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MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
7-8-9 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

Species selection of microgreens to be produced in space as functional food for astronaut consumption

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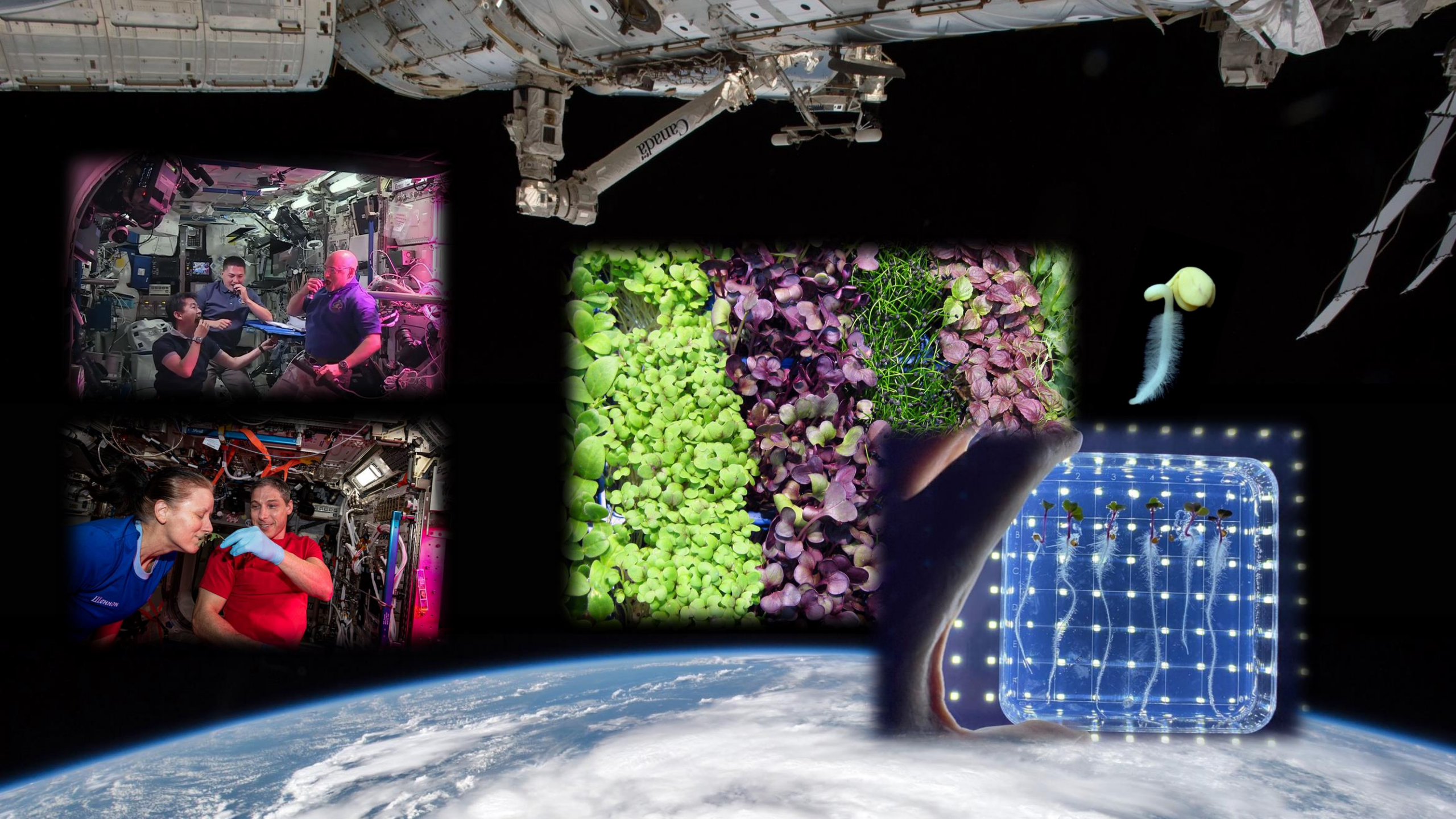
Canada

«Sistemi e tecnologie per la produzione di microortaggi nello Spazio»

(*Microgreens × Microgravity*)

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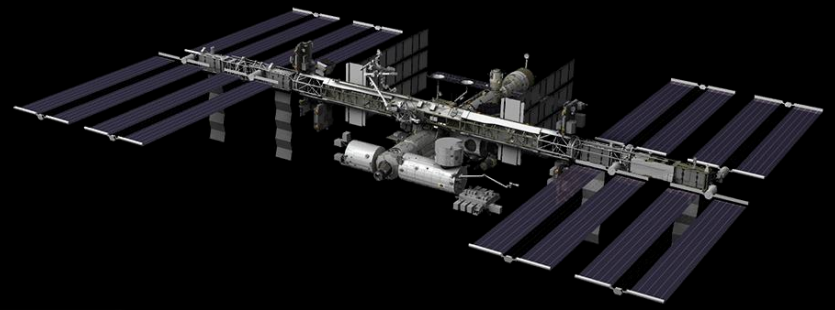
De Micco et al. 2012

Available online at www.sciencedirect.com
SciVerse ScienceDirect
Advances in Space Research 49 (2012) 1415–1421
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Soybean cultivar selection for Bioregenerative Life Support Systems (BLSS) – Theoretical selection



Massa et al. 2015

45th International Conference on Environmental Systems
12-16 July 2015, Bellevue, Washington
ICES-2015-[252]

Selection of Leafy Green Vegetable Varieties for a Pick-and-Eat Diet Supplement on ISS

Dueck et al. 2016

46th International Conference on Environmental Systems
10-14 July 2016, Vienna, Austria
ICES-2016-206

Choosing crops for cultivation in space

Aronne et al. 2020

Contents lists available at ScienceDirect
Life Sciences in Space Research
journal homepage: www.elsevier.com/locate/lssr

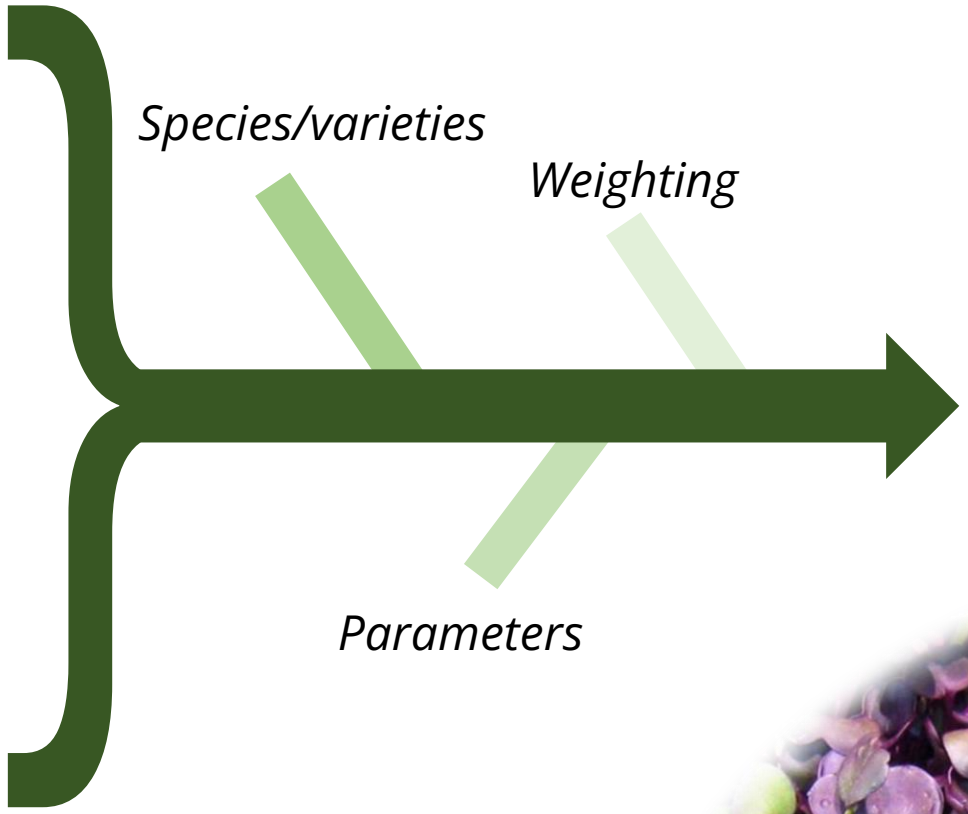
Subsequent inclusion/exclusion criteria to select the best species for an experiment performed on the ISS in a refurbished hardware

Species selection of microgreens

a) Literature analysis

b) Data elaboration

c) Prioritization



Literature analysis

- More than 300 documents with the word *microgreens* in title, abstract or keywords (Source: *Scopus*)
- 80% of documents indexed in *Agricultural and Biological Sciences*
- Comparative analyses in standard growth conditions
- 39 species/varieties of microgreens

List of candidate species/varieties of microgreens for astronaut consumption

N	Family	Genus	Species	Variety	Common name
1	Amaranthaceae	*Amaranthus*	*hypochondriacus*		Amaranth
2	Apiaceae	*Apium*	*graveolens*		Celery
3	Apiaceae	*Coriandrum*	*sativum*		Coriander
4	Brassicaceae	*Barbarea*	*verna*		Cress
5	Brassicaceae	*Brassica*	*juncea*		Brown mustard
6	Brassicaceae	*Brassica*	*napus*	*napobrassica*	Rutabaga
7	Brassicaceae	*Brassica*	*oleracea*	*acephala*	Black cabbage
8	Brassicaceae	*Brassica*	*oleracea*	*alboglabra*	Chinese kale
9	Brassicaceae	*Brassica*	*oleracea*	*botrytis*	Cauliflower
10	Brassicaceae	*Brassica*	*oleracea*	*capitata* f. *alba*	White cabbage
11	Brassicaceae	*Brassica*	*oleracea*	*capitata* f. *rubra*	Red cabbage
12	Brassicaceae	*Brassica*	*oleracea*	*capitata* f. *sabauda*	Savoy cabbage
13	Brassicaceae	*Brassica*	*oleracea*	*gongylodes*	Kohlrabi
14	Brassicaceae	*Brassica*	*oleracea*	*italica*	Broccoli
15	Brassicaceae	*Brassica*	*oleracea*	*pekinensis*	Napa cabbage
16	Brassicaceae	*Brassica*	*rapa*	*chinensis*	Pak choy
17	Brassicaceae	*Brassica*	*rapa*	*gemmifera*	Brussels sprouts
18	Brassicaceae	*Brassica*	*rapa*	*narinosa*	Tatsoi
19	Brassicaceae	*Brassica*	*rapa*	*nipposinica*	Mizuna
20	Brassicaceae	*Brassica*	*rapa*	*perviridis*	Komatsuna
21	Brassicaceae	*Brassica*	*rapa*	*rapa*	Turnip
22	Brassicaceae	*Brassica*	*rapa*	*ruvo*	Rapini
23	Brassicaceae	*Eruca*	*sativa*		Rocket
24	Brassicaceae	*Lepidium*	*bonariense*		Peppercress
25	Brassicaceae	*Lepidium*	*sativum*		English cress
26	Brassicaceae	*Nasturtium*	*officinale*		Watercress
27	Brassicaceae	*Raphanus*	*sativus*	*longipinnatus*	Daikon radish
28	Brassicaceae	*Raphanus*	*sativus*		Radish
29	Brassicaceae	*Wasabia*	*japonica*		Wasabi
30	Chenopodiaceae	*Atriplex*	*hortensis*		Garden orache
31	Chenopodiaceae	*Beta*	*vulgaris*		Beet
32	Chenopodiaceae	*Spinacia*	*oleracea*		Spinach
33	Fabaceae	*Pisum*	*sativum*		Pea
34	Lamiaceae	*Ocimum*	*basilicum*	*purpurascens*	Red rubin basil
35	Lamiaceae	*Ocimum*	*basilicum*		Basil
36	Malvaceae	*Corchorus*	*olitorius*		Jute mallow
37	Poaceae	*Zea*	*mays*		Maize
38	Polygonaceae	*Rumex*	*acetosa*		Sorrel
39	Polygonaceae	*Rumex*	*acetosella*		Red sorrel

Algorithm for ranking

- 39 species/varieties
- 25 parameters
- 3 categories
- Priority levels
- Data normalization (min=0; max=1)
- Factors desirable at lower value were inverted

Priority levels of categories and parameters used for the selection of microgreens

Category	Category priority (P)	Parameter	Parameter priority (p)
Growth	2	Yield	5
		Dry weight	4
		Growth period	3
		Sowing density	1
		Seed weight	1
Nutrition	3	Ascorbic acid (Vitamin C)	5
		Antioxidant activity	5
		Polyphenols	5
		Tocopherol (Vitamin E)	5
		β-carotene	4
		Phyllochinon (Vitamin K)	4
		Lutein	4
		Violaxantin	4
		Chlorophylls	1
Elements	1	Calcium	5
		Phosphorus	5
		Magnesium	5
		Nitrate	5
		Potassium	5
		Sodium	5
		Sulfur	5
		Iron	4
		Manganese	4
		Copper	4
		Zinc	4

Algorithm for ranking

For each species the score of individual parameters (s) was calculated as the product of the normalized value (x_i) and the priority level (p_i) of the parameter:

(1) $$s_i = x_i \cdot p_i$$

The score of the individual categories (X_i) was then calculated as the average of the scores of the parameters included in the category:

(2) $$X_i = \mu (s_i)$$

The final score of species/varieties (S) was obtained as the sum of the products between the scores of the categories and their respective priority levels (c_i):

(3) $$S = \Sigma (X_i \cdot c_i)$$

Priority levels of categories and parameters used for the selection of microgreens

Category	Category priority (c)	Parameter	Parameter priority (p)
Growth	2	Yield	5
		Dry weight	4
		Growth period	3
		Sowing density	1
		Seed weight	1
Nutrition	3	Ascorbic acid (Vitamin C)	5
		Antioxidant activity	5
		Polyphenols	5
		Tocopherol (Vitamin E)	5
		β-carotene	4
		Phyllochinon (Vitamin K)	4
		Lutein	4
		Violaxantin	4
		Chlorophylls	1
Elements	1	Calcium	5
		Phosphorus	5
		Magnesium	5
		Nitrate	5
		Potassium	5
		Sodium	5
		Sulfur	5
		Iron	4
		Manganese	4
		Copper	4
		Zinc	4

Ranking list

Scores calculated by the algorithm based on growth and nutritional parameters of microgreens species

TOP SPECIES:

1. Coriander
2. Savoy cabbage
3. Daikon radish
4. Red cabbage
5. White cabbage
6. Radish

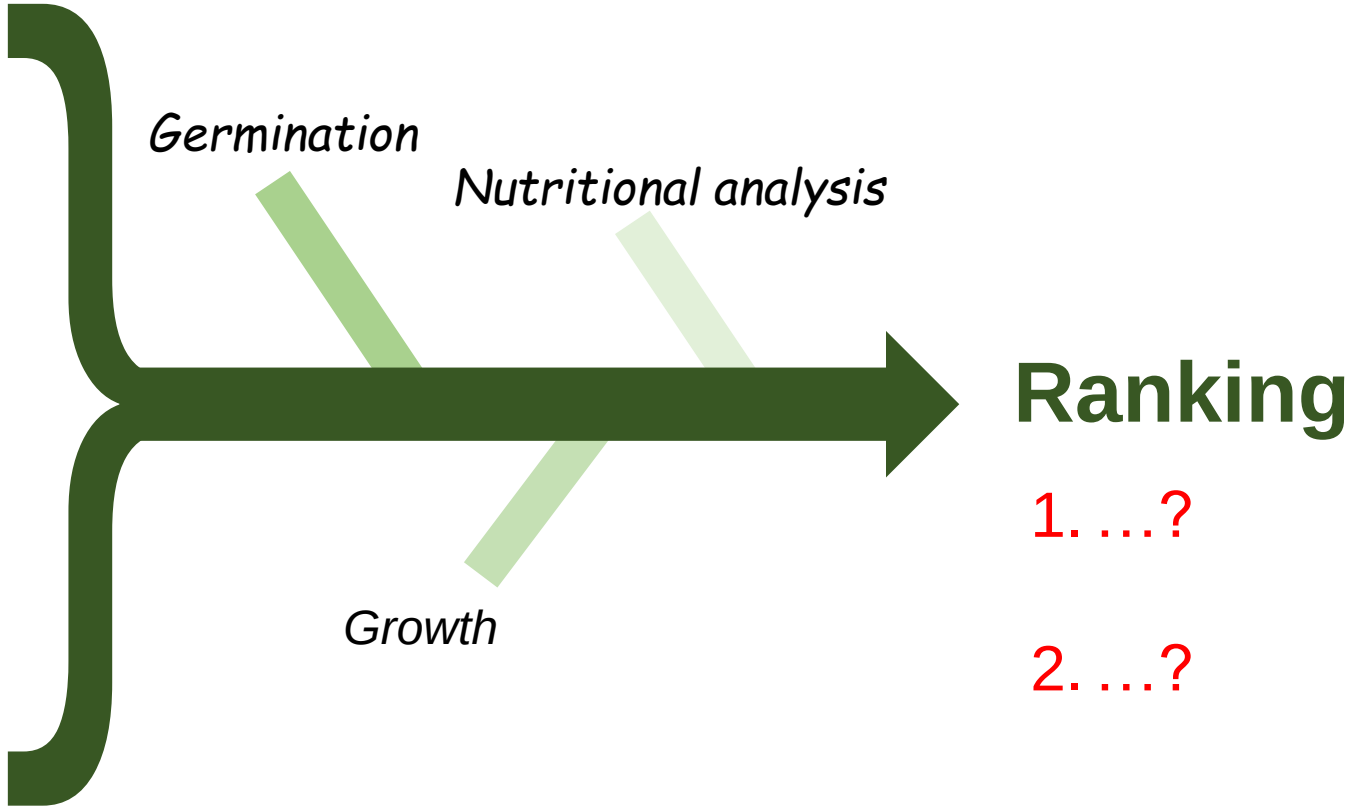
Ranking list of candidate species/varieties of microgreens

Rank	Species	Common name	Score
1	Coriandrum sativum	Coriander	4.687
2	Brassica oleracea var. capitata f. sabauda	Savoy cabbage	4.632
3	Raphanus sativus var. longipinnatus	Daikon radish	4.586
4	Brassica oleracea var. capitata f. rubra	Red cabbage	4.541
5	Brassica oleracea var. capitata f. alba	White cabbage	4.487
6	Raphanus sativus	Radish	4.375
7	Brassica oleracea var. italica	Broccoli cabbage	4.373
8	Brassica oleracea var. acephala	Black cabbage	4.232
9	Brassica oleracea var. alboglabra	Chinese kale	4.214
10	Brassica oleracea var. botrytis	Cauliflower	4.209
11	Brassica rapa var. ruvo	Rapini	4.203
12	Brassica oleracea var. pekinensis	Napa cabbage	4.053
13	Brassica oleracea var. gongylodes	Kohlrabi	4.035
14	Brassica rapa var. narinosa	Tatsoi	3.829
15	Brassica rapa var. chinensis	Pak choy	3.746
16	Brassica rapa var. perviridis	Komatsuna	3.720
17	Brassica rapa var. rapa	Turnip	3.693
18	Brassica napus var. napobrassica	Rutabaga	3.673
19	Brassica rapa var. nipposinica	Mizuna	3.523
20	Brassica rapa var. gemmifera	Brussels sprouts	3.434
21	Ocimum basilicum	Basil	3.181
22	Ocimum basilicum var. purpurascens	Red rubin basil	3.162
23	Beta vulgaris	Beet	3.024
24	Amaranthus hypochondriacus	Amaranth	2.974
25	Brassica juncea	Brown mustard	2.872
26	Wasabia japonica	Wasabi	2.714
27	Lepidium sativum	English cress	2.701
28	Lepidium bonariense	Peppercress	2.658
29	Eruca sativa	Rocket	2.500
30	Rumex acetosella	Red sorrel	2.376
31	Corchorus olitorius	Jute mallow	2.250
32	Pisum sativum	Pea	2.022
33	Apium graveolens	Celery	1.550
34	Barbarea verna	Cress	1.514
35	Atriplex hortensis	Garden orache	1.272
36	Nasturtium officinale	Watercress	1.209
37	Spinacia oleracea	Spinach	1.050
38	Zea mays	Maize	0.972
39	Rumex acetosa	Sorrel	0.956

2nd ranking

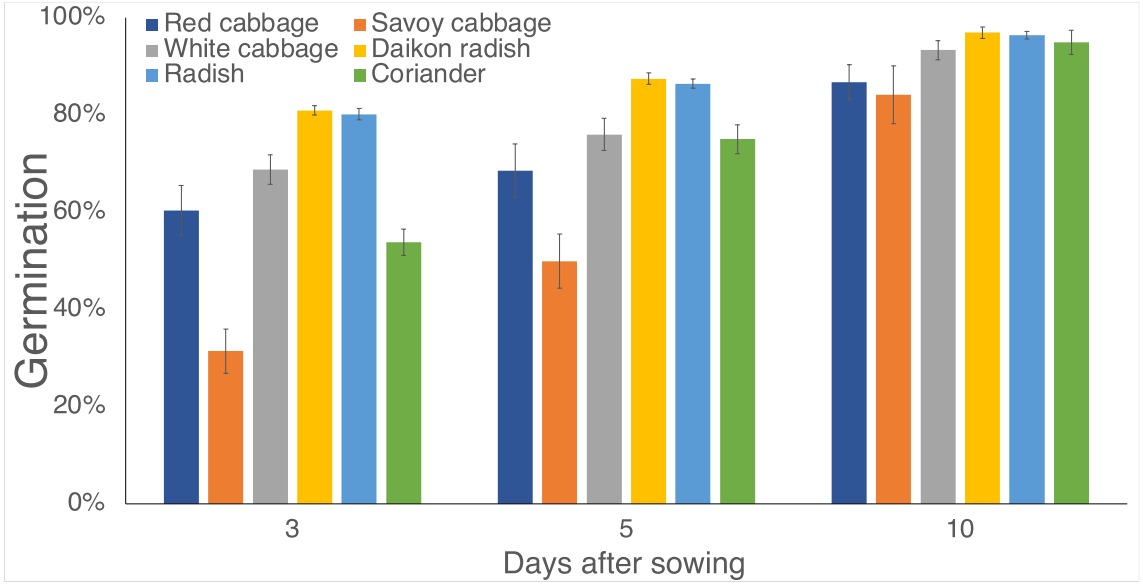
TOP SPECIES:

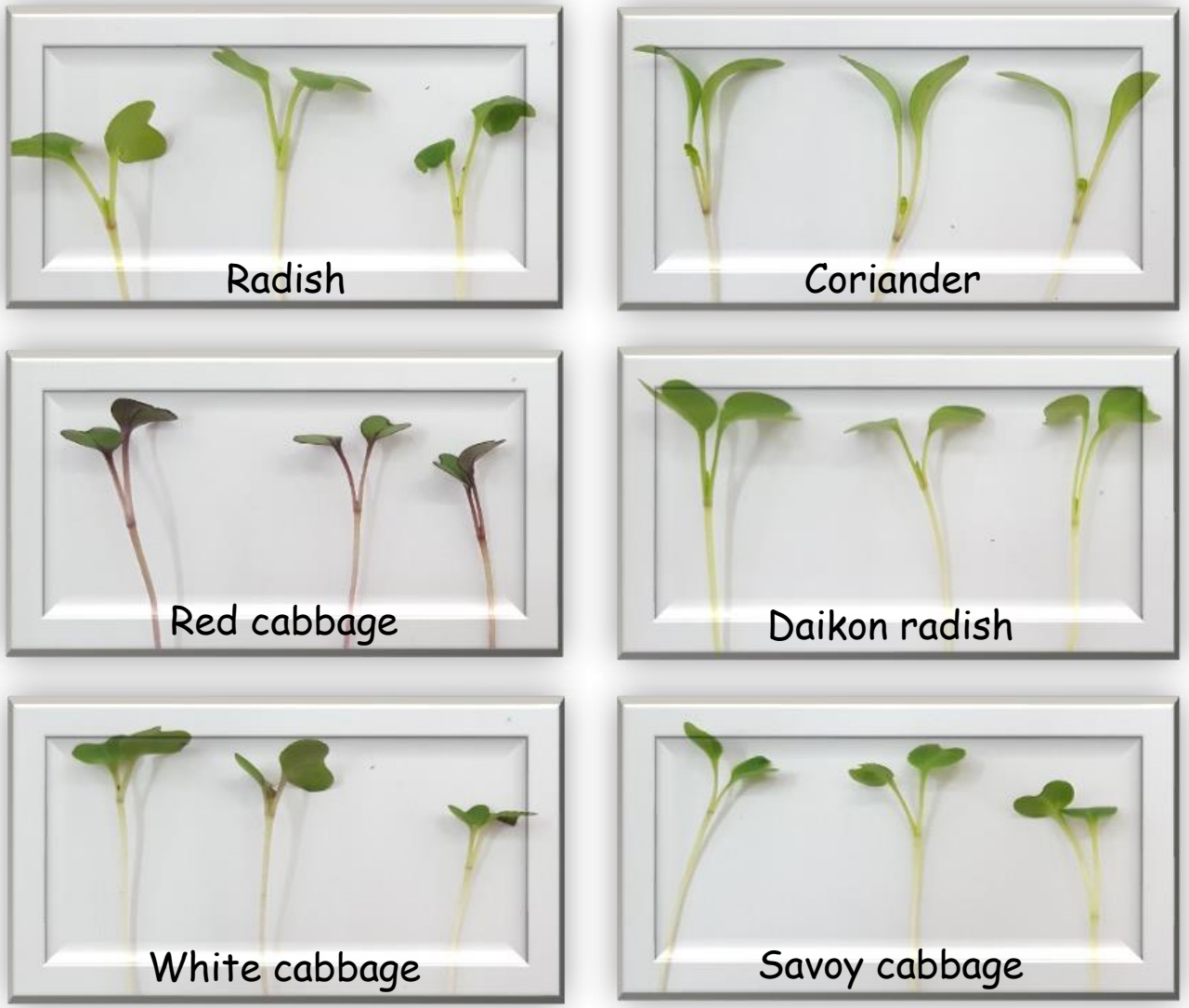
1. Coriander
2. Savoy cabbage
3. Daikon
4. Red cabbage
5. White cabbage
6. Radish



Experimental data

- Germination analysis and plant growth
- Colorimetric measurements and harvest
- Nutritional analysis





2nd algorithm for ranking

- 6 species/varieties
- 30 parameters
- 3 categories
- Priority levels
- Data normalization (min=0; max=1)
- Factors desirable at lower value were inverted
- Nutritional data expressed as daily production per m^2

Priority levels of categories and parameters used for the selection of microgreens

Category	Category priority (c)	Parameter	Parameter priority (p)
Growth	2	Germination	3
		Hypocotyl length	2
		Fresh yield	5
		Dry biomass	2
		Dry matter	2
		L*	1
		a*	1
		b*	1
		Chroma	1
		Hue	1
		Growth period	5
Nutrition	3	Total Ascorbate	5
		Ascorbic Acid	5
		Dehydroascorbic acid	4
		Anthocyanins	4
		Total polyphenols	4
		Lutein	3
		Total chlorophylls	1
		β-carotene	1
		Violaxanthin	1
		Neoxanthin	1
		Total carbohydrates	2
		Total soluble	2
		Starch	1
		Sucrose	1
		Glucose	1
		Fructose	1
Elements	1	Nitrate	1
		Sulfate	1
		Phosphate	1

Ranking list

Rank	Species	Common name	Score
1	*Raphanus sativus*	Radish	9.383
2	*Brassica oleracea* var. *capitata* f. *sabauda*	Savoy cabbage	6.917
3	*Brassica oleracea* var. *capitata* f. *rubra*	Red cabbage	6.390
4	*Brassica oleracea* var. *capitata* f. *alba*	White cabbage	4.844
5	*Raphanus sativus* var. *longipinnatus*	Daikon radish	4.586
6	*Coriandrum sativum*	Coriander	3.888

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Conclusions

RANKING

- Literature analysis
- Experimental data
- Phytochemicals for astronaut diet

NOVELTIES

- No articles on microgreens selection
- Daily production of phytochemicals per m^2

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