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Evaluation of Cucumber and Melon Cultivars as Space Crop Candidates for Long-term Space Missions

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Abstract. **Space crew members currently have access to limited options regarding fresh produce, highlighting the need for space crop production for long-term space missions. To expand the list of fresh crops that can be grown and consumed by crew members in space, cucumber cultivars H-19 Little Leaf and Iznik Hybrid and melon cultivars Early Silver Line and Minnesota Midget were assessed on growth performance and fruit production as a ground-based simulation under International Space Station atmospheric conditions (23 °C, 40% to 60% relative humidity, and 3000 ppm CO_2). All cultivars reached maturity and produced fruit. Although all cultivars produced fruit, yield and some aspects of nutritional quality varied among cultivars, underscoring the importance of cultivar selection for space-based cucurbit production.**

Introduction

Space crops may support long-term space travel by adding whole food nutrition to crew diet, reducing menu fatigue, and boosting psychological health of crew members (Bunchek et al. 2024; Perchonok et al. 2012). To determine candidates for long-term space crop production, crops undergo extensive screening and advance through the crop readiness levels (Romeyn et al. 2019; Fritsche et al. 2024) before they are flown and consumed in space. According to an overview by the National Aeronautics and Space Administration (NASA) overview of plant experiments aboard the International Space Station (ISS), a variety of leafy greens, zinnia flowers, tomatoes, and peppers have been cultivated in space, but cucurbit crops have yet to be tested (National Aeronautics and Space Administration 2023). To explore growing cucurbits as a space crop, selection criteria emphasize compact growth, parthenocarpy, prolific fruit production, and acceptable fruit quality at harvest. Two dwarf cucumber cultivars, *Cucumis sativus* var. 'H-19 Little Leaf' and *C. sativus* var. 'Iznik Hybrid', and two melon cultivars, *Cucumis melo* var. 'Early Silver Line' and *C. melo* var. 'Minnesota Midget', meet these criteria. These cultivars were evaluated for growth volume, fruit yield, crop performance, and nutritional quality. All crops are hereafter referred directly by their cultivar name for brevity.

Materials and Methods

Seeds were sown in 6-inch round pots filled with a volume ratio of 7:3 peat-based potting mix (Sun Gro Sunshine Mix #12; Sun Gro Horticulture, Agawam, MA, USA) to porous ceramic substrate (Pro League Elite; Turface Athletics, Buffalo Grove, IL, USA) and drip-irrigated daily with nutrient solution (Peters Professional 13N–2P–13K; ICL Growing Solutions, Tel Aviv-Yafo, Israel). Vines were secured onto 3D-printed trellises to support the crop while maintaining compact growth (Supplemental Fig. 1).

All cucurbits were grown in growth chambers (PGW-48; Percival Scientific, Perry, IA, USA) that simulated ISS atmospheric conditions [22 to 23 °C ambient temperature, 40% to 60% relative humidity (RH), and 3000 ppm CO_2] following Fritsche et al. (2024) as a ground-based simulation. Two growth trials were conducted with four replicates per cultivar. Trial 1 was conducted for 105 d (22.89 ± 0.18 °C, 50.00% ± 0.85% RH, 2982.87 ± 210.86 ppm), and trial 2 was conducted for 146 d with an increased RH setpoint to 65% (22.99 ± 0.12 °C, 63.68% ± 5.78% RH, 2836.12 ± 638.47 ppm). LED lighting provided 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ averaged across the growth area with a 16-h light/8-h dark photoperiod (Phytofy; OSRAM, Munich, Germany).

Although all of the selected cucurbit cultivars are parthenocarpic, the flowers were manually pollinated with a paintbrush to maximize fruit set. Two ripe fruits from each cultivar were randomly selected during the second growth trial for analysis: one for nutritional analysis conducted off-site (Eurofins, Tucker, GA, USA) and the other for in-house microbiological testing. Due to the screening focus of this study, only one fruit from each cultivar was submitted for analysis.

Microbiological analyses followed protocols listed in the *Bacteriological Analytical Manual* (Human Foods Program 2023). Each sample was tested for human pathogens such as *Escherichia coli, Staphylococcus aureus,* and *Salmonella* spp. (see Supplemental Material and Methods for additional information).

Results

All cultivars produced ripe fruit under the prescribed environmental conditions but also displayed signs of intumescence, with visible cosmetic damage on the leaves (Supplemental Fig. 2). When comparing cucumbers, 'Iznik Hybrid' yielded more ripe fruit and outperformed 'H-19 Little Leaf' for both growth trials. 'Iznik Hybrid' yielded a total of 1.58 and 3.48 kg of ripe fruit for trial 1 and 2 with 'H-19 Little Leaf' yielding 0.97 and 1.81 kg of ripe fruit. Between 'Early Silver Line' and 'Minnesota Midget', 'Early Silver Line' produced seven mature fruits across two growth trials compared with only three from 'Minnesota Midget'. 'Minnesota Midget' yielded an average fresh mass of 290.27 g, compared with 139.23 and 111.34 g for 'Early Silver Line' in trials 1 and 2, respectively (Table 1).

Between cucumber cultivars, H-19 Little Leaf and Iznik Hybrid were nutritionally similar in value across proximate composition, minerals, and vitamin levels. Both samples had comparable levels of nutrition except for

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Table 1. Crop performance by cultivar.

Harvest parameters	Unit	Cucumber		Melon	
		'H-19 Little Leaf'	'Iznik Hybrid'	'Early Silver Line'	'Minnesota Midget'
Trial 1					
Total ripe fruit	*n*	23	32	6	0
Total ripe fruit harvest weight	g	967.3	1582.3	835.4	NA
Individual fruit weight average ± *SD*	g	57.9 ± 22.7	54.1 ± 19.91	139.2 ± 73.6	NA
Trial 2					
Total ripe fruit	*n*	22	39	1	3
Total ripe fruit harvest weight	g	1807.7	3484.1	222.7	870.8
Individual fruit weight average ± *SD*	g	88.9 ± 32.2	92.8 ± 27.7	222.67	290.3 ± 24.4

NA = not applicable; *SD* = standard deviation.

vitamin C, where 'H-19 Little Leaf' has 276% more vitamin C than 'Iznik Hybrid' (2.46 and 0.654 mg/100 g, respectively) (Supplemental Table 1). A similar pattern could be observed between the two melon cultivars Early Silver Line and Minnesota Midget as well, where all categories were similar with the exception of vitamin B_9 (folate), where 'Early Silver Line' had 135% higher levels of vitamin B_9 than 'Minnesota Midget' (0.0147 and 0.00625 mg/100 g, respectively) (Supplemental Table 1).

All samples were below detection limit for microbiological testing on all media types.

Discussion

In ISS-like growth environments, cucumbers and melons differed in fruiting performance. Cucumbers fruited steadily and prolifically despite signs of intumescence on leaves. Both 'Iznik Hybrid' and 'H-19 Little Leaf' were able to produce edible fruit, suggesting that cucumbers are a suitable space crop. Melons produced few fruit and had poor leaf health in both trials. Intumescence on the leaves may be associated with CO_2 equivalent elevated CO_2 (eCO_2) and cultivation using LED lighting (Bunce et al. 2004; Prior et al. 2011; Williams et al. 2016), which could have negatively affected melon fruit yield and fruit quality (Sita et al. 2024). Because of the low number of fruit produced across both trials (Table 1), additional melon trials in ISS-like environments will be needed to evaluate melons as a space crop candidate.

Nutritionally, the cucurbits grown in ISS-like environments had similar nutritional composition except for vitamin C when comparing between the two cucumber cultivars, and total vitamin B_9 when comparing between the two melon cultivars. While no comparative statistical analysis could be conducted due to the small sample size, the large difference in vitamin C content in cucumbers could be explained by cultivar differences, as noted in a volatile compound and nutritional profile study of cucumbers conducted by Lu et al. (2025). On top of baseline cultivar differences, ISS-like atmospheric environmental conditions such as eCO_2 could have also contributed to the different nutritional composition of crops (Ahammed and Li 2022; Dakora et al. 2025).

This ground-based cultivar evaluation of 'H-19 Little Leaf', 'Iznik Hybrid', 'Early Silver Line', and 'Minnesota Midget' simulated cucurbit cultivation to supplement astronaut diets with nutritious whole foods during long-term space missions. The exploratory nature of this study with iterative changes to experimental design between trials 1 and 2 and low sample number for nutritional data resulted in limited opportunities for comparative statistical analysis. Further research is necessary to widen the scope of evaluating cucurbits as a suitable crop for production in space. Subsequent research includes nutritional comparison studies between cultivars with increased replication and additional cultivars to fully assess cultivar suitability for potential nutritional contribution to space crew members' diet. Additionally, observations on physiological developments, including development of intumescence and its impact on fruiting, in response to adjustments in humidity and light spectrum, would be necessary to assess the feasibility of growing melons and other cucurbit cultivars for long-term space missions. Last, as NASA crop research and production systems develop and mature, future research is needed on how cucurbits integrate into multicrop systems and how resource demands differ compared with previously flown crops. Evaluation involving these future research foci would provide further clarity and feasibility for the addition of cucurbits as a space crop to support crew during long-term space missions.

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