# GROUND CONTROL EXPERIMENT TO STUDY THE IMPACT OF MICROGRAVITY-SPECIFIC WATER AND OXYGEN DISTRIBUTION IN SUBSTRATE MEDIUM ON PLANTS*

*Iliana Ilieva, Plamen Kostov, Tania Ivanova, Svetlana Sapunova*

*Space Research Institute - Bulgarian Academy of Sciences,*

***Abstract***

*The plant growth experiments conducted in space in the recent 10 years showed that microgravity-specific environmental factors may alter plant growth. Microgravity changes the behavior of fluids and gases and the constructed plant growth facilities often utilized technical constraints than plant physiological requirements. The combination of these factors led to plant stress and poor growth.*

*A ground control experiment studding the impact of altered water and oxygen distribution in substrate medium is presented in this article. Plant root and shoot responses and adaptations to low oxygen content into the root zone are described.*

## INTRODUCTION

Plant root system physiology is dependent upon water, nutrients and oxygen availability. A great deal of research has been directed towards the development of plant nutrient delivery systems for spaceflight application that utilize the requirements for appropriate water and nutrients delivery, but little attention has been paid to the oxygen content in the root zone during the design process. The lack of nutrients and water delay plant growth and development, but the lack of oxygen might affect the overall biochemical and physiological status of the plant.

Oxygen content in the root zone depends on the size of the substrate particles. As the size of the particles decreases substrates can hold more water by capillary forces and thus the volume of air per bulk volume decreases. The diffusion of gases in water is 10 000 fold less than in free air. The displacement of air by water may further increase because water does not drain in microgravity. [1]

The above-mentioned characteristics of water and oxygen distribution in substrate medium and the difficulties to maintain both adequate water content for liquid flux and adequate air-filled porosity for gas flux lead to a

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lower level of oxygen in the root medium in microgravity than on earth. Plants grown in different space plant growth facilities showed signs of oxygen depletion stress [2,3].

The objective of this experiment was to study on earth plant physiological responses during growth in saturated substrate medium – process that occurs in microgravity and to qualify plant stress by nondestructive methods - measurement of plant heights and leaf color image processing.

## MATERIALS AND METHODS

### Hardware

The experiment was conducted in the laboratory prototype of the flown on the MIR Orbital Station SVET Space Greenhouse (SVET SG). SVET SG consists of Plant Growth Chamber (PGC) of an open type that contains Light Unit (LU) and mounted like a drawer Root Module (RM). The LU provides 400 μmol.$m^{-2}$.$s^{-1}$ PAR at the top of the canopy. The RM has 0,1 $m^2$ growing area and is divided into two 5,2 L Vegetation Vessels (VV1,2) each with two flowerbeds. Both VVs have independent moisture control maintained by a moisture sensor placed at 3 cm depth below the surface. The two VVs were filled with 1,0-1,5 mm particle sized substrate Balkanine.

### Plant culture and cultivation procedures

Pea (*Pisum sativum L.* cv “Ran-1”) was cultivated for 56 days. Plants were sown at 2,5 cm depth. Initially, all plants were grown at one and the same conditions - 16/8 hours light/dark period, substrate moisture 1/3 from saturation, air temperature varying between 23-25$^o$C and upward air flow (from the laboratory through the PGC and out of it) at 0,2 m/s speed. On the 17$^{th}$ day of plant development, i.e. during the active vegetative plant growth – water-logging stress was applied in VV1 (test) by rising the moisture threshold for 1 week and slowly submerging the substrate. At the same time, the Light Period (LP) was daily increased with 1-hour step to 23 hour light / 1 hour dark in order to eliminate plants stress compensation mechanism during the dark period. Plants in VV2 (controls) continued to grow at the same substrate moisture as before and the new LP as for VV1. During the stress treatment the air temperature varies between 16-23$^o$C for the test and control plants.

Plant responses to the maintained substrate moisture in both VVs were detected by measuring plant height and leaf color image processing obtained from a photo camera. Plant heights were measured on the 4, 7, 10, 13, 17, 21, 25, 29, 56 day of development and photo images were made during this period.

## RESULTS AND DISCUSSION

Seeds started to germinate 4 days after planting. Plants developed normally for 11 days when yellow-brown-red spots were noticed on the lower leaves. The affected leaves than withered and dropped. As “Fig. 1” shows the air temperature in the laboratory was higher than the required optimum for pea growth at the beginning of the experiment. The interaction between high air temperatures, low relative air humidity and dry air with 0,2 m/s speed in the PGC was the main reason for the observed phenomenon.

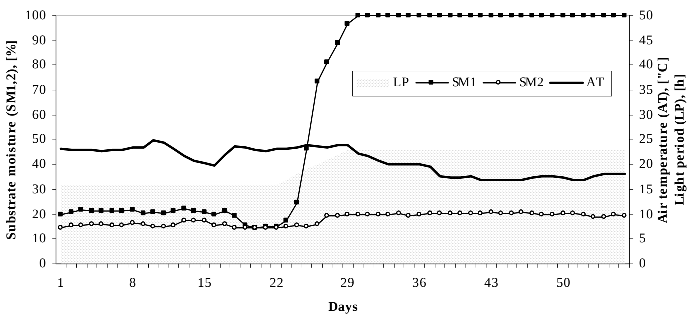


**Fig. 1.** Environmental parameters maintained in SVET SG

During the water-logging stress test plants showed typical responses to oxygen depletion stress. Plants stopped to develop in height “Table 1” and chlorosis was observed on the 10$^{th}$ day after treatment. A few new leaves developed but they were small and stunted. The leaf wither and sencense continued during the treatment and plants died before reaching maturity.

Extra elongation of the vegetative growth and delay in the reproductive phase was observed in the control plants. Flowers were obtained on the 39-day of plant development and fruits on the 41-day, and the plant yield was low. Two reasons might contribute for these results – 1) plants lost 2/3 of their leaves before reaching reproductive phase due to unexpected leaf sencense. 2) Post-experimental analysis of the RM reviled that due to insufficient water conductive properties of substrate Balkanine a water-logging zone had also formed in VV2 at nearly one half of the substrate volume. For this reason root systems of the control plants were situated in layer of 4,5 cm in depth. The analysis of the root systems reviled welldeveloped main and secondary roots. The root systems of the test plants were shallow without main root and with many secondary roots growing upwards in the substrate and out of it.

**Table 1.** Plant heights measured during the experiment

| Days after emergence | Cultivation period | Height in VV1 | | Heights in VV2 | |
|---|---|---|---|---|---|
| | | Line 1 | Line 2 | Line 1 | Line 2 |
| **4** | Shoot emergence and initial development | 1,2 | 0,8 | 0,9 | 1,0 |
| **7** | | 2,8 | 2,2 | 2,3 | 2,7 |
| **10** | Active vegetative growth | 4,8 | 5,2 | 4,8 | 5,7 |
| **13** | | 8,3 | 8,0 | 8,2 | 9,2 |
| **17** | Start of step-by-step moisture increase in VV1 | 12,3 | 12,7 | 13,7 | 14,5 |
| **21** | | 16,2 | 17,2 | 18,8 | 20,2 |
| **25** | Start of water-logging stress in VV1 | 20,7 | 22,7 | 26,7 | 27,6 |
| **29** | Water-logging stress in VV1 | 25,2 | 26,3 | 29,2 | 29,3 |
| **56** | End of water-logging stress in VV1 | 28,8 | 29,8 | 50,5 | 49,9 |

During the water-logging stress air temperature in the laboratory started slowly to decrease reaching 16-18$^{o}$C “Fig.1”. New shoot growth from the dead stems of the test plants was observed on the 39$^{th}$ day of plant development. Low temperature stimulated reproductive development of the control plants and only in a few days flowering and fruiting phase was reached. The decrease of temperature showed to be an anti-stress factor and could decrease the impact of water-logging stress.

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