**Amazing Plants Poster - Teaching Notes**

**Introduction**

All too often, plants are relegated to a ghetto of photosynthesis, yet plants provide us with dramatic illustrations of how to overcome all the challenges of life on Earth, from reproducing and responding to respiring, obtaining nutrients and excreting. Add in communication systems, adaptions and a key role in ecosystems, and plants are ready-made for a starring role in biology lessons for 14–16 year-old students. As absorbers of carbon dioxide, providers of oxygen, producers in most food webs and chains, the basis of human food security, and providers of an almost endless supply of recreational and medicinal drugs, plants are a gift to biology teaching.

Plants and their adaptations make perfect attention grabbers - as lesson starters, illustrations of biological principles, plenary starting points or revision aids. What’s more, there are no ethical issues with keeping plants in the classroom, experimenting on them, or dissecting them. Use this poster to help you give plants the starring role they deserve in your lessons for 14-16 year old students, beyond the constraints of traditional plant-based curriculum areas.

These teaching notes give additional information about the contexts on the Amazing Plants poster and provide you with some suggestions for curriculum links and additional activities.

In addition there is an accompanying PowerPoint presentation containing photos of these contexts so that you can further bring these real-world examples to life for your students.

Other posters in the series:

* Awesome Plants – aimed at 11-14 year-old students
* Incredible Plants – aimed at students aged 16+

**Breeding bacteria**

Legumes such as clover, peas and beans have nodules on their roots full of bacteria producing the organic nitrogen compounds the plants need to grow. In exchange they get nutrients from the plant. To select the best bacteria, colonies producing lots of nitrogen compounds are rewarded with extra sugar-rich sap. Plant scientists have discovered that the plants train the bacteria in their root nodules. Colonies producing lots of nitrates are rewarded with extra sugar-rich sap. Less productive bacteria are starved and die off. The plant only shares its sugar with the bacteria providing the most benefits – selective breeding in action!

Students often regard plants as passive organisms – this amazing piece of unfolding science shows clearly that they are not. Based on relatively recent research, evidence suggests that some leguminous plants selectively breed the most productive strains of nitrogen compound producing bacteria by controlling the food supply. This can be a revelation for students. Some leguminous plants are selective in the flow of sugar-rich sap that they supply to different root nodules. Put simply, the plants feed the microorganisms that make greatest quantities of organic nitrogen compounds and so give them the most benefit, and cut off supplies to nodules that under produce, killing off the under-performing colonies. The intrigue deepens when you investigate the evidence – some colonies ‘cheat’, producing nitrogen compounds for the plant until a good food supply is established and then only make enough for themselves… This material will certainly make students think, whether used to add a level of interest and challenge to work on the mineral requirements of plants and the nitrogen cycle, to illustrate the principles of adaptation and natural selection or to raise questions about what we mean by selective breeding.



Most farmers who plant leguminous plants like these, to add nitrates to their soil, have no idea about the life and death struggles going on in the root nodules as bacteria and plant try to outwit each other.

**Curriculum links include*:***

* ***cycles in Nature*** *– highlighting the role of the nitrogen cycle and nitrifying bacteria*
* ***the role of leguminous plants in ecosystems*** *– how these plants add nitrogen compounds to the soil through the microbiome of the root nodules*
* ***mineral requirements in animals and plants*** *– this makes a good introduction to the importance of mineral nutrition in all organisms, not just plants. For plants, photosynthesis is not enough, nitrogen compounds (and other minerals) are needed to make proteins and other compounds.*
* ***selective breeding*** *– carried out by humans for many thousands of years – but by plants for longer! Introduction to the idea of selective breeding for the best plants, animals or bacteria, or a useful summary/discussion area at the end of the topic*
* ***adaptation, natural selection, and evolution*** *– a unique and unusual example of adaptation andl selection*
* ***gene switching and epigenetics*** *– the development or removal of transport vessels to change the food supply of bacteria is an example of epigenetics and gene switching in response to environmental change.*

**Suggested activities:**

* Students make a story board of the sequence of events as a clover plant grows, resulting in the most effective bacteria-filled nodules.
* SAPS activities for KS4 linked to selective breeding -<https://www.saps.org.uk/teaching-resources/resources/1458/selective-breeding-and-genetic-engineering/>
* SAPS activities for KS4 linked to natural selection e.g.
<https://www.saps.org.uk/teaching-resources/resources/694/adaptation-natural-selection-and-winged-fruits-science-club-activity/>

**Cleaning up explosives**

Huge areas of land around the world are contaminated by toxic explosives from military activities, mining and construction. This land can be too dangerous to even walk on. Scientists have produced gene edited plants can remove the explosive residues, using them like a fertiliser for their own growth.

Bioremediation – using microorganisms and plants to remove pollutants from soil or water – is a growing field of biotechnology. The poster shows a fascinating example, where the problem is the result of human actions, but the solution is an elegant demonstration of what can be achieved both within plants themselves and by biotechnology. This cleaning of explosives from the soil and the conversion of explosive residues to useful compounds within the plants demonstrates both the power of plants, and of plant scientists. Scientists identified microorganisms that have evolved the ability to breakdown the explosive RDX, enabling them to harvest the nitrogen it contains as a source for growth. The scientists then transferred the genes responsible into switchgrass (*Panicum virgatum*), enabling these plants to also degrade RDX. They developed seed balls to drop from aircraft onto soil too dangerous for people to walk on. Trials so far have been successful, with the gene edited plants absorbing and breaking down explosive residues, using the products within their cells and making the soil safe again.

**Curriculum links include*:***

* ***negative and positive human interactions with the environment*** *– we created the problem of explosives and explosive residue in soils, but also found ways to recruit plants to solve it.*
* ***genetic variation in populations of a species –*** *knowing some bacteria have the genes to break down explosives is intriguing in itself, before inserting them into plants.*
* ***using gene technology to solve environmental problems*** *– this provides an unusual example of the power of gene editing, making a change from looking at using the technology to get bacteria to make insulin/improve crop yields/produce drought- resistance etc*.
* ***the potential of modern biotechnology -*** *including some practical and ethical considerations, can be used alongside examples of gene editing in other animals and people.*
* *Also links to chemistry curriculum on environmental impacts of products and pollution*

**Suggested activities:**

* Students compare the ‘selective breeding’ of the legumes with the ‘gene technology’ of the phytoremedial project
* Discuss the different specialisms required – including microbiologists, plant scientists, chemists, genome editors, engineers to develop the seed balls that had to be dropped on the contaminated soil etc. as an example of the multidisciplinary approach widely used in modern science.
* SAPS activities for KS4 linked to genetic modification

<https://www.saps.org.uk/teaching-resources/resources/822/phytoremediation-and-phytomining-a-practical-activity/>

<https://www.saps.org.uk/teaching-resources/resources/1355/gene-technologies-the-science-behind-the-poster/> (16+ but could be used with able students)

**Drugs in nectar**

Spiked drinks are a human problem – but spiked nectar is common in the plant world too. Some orchids add alcohol and opioids to their nectar. When a wasp drinks the nectar it becomes too drunk and drugged to clean off the pollen-filled pollinia that has become attached to its head. The drunk wasp transfers the pollen to another plant, helping the orchid reproduce. Many plants add a dash of caffeine to their nectar to improve the memory of visiting bees.

The idea of plants producing drugged nectar is completely contrary to the normal perception of nectar/flowers/honey as pure and healthy! In the case of the helleborine orchid on the poster, the story is more complex than the headline: it may be yeasts and bacteria living in the nectar which produce ethanol although there is evidence that the plants may also make their own. They also produce opioids which are added to the alcoholic nectar. The final flourish is that the orchid produces a communication compound that mimics the scent of a cabbage under attack by caterpillars. This attracts the wasps which normally attack and parasitise the caterpillars on the cabbages. Once they come to the orchids, they are attracted by the sweet, drugged nectar. Wasps are normally fastidious, regularly cleaning themselves, but their intoxicated state means they cannot remove the pollen-filled pollinia from their heads. They become effective pollinators for the orchids when they visit another plant for more drugged nectar. This, along with awareness of the caffeinated nectar that helps bees remember where flowers are, encourages students to re-evaluate the world of plants. A great story for use in several curriculum areas:

**Curriculum links include*:***

* ***plant reproduction*** *– the importance of insect pollinators and the adaptations of plants to ensure that they are pollinated*
* ***animal behaviour and chemical communication systems******–*** *the communication systems used between plants, and between plants and animals such as insects, as examples of the importance of non-nervous communication and the responses of insects to their environment*
* ***interdependencies between organisms in an ecosystem*** *– the interdependencies between plants and insects both in terms of pollinators*
* ***adaptations and natural selection*** *– adaptations for pollination by particular organisms, how complex interdependencies evolve over time through natural selection.*

**Suggested activities:**

* SAPS activities for 14-16 linked to flowers, pollination and adaptations e.g. films on pollen and pollination, the basic structures of flowers, investigation how plants use colour to attract pollinators, caffeine in nectar.

<https://www.saps.org.uk/teaching-resources/resources/681/films-on-pollen-and-pollination/>

<https://www.saps.org.uk/teaching-resources/resources/547/the-structure-of-flowers/>

<https://www.saps.org.uk/teaching-resources/resources/846/investigating-how-plants-use-colour-to-attract-pollinators-introducing-stem-careers/>

* Human food security: students research and develop presentations on the importance of pollinators, including bees, wasps and hoverflies, for human food security, including reliable evidence on threats to pollinators and potential solutions to the problems.
* A short article about beese and caffeine: <https://www.sciencedaily.com/releases/2021/07/210728111319.htm>
* Video of wasps drinking nectar from helleborine orchid and being visibly affected: <https://www.youtube.com/watch?v=NOyIwKZl4dU>

**Can trees save the world?**

Scientists are increasing the carbon dioxide levels around full-size trees and measuring the effects. Can trees really soak up (some of) our excess CO2 or are there limiting factors?

Increasing levels of carbon dioxide and other greenhouse gases in our atmosphere, global heating and the climate change that is resulting are all topics high on the agenda of many 14-16 year old students – and on exam papers too. This element of the poster introduces a fascinating project for students to investigate and gives you and your students access to real-time data on the impact of carbon dioxide levels on trees. BIFoR (Birmingham Institute of Forest Research) is the site of a scientific experiment on a massive scale. Using massive scaffolding structures, scientists are changing the carbon dioxide concentration around trees growing in different parts of the forest and monitoring how this affects their growth in different ways. Are trees really the answer to rising carbon dioxide levels? Will trees soak up excess carbon dioxide and grow better than ever or will there be problems in the long term? These questions, and this part of the poster, provide opportunities to both challenge students and to give them real data to manipulate and consider.

**Curriculum links include*:***

* ***what plants need to survive and grow (including photosynthesis)*** *– carbon dioxide from the air, light, water and dissolved mineral ions from the soil, and the impact of an excess of CO2*
* ***stomata and their role******in******transpiration*** *- the importance of stomata in gas exchange and the impact of raised carbon dioxide levels on stomatal opening, transpiration and the movement of water from roots to shoots. This can be followed up with consideration of the impact of prolonged stomatal opening on water demand etc.*
* ***data analysis and drawing conclusions*** *– this provides students with real data from a long term, large-scale investigation and presents opportunities for exploring issues around data collection, analysis and use in the real world*

**Suggested activities:**

* SAPS activities for 14-16 students linked to photosynthesis and water and mineral requirements, stomata and stomal opening, transpiration, and the impact of carbon dioxide levels on photosynthesis, plant growth, stomatal opening and transpiration e.g.
* <https://www.saps.org.uk/teaching-resources/resources/1220/investigating-photosynthesis-and-respiration-using-a-carbon-dioxide-probe/> <https://www.saps.org.uk/teaching-resources/resources/799/video-clip-leaf-structure-stomata-and-the-absorption-of-carbon-dioxide/> <https://www.saps.org.uk/teaching-resources/resources/1263/investigating-transpiration-with-a-potometer/>
* This is the website of BIFoR. Students can have a virtual tour of the site. They can link to resources where they find out about investigations into transpiration rates and sap flow, measured using a sap flow meter, and about tree growth, measured using a dendrometer. The latter two areas of the site provide data for students to download and manipulate, and questions to help them understand what is going on and what scientists are discovering.
* <https://canvas.bham.ac.uk/courses/52405> <https://canvas.bham.ac.uk/courses/52405/pages/sap-flow-meter-activity>

<https://canvas.bham.ac.uk/courses/52405/pages/dendrometer-activity>

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