GROWTH OF THE GRAPEVINES IN THE CONTROLLED GREEHOUSE ENVIRONMENT AND PROSPECTS OF THE SPACE AGRICULTURE. M. V. Tarasashvili[1,2,3], marika.tarasashvili@btu.edu.ge; N. G. Aleksidze[3], aleksidze.nugzar@yahoo.com, N. G. Doborjginidze[1], dobo78@gmail.com; N. G. Gharibashvili[1,4], Tusa.ghari@gmail.com . [1]Georgian Space Research Agency, 4 Vasil Petriashvili Street, 0179, Tbilisi, Georgia; [2]Business and Technology University, 82 Ilia Chavchavadze Avenue, 0162, Tbilisi, Georgia; [3]Javakhishvili Tbilisi State University; 1, Ilia Chavchavadze Avenue, 0179 Tbilisi, Georgia; [4]Spase Farms Ltd, 14 Merab kostava Street, 0108, Tbilisi, Georgia.

Introduction: Thus far, suitable life-support conditions on space flights and on the space stations have been maintained solely via physical and chemical means. However, for long-duration missions to distant destinations, such as Moon Base or exploratory missions to Mars, biological life support systems (BLSSs) may be needed to ensure sustainable functioning of the living environment, food supply and water purification. As on Earth, this conversion process would need to be based on photosynthesis [1]. Here we review preliminary data from the experiments of the grapevine growth within artificial ecosystem of Ltd. Space-Farms Greenhouse, with particular attention to their suitability for the use in harsh Lunar and Martian conditions, i.e. low temperatures, low atmospheric pressure, high CO_2 concentration, high UV radiation and dryness.

Sample and site description: Planet Earth has the immense diversity of photosynthetic organisms, from unicellular to the highest plants, however not many of them are able to adjust to the harsh conditions of space ecosystems. Grapevine (*Vitis Vinifera*) is the liana plant with flaky bark and both ordinary and aerial root systems, therefore successfully reduces humidity in the environment and at the same time in conditions of water shortage assimilates it directly from the atmosphere evaporates. Thanks to the roots in the ground, the plant extracts minerals, broad leaves provide intensive photosynthesis and effectively neutralize high carbon dioxide concentration, at the same time purifying the air from the variety of harmful mixtures [2]. In addition to these values, Grapevine is a fruiting plant and can provide space settlers with variety of food, drinks, sweets, vitamins and medicines. From the wide varieties of the substances Grapevines have, for the healthy diet of the future astronauts antioxidants are of utmost importance [3].

Location: From more than 500 Georgian grapevine cultivars 10 most cold-hardy varieties have been grown at Ltd. Space Farms controlled greenhouse environment (Figure 1). Here the plants are illuminated 12h/12h by typical LED growth lights with the enhanced blue and red spectra for the intensification of photosynthesis. Humidity is maintained between 15%-25% and the average concentration of CO_2 is 1000-1200 ppm. Minimum night temperature was 2˚C and daylight temperature was around 20˚C. Parallel Cultures have been grown at Moon and Mars Research Laboratory under natural light environment at BTU – Business and Technology University (https://btu.edu.ge), which operates under the supervision of GSRA - Georgian Space Research Agency.

Fig. 1. *10 initial Georgian cold-hardy cultivars of Grapevine grow under the controlled greenhouse conditions (similar to the ones that operate at ISS - International Space Station) at Ltd. Space Farms:* R*qawiteli; Kakhuri Mtsvane, Tsintska, Odessa, Tsolokauri, Ojaleshi, Sakmiela, Saferav and Aleksandrouli.*

Methods: The samples are regularly monitored for the intensity of growth, cell-tissue morphogenesis, intensity of photosynthesis and entire physiology. Biochemical and sensory-based methods are used to monitor the changes in the antioxidant and vitamin content, as well as secondary metabolics such as phenolic and flavonoid compounds in Plants. Microbiological health is constantly monitored and damages (if any) are assessed at microscopic level.

Results: After 12 months only 4 cultivars have survived the greenhouse conditions of the Space Farms: Rqawiteli, Ojaleshi, Sakmiela and Saferavi; however it remains unclear whether the survival of these species was due to their hardiness against biotic (fungi, bacteria) or abiotic (illumination, high CO_2 concentration, etc.) factors.

Growth: Initially small plants have been enclosed within small space 1mX1m similar to that growth chamber on ISS, however plants have shown very intensive growth rate and in only 2 months have been transferred to the larger 4mX4m isolated bunker with controlled environment (Figure 2). From the very beginning, significant differences have been found in the growth rates of the control and experimental samples. Unlike control samples grown outdoors, the overall thickness of the main stem of the greenhouse plants are significantly thinner - the average cross-section of the control plants' main stems measure about 20 mm, others measure about 10-15 mm, almost twice as less. Area of the leaves are about 70-75% that of the plants grown outdoors and appear significantly brownish, although the overall health of the plants are quite satisfactory.

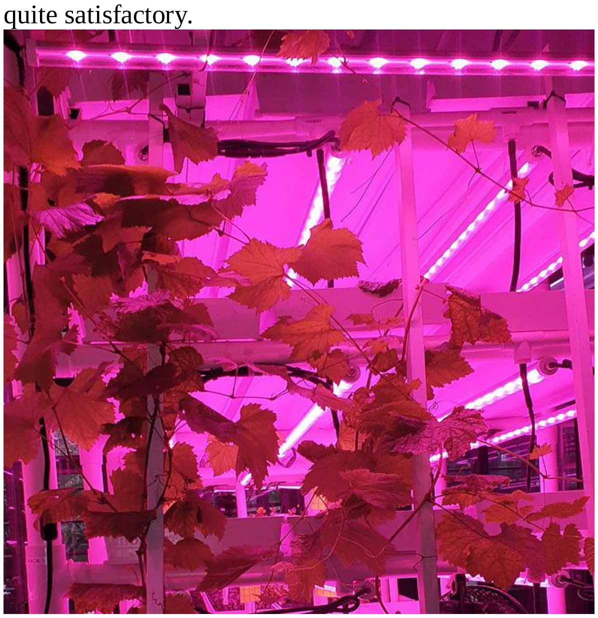

Fig. 2. *4 Grapevine cultivars have survived out of initial 10 after the exposure to the controlled greenhouse environment resembling ISS growth chamber: Rqawiteli, Ojaleshi, Sakmiela and Saferavi.*

Rate of Photosynthesis of the 2 moths leaves are at maximum in control and outdoor samples, however stress-altered chlorophyll a/b ratio in the greenhouse samples demonstrates inhibition in the rate of the activity of the numerous photosynthetic enzymes in contrary to which it could be expected with elevated CO_2 concentration in the growth chamber.

Antioxidant content decreases significantly in the leaves of the plants grown indoors and affects the content of the related vitamins and secondary metabolics to which these substances serve as biochemical precursors. Quantitative analysis of flavonoids and phenolic compounds from the leave extracts have shown significant differences as well (0.68 mg/mL *vs* 4.44 mg/mL and 1.08 mg/mL *vs* 26.01 mg/mL respectively).

Conclusions: Preliminary data have shown significant differences in the morphology and physiology of the Georgian Grapevine cultivars grown within ISS greenhouse analogue and outdoors. Our year-long studies prove that UV and green portion of the light spectrum might be necessary for the effective growth of grapevines [4] and the lack of these environmental factors may lead to the discrimination of the content of the "substances of Space Settlement interest", such as glucose, antioxidants and vitamins. Most importantly, lack of UV radiation alters the chlorophyll content decreasing the rate of photosynthesis, undesirably reducing CO_2 uptake capability of the plants. Thus, at this stage of investigations, an introduction of the additional light-sources containing incandescent spectrum is recommended.

Further work: Apart from scientific investigations, Greenhouse of Space Farms additionally operates as hydroponics vertical farm and supplies clients with wide variety of edible plants. Water usage and energy uptake maintained in this system is significantly more efficient than in traditional ground-based farms here on Earth. However, due to the expected shortage of pure water-supply, it has been suggested that biological remediation of the Lunar and Martian regolith could be much more effective in terms of maintaining sustainable space agriculture [5]. Next step is to investigate the growth of the grapevines in the Lunar and Mars soil simulates enriched with agronomically significant species of bacteria.

In future, the research carried out on the ISS and in the proposed terrestrial facility for Advanced Life Support testing will bring the requirements for establishing extraterrestrial plant-based life support systems into clearer focus.

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