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# COMPARATIVE ANALYSIS OF PLANT GROWTH IN TWO DIFFERENT SUBSTRATES DURING EARTH EXPERIMENT

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***Abstract***

*One-month, earth-based experiment with onions carried out in the prototype of SVET-2 Space Greenhouse which has operated for 10 years on the MIR Orbital Station is described in this paper. A new substrate (**Ekolin**) is used which is compared with the substrate used before (**Balkanin**) on the biological indications of the grown plants. The equal environmental parameters in the root zone were maintained by automatic substrate moisture control in both Vegetation Modules. **Balkanin's** relatively low water-conductivity is an essential disadvantage as a result of which twice fewer plants were grown; moreover, they were shorter and with twice less biomass compared to that grown in **Ekolin**. For its good water-conductivity **Ekolin** could be used in the future Space Greenhouses.*

## 1. Introduction

**Balkanin** is Bulgarian invention and patent and was the first substrate used in five space and many on-earth experiments carried out in the period 1985 - 1997. Because of its high relative weight and radioactive background, low water-capacity and low water-conductivity, the American scientists replaced **Balkanin** with **Turface**.

The aim of this experiment was to use new substrate – **Ekolin** and to compare it to the used before **Balkanin** on the biological indications of the grown plants. As the environmental parameters in the Growth Chamber are the same for all plants we also tried to maintain equal environmental parameters in the two Vegetation Modules by automatically controlling the substrate moisture.

*Allium cepa* – onion was chosen as a biological material in this experiment because of its fast growth and rich vitamine content. The plant is also a candidate for growth in the Biological Life Support Systems providing food, water and air recovery for the future long-term space

missions. Onion is also a suitable model plant for studding the impact of different environmental stress factors. The plant is especially sensitive to water stress and indication for this is the lowered rate of transpiration, photosynthesis and growth.

The basic biological indications that will be measured and will serve for estimation in this experiment are: germination and plant height, row biomass and root development.

## 2. Technical description of the experiment

SVET Space Greenhouse consists of Plant Growth Unit and Control Unit. The Vegetation Vessel is divided into two Vegetation Modules (VM), and is mounted on rails (like a drawer) in the Plant Growth Unit [1]. Each VM has independent, automatic moisture control maintained by moisture sensor operating on thermodynamic principle [2].

**Ekolin** – the new substrate is placed in VM 1 and **Balkanin** – the previously used substrate - in VM 2. The new substrate is developed by NIPRORUDA and consists of natural clinoptilolite in composition with expanded perlite and vermiculite, natural vermiculite, fertilized clinoptilolite and water-soluble polymers, modified and activated by original Know How technology of the firm. Its basic nutritional compounds are shown on Table 1 [3].

**Balkanin** is natural zeolite enriched with nutrients on original Bulgarian technology Table 2 [4].

**T a b.1.** Agrochemical characteristics of **Ekolin** for space greenhouse

| PH | EC | $P_2O_5$ | $K_2O$ | $N\text{-}NH_4$ | $N\text{-}NO_3$ |
|---|---|---|---|---|---|
| | mS/cm | Water soluble forms | | Extraction with KCl solution | |
| | mg/100g | | | | |
| 6.2 | 0.79 | 18.50 | 7.22 | 32.38 | 15.75 |

**T a b. 2.** Nutrient content of substrate **Balkanin**

| **Total content** | **%** | **Easy assimilable forms** | **mg/100g** | **Microelements** | **ppm** |
|---|---|---|---|---|---|
| N | 0.20 | $NH_4$ | 72 | B | 2.0 – 4.0 |
| $P_2O_5$ | 0.04 | $P_2O_5$ | 12 | Cn | 15 - 20 |
| $K_2O$ | 2.39 | $K_2O$ | 1440 | Zn | 40 - 80 |
| $Na_2O$ | 0.58 | $Na_2O$ | 400 | | |
| CaO | 3.65 | CaO | 574 | | |
| MgO | 1.90 | MgO | 60 | | |

The two VMs were filled only with substrate, without the linen wicks and the air-pipe system for artificial aeration of the substrate as was in the original construction. The position of the two sensors was different, too. They were situated 2,5 cm off the bottom of each VM, and not 3 cm off the covering lid. This position allowed us to control the moisture so as to avoid gravitational flow out of water – a phenomenon typical for ground-based experiments.

### 3. Experimental course

The experiment was started on 18 November 2002 and continued till 18 December 2002. It was worked out in another ground-based experiments that it is better to repeat Program 2 – the program for initial substrate moistening for twice better and more even water distribution in the volume with small water doses. So, Program 2 was repeated twice with approximately 13 ml water dose. Program 3 – the program maintaining automatic control of the environmental parameters during plant growth was started on 22 November. Before that the biological material – the onions were planted. Each VM has two beds and 9 onions were planted on each of them or totally 18 onions for each substrate. Analyzing the received data from the twice-repeated Program 2 we decided to set the following initial parameters for Program 3: moisture threshold - 45% and 37 ml water dose for both VMs. Some of the environmental parameters monitored during the experiment are shown on Figure 1. Although we set equal initial parameters one week later twice less water was input in **Balkanin** due to substrate's bad

water conductivity. This led to different conditions in the root zones. **Balkanin** was twice drier than **Ekolin**. To equalize the conditions in the root zones we raised the moisture threshold in **Balkanin** from 45% to 50 % and kept the same water dose – 37 ml.

In the beginning of the experiment when plants have not germinated yet nor grown up enough water consumption is less, being needed only to compensate water loss during evaporation. But the situation was different with **Ekolin** - too much water was consumed without plants. Analyzing the data from the received telemetric frames it was determined that the substrate in VM1 was subject to more intensive evaporation than the substrate in VM2. X-ray photograph was stick on beneath the VV to prevent electronics from damage if some gravitational water flow out occurred. The X-ray photograph gave negative impact on the equal water evaporation from both VMs, but as it was impossible to remove it without interrupting the experiment we decided to leave it. On the 21$^{st}$ day when all of the plants in **Ekolin** and half of the plants in **Balkanin** germinated and twice more water was input in VM1 at one and the same moisture threshold the evaporation from both VMs equalized and remained still till the end of the experiment.

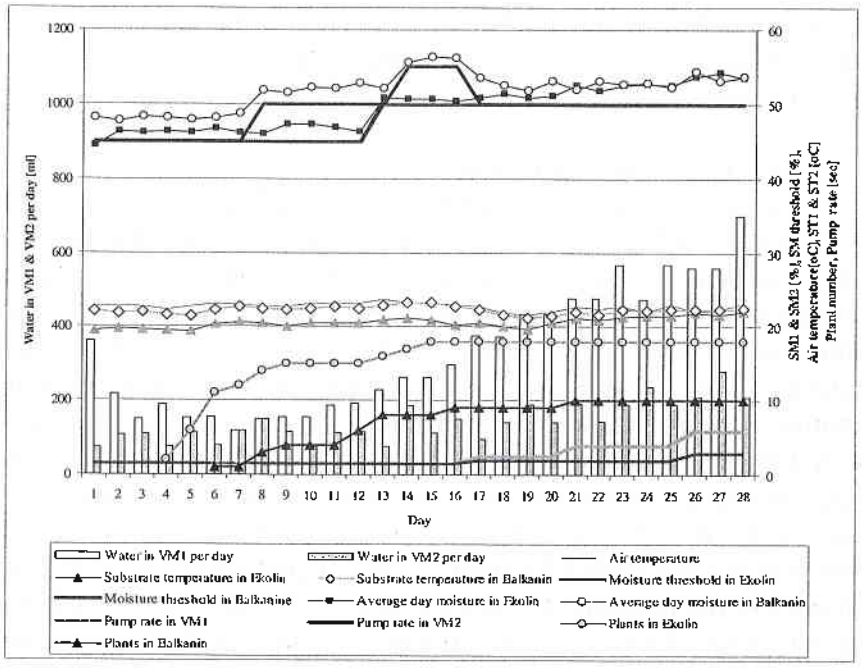


**Fig 1.** Environmental parameters in VM1 and VM2 during the experiment

The bad **Balkanin** water-conductivity allowed only half of the planted plants to germinate although we raised the moisture threshold to 55% for several days and almost reached the point when gravitational flow out of water was very possible to occur.

The moisture thresholds set during the experiment were as follows: in VM1 - 45% and 50% and in VM2 - 45%, 50%, 55% and 50%. These thresholds were maintained by different doses depending on pump operational time.

## 4. Results

From the very beginning of the experiment we measured some of the plant biological parameters. The first indication observed was plant germination. With two times less water in **Balkanin** due to its bad water-conductivity two times less plants germinated. Four days after starting Program 3, the first plant in **Ekolin** germinated, and two days later, the first one in **Balkanin** germinated. 100 % germination was achieved on the 15$^{th}$ day of the experiment in **Ekolin** and 51% germination on the 21$^{st}$ day in **Balkanin**. The plants in **Balkanin** were smaller with softer leaves with less biomass compared to those grown in **Ekolin**. The average plant height in substrate **Ekolin** was 49.6 cm in the first row and 53.1 cm in the second row. Approximately 12 cm smaller were the plants in **Balkanin** - 37.4 cm in the first row and 40.3 cm in the second row. The average plant weight in **Ekolin** was 8.375g and almost twice less in **Balkanin** - 4.794g.

Observation of root growth was made after the experiment had finished. The upper layers in **Balkanin** were completely dry; it was wet near the hydroaccumulators and below in the substrate's volume. Approximately 2 cm of substrate from the covering lid were completely dry in **Ekolin**. The whole volume below was evenly wetted. The plants grown in **Ekolin** were with fine, more branched off roots, distributed like a net in the whole volume of the substrate. The strongest roots were mainly near the hydroaccumulators. The plants grown in **Balkanin** were with not so well developed root system. The roots grew downward mainly near the hydroaccumulators.

Both root systems suffered from anoxia as the roots reached the wettest layers of the substrates at the bottom of the VMs. The roots grew through the polyvinylchloride foam and outside the perforations in the VV walls. Artificial aeration of the substrate is necessary on Earth as well to prevent roots from anoxia.

## 5. Conclusions

Moisture is vital for faster plant germination and normal plant growth. **Ekolin** - the new substrate is with good water-conductivity and thus ensures twice faster germination and better plant growth. **Ekolin** could be used in the future Space Greenhouses after successfully passing the other space-qualified tests.

## References


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## СРАВНИТЕЛЕН АНАЛИЗ НА РАЗВИТИЕТО НА РАСТЕНИЯ В ДВА РАЗЛИЧНИ СУБСТРАТА ПРИ НАЗЕ4МЕН ЕКСПЕРИМЕНТ


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### Резюме


В статията е описан едномесечен наземен експеримент с кромид лук, проведен с прототипа на космическата оранжерия "СВЕТ", работила успешно 10 години на Орбитална станция "МИР". Използван е нов субстрат (еколин), който е сравнен с биологическите показатели на използвания по-рано субстрат (балканин). Постоянните показатели в областта на корена за двата вегетационни модула бяха поддържани с автоматичен контрол на влагата. Сравнително по-ниската водопроводимост на балканин е основен недостатък, в резултат на който бяха отгледани двойно по-малко растения; освен това, растенията бяха по-ниски и с двойно по-малка биомаса от масата, получена при използването на еколин. Добрата водопроводимост на еколин го прави особено подходящ за използване в бъдещи космически оранжерии.