Evaluation of an Irrigation Water Treatment Technology (MAXGROW) on its Effects to Vegetable Species Yield

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Abstract. Irrigation water quality became worst in terms of increasing its salinity and causes severe problems in many cultivated crop species, resulting in lower yield. In addition, the scarcity of irrigation water due to overuse or runoff is another limitation for increasing food and feed production. Saline water treatment technology offers potential solutions; however this technology is yet expensive and not cost effective for large scale. This study evaluates a water treatment technology (MAXGROW) using ultra sound for treating saline water, for its potential to minimize effects of saline irrigation water and its possible effects of crop productivity. A greenhouse study in pots was undertaken using two substrates (a sandy loam soil and a mixture of pumice and a composted material), four vegetable species (green onions, spinach, radishes and arugula) which were irrigated with two qualities of irrigation water (a highly saline and a regular irrigation water) treated and untreated with the MAXGROW technology. The results showed an increased yield caused by the treated saline water in almost all species and in both growth substrates. The potential of this device was shown to be promising and it is currently under continuous evaluation using more species and higher salinity level irrigation water. Irrigation water efficiency is a potential deliverable from the system.

Keywords: saline water, desalinization, MAXGROW system, vegetables, irrigation efficiency

1 Introduction

The scarcity of fresh water in arid and other regions necessitates use of saline water as a valuable alternative input for crop irrigation. Saline water has an agricultural potential but it is necessary to develop special management techniques and use of special water technologies, to obtain optimal yield and maintain high quality of commercial products. Field experiments, which were carried out in a pear orchard, have shown that by using saline water through subsurface drip irrigation (SDI) reasonable yields can be obtained (Gideon et al., 2002). Saline water use for agricultural production offers several additional benefits: (1) re-use (instead of

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disposal as with fresh water) during the entire year, with minimal environmental risk of groundwater deterioration (Oron, 1993); and (2) a premium market price for the fruits and vegetable products because of a high content of total soluble solids and an extended shelf life, due to the adaptation of the plant to the stressful growing conditions (Mizrahi & Pasternak, 1985)

Salinity is one of the major abiotic stresses that adversely affect crop productivity and quality. About 20% of irrigated agricultural land is adversely affected by salinity (Flowers and Yeo, 1995). Progress in breeding for salt-tolerant crops has been hampered by the lack of understanding of the molecular basis of salt tolerance and lack of availability of genes that confer salt tolerance. Most crop plants are susceptible to salinity even when ECe is _3.0 dS m^{-1} which in terms of osmotic potential is less than –0.117 MPa (osmotic potential =0.39 x ECe). At these salinity levels, the predominant cause of crop susceptibility appears to be ion toxicity rather than osmotic stress (Chinnusamy et al., 2005) Throughout the world, water scarcity is being recognised as a present or future threat to human activity and as a consequence, a definite trend to develop alternative water resources such as desalination can be observed. The most commonly used desalination technologies are reverse osmosis (RO) and thermal processes such as multi-stage flash (MSF) and multi-effect distillation (MED) (Fritzmann et al., 2007). Little information is available about the ability of horticultural crops to detoxify reactive oxygen species and to synthesize compatible solutes and hence on the potential contribution of these mechanism to induce salt tolerance in horticultural crops (Paranychianakis and Chartzoulakis, 2005). The U.S. Geological Survey (8) Gleick, 1996) found that 96.5% of Earth's water is located in seas and oceans and 1.7% of Earth's water is located in the ice caps. Approximately 0.8% is considered to be fresh water. The remaining percentage is made up of brackish water, slightly salty water found as surface water in estuaries and as groundwater in salty aquifers. Water shortages have plagued many communities, and humans have long searched for a solution to Earth's meager fresh water supplies. Thus, desalination is not a new concept; the idea of turning salt water into fresh water has been developed and used for centuries (Greenlee et al., 2009(). Most of the technologies used to treat saline irrigation water are expensive. There is not adequate information on simple and yet effective technologies to utilize saline water and sustain crop productivity. The objective of this study is to evaluate in a long-term and in various crop species and substrates, the efficiency of the MAXGROW technology system, using highly saline irrigation water (treated and untreated) and its effects in crop productivity and changes in substrates chemical properties, mainly pH and Electrical Conductivity (EC).

2 Materials & Methods

The study is a long-term assessment and the first set of yield results are presented herein. The experiment was set in a greenhouse, using 15-liter black PE pots filled with two "substrates": 1.a sandy loam soil and 2. a mixture of medium size pumice with a composted material (by BIOSOLIDS) in a volume ratio of 4:1. Within each substrate, two irrigation water qualities treatments (each treated and untreated by the device) were set: a mixture of sea water with regular water with an Electrical conductivity (EC) of ~8.0 dS/m and a regular irrigation water with an EC~0.7 dS/m. Four lines of 20 pots each per substrate were formed, with the following arrangement: Line A=Treated with the MAXGROW device irrigation (High salinity water) Line B= Treated with the MAXGROW device irrigation (regular salinity water) Line C= Non Treated with the MAXGROW device irrigation (High salinity water) and Line D= Non Treated with the MAXGROW device irrigation (regular salinity water). There were 160 total pots with 5 replications for each of the imposed treatments (Figure 1).

The MAX GROW is an electronic water treatment system (Figure 2) using multiple transmissions of low radio frequencies to tackle the problems caused by saline water. It works by generating up to million vibrations per second and it differentiates the mineral salts to produce safe, easily removed by-forms. The device transmits radio waves in constantly altered frequencies, which dissolve totally the calcium carbonate ions in water. It transmits radio waves in constantly variable frequencies which are programmed automatically, virtually every tenth of a second from the device itself based on a mathematic algorithm.

Four vegetable species sensitive to salinity used:

1. Green onions (*Allium cepa*) 2. Spinach (*Spinacia oleracea*) 3. Arugula (*Eruca sativa)* and 4. Radishes (*Raphanus sativus*) and they all received equal and minimum fertilizer and no pesticides were used. At maturity stage for each species, the fresh yield was harvested and weighted. Soil properties measured included pH and ECs (using 1:1 ratio of d. water and substrate) C electrode, in the beginning (before any water treatment) and at the end of the first cycle of plants grown.

Means comparisons using Student's *t* test was conducted using JMP 8 statistical software (www.jmp.com), wit in each main and secondary treatment. Samples from each substrate were analyzed for pH and EC in the beginning and at the harvesting time.

Fig. 1. The layout of the greenhouse study with the four vegetables used.

Fig. 2. The MAXGROW water treatment technology system used

3 Results & Discussion

3.1 Yield results

The four species used received minimum chemical fertilizer. The data analyses for yield are presented in Table 1, pooled across all treatments and separately for each of the two substrates and each plant species within each, and for the four water irrigation type treatments (saline & regular water, treated & untreated).

The saline water treated with the MAXGROW device increased statistically the yield in many cases, while it was in all cases of the higher yielding types. The only crop that was not affected by irrigation type was spinach in the sandy loam soil. In the sandy loam substrate, the saline water treated produced the highest yields in all four crop species (spinach, radish, green onions and arugula), while in the Pumice+Compost substrate the yield was among the top in all crop species but not as high and significant as in the sandy loam substrate. The real cause of this is not clear yet, but it is hypothesized that the system provides a high level of break-down of macromolecules of various salts, making them more transportable through the plant cell membrane system. This hypothesis can be further tested using sophisticated microscopy techniques and additional validation studies, which are in progress.

Table 1. Yield results for each substrate, irrigation type and plant species

SUBSTRATE	Irrigation type	Crop species	Fresh Yield (g/pot)	Statistical significance*
Pumice+Compost	Saline water-Treated	Arugula	195,4	ab
Pumice+Compost	Regular water-Treated	Arugula	203,6	a
Pumice+Compost	Saline water-Non treated	Arugula	180,2	ab
Pumice+Compost	Regular water-Non treated	Arugula	171,8	b
Sandy loam soil	Saline water-Treated	Arugula	176,2	a
Sandy loam soil	Regular water-Treated	Arugula	135,4	b
Sandy loam soil	Saline water-Non treated	Arugula	124,6	bc
Sandy loam soil	Regular water-Non treated	Arugula	106.0	c
Pumice+Compost	Saline water-Treated	Green onions	106,8	ab
Pumice+Compost	Regular water-Treated	Green onions	81,8	b
Pumice+Compost	Saline water-Non treated	Green onions	115,2	a
Pumice+Compost	Regular water-Non treated	Green onions	92,6	ab
Sandy loam soil	Saline water-Treated	Green onions	142,8	a
Sandy loam soil	Regular water-Treated	Green onions	97,4	b
Sandy loam soil	Saline water-Non treated	Green onions	101,4	b
Sandy loam soil	Regular water-Non treated	Green onions	142,8	a
Pumice+Compost	Saline water-Treated	Radish	70,6	b
Pumice+Compost	Regular water-Treated	Radish	82,2	ab
Pumice+Compost	Saline water-Non treated	Radish	106,6	a
Pumice+Compost	Regular water-Non treated	Radish	89,4	ab
Sandy loam soil	Saline water-Treated	Radish	129,6	a
Sandy loam soil	Regular water-Treated	Radish	70.0	b
Sandy loam soil	Saline water-Non treated	Radish	34,8	c
Sandy loam soil	Regular water-Non treated	Radish	63,4	b
Pumice+Compost	Saline water-Treated	Spinach	77,4	ab
Pumice+Compost	Regular water-Treated	Spinach	57,2	b
Pumice+Compost	Saline water-Non treated	Spinach	100,6	a
Pumice+Compost	Regular water-Non treated	Spinach	63,6	b
Sandy loam soil	Saline water-Treated	Spinach	129,2	a
Sandy loam soil	Regular water-Treated	Spinach	112,4	a
Sandy loam soil	Saline water-Non treated	Spinach	130,4	a
Sandy loam soil	Regular water-Non treated	Spinach	110,2	a

* Treatments not connected by same letter are significant different (Student's *t* test)

In addition to yield measurements, some preliminary sensory characteristics were prematurely evaluated from a panel of 10 people and the general consensus was that the crops irrigated with saline water had a more "spicy" and pleasant taste compared with those irrigated with regular water. The panel's opinion was based on the taste of the "control" plants considered to be the plants irrigated with regular water untreated.

3.2 Soil properties results

Table 2. The soil properties as affected by the quality of irrigation water, at the harvest stage.

Substrate	Irrigation type	pH	ECs (dS/m)
Sandy loam soil	Saline water-Treated	7.7	2.315
Pumice+compost	Saline water-Treated	7.7	2.265
Sandy loam soil	Regular water-Treated	7.8	0.780
Pumice+compost	Regular water-Treated	7.8	0.935
Sandy loam soil	Saline water-Non treated	7.7	1.585
Pumice+compost	Saline water-Non treated	7.6	2.085
Sandy loam soil	Regular water-Non treated	7.8	0.670
Pumice+compost	Regular water-Non treated	7.8	0.445

The results from the two soil properties (pH, EC) initially evaluated (Table 2), indicated that the water treatment system did not affect the soil's reaction (pH), while there were differences on the electrical conductivity (ECs); however, the levels of EC are not considered yet to be of any potential risk since most plant species can tolerate these levels (Maas and Hofman, 1997). The two properties will be continuously monitored in the next phases of this study and for a long period, in order to record the short and long term changes in both properties.

4 Conclusions

This phase of the study provided initial data for comparisons between saline and regular water (treated and untreated with the MAXGROW system) used for irrigation. The results have shown that the saline water treated by the MAXGROW technology increased yield and in many cases the increase was statistically significant. Therefore, this technology can be efficiently used to irrigate the four species using high EC (salinity) lever irrigation water. The long term effects on the examined and other crop species are under evaluation, for further validation of the trends and results shown in this phase. Also, the level of salinity will be progressively increased. The benefits of the device can be translated in positive economic outputs. A financial analysis will be provided in a follow up study. The short and long term benefits are expected to be substantial, in terms of the reduction of fresh water supplies for irrigating crops or use of high EC irrigation water for efficient irrigation.

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