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Effects of Salinity Stress on Growth of Lettuce (*Lactuca sativa*) under Closed-recycle Nutrient Film Technique

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ABSTRACT

Soil and water salinity are amongst major limiting factors affecting crop growth, quality and yield throughout the world. An experiment was conducted to investigate the effects of salinity stress (NaCl) on growth of lettuce (*Lactuca sativa* L.) cv. Paris Islands Cos under closed-recycled nutrient film technique (NFT). Different salinity levels i.e. 50 mM and 100 mM along with control (0 mM) were used. It was observed that number of leaves, plant fresh weight, shoot fresh weight, shoot dry weight, shoot dry matter percentage, root fresh weight, root dry weight, root dry weight percentage, leaf area and leaf area index were significantly effected by salinity levels, while shoot and root water contents percentage, ratio of the shoot to root fresh weight and ratio of the shoot to root dry weight showed insignificant effect in response to salinity. Overall studies revealed that lettuce is sensitive to salt stress in NFT, which resulted in poor growth and quality of lettuce.

Key Words: Salinity stress; Lettuce; Nutrient film technique; Growth

INTRODUCTION

Limiting good quality water resources are forcing growers to use water with relatively high salt concentration for crop irrigation (Reed, 1996). The scarcity of water resources demands reduction in water use. This may force to abandon the conventional flood irrigation system to reduce wastage of fresh water resources that results in wastage of the precious fresh water due to run off and deep percolation. Under such conditions, soilless culture techniques offer a way of improving water use efficiency and obtaining better water and fertilizer management in crop production (ICARDA-APRP, 2001). In addition, many problems are associated with soil, because of the continuous use of same soil for growing vegetables, which has resulted in a build up of soil born diseases and accumulation of salts. Salinity affects almost every aspect of the physiology and biochemistry of plants as well as reduction in crop yield significantly. Salinity is the most serious threat to agriculture (Parida & Das, 2005; Munns & Tester, 2008) and major environmental factor that limit crop growth and productivity (Munns, 2002; Mididi *et al*., 2004; Afzal *et al*., 2006). Soil salinity affects 1000 million ha of land, which is 7% of all land area (Szabolcs, 1994). About 20% of irrigated agricultural land is adversely affected by salinity (Chinnusamy *et al.,* 2005). Moreover about one-third of the irrigated land on the earth is affected by salinity (Taiz & Zeiger, 2006). Lettuce (*Lactuca sativa* L.) is categorized as being moderately salt tolerant (De Pascale & Barbieri, 1995). Salinity levels of more than 2.0 and 2.6 dS m^{-1} reduce lettuce fresh yield and plant growth, respectively (De Pascale & Barbieri, 1995). It has been reported that lettuce has a threshold value of 1.1 dS m^{-1} and the relative yield decrease in slope after this threshold as 9.3% (Ünlükara *et al*., 2008).

Agricultural productivity and sustainability are the main challenges faced by many arid and semiarid regions as these regions have severe shortage of good quality water, where saline water is used for irrigation of different crops. A number of measures including hydroponics technique has been introduced Ministry of Agriculture, Oman (MOA) introduced for cultivation of different agricultural crops to overcome the above dilemma and to uplift the economic return of farmers in the country by producing good quality crop. Recently a growing trend towards soilless culture has been observed, which is considered more efficient system for crop growth. The objective of the present study was to observe the effect of different salinity levels under hydroponics system for the benefit of small scale farmers, researchers and home gardeners.

MATERIALS AND METHODS

The experiment was conducted in glasshouse at Agriculture Experiment Station, Sultan Qaboos University, Oman (latitude 35º7´N, longitude 20º56´E, altitude 7m).

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Lettuce (*Lactuca Sativa* L. cv. Paris Islands Cos) seeds were sown singly in seedling tray (ST) (2.5×2.5×3.8 cm^3) filled with commercial peat moss (IRISH, UK), vermiculite and perlite. These trays were kept moist at 25±2°C until germination. Seedlings were kept in seedling tray for four weeks and afterwards transplanted according to completely randomized design (CRD) in the nutrient film technique (NFT) with thirteen replications per row and plant density was one plant for every 16 cm^{-2} per system. Three salinity levels 0 (control), 50 and 100 mM were used as treatments. To impose salinity, sodium chloride (NaCl) salt was used in this experiment. Seedlings were fertilized with full strength Hoagland solution (Hoagland & Arnon, 1950). The pH level of the three treatments was maintained at 6.5 to 8.0.

Three individual channel frame made of wood with a size of (2.3 m length × 0.4 m width × 0.1 m height) were mounted at 60 cm above the bench top. Double layer of polyethylene plastic of size 500G (10 m × 6.3 m), (Al Amoudi Plastic, Qatar) placed on the top of each channel frame and Styrofoam sheet of size (2.3 m length × 0.4 m width) placed on the top of each system. Thirteen small squares (0.45 × 0.45 m) holes were pierced along the Styrofoam sheet in two rows with 12 cm spacing between each square hole. A PVC plastic pipe of size (2.3 m length × 0.4 m width) placed on top and in the middle of the Styrofoam sheet and connected to the water pressure pump of power 35W (SUBMERSIBILE, MODEL KING-3, 220-240V). Each pump was placed in a water tank (fertigation tank) of capacity (70 L) and linked to an electrical power supply.

Shoot length and number of leaves were counted weekly after transplanting throughout the experiment. In addition, plant biomass as well as water contents were determined after counting the number of leaves. The leaf area (LA cm^2) and leaf area index (LAI) determined by using portable area meter (CI-202) at harvest stage.

The experiment was arranged according to completely randomized design. Data recorded were analyzed statistically using Fisher's analysis of variance technique and Duncan's Multiple Range Test at 5% probability level to compare the differences among treatment means (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Results revealed significant differences among three different salinity levels (0, 50 & 100 mM) on growth of lettuce (Table I). A decreasing pattern in growth of the lettuce was observed with increasing salinity levels. Plants with control treatment produced highest root and shoot length than plants treated with 50 and 100 mM salt, respectively (Fig. 1). In this experiment, number of leaves, plant fresh weight, shoot fresh weight, shoot dry weight, shoot dry matter percentage, root fresh weight, root dry weight, root dry weight percentage, leaf area and leaf area index were found to be significant, while shoot and root water contents percentage, ratio of the shoot to root fresh weight and ratio of the shoot to root dry weight were non-significant in their response to salinity stress. The highest growth was observed in 0 mM salt, while it was lowest at 100 mM salinity stress. Although, shoot fresh and dry weight was significantly affected but insignificant differences were observed between 0 mM and 50 mM salinity treatments. In addition, similar results were observed in case of root fresh and dry weight of lettuce under salinity. Similarly leaf area and leaf area index also didn't differ significantly at 0 mM and 50 mM salinity levels. There was no consistent pattern between three salinity levels. The findings were similar to those reported by Bar-Yosef *et al.* (2005). Number of leaves was reduced significantly with increasing salinity levels, which confirms the results of Ünlükara *et al.* (2008) but this is in contrast to the findings of Andriolo *et al*. (2005) who reported that number of lettuce leaves was not affected by salinity treatments. Plant dry matter was significantly reduced with increasing salinity but this is inconsistent with the results of Ünlükara *et al.* (2008) who found that plant dry matter content increased with increasing salinity for the salinity range studied.

Significant differences were found between 0, 50 and 100 mM for leaf area, leaf area index of the leaves (Fig. 2). No direct correlation was found between the leaf area measurements and plant fresh weight in all three salinity levels. Each studied growth parameter was affected individually and independently from each other. However, strong correlation was found in number of leaves and plant fresh weight at all three salinity levels over period of seven weeks. This describes direct relationship in the two growth measurements in term of yield.

Lettuce yield response to the three salinity levels in recycled NFT solutions was similar with the findings of Karam *et al.* (2005). Ünlükara *et al.* (2008) also reported that salinity reduced the yield of lettuce in a constant manner. Salt-treated (1% NaCl) endive and fennel had decreased marketable yield by about 60%; lettuce yield was reduced about 15% (lettuce & endive appeared to be more sensitive to tip-burn & necrotic symptoms occurring in the crop under saline-sodic conditions). In addition, gas exchange rates, stomatal conductance and product quality were reduced by salinity level (De Pascale & Barbieri, 1995). These may be attributed to low uptake or decreased xylem transport of calcium or to disturbed partitioning of cations in plant tissues at high concentration of sodium ions in the soil solution (Sonneveld, 1988).

Based on observations, most of lettuce root became long over the period of 50 days from transplantation and overlapped with each other which indicated that the width, length and depth of the closed-system frame (2.27 m length × 0.4 m width × 0.1 m height) was less and not sufficient for root expansion and growth. This might take in account as a limiting factor of NFT system. Further modifications of this system are required for future

Table I: Means of growth and biomass measurements in Lettuce after 50 days of transplantation in NFT

Data	Salinity Levels 0 mM	50 mM	100 mM
No. of Leaves per plant	14.23±1.67a	12.65 ± 0.92b	12.08 ± 1.96c
Plant fresh wt (g)	84.94±2.91a	76.47 ± 6.20b	50.00 ± 3.33c
Shoot fresh wt.(g)	75.65±0.85a	62.35 ± 3.35a	45.62 ± 2.26b
Shoot dry wt.(g)	13.19±0.52a	8.95 ± 1.12a	6.58 ± 0.75b
Shoot DM (%)	18.09±0.71a	14.97 ± 0.36b	13.89 ± 1.21c
Shoot WC (%)	85.03±2.52	84.09 ± 4.26	81.91 ± 3.96
Root fresh wt.(g)	6.64±0.55a	5.88 ± 0.94a	4.04 ± 0.47b
Root dry wt.(g)	3.47±0.09 a	2.89 ± 0.12a	2.07 ± 0.75b
Root DM (%)	52.49±4.25 a	51.42 ± 2.14b	49.63 ± 3.25c
Root WC (%)	50.37±2.67	48.58 ± 1.12	47.51 ± 2.35
Shoot/Root FW ratio	11.58±1.62	11.55 ± 0.56	10.86 ± 1.12
Shoot/Root DW ratio	3.96±0.15	3.51 ± 0.10	3.28 ± 0.25

Numbers followed by the same letter in the same row are not significantly different at (P>0.05) levels by LSD. The values without letters in the rows are non-significant (P>0.05)

Fig. 1: Effect of salinity on shoot and root length of Lettuce under NFT

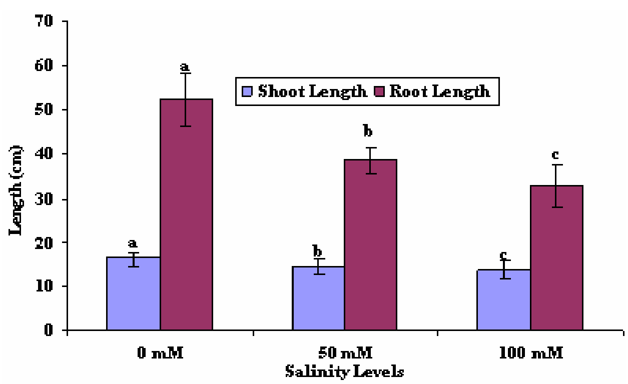
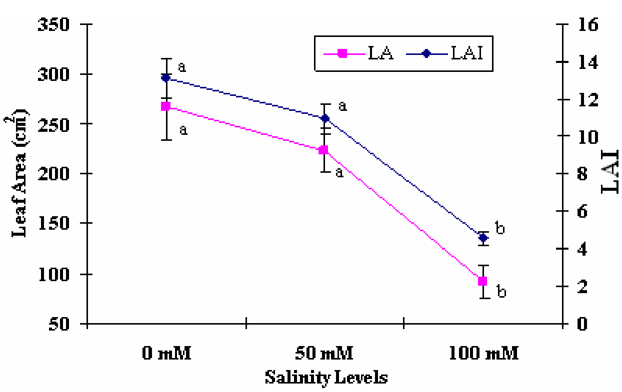


Fig. 2: Effect of salinity on leaf area (LA) and leaf area index (LAI) of Lettuce under NFT



manipulation of this system.

This system showed some variations between three salinity levels in the lettuce crop with the re-circulated closed system (0, 50 & 100 mM) by ±1.5 throughout the experiment. This can be explained as follow: (i) High evaporation rates up to half way tank of water that was observed during May and June, (ii) Accumulation of nutrient solution on the long term by week 13-15 after transplantation and (iii) changes in pH. Change in EC levels in re-circulated closed systems is the most important. Graves (1983) reported that fluctuations in EC levels would be very difficult to monitor and maintain at low or narrow concentrations of because of the apprehension of contamination. Nutrient Film Technique is a closed system and it is economical in the use of nutrients but has a disadvantage of impurities or unwanted ions from the water or from the chemicals, which may accumulate to toxic levels and the original balanced nutrient solution formulation will be lost even if you try to maintain the same EC (Hurd, 1978). In soilless culture, accumulation of salts (e.g., Na^+, Cl^-) in the recirculating nutrient solution in irrigation water is a problem and can result in inefficient absorption of these salts by plants (Tzortzakis, 2009). Use of poor-quality water accelerates salinity buildup in the substrate medium and may produce negative effects on salt-sensitive crops (Incrocci *et al.*, 2006). Therefore a nutrient analysis is required every 2 weeks intervals for major nutrients. However in the present experiment, it had a direct effect on the growth and biomass measurements of lettuce. Re-circulation is possible and it does not present a great problem for growing lettuce in hydroponics NFT system; but it is necessary to adjust multiple factors of this system, which will improve the yield (Graves, 1983).

CONCLUSION

Better management of the system is required to avoid salt accumulation in NFT system. Future research should be focused to investigate the threshold level of salinity that does not affect lettuce, modifications in NFT system are needed to minimize depressed growth rate and root overlapping between the individual plants.

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