NEW BIOTECHNOLOGICAL EXPERIMENT "GREENHOUSE SVET-2" FOR THE "MIR-SHUTTLE-95" MISSION

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Abstract

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The new 'Greenhouse SVET-2' experiment is a Russian-American-Bulgarian Experiment planned for the Spacelab-Mir-1 (SLM-1) mission in 1995. It includes two plantings, desigened (1) to test the capability of the Bulgarian "SVET" space greenhouse with the American SIS to grow a crop of wheat from seed to seed for 120 days, and (2) to provide green plant material for post flight analysis.

The 'Greenhouse SVET-2' experiment was prepared by the Russian crew (January and February 95) and continued by the American astronaut (from March to June 95). The plant samples and root modules used during the experiment will be returned to Earth on the SHUTTLE.

Plants, growth, leaf area, soil, moisture, sensors

The investigation of ecological problems concerning the creation of closed biospheric systems, based on the biological recycling of the chemical elements is one of the basic scientific problems of our civilization. It is related to the future manned space missions and will be of essential importance if an ecological disaster takes place.

Scientific research on these problems entitled 'Study of the ways and means for the use of higher plants, algae and animals in the biological life support systems for the space crews' within the INTERCOSMOS Program started in 1984. Under the co-ordinating role of the Institute of Biomedical Problems (IBMP), Moscow, Russia, scientists from several countries joined their efforts to design and develop instruments and new technologies. These are directed towards the design of separate units of the future Biological Life Support System (BLSS) which allows a natural food production, air and water regeneration (Ivanova et al. 1993).

A new model of device 'INCUBATOR-2' was designed in Bratislava, Slovakia, and tested onboard 'MIR' orbital station for chicken incubation (Japanese quail) in 1990 (Boďa et al. 1991). In an experiment with 43 incubated eggs 21 were fertilized and 8 viable quail were hatched. After emerging from the shell, they were rotating, unable to stop and orient themselves in space and also unable to feed. They were fed by the cosmonauts. In the next flight experiment with adult Japanese quail running from 1 to 9 of August 1990 on the 'MIR-KVANT' complex the behaviour of animals in weightlessness and after their bringing back to Earth was observed (Boďa and Baranov 1992). The experiments in the field of avian microgravity were carried out in 1992 and will continue in the MIR-SHUTTLE-95 mission.

A new type of space greenhouse named 'SVET' for higher plants growing was created in Sofia, Bulgaria. 'SVET' Space Greenhouse (SG) is a full-automatic operating and controlling system for higher plant growth. The 'SVET' SG was mounted on the 'KRISTALL' technological module, docked with the 'MIR' orbital space station on June 10, 1990. The Soviet cosmonauts Balandin and Solovyov started the first experiments with sowing seed of radish and cabbage on June 15, 1990. The first 29-days (dried) and 54-days fresh plants were obtained and brought back to Earth to be studied on August 10, 1990 (Ivanova and Dandolov 1991).

Materials and Methods

The block-diagram of 'SVET' SG is given in Fig. 1 (I v a n o v a et al. 1994). The Vegetation Module (VM) full of the substrate 'BALKANIN' is mounted on rails (like a drawer) in the Plants Growth Unit (PGU). The operating devices of the Air-Water System (pump, compressor and valves) and electronic measuring control system are fastened to the bottom of the PGU. The Illumination Unit (IU) can be vertically moved and fixed in different positions in the top side of the PGU. Lamp cooling and air movement within the PGU are ensured by a ventilator. Two of the PGU walls may be opened for easy service by the operator (when he sows the seeds, takes experimental samples and other manipulations) and one of them is transparent. The sensors for measurement of the climate parameters (air and substrate temperature, air humidity, substrate moisture and so on) in the PGU and VM are mounted.

The Control Unit (CU) receives and processes the data obtained by the sensors in the course of the vegetation cycle and carries out an automatic control of all operating mechanisms under preliminary made programs according to the values of current parameters. A special microprocessor program ensures automatization of all processes as well as the possibility for visual control and manual guidance by the cosmonaut-operator in case of failure in the sensors. The CU measures the climate parameters during the vegetation process and every 4 h they are written in a telemetric frame in the output buffer memory. The last 24 h information is transmitted to Earth by the Telemetric System (TMS). It is received in the Flight Control Centre in IBMP, Moscow, 3 times per day. The Test Equipment, including a computer, videomonitor and printer allows ground-based processing, visualisation and telemetric data storage for further analysis (I v a n o v a a n d D a n d o l o v 1992).

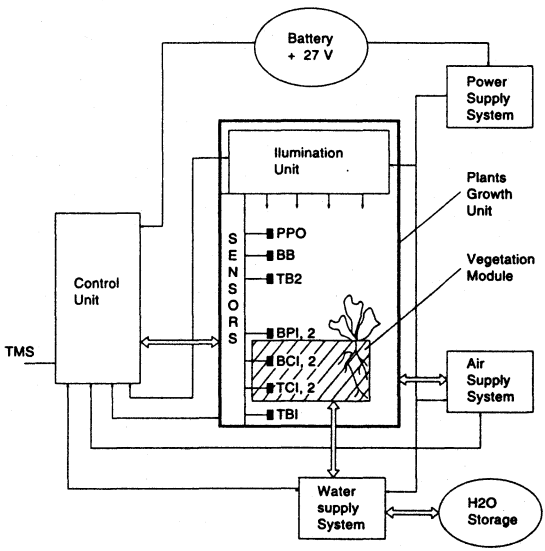

Fig. 1 Principle diagram of the 'SVET' Space Greenhouse with measurement of the environmental parameters: TB1 – air temperature entering PGU; TB2, BB – air temperature and humidity within PGU; BP1, 2 – presence of overmoistening of the substrate in cell K1 (K2); BC1, 2 – substrate moisture in K1 (K2); TC1, 2 – substrate temperature in K1 (K2) and PPO – duration of the period of lighting.

The sensor system includes sensors located in PGU (I v a n o v a et al. 1992) as follows:
* Air temperature entering the PGU-TB1;
* Air temperature in the plant area-TB2;
* Relative air humidity in the plant area-BB;
* Substrate temperature in cell K1 of VM-TC1;
* Substrate temperature in cell K2 of VM-TC2;
* Substrate moisture in K1-BC1;
* Substrate moisture in K2-BC2;
* Duration of the period of lighting-PPO;
* Presence of overmoistening of the substrate-BP1,2.

The sensors measuring TB2, BB and PPO mounted on a unit fastened to the IU will be dropped out in the 'Greenhouse 'SVET-2' experiment. Only TB2 will stay (on the top of IU) to control switching off the light in case of exceeding the admissible temperature in PGU (about 23 °C).

Results

The 'Greenhouse 'SVET-2' experiment used the Russian-Bulgarian developed 'SVET' SG system and supplement it with a new Russian-American developed physical and physiological monitoring system that allowed the measurement of most leaf and root environmental variables. The SVET Instrumentation System (SIS) added to the 'SVET' SG, consists of four primary modules (Fig. 2): a gas exchange monitoring system, an environmental monitoring system (EMS), a power supply system (PSS), and a data collection and display system (DC+DS) (SDL/94–001 1994).

The gas exchange system has for an object to provide accurate measurement of absolute and differential CO_2 and H_2O levels in the air entering and exiting the PGU as well as absolute and differential pressures in the measured gases. It is necessary to evaluate some prime indicators of plant health as photosynthesis, respiration, and transpiration.

The environmental measurement system provides the capability to measure the air and soil conditions in which plants are growing.

Leaf area measurements are critical to understanding plant growth. The system is a modified version of a commercial leaf area scanner. In flight, leaves are attached to the leaf board and scanned using a hand-held scanner.

SIS encloses two separate transparent bags, called leaf chambers which cover the plants growing in each vegetation module (VM) of 'SVET' SG. It allows gas exchange and leaf environment measurement.

SIS supplements the 'SVET' SG with additional sensors (Fig. 2) that will give the possibility to gain more information about the air and soil conditions for growing of the plants.

The additional variables to be measured are:

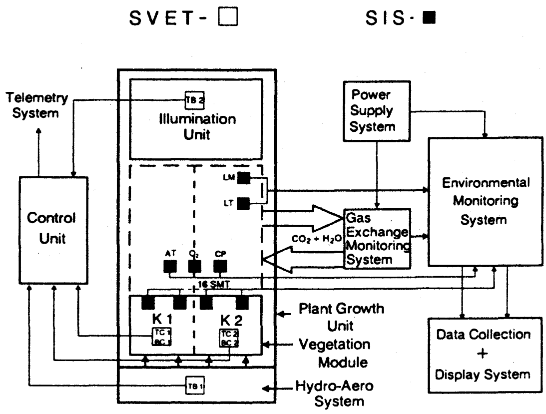

Fig. 2 Location of the sensors in 'SVET' SG and SIS with measurement of some additional parameters: LM – plant light monitor; LT – plant leaf temperature; AT – plant air temperature; CP – cabin pressure and SMT – substrate temperature and moisture in VM (16 units).

- Plant air temperature (AT)
- Plant lihgt monitor (LM)
- Plant leaf temperature (LT)
- Soil temperature and moisture (SMT)
- Cabin pressure (CP)
- Cabin O_2
- Cabin H_2O (air humidity)
- Cabin CO_2

The chamber environmental variables are measured by an instrument cluster with sensors located on the upper end of a rod in one corner of each leaf chamber. These sensors detect leaf temperature (LT) (IR thermometer), and irradiation (LM). Cabin O_2, pressure (CP), and temperature (AT) are measured in the cabin air stream.

The 'SVET' system provides one root moisture sensor per module that measures and controls the soil moisture level by mean of the CU and hydrosystem. To monitor the distribution of water, 16 additional sensors (16 SMT) (8 per module) are supplemented by SIS. They are designed to be integrated in the existing root module on flight. The moisture sensors use the thermal impulse method and can be inserted through the ventilation holes in the modules.

The SIS contains 4 gas analyzers designed to provide accurate measurement at mean concentration up to 3% CO_2. CO_2 and H_2O are measured by one sensor as the air enters the leaf chambers and by another sensor in the air stream exiting the chambers. The difference between these measurements provide the data to calculate photosynthesis, respiration, and transpiration.

Discussion

Greenhouse 'SVET-2' experiment include first planting, growing of Superdwarf wheat through a complete life cycle and to grow a second crop for approximately 30 days to provide fresh and frozen samples to be returned to Earth for analysis (B i n g h a m et al. 1994). Measurements of the plant gas-exchange rates (transpiration and photosynthesis) will be followed continually and summarized data will be downlinked for use by the science team and ground controller. If the plants grow well enough, they will be sampled and fixed five times during the seed-to-seed experiment and the mature plants will be harvested. The five sampling planned times are: 6–14–35–48–62– and 90 days. The samples will be fixed using 4F; 1G fixative and stored in bags. Plants will be photographed at least weekly and at each sampling interval. After the plants from the I planting have been harvested, a fresh crop will be planted for II cultivation. In 'Greenhouse 'SVET-2' experiment 'SVET' SG measurements will be extended by the US SIS and the systems should begin to provide the information needed to determine the factors limiting plant growth in space. It will provide important information concerning especially air recycling in the future BLSS.

Nový biotechnologický pokus „Greenhouse Svet-2“ pre misiu „MIR-SHUTTLE-95“

Nový pokus „Greenhouse-Svet 2“ je rusko-americko-bulharský pokus plánovaný pre Spacelab-Mir-1 (SML-1) misiu 1995. Zahrnuje dve výsadby zeleniny pre otestovanie schopnosti bulharského vesmírneho skleníka „Svet“ na pestovanie pšenice zo semena až po úrodu za 120 dní a na poskytnutie zeleného rastlinného materiálu na analýzu po ukončenom vesmírnom lete.

Pokus, v ktorom je zahrnutý skleník „Greenhouse-Svet-2“ bol pripravený ruskou posádkou a pokračoval pomocou americkej posádky. Vzorky rastlín a koreňov budú po návrate vesmírnej lode Shuttle podrobené analýzam.

Новый биотехнологический эксперимент »GREENNHOUSE-SVET-2« для программы »MIR-SHUTTLE-95«

Новый эксперимент »GREENNHOUSE-SVET-2« является российско-американско-болгарским экспериментом, планированным дл. миссии космической лаборатории Spacelab-Mir-1 (SLM-1) в 1995 г. Эксперимент включает две посадки, направленные (1) на определение способностей болгарской космической теплицы »СВЕТ« и американской SIS добиться урожая пшеницы из зерен в зерна в течение 120 суток и (2) на предоставление зеленого растительного материала для анализов по окончании полета.

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