Ecotoxicological impact of semi-open horticultural systems on irrigation water quality

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Introduction

- Soilless cultivation can be highly efficient in the use of water and fertilizers, when the drained nutrient solution is recirculated (closed systems).

But…

Open (free drainage) and semi-open systems (Cascade ReUse Systems or CRUS) (drainage reuse for fertigation of secondary crops grown on soil) are still very common even in regions (e.g. Mediterranean) where forecasted climate changes point for less water availability.

- Poor use efficiency of water and nutrients;
- Releases of fertilizers and Plant Protection Products (PPPs) residues to the environment.

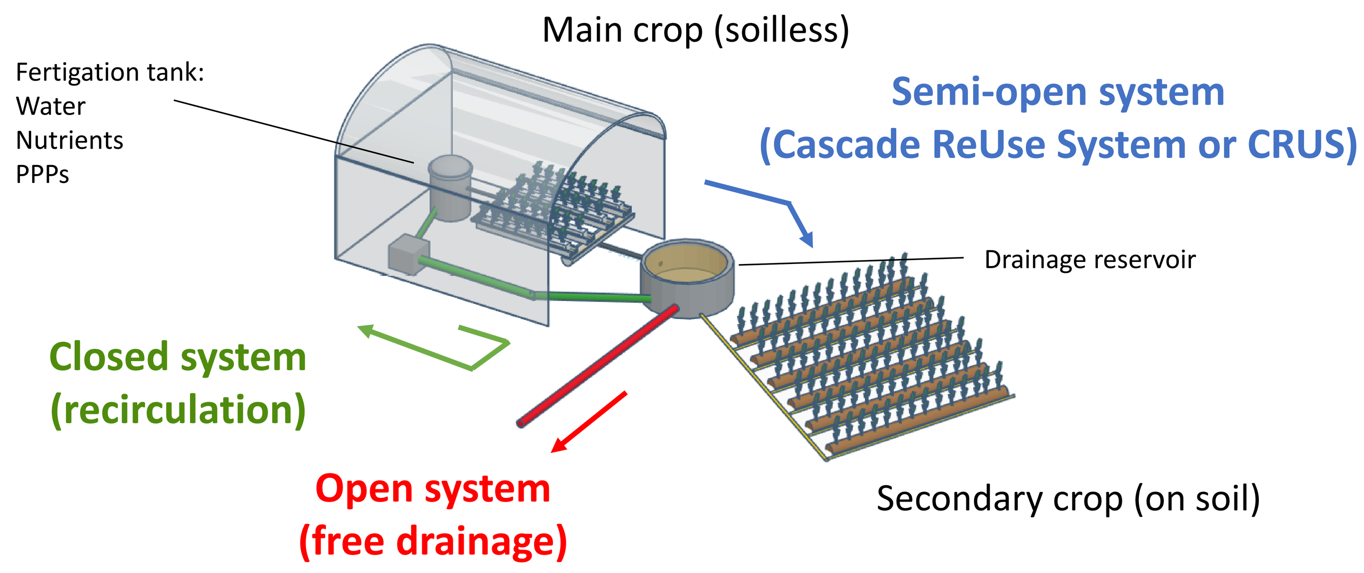

Figure 1. Schematic representation of the types of semi-hydroponic systems, regarding drainage reuse.

AGRINUPES

- The Project AgriNuPes (www.agrinupes.eu) is developing a NPK optical sensor and a biosensor (detection of PPPs) to:
  - Improve the fertigation management in soilless cultivation;
  - Increase the implementation of closed systems;
- Consortium of 8 entities from 5 countries;
  - FCUP (Portugal) is responsible for the Work Package targeting the environmental safety of drainages from CRUS.

Objective

- As part of the aforementioned project, this work aims to assess the quality of drainages from CRUS and their potential reuse through the characterization of their chemical composition and toxicity to aquatic organisms.

Materials and methods

- Two case studies (CRUS from Portuguese commercial growers):
  - Rose CRUS;
  - Strawberry CRUS.
- Collection points of drainage samples:

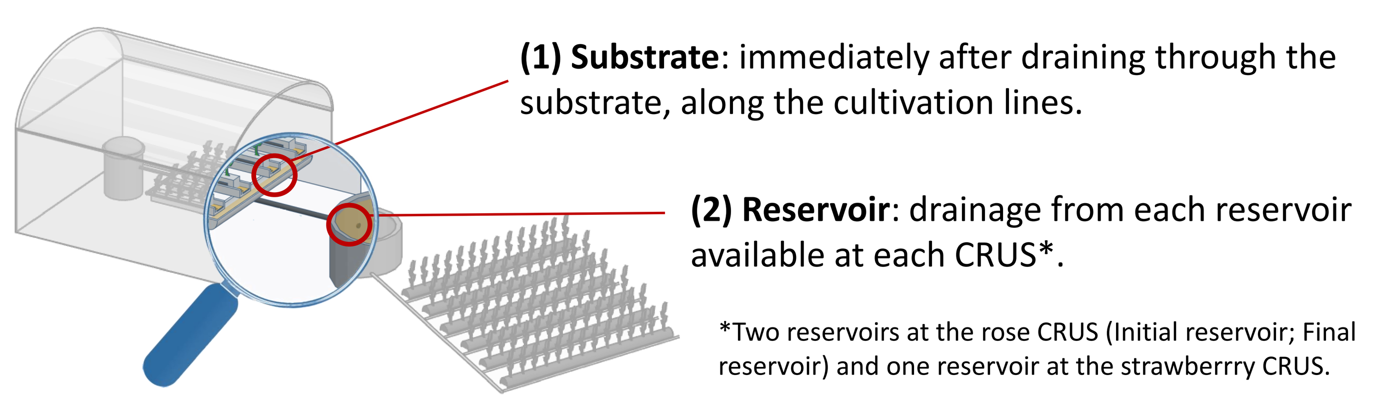

Figure 2. Schematic representation of the sampling points where the drainages from CRUS were collected.

- Ecotoxicological assays using aquatic species and standard protocols:
  - *Raphidocelis subcapitata* (green microalga) – growth inhibition assay (OECD 201, 2011);
  - *Daphnia magna* (microcrustacean) – immobilization assay (OECD 202, 1984);
  - *Aliivibrio fischeri* (bioluminescent bacteria) – Microtox® acute toxicity assay (81,9% Basic Test Protocol, Modernwater).
- Quantification of total nitrogen and total phosphorus (colorimetric method, Hanna Inst.);
- Quantification of PPPs residues by LC-MS.

Results and discussion

- *R. subcapitata* growth was inhibited only by the drainages from the rose CRUS (Table 1);
  - Probably due to the higher PPPs residues in the drainages from this CRUS (Table 2);
- The drainages from both CRUS were highly toxic to *D. magna*;
  - The electrical conductivity (EC) may be responsible at least in part for the toxicity of the drainages to the cladocerans, as they still have considerable levels of nutrients (Table 3);
  - The PPPs residues found in the drainages, might also have contributed to this toxicity.
- No toxic effect to *A. fischeri* were recorded. In opposition the drainages provoked a stimulation of the bacteria bioluminescence;
  - The large availability of nutrients in the drainages can be suggested as one of the reasons for the stimulation on the bacterial metabolism;
- The results suggest that the drainages of rose cultivation might be more harmful to the environment due to higher nutrient levels and PPPs residues, as compared to strawberry cultivation.

Table 1. Results of the ecotoxicological assays performed to assess the drainages from the two CRUS under evaluation.

Drainages		*R. subcapitata* 72h-EC_{20} (%)[a] (95% CI)	*D. magna* 48h-EC_{50} (%)[b] (95% CI)	*A. fischeri* HE (%)[c]
Rose CRUS	Substrate	63 (57-70)	8 (nc)	19
	Initial Reservoir	Non-toxic	21 (11-28)	-11
	Final Reservoir	Non-toxic	18 (9-26)	-24
Strawberry CRUS	Substrate	Non-toxic	48 (43-52)	-47
	Reservoir	Non-toxic	11 (9-12)	-41

[a] 72h-EC_{20} is the effective concentration of drainage at which growth of *R. subcapitata* was inhibited by 20%, after 72 h of exposure.
[b] 48h-EC_{50} is the effective concentration of drainage that caused immobilization in 50% of the cladocerans *D. magna,* after 48 h of exposure.
[c] HE is the highest effect on the bioluminescence of *A. fischeri*. Negative values indicate stimulus, rather than inhibition.
Non-toxic: maximum effect <10% | nc: not calculated.

Table 2. Plant Protection Products residues in the drainages from the two CRUS under evaluation.

Drainages		Methiocarb (µg/L)	Pyraclostrobin (µg/L)	Azoxystrobin (µg/L)	Dimethoate (µg/L)	Difeconazole (µg/L)	Myclobutanil (µg/L)	Boscalid (µg/L)
Rose CRUS	Substrate	2.14	0.09	0.72	12.1	0.272	3.30	0.93
	Initial Reservoir	0.45	0.14	0.23	300.0	0.321	0.73	1.29
	Final Reservoir	0.20	0.17	0.26	36.1	0.396	1.64	2.89
Strawberry CRUS	Substrate	0.03	0.17	0.18	1.2	<0.005	0.12	5.36
	Reservoir	0.01	0.05	0.17	36.2	<0.005	0.14	3.97

Table 3. Total nitrogen, total phosphorus and electrical conductivity (EC) of the drainages from the two CRUS under evaluation.

Drainages		Total N (mg/L)	Total P (mg/L)	EC (dS/m)
Rose CRUS	Substrate	124.7 ± 9.8	42.2 ± 0.2[a]	1.6
	Initial Reservoir	121.3 ± 6.4	34.7 ± 0.9[b]	1.5
	Final Reservoir	140.7 ± 4.1	28.7 ± 0.2[c]	1.4
Strawberry CRUS	Substrate	86.0 ± 12.1	20.6 ± 0.6[a]	1.5
	Reservoir	51.3 ± 3.7	14.8 ± 0.2[b]	1.3

Different letters indicate significant differences through Tukey´s test ($p<0.05$), after one-way ANOVA.

Conclusions

- For a better environmental performance of soilless cultivation, it is stressed here the importance of preventing drainages to be released into the environment, especially directly to the aquatic environment;
- This study is being complemented with the assessment of the impacts on soil of the drainages applied to secondary crops;
- The high levels of nutrients that persist in the drainages reinforces the importance of testing their potential reuse with target crops. This will be a step forward for increasing the life-cycle of drainages, to reduce this externality and the consumption of water and nutrients.

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