

Astrobiology and Plant growth on the Moon

B.H. Foing, N. Kozyrovska, D. Wills et al

Study of solar system samples in lunar treasure trove

- Cometary and meteoritic record
- Search for organics in regolith and polar ices
- Extinct/extant life in polar ices ? From Earth?
- Fossils of organics & ancient life from Early Earth

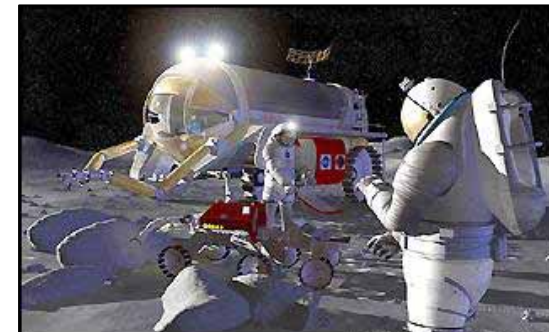
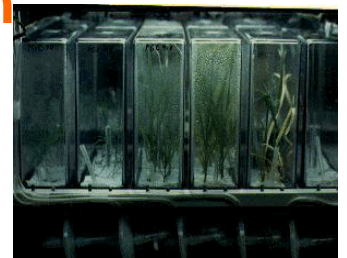
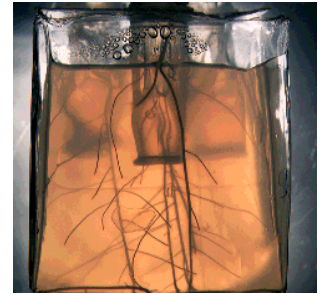
Expanding life beyond Earth

- Radiation exposure experiments
- Bacteria and extremes of life
- Botanic ecosystems
- Validation of life detection technologies
- Planetary protection issues

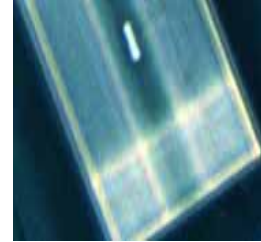


Expanding life beyond Earth

- **Radiation environment and exposure studies**
- **Bacteria and extremes of life: Survival, replication, mutation and evolution**
- **Extraterrestrial botanics: Growing plants on the Moon**
- **Animals: physiology and ethology on another planet**
- **Closed Ecological Life Support Systems**
- **Greenhouses, Local Food Production**
- **Living off the land**
- **Support to human exploration**
- **Permanent human presence**
- **Biospheres on the Moon**
- **Planetary and environment protection issues**
- **Protection of Earth life (Noah's ark , DNA bank)**

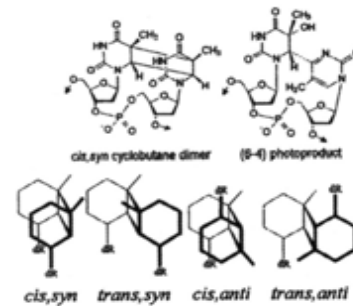
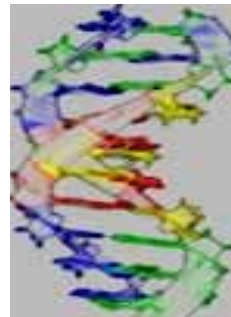
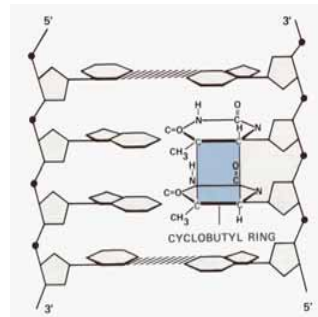
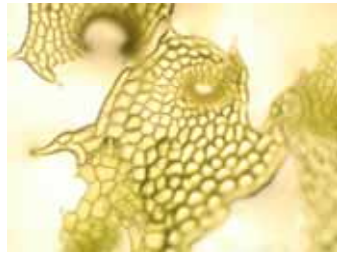


EXPOSE: Response of Organisms to Space Environment



1. Investigation of the survivability of terrestrial organisms in space
2. Understanding of the organic chemistry processes in space
3. Contribution to the biological adaptation strategies to extreme conditions on early Earth and Mars

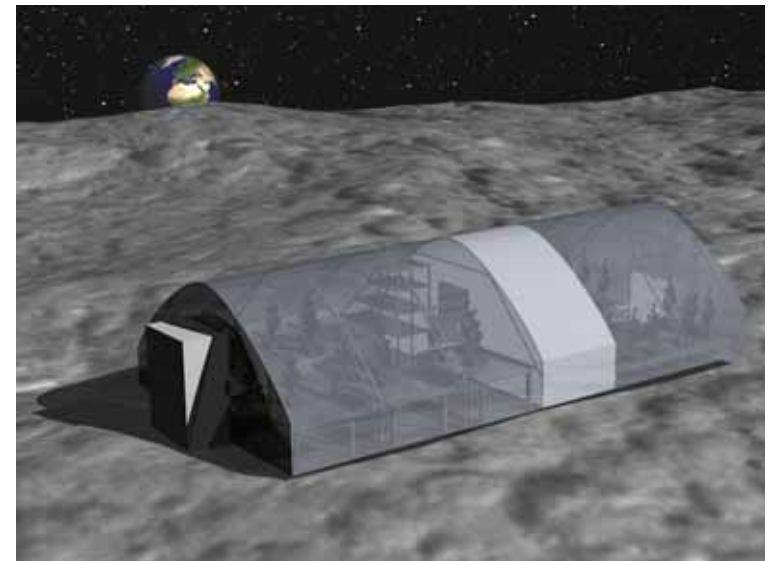
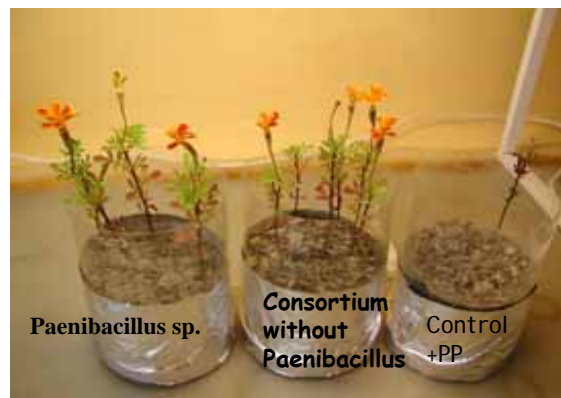
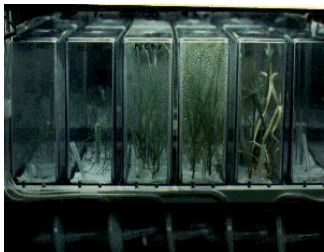
EXPOSE will give new insights to the origin of life and the chances and limits of life to be transported from one body of our solar system to another by natural processes.



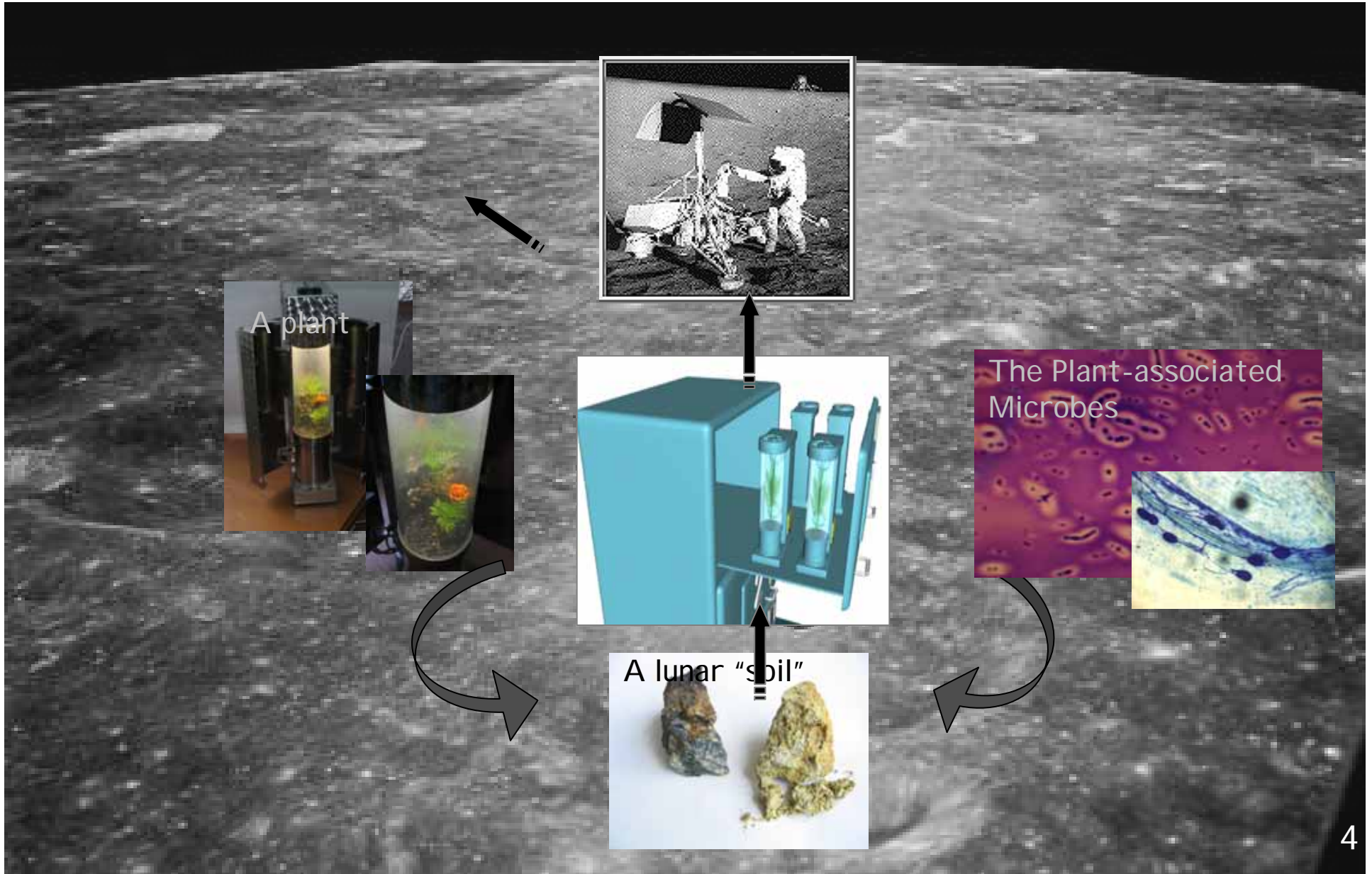
A precursor technology for growing first plants from lunar rocks in a lunar base

**N. Kozyrovska (1), I. Zaetz (1), T. Voznyuk (1),
I. Rogutskyy (2), O. Mytrokhyn (3), D. Lukashov (3),
S. Mashkovska (4), R. Ernst, B. Foing (5)**

(1) Institute of Molecular Biology & Genetics of National Academy of Sciences, Kyiv, Ukraine, (2) Institute of Physics of National Academy of Sciences, Kyiv, Ukraine, (3) T. G. Shevchenko Kyiv National University, Kyiv, Ukraine, (4) Botanical Garden of National Academy of Sciences, Kyiv, Ukraine, (5) ESA Research and Scientific Support Department, ESTEC/SRE-S, Noordwijk, The Netherlands, Europe.



Scenario for Growing Pioneer Plants at a Lunar Greenhouse



The peculiarity of growth and development of bacteria in microgravity being investigated within many years by Ukrainian researchers at the USSR spaceships *Salut*, *Soyuz*, the space station *Mir* and participated in the France-USSR experiment, USA-USSR experiment at *Appolo* (Kordyum et al., 1978; 1983; Man'ko et al., 1986). In particular, our data exhibited the unusual interrelationships between *Anabaena Azolla* and cyanobacteria (Kordyum et al., 1983), and also eubacteria and a plant host in space flight (Tarasenko et al., 1990).



The modeling a light design by LED

The working models of the chamber for cultivating plant in aseptic conditions



MULTI-PURPOSE GREENHOUSE OF CHANGEABLE GEOMETRY



The greenhouse is designed as a three-level stand with external dimensions size 1100x700x2000 mm and consists of the stand (1) and three blocks joined to it (2), unified by external dimensions and arranging sizes: technological, experimental-technological and experimental.



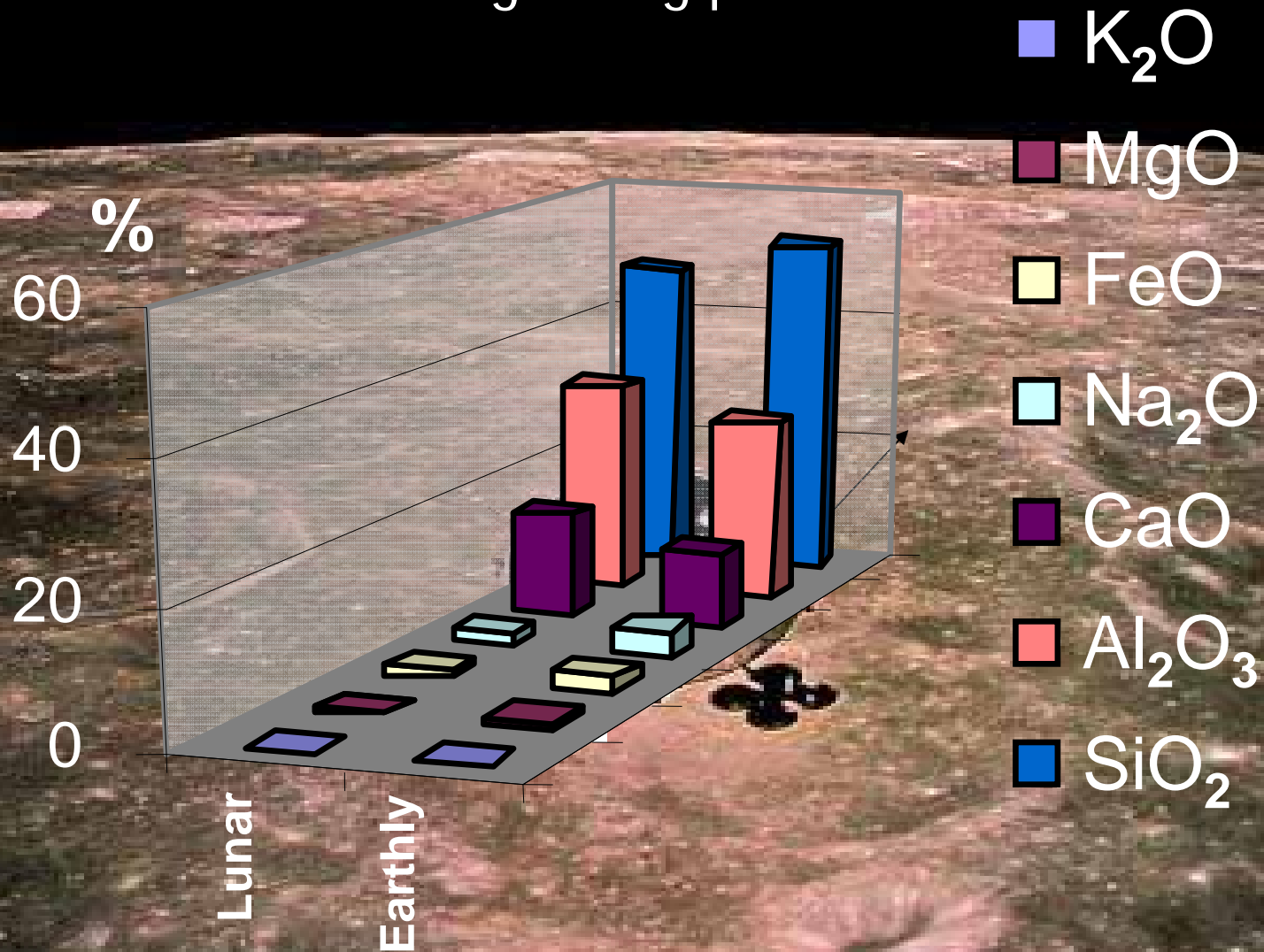
THE PLANTKORD

a laboratory prototype of plant cultivating chamber with the supply systems



1 - a locker-based facility with an experiment hardware and facility infrastructure;
2 - the PlantKord lids are cocked, the chambers are opened.

Lunar anorthosite is a promising substrate for growing plants





Ukrainian analogs of Lunar Rocks



Anorthosite of
Penizevichi type



Basalt



Anorthosite of
Turchynka type



Corrosion of terrestrial silicate rocks by *Paenibacillus* sp. | MBG221





French marigold, A Potential Pioneer Plant in a Lunar Base



"Marigolds".
Nina Vinogradov

- Undemanding to soil, humidity, light, etc
- Resistant to diseases and environmental stresses
- A beautiful image
- Non-stop flowering
- Medicinal plant (an anti-inflammatory, a pain-releasing, radio- and oncoprotection, etc)
- Spices
- Biopesticide
- A habitat for mycorrhizal fungi...

Tagetes erecta cv. The Moon Light



cv. Carmen



cv. Petite Harmony



T. tenuifolium



T. anisala



cv. Petite Gold



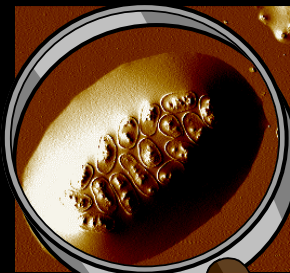
T. patula





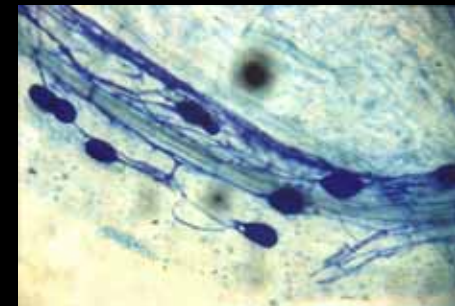
Microbial Community

Silicate bacteria could leach the plant-essential ions from lunar silicate rocks



Paenibacillus sp.

A rationally assembled consortia of microorganisms could provide homeostasis in ecosystem



Glomus intraradices

Arbuscular-mycorrhizal fungi could translocate leached ions to the plant

Model Defined Bacteria

Paenibacillus sp.

Klebsiella oxytoca

Pseudomonas sp.

P. aureofaciens

Pantoea agglomerans

Bioleaching

Plant growth stimulation

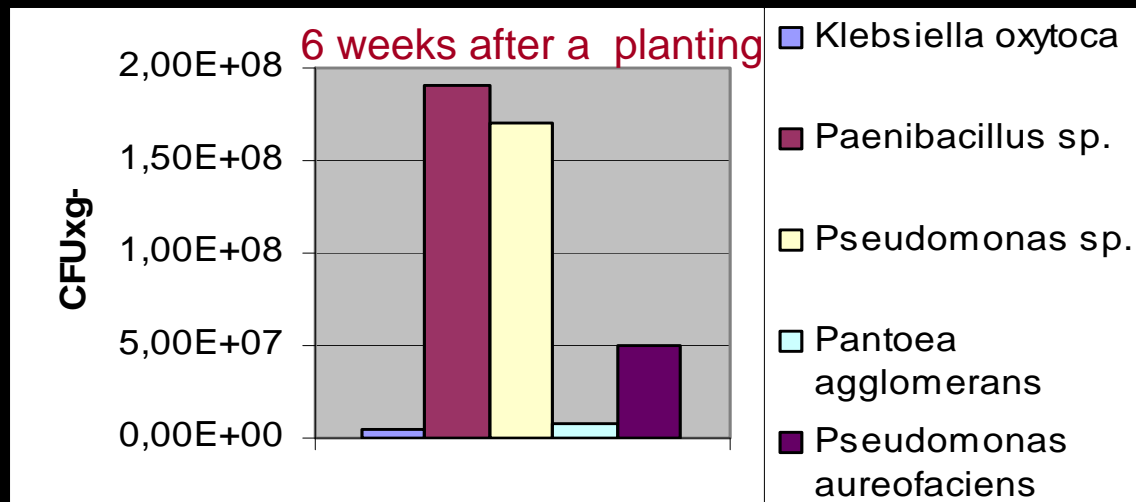
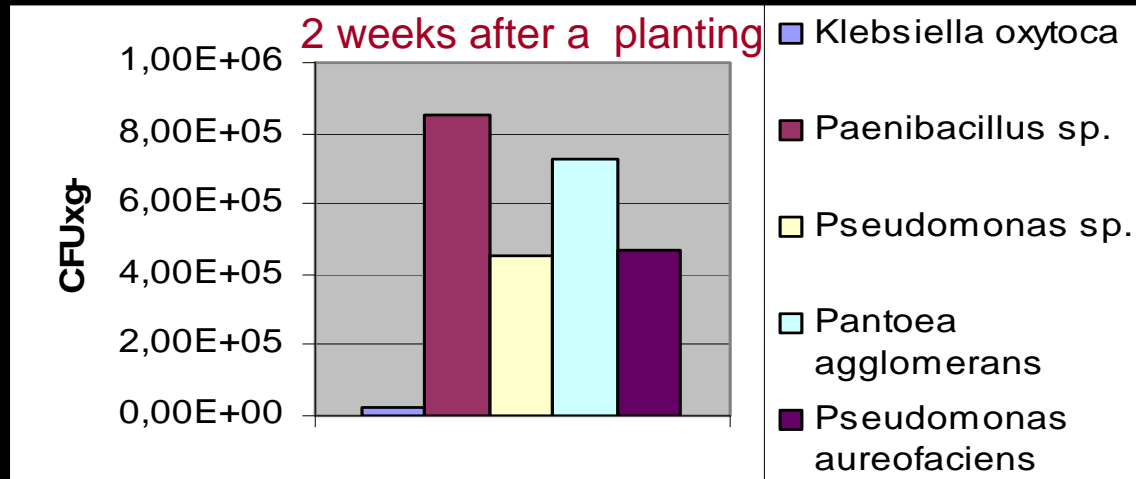
Feeding

Priming a defense system

Improving a water regime



Colonization of marigold roots by model bacteria

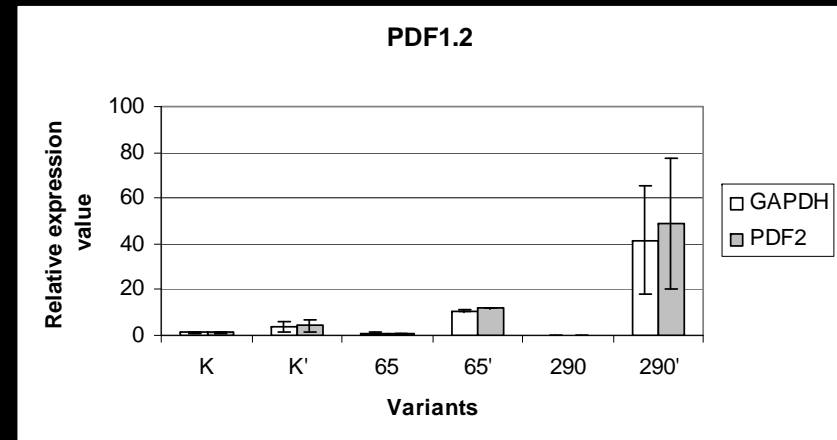
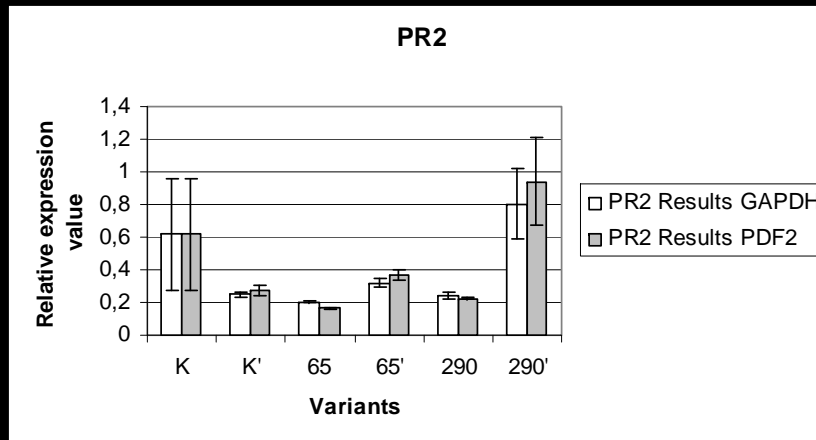




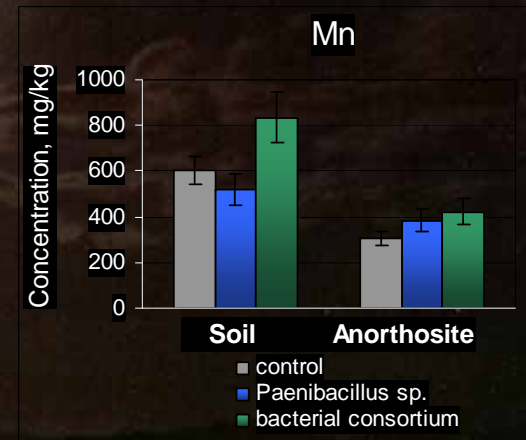
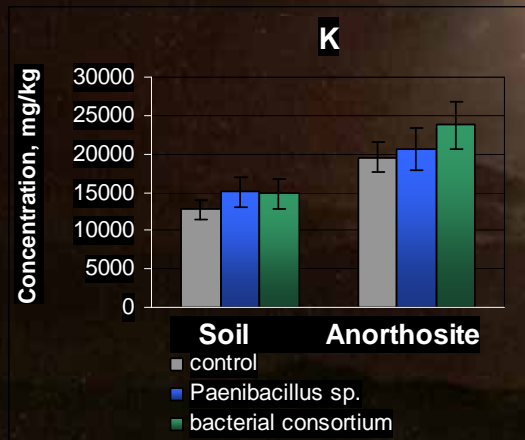
Priming of *Arabidopsis* by model bacteria leads to a resistance to disease caused by pathogen



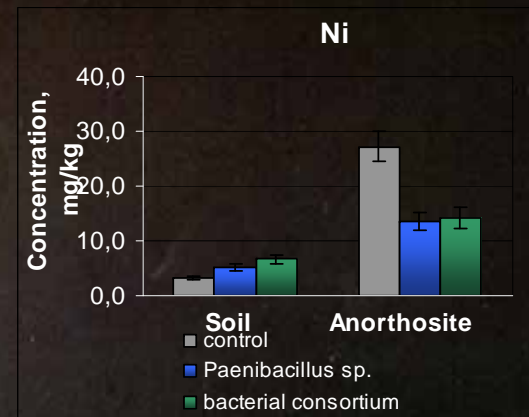
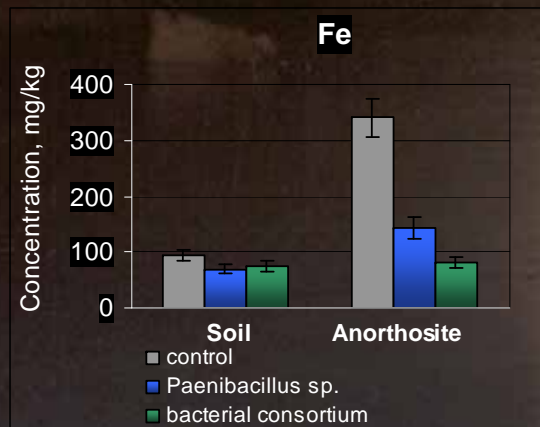
Real-time RT-PCR shows higher level-expression of defensive genes in primed plants



Microbial community enhances accumulation of some plant-essential nutrition elements (Mn, Mg, K) (mg/kg)

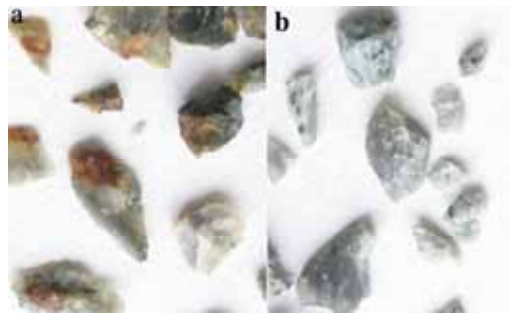


...and prevents hyperaccumulation of other elements (Zn, Cr, Ni, Fe) and therefore plant intoxication

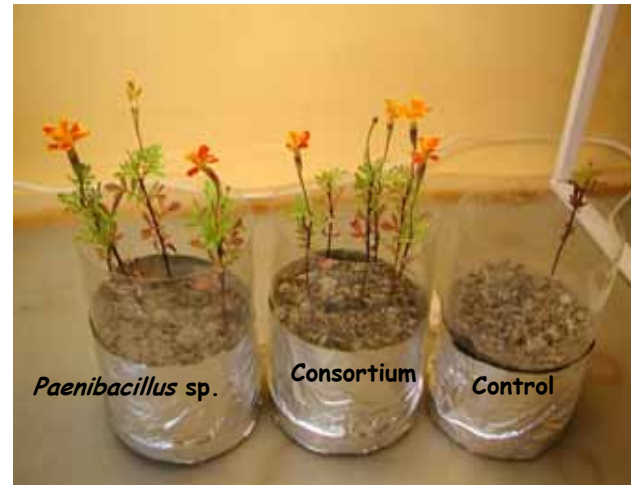


Growing pioneer plants for a lunar base

- Incrusted seeds of undemanding plants for germinating in a mineral substrate made from grinded local lunar-like material (anorthosite).
- Watering of seeds and seedlings periodically, without application of nutritional compounds:
- microorganisms provide the plant with essential minerals leached from the silicate substrate:
 Zn^{+2} Mn^{+2} Fe^{+3} Cu^{+2} Ni^{+2} Ca^{+2} SiO_3^{2-} and protect the plant from environmental stressors.



Paenibacillus corrosion of anorthosite rocks





marigolds in fragmented anorthosite of the Turchynka type.
Two variants of microcosms inoculated with suspension of
Paenibacillus sp. or a mixture of bacterial strains;



- French marigolds in fragmented anorthosite of the Turchynka type.
- Two variants of microcosms inoculated with suspension of *Paenibacillus* sp. or a mixture of bacterial strains;

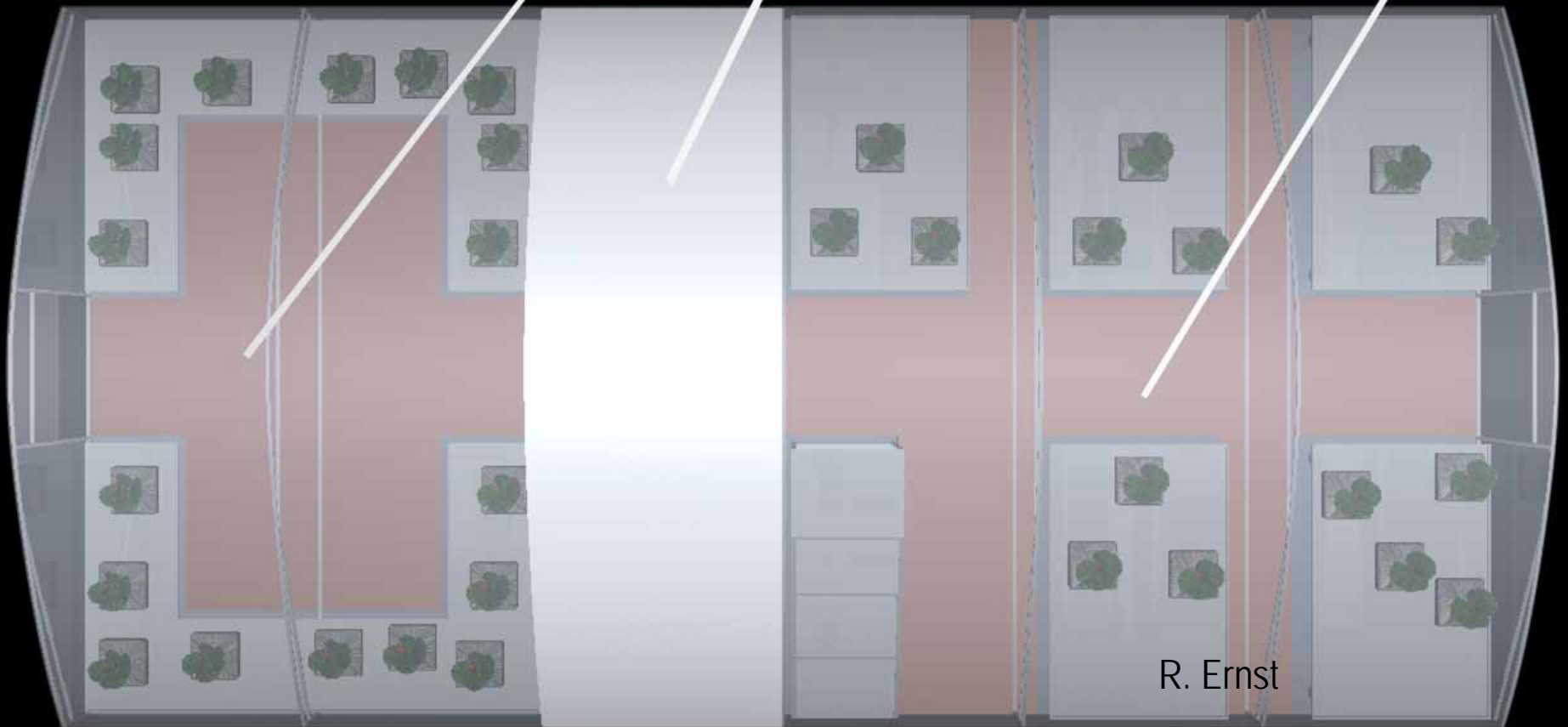
Model experiments

- Well-defined plant-associated microorganisms were used for growing French marigold (*Tagetes patula* L.)
- **anorthosite**, a substrate of low bioavailability, analogous to a lunar rock.
- **microorganisms promoted germination** of marigold seeds and supported the plant development and flowering (control plants did not blossom) under growth limiting conditions, providing the essential for growth elements, and, on the other hand,
- **protecting the plant against stressors** as seen on activity of plant enzymes and other biomolecules indicated adaptive reaction of plants grown under any stress.

Moon / Mars Environment Simulation

Automated Environment
Area

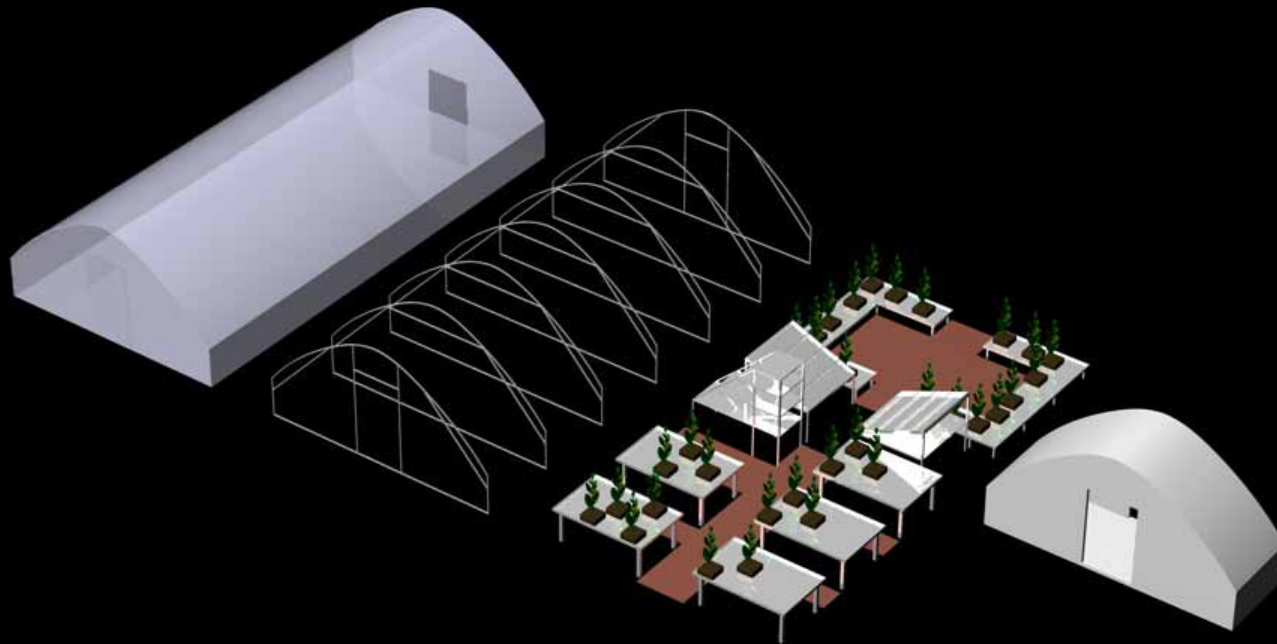
Common Research
Area



Moon-Mars green house demonstrator

Special plastic foil to control the sun light input parameters

Lightweight structure for easy handling and assembly



special equipment for each section of the greenhouse

Thermal isolation for moon and mars environment simulation

- Monitoring of environmental parameters

- CO2 concentration
- O2 concentration
- Air / Ground Temperature
- Air / Ground Humidity
- Light intensity
- UV intensity
- Fire, toxicity



Forthcoming Tasks

An including cyanobacteria and arbuscular-mycorrhizal fungi *Glomus* sp. into microbial community

A study of the marigold endophytic bacteria and their role in adaptation of plants to stresses

Bioconversion of marigold residues

Arabidopsis thaliana as a model habitat for bacterial communities

Impact of metal accumulation on marigold resistance during chronic irradiation



