MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

CREATING A CIRCULAR FUTURE

Urine running in circles – human „waste“ as a resource for horticulture & agriculture

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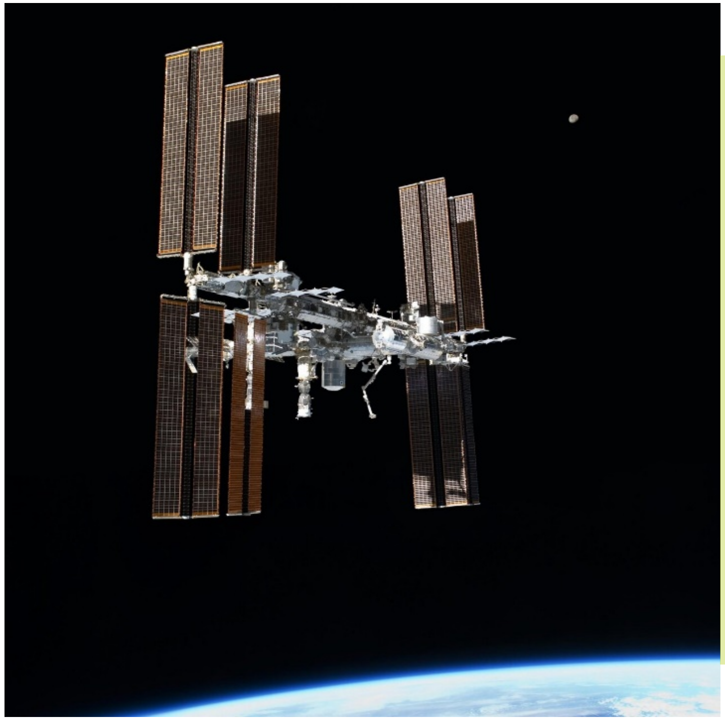
introduction

Current and future ways to closed life support systems



<u>Aim:</u>
100 % closed material cycles (water, oxygen, carbon, nutrients, …)
&
100 % solar energy

Pictures: ESA

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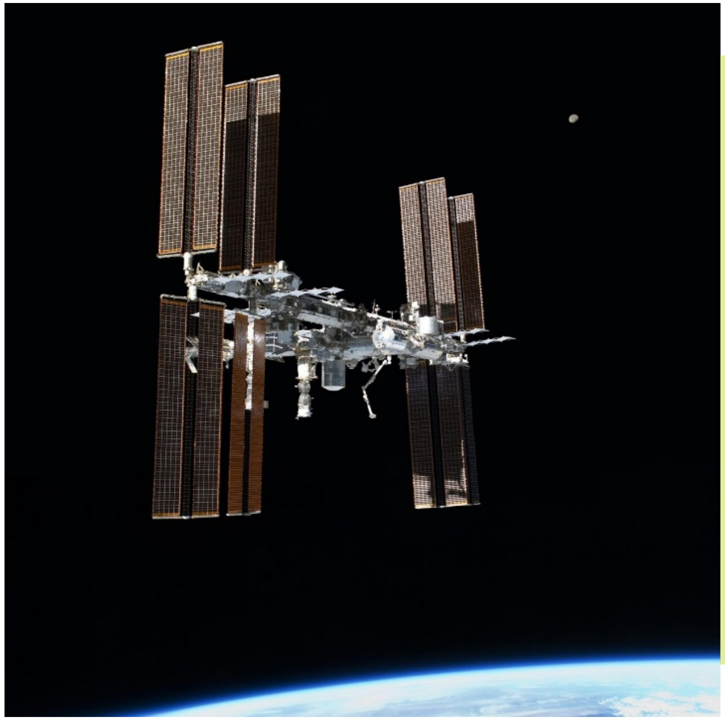
Current and future ways to closed life support systems

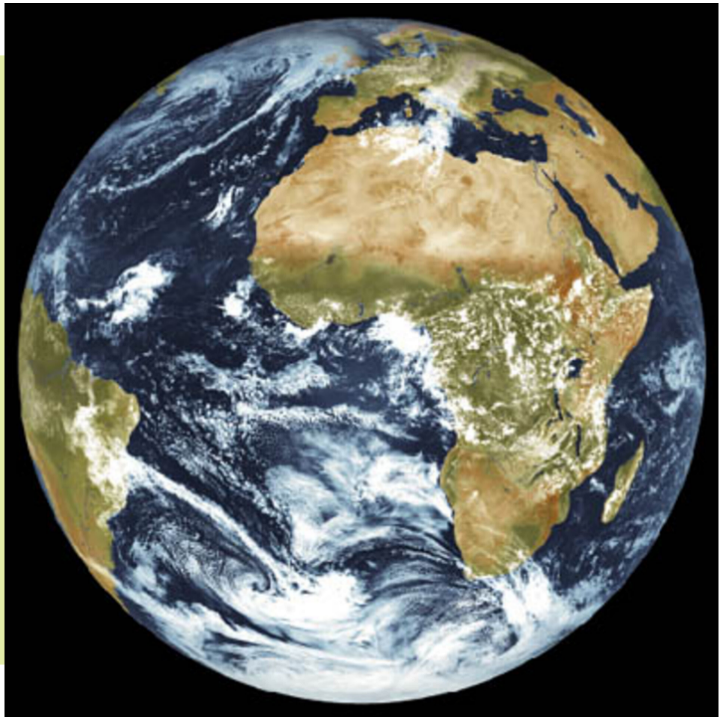


Aim:

100 % closed material cycles (water, oxygen, carbon, nutrients, ...)

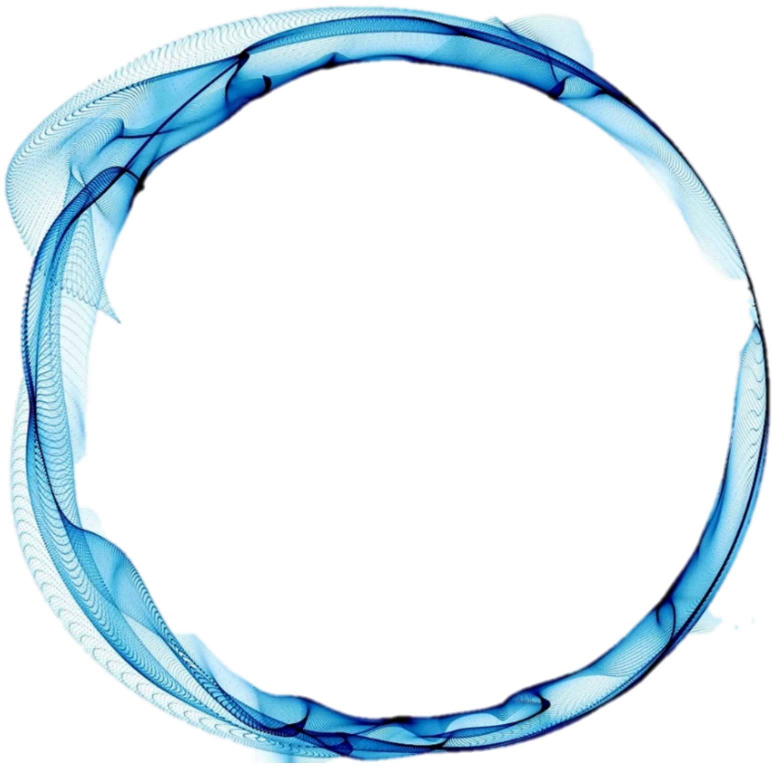
&

100 % renewable energy



Pictures: ESA

Current and future ways to closed life support systems



‘Operating within the scheme of a **circular economy**, and the incorporation of **nutrient cycling**, are principle components of **future sustainable food systems**’

Springmann et al. (2018)

Picture: Susanne Rotter
German Council of
Environmental
Advisers

Establishing a circular, climate-resilient and community-supportive agri- & horticulture

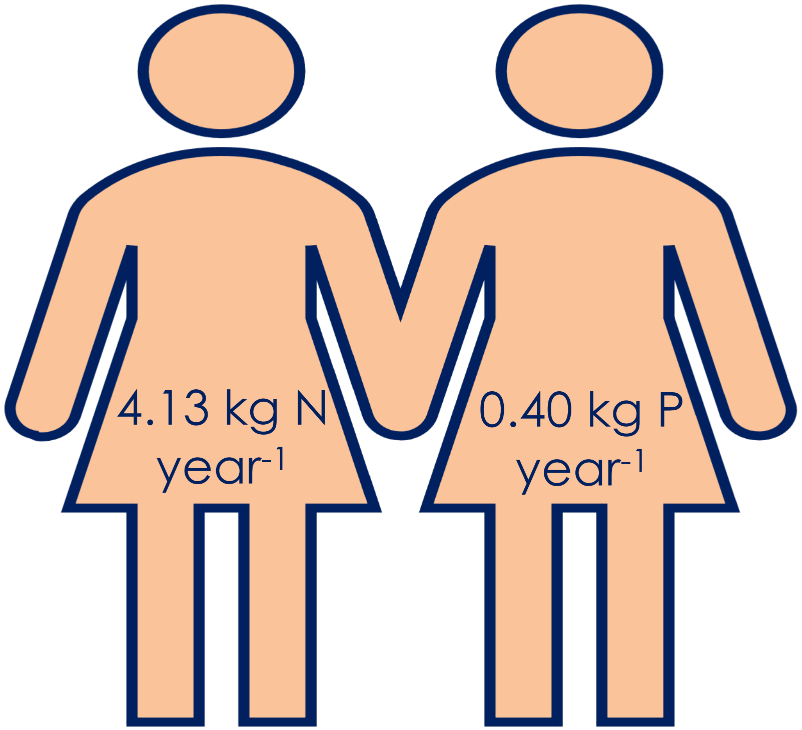
Based on (i) nutrient cycling, (ii) humus formation & carbon sequestration, (iii) elimination of pollutants, and (iv) low emissions.

Own picture

Urine is a resource!

- → Contributes up to 80 % of the Nitrogen (N) and up to 60 % of the Phosphorus (P) comprised in urban municipal wastewater
- → Accounts for only 1 % of the volume

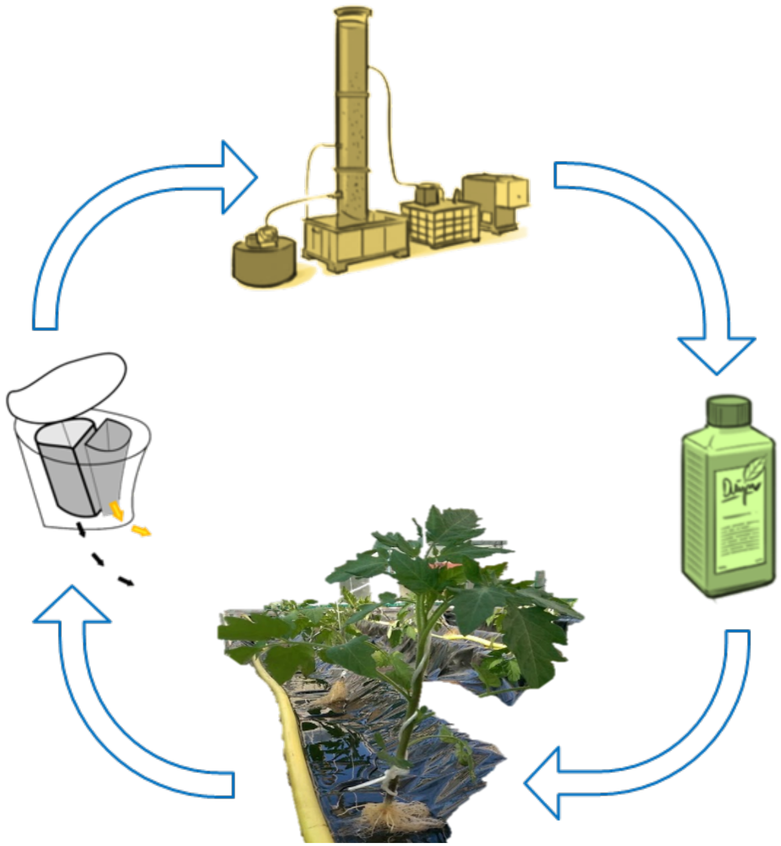
Herrmann and Klaus (1997)
Simha and Ganesapillai (2017)



Data adapted from: Viskari et al. (2018)

Urine processing

We conduct research on the use of **nitrified urine-based fertilizers (NUF)** in horticulture with respects to fertilizer efficiency in different production systems, and the assessment of potential trade-offs, such as higher GHG emissions.



materials & methods

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Nitrified Urine-based Fertilizers (NUF)

	C.R.O.P. DLR	Aurin VUNA eawag aquatic research ETH zürich
Stabilization process	Nitrification with addition of a base ($CaCO_3$)	Nitrification up to natural equilibrium
Pharmaceutical removal	Biological degradation; R&D progress	Activated carbon filtration
Sanitization	Pasteurization	Distillation/Pasteurization

C.R.O.P. = Combined Regenerative Organic food Production

Picture: G. Bornemann

www.vuna.ch

Nutrient concentrations found in the two NUFs

End product		Urine-based fertilizer solution enriched with calcium	Concentrated urine-based fertilizer solution
Mineral nutrient	**Unit**	**'Crop'**	**'Aurin'**
NO_3^--N	g L^{-1}	4.69 ± 0.07	30.9 ± 4.66
NH_4^+-N	g L^{-1}	2.29 ± 0.19	32.2 ± 5.88
P	g L^{-1}	0.33 ± 0.02	3.09 ± 0.03
K	g L^{-1}	1.85 ± 0.06	21.4 ± 1.15
S	g L^{-1}	0.49 ± 0.02	3.57 ± 0.26
Ca	g L^{-1}	3.29 ± 0.30	0.38 ± 0.01
Na	g L^{-1}	2.78 ± 0.09	25.9 ± 1.09
Cl	g L^{-1}	5.49 ± 0.09	46.7 ± 0.67

$NO_3^-:NH_4^+$ — 'Crop': ~ 2:1; 'Aurin': ~ 1:1

Mean ± standard error

Evaluation of NUF with regards to plant growth and GHG emissions

Pot experiment in climate chamber with maize

Master thesis
Oscar Rodrigo Monzon

Field experiment in three soil types with white cabbage

Hydroponics experiment with tomato

Master thesis
Aladdin Halbert-Howard

experimental design & selected results

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Pot experiment in climate chamber with maize

Master thesis Oscar Rodrigo Monzon

Crop: **maize** (*Zea mays convar. saccharata L.*, cultivar Sugrano) (Feb-May 2019)

4 l pots, in peat-free substrate
Completely randomized two-factorial block design

4 fertilizer treatments; n=5:

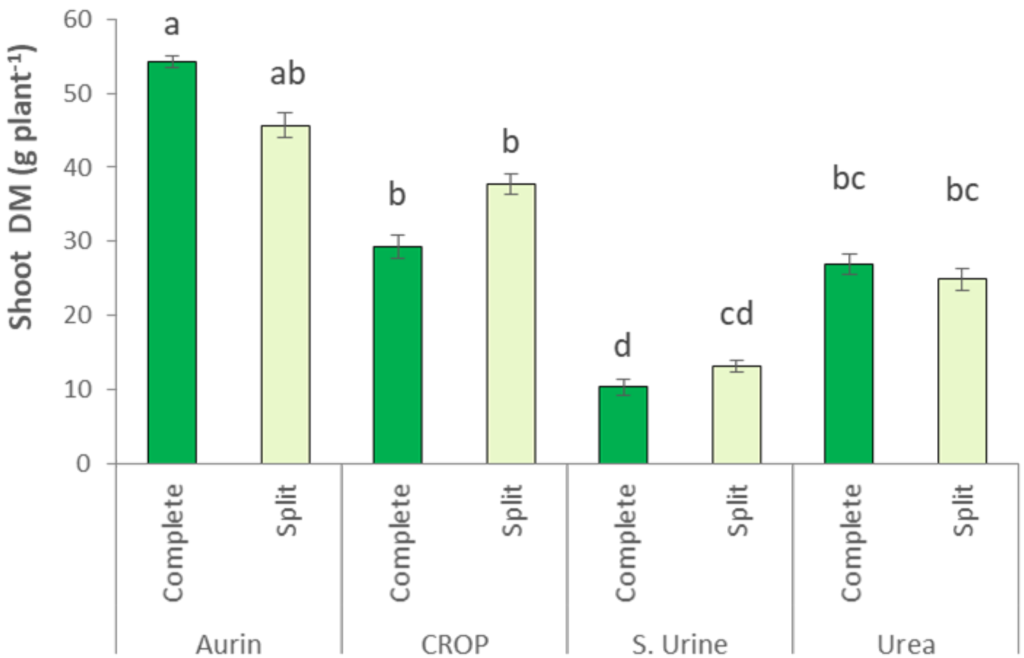
- 2 NUF (Aurin, C.R.O.P.)
- 1 human urine mimic (synthetic urine)
- 1 mineral fertilizer (urea)

2 application modes variating during time:

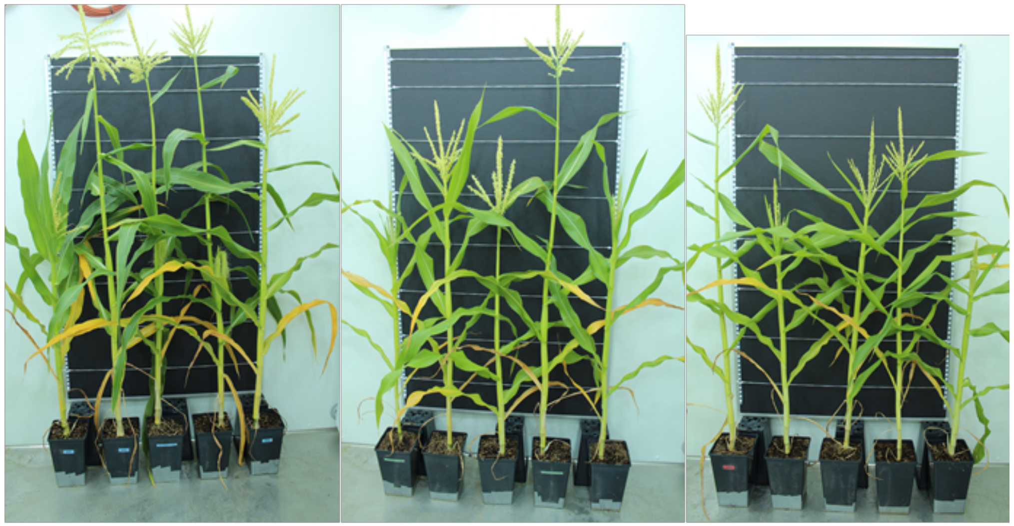
- Full N fertilizer application before sowing ("complete")
- Two applications of 50% of the N demand ("split") with 1. before sowing and 2. after two weeks.

Pot experiment: results
Plant dry matter (DM) production

Shoot DM biomass



Maize plants 49 days after sowing



Aurin complete | CROP complete | Urea complete

Variation of application timing: „Complete“= full fertilizer application before sowing; „Split“= 50% of total N before sowing and 50% of total N after two weeks

Pot experiment: results
N-losses

Treatments			NH_3-N loss % pot^{-1}	
pH	NH_4^+		Complete	Split
<4-5	50%	Aurin	0.50 ± 0.03 e	0.54 ± 0.02 e
<4-5	20%	CROP	0.48 ± 0.03 e	0.43 ± 0.02 e
~7	100%	S. Urine	11.7 ± 0.32 a	5.22 ± 0.27 b
		Urea	2.01 ± 0.07 c	1.21 ± 0.03 cd

Evaluation of NUF with regards to plant growth and GHG emissions

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Two 60 m^2 greenhouse cabins @ IGZ, March till July 2019

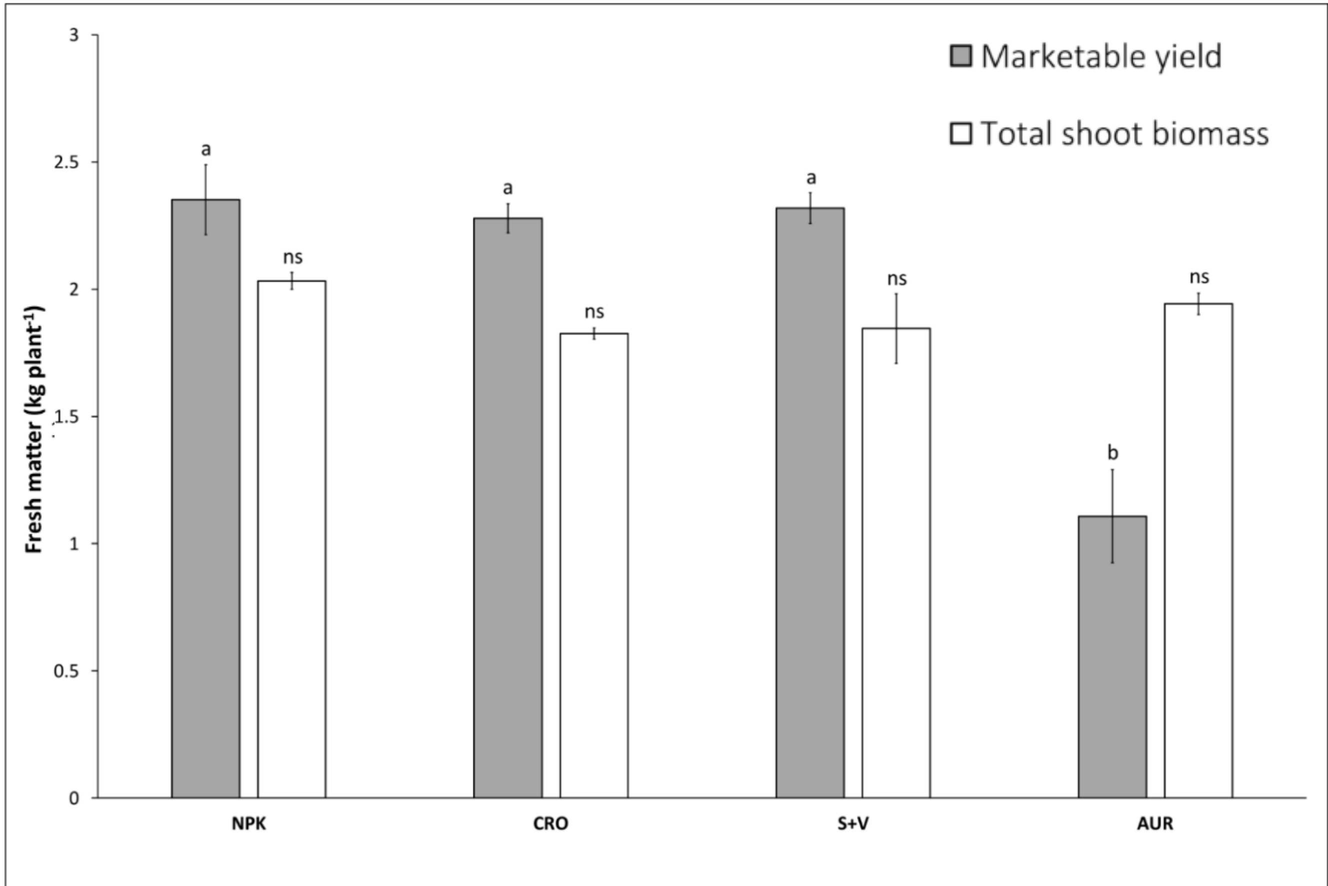
Crop: **tomato** (*Solanum lycopersicum* L. cv. *Pannovy*), Apr-Jul 2019
Nutrient film technique (NFT) hydroponics system

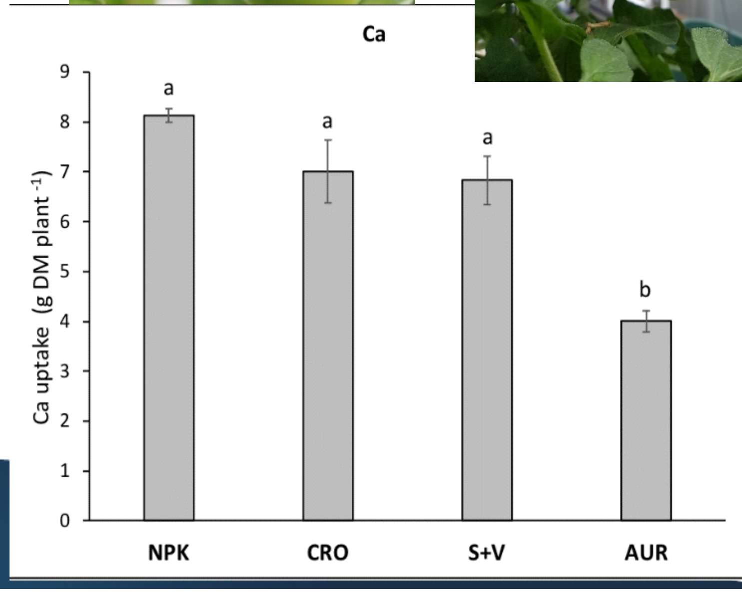
4 fertilizer treatments; n=4:

- 2 NUF (Aurin, C.R.O.P.)
- 1 Organo-mineral recycling fertilizer, Struvite + Vinasse (S+V)
- 1 Mineral fertilizer ("control")

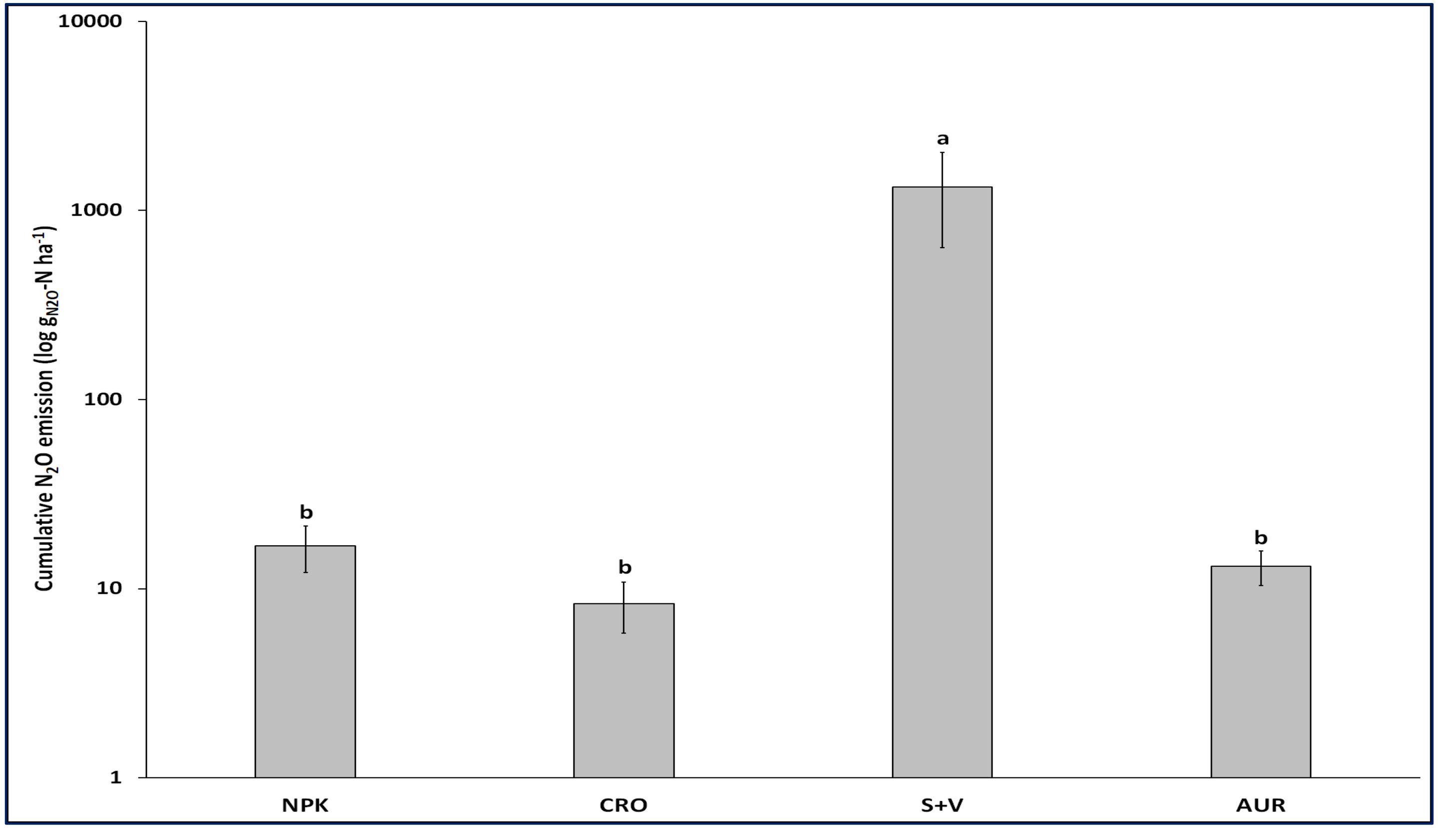
Photos:
F. Häfner

Hydroponics experiment: results
Plant fresh matter production





Hydroponics experiment: results
Cumulative N_2O emissions



re-cap & conclusions

Re-cap results

Pot experiment - maize

- ✓ Fertilizer effect:

Aurin > C.R.O.P. ≥ urea > synthetic urine

- ✓ Nitrification of urine decreases NH_3 volatilization

Hydroponics experiment - tomato

- ✓ Fertilizer effect:

Aurin ~ CROP ~ struvite&vinasse ~ NPK

- ✓ Fruit yield: higher NH_4^+ content in Aurin prevented Ca-uptake and caused increased blossom-end-rot
- ✓ NUF with minimal N_2O emissions

Synthesis I

- **Both NUF are adequate recycling fertilizers** and viable substitutes to established synthetic mineral fertilizers (urea) and organo-mineral recycling fertilizers (struvite, vinasse).
- No difference in yield between the two NUF with differing NH_4^+/NO_3^--ratio in substrate but in hydroponic.
- In hydroponics, NH_4^+/NO_3^--ratio matters due to lack of (natural) buffering systems.
- **The level of nitrification during urine processing determines the NH_4^+/NO_3^--ratio and, thus, the application options for NUF products in different horticultural systems.**

Synthesis II

- ✓ No negative trade-off, but **potential ecological benefit identified for NUF with regards to GHG**.
- ✓ Nitrification of urine increases fertilizer efficiency and decreases NH_3 volatilization.
- ✓ Future research needed for the adaption of recycling fertilizers to reach a 100% recycling rate, and the role of different hydroponic systems with regards to GHGs.

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Acknoledgments

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SiEUGreen
Sino-European innovative green and smart cities

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THANK YOU.

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