield and yield components is still in great interests and actual issues that must be studied in future field works since salt-affected soils are great share in worldwide especially in dry environments and whole or at least some parts must be added into production for contribution of food demand of growing population. The reactions of plants for salinity can be well understood by knowing the types of the salts and their accumulation processes in regard to different soil properties.

The aim of the current study is, thus, to describe the saline soils, the role of the irrigation methods in reclamation of salt-affected soils, some previous studies relevant to the salinity management and recommendations for sustainable soil salinity management especially in water shortage environments.

## General Characteristics of Saline Soils

Horneck *et al.* (2007) classified saline soils into three main groups: 1- Saline soils: they have calcium and magnesium elements in soil profile. In these soils, plants have difficulty to extract water from the soil, 2 – Sodic soils: they have rich of sodium element in soil profile. Presence of plenty sodium in soils leads to dispersion of soil particles. In such condition, soil pores are blocked causing difficulty in water movement within soil profile, 3 – Saline-sodic soils: they have problems about both sodium and other salts. They also added that inadequate crop yield as well as poor irrigation efficiency is resulted from the high level of salts in soils. Some crops are more tolerant to the saline soils and crops response different to the soil salinity level at various growth stages e.g more sensitive in germination and seedling stage. Sustainable drainage is viable solution for successful salinity management in farmlands. Leaching of salts is efficient by hydro-technique for sustainable crop production in saline soils. In soils having high sodium element, addition of calcium for replacing sodium is a viable strategy for improvement of alkaline soils. Addition of calcium through soil profile improves the soil structure as forming flocculation of soil particles. Gypsum as a source of calcium applications is economical way for efficient management of alkaline soils. The alkaline soils can be also improved by applications of sulfur in case of availability of free lime within the soil profile.

## Crop Response to Soil Salinity

Rises of osmotic pressure is resulted from increase of salt concentration within the soil. In such condition, depending on the salt concentration availability of water for crops has declined or completely ended. Excess elements like chloride (CI), sodium (Na) and boron (B) may result toxicity for crops after certain point. High concentration of Na in relation to Ca and Mg may have deterioration effects on soil structure and reduces the water, air and root movement within the soil profile. Under saline soil conditions, nutrient availability for crops may also reduce (Anonymous, 2012).

Saline soils can be converted to fertile soils by means of removing salts via leaching from soil profile. The purpose of leaching is to minimize the soil salinity levels that are equal or lower than threshold level of soil salinity for crops (Hanson and May, 2011).

The effects of saline irrigation water on crop yield highly depends on soil properties, irrigation methods, amount of irrigation water and crop growth systems. Leaching performance is highly relevant to the soil properties e.g sandy soils can wash away of salts easy and have satisfactory leaching efficiency by comparison to the clay soils (Yurtseven *et al.* 2012; Bortolini *et al.* 2018).

Salt tolerance of vegetables varies from types of crops. Bean, broccoli, lettuce, pepper, potato and tomato are some vegetables growing in Konya closed basin of Turkey.

Table 3. Response of some vegetables for different salinity (Machado and Serralheiro, 2015).

| Vegetables | Soil | Irrigation water |
|---|---|---|
| | Threshold (dS / m) | Threshold (dS / m) |
| Bean | 1.0 | 0.7 |
| Broccoli | 2.8 | 1.9 |
| Lettuce | 2.0 | 0.9 |
| Pepper | 1.5 | 1.0 |
| Potato | 1.7 | 1.1 |
| Tomato | 2.5 | 1.7 |

As seen in Table 3, broccoli is the most salt-tolerant vegetable followed by tomato and lettuce. In Konya closed basin of Turkey, groundwater is the main irrigation water source and salt content increases at the end of the irrigation season. Fortunately, salinity is not a big problem and has no limitation for sustainable crop production in irrigated lands of Konya Closed Basin. In accordance of our experiences, there are two possible reasons behind. First, sprinkler irrigation system is common irrigation methods in field crop production and is highly efficient for salt movements towards to the lower parts of soil. Second, precipitation amount and its distribution through the year are satisfactory for leaching salts to downward direction.

Hossain (2019) stressed that strong relationships between scientists, farm advisors and farmers are possibly vital important strategies to improve of salt-affected soils. He added that development of salt tolerant crop cultivars is also practical solution to combat salinity problems. Studies relevant to development of new crop cultivars that are highly tolerant to the saline soils are very important for putting those areas into production especially in drought ecology.

## Irrigation Techniques-Soil Salinity Relationships

In drip irrigation, water application twice a week more suitable than water application at frequently such as daily. Daily irrigation can be more beneficial for crops that are very sensitive to the salinity at soil. Leaching is more efficient in areas close to the drip lines by using saline water in irrigation event. On the other hand, little water application by using saline water is not recommended since salts are accumulated nearby drip lines. In that regard, increase in applied water results increase in area having low-saline soil around the drip lines. Applied water must be at least equal to crop water use. Emitters are very important component of the drip irrigation system components so they should be maintained with great care for better water delivery performance. Performance of drippers is vital important for salinity management of salt-affected soils (Hanson and May, 2011).

Aegerter (2016) performed a field research about efficiency of leaching for furrow and flood irrigated tomato or alfalfa crops. In result, upper parts of the fields where the Irrigation water introduces were found more easily leached than the lower parts of the fields since upper sides of the farmland had greater contact time with soil surface for water entrance to the soil. Movement of salts towards to lower parts of the soil profile at the tile of the field will be enough under allowing long-run time but plenty irrigation water will loss by runoff in that case. The researcher also pointed out that monitoring salinity of both soil and irrigation water and better understanding of the contributions of soil and groundwater properties on soil salinity will be beneficial for farmers for efficient leaching or sustainable agricultural production.

Hanson and May (2011) stressed that drip irrigation technique has facilitated more agro-production with less water application under correct water management. It has additional advantages at salt-affected soil by comparison to furrow and sprinkler irrigation systems. Leaves of some field crops can be injured by application of saline water with sprinkler irrigation system.

## Managerial Strategies In Salinity Control

Some applicable solutions to manage soil salinity are as follows (Anonymous, 2012);

a) <u>Reducing application of salts</u>: amount of water application in irrigation event should be minimized and if possible crop-growing system should be changed as rain-fed farming in regions having saline soils. In the other word, amount of water applied by precipitation should be as maximum as possible. In that regard, some runoff harvested from nearby bare-compacted soils can be diverted to the cropped lands directly if possible or can be collected within the huge capacity tanks before transferring to the soils in dry ecology. By this way, more water is applied to the cropped lands so that both crop yield and leaching efficiency will enhance.

b) Selection of suitable crops: farmers should growth the plant cultivars by taking into consideration of soil salinity level. Barley or sugar beet, common field crops in Konya Closed Basin, is salt tolerant plants in later growth stages. Agronomists should focus on development of crop species that are more tolerant to high soil salinity.
c) Irrigation management: irrigation program or irrigation schedule means when and how much water will be applied in each irrigation event. When means irrigation interval as day and how much means amount of water. Little and frequent irrigation process may result small area wetting in the soil profile. In that case, dilution of salts or leaching of salts towards to lower parts of the crop zone depths will reduce. The salts are deposited near by soil surface under the little amount of water application. In dry or hot regions, smaller wetted volume of soil will cause smaller movement of roots so crops are exposed to salt damage.
d) Leaching of salts: Leaching of salts towards to the crop zone depth is well known control of soil salinity in field conditions. In such process, excess irrigation water is applied occasionally for dissolving, dilution and then movement of salts. The amount of irrigation water to be applied for saline soil reclamation depends on amount of salts and their types in soil and in irrigation water.

**Some Studies With Salinity Leaching**

Semiz and Yurtseven (2010) performed a field research relevant to trickle and furrow irrigation techniques affect on yield, crop water use and salinity improvement for two tomato cultivars namely grafted or ungrafted under Clay-Loam (CL) soil conditions. They allowed 1 m space between drip and furrow irrigation plots. The lengths of lateral tube and furrow were constant as 8 m. The space of plant on the row was 0.5 m. The soil moisture content was monitored by Neutron probe. They started to the irrigation in the times of soil moisture depletions of 40-50% and 30-40% from the field capacity moisture status for drip and furrow methods, respectively. In result, drip irrigation system was found more favorable over furrow system in regard to yield of both tomato cultivars. The applied water for drip and furrow irrigation system varied from 881 mm to 871 mm, and from 731 mm to 714 mm in 2005 and 2006 growing seasons, respectively. The crop water use in those two years was between 810 mm and 772 mm, and between 957 mm and 928 mm for drip and furrow systems, respectively. Soil salt content increased towards to furrow ridges and declined towards to drip lines. In result, drip irrigation had better performance over furrow irrigation system in salinity management.

Hanson and May (2011) witnessed the wettest and the driest soil was close to the drip line and outer perimeter of the wetting front, respectively. In drip irrigation system, salinity level of the soil is affected from the multiple sources such as irrigation water quality, amount of water application in irrigation process, hydraulic characteristics of the soils, placement of the lateral lines at farmland as well as depth of the water table. The minimum or almost none salinity could be observed just under the emitters. The management of the salinization for drip-irrigated farms is very important role to play in sustainable agriculture. In general, salts within the soil profile can be removed by more water application than the crop water requirement.

Abdel Rahman Salih *et al.* (2015) suggested that soil salinity could be improved by considering two factors namely maintaining drainage conditions in root zone and well irrigation water management.

Bhatti *et al.* (2015) carried out a pot experiments about the effects of saline water use at different crop growth stages on yield and development status of wheat crop. The pot was the capacity of 5 kg, 20 cm in height with 18 cm in diameter, containing air-dried soil at 4 mm diameter with alkaline as well as moderate organic matter content. They placed plastic trays under pots for collecting percolation water. Total 39 pots, 13 treatments x 3 replicates, was put on the wooden desks. The soil water content reached up to the 50% of field capacity moisture level of soil for facilitating better seedbed. The seeds were planted as 4 cm between plants. The irrigation water was EC= 2 dS/m (S1), EC= 3 dS/m (S2), EC= 4 dS/m (S3), EC= 5 dS/m (S4) with EC= 0.6 dS/m, and top water, as control treatment. The straw and grain yield reduced as 20% and 50% for irrigation water use having EC= 3 dS/m and EC= 5 dS/m, respectively by comparison to irrigation water use with EC= 0.6 dS/m. They summarized that wheat crop was more sensitive to salinity at early stages. Therefore, wheat crop should be irrigated with irrigation water source having EC= 5 dS/m in later stages such as grain formation for minimum yield losses.

Ahmed *et al.* (2017) conducted field experiment about different levels of saline water on furrow irrigated tomato yield, yield reduction and water use efficiency, WUE, at Bangladesh during the periods October 2007- April 2008. The study region is 19 m above the sea level. In region, summers are hot and humid and winters are moderate with occasional precipitation. The tomato plants were planted on 3-6 December 2007 with 60 cm x 40 cm spacing. The experimental soil was Silt-Loam (SiL) and Sand-Loam (SL) with bulk density of 1.33 g/cm$^3$. The field capacity, FC, and permanent field point, PWP, of research soil as volumetric percentage were about 38.0% and 18.4 %, respectively. They planned plot sizes of 40 m$^2$ (8 m x 5 m). Total 120 mm irrigation water was applied to the experimental plots by three different time namely 25-30 DAT (Days after transplanting), 45-50 DAT (Days after transplanting), and 60-65 DAT (Days after transplanting), for all treatments. Following 5 irrigation treatments were examined in the research: T1: application of fresh water, T2: application of irrigation water having EC of 4 dS/m, T3: application of irrigation water having EC of 6 dS/m, T4: application of irrigation water having EC of 8 dS/m, and T5: application of irrigation water having EC of 10 dS/m. Fruits were harvested at early ripening stage by 2-3 days interval after fruits having slightly red color signs. The harvest periods were between 20 March and 30 April 2008. In results, different level of saline water application had significant effect on fruit yield of tomato. As expected, maximum fruit yield was obtained from the T1 while the minimum was from T5 treatment. The fruit yields for T1, T2, T3, T4 and T5 treatments were about 37 t/ha, 35 t/ha, 30 t/ha, 28 t/ha, and 22 t/ha, respectively. The yield reductions for T2, T3, T4 and T5 treatments in accordance of T1 were 4.65%, 17.23%, 23.90%, and 40.20%, respectively. The yield reduction between T1 and T2 was very little. Water Use Efficiency (WUE) defining as ratio of yield (kg/ha) to applied water (mm) for T1, T2, T3, T4 and T5 were calculated as about 212, 202, 175, 161, and 127 kg/ha, respectively. As a result, WUE reduced gradually by increasing salt content of irrigation water.

## Conclusion

In case of low precipitation, leaching, hydro-technique, is only way to remove the salts from the soil profile under well drainage condition. Diverting precipitation towards to salt-affected soils in dry environments is friendship strategy for sustainable use of those soils in agro-production. It is noted that more frequent water application is very beneficial for crops that are sensitive to the soil salinity. In general, seedling is more sensitive stage to the salinity by comparison to later stages. In addition, monitoring soil and water salinities with great care are possibly very useful strategies for well management of saline soils. On of the most important practical and friendly-environmental solutions is development of salt tolerant crop cultivars. Future studies should focus on determination of critical stages of crops or plants for the different soil salinity levels.

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