Innovative technologies (nanobubbles and electronic water treatment) to manage highly saline irrigation water in hydroponic systems*

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Abstract

Irrigation water salinity presents a major and increasing problem worldwide. Methods to treat it and achieve higher efficiency will provide valuable tools to farmers to achieve more sustainable and profitable crop production systems. Most systems currently used for saline water treatment represent high energy consumption and large costs. Any new systems that can reduce the irrigation water salinity effects, will contribute significantly to the more sustainable crop production and indirectly mitigate the climate effects, by reducing the crop stresses by abiotic factors. The objective of this study was to evaluate high salinity levels of irrigation water, for growth and productivity of leafy vegetables. Two innovative and inexpensive technologies were used. One is the application of a nanobubbles system (NB: http://hal.teiemt.gr/index.php/agronb) and the other is an electronic water treatment system, based on low frequency radiation waves (MAXGROW: https://MAXGROW.tech/).

The NB system produces very small size water cavities. The MAXGROW cutting edge electronics ensemble generates up to two million pulses per second in a constantly altering transmission bandwidth, enabling the system to dissolve all the ions of the metallic salts.

The research was conducted in the Greenhouse Laboratory of Perrotis College/American Farm School Thessaloniki, Greece under a floating disks hydroponic system, in which three leafy vegetables species (endive, and two lettuce varieties- COS and Batavia) were grown in 4 different sections/tanks each one filled with different salinity irrigation water: a. Control ($E.C._{i}$ ~1 dS/m), b. saline water ($E.C._{i}$ = 10 dS/m) enriched with NB, c. saline water ($E.C._{i}$ = 10 dS/m) + MAXGROW and d. saline water ($E.C._{i}$ = 10 dS/m) + MAXGROW + NB). Various vegetable agronomic parameters (total fresh weight, height, root weight, SPAD units, etc.) and water parameters (Dissolved Oxygen, pH, EC, nutrients, temperature, size and concentration of NB, etc.) were periodically recorded. The results indicated that a combination of the two devices was the best treatment used, as compared to using one device separately and provided higher final fresh yield than the regular water treatment. A very important result that was also shown, refers to MAXGROW's system ability reduce the size of water cavities by itself, thus producing additional NBs and in combination with the NB system increased the concentration of NBs. Therefore, the two devices can provide a very sustainable and affordable tool to mitigate high salinity problems in crop production systems.

Keywords

nanobubbles (NB), electronic water treatment system (MAXGROW), floating disk systems, hydroponics, leafy vegetables, saline water

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1. Introduction

Green leafy vegetables are praised for its high nutritional source for vitamins, minerals and phenolic compounds, which take part in various health-related issues and take part on special significance for improving food and nutrition security [1]. The World Health Organization (WHO) recommends at least 400 g of fruit and vegetables per day, excluding potatoes, sweet potatoes, cassava and other starchy roots [2]. Additionally, it is advised that one of the five servings of vegetables should diversify their meals and be green leafy vegetables.

Soils with high amounts of soluble salts and/or sodium ions, called salt-affected soils. The salts hold water in the soil at high osmotic potential, which could create problems of absorption of nutrients and water) by the roots of plants. Salt-affected soils also develop when salts accumulate due to long term irrigation with saline water [3]. Salinization is provided due to poor management of irrigation, which is one of the major problems for global food production. Most of the salt-affected soils, are founded in arid or semi-arid climates, food production systems where in these regions requires irrigation. Some statistics shows that 20-50 % of irrigated soils are salt-affected [4]. The salt concentration in full-strength seawater causes hazardous effects for almost all cultivated plants. It destroys soil structure, particularly without an adequate leaching mechanism, making large-scale sustainable agriculture dependent on seawater impossible. However, on a smaller scale, such as in naturally salty coastal locations, ocean irrigation could be practical and cost-effective [5]. Especially desalinized or mixed with fresh water, salt water is a reasonable choice in farming [6].

Many scientists have studied the problem of groundwater salinization and soil salinization through remote sensing and new technology, like the ultrasonic irrigation water treatment (MAXGROW) [7]. Furthermore, one more new technology that could mitigate the salinization problem is generator of Agro-NB, which the solubility of gases in aqueous salt solution decreases with the salt concentration, and called "salting-out effects" [8].

Hydroponics is a cultivation method that involves the growth of plants by using a water-based nutrient solution without soil in mostly inert inorganic growth substrates and in water only (floating systems). [9]. Europe and specifically France, Netherlands and Spain are considered the top producers in hydroponic systems. Hydroponic cultivation in relation to conventional cultivation could produce fresh vegetables with accumulation of some beneficial nutrients [10]. In addition, the rapid increase in urbanization and population growth combined with limited water and land resources, food security in large cities is insecure. The small-scale farms and high labor costs for vegetables production and the new soilless culture technologies, given the opportunity to the various forms of soilless culture (including hydroponics, aeroponics, aquaponics) to be considered as the most sustainable agricultural management systems to produce healthy and safe vegetables by reduced crop yield loss caused by soil-borne pests and by soil salinity accumulation [11].

The objective of this study was to evaluate high salinity levels of irrigation water, for growth and productivity of leafy vegetables, using and testing two innovative and inexpensive devices.

2. Materials and Methods

The study was conducted through experimental research in the greenhouse at Perrotis College/American Farm School (lat. 40° 34′ N, long. 22° 59′ E) Thessaloniki, Greece. The study conducted from 20/11/2023 until 22/02/2024. More growing cycles are in progress.

In this experiment, hydroponic system of floating disc cultivation was used and the 4 different treatments in sections/tanks (Fig. 1) filled with irrigation water with nutrient solution (50% of Hoagland solution), were: The first section was the Control filled with regular tap water/nutrient solution (E.C. = 0,850 dS/m or called $E.C._i$ <1). The second section used water/nutrient solution with high $E.C._i$ (10 dS/m) enriched with Nanobubbles every 3 days [8]. The third section filled with water/nutrient solution ($E.C._i$ = 10 dS/m) and was treated continuously with MAXGROW. The fourth section filed with water/nutrient solution ($E.C._i$ = 10 dS/m) and treated with the updated version (Generation 6) of the MAXGROW device and enriched with Nanobubbles every 3 days. All treatments in sections had 45 plants inside (15 plants of endive, 15 lettuces of Batavia Epsilone lettuces and 15 of COS lettuces). Various vegetable agronomic parameters (total fresh weight, root height, root weight), NDVI (Normalized Difference Vegetation Index) and SPAD (measured by Trimble Green Seeker Handheld Crop Sensor, etc.) were measured in the end of experiment and water parameters (Dissolved Oxygen, pH, EC, temperature, size and concentration of NB) were recorded. Measurements of the environmental conditions [temperature (°C) and humidity (%)] inside in the greenhouse were recorded continuously from portable meteorological station.

MAXGROW is an electronic water treatment system (https://MAXGROW.tech/) and the technology is based on the transmission of constantly altering variable radio- wave frequencies which have the ability to dissolve all the ions in water that form deposits inside the irrigation system and the soil. Some of the benefits are: a) removes/dissolves all the existing lime scale and salt deposits, b) removes all the existing calcium carbonate deposits, c) it does not produce waste water and has an unlimited life span, d) it has zero maintenance, does not require any filters or the addition of chemicals or any human operation and e) it has very low energy consumption and is a low-cost device.

Agro - Nanobubbles system (http://hal.teiemt.gr/index.php/agronb) is a dynamic research group in the cutting edge of NB technology. AgroNB generator produce a long stability NB of 150 nm diameter and concentration of 5.000.000 NB/ml. AgroNBs demonstrate an extended lifetime compared to larger size bubbles. The last few years, AgroNBs have drawn great attention due to their special properties. AgroNBs remain stable for extended periods of time and still exist even after several months (~ 1 year) [12].

The measured data were statistically analyzed for treatment mean differences, using the student's *t* test, since data were normally distributed and any outlier values were excluded. The statistical software JMP v 18 was used (www/jmp.com).

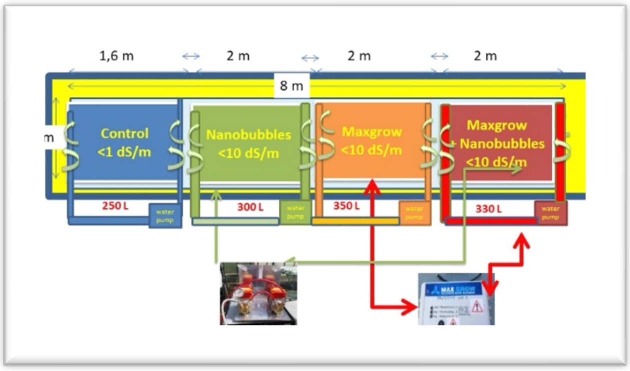

Figure 1: Experimental Design –layout of the four treatments in sections/tanks

3. Results and Discussion

The results for each plant species and varieties varied and are shown in Table 1. A combination of the two technologies was the best treatment used for the fresh green biomass weight of lettuce varieties and demonstrate statistically significant difference from the regular tap water treatment, while the endive did not show any significant increase. In Table 2, the combination of NB and MAXGROW produced the maximum increase in Batavia lettuce in the measurement of fresh green root weight have the maximum measurement and demonstrate statistically significant difference with the regular tap water treatment. The results in root weight and in root length (Table 3) reflected the same trend shown in the previous fresh weight for each plant species. Also, other agronomic properties measured, such as NDVI (Normalized Difference Vegetation Index (Table 4), Relative Leaf Chlorophyll Level (SPAD units - Table 5) and Chlorophyll fluorescence emission (PSII) (Table 6), confirmed the trend shown in fresh weight of lettuces. All results supported the superior treatment and increase caused by the combination of the two devices and by each one alone as well, as compared to Control treatments.

Table 1
Fresh green biomass weight of lettuce and endive (g/plant) by water treatment

	Fresh green biomass average and ± standard deviation weight (g/plant) *		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	5,69 ± 0,78 a	8,87 ± 2,72 bc	8,74 ± 3,62 b
Tap water (E.C. 10 dS/m) + NB	5,16 ± 1,38 a	12,19 ± 3,75 a	8,36 ± 0,99 b
Tap water (E.C. 10 dS/m) + MAXGROW	5,49 ± 2,12 a	8,61 ± 1,25 c	8,52 ± 1,35 b
Tap water (E.C. 10 dS/m) + MAXGROW + NB	5,68 ± 1,44 a	11,50 ± 4,24 ab	10,43 ± 1,39 a

*Means with the same letter are not significantly different at the level of significance of 5% ($p<0.05$) of overall comparisons

Table 2
Fresh roots weight of lettuce and endive (g/plant) by water treatment

	Fresh root weight (g/plant)		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	4,29 ± 1,15 a	5,31 ± 2,64 a	3,90 ± 1,69 ab
Tap water (E.C. 10 dS/m) + NB	4,11 ± 1,32 a	5,95 ± 3,38 a	3,18 ± 1,31 bc
Tap water (E.C. 10 dS/m) + MAXGROW	4,17 ± 1,63 a	5,69 ± 1,36 a	2,6 ± 0,75 c
Tap water (E.C. 10 dS/m) + MAXGROW + NB	4,61 ± 1,56 a	7,68 ± 3,80 a	4,43 ± 1,95 a

Table 3
Fresh root length of lettuce and endive (cm/plant) by water treatment

	Fresh root length (cm/plant)		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	30,25 ± 8,57 a	29,30 ± 10,09 a	25,0 ± 11,15 b
Tap water (E.C. 10 dS/m) + NB	36,27 ± 11,58 a	36,03 ± 17,27 a	31,20 ± 13,10 ab
Tap water (E.C. 10 dS/m) + MAXGROW	40,10 ± 11,70 a	29,33 ± 11,22 a	30,93 ± 8,79 ab
Tap water (E.C. 10 dS/m) + MAXGROW + NB	43,27 ± 11,28 a	32,57 ± 8,71 a	35,37 ± 7,31 a

Table 4
NDVI of lettuce and endive (cm/plant) by water treatment

	NDVI		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	0,42 ± 0,03 b	0,40 ± 0,03 b	0,39 ± 0,04 c
Tap water (E.C. 10 dS/m) + NB	0,44 ± 0,05 ab	0,47 ± 0,06 a	0,41 ± 0,05 bc
Tap water (E.C. 10 dS/m) + MAXGROW	0,45 ± 0,07 ab	0,47 ± 0,05 a	0,46 ± 0,05 a
Tap water (E.C. 10 dS/m) + MAXGROW + NB	0,46 ± 0,04 a	0,48 ± 0,05 a	0,43 ± 0,04 ab

Table 5
Relative Leaf Chlorophyll Level (SPAD units) of lettuce and endive (by water treatment

	Relative Leaf Chlorophyll (SPAD units)		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	20,45 ± 6,83 b	23,29 ± 6,62 b	14,53 ± 6,31 b
Tap water (E.C. 10 dS/m) + NB	29,68 ± 6,87 a	36,28 ± 4,97 a	26,88 ± 5,19 a
Tap water (E.C. 10 dS/m) + MAXGROW	30,50 ± 6,23 a	34,94 ± 6,66 a	26,97 ± 5,86 a
Tap water (E.C. 10 dS/m) + MAXGROW + NB	30,54 ± 6,14 a	35,76 ± 4,73 a	30,39 ± 7,50 a

Table 6
Chlorophyll fluorescence emission (PSII) of lettuce and endive by water treatment

	Chlorophyll fluorescence emission (PSII)		
Main treatment	Endive	COS Lettuce	Batavia Lettuce
Control - tap water (E.C. <1 dS/m)	0,782 ± 0,02 b	0,827 ± 0,019 a	0,806 ± 0,04 a
Tap water (E.C. 10 dS/m) + NB	0,809 ± 0,03 ab	0,824 ± 0,020 a	0,836 ± 0,01 a
Tap water (E.C. 10 dS/m) + MAXGROW	0,802 ± 0,05 ab	0,812 ± 0,032 a	0,780 ± 0,04 b
Tap water (E.C. 10 dS/m) + MAXGROW + NB	0,828 ± 0,03 a	0,826 ± 0,010 a	0,828 ± 0,02 a

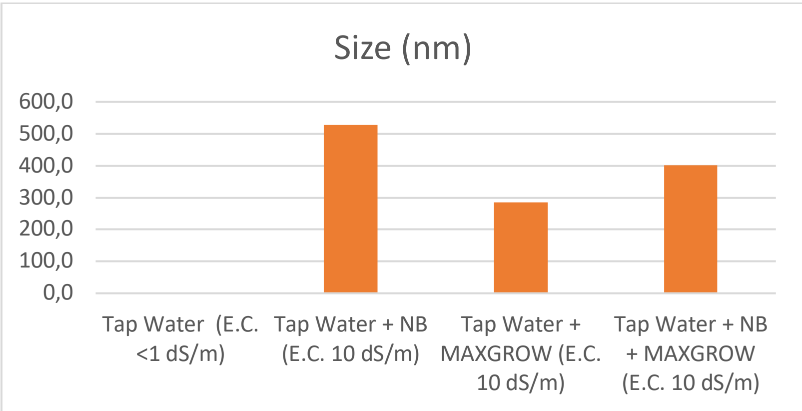

Figure 2: Size (nm) of Nanobubbles by salinity water treatments (Tap water = zero reference)

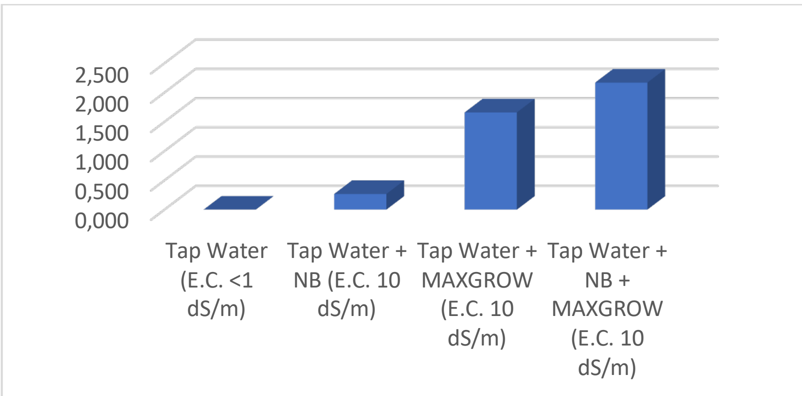

Figure 3: Concertation (107) particles of Nanobubbles / ml

The optimum size of NBs (~200 nm) was measured (Figure 2) at the third section where we have water/nutrient solution ($E.C._i$ = 10 dS/m) treatment with MAXGROW (285 nm). The maximum concertation 2170 (10^7) particles of Nanobubbles/ml (Figure 3), we founded in the combination of NB and MAXGROW, where we found the best results in agronomic traits.

A very unique result was that the MAXGROW device used (Generation 6) was in additional effective to produce NB and increase the concentration significantly by itself at this very high-water salinity (ECi 10 dS/m). The two innovative and inexpensive technologies (NB and MAXGROW) could provide very promise, sustainable and low-cost system to mitigate high salinity irrigation problems in floating dick hydroponic system. Additional research is carried on and years studies have to further validate the results presented herein.

4. Conclusions and Recommendations

This study demonstrated the advantage of the two-device used in very high salinity water, in floating systems with leafy vegetable production. Each device resulted in sustainable production levels while the combination of both produced significant higher yields. The three vegetables species used showed variable responses in the treatments, however, the overall trends in all measured properties confirmed the superiority of the combination system of the two devices. Therefore, the use of each device alone and mostly in combination, is highly recommended for sustainable grow of the tested vegetables under hydroponic floating disk systems. This study is currently continued with evaluation of more vegetable species and in different growing seasons, to further evaluate the potential of the innovative systems used.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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