# 18th INTERNATIONAL SOIL MEETING (ISM)

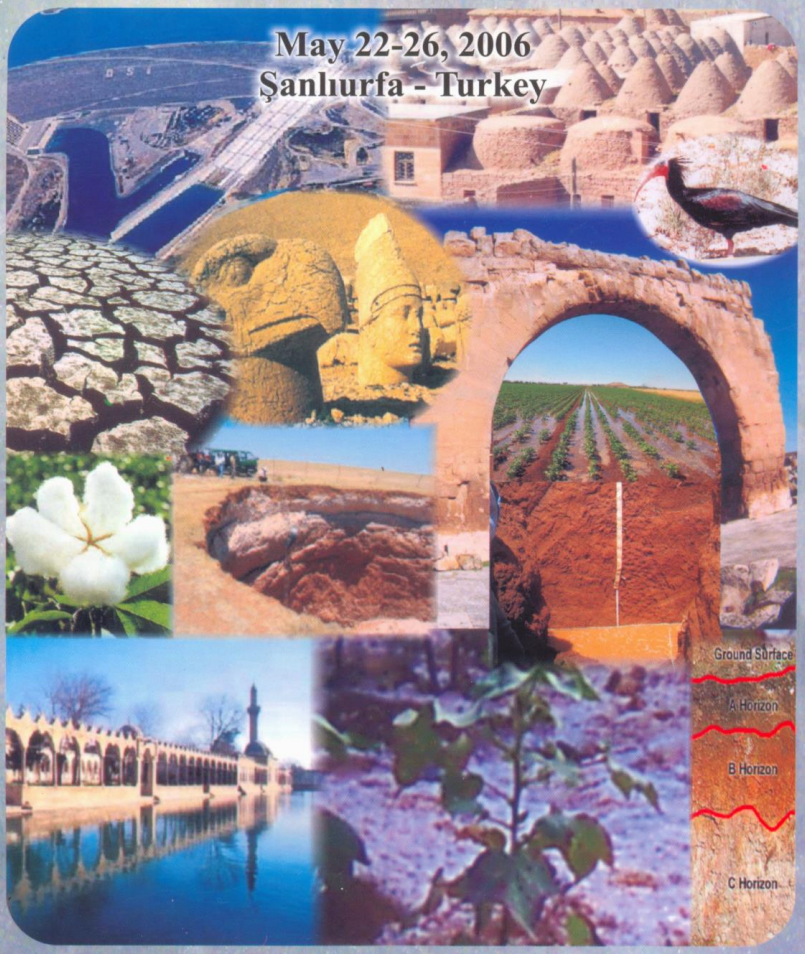
on

"Soil Sustaining Life on Earth, Managing Soil and Technology"

## PROCEEDINGS

## Volume II

May 22-26, 2006
Şanlıurfa - Turkey




Organized by
Harran University, Faculty of Agriculture,
Department of Soil Science
&
Soil Science Society of Turkey

# The Effect of Saline Irrigation Water on Water Use Efficiency and Mineral Matter Content of Lemon Balm (*Melissa Officinalis L.*)

**Ali Ünlükara[1], G. Duygu Kesmez Sağlam[2], Ahmet Öztürk[2]**

[1]Department of Farm Structures and Irrigation, Agricultural Faculty, Gaziosmanpaşa University, Tokat/Turkey.
[2]Department of Farm Structures and Irrigation, Agricultural Faculty, Ankara University, Ankara/Turkey.
[2]Department of Farm Structures and Irrigation, Agricultural Faculty, Ankara University, Ankara/Turkey.
unlukara@gop.edu.tr

## Abstract

The study was carried out to determine the effects of saline irrigation water on water use efficiency, soil salinity, Na, K, Ca, Mg, Cl, and N content in lemon balm (*Melissa officinalis L.*). Five water salinity levels (0.25, 1, 2, 4 and 6 $dSm^{-1}$) were performed for irrigations. The experiment was cond
ucted as a randomized block design with three replications under greenhouse conditions. Ten lemon balm seedlings were planted in a pot for each replication. Fresh yield per plant under salt stress varied from 20.83 to 68.15 g and the highest value was obtained from the treatment irrigated 1 $dSm^{-1}$ saline water. All plants died at 6 $dSm^{-1}$ concentration of irrigation water salinity level. The highest WUE was obtained from 1 $dSm^{-1}$ salinity level with 5.63 kg $m^{-3}$. The effects of salinity on Na, K, Cl, and K content in leaves were statically significant but N and Mg accumulation was not. Na, Ca and Cl accumulations in leaves increased but K accumulation decreased with increasing salinity level.

**Key words;** lemon balm (MELISSA OFFICINALIS L.), salinity, water use efficiency, mineral matter content, threshold value.

## Introduction

Increasing water demand and competition for fresh water became crucial. Fresh water for agricultural production does not mean only higher yield but also a key factor for sustainability. This limited water resources, now, must be shared among industrial, urban and agricultural usage. In this respect scientists have to investigate what kind of plants can be growth under saline condition. In literature review, we could not found enough paper to demonstrate the effects of water quality on herbs. The researchers have been studied widely on vegetable plants but not herbs. In addition, there is an increasing demand for the utilization and consequent industrial processing of aromatic and medicinal plants. This is creating a large market and presently, over 4000 species with a high final product value are harvested each year. Over 80% of species, more than 750,000 tones annually are being collected from the wild. This plant material is a source of natural products used as flavors, fragrances, cosmetics, pharmaceuticals and as agrochemicals (Bauer et al., 1997). Lemon balm (*Melissa officinalis L.*) has unique antioxidant capacity and is very important for human diet (Katalinic et al. 2006). Öztürk et al. (2004) were studied effects of salt stress and water deficit on plant growth and essential oil content of lemon balm and determined out that yield, water consumption and essential oil content were decreased with increasing soil and irrigation water salinity. In our study, salt effects on lemon balm leaf mineral content such as N, Na, K, Ca, Mg and Cl were investigated. Leaf materials for this experiment derived from the experiment of Öztürk et al. (2004).

## Material and Methods

This study was carried out at the laboratories and under greenhouse conditions, in Agricultural Faculty, University of Ankara in 2003. The seeds of lemon balm collected from nursery of perennial medicinal plants which were sown into strong boxes in the greenhouse. About 6 weeks later after sowing, seedlings were transplanted to lysimeters having 62 cm diameter and 22 cm depth in the greenhouse. Each lysimeters had 10 lemon balm plants. Irrigation water salinity levels (0.25, 1, 2, 4 and 6 $dSm^{-1}$) were used as treatments with three replications for each factor in the study. To prepare irrigation water with different salinity levels, highly soluble NaCl, $CaCl_2$ and $MgCl_2$ salts were used. Sodium adsorption ratio was kept under 1 in all salinity levels so that only effect of salinity was evaluated. A basic program was used to determine the amount of chemical materials added to water (Yurtseven et al., 2001) and controlled EC levels after preparing saline water.

At the beginning of the experiment the pots filled up with soil, saturated and covered with polyethylene cover to prevent evaporation. There was free drainage condition in the pots for applied water. Drainage water from the pots was monitored when the drainage from the pots was ceased (after two days), it is assumed that the soils of the pots have reached to the field capacity. Considering the plant growth, the values of field capacity of each pot was increased through the study period. Soil moisture content of lysimeters monitored by weighing at 3-4 day intervals and irrigation application were performed at the same time intervals. For irrigations, lack of water from field capacity and 20% more water were applied.

Soil samples were taken from the entire depth of the container at the end of the experiment. Soil salinity was determined by using of saturation paste extract. Mineral matter contents of leaves were determined

by using flamephotometric (for K and Na), EDTA titration (for Ca and Mg) and $AgNO_3$ titration (for Cl) methods (Richards, 1969).

## Results

### Soil Salinity

At the harvest, soil samples were taken from each pot then soil saturation pastes were prepared and extracted. Electrical conductivity of soil saturation extracts (ECe) were 1.02, 3.86, 6.32, 10.43 and 17.16 $dS.m^{-1}$ in the result of 0.25, 1.0, 2.0, 4.0 and 6.0 $dS.m^{-1}$ saline irrigation water applications respectively (Table 1). At the beginning of the experiment, intended leaching fraction (LF) was 0.20 but according to soil salinity levels (ECe), this LF was not achieved. Rhoades and Merrill (1976) were showed relationships between soil saturation extract salinity (ECe), irrigation water salinity (ECi) and leaching fraction (LF). According to these relations, estimated LF for the experiment was about 5-8%.

Table 1: Soil salinity and leaching fraction results

| Treatment Symbol | Irrigation Water Salinity (ECi) $dS.m^{-1}$ | Soil Saturation Extract Salinity (ECe) $dS.m^{-1}$ | Estimated Leaching Fraction (LF)* |
|---|---|---|---|
| $S_0$ | 0.25 | 1.02 | 0.052 |
| $S_1$ | 1.0 | 3.86 | 0.055 |
| $S_2$ | 2.0 | 6.32 | 0.068 |
| $S_4$ | 4.0 | 10.43 | 0.083 |
| $S_6$ | 6.0 | 17.16 | 0.075 |

* Estimated Leaching Fraction, $LF=\frac{ECi}{[5ECe-ECi\ ]}$

Although more water applied for leaching (LF= 0.20), higher than expected soil salinity values were obtained at the end of the experiment. The reason of the high soil salinity may be due to water flow from the gap between the pot edges and soils that may decrease the effectiveness of leaching.

### Effects of Salinity on Yield

Maas and Hoffman (1977) developed a salt tolerance model by means of a piecewise linear response function (Figure 1). The tolerance of various crops were expressed, in terms of relative yield (Yr), threshold salinity value (a) and percentage decrement value per unit increase of salinity excess of the threshold (b). In the model soil salinities expressed in terms of ECe, in $dS.m^{-1}$. Salt tolerance model of *Melissa officinalis* showed in Figure 1. As seen in Figure 1, the salt tolerance model was $Yr=1-0.124 \times (ECe-5.52)$. The threshold value was 5.52 $dS.m^{-1}$ and the slope was 12.4%. Zero yield point was obtained at 13.5 $dS.m^{-1}$ soil salinity level from the salt tolerance model. Consequently, lemon balm couldn't survive at excess salinity above 13.5$dS.m^{-1}$ and the plant could not survive at 17.2 $dSm^{-1}$ salinity level in green house conditions for this experiment.

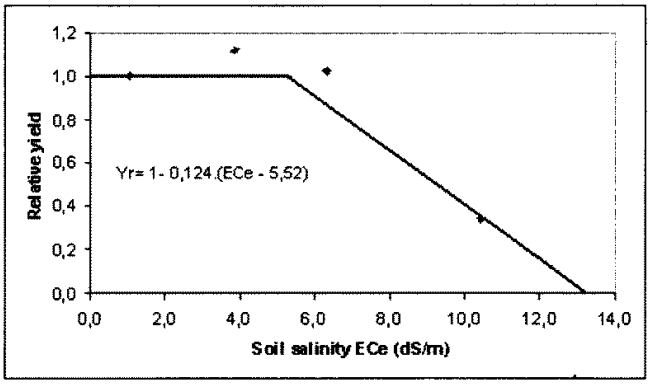



Figure 1: The effect of salinity on fresh yield and Salt tolerance model of *Melissa officinalis*

### Effects of Salinity on Water Use Efficiency (WUE)

Water use efficiency was determined as ratio fresh yield (kg) /water consumption ($m^3$) (Doorenbos, J. and A.H., Kassam, 1979). As seen in Figure 2, WUE increased with increasing salinity up to 3.86 $dSm^{-1}$ soil salinity level and at higher salinity levels WUE value decreased again. This decrease, comparing to control treatment, was 52% for 17.16 $dSm^{-1}$ soil salinity level. The highest WUE value was obtained from 3.86 $dSm^{-1}$

soil salinity level due to decrease in water consumption against increasing yield. The smallest WUE value was obtained from 17.16 $dSm^{-1}$ soil salinity level because of decreasing both water consumption and yield together.

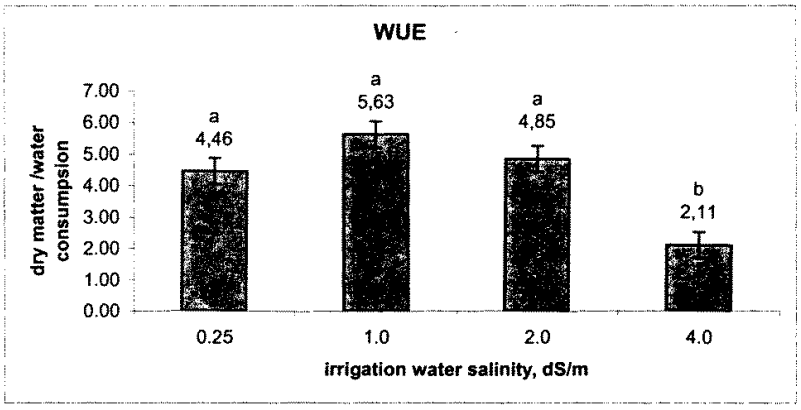



Figure 2: The effect of salinity on WUE

**The Effects of Salinity on Leaf Mineral Matter Contents**

**Sodium (Na)**

The results showed that increasing salinity level led to increase in leaf Na accumulation. Duncan test results indicated that the increase started after 3.86 $dSm^{-1}$ soil salinity level statistically (Figure 3). Comparing to control treatment the increase were 121% and 179% for 6.32 and 17.16 $dSm^{-1}$ salinity levels respectively. Comparing to yield decrease, it might be suggested that the plant can cope with sodium accumulation till 10.43 $dSm^{-1}$ salinity level and after this salinity level the yield decrease started. In other words, until the accumulations of Na in leaves reached at 0.0797%, the yield was not affected.

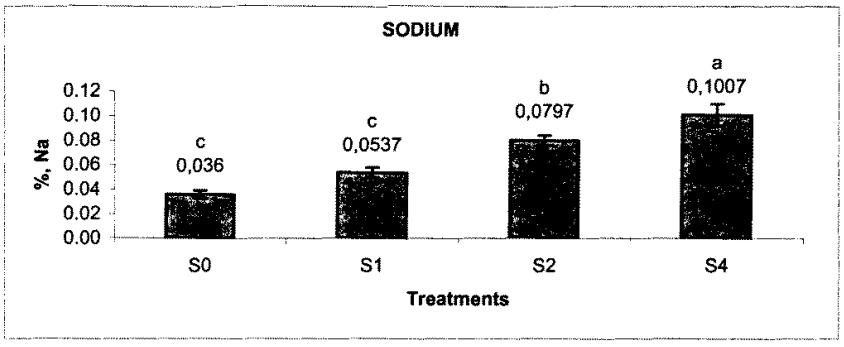



Figure 3. Sodium accumulation in leaves

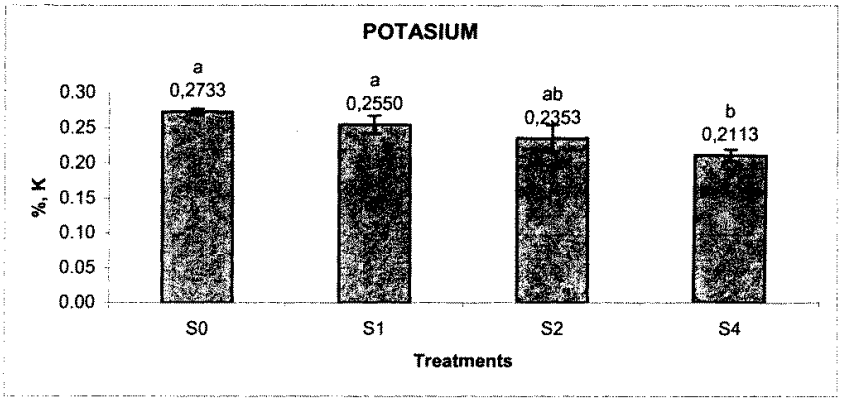



Figure 4. Potassium accumulation in leaves

**Potassium (K)**

In plants K selectivity is a major indicator which shows how much tolerant it is to salinity because of competitive uptake for Na and K ions by plants. According to the results, leaf K content was decrease with increasing salinity level but this decrease started after 6.32 $dSm^{-1}$ salinity level, on contrary to Na accumulation (Figure 4). Comparing to control treatment the decreases were 13% and 22%, for 6.32 and 17.16 $dSm^{-1}$ treatments, respectively.

**Calcium (Ca)**

Leaf Ca content increased with increasing salinity levels (Figure 5). Duncan test results indicated that after 3.86 $dSm^{-1}$ of irrigation water salinity level the augmentation started. Comparing to control treatment, the increases in leaf Ca accumulation were 49.9% and 75.9% for 6.32 and 17.16 $dSm^{-1}$ treatments, respectively.

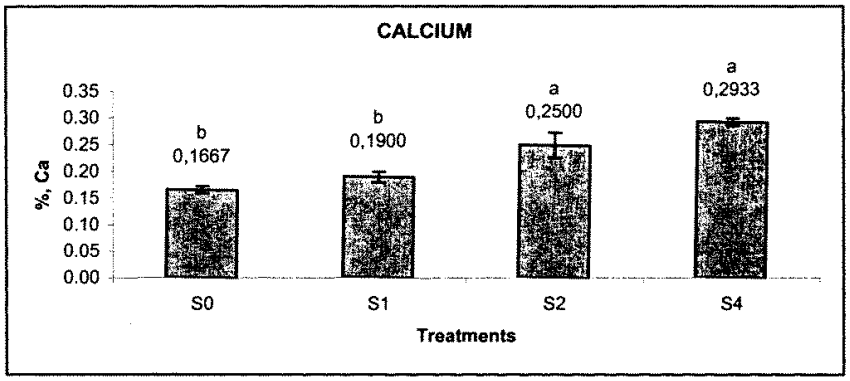



Figure 5: Calcium accumulation in leaves

**Chloride (Cl)**

Leaf Cl content also increased with increasing salinity levels (Figure 6). Duncan test results showed that the augmentation started after 6.32 $dSm^{-1}$ of soil salinity level. Comparing to control treatment the increases in Cl accumulation in leaf were 265% and 415% for 6.32 and 17.16 $dSm^{-1}$ treatments, respectively. Chloride content in leaf is another important factor to estimate the toxicity. For our results, comparing to yield decrease and Cl accumulations, we may interpret that increasing Chloride ions may cause the yield decrease.

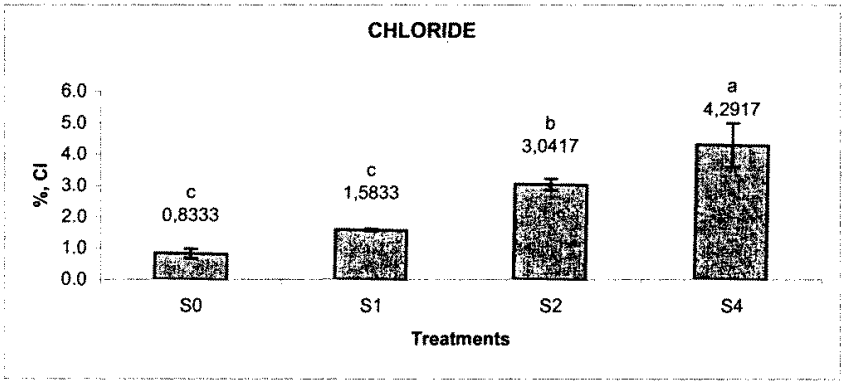



Figure 6. Chloride accumulation in leaves

**Magnesium (Mg) and Nitrogen (N)**

Leaf Mg and N content did not show any statistical response to water salinity, in other words increasing salinity levels did not affect on Mg and N accumulation by plants.

**Dustacion**

In summary, in this research we examined the effects of salinity on fresh yield, WUE, Na, K, Ca, Mg and N content of lemon balm (*Melissa officinalis L.*). According to the salt tolerance model, soil salinity didn't

affect plant growth until a threshold value and the threshold value of lemon balm was obtained as 5.52 dS/m and the slope as 12.4%. Most of the observed parameters include fresh yield, WUE, Na, K, Ca and Cl content in leaves did not show any change until 6.32 $dS.m^{-1}$ soil salinity level. In other words the effects of salinity appeared after the threshold salinity level. According these results we can conclude that lemon balm (*Melissa officinalis L.*) is moderately tolerant to salinity.

The increase of $CaCl_2$ and NaCl in irrigation water caused to increase in Ca, Na and Cl ions in soil solution hence Na, Ca, and Cl content in leaves increased with increasing salinity level. Finally, we examine K, N and Mg accumulations in leaves and WUE, in presence of rising amount of Na, Ca and Cl ions in soil solutions. Mg and N uptake by plant did not change statistically. We found reverse relations with Na and Cl accumulation to yield, the regression for Na-yield was $r^2$=98.21 and Cl-yield was $r^2$=1. Consequently, we can conclude that increasing Na and Cl accumulations in leaves are an indicator of yield lost. On the other hand we found that K accumulation by plant strongly affected the presence of Na in soil solutions. An important correlation observed between K and Na ions uptake by plant. This antagonistic linear relation was found as $r^2$=99.37.

## References


Bauer, K., Garbe, D. and Surburg, H., 1997. Common Fragrance and Flavor Materials, Wiley-VCH, Germany.

Doorenbos, J. and Kassam, AH., 1979. Yield Response to Water. FAO Irrigation and Drainage Paper 33, Rome.

Katalinic, V., Milos, M., Kulisic, T., and Jukic M., 2006. Screening of 70 medicinal plant extracts for antioxidant capacity and total phenols. Food Chemistry. 94: 550–557.

Öztürk, A., Ünlükara, A., Ipek, A. and Gürbüz, B., 2004. Effects of Salt Stress and Water Deficit on Plant Growth and Essential Oil Content of Lemon Balm (Melissa officinalis L.). Pak. J. Bot., 36(4): 787-792.

Maas, E.V. and Hoffmann, G.J., 1977. Crop salt tolerance–current assessment. ASCE J. Irrigation and Drainage Div. 103(IR2): 115-134.

Rhoades, J.D. and Merrill, S.D., 1976. Assessing the suitability of water for irrigation: Theoretical and empirical approaches. In: prognosis of Salinity and Alkalinity. FAO Soils Bulletin 31. FAO Rome.

Yurtseven, E., A. Unlukara, A. Top and A. Tek., 2001. Effect of salinity and irrigation interval on yield and vegetative growth of kolza (*brassica napus oleifera*). First National Irrigation Congress, 8-11 November 2001, Antalya-Turkey, pp 215-220.