Nutrition of Antarctic-Grown Crops to Supplement the Crew Diet, with Applications for Spaceflight

Jess M. Bunchek[1,2], Mary E. Hummerick[3], Carolina Franco[3], Gioia D. Massa[4]

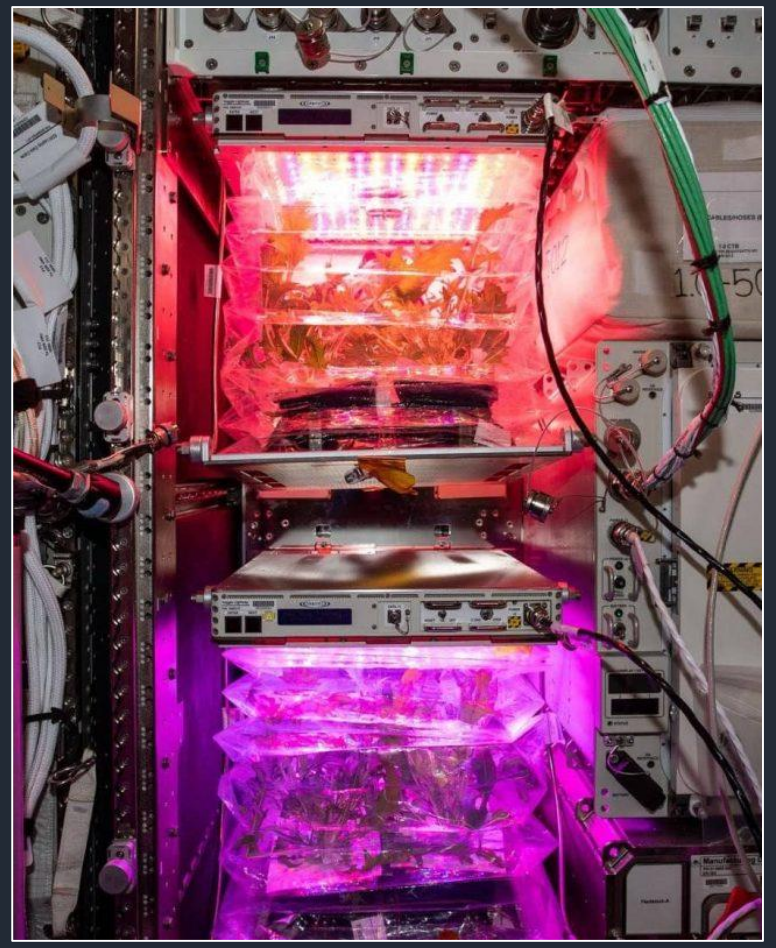
[1]DLR, Bremen, Germany; [2]University of Bremen; [3]LASSO II, KSC; [4]NASA, KSC

Contact: jess.bunchek@dlr.de

Photo: Personal collection

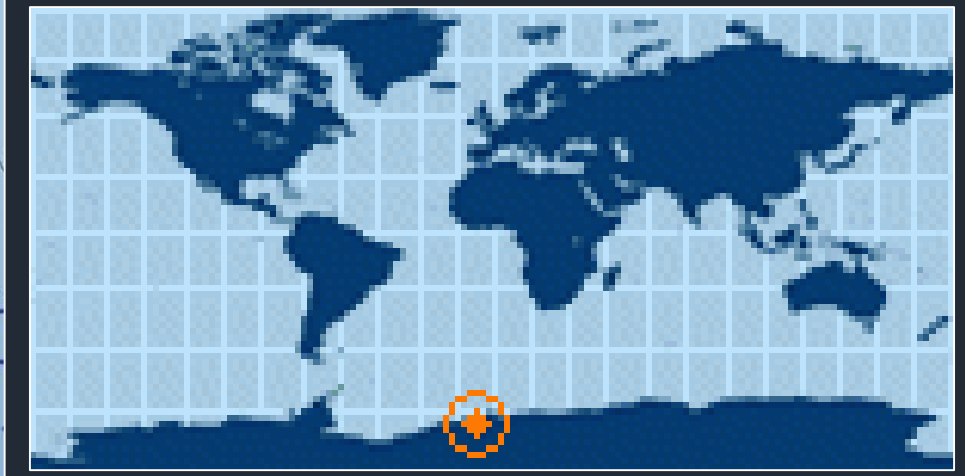
Motivation

- Space-grown crops can supplement the crew pre-packaged diet and promote crew biobehavioral health.
- Previous research on ISS with mizuna mustard showed that crop nutrition content can be influenced by light treatment, harvest approach, and the spaceflight environment.
- As sample sizes on-orbit are small, more testing is needed to determine influencing effects and to better select crops, hardware, and cultivation methods to fit astronaut needs.
- Currently, nutrient solution cannot be measured in-situ.



VEG-04 study with mizuna mustard on ISS. Photo: NASA/Sierra Space.

Neumayer Station III, Antarctica



Graphics & Photo: Alfred Wegener Institute

EDEN ISS

- Deployment: 2018-2022
- Presented data: 2021
- 12.5 m^2 crop cultivation space with aeroponics
- Project total: >1 metric ton fresh food

Photo: DLR; Drone Video: Personal Collection

Nutrient Solution Over Time

Kohlrabi in EDEN ISS exhibiting nutrient deficiency stress symptoms. Photo: Personal collection.

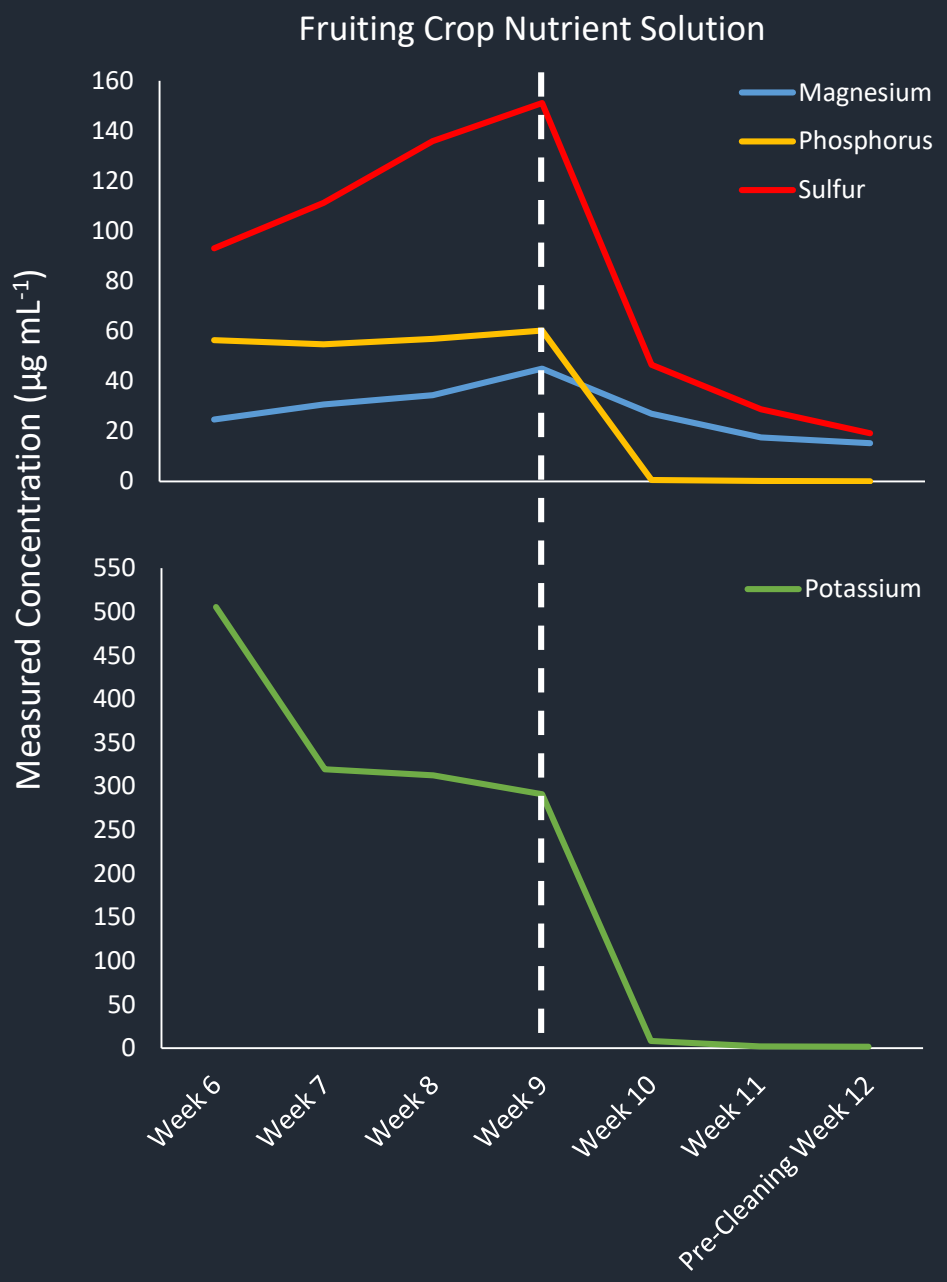
Nutrient Solution Over Time

Methods

- Both nutrient tanks sampled
- Total 39 nutrient solution samples for 2021 season
- Samples shipped to KSC for IC analysis

Takeaways

- Distinct decrease in nutrients
- Nitrogen stable over time, potentially due to biofilm
- Sensors needed to detect real-time nutrient changes



Crop Nutrition

Methods

- 164 plant samples for nutrient analysis, 33 of which have been analyzed
- 26 of 37 crops sampled (those with enough biomass, >50 g)
- Samples dried & shipped to KSC for ICP-OES
- 14 elements, total phenolic content, and antioxidants (ORAC)
- Statistical analysis: R Version 4.3.2

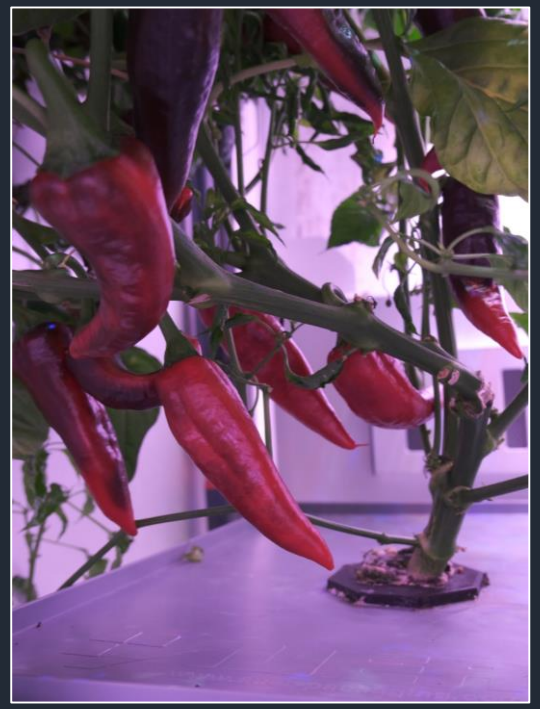
Harvesting mizuna mustard leaves for analysis.

Weighing and preparing peppers to dry.

Crushed, dried samples packed for shipping.

Photos: Personal collection

Crop Nutrition



NuMex ‘Española Improved’ chile pepper.

‘Outredgeous’ red romaine lettuce in NASA’s Passive Porous Tube Nutrient Delivery System (PPTNDS) hardware.

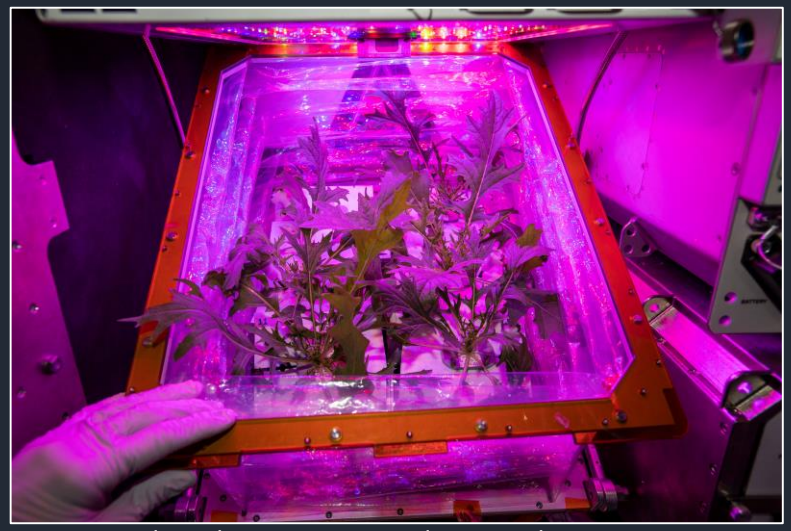
‘Red Robin’ dwarf cherry tomato.

Photos: (Left & Right) Personal collection; (Center) DLR

EDEN ISS vs Veggie

*Grand averages across treatment variables.

	VEG-04*	EDEN ISS
	µg g^{-1} dry mass	
Al	29	4
B	82	47
Cu	10	9
Fe	58	73
Mn	221	20
Na	588	220
Zn	33	110
Phenolics	16	14
	mg g^{-1} dry mass	
Ca	6	40
K	30	90
Mg	8	3
P	4	10
S	6	9
	µM TE g^{-1} dry mass	
ORAC	111	81



VEG-04 study with mizuna mustard on ISS. Photo: NASA.

Crop Nutrition

Results

- Fruiting crops lower in some nutrients (B, Zn, Ca, Mg all $P < 0.001$).

- Fruiting crops still desired for sensory input and additional nutrients like Vitamin C.

	Boron	Zinc	Calcium	Magnesium
	μg g^{-1} dry mass		mg g^{-1} dry mass	
Lettuce (Tray)	32 (3.1)	90 (7.0)	17 (1.7)	3.3 (0.3)
Lettuce (PPTNDS)	45 (3.6)	77 (6.7)	19 (1.7)	4.0 (0.6)
Mizuna	47 (6.2)	110 (9.0)	40 (3.6)	3.5 (0.3)
Tomato	6.9 (0.8)	26 (4.3)	0.8 (0.1)	1.5 (0.1)
Pepper	6.8 (0.7)	38 (7.5)	0.6 (0.2)	1.4 (0.2)

Takeaway

- Crop diversity needed to meet crew needs.

Conclusions

- In-situ nutrient solution monitoring capabilities are needed to reduce inputs and optimize crop production.
- Nutrient concentrations can vary by plant growth system and/or environment, so testing should be continued to know nutrient availability for the crew.
- Having the ability to exchange and adjust nutrient solution in plant-growth hardware (i.e., EDEN ISS) will be key to limiting nutrient changes in crops over time.
- Crops should be selected to supplement target nutrients for the crew diet, while considering factors like inputs/outputs and organoleptic acceptability.

Photo: H. Müller

Next Steps

- Statistical analyses on:
  - If individual plant size affects nutrition concentrations (K and Mn may be more sensitive, based on data)
  - Potential light treatment effects in Veggie vs EDEN ISS
  - Nutrient solution composition vs crop nutrient content
  - Comparison to crew daily nutrition recommendations
- Sensor testing for in-situ nutrient solution monitoring

Photo: H. Müller

EDEN ISS – Data Collection & Research Areas in 2021

Systems Configuration & Analysis

- Power requirement
- Supplemental CO_2 requirement
- Data handling & transfer

Consumables

- Freshwater & nutrient consumption
- Wastewater production

Hardware

- Remote monitoring & data capturing capabilities
- Remote daily photographs
- Plant health monitoring cameras
- Supplies & spare parts
- NASA passive system prototype

Horticulture

- Testing new crops
- Data taken at plant level
- Fresh edible and inedible biomass
- Nutrition subsamples
- Crop stress & multispectral imaging (University of Florida)

Micro/Molecular Biology

- Surface swab, nutrient solution, and plant tissue sampling

Crew Time

- Collected in greater detail
- NASA Task Load Index workload assessment

Crew Metrics

- Expanded from ISS Veggie crew surveys (U Penn/Charité)
- Gut microbiome (LMU-Munich)

Special Thanks

NASA AES & HRP

NASA HRP Grant Augmentation Award Program

German Aerospace Center (DLR)

Alfred Wegener Institute—Helmholtz Center for Polar & Marine Research

Reederei F. Laeisz

Space Crop Production Group at KSC & EDEN ISS Team at DLR

41st Overwintering Expedition, Neumayer III Station

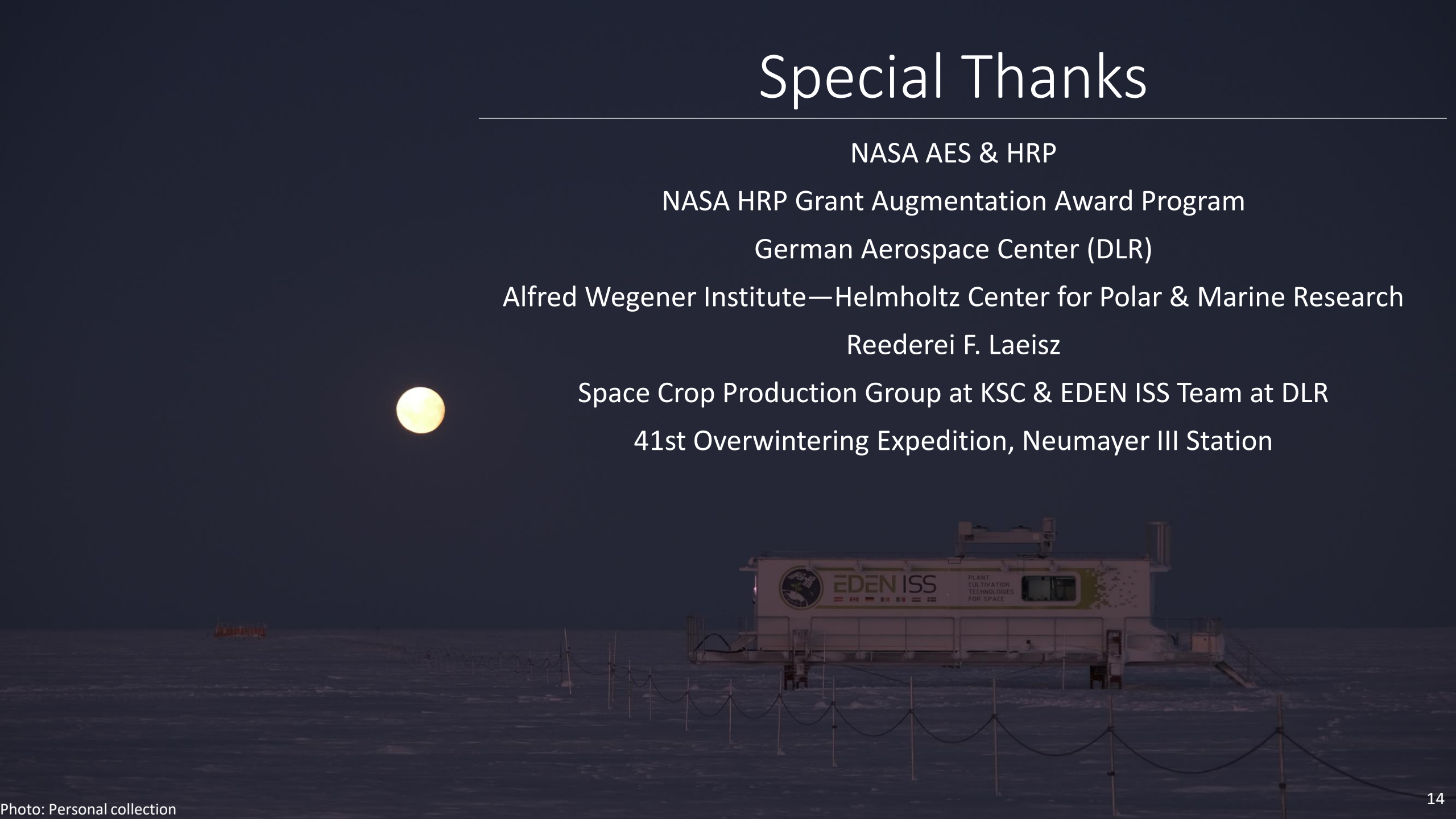


Photo: Personal collection