Astrofarmer: how to grow plants in space

Investigate the factors affecting plant growth and devise a plan for growing plants on the Moon.

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The extreme conditions of space pose many challenges for cultivating plants on the Moon.

By Keith Hardie and Cátia Cardoso

When we think about space exploration, farming and agriculture are not often the first things that come to mind. Although they have been commonplace in human civilisation for millennia, these essential activities are fast becoming an integral part of research for enabling space exploration. Currently, the only human outpost in space is the International Space Station (ISS), which is supplied with air, food and water from Earth. Each astronaut needs approximately 1 kg of oxygen, 1 kg of dehydrated food and 3 litres of water per day. Providing these supplies for all astronauts on board the ISS is costly and impractical for long space missions. If humanity is to explore further into the cosmos, plants will have to be grown in flight – as a food source and more.

Growing plants in space

In space, the conditions required for plants to grow (such as water, light, nutrients and suitable temperature) are difficult to meet. This makes growing plants in space a challenging

REVIEW

- ✓ Plant growth
- ✓ Conditions in space
- ✓ Experimental variables
- ✓ Ages 11–14 and under

This enlightening article combines two areas of science to create an interesting project for young students. In the set of activities, students understand the factors that affect plant growth and relate these to growing plants in space. All activities are easy to conduct and could be a good basis for understanding control variables in experimental design. The article is very useful and can be used for both upper elementary and lower secondary levels.

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– but not impossible – task. In 2015, crew members of the ISS Expedition 44 had their first taste of space-grown food when they harvested a red romaine lettuce grown as part of NASA's Veg-01 plant experiment. Since then, scientists have been researching novel ways of growing other plants in space.

When choosing which plants to grow, a variety of factors are considered – such as dietary value and yield. Two prime candidates are potatoes and dwarf wheat. Both are carbohydrate-rich foods with high calorific content, so they can help provide astronauts with enough energy to sustain them throughout a long mission. They are also robust plants that are adaptable to most conditions on Earth and provide a high yield without taking too much space to grow.

A self-sustaining system

Plants are useful in space not only as a food source: astronauts are also hoping to use plants to create a self-sustaining circuit to supply astronauts with all the oxygen, water and food they need – without any resupply from Earth. For over 25 years, the European Space Agency (ESA) has been working towards this goal with its Micro-Ecological Life Support System Alternative programme (MELiSSA). The project seeks to perfect a life support system that could be flown to space. Human waste products (such as urine and exhaled carbon dioxide) would supply plants with the essential ingredients for growth, and in turn the plants would provide oxygen and food for humans, as well as filtering waste water. This area of research also has the potential to create methods for more sustainable food production on Earth.

Conditions for plant growth

In the following activities, students learn about the basic elements that plants need to grow. After completing activities 1–3, students apply what they have learned about plant growth to activity 4, in which they explore how to grow plants in space – a real-life challenge facing scientists today.

The activities use simple household materials and are suitable for students aged 8–12. The procedures require a number of small pots or containers: we created these from old plastic bottles by cutting off the bottom third of the bottle and using this as a pot.

Activity 1: Do plants need light?

Working in groups of two to four, students investigate how cress grows in different light conditions: constant darkness and the normal day-night cycle. It takes 30 minutes to complete the hands-on part of this activity and approximately one week for the cress to grow after planting.

Materials

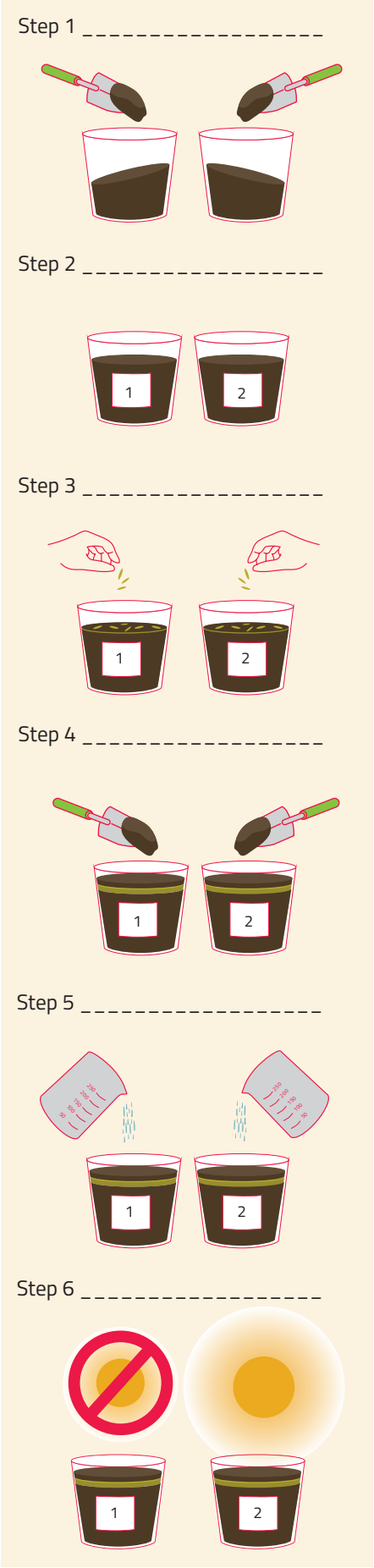
Each group needs:

- Cress seeds
- Two identical pots or containers
- Potting soil
- Small trowel or spoon
- Beaker or measuring cup
- Cardboard box or a dark cupboard
- Self-adhesive labels
- Marker pen

Procedure

Instruct the groups as follows:

1. Using a small trowel or spoon, fill the two pots with potting soil, leaving about 1 cm of space at the top of each pot.
2. Number the pots 1 and 2 using self-adhesive labels and a marker pen. Label the pots with your names so that you can distinguish them from other pots later.
3. Scatter 10–20 cress seeds over the soil in each pot, ensuring that you add roughly the same number of seeds to each pot.
4. Cover the cress seeds with some extra soil.
5. Fill a beaker or measuring cup with water. Add roughly the same amount of water to each pot, ensuring that the soil is damp.
6. Place pot number 1 in a cardboard box or dark cupboard, and place pot number 2 near a window where it will be exposed to sunlight.



ESA

Procedure for activity 1, which explores whether plants need light

ESA

Two pots of cress, planted in the same type of soil and with equal amounts of water. The pot on the left was placed in darkness, while the pot on the right was placed in sunlight.

7. What do your students predict will happen, and why? What will happen if a plant doesn't receive sunlight? Ask them to write and/or draw their predictions in a workbook.
8. Leave the cress to grow for approximately one week. It should not need more water during this time. After this time, students can retrieve their pots. What differences do they observe between the two pots in each group?

Discussion

Students will observe that cress grown in the dark has white stems and yellow leaves, in contrast to cress grown with a normal day-night cycle, which has light green stems and bright green leaves. This is because in the absence of light, plants do not develop any chlorophyll – the pigment that gives plants their healthy green colour. The cress grown in the dark should also be noticeably taller, having used the energy stored in the seeds to accelerate their growth in search of light.

Compare your students' predictions with their results, and discuss some of the following questions:

- Which plant is healthier, and why?
- How important is light for the healthy growth of plants?
- Do plants need light to germinate?
- Do plants need light to grow after germination?

Activity 2: Do plants need soil?

As a whole class, students plant radish seeds in different materials to determine which are best for growing plants. The hands-on part of this activity takes approximately 30 minutes, and there is a waiting period of one week.

Materials

- 16 radish seeds
- Eight clear pots or containers
- Small trowel or spoon
- Beaker or measuring cup
- Liquid plant food
- Cling film
- Self-adhesive labels
- Marker pen

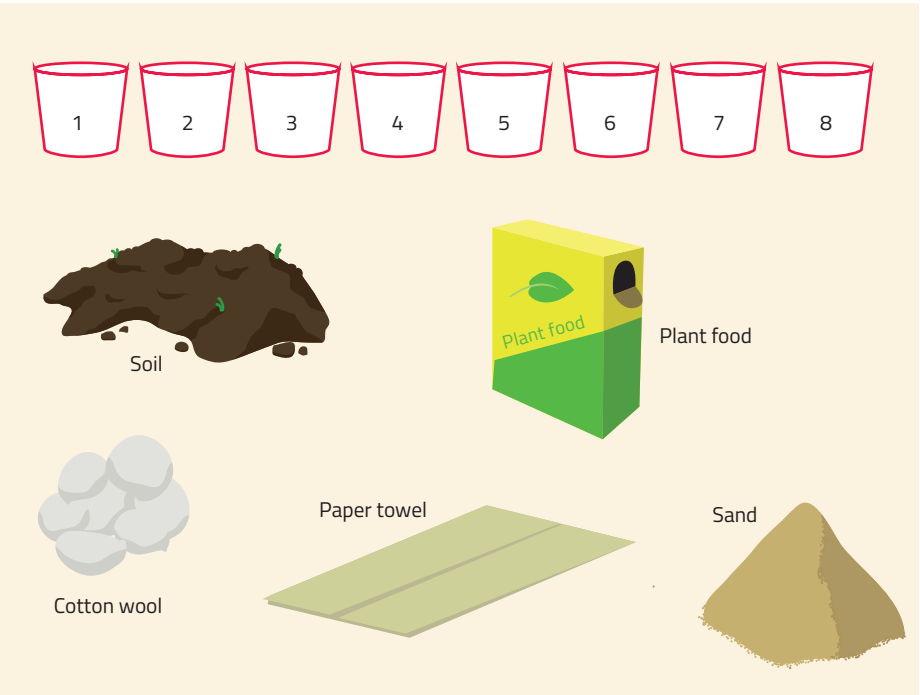
The following materials, each to fill two pots:

- Soil
- Sand
- Cotton wool
- Paper towels

Procedure

Ask individual students to carry out different steps in the following procedure:

1. Number the pots 1–8 using self-adhesive labels and a marker pen.
2. Using a small trowel or spoon, add soil to pots 1 and 2.
3. Add sand to pots 3 and 4.
4. Place cotton wool in pots 5 and 6.
5. Scrunch up the paper towels into balls and add them to pots 7 and 8.
6. Fill a beaker or measuring cup with water. Add roughly the same amount of water to pots 1, 3, 5 and 7, ensuring that the material is damp.
7. Fill the beaker again with water, and add the liquid plant food. Add the solution to pots 2, 4, 6 and 8. Ensure that you add roughly the same amount of liquid as you added to the pots in the previous step.
8. Add two radish seeds to each pot and place cling film over the top.
9. Place all the pots near a window, i.e. in identical conditions.
10. What do your students predict will happen? Will the plants grow in all four materials? In which pot will the plants grow best? How might liquid



ESA

Materials for activity 2, which investigates whether plants need soil

NASA

Astronauts plan to grow food on future spacecraft and other planets to enable self-sufficient space exploration.

plant food affect plant growth? Ask them to write and/or draw their predictions in a workbook.

11. Leave the plants to grow for one week before presenting the pots to your students. How has each plant developed?

Discussion

Students may be surprised to find that the seeds germinate in all eight pots. This is because seeds already contain some nutrients that allow the plant to begin growing. If the substrate contains nutrients, the plant will continue to grow. Nutrients are naturally present in soil, but for other materials (such as sand, cotton wool and paper towel) they can be added, for example in the form of liquid plant food. In the absence of added nutrients, the plant grows more slowly and eventually stops growing when the nutrient supply stored in the seed is depleted. This is why the radish seeds do not grow well in the pots with sand, cotton wool or paper towel without plant food.

The radish seeds usually grow best in cotton wool with the plant food mix. This is because cotton wool is more effective at holding water than soil or the other substrates, and because the plant food provides all the necessary nutrients for the plant's initial development. If the plants were grown for a longer period, soil would provide the best base for their roots to expand, giving support and stability to the plant shoots.

Compare your students' predictions with the results and discuss some of the following questions:

- What are the advantages and disadvantages of growing plants without soil?
- Which pot was best for growing plants and why?
- Do plants need soil to germinate?
- Do plants need soil to grow?

Activity 3: How do plants transport water?

To investigate how water is transported within plants, students observe how flower petals change colour when dye is added to plant water. The procedure can be completed by small groups of 2–4 students or as a classroom demonstration. It takes approximately 15 minutes to complete the hands-on part of the activity and one day for the effects of the experiment to become visible.

Materials

Each group needs:

- Two white flowers without roots (cut at the stem)
- One white flower with roots intact
- Three clear pots or containers
- Red or blue food colouring
- Spoon

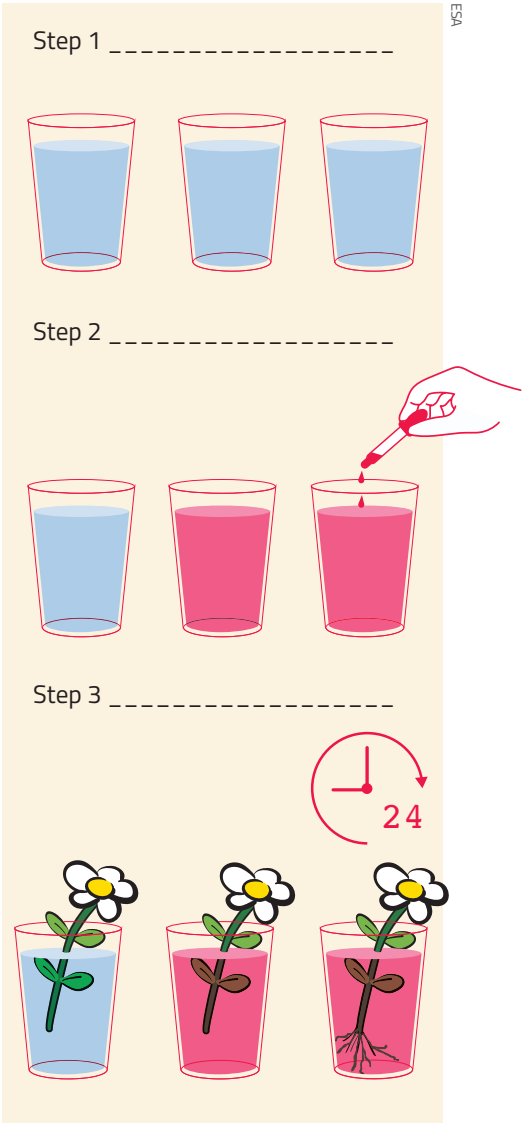
Procedure

Instruct the groups as follows:

1. Fill the three pots with water.
2. Add food colouring to two of the pots and stir using a spoon.
3. Place one of the two flowers without roots in a pot with food colouring, and the other in the pot without food colouring. Place the flower with roots in the other pot containing food colouring.
4. What do your students predict will happen, and why? Will both flowers placed in coloured water change colour? Ask them to write and/or draw their predictions in a workbook.
5. Leave the flowers for one day before presenting the results to your students. What has happened to each flower?

Discussion

Students will observe that the flower without roots changes colour from the



ESA

Procedure for activity 3, which looks at how water is transported in plants

food colouring, especially along the edges of the petals. This is because plants transport water through their stem to other parts of the plant. The flower with roots, however, does not change colour from the food colouring. The roots act as a filter, preventing the food colouring from being transported to the rest of the plant. As a result, there is no colour change.

Compare your students' predictions with the results, and discuss some of the following questions:

- Why did the flower with intact roots not change colour?
- What was the purpose of adding one flower to a cup containing only water?
- Is water essential for plants?

Activity 4: What do plants need to grow in space?

In teams of three or four, students apply their knowledge from the previous activities to devise a strategy for growing plants on the Moon. Students are provided with a fact card about the Moon to help them consider the particular space environment.

Materials

Each group will need:

- Moon fact card[w1]

Procedure

Instruct the groups as follows:

1. Read the fact card to learn about the conditions on the Moon, such as its day-night cycle and temperature.
2. Consider the factors that plants need to grow. How will the plants access light, water and nutrients on the Moon?
3. Devise a plan for growing plants on the Moon, such as building a greenhouse. Can the system be self-sustaining? What type of plants would grow best, and why?
4. Select one person from the group to explain the strategy to the rest of the class.

Moon fact card, used in activity 4 to devise a plan for growing plants in space

Discussion

One of the first challenges to growing plants on the Moon is the lack of liquid water and nutrients. Water is not readily available in rivers and oceans as it is on Earth, and lunar soil does not contain the nutrients required for growing plants. Students could suggest using a hydroponic system to overcome this challenge: plants are grown in a water-based, nutrient-rich solution without the need for soil. Water could potentially be sourced from surface ice near the Moon's north and south poles, which under certain conditions could be converted to liquid water.

Another challenge is the Moon's day-night cycle. One day on the Moon lasts approximately the same time as four weeks on Earth, so plants would need to adapt to two weeks of daylight and two weeks of darkness, or be placed in a light-controlled environment. This environment would need to be temperature-controlled to counteract extreme temperature variations. What's more, there is virtually no atmosphere on the Moon so plants would need to be kept in a pressurised container filled with gases. Without an atmosphere for protection, the container would also help safeguard plants from space radiation.

To be sustainable, the container should have a system for recycling gases and water.

Acknowledgements

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Web reference

w1 The Moon fact card is available to download from the *Science in School* website. See: www.scienceinschool.org/2020/issue49/spaceplants

Resources

Further resources for learning about plants in space are available on the ESA website:

'Astrofarmer' explores the factors that affect plant growth. See: www.esa.int/Education/Teachers_Corner/Astrofarmer_-_Learning_about_conditions_for_plant_growth_Teach_with_space_PR42 or use the direct link: https://tinyurl.com/y5e6v733

'Astrofood' investigates the different components of plants and potential future space foods. See: www.esa.int/Education/Teachers_Corner/Astrofood_-_Learning_about_edible_plants_in_Space_Teach_with_space_PR41 or use the direct link: https://tinyurl.com/y4vnxyoz

'Astrocrops' studies one full growth cycle for different plant species to understand germination and plant growth. See: www.esa.int/Education/Teachers_Corner/Astro_crops_-_Growing_plants_for_future_space_missions_Teach_with_space_PR43 or use the direct link: https://tinyurl.com/y48znwrl

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