



→ GREENHOUSE IN SPACE

Results and Conclusion part 2

In order to meet the challenges of long duration flights, astronauts will need to be able to meet their nutritional and dietary requirements. For the crew to be able to grow some of the food on board would enable them to be partly self-sustained. In the limited environment of an orbiting space station or even on the surface of planets this can be only achieved using special greenhouses.

Greenhouses are used on earth to control conditions of temperature, humidity and water as well as light. Ventilation is also very important – it helps prevent infections or unwanted growth such as mould.

Greenhouses are used to provide us with vegetables and fruits throughout the year especially in countries where the winter months mean changes in temperature and sunshine. This is seen very clearly for example in the Netherlands where these ‘glasshouses’ such as the one below are famous.



In order for plants to grow they need to take up essential nutrients through their roots. The soil acts as a medium for these nutrients however, soil itself is not essential to plant growth.

Space Fact

In space, organic materials such as soil are not taken on board for safety reasons and instead a sterilised medium called perlite can be used. Adding fertiliser provides necessary nutrients containing all necessary ions and compounds required to allow plants to grow.

In **Part I** the process by which green plants make food from sunlight energy (photosynthesis) is described as well as the conditions needed for seeds to germinate.

The Greenhouse in Space project investigated if plants could be grown successfully from seeds in conditions of microgravity in space. Seeds of *Arabidopsis thaliana*, a small self-pollinating flowering plant were grown in a special mini greenhouse which contained perlite growth medium with added fertiliser to give the necessary nutrients required for healthy plant growth.

From tiny seeds, *Arabidopsis thaliana* germinates to produce leaves in a rosette base from which long stems shoot to give rise to small groups of white flower heads. The flowers self-pollinate and eventually develop long fused carpels which is the fruiting body or siliqua. These turn from green to brown and dry out eventually shedding their tiny seeds to start the life cycle once again.

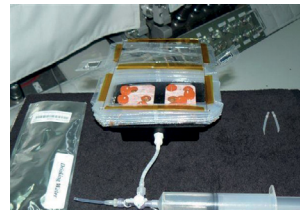


Did you know?

The space greenhouse had to be specially developed so that seeds and growth medium were kept inside a growth chamber or they would float away! Water (a precious commodity in space) was introduced with a syringe from a special drinking water bag. The whole chamber had to be kept sealed so once the plugs (in red) were removed by the astronaut, the greenhouse was ready. Some ventilation was allowed to take place as it was not hermetically sealed.

The European Space Agency set up a similar greenhouse as a control and observations were made to see how this experiment would proceed on the ground.

The greenhouse was placed inside a similar module which had the same conditions as the space Columbus module.



On the left you can see how the plant on the ground module grew after several weeks.



Schools started their experiments and grew the similar seeds in their own mini greenhouses. The students monitored their greenhouse conditions and the plan was to see how similar seeds grew in conditions of microgravity compared to earth's gravity.

Some results and observations

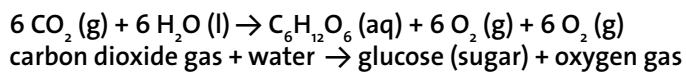
This project ran for 10 weeks. An active [Facebook](#) page enabled schools and ESA to communicate with each other over the period of the investigation.

The direct comparison between the space experiment and the ground results could not happen. The space experiment developed growth of mould like substance around the perlite where the first *Arabidopsis* plants had germinated. Due to safety reasons it was important to stop the space experiment. You can see how ESA astronaut Paolo Nespoli dealt with this by clicking [here](#).

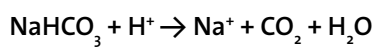
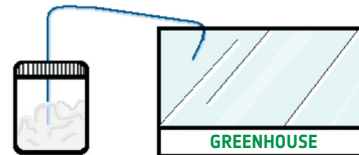


The student greenhouse

Some schools found this also happened with their experiments. Erich Kaestner school in Germany tried to give extra carbon dioxide to their seeds by using a mixture of soda tablets and acetic acid. The increase in carbon dioxide concentration increases the rate at which photosynthesis takes place, up to a point. During photosynthesis carbon dioxide combines with water to form sugar and oxygen gas.



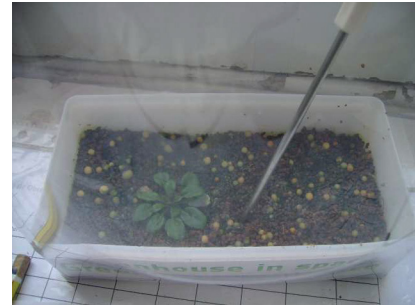
The sodium hydrogen carbonate (soda) reacts with the hydrogen in the acetic acid (vinegar) and produces carbon dioxide as one of the products.



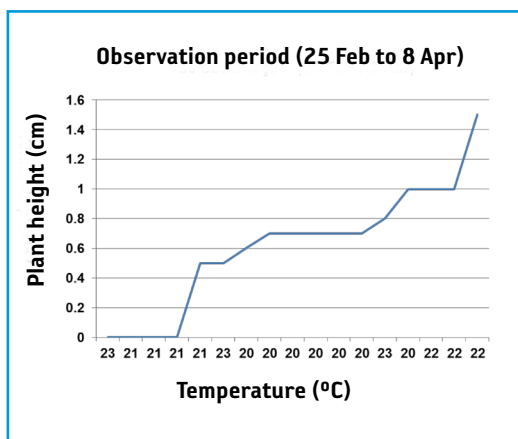
These determined students also tried to remove the growth of mould with tweezers but this still did not stop the deterioration of their plants. By growing the seeds in commercial potting soil, they found a high degree of success and concluded that the quality of perlite needed to be improved. This substitution of the growth medium was also done by other schools as well as at ESA and resulted in the growth of a full life cycle of the plants after several weeks of healthy growth. Check [this](#) Facebook page for more information.



C.E.I.P León Filipe from Madrid, Spain managed to get one good plant as did students of the secondary school Antero de Quental Ponta Delgada in Açores – Portugal who sent us their pictures.



Results were displayed in different ways:

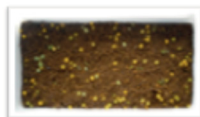
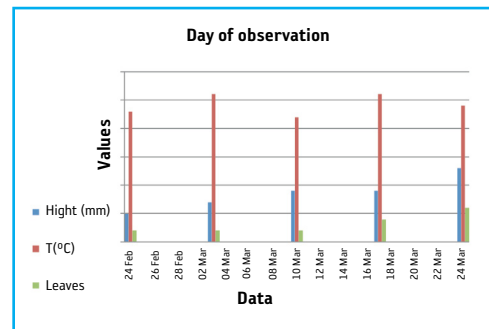


Students from Colégio Nossa Senhora do Alto from Faro in Portugal observed that after about 3 days the seeds germinated but grew slowly for the following 6 weeks till they reached a height of 1.50 cm. The temperature remained within 20-23 C. The results were not optimal and the students could not tell why the plants did not mature. This may have had to do with the fertiliser pellets not dissolving well into the perlite. Plants need to have a good supply of macronutrients to keep growing.

The building blocks of plant growth or macronutrients are:

- Nitrogen salts(NO₃ or NH₄)
- Phosphorus salts(PO₄)
- Potassium (potassium salts)
- Sulfur salts (SO₄)
- Calcium salts(calcium nitrate)

Students from EB 2/3 de Olival – Vila Nova de Gaia, Portugal found that there was a gradual increase in the number of leaves over time and this was proportional to the growth observed. The temperature in their greenhouse varied from 22-26C. Most reported growth of mould like substance which can be a result of too much watering and lack of ventilation in the mini greenhouse.



Week 3: The plant has 3 leaves and measures 7mm



Week 5: The plant has 5 leaves and measures 1cm



Week 7: The plant has leaves with red stems. On the base there was appearance of fungus.



Week 8: After the weekend of hot weather the plant has shrunk and covered with fungus. It looked very dry.

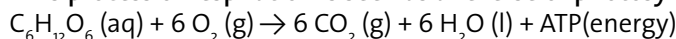
The pictures on the left were sent by EB 23 D. Duarte – Viseu, Portugal who experienced similar problems with their plants which eventually succumbed to mould growth.

Conclusions:

One of the main observations was that whilst most schools saw some Arabidopsis seeds germinate, the seedlings deteriorated within 2-3 weeks. There could be some clear reasons why for example with schools who like Alexander-Lebenstein-Realschule in Germany did get germination but left their greenhouse in direct sunlight (42 °C) and this caused the seedlings to die.

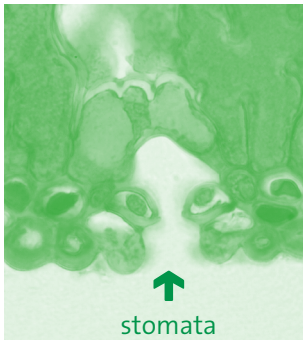
Seedlings need to photosynthesize to continue to store energy in a chemical form (sugar) to enable them to keep growing. However, plants also need to respire. (Respiration is the process when cells metabolize sugar in the presence of oxygen gas (aerobic respiration) to produce energy in the form of ATP (Adenosine triphosphate – which is the energy used by living things to carry out the processes of life.)

This process of respiration is seen as a reverse of photosynthesis:



If the external temperature rises to very high levels some plants can adapt by producing waxy surfaces on their leaves to prevent water loss. This can be seen in peas and cabbages. Some plants have adapted to produce needles instead of leaves such as cacti.

Water vapor is lost through tiny opening on the underside of a leaf surface called stomata. These openings also enable plants to take in carbon dioxide for photosynthesis. In the process of exchanging the water vapor for carbon dioxide gas water is lost from the plants in the process called transpiration.



Students from Liceo Claudio Eliano in Palestrina, Italy found that the scarcity of light and warmth lead to their seedlings lasting only 3 weeks. Light and warmth are of course essential to good plant growth. It would have been useful to place the plants under an artificial light source to ensure continuous source of light energy for photosynthesis to take place.

From Escola Secundária Antero de Quental (ESAQ) Ponta Delgada, Açores in Portugal the children managed to get one really good plant from their greenhouse even though all the seeds did not germinate. It shows the classic rosette base.

The Portuguese school Abel Salazar in Matosiños tried various means of getting the seeds to germinate. They planted some seeds in gelatine which died soon after germination; some seeds were sown in peat which germinated slowly. Finally they were able to find a suitable compost where the seeds germinated to the full lifecycle.

After experiencing a poor plant growth in February and concluding that the low temperatures and water retention of the perlite were responsible, the students from the Don Carlo Martino school in Italy decided to not give up. They re-planted their seeds in early April using moist soil. By carefully managing the conditions of watering and temperature their plants produced flowers within the first month of growth and by mid-June had their first seeds. By the end of their experiment their mature plant had 58 leaves and 25 flowers and the temperature in the greenhouse was 28 degrees.



For successful growth plants need to have water, sunlight and carbon dioxide. In a greenhouse you can control temperature and humidity changes by adjusting the conditions inside but you could still end up with problems from unwanted fungi and mould. This can often be caused by too much water and not enough ventilation. Students who participated in the Greenhouse in Space project explored various methods to test what could have led to the life cycle of their plants not being completed. By examining changes in growth medium, adding extra nutrients and even trying different types of greenhouses they tried to come up with hypotheses which could explain the low yield of plant growth. The 'space experiment' triggered several schools to put their scientific hats on and they continued to explore how to get their seeds to grow and mature.

Final thoughts

Plant growth experiments have been part of Space programs for a long time. Plant experts will continue to explore how astronauts can sustain themselves on long term missions by being able to grow some of their food.

The **Mars500** crew were our 'space gardeners' for 17 months. They carried out the same experiment as did Paolo Nespoli did on the ISS. They managed to grow their seeds to maturity as well as harvesting new seeds.



Their results are summarised by Romain Charles – one of the crew members:

*“We started the **Greenhouse in Space** experiment with 4 small greenhouses on the 17th of February 2011. We sowed a total of 36 seeds. After one month, only 5 sprouts appeared in 2 of the greenhouses. Then I took the decision to prepare the 2 other greenhouses with a new soil and 16 new seeds. After a few weeks, we had a total of 7 different plants but some of them were already dying. After 12 weeks (3 months), the pods of the only surviving plant opened and I could harvest its seeds. I prepared a new greenhouse (new soil) for the seeds newly produced to check if our production was sustainable. Unfortunately, after 3 weeks, no sprout appeared.”*

You can also follow their results on [Facebook](#).

To learn more about how ESA is investing in research for preserving and growing food for long flights, as well as valuable technology for future food supplies on Earth, where climate change and population growth are global challenges check out the [DVD Feeding our Future- Nutrition on Earth and in Space](#). to carry out the processes of life.