MARTIAN PHOTOSYNTHESIS OF THE EARTH PLANTS – INDUCED BIOCHEMICAL ADAPTATIONS

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ABSTRACT

Human Mars missions and long-term settlements followed by the Terraformation of the Planet are those of the most important challenges for 21st century scientists. Invention of the practical methods for the possible bioremediation of Martian ground and atmosphere seams prospective and is of great scientific interest.

Normal functioning of the photosynthesizing organisms is very important for the long-term sustainability of human Mars settlements as there are no other alternatives for the stable oxygen/food supply for such stations. It is certain that plants will play the crucial role in the Terraformation of the Red planet.

We have simulated the possible environmental conditions of the human Mars settlements and studied various adaptations of the optically active organisms to it. Specific biochemical aspects of the Martian photosynthesis during Terraformation have been investigated.

Although many organisms have been used, only the results obtained from the experiments on the vascular plants are presented in this particular work.

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METHODS AND MATERIALS

Greenhouse conditions of the human Mars settlement has been simulated within MCSC – Mars Climate Simulation Chamber [1] (Figure 1).

Sweet basil (*O. Basilicum*) and its cultivar Dark "Opal" basil (*O. Basilicum* L.) have been chosen for these experiments as they are closely related taxonomically and contain the significant variety of the substances known to act as anti-oxidant and radiation-screening agents.

Seedlings have been grown for two weeks under the dim light to prevent the formation of the starch grains inside chloroplasts.

Figure 1. Sweet basil (*O. Basilicum*) and its cultivar Dark "Opal" basil (*O. Basilicum* L.) thriving under simulated Martian surface irradiation.

Plants have remained within MCSC for two months. Temperature varied from +30ºC to -1ºC as would be within Martian greenhouse. Surface Irradiation Parameters inside MCSC and the technical details of its operation is described in details in publications [2, 3].

Fine-grinded Zeolith has been used for the simulation of the Martian ground. Zeolithe is widely used for the growth of various crops and in sterile conditions shows significant similarity to the chemical composition of the Martian ground (Figure 2).

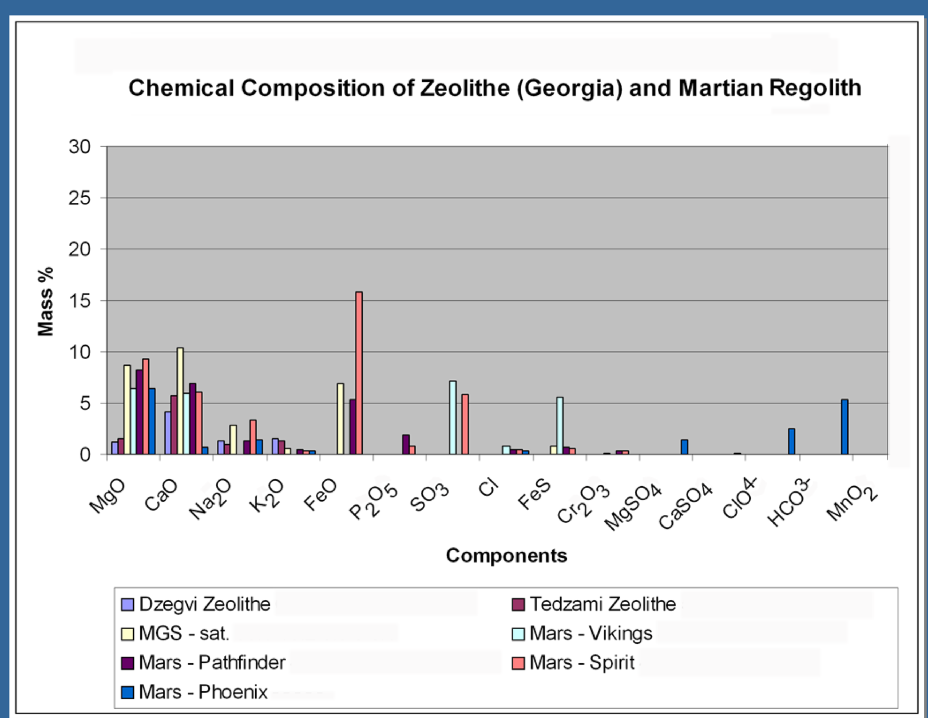

Figure 2: Similarities between the chemical composition of the Zeolithe and Martian ground.

RESULTS

Results show the significant changes of the pigment and anti-oxidant content within the plants placed in the lab and MCSC conditions. These data are also highly dependent on the illumination intensity and temperature variation during daily cycle. Presented data show the results obtained at maximum irradiation intensity (Figure 3).

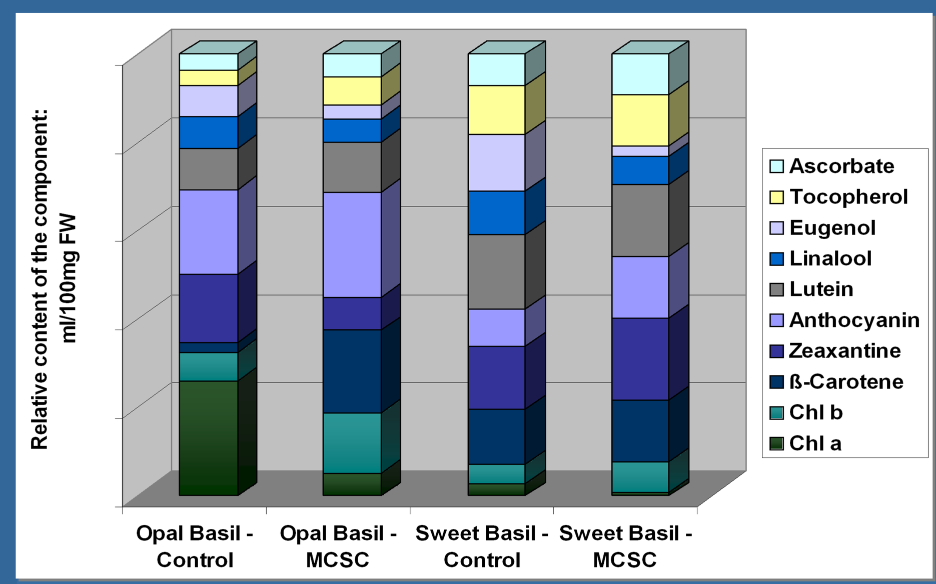

Figure 3: Pigment and antioxidant content of the Basil leaf extract (ml/100mg FW) of the "Opal" and Sweet Basil under the Earth and Mars surface greenhouse illumination conditions . FW – Fresh Weight. MCSC – Mars Chamber.

Under the MCSC "Martian" conditions *Chl a* concentration decreases sharply unlike that of *Chl b*, amount of which increases almost twice of the initial number. Content of the anti-oxidants, such as *Carotenoids* and *Tocopherols* rises significantly in both species, however, based on the preliminary data from the measured Hill Reaction, photo-reduction system of the "Opal" basil more likely relies on *anthocyanin*-based scavenging of the free radicals, whereas Sweet basil responds with the intensified synthesis of *anti-oxidant oils* (Figure 4).

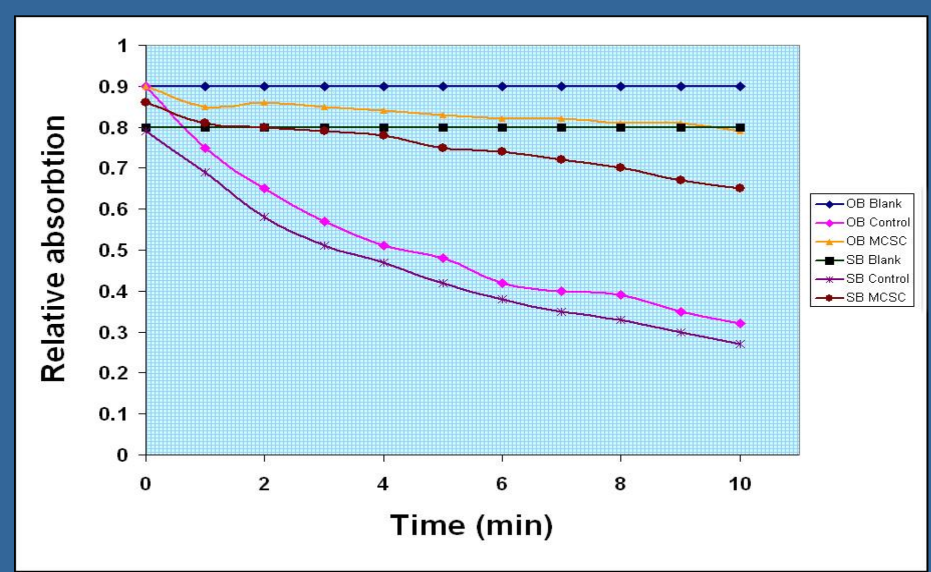

Figure 4: *Hill Reaction* has been measured in the leaf extracts of both plants under MCSC and lab conditions. In general, rate of the Hill reaction increases sharply under simulated Martian conditions, however within Sweet Basil the rate of the Hill Reaction increases much more rapidly than within it's "Opal" cultivar. Photodesaturation in Sweet Basil is much higher, more likely due to the absence of the intensive pigmentation, as it relies of the lower-rate free-radical scavenging of the anti-oxidant oils (Mevalonate Pathway).

One of the noticeable effects (during experiment) is the strong odor followed by the depositions of the oil-like compounds on the walls of the container. Biochemical and spectral analysis of these compounds reveals various types of the *Arenes* and *PAH* – Polycyclic Aromatic Hydrocarbons.

DISCUSSION

One of the principal pathways of the biosynthesis of *aromatic compounds* is the formation of the *Shikimic acid* that undergoes the phosphorillation to give *shikimate-3-phospate* and, eventually, *chorismic acid*. From here, "Opal" basil most likely synthesizes *anthraquinones* and *aromatic compounds* and Sweet basil "switches" to *mevalonic acid* synthesis of the *Arenes* and *PAH*. Either way, preliminary results of this experiments have shown that *Shikimate pathway of photosynthesis* may become the preferred metabolic adaptation of the high plants growing within Martian greenhouses or that of synthetic plants growing outdoors.

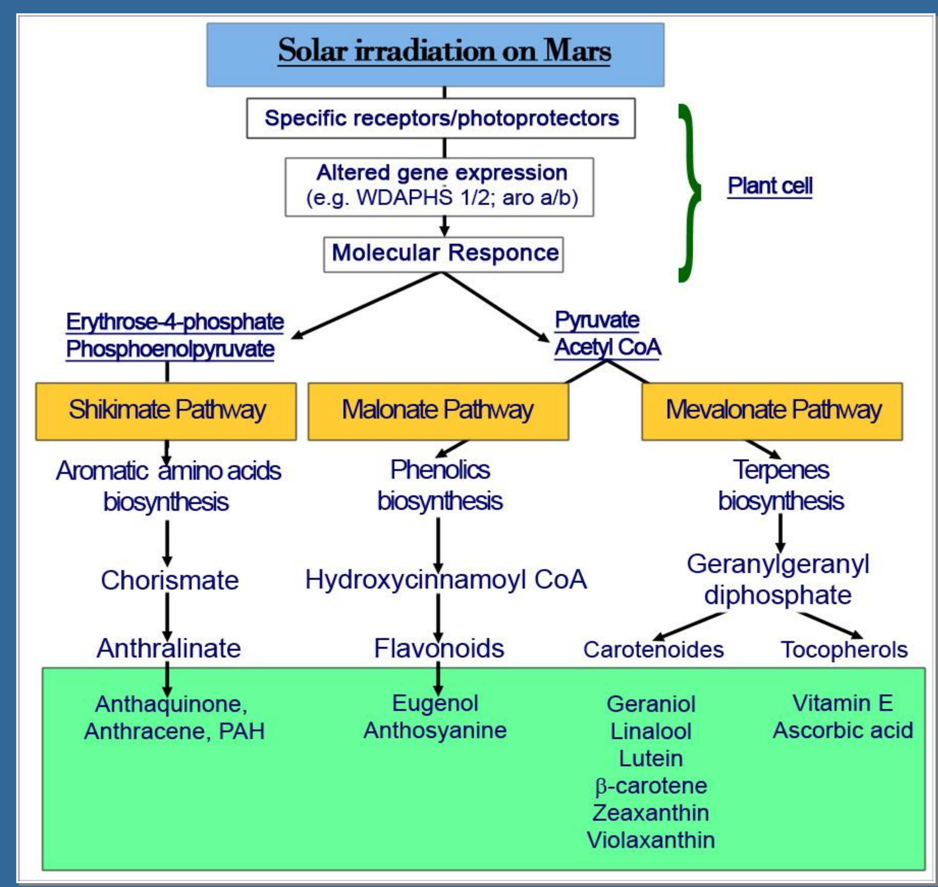

Figure 5: Induced biochemical pathways of Martian Photosynthesis in "Opal" and Sweet Basil – results of the experiment correspond to the data from the existing scientific literature.

CONCLUSIONS

Unlike bacteria and lichens, vascular plants can not survive within simulated outdoor conditions of Mars, however the results obtained from these experiments demonstrate that with the presence and expression of appropriate genes some species may survive conditions of the out-door greenhouse on Mars. Induced biochemical adaptations (e.g. switching to the alternative photosynthetic pathway, increased production of the photo-protective substances) may play the major role in the radiation protection of the synthetic organisms genetically modified for the Terraformation of Mars. Use of basil can significantly reduce carcinogenic effect of some PAHs dissolved in human blood and therefore shows the potential for becoming the necessary food supplement for Martian colonists.

1. Tarasashvili M. V. "Specific patterns of the photosynthesis within imitated Martian conditions". (2014) *Iv. Javakhishvili Tbilisi State University; Second Scientific Conference in Exact and Natural Sciences ENS-2014*;
2. Tarasashvili, M.V., Sabashvili, S.A., Tsereteli, S.L., Aleksidze, N.D. and Dalakishvili, O. (2016) "Semi-automated operation of Mars Climate Simulation chamber - MCSC modeled for biological experiments', *International Journal of Astrobiology*, pp. 1–15.