

New Crop Selection

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I. Abstract

For extended space flight, reliable food supplies are a necessity. Most of the food products consumed by astronauts today are stored for flight via freeze drying. Fresh food is needed to supplement known national deficiencies in the stored food diet (Cooper et al.). This is so because stored foods can lose nutritional value. Fresh food is the answer to the nutritional demands of space flight. Kennedy Space Center's Utilization and Life Sciences Office (UB-A), under the Exploration Research and Technology Program (UB), conducts research on plant growth and development under International Space Station (ISS) conditions. UB-A analyzes the growth responses of leafy greens in microgravity and through the manipulation of environmental conditions (CO₂ levels, light intensity, relative humidity, and water delivery). By manipulating growing conditions researchers can optimize food production using minimal/restricted resources. The New Crop Selection experiments are testing the suitability of leafy crops to ISS conditions. Results from this study showed that 'Dragoon Lettuce and Red Russian Kale having the largest fresh mass.

II. Introduction

Currently the International Space Station (ISS) is home to two plant growth module, the Vegetable Production System (Veggie), which can test responses of food crops to microgravity. This module delivers water, supplies LED lighting, aid overall growth, and can be used as a tool to determine plant-microbial interactions in microgravity. The two crops widely used in Veggie are 'Outredeous' lettuce (*Lactuca sativa*) and Mizuna (*Brassica rapa* var. japonica). These plant species have served as model plants. Now that researchers here at NASA have some understanding of growth response of these two crops, they are looking to expand the selection of food crops suitable to space flight. The New Crop Selection experiments, as seen in Figure 1, are designed to test the growth response of common leafy green crops to conditions similar to those on ISS, just as 'Outredeous' lettuce and Mizuna have been tested. This experiment evaluates leafy greens and their response to certain environmental parameters.



Figure 1: New crop testing, Chamber C

Research conducted by the Fairchild Tropical Botanic Gardens and combing of USDA nutritional databases helped with the selection of 16 crops, which were tested over a 35 day time period. The environmental conditions used were set in the both of the growth chambers, using separate fixtures for LED lighting.

III. Materials and Methods

The major conditions examined during this experiment were carbon dioxide (CO₂) levels, relative humidity, temperature, and light intensity. During this experiment, all of these parameters were adjusted and controlled to examine the growth response of common leafy greens. On the International Space Station levels CO₂ average 3000 parts per million (ppm), the temperature averages 23 degrees Celsius, and relative humidity is at 50%. We tested sixteen species of leafy greens in this experiment. Species included (with common names followed by scientific names), Amara Mustard (*Brassica carinata*), Green Sorrel (*Rumex acetosa*), Wasabi Green (*Brassica rapa*), Arugula (Rocket) (*Eruca vesicaria ssp. sativa*), Shungiku (*Glebionis coronaria*), Red Russian Kale (*Brassica napus pubularia*), ‘Extra Dwarf’ Pak Choi (Bok Choi) (*Brassica rapa subsp. chinensis*), ‘Eros’ Escarole (*Cichorium endivia*), ‘Vit’ Mache (*Valerianella locusta*), ‘Outredgeous’ Lettuce (*Lactuca sativa*), Bright Lights Swiss Chard (*Beta vulgaris*), ‘Fiero’ Radicchio (*Cichorium intybus*), ‘Bel’ Radicchio (*Cichorium intybus*), ‘Toscane’ Kale (*Brassica oleracea*), ‘Giant Red’ Mustard (*Brassica juncea*), ‘Draagoon’ Lettuce (*Lactuca sativa*). For each species there were twelve replications. 4-inch (10-cm) pots were used for this experiment. The pots were filled with a mix of 70% Fafard 2B potting mix (primarily composed of peat moss and perlite), and 30% arcillite (Turface MVP 0.841–3.36mm average size). This blend of Fafard and arcillite provides the root systems with the proper ratio of air and water during the whole experiment. Data collected from the chamber or from the plants was recorded relative to days after planting (DAP)

Three seeds were planted in each of the twelve pots per species on January 30th, 2018. This ensured that there was a germinated seed/ seedling in each pot at the beginning of the experiment. Each pot was thinned of excess plants, leaving only one plant per pot on 7 DAP. On zero DAP the relative humidity (RH) was set at 75% in the growth chambers. This ensures that the seeds do not dry out after planting. If the seeds are at any time dried out it could kill the embryo within the seed. The seeds in each pot were misted twice a day for the first week and covered with plastic clear pot covers. The RH was adjusted from 65, 55, and 50% on 5, 6, 7 DAP respectively, set to a final RH of 50% for the rest of the experiment. We had two growth chambers with the layouts of the chambers in Figures 2 and 3.

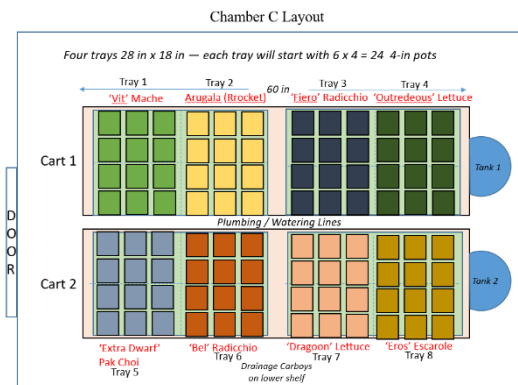


Figure 2: Chamber C Layout and species positioning

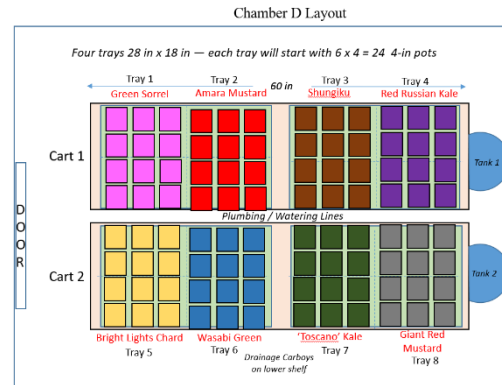


Figure 3: Chamber D Layout and species positioning

Each chamber had two carts with two trays per cart. Drip irrigation tubing, Figure 4, was used to water the plants and tilted trays allowed for proper drainage. The plants were fertilized using Peter’s 13-2-13 water soluble fertilizer at 1200 μS electrical conductivity and 6.0 pH. The fertilizer solution was continuously replenished into stock solution containers connected to a pump attached to the irrigation tubing and drippers. The lights we used were Heliospectra RX30 (4 fixtures / chamber): near UV (385 nm) = $\sim 5 \mu\text{mol m}^{-2} \text{s}^{-1}$; B (450 nm) = 23%; G (from white phosphor) = 28%; R (630 and 660 nm) = 48%; FR (730 nm) = $\sim 25 \mu\text{mol m}^{-2} \text{s}^{-1}$. Light measurements were taken at 1, 7, 13, 16, and 27 DAP using a light meter (unit: $\mu\text{mol m}^{-2} \text{s}^{-1}$). The light fixtures’ intensity and distance were adjusted accordingly after each harvest to keep lights averaging $350 \mu\text{mol m}^{-2} \text{s}^{-1}$ throughout the whole chamber.



Figure 4: Drip irrigation set-up

Every week, three plants from each species was harvested. The plants were randomly selected for harvest using a random number generator. The pots were then labeled and pulled out of the chambers. A photograph of each plant was taken and data was collected from each plant. The data we collected from the plants were shoot height (from soil line to highest tip of the leaf), shoot diameter (two measurements taken and averaged), total fresh mass (taken right when the plant was cut from its root ball), and total dry mass (taken after three days of drying in a 70 degrees Celsius forced air oven).

IV. Results

Many of the plant grew at different rates. Some were more compact while others were leggy and spread out

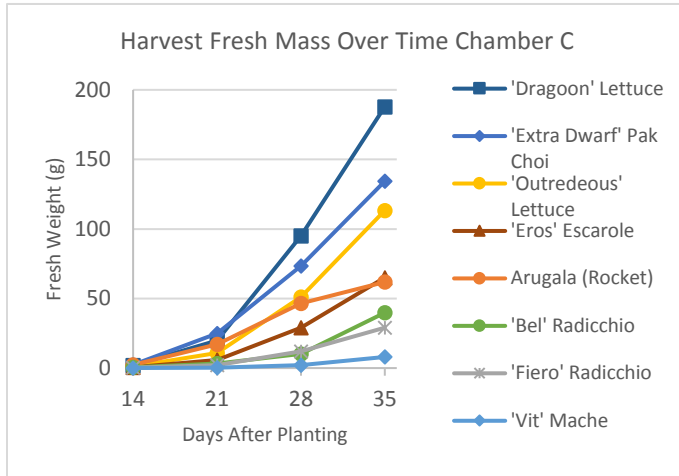


Figure 5: Chamber C growth curve

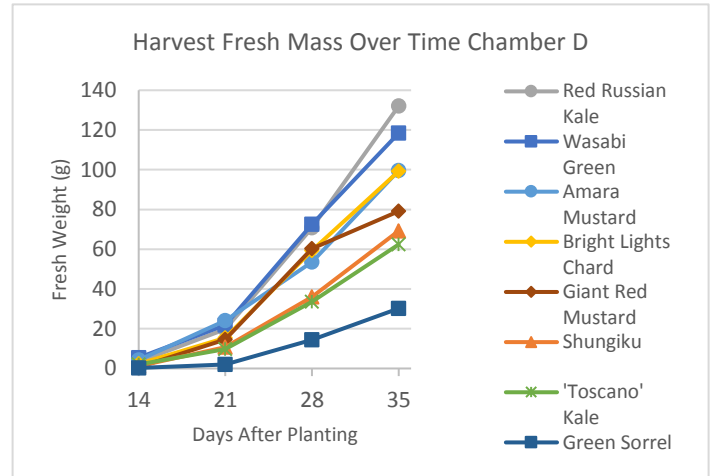


Figure 6: Chamber D growth curve

greatly. Based on the data we collected, growth curves, figures 5 and 6, were made to analyze the plants over time. As seen in Figures 1 and 2, the crops that had the largest fresh mass were Red Russian Kale and Dragoon Lettuce, both more than 130 grams at 35 DAP (final harvest). The plants with the largest spread from each chamber were Bright Lights Swiss Chard and Arugula (Rocket). The plant that had the greatest height was Wasabi Green. This was so because the plant bolted, which means it quickly developed flowers in order to produce seeds. This usually happens when the plant is stressed and thinks it is about to die. Therefore, to ensure its next generation, it starts to produce seeds. The flower heads on the Wasabi Greens became very tall and grew past the light fixtures, making the average height at 35 DAP very large. The heights averaged 763 centimeters.

During the course of the experiment we observed many growth responses that were not typical of some of

these plants. At 27 DAP, we observed tip burn on 'Dragoon' Lettuce, 'Eros' Escarole, and 'Bel' Radicchio (figures 7, 8, and 9 respectively). This could be caused by many things, such as excess



Figure 7: 'Dragoon' Lettuce



Figure 8: 'Bel' Radicchio



Figure 9: 'Eros' Escarole

fertilizer causing cell death on the tips, calcium deficiency in the new growth of the plants. This deficiency is caused by poor air circulation around the plants. At 29 DAP, the 'Outredeous' Lettuce and Arugula (Rocket) also

experienced tip burn. On top of the Wasabi Greens (figure 10) bolting, the ‘Extra Dwarf’ Pak Choi (figure 11), Arugula (Rocket), Shungiku, and Giant Red Mustard also bolted. In this experiment, bolting could be caused by any number of things. They include water stress (plants not receiving enough water during growth), high levels of CO₂ accelerating growth and causing maturity sooner than expected, or rapid change in temperature. We also observed leaf spots on the Shungiku, necrotic leaves on the ‘Eros’ Escarole, and interveinal chlorosis on the Arugula (Rocket). We are not sure what caused these problems, but it could be any of the stressors mention above.



Figure 10: Wasabi Greens



Figure 11: Extra Dwarf Pak Choi

Impromptu taste test were also conducted on each one of the 16 species. Each of the plants were cut into small pieces and placed in plates with only a number. Taste testers were asked to rank the best tasting five plants and the worst tasting five plants. Based on the results, Amara Mustard was the best tasting with Shungiku a close second. The worst tasting were the ‘Fiero’ Radicchio and the ‘Bel’ Radicchio.

V. Conclusion

Overall, the 16 crops used grew very well and provided us with valuable information on the growth habits and responses of plants under ISS conditions.

Using the data collected, researchers can determine what crops will grow best in space, as well as what crops will be the most pleasing to the pallet for astronauts. Both the Veggie system have the potential to provide fresh and nutritious food to astronauts using minimal resources and for extended periods of space flight.

VI. References

Cooper, M., Perchonok, M., Douglas, G. L., “Initial assessment of the nutritional quality of the space food system over three years of ambient storage”

Gioia, M., et al., Selection of Leafy Green Vegetable Varieties for a Pick-and-Eat Diet Supplement

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