

Recycling Nutrient Solution Management in Hydroponic Production

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Crops require 14 essential elements for normal growth and development

Percentage (%) of elements in plant tissue

	N	P	K	Ca	Mg	S
Macronutrients	4.5	0.5	5	0.5	0.3	0.3

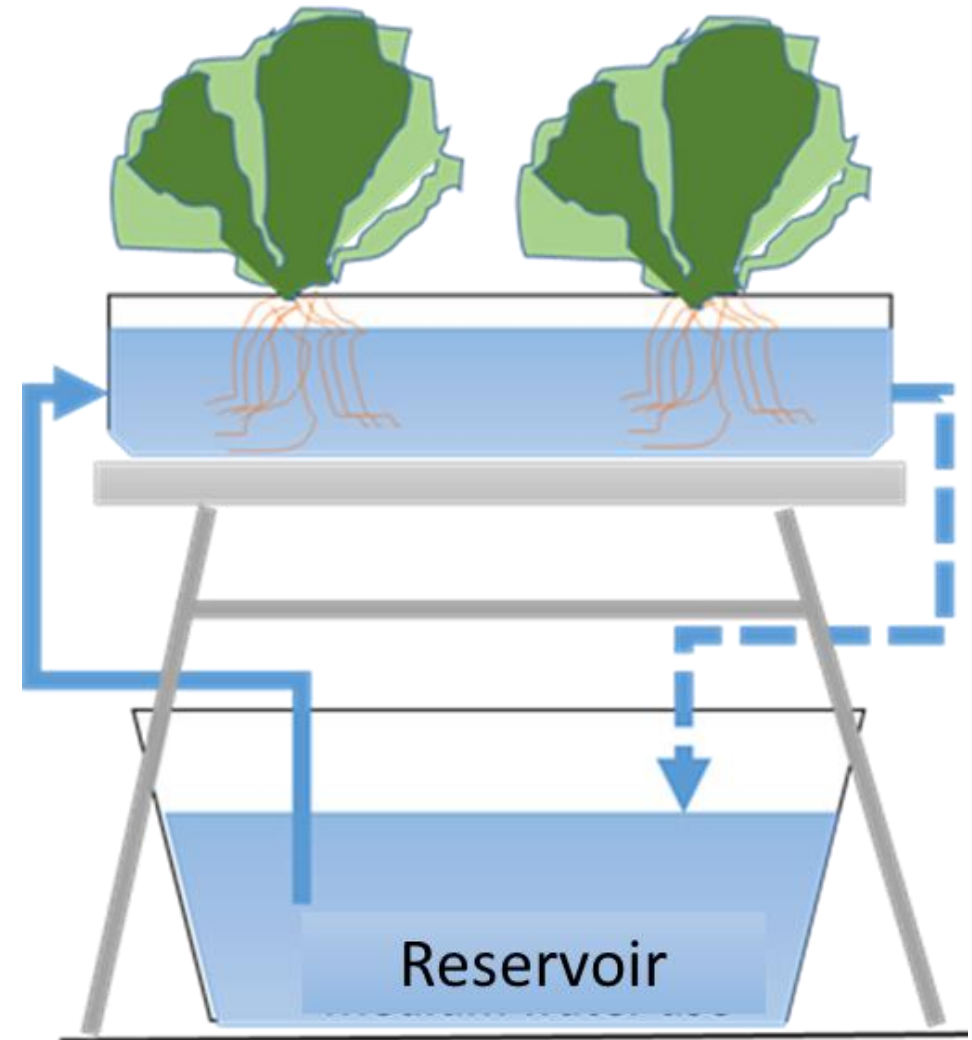
	Fe	Zn	Mn	B	Cu	Mo, Ni, Cl,
Micronutrients	0.0015	0.0005	0.0005	0.0003	0.0002	trace

Note that element levels are different inside the plants

Nutrients are recycled in hydroponic lettuce production.

Electrical conductivity: A measure of the total concentration of dissolved elements in the solution

In hydroponics, the target is to maintain EC but not fertilizer composition in the solution

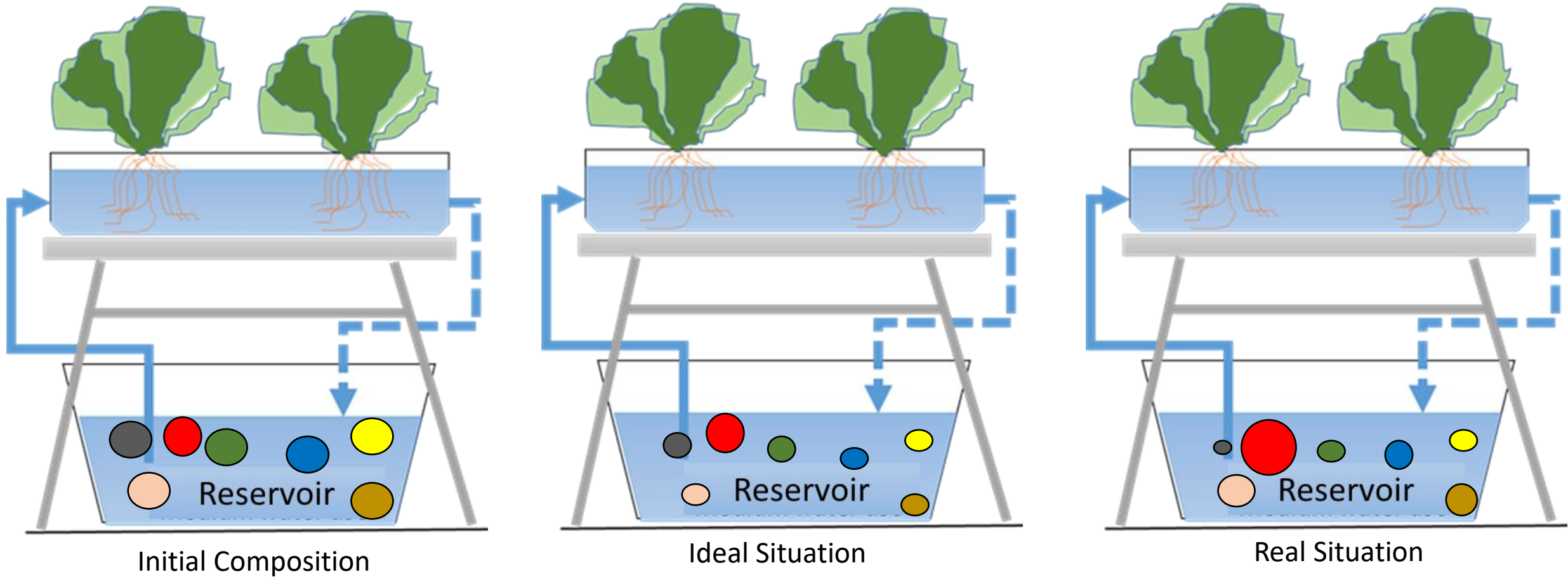


Irrigation water quality in Indiana

Regular irrigation water has high pH, and high levels of alkalinity and bicarbonates

Measurement	Units	Irrigation Water	RO Water
pH	n.a.	7.5	7.1
EC	(dS·m ⁻¹)	0.7	0.06
NO ₃ -N	(mg·L ⁻¹)	0.8	–
NH ₄ -N	–	–	–
P	–	1.1	–
K	–	3	–
Ca	–	102	–
Mg	–	38	–
Na	–	14	13
S	–	35	–
Zn	–	–	–
Mn	–	0.1	–
Fe	–	0.47	–
Cu	–	0.05	0.03
B	–	0.03	0.03
Al	–	–	–
Mo	–	–	–
Si	–	7	1
Cl	–	38	3
Alkalinity	–	250	20
CO ₃	–	–	–
HCO ₃	–	305	24

Plant uptake pattern varies by element

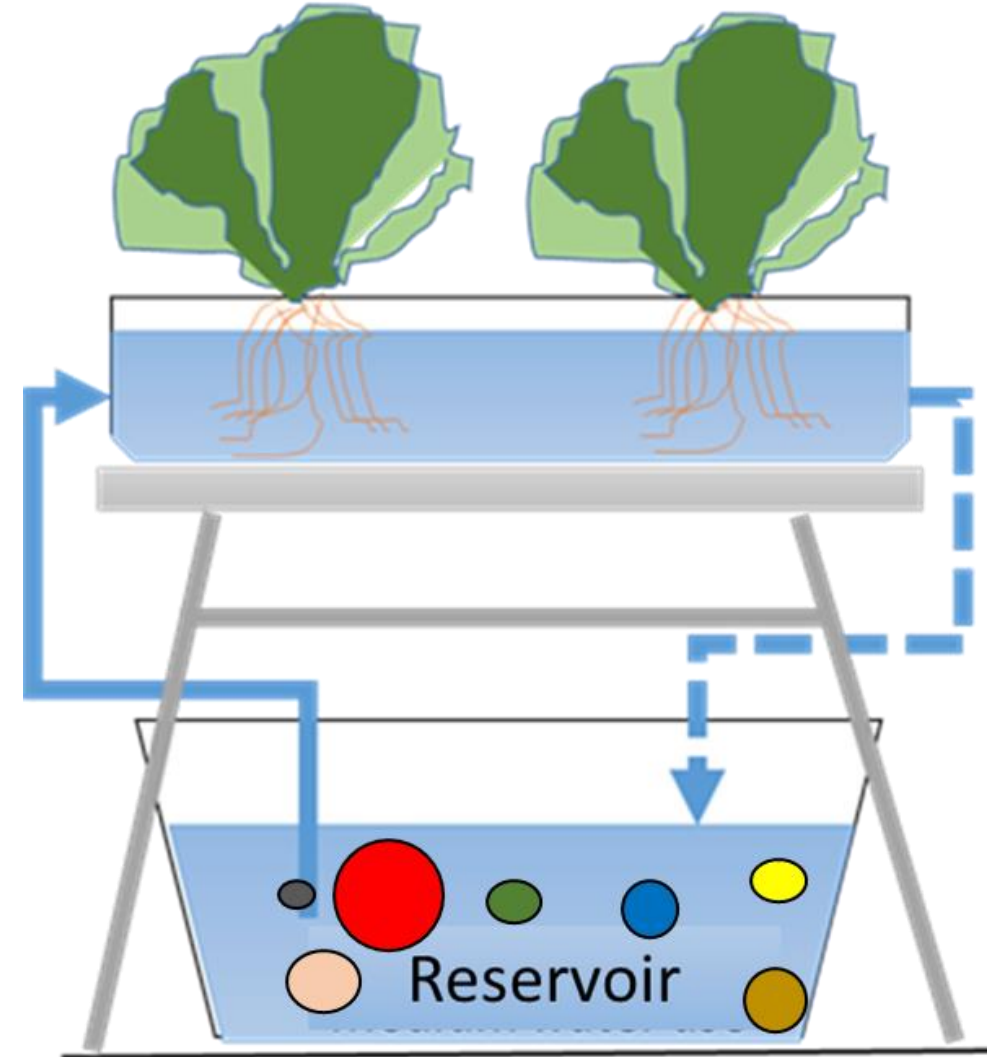


Elements like calcium and sodium can accumulate in the recycled solution. These have high ionic conductivities and can significantly affect EC values

Moreover, levels of some unwanted (bicarbonates) elements increase with the addition of water

Apparent high EC levels in the solution can happen from unwanted and slowly taken elements

- The increased levels of accumulated elements and salts can maintain higher EC levels
- However, the high EC is not from the presence of the right amounts of essential elements but from those that are not required or slowly taken by plants
- Further, some of the unwanted salts affect pH and chemical reactions in the solution, and further change the composition of the solution in the reservoir



Continuous recycling can reduce crop growth in hydroponics













TABLE 2 | Shoot fresh weight (SFW), shoot dry weight (SDW), electrical conductivity of nutrient solution before adjustment to the target level (EC_{adj}), evapotranspiration rate (ET), and relative canopy growth rate (RCGR) of leaf lettuce in experiment 2.

Treatment	SFW	SDW	EC_{adj}	ET	RCGR
	$g \cdot plant^{-1}$	$g \cdot plant^{-1}$	$dS \cdot m^{-1}$	$L \cdot d^{-1}$	d^{-1}
Control	35.3 (0.89) a	1.3 (0.05) a	2.3 (0.05) b	0.73 (0.041) a	0.191 (0.0064) a
Recycle	27.6 (0.61) b	1.2 (0.05) b	2.6 (0.07) a	0.74 (0.042) a	0.164 (0.0038) b

Means followed by the same letter are not statistically different ($P \leq 0.05$). Standard error of mean is shown in parenthesis.

We maintained similar EC in both control and recycled treatments during the experiment. EC was adjusted daily in the recycling treatment while a fresh solution was supplied in the control

Differences could be seen from the early growth stages (two weeks after start)

Control						
Recycle						
	Day 13	Day 15	Day 18	Day 20	Day 21	Day 22

Uptake of elements was affected by recycling

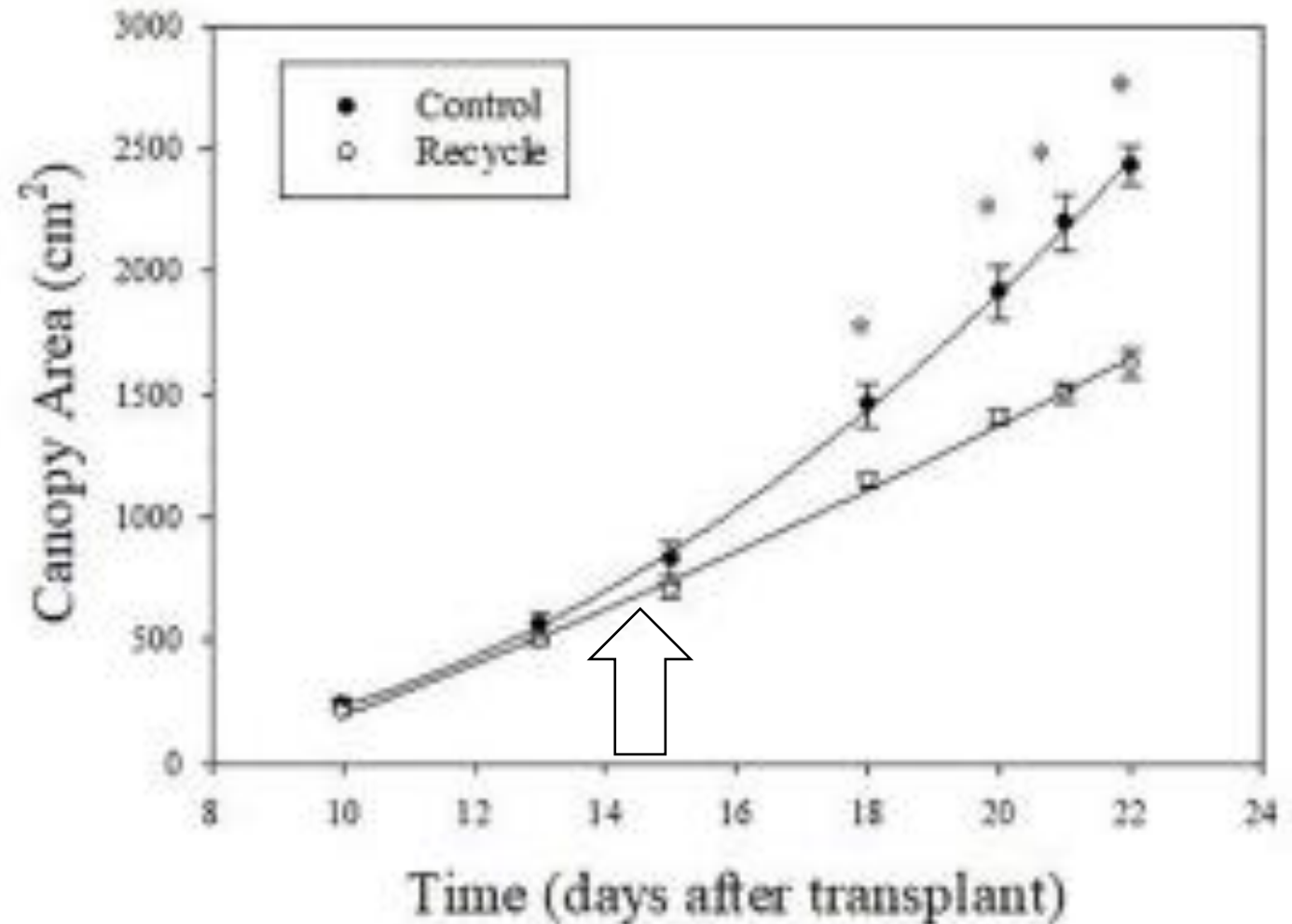
Further investigation showed lower levels of several essential elements in plants grown with a recycling solution

Nutrient	Units	Treatment	
		Control	Recycle
N	(mg·g ⁻¹)	37.6 (1.29) a	24.3 (0.70) b
P		5.4 (0.11) a	2.7 (0.20) b
K		42.0 (1.15) a	25.4 (1.01) b
Ca		10.7 (0.40)	11.0 (0.34)
Mg		5.2 (0.20)	5.3 (0.27)
S		3.2 (0.17)	3.0 (0.12)
Na		1.9 (0.08) b	3.2 (0.20) a
B	(mg·kg ⁻¹)	38.8 (2.37)	33.4 (1.79)
Zn		43.1 (2.72)	39.8 (3.16)
Mn		91.8 (5.24)	77.7 (8.65)
Fe		74.2 (8.41) a	46.3 (5.73) b
Cu		13.2 (1.56) b	20.0 (2.68) a
Al		47.4 (9.01)	53.6 (15.44)

Mean values for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), sodium (Na), boron (B), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu) and aluminum (Al) are shown. Means followed by the same letter within a measurement are not statistically different ($P \leq 0.05$). Values in parenthesis indicate standard error of mean.

Recycling solution affected crop growth during the rapid growth stage

Differences in growth were observed starting from two weeks of recycling



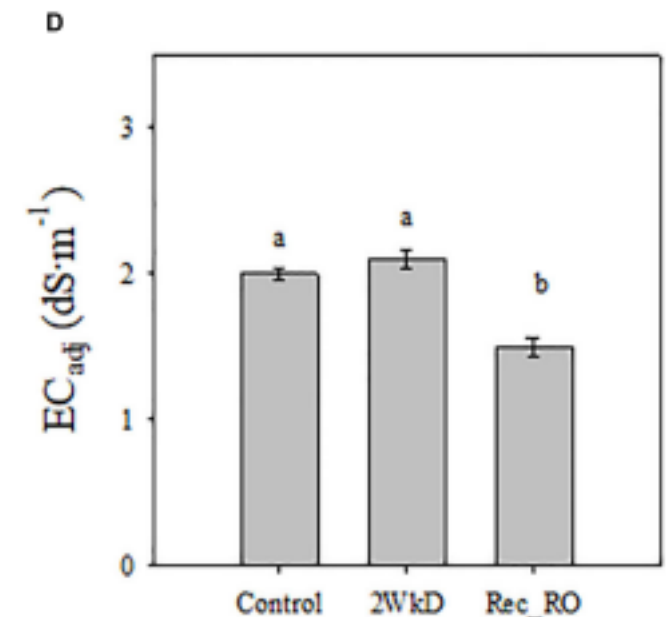
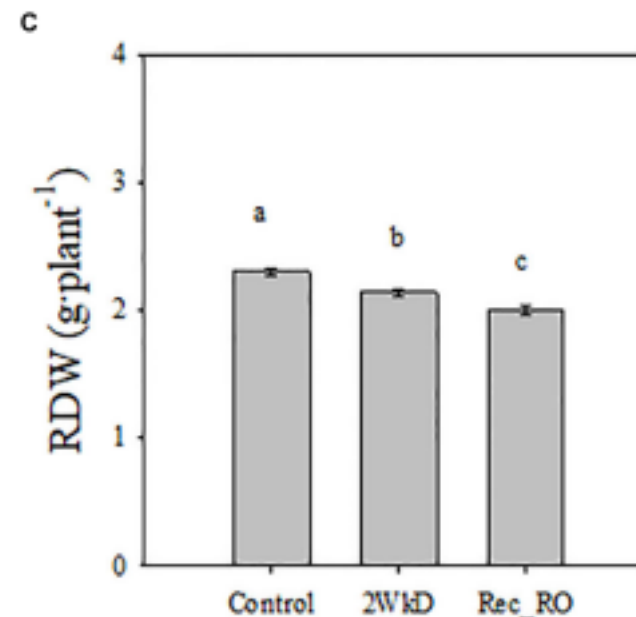
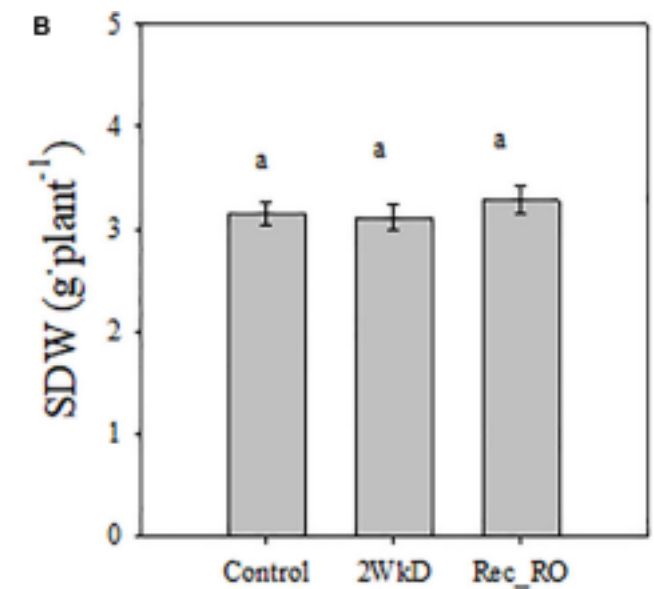
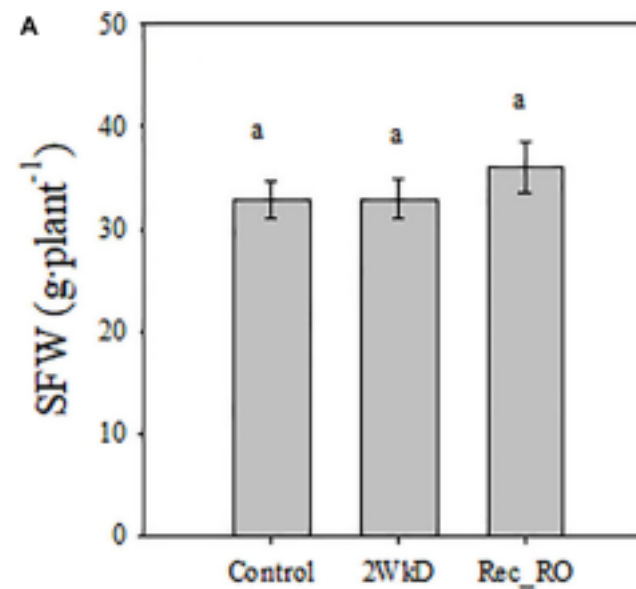
Managing recycling solution

Control= daily replaced with fresh solution

2WkD = recycled solution replaced with fresh solution after two weeks

Rec_RO = recycling solution made with RO water but not thrown away

SFW= Fresh plant weight
SDW = Dried plant weight
RDW = Root dried weight
Ec_{adj} = EC before adjustment



Solution Treatment

Summary

1. Continuous recycling reduced crop growth in hydroponics
2. Lower growth is due to decreased availability and/ or uptake of essential elements albeit maintaining EC
3. Reverse osmosis water or dumping old solution can reduce the negative effects of recycling in hydroponics

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