Urban raw or treated wastewater drip-irrigation for lettuce and leek crops: chemical and microbiological properties of soil and plants

Annabelle Mange, Nathalie Wéry, Nassim Ait-Mouheb

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Introduction

Impact of the REUSE :

Soil :

Excessive salt content will result of soil aggregates dispersion, decreasing the hydraulic conductivity and aeration of the soil matrix (Urbano et al.2017).

Plant :

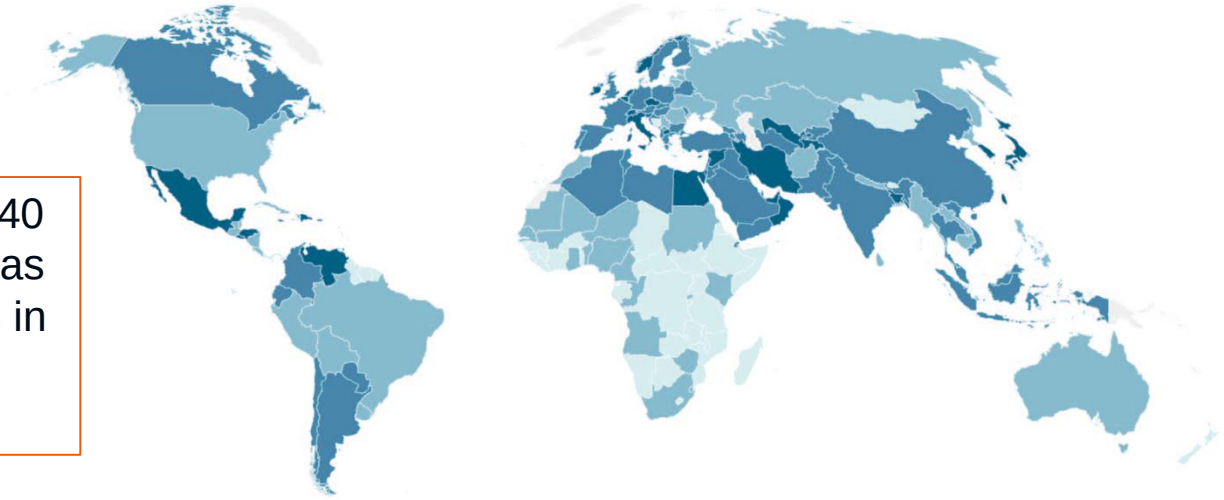
Wastewater is loaded with organic matter and nutrients which can be positive to the crop yields (Cirelli, et al.2012)

Pathogens:

The main exposure factors to pathogens are ingestion of wastewater, consumption of food in contact with wastewater, or inhalation of bioaerosol contaminated with pathogens (EPA 2012)

Introduction

Irrigated croplands located within 40 km downstream of an urban area as a percent of all irrigated croplands in each country
(Thebo et al. 2017)



- Using GIS model, Thebo et al. 2017 found that 65% (35.9 Mha) of the irrigated cropland downstream urban areas depend on urban wastewater flows

- A portion of these cultivated lands, 29.3 million hectares was in countries with low wastewater treatment rates and housed 885 million urban residents

Objective

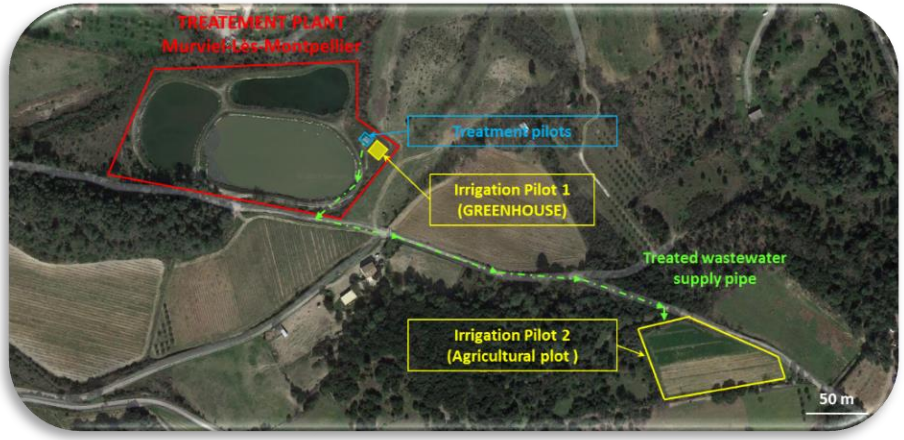
The aim of study is to analyze the effects of using 3 différent types of wastewater to irigate Lettuces and Leeks:

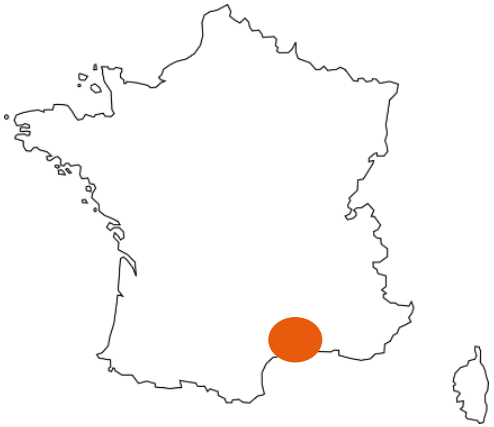
Drinking Water (DW) , Treated Wastewater (TW), Raw Wastewater (RW)

Soil	Plant	Microbiology
Physico-chemical and microbiological analyses	Microbiological analyses Crop yield	Internalization and survival rates of pathogens

Material and methods

Experimental platform of treated wastewater reuse in irrigation: Murviel les Montpellier





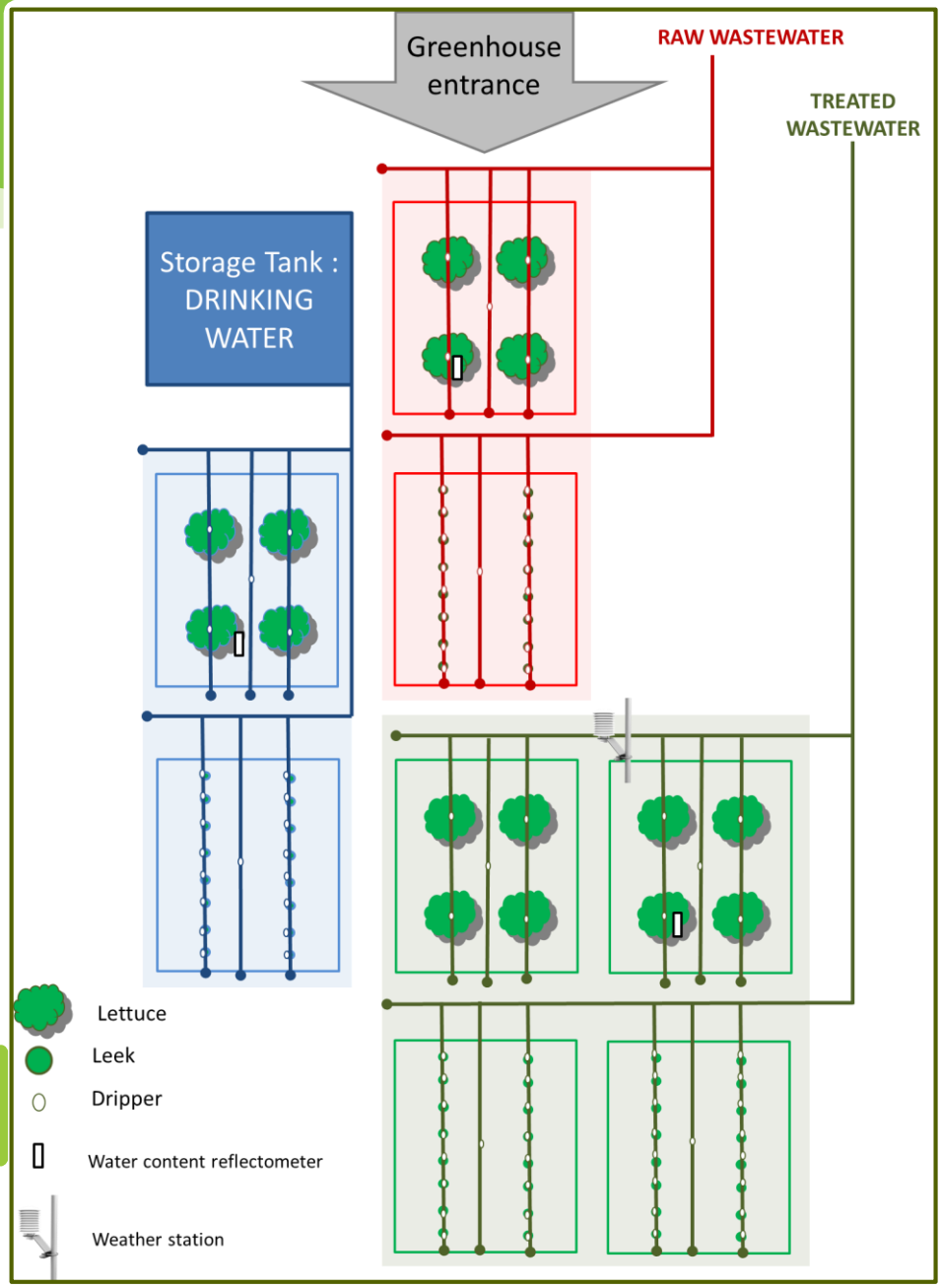
- The REUSE platform, located in a Mediterranean context in Murviel-lès-Montpellier
- Treatment process with 3 waste stabilization pounds for 2000 eq. hab

Material and methods

- Installation in the greenhouse (from March 2018)
- 8 Soil Bins : Surface = 1 m² / depth = 70 cm / loamy clay soil
- Crops : Lettuces and Leeks
- Irrigation system : Drippers (2L h^{-1})
- Weather station (Temperature, Relative humidity, Solar radiation)
- Soil moisture monitoring (Water Content Reflectometer)

Measurement :

- <u>Physico-chemical analyses :</u>
  - ✓ Irrigation water (1/week)
  - ✓ Soil (before/after each cycle)
- Crop yield :
  - ✓ Fresh mass of lettuces and leeks at harvest
  - ✓ Diameter of lettuces (1/week during cycle)



4 lettuces/bin

16 leeks/bin

1 dripper/plant

	Duration of cycle	Irrigation (mm)
CYCLE 1 Lettuce (2018)	6 weeks	58 mm
CYCLE 2 Lettuce (2018)	5 weeks	52 mm
CYCLE 3 Lettuce (2019)	6 weeks	72 mm
CYCLE 1 Leek (2018)	14 weeks	198 mm

Material and methods

3 water qualities tested :

Drinking Water (DW)

Treated Wastewater (TW)

Raw Wastewater (RW)

Parameters	Units	DW	TW	RW
EC at 20°C	mS cm^{-1}	0.56 ± 0.16	1.28 ± 0.15	1.39 ± 0.10
N-NO_3	mg L^{-1}	0.4 ± 0.49	0.59 ± 0.17	0.98 ± 0.12
P	mg L^{-1}	0.57 ± 0.09	6.97 ± 1.49	7.80 ± 3.08
Cl	mg L^{-1}	41.68	120.1	168.84
N-NH_4	mg L^{-1}	0.39 ± 0.16	28.40 ± 0.17	33.4 ± 7.5
K	mg L^{-1}	1.03	20.21	24.79
Mg	mg L^{-1}	7.18	13.15	14.51
Ca	mg L^{-1}	51.74	93.26	82.49
Na	mg L^{-1}	18.95	83.68	125.34
SAR	meq L^{-1}	2.55	8.37	13.23

SAR : Sodium Adsorbtion Ratio

Material and methods

Internalization and survival rates of pathogens

- **Monitoring of Fecal Indicator Bacteria in water, soil and plants by 2 techniques :**
  - ✓ Irrigation water (1/week)
  - ✓ Soil (before/after each cycle)
  - ✓ Plant (After each cycle)

Parameters	Units	DW	TW	RW
E. Coli	NPP/100 mL	Not detected	1,42E+04	1,47E+06
Enterococcus	NPP/100mL	Not detected	4,11E+03	5,20E+04

- Culture *: Escherichia coli*, *Enterococcus* sp.

- digital droplet PCR : gene specific of *Escherichia coli*

Results and Discussion

SOIL:

- Chemical characteristics of soil (0-30 cm depth) before planting and after the end of irrigation cycles by DW, TW, and RW

			Lettuces (After 2 Cycles)			Leeks (After 1 Cycle)		
Parameters	Units	Before planting	DW	TW	RW	DW	TW	RW
EC	mS/cm	0.13 ± 0,01	0.21	0.37	0.4	0.2	0.26	0.41
NO_3-N	mg/kg	7.20 ± 1,90	29.2	64.9	96.6	2.2	45	44.1
NH_4-N	mg/kg	0.43 ± 0,23	2.9	4.7	4.1	3.7	1.6	4.7
Na	mg/Kg	13.23 ± 1,93	40	172.8	150.5	46.5	232.3	249
Cl	mg/kg	44.67 ± 2,31	135	283	320	151	253	313

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- Accumulation of elements in the root zone probably due to the the loamy clay soil which have a low hydraulic conductivity

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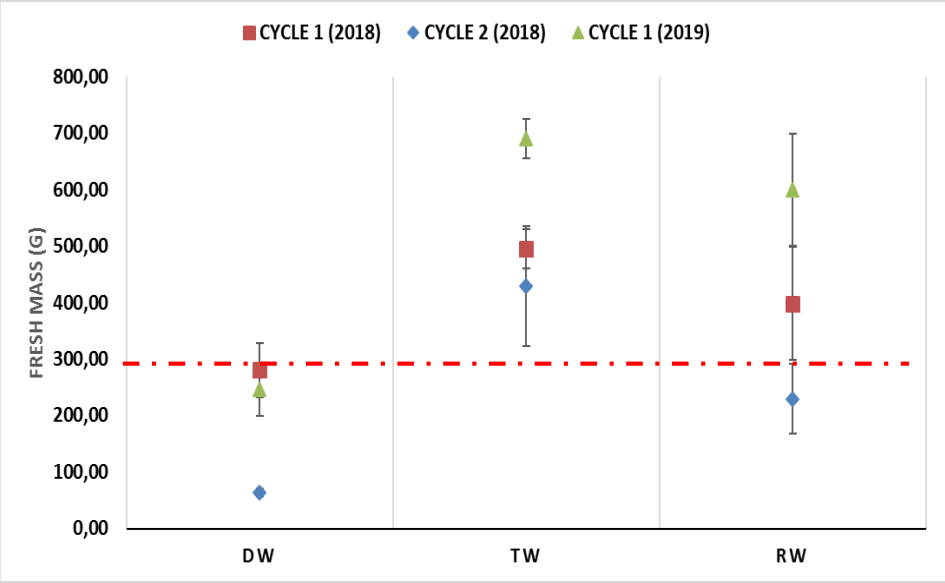
- NO_3-N concentration in soil is more important than NH_4-N probably induce by the nitrification process

Results and Discussion

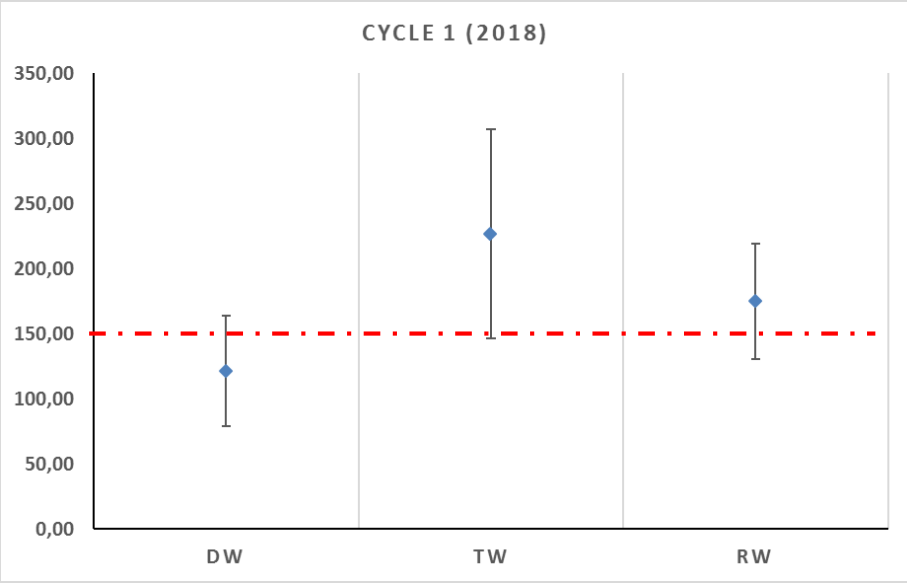
CROPS YIELD:

- Comparison of the fresh mass after Lettuce and Leek harvest

LETTUCES



LEEKS



Average commercial mass

Results and Discussion

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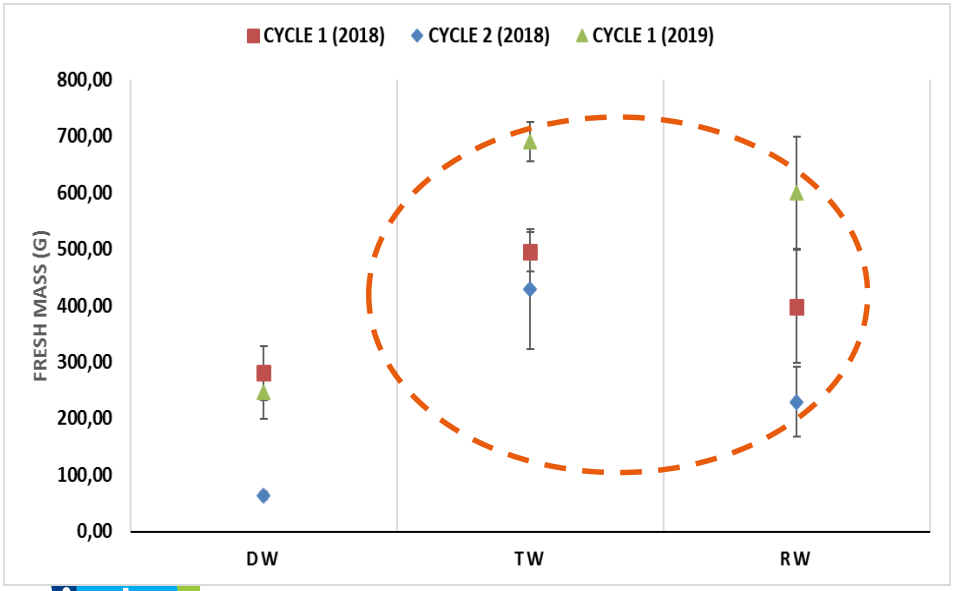

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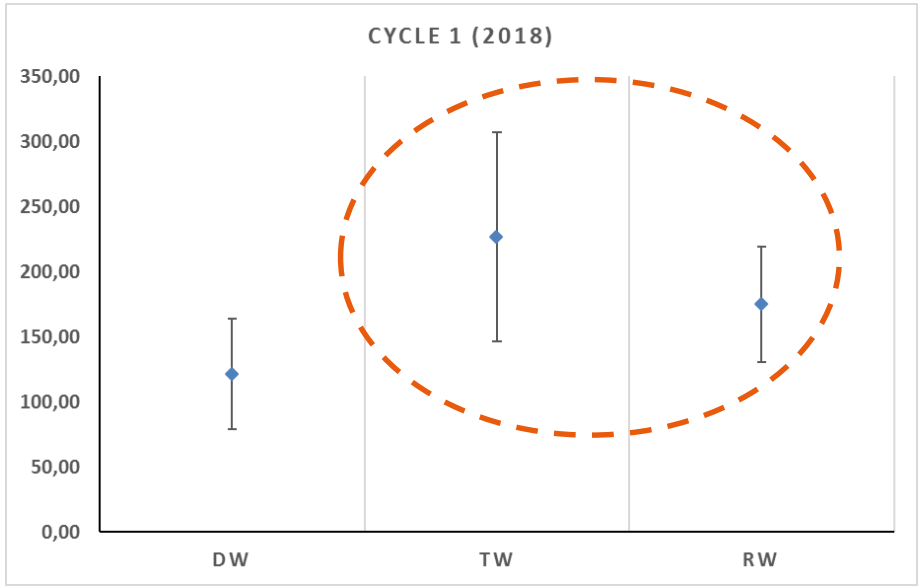


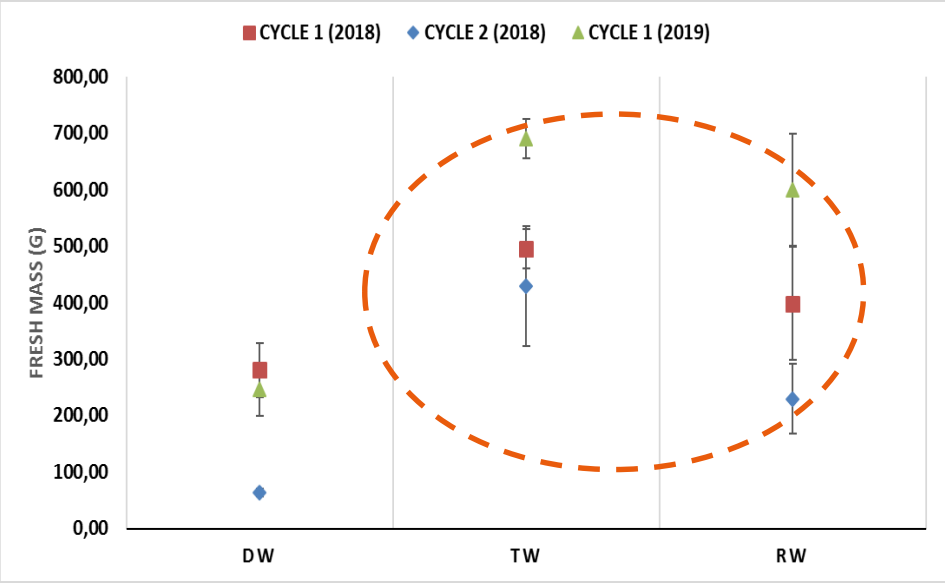
- For both lettuce and leeks, fresh mass is more important for TW to RW, probably induced by the high concentration on nutrients

Results and Discussion

CROPS YIELD:

- Comparison of the fresh mass after Lettuce and Leek harvest

LETTUCES



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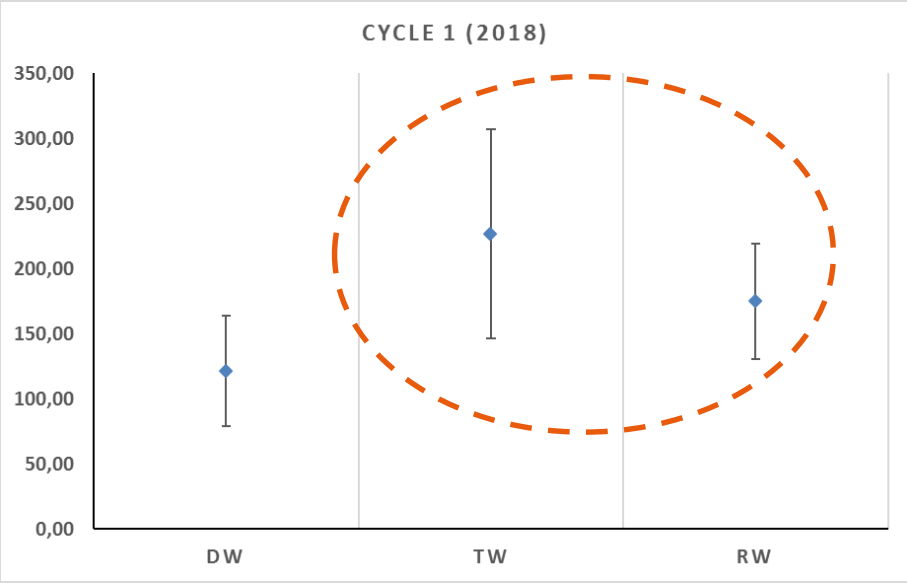
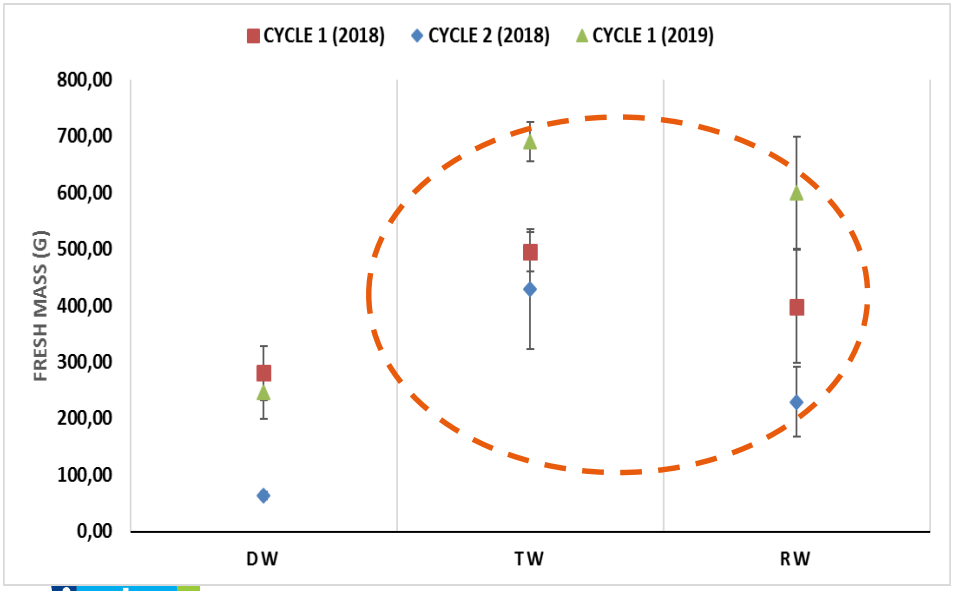
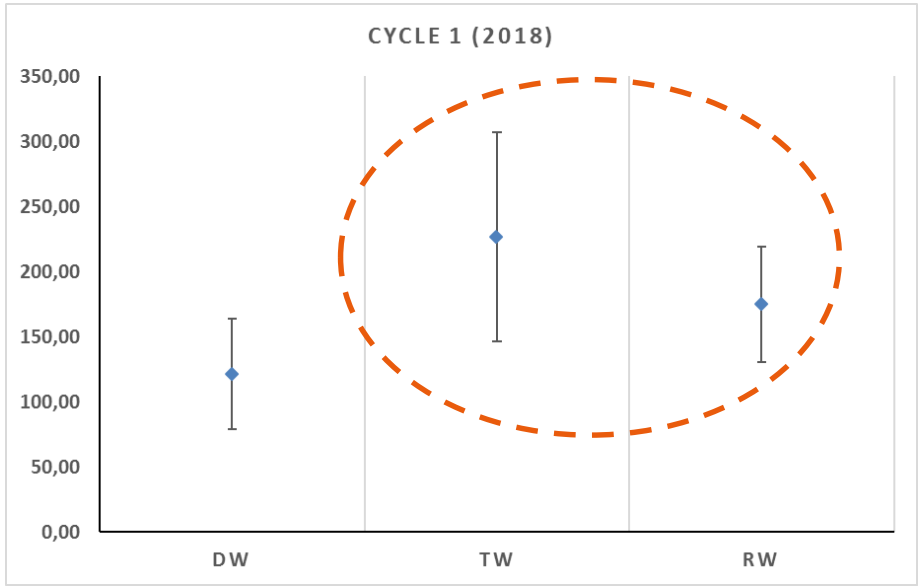


- Difference between TW and RW can be explain by higher concentration in Na in RW

➔ Leaves of **lettuces in contact with soil irrigated with RW were burned**

LEEKS





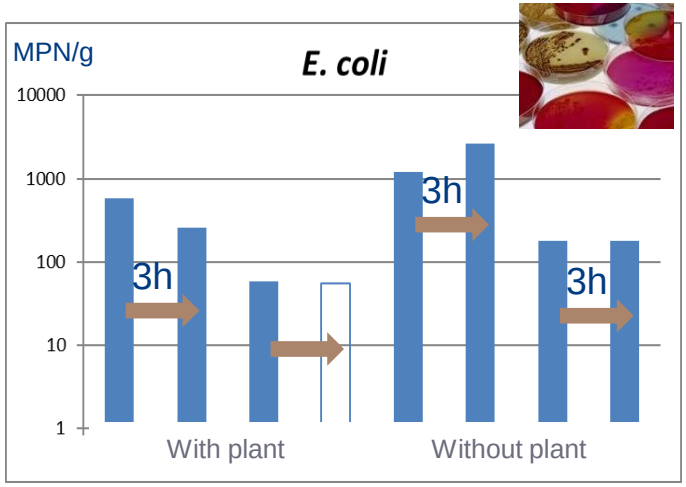
➢ Difference between TW and RW can be explain by higher concentration in Na in RW

Results and Discussion

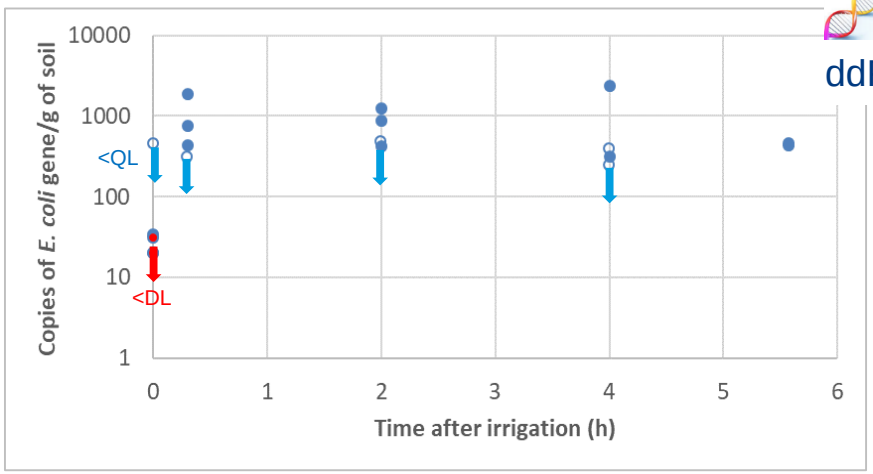
MICROBIOLGY after drip irrigation RW

- Monitoring of fecal indicators in soil and plants after irrigation with **RW**

- Slow decay of *E. coli* and *Enterococcus* in topsoil (0-5 cm) 3h after irrigation



ddPCR



- ***E. coli* present in roots of leeks and salads but not detected in the edible parts of the plants, *Enterococcus* not detected;**

Conclusion

- SOIL :
  - Increased salinity = loamy clay soil
  - Problems for sensitive plants in time
- NUTRIENTS :
  - Accumulation of nitrogen in soil ➔ better crop yield
  - But risks for environment due to leaching
- CROP YIELD :
  - Lettuces of TW treatment have a fresh mass more important of **40%** than DW and **20%** than RW
  - Leeks of TW treatment have a fresh mass more important of **50%** than DW and **20 %** than RW
- MICROBIOLOGY :
  - RW : The decay of E. Coli in topsoil is low
  - Internalization in the case of RW : E.Coli in lettuce and leek roots but not in the edible parts of the plants

Thanks for your attention

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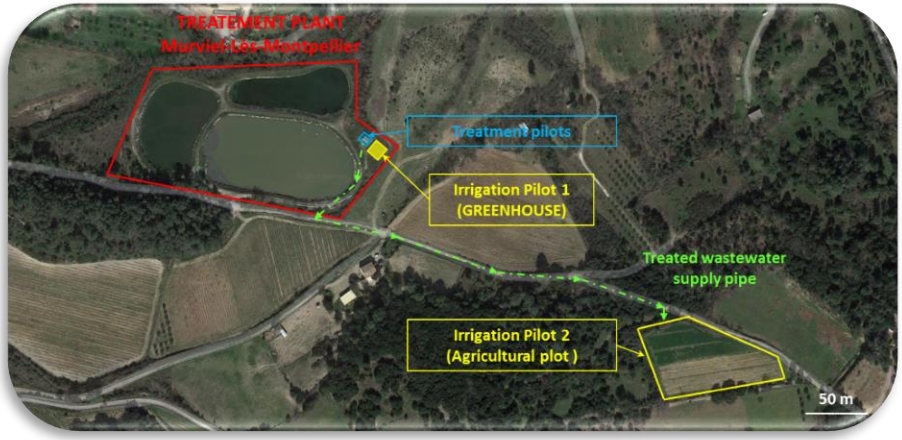
Material and methods

Experimental platform of treated wastewater reuse in irrigation: Murviel les Montpellier



The REUSE platform, located in a Mediterranean context in Murviel-lès-Montpellier:

- Adaptatif treatment of wastewater for agricultural uses (irrigation) or disposal
- Optimize the sustainability and efficiency of irrigation systems
- Valorize treated wastewater from an agronomic point of view
- To control health and environmental risks
  - survival of pathogens in irrigation systems, the crops or the soil,
  - analysis of emerging pollutant impacts