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EFFECTS OF SALT STRESS AND WATER DEFICIT ON PLANT GROWTH AND ESSENTIAL OIL CONTENT OF LEMON BALM (*MELISSA OFFICINALIS* L.)

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Abstract

Studies were carried out to determine the effects of salt stress (0.25, 1.00, 2.00, 4.00 and 6.00 dSm^{-1}) and water deficiency (0, 12.5, 25.0, 37.5 and 50.0 %) on some yield components and essential oil contents of lemon balm (*Melissa officinalis* L.). The results showed moderate tolerance of lemon balm against salt with death of all plants when irrigation water had salinity level of 6 dSm^{-1}. Dry yield per plant under salt stress varied between 4.33-14.87 g with maximum yield at 1 dSm^{-1} salt concentration. Lemon balm was found highly tolerant against water stress. Dry yield under water deficit varied from 13.05 to 19.20 g per plant. Reduction in yield was not statistically significant till 25 % water deficiency. Each increase in salt stress was accompanied with reduction in essential oil, whereas its ratio increased with each increase in water deficiency.

Introduction

Lemon balm (*Melissa officinalis* L.) of the family *Lamiaceae* is an aromatic perennial subshrub native to the eastern Mediterranean region and western Asia is also widely cultivated in Europe. The material of commerce comes from Bulgaria, Romania and Spain (Anon., 1996; Bruneton, 1995; Leung & Foster, 1996; Wichtl & Bisset, 1994). Lemon balm is one of Turkey's important medicinal crops. There are three subspecies of *Melissa officinalis* subsp. *officinalis*, subsp. *inodona* and subsp. *altissima*; however, only subsp. *officinalis* has a commercial value with characteristic lemony odor (Davis 1982), which makes it favorite for cultivation in Turkey and Balkan countries (Nunez & Castro 1992). It has long been used for its soothing medicinal effects and herbal aromatic properties (Dwyer & Rattray 1997, Sari & Ceylan 2002) in folk therapy. This plant has been traditionally used to treat fever, catarrh, headaches, influenza and insomnia. Essential oil is also believed to have spasmolitic, sedative and moderate antibacterial characteristics (Schultze *et al*., 1992).

Irrigated agriculture in arid and semi-arid areas of the world may eventually lead to salt build-up in the soil and deterioration of productivity. Salts come with the irrigation water and are accumulated and concentrated in the soil as water evaporates and is taken up by crops. Management practices must be selected to ensure that the levels of salinity in the soil are not harmful to crop growth. This is usually done by applying enough water to satisfy crop requirements and leach out salts from the root zone (Rhoades, 1974). However, the implementation of this approach is limited by drainage and shallow water table problems, environmental concerns regarding the amount and composition of the drainage effluents, limited quantity and low quality of the water for agriculture as well as economic aspects (Tanji, 1990).

The response and growth of plants to saline conditions vary at different stages of growth depending upon the genotype. All plants tolerate salinity up to a certain threshold level without any yield reduction. After which, an increase in salinity level significantly reduces yield.

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Effect of water salinity has been reported for many crops including alfalfa (Keck *et al*., 1984), cotton (Howel *et al*., 1984), pea (Lal, 1985), tomato (Vinten *et al*., 1986), mentha (Ozturk, 1997) etc., showing drastic reduction in crop yield at higher salt concentrations.

The present report describes the effect of salt and water stress to account for soil salinity effects on growth of lemon balm and perform a qualitative analysis of simulated crops responses to soil salinity and water stress.

Material and Methods

This study was carried out during 2003 by collecting seeds of a local ecotype of lemon balm from the nursery of perennial medicinal plants, Field Crops Department, Faculty of Agriculture, University of Ankara, Turkey. The seeds were sown in wooden boxes (45 cm X 60 cm X 20 cm) in greenhouse and after about 6 weeks 10 germinated seedlings were transplanted to 30 lysimeters having 62 cm diameter and 22 cm depth containing sandy loam soils. Irrigation water salinity (salt stress) and water deficit (water stress) were considered as two factors in the research with three replications; using randomized plot design for each factor. Irrigation water salinity levels of 0.25, 1.00, 2.00, 4.00 and 6.00 dSm^{-1} and water deficit levels of 0% (no water deficiency=normal irrigation), 12.5% (12.5% reduced irrigation water), 25% (25% reduced irrigation water), 37.5% (37.5% reduced irrigation water) and 50% (50% reduced irrigation water) were maintained in the root zone.

Plant water consumption values were determined by using weighing type lysimeters. These lysimeters were balanced before all irrigations and deficient water below field capacity was added to the soil; 20% more water was added to the soil as leaching requirement in salt stress part of the study.

To prepare irrigation water with different salinity levels, highly soluble NaCl, $CaCl_2$ and $MgCl_2$ salts were used. Sodium adsorption ratio

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

was kept about 1 in all salinity levels so that only effect of salinity could be evaluated without any negative effect of sodium. When SAR value is more than 10, evaluation of Sodium is important but when it is around or below 1 there is no effect of Sodium (Richards, 1954). As all treatments had a SAR value around 1, therefore, only salinity was evaluated, without considering effects of Sodium. A computer programme based on “Visual Basic” was used to determine the amount of chemical materials added to water (Yurtseven *et al*., 2001). In water deficit part of the research, irrigation water salinity was 0.25 dSm^{-1} so only the effect of water stress was evaluated since there was not a possible salt stress.

Fresh yield per plant (g), dry yield per plant (g), dry matter (%), plant height (cm), number of branches per plant, root length (cm), stalk diameter (mm), root dry weight (g), evapotranspiration (L/plant), root zone salinity (dSm^{-1}) and essential oil content (%) were determined using standard techniques. Essential oil content was determined by hydro distillation method by submitting aerial part of dried plants (100g) in modified Clevenger apparatus (Esquivel *et al*., 1999; Gurbuz *et al*., 1999). After 3 hours distillation was stopped so essential oil ratio was measured by using dry yield (biomass yield) of lemon balm.

Data was statistically analyzed to determine the analysis of variance (ANOVA) and differences between the means were compared by Duncan's Multiple Range Test using MSTAT-C computer program.

Results

Effects of salt stress: The results showed that irrigation water salinity up to 2 dSm^{-1} had insignificant effects on fresh yield per plant (g), dry yield per plant (g), root length (cm) and essential oil ratio (%). Statistically insignificant changes were recorded at any level of irrigation water salinity for dry matter (%) and stalk diameter (mm). No statistical change was observed in number of branches per plant, evapotranspiration (L/plant) and root dry weight (g) up to 1 dSm^{-1}. There after a sharp decline in these parameters was observed with each increase in irrigation water salinity. Plant height (cm) was significantly affected with each increase in irrigation water salinity and showed a range of 39.87 to 58.73 cm. All seedlings died at 6 dSm^{-1}, which appeared toxic for plant growth and development. Essential oil ratio was affected negatively by salt stress and it decreased from 0.15% to 0.12% (Table 1).

Effects of water deficit: The results showed that in general no or statistically insignificant reduction in fresh yield per plant (g), dry yield per plant (g), plant height (cm), number of branches per plant, root length (cm), root dry weight (g), evapotranspiration (L/plant) was observed at or below 25% water deficit (Table 2). Thereafter, reduction in the respective parameters was very sharp with minimum recorded values at 50% water deficit. Moreover, dry matter and stalk diameter remained unaffected under any treatment and were statistically similar. However, essential oil ratio that ranged between 0.12 and 0.16 % increased with each increase in the water deficit (%) such that the highest water deficit (50%) was accompanied with the highest essential oil ratio (0.16%).

Discussion

Depending on the classification system of Ayers & Westcot (1989), the results indicated that lemon balm was highly tolerant to water deficiency and moderately tolerant against salt stress. The results showed high potential of this important medicinal plant for extended cultivation in Turkey with salinity level of 10 dSm^{-1}in the root zone and with water deficit of 25%. A 10.43 dSm^{-1} of soil salinity in root zone with 4 dSm^{-1} concentration of irrigation water salinity showed that lemon balm was more salt tolerant compared to corn, sugar beet, celery, potato, spinach and tomato (Tanji, 1990).

Plant height of lemon balm plant was affected significantly by irrigation water salinity and water deficit which is in agreement with Sari & Ceylan (2002), who recorded plant height of 41.61-55.79 cm in Aegean conditions. Also fresh yield, dry yield, number of branches, root length, root dry weight and evapotranspiration were affected significantly by both treatments. Stalk diameter and dry matter were not affected by both applications.

Dry yield per plant decreased by increasing of salt concentrations and water deficit (Fig. 1). Especially, there was a great yield reduction from 2 dSm^{-1} concentration to 4 dSm^{-1} concentration. This result shows that the irrigation water salinity level must be less than 2 dSm^{-1} for suitable lemon balm production.

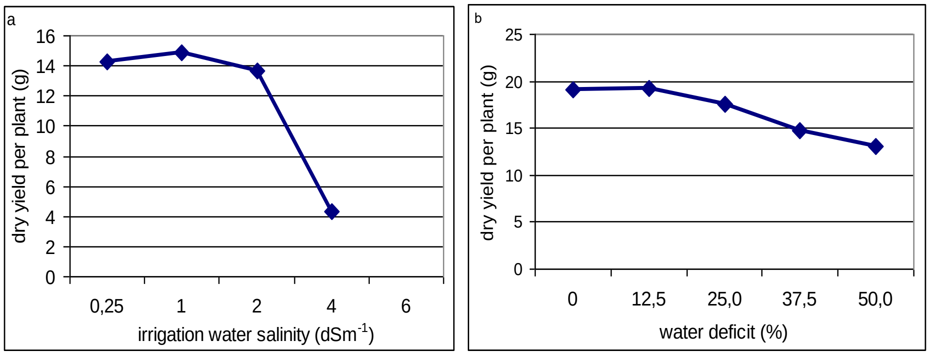

Fig. 1. Effects of irrigation water salinity (a) and water deficit (b) on dry yield per plant in lemon balm.

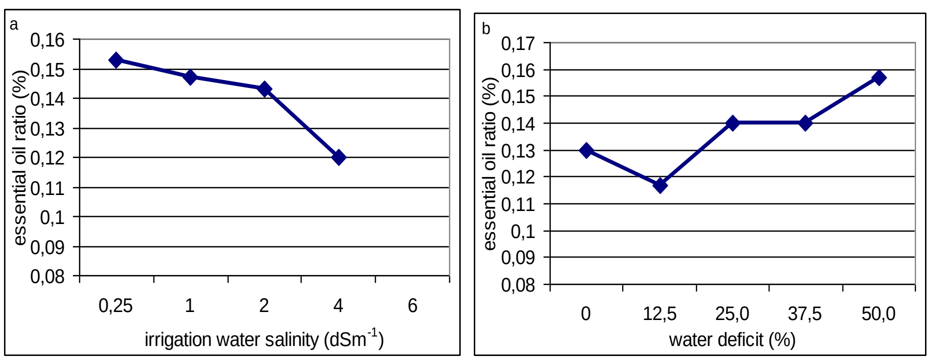

Fig. 2. Effects of irrigation water salinity (a) and water deficit (b) on essential oil ratio in lemon balm.

Essential oil ratio was affected positively by increasing water deficit while it was affected negatively by increasing salt concentration (Fig. 2). Water deficiency increased essential oil from 0.12% to 0.16% and similarly Pitarevic *et al*., (1985) reported that a long dry season should give a high oil production. Since the significant yield reduction starts at 25% water deficit, irrigation water deficiencies must not be applied over this level.

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