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Importance of Water Quality in Hydroponic Leafy Greens Production

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Hydroponics is defined as “the process of growing plants in a nutrient solution with or without a supporting medium to anchor the roots.” The most common hydroponic systems are nutrient film technique (NFT), floating raft systems like deep water culture (DWC), and medium-based systems that use rockwool, gravel, sand, peat, coco coir, perlite, or polyester matting.

Hydroponic systems can be classified as either an open or closed system. In open systems, the nutrient solution delivered to the plants is not reused, while in closed systems, the surplus solution is recovered, replenished, and reused. Nutrient film technique and floating raft systems are closed systems, while medium-based systems can be closed or open.

In a recirculating hydroponic system, high-quality water is needed, such as rainwater or reverse osmosis (RO) water. High-quality water is defined as “low salinity water containing no phytotoxic substances or plant pathogens.” Municipal tap water or groundwater can be used depending on their salinity level, which varies with location. In Texas, the electrical conductivity (EC) of tap water ranges from 0.5 to 1.8 deciSiemens per meter (dS/m) in cities across the state, while the EC of groundwater can be much higher in water-scarce regions such as West Texas.

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In this article, we demonstrate the role and importance of water quality in an NFT hydroponic system with a specific focus on macronutrient depletion, replenishment, and salinity. We conducted two greenhouse experiments using NFT hydroponic systems (Table 1, Fig. 1). In the first experiment, we prepared an initial nutrient solution using RO water. When it was time to top-off the tanks to compensate for water loss, we refilled with RO water, tap water, or nutrient solution. In the second experiment, we prepared the initial nutrient solution using three different water sources: RO water, tap water, or tap water plus sodium chloride salt (NaCl). The purpose of adding NaCl was to simulate well water with high NaCl salinity. We topped-off tanks with the same three water sources at one-third of the strength of the initial nutrient concentration. For both experiments, we grew pac choi (‘Tokyo Bekana,’ ‘Mei Qing Choi,’ and ‘Rosie’) and leaf lettuce (‘Tropicana’).

Figure 1. NFT system used in our experiments. Each system consisted of 4 channels and 48 plants.

Table 1. Description of treatments in both experiments.

Expt. 1 Treatments	Initial Solution	EC	Replenishment Solution	EC
CNS17	CNS17 NS made with RO water	1.58	CNS17 NS made with RO water	1.58
RO water	CNS17 NS made with RO water	1.58	RO water	<0.01
Tap water	CNS17 NS made with RO water	1.58	Tap water	0.88
Expt. 2 Treatments	**Initial Solution**	**EC**	**Replenishment Solution**	**EC**
RO2	CNS17 NS made with RO water	1.58	1/3 strength of CNS17 NS made with RO water	0.72
Tap2	CNS17 NS made with tap water	2.35	1/3 strength of CNS17 NS made with tap water	1.62
Tap2 + NaCl	CNS17 NS made with tap water + NaCl	3.20	1/3 strength of CNS17 NS made with tap water + NaCl	2.40

Abbreviations used in Table 1: CNS17 = a concentrated hydroponics fertilizer formula; NS = nutrient solution; EC = electrical conductivity (dS/m); RO = reverse osmosis.

How macronutrients changed over time

In Experiment 1, the nitrate (NO_3) and phosphorus (P) in the tanks decreased when we topped-off the nutrient tanks with RO or tap water, while tanks topped-off with nutrient solution remained at similar or higher levels than the initial concentrations (Fig. 2). However, Potassium (K) decreased to zero at the end of the experiment (19 days after transplanting) when topped-off with RO or tap water, while those that were topped-off with the nutrient solution decreased from about 150 to 30 parts per million. Calcium (Ca) did not change substantially over time, magnesium (Mg) increased when topped-off with the nutrient solution, while sulfate (SO_4) increased when topped-off with the nutrient solution or tap water (data not shown). The electrical conductivity of the nutrient tanks decreased the most when topped-off with RO water, and no substantial changes were observed when topped-off with the nutrient solution (data not shown). The pH steadily increased, especially when topped-off with RO or tap water and reached about 7.5 by the end of the 19-day experiment (Fig. 4). Sodium (Na) and chloride (Cl) in the recirculating solution steadily increased when topped-off with tap water.

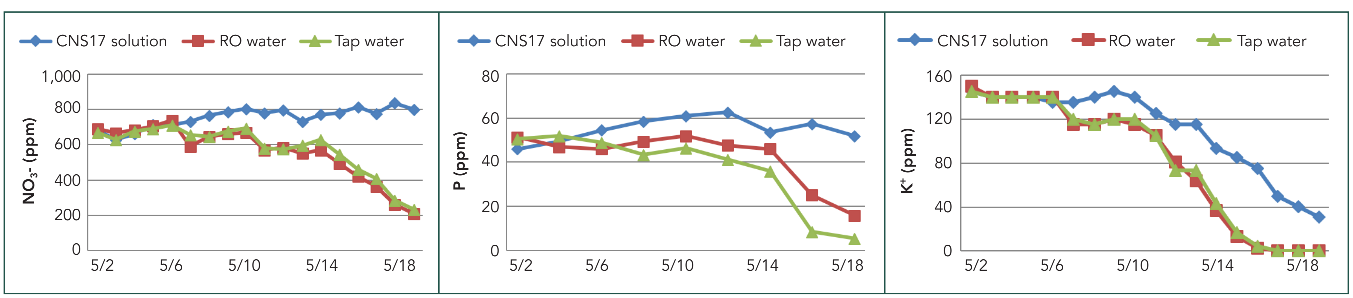

Figure 2. Dynamic changes in Experiment 1 of nitrate (NO_3), phosphorus (P), and potassium (K) in nutrient tanks of the NFT system topped-off with nutrient solution (CNS17), reverse osmosis (RO) water, or tap water.

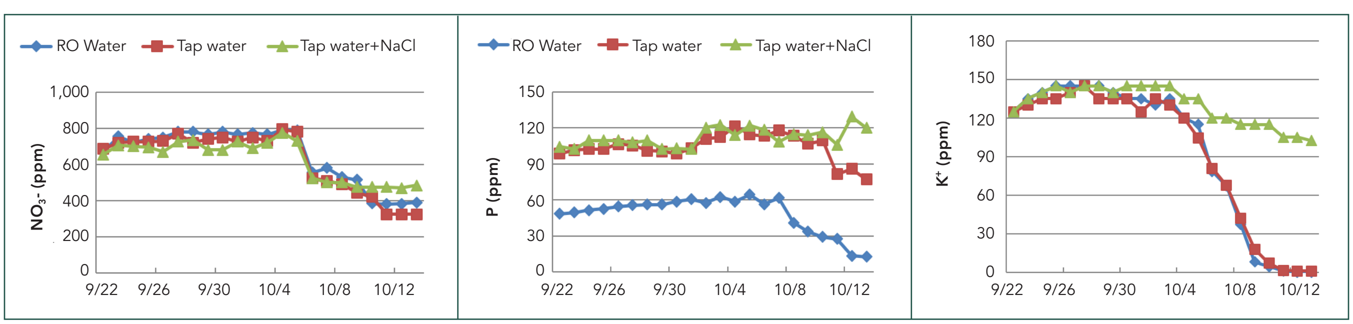

Figure 3. Dynamic changes in Experiment 2 of nitrate (NO_3), phosphorus (P), and potassium (K) in nutrient tanks of the NFT system with the nutrient solution prepared with reverse osmosis water, tap water, or tap water + NaCl.

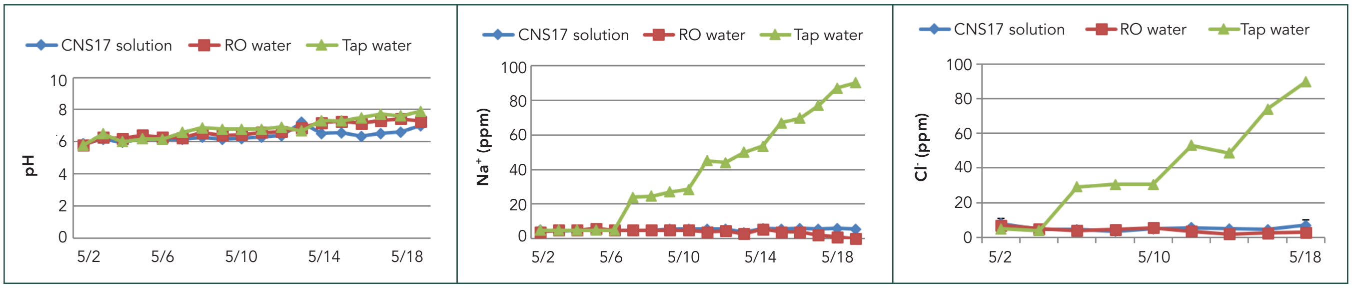

Figure 4. Dynamic changes in Experiment 1 of pH, and sodium (Na) and chloride (Cl) contents in nutrient tanks of the NFT system topped-off with nutrient solution (CNS17), reverse osmosis (RO) water, or tap water.

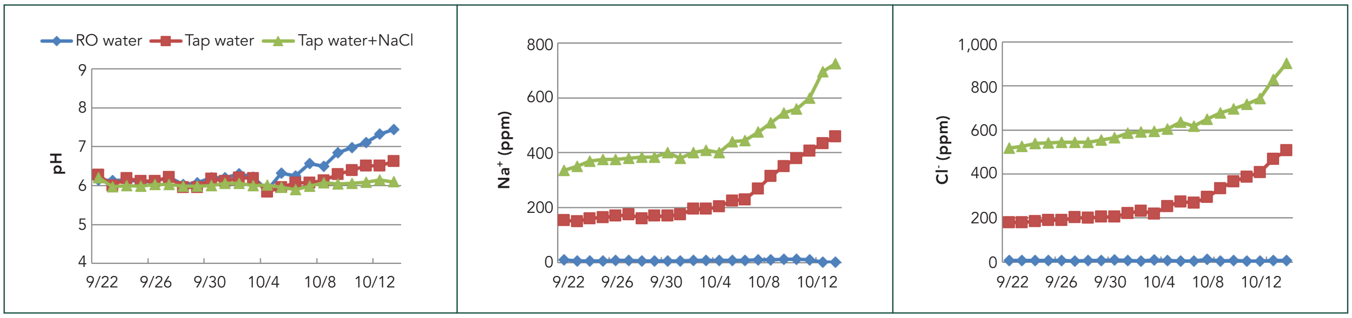

Figure 5. Dynamic changes in Experiment 2 of pH, and sodium (Na) and chloride (Cl) contents in nutrient tanks of the NFT system with the stock nutrient solutions (CNS17) prepared with reverse osmosis (RO) water, tap water, or tap water + NaCl.

In Experiment 2, NO_3 decreased in the last week in all treatments (Fig. 3). Phosphorus was lower with RO water when compared to the other two water sources. Potassium dropped to zero at the end of the experiment when RO or tap water was used. Potassium did not decrease as much as in the other treatments when NaCl was added to the solution because plant growth was significantly reduced, which reduced K absorption. Calcium increased over time in all treatments, and Mg was slightly higher in tap water in comparison to the other two water sources. Sulfate was the lowest in RO water as compared to the other two water sources and increased with time in all treatments.

Na and Cl accumulation over time

In both experiments, the unwanted ions Na and Cl increased over time as we topped-off the tanks with water that contained Na and Cl (Figs. 4 and 5). Greater Na and Cl levels in original or top-off water resulted in higher accumulation of these ions in the final solution. The maximum threshold of Na and Cl are crop specific. In our study, lettuce growth and yield were significantly reduced compared to the three pac choi varieties. Among the three pac choi, 'Mei Qing Choi' was more salinity tolerant than 'Rosie' and 'Tokyo Bekana.' (Fig. 6)

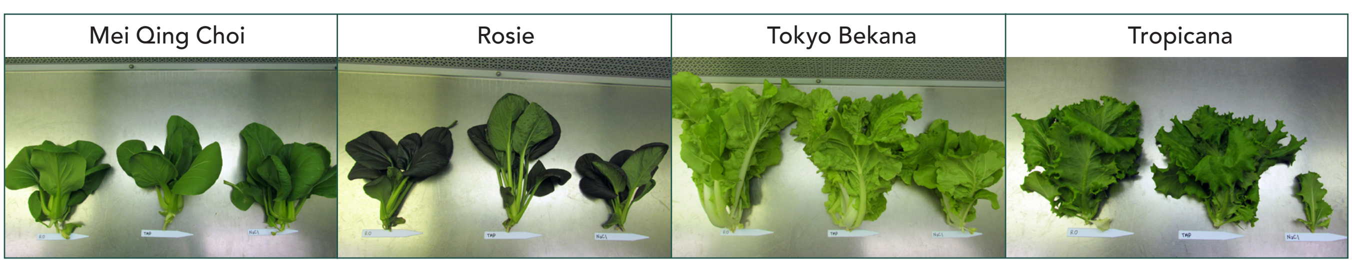

Figure 6. Effect of NaCl on the growth of pac choi and lettuce (Experiment 2). For each photo, treatments from left to right are: RO, tap water, tap water + NaCl.

Conclusions

1. No salinity or very low salinity water should be used to optimize hydroponics production.
2. When higher NaCl salinity water is used initially or to top-off, Na and Cl ions will accumulate over time.
3. The impact of NaCl salinity in the nutrient solution is crop and cultivar specific.
   a. Lettuce is less tolerant of NaCl salinity compared to pac choi.
   b. Among pac choi varieties, 'Rosie' and 'Tokyo Bekana' are less NaCl salinity tolerant than 'Mei Qing Choi.'
   c. When a source of no or very low salinity water is unavailable, 'Mei Qing Choi' pac choi is a preferred production crop compared to leaf lettuce or 'Rosie' and 'Tokyo Bekana' pac choi.
4. N, P, and especially K, deplete faster than other macronutrients.
5. Topping-off with a full-strength nutrient solution is unnecessary because other macronutrients will accumulate. A diluted (1:3 to 1:2) solution with proper replenishment of depleted nutrients is recommended.
6. Since EC is a total measurement of all ions, adjusting nutrient solution based on EC will cause nutrient imbalance over time.
   a. Electrical conductivity is a poor indicator of macronutrients available in hydroponic solutions compared to the measurement of specific ion concentrations.

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