MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

CREATING A CIRCULAR FUTURE

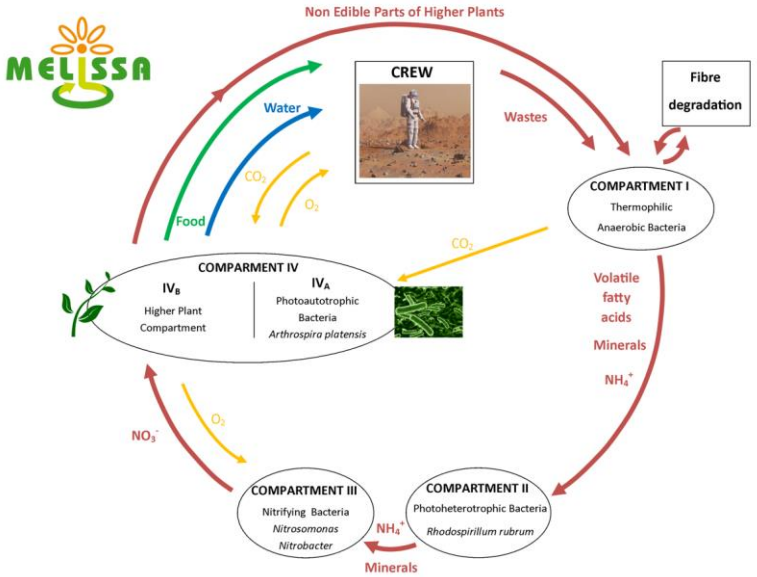
Lettuce cultivation in a urine recycling scenario: Effects of different NH_4^+:NO_3^- ratios

M. Schiefloe[1],Ø.M. Jakobsen[1], A. Pannico[2], C. Quadri[3], A.I.K. Jost[1]

[1] CIRiS, NTNU Social Research, Norway
[2] University of Naples, Italy
[3] EnginSoft S.p.A, Italy

INTRODUCTION

Urine-based fertilizer for cultivation of higher plants



Hypothesis:

the outcome of the upstream process for urine nitrification may result in a varying ammonium:nitrate ratio, which can affect plant growth and development

Test campaign:

Two tests with different NH4:N ratio

(N provided as a mix of NO_3^- and NH_4^+)

Urine-based fertilizer for cultivation of higher plants

Urea conversion

NH_4^+ nitrification

NH4:N?

?

Nutrient solution strategy

Reference crop: control and starting point

- Lettuce test performed by the University of Naples in standard nutrient solution

NaCl addition to mimic urine

- Based on natural NaCl:N ratio in urine (5 mM Na in final nutrient solution, not accounting for possible accumulation)

Nutrient solution strength reduced to allow EC comparable to Reference

	Reference	LoNH4:N	HiNH4:N
NH4:N	0.22	0.11	0.50
Na:N	0.01	0.42	0.42
Cl:N	0.02	0.42	0.42
EC /pH	1.9 / 5.9	1.9 / 5.9	2.2 / 5.9

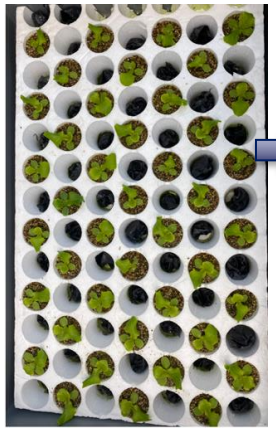
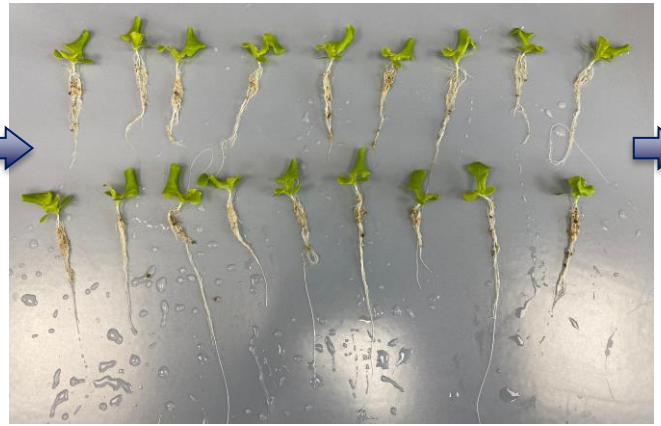
Nitrate control

- Feeding of nutrient stock solutions based on nitrate level
  - Optical nitrate sensor in the hydroponic loop
- Same total N concentration in both tests 146 mg/l N, 10.4 mM
- Test 1 (LoNH4:N): NH4:N = 0.11, 130 mg/l NO_3-N (9.3 mM)
- Test 2 (HiNH4:N): NH4:N = 0.50, 73 mg/l NO_3-N (5.2 mM)

PCU – Plant Characterization Unit

- Developed in the MELiSSA PaCMan1 project (2018-2020)
- Located at the Federico II University of Naples
- Closed atmospheric and hydroponic loop

- 18 plant positions
- Advanced gas and liquid monitoring
- Color and thermal camera systems


Seedling selection

Lettuce *Lactuca sativa* L.

cultivar 'Grand Rapids'

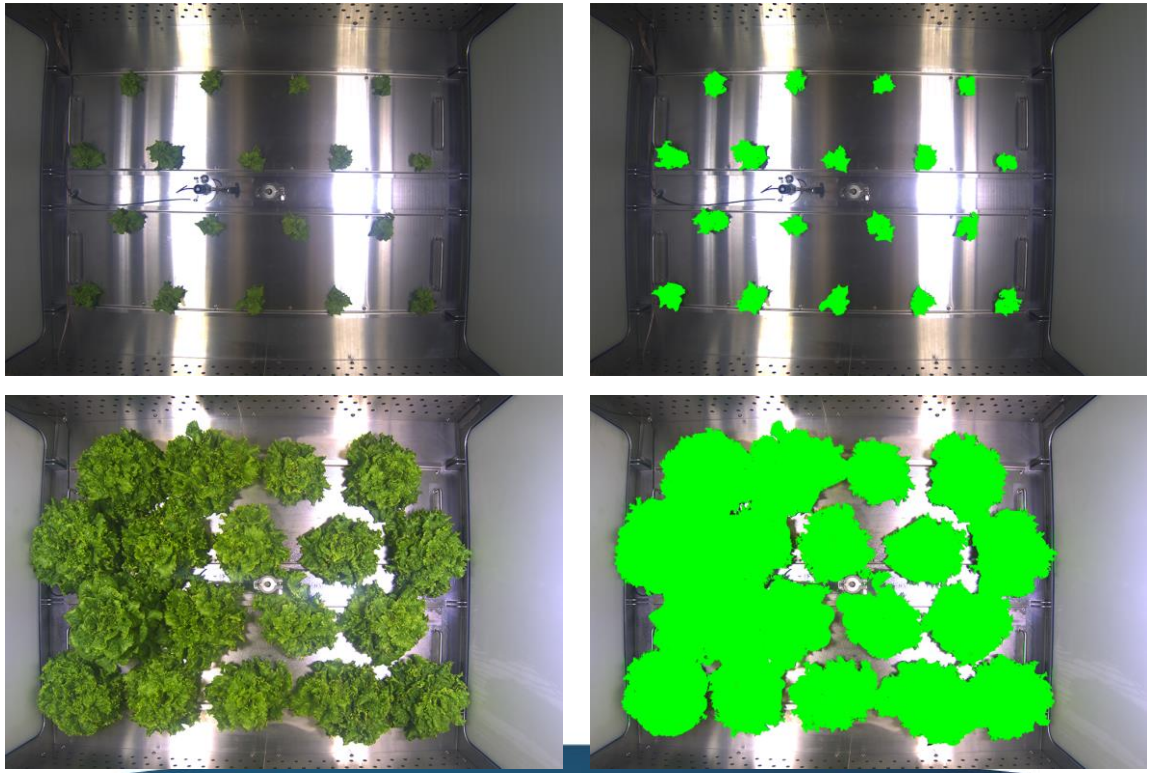
RESULTS

Harvest after
28 days in PCU
38-day old plants

Parameter	LoNH4:N (0.11)	HiNH4:N (0.50)	Significance
Shoot FW (g)	290	120	$P < 0.01$
Plant DW (g)	21	13	$P < 0.01$
No. of leaves	40	26	$P < 0.05$
Leaf area (cm^2)	3907	1961	$P < 0.01$

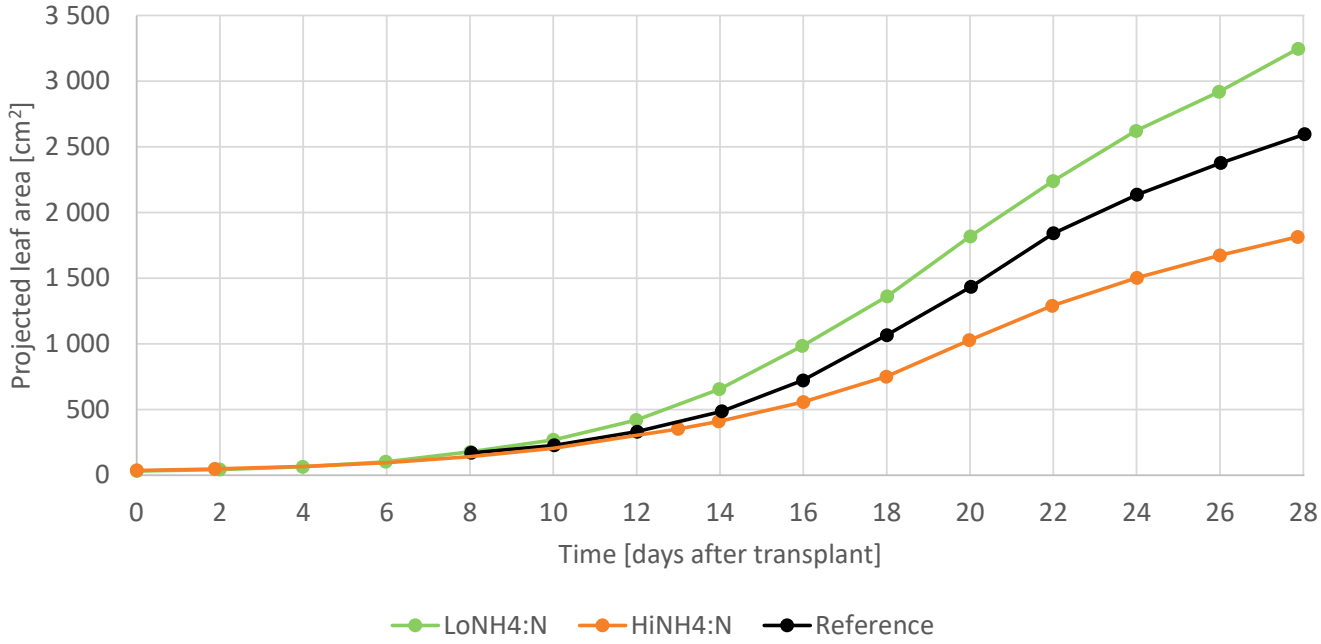
Projected leaf area

Image segmentation of top view images



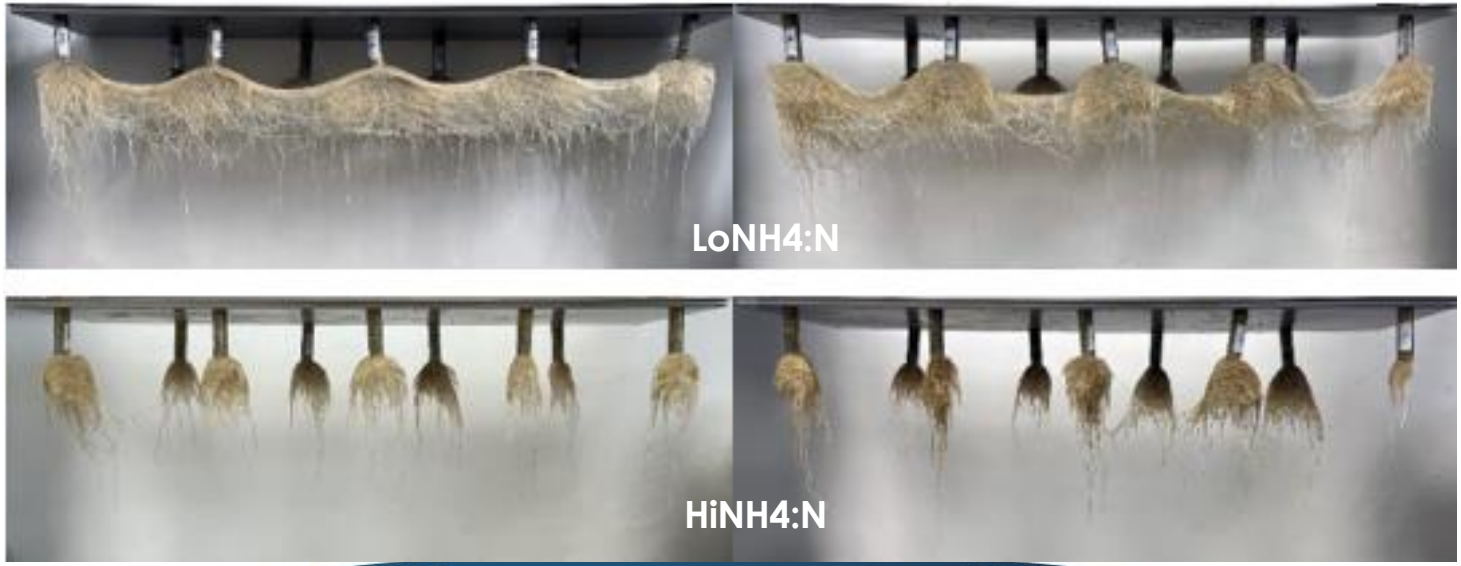
Shoot growth

as projected leaf area

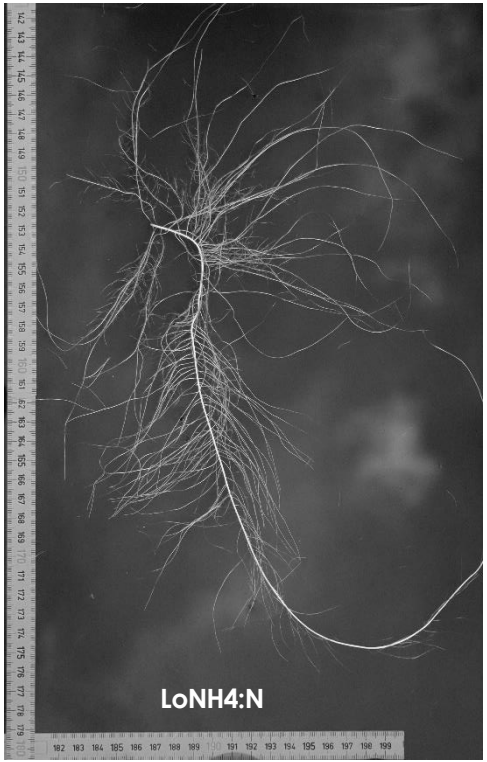


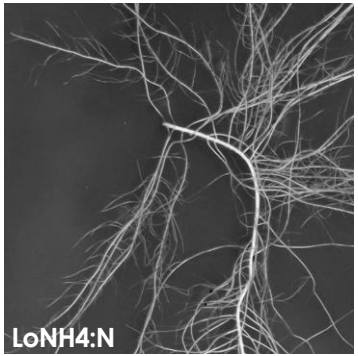
Root growth

Parameter	LoNH4:N (0.11)	HiNH4:N (0.50)	Significance
Root DW (g/plant)	2.4	1.9	--
Root:Shoot ratio	0.14	0.19	P < 0.01
Harvest index	0.88	0.85	P < 0.01



Root morphology



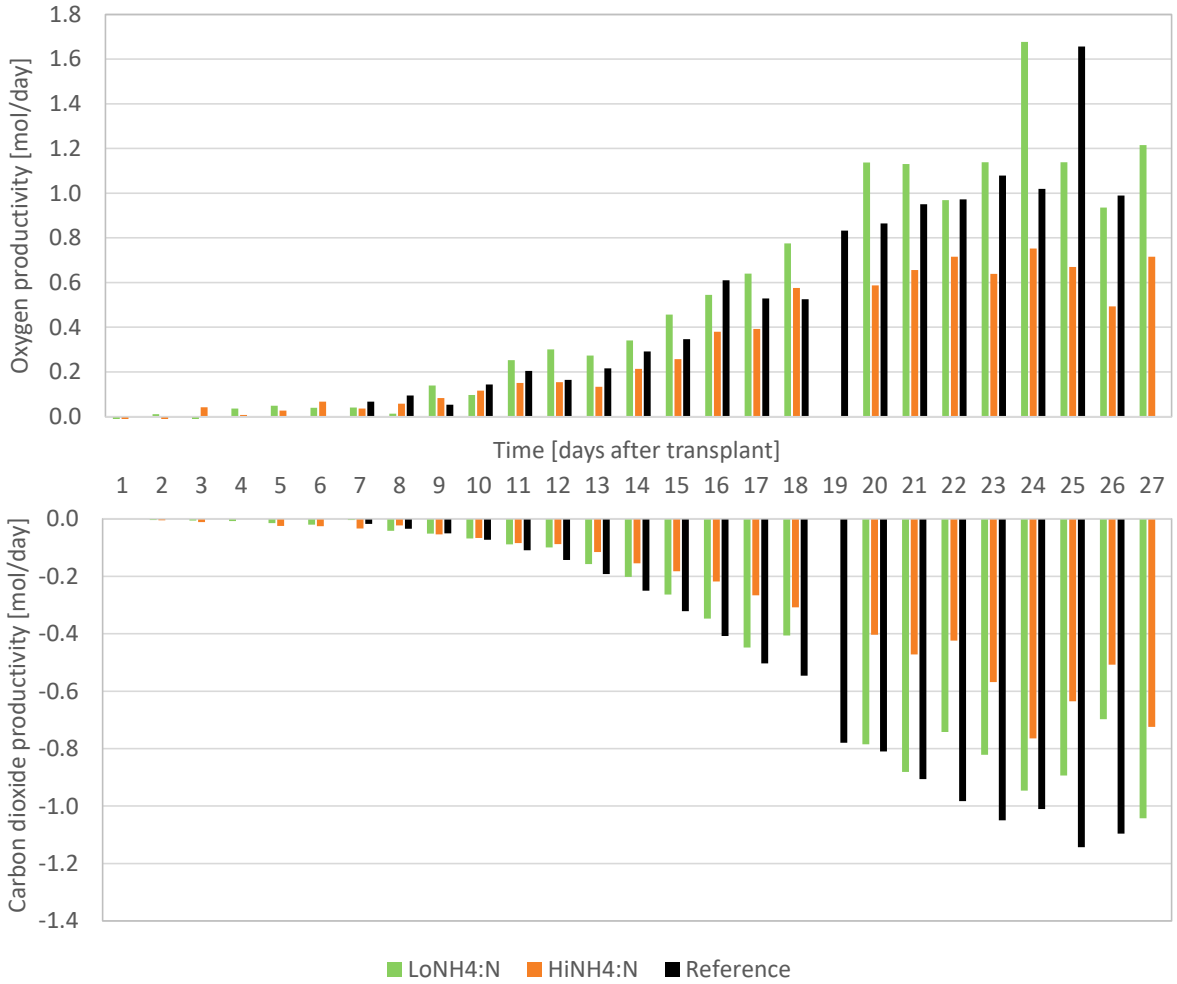


10 x 10 cm

Leaf chlorophyll and color

- SPAD: LoNH4:N significantly lower than HiNH4:N
- Color index: LoNH4:N had color index significantly more towards yellow than HiNH4:N.

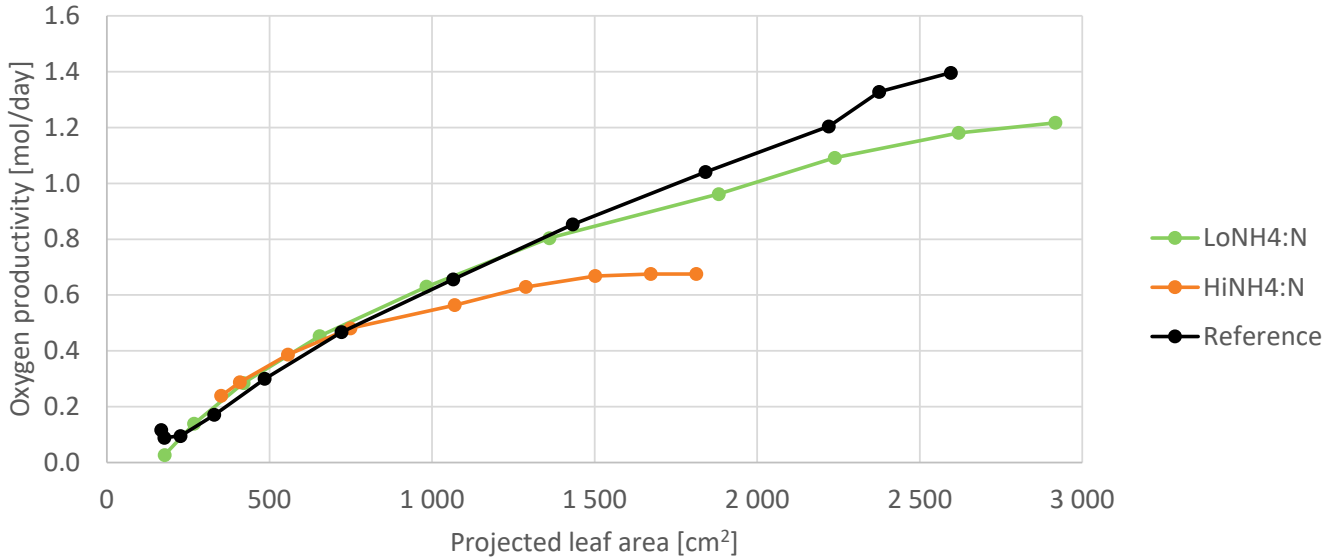
O_2 and CO_2 productivity



Estimated O_2 production (moles), day 7 – 28		
Ref	Lo	Hi
12.9	14.2	8.4

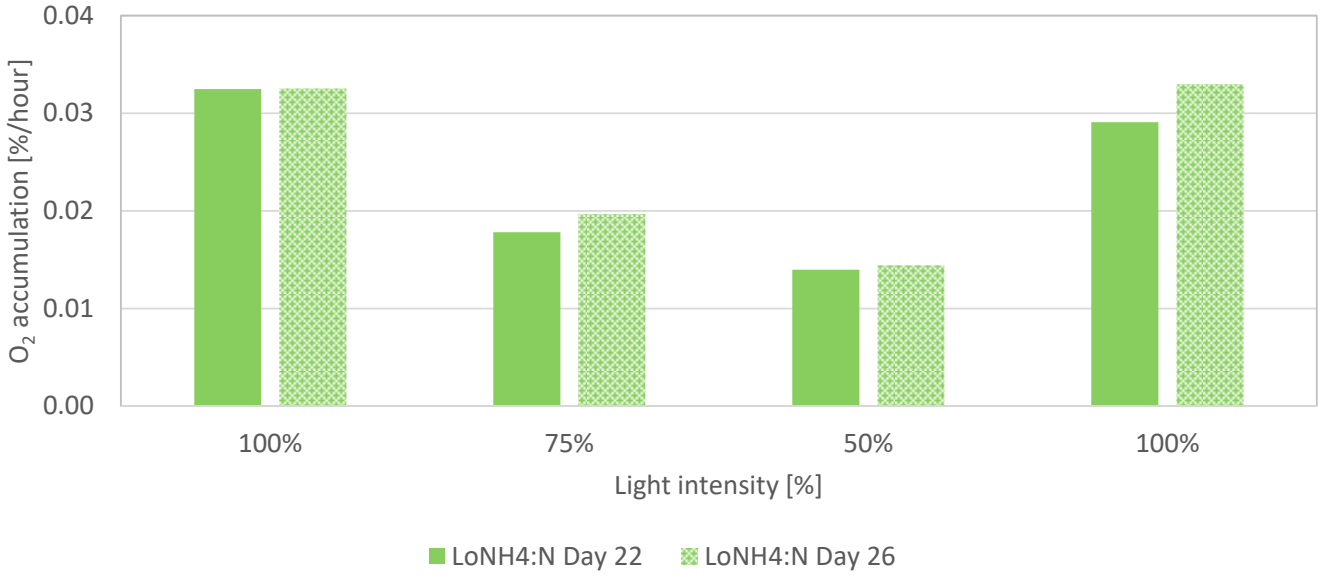
Specific oxygen productivity

relative to projected leaf area



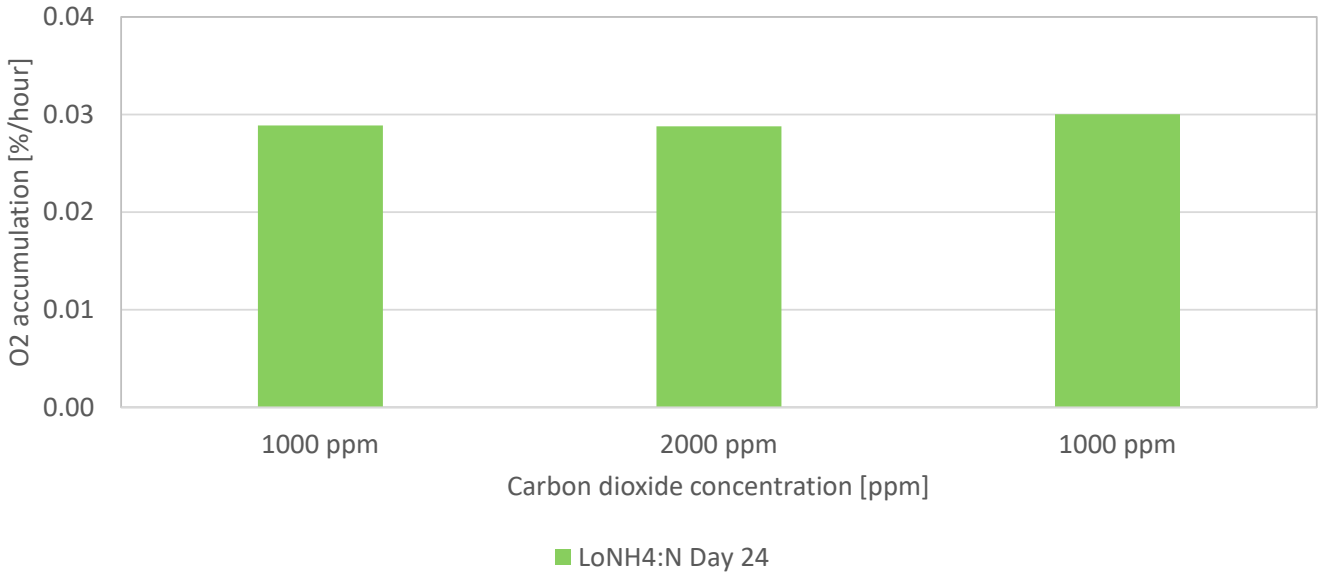
Light test

2-hour stabilization



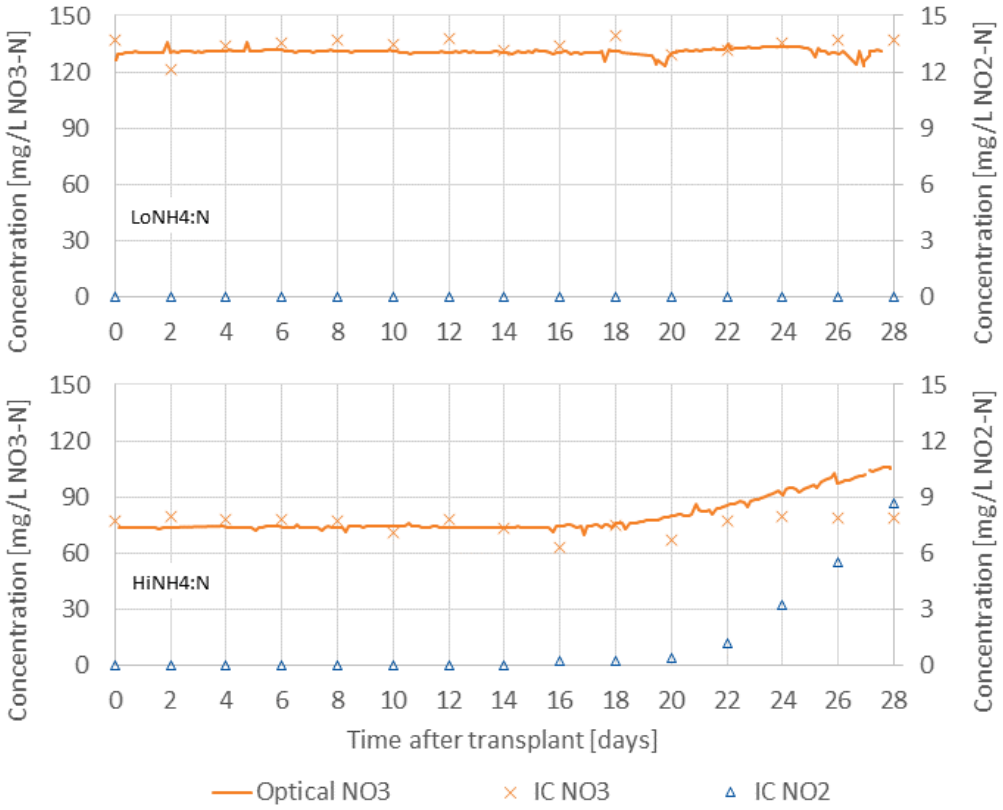
CO_2 test

2-hour interval

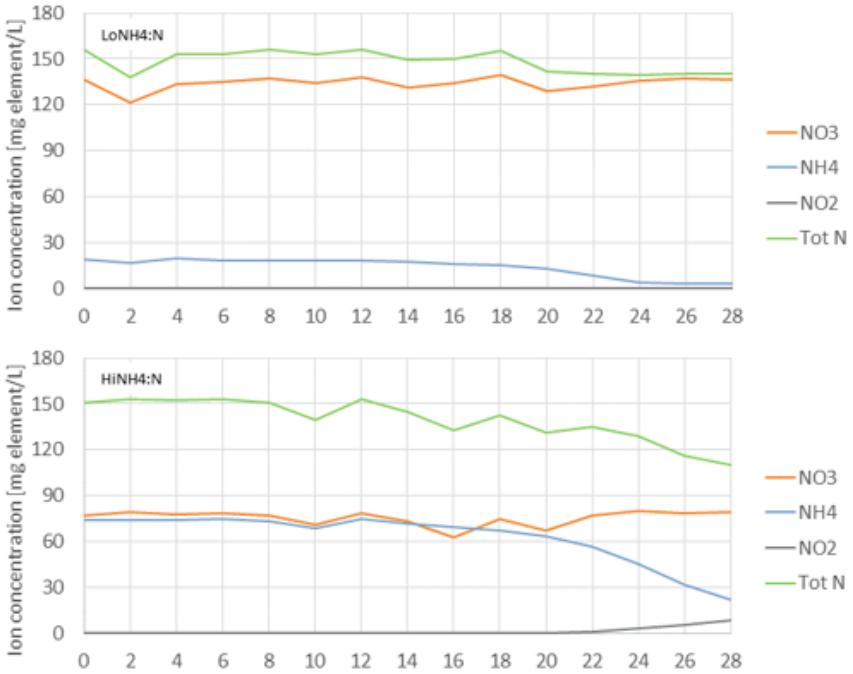


Nutrient solution development

NO_3^- control - Sensor measurements vs offline Ion chromatography

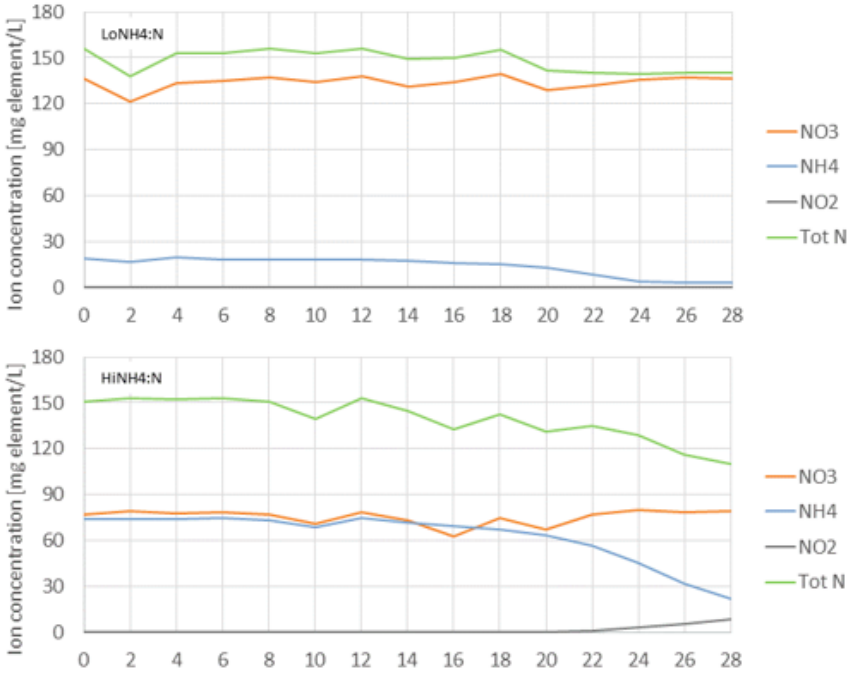


Nutrient solution development

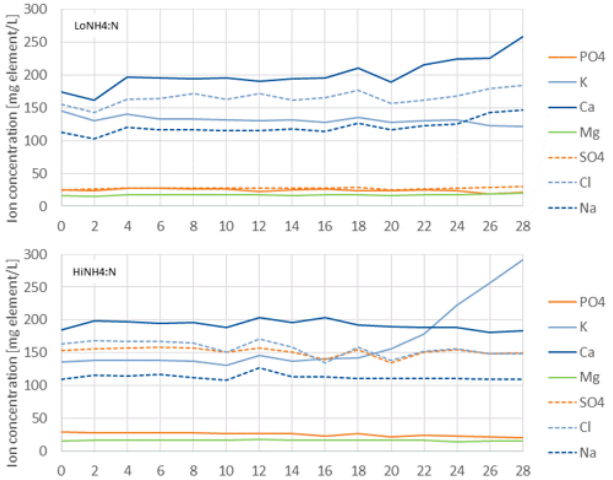


NO_3^- constant due to control, NH_4^+ "free"
NH4:NO3 ratio as function of time: HiNH4:N moves towards LoNH4:N with respect to NH4:N ratio, as NH_4^+ is depleted over time

Nutrient solution development



NO_3^- constant due to control, NH_4^+ "free"
NH4:NO3 ratio as function of time: HiNH4:N moves towards LoNH4:N with respect to NH4:N ratio, as NH_4^+ is depleted over time



Element content in plants (g/kg DW)

	Shoot			Root		
	Reference	LoNH4:N	HiNH4:N	Reference	LoNH4:N	HiNH4:N
NO_3^-	17	27	4	47	79	12
NH_4^+	0.5	1.3	1.4	0.5	1.6	4.5
Na	1.6	4.6	3.1	1.4	4.7	3.7
Cl	17	20	17	3.9	6.7	1.9
Ca	16	4	2	4.1	1.0	0.9
K	58	70	34	97	97	62
Mg	3	2	1	1.7	1.1	1.2
PO4	14	15	8	45	43	47

Highest

Middle

Lowest

Different color
= statistically different

CONCLUDING REMARKS

Concluding remarks

- The upstream process makes a difference
  - Lower growth rate with high NH_4^+
  - Differences in root size and morphology between high and low NH_4^+
  - Lower specific O_2 production with high NH_4^+
  - NH4:NO3 and NaCl influences element composition of the plant
- Plant uptake affects the NH4:N ratio
  - The NH4:N ratio decreases over time due to higher uptake rate of NH_4^+
- Photosynthetic rate at increased CO_2
  - Plants not capable of utilizing the additional CO_2 in the 2-hours test (biomass not adapted)
- Photosynthetic rate at decreased light
  - Immediate photosynthetic response to reduced light intensity
- The PCU allows for measurements of O_2 and CO_2 produced/used by the canopy
  - Offers evaluation of O_2 production as a function of projected leaf area - with interesting potentials
- The automatic nitrate control worked well
  - Opens new possibilities together with multiple nutrient stock solutions
- Accumulation of nitrite
  - Nitrifying bacteria in the system (buildup over time or increase due to high NH_4^+)
  - To consider in recirculating systems

MELISSA

MICRO-ECOLOGICAL
LIFE SUPPORT SYSTEM
ALTERNATIVE

THANK YOU.

Mona Schiefloe

Centre for Interdisciplinary Research in Space (CIRiS)

NTNU Social Research, Trondheim, Norway

mona.schiefloe@ciris.no

www.**melissafoundation**.org

Follow us