Vegetable Section

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Cosmic Growth: Optimizing Media Selection for Edible Plant Production in Long Term Space Flights

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Microgravity changes the physical properties of liquids and gases, which leads to unique media requirements for plants grown in space. Organic media mixes provide additional nutrition but promote a higher bacterial load among crops and are difficult to rehydrate. Using inorganic media reduces the bacterial load but adds different challenges, such as the lack of nutrients and water holding capacity. The goal of this research is to test potential space crop candidates 'Extra Dwarf' pak choi (*Brassica rapa* var. *chinensis*) and mizuna (*Brassica rapa* var. *japonica*) for growth and biomass production in different inorganic media mixes by eliminating the organic component and changing to media mixes of different particle sizes. Six media mixes, composed of different ratios of peat moss and calcined clay of different particle sizes, were trialed from a 1:1 media mix to solely calcined clay. Pak choi and mizuna were grown over a 42 to 44 day period and plant growth, edible fresh weights, and dry weights were collected. Chemical and physical properties of the media mixes were analyzed at the beginning and end of each trial. Results showed plant growth changed minimally, but the overall health was affected by the reduced water holding capacity of the larger particle sized clay, mostly of mizuna. Increasing the smaller particle sized clay to the mix improved the growing conditions. Using only the smaller particle sized clay, or with as little as 30% larger particle sized clay, will optimize results.

During long term space flights, astronauts require a viable and replenishable source of nutrients. Growing plants in space is a great means of producing this source of nutrients (Massa et al. 2015), but the optimal media mix for growing plants on the International Space Station (ISS) has yet to be determined (Massa et.al. 2013). An organic medium promotes a high bacterial load while providing additional nutrition for plants; it is also difficult to rehydrate under microgravity conditions. An inorganic medium does not promote a high bacterial load but it also does not provide much nutrition for plants, although it is easily rehydrated under microgravity conditions. For this research organic and inorganic media mixes were tested to determine which mix produced the highest percentage of edible weight over total weight and dry weight. Six different media mix treatments were tested using 'Extra Dwarf' pac choi (*Brassica rapa* var. *chinensis*) and mizuna (*B. rapa* var. *japonica*) as test specimens. The current media mix used on the International Space Station (ISS) is a 100% fine particle calcined clay which is treatment six in this trial. This research will determine if treatment six is indeed the best media mix or if another mix will out-perform it on the ISS. Similar research has been conducted by researchers at Kennedy Space Center (KSC). This research will add to the information known about growing plants in space (Massa et al. 2015).

Materials and Methods

A series of the six treatments with varying proportions of peat moss and calcinated clay were tested over a period of nine months. Treatments one through four required approximately 40–42 d to complete, however treatments five and six only required a 28-d growth period. Media mixes used included peat moss (Sunshine® Mix #8 Fafard®), and calcined clay with two different particle sizes (Turface MVP® and Profile®;Greens Grade™, Profile, Buffalo Grove, IL) (Table 1). Each mix was supplemented with 10g/L polymer coated slow release fertilizer (18–6–8, type 70 Nutricote Total, Florikan ESA Corporation, Sarasota, FL). Plants were grown in simulated "Veggie" systems at Fairchild Botanic Tropical Garden as part of the Growing Beyond Earth project. Each treatment was used in four grow units with 16 pots per grow unit, n = 32 per variety and treatment. Two seeds were planted in each 500 mL pot (Second Sun, Lebanon, PA) for 'Extra Dwarf' pak choi (Kitazawa Seed Co, Oakland, CA) and mizuna (Johnny's

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Table 1. Treatment application in percent of media mix.

Treatment	Peat moss	Calcined clay[z]	Calcined clay[y]
1	50	50	0
2	30	70	0
3	0	70	30
4	0	50	50
5	0	30	70
6	0	0	100

[z]Standard particle size (% retained): 8–12 mesh 64.8% ± 6.3% (turface)
[y]Sieve analyses: –20 + 50 mesh 98% (greens grade).

Table 3. Edible and dry weight after harvesting (trial one through four 42 days, trial five and six 28 days), n =3 2.

	Pac choi		mizuna	
Treatment	Edible wt (g/plant)	Dry wt (g/plant)	Edible wt (g/plant)	Dry wt (g/plant)
1	40.4 ± 18.3	1.8 ± 1.0	64.6 ± 27.3	4.2 ± 1.9
2	37.7 ± 16.3	1.6 ± 0.6	66.4 ± 23.5	4.2 ± 1.6
3	54.7 ± 20.0	2.9 ± 1.2	45.7 ± 29.6	7.6 ± 2.0
4	55.1 ± 34.3	2.7 ± 1.4	67.4 ± 33.1	8.2 ± 3.6
5	47.2 ± 26.7	2.7 ± 3.4	69.0 ± 36.6	4.6 ± 2.7
6	50.5 ± 33.9	2.8 ± 3.0	57.1 ± 19.7	4.8 ± 2.5

Selected Seeds Winslow, ME). A randomization generator <www.random.org> was used to determine the placement of the pots and shelf locations. All were exposed to a 12-h photoperiod. Germination data were recorded within the first week. For the following weeks leading up to harvest, plants were watered as needed and weekly measurements of height, width, depth, air temperature, and ambient humidity were recorded. At harvest (28 or 42 d after planting), plants were measured for volume, edible mass, and non-edible mass using a Fisher Science Education™ Precision™ Balance (Fisher Scientific, Fair Lawn, NJ). Dry weight was measured after plants were placed in a dryer for more than three days at 72° C. Samples of the initial moistened media were collected in reclosable plastic bags for chemical and physical analysis. Once the plants were harvested, media samples were taken from each crop and treatment. The chemical analysis of the media included pH, electrical conductivity (EC), and cation exchange capacity (CEC) . pH was measured using a LabQuest® 2 and Tris Compatible Flat pH Sensor; was measured using LabQuest® 2 and a Conductivity Probe (Vernier Software & Technology, Beaverton, OR 97005). CEC was to be measured however, due to equipment failure, no data could be collected. The physical analysis of the soils was also determined (Tripepi, undated, Storer 2005).

Results and Discussion

Treatment six (100% Greens Grade™ calcinated clay) produced the highest percentage (100%) of edible mass over total mass for both pac choi and mizuna as shown in (Table 2). Treatment six also required medial amounts of watering, on average 0.33 L/day over the growing period compared to the other inorganic media-based treatments three and four of 0.45 L/d, while also encouraging fast plant growth. The media mixes including organic materials (Treatment 1 and 2) also used less water, on average 0.3 L/d. Treatments three and four (70% Turface: 30% Greens Grade and 50% Turface : 50% Greens Grade respectively) produced the highest dry weight for mizuna but not the highest fresh weight, possibly due to the water stress induced by the medium. Treatment three (70% Turface: 30% Greens Grade) produced 98% edible over total mass for pac choi, which was high. Treatments five and six were harvested after 28 d, which was14 d earlier than the other treatments. mizuna fresh weight varied among treatments. For mizuna, the highest dry weights were recorded for Treatments three (7.6 g/plant) and four (8.2 g/plant). Pak choi had the highest fresh weight in Treatments three (54.7 g/plant) and four (55.1 g/plant). Dry weights for pak choi were similar to Treatments five and six. (Table 3) Initial average pH in most of the media was 5.8. After harvest, all media had slightly lower pH, ranging from 4.9 to 5.6. The smallest change was observed in the100% inorganic fine particle calcined clay (Treatment six). No noticable differences were observed for EC measurements.

Table 2. Percentage of edible mass to total mass for 'Extra Dwarf' pac choi and mizuna for each corresponding treatment.

Treatment	Pac choi	mizuna
1	96	94
2	97	73
3	98	76
4	73	100
5	96	97
6	100	100

Treatment six,100% fine particle calcined clay (Greens Grade), was the best medium for both pak choi and mizuna, producing the highest percent (100%) edible mass in only a 28-d growing period. It was also the most efficient treatment regarding water consumption. The large particle calcined clay (Turface) dried out quickly and required more frequent watering. Pak choi dry weight was greater in media treatments with higher proportions of inorgnic media. Dry weight of mizuna was not affected by media. The two *Brassica* types did not grow uniformly in the growth chambers. Competition between types seems to be one of the main factors affecting uniform growth and warrants futher inquiry.

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