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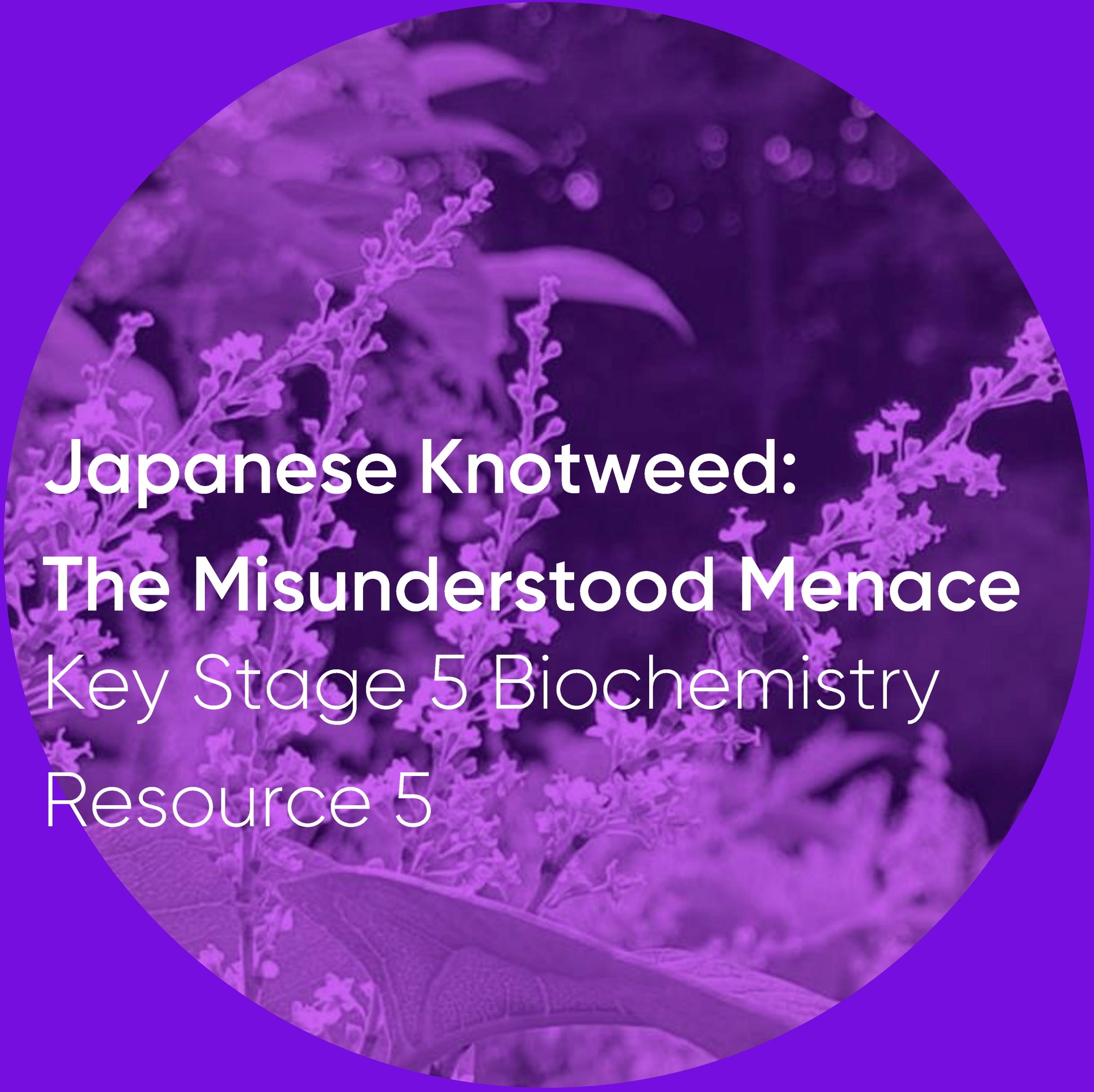

Japanese Knotweed: The Misunderstood Menace

Key Stage 5 Biochemistry

Resource 5

2019

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Resource Five Overview

Topic	Chemical Communication
A-Level Modules	Organisms exchange substances with their environment

Objectives

By the end of this resource, you will be able:

- ✓ To understand that organisms can communicate with each other through chemical signals
- ✓ To understand that organisms can respond to these chemicals

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Context

Humans are constantly communicating with each other, through body language, speech, and social media. From infancy we sing Old MacDonald had a farm, and become familiar with the concept of animals communicating with each other through sounds. However, the communications of the quieter life on the planet, like plants and bacteria, go unnoticed. Chemicals emitted from one organism to another can act as a silent signal, simply to say 'I'm here', alert others of danger, or call for help. Plants are constantly interacting with their environment through these chemical signals.

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Section A

Introduction

Imagine the smell of freshly cut grass. What comes to mind? Carefree summer days? The primary school playing field? The smell of freshly cut grass is actually a distress signal sent out by the grass after wounding. It is warning other nearby plants to arm themselves ready for attack by insects, triggering them to produce more chemicals in defence.

Plants can use chemical signals to communicate, as well as change their external environment. These chemicals are called allelochemicals. Allelochemicals are one subclass of a group of biochemicals called semiochemicals, which are emitted from one organism to affect the behaviour of another organism. Allelopathy works between different species.

Although this phenomenon is not limited to plants, allelopathy is thought to be the driver of the success of some invasive plant species, and may play a role in weed management. Allelopathic plants interfere with their community through the release of biochemicals. They produce a subset of secondary metabolites, unrequired for their own metabolism, called allelochemicals.

These biochemicals released from allelopathic plants can affect germination, growth, survival, and reproduction of other organisms. Allelopathy is present in many plant communities. The effect of allelochemicals on the target community can be either detrimental, known as negative allelopathy. Indeed, the origin of the term is from the Greek "allelo", meaning 'each other', and "patho" meaning 'suffering'. However, allelopathy can also have a beneficial effect on its target community, known as positive allelopathy. Allelochemicals come in three categories; allomones, kairomones, and synomones. Biotic factors such as nutrient availability and abiotic factors such as temperature and pH have an impact on allelochemical production.

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Section B

Negative and Positive effects

Allelochemicals can have both negative and positive effects on both their emitter and the wider community. To differentiate between these, they have been sub-categorized into allomones, kairomones, and synomones.

An allomone is a biochemical signal which triggers a response favourable to the emitter but not to the receiver. These are primarily a form of defence.

Kairomones are a subset of allelopathic chemicals which are detrimental to the allelopathic organism but benefit the surrounding community, they are the opposite to an allomone. For example, upon wounding or herbicide treatment, water hyacinth releases a chemical attractant of both a weevil, Necochetina eichhorniae, and a water hyacinth mite, Orthogalumna terebrantis (Messersmith & Adkins, 1995).

Synomones are beneficial to both the emitter and the receiver. Plant volatiles released which attract insects can often be synomones. For example, pollinators are attracted to floral scents, allowing fertilization of plants, and food for the insects. Tomato plants release volatiles which attract species of the Trichogramma genus, which use the tomato pests Hymenopterous as their parasitic hosts. Terpenes released from damaged pine trees act as both synomone and kairomones, as they attract both the pine-feeding beetles and the beetle-targeting pteromalid hymenopterous parasites.

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Section C

Transportation Pathways

Allelochemicals are introduced by plants into their environment in a number of ways; foliar leaching, root exudation, residue decomposition, volatilization and debris incorporation into soil (Inderjit & Keating, 1999).

Foliar leaching is when rainwater passes through the canopy and causes chemicals from the leaves to leak out into the environment.

Plant volatiles act as airborne communication signals, for example the triggering of fruit ripening by ethylene, and the attraction of parasitic wasps to ward off pests like caterpillars. Bean plants, Vicia faba, release a volatile, methyl salicylate, which is repellent to aphids but attractive to aphid enemies such as parasitoids.

Evidence of underground signals have also been found. The airbourne aphid-repellent chemical, methyl salicylate, is released by bean plants, Vicia faba, upon attack by aphids. However, other adjacent aphid-free plants can be triggered to produce this repellent, despite being unaffected by aphids, so long as they are connected to the aphid-infected plants via a mycorrhizal mycelial network of fungi (Babikova et al., 2013). This aids both the signal-producing infected plant, by triggering an increase in volatile repellent production in the vicinity, and the signal-receiving aphid-free plant, by warding off an attack pre-emptively. For more about how plants can use the fungal network to communicate, see the BBC article in the further reading.

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Section D

How do plants use allelopathy?

Deep Dive

Plants use allelopathy to their advantage in a number of ways, including alteration of the soil biochemistry to suit the preferences of the donor plant, defence against insect herbivory, and kin-recognition.

Similarly to quorum sensing in bacteria, plants can recognize their own species using allelochemicals and alter their growth patterns accordingly. In one study using the annual plant, Cakile edentula, Dudley et al found an increased resource allocation to roots when groups of strangers shared a common pot, but not when groups of siblings shared a pot (Dudley & File, 2007). Dudley was also involved in a follow up study of this observed kin-recognition effect. In which a mechanism for the effect was sought. Using Arabidopsis thaliana as a model, this group investigated the role of soluble chemicals in signalling among roots. Young seedlings were treated with liquid media containing exudates from siblings, and strangers (defined as non-siblings) or only their own exudates. The exposure of plants to the root exudates of strangers induced greater lateral root formation than exposure of plants to sibling exudates. Stranger recognition was abolished upon treatment with the an inhibitor of root secretions (Biedrzycki et al., 2010).

Allelopathy can aid succession

Allelopathy has been suggested to have a role in succession (Jackson and Willemsen 1976, Quinn 1974, Gant and Clebsch 1975). Native to Asia, Japanese knotweed is a pioneer species on volcanic sites. Japanese knotweed is thought to allow succession by making the post eruption environment more favorable to other species, for more on this see Resource 1.

In primary successional stands on Mt. Fuji, researchers Tateno and Hirose, found that organic nitrogen, ammonium, and nitrate concentrations were 14, 4, and 2-fold higher, respectively, under R. japonica stands than in bare soil (Tateno and Hirose 1987). Many early successional species, like R. japonica, are known to increase soil formative processes, specifically by decreasing soil bulk density and increasing organic matter content, water content, and nutrient levels (Hirose and Tateno 1984).

Allelopathy can aid the invasive success of weeds

Japanese knotweed releases allelochemicals which can inhibit the growth of other plants. Plants which themselves produce phytotoxic compounds are also susceptible to develop resistance to allelochemicals to prevent autotoxicity through detoxification mechanisms (Inderjit and Duke, 2003). This has implications for restoration of contaminated land, suggesting that some species which are allelopathic themselves will be less susceptible to the Japanese knotweed residues left in soil.

Section E

Quorum Sensing in Bacteria

The phenomenon of plants talking to each other through chemical signals, even via fungal networks, extends further to bacteria, which use a similar phenomenon called quorum sensing to communicate.

One example of quorum sensing is exhibited in the Hawaiian bobtail squid, Euprymna scolopes. This squid is just 3 cm in length and dwells in the shallow moonlit waters off Hawaii. Rather than casting a shadow over the light of the night's sky and scaring its prey, the squid has light organs to mimic the light of the moon, and allow it to hunt at night. The light comes from a marine bacterium, V. fischeri, which live in the light organ of the squid. The production of light is called bioluminescence. This species of bacteria can also live freely and float around the sea like plankton. When the density of

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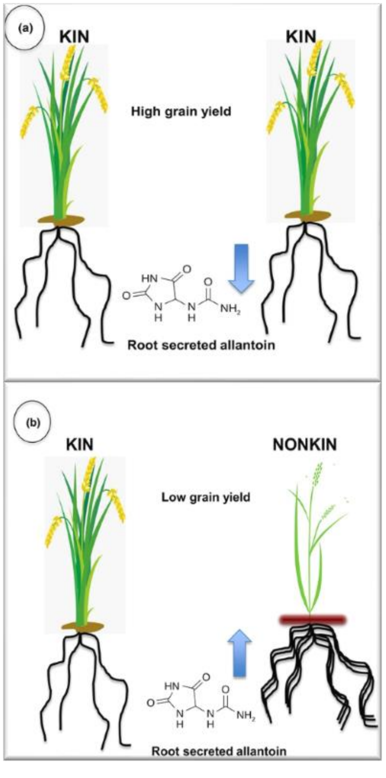
the bacteria is low, it would be a waste of energy for the bacterium to produce such a small quantity of light. However, in the light organ of the squid, where the density of bacteria is high enough that the light produced would be clearly seen, the bioluminescence is switched on. How do the bacteria know the density of bacteria of their own species surrounding them? Much like the kin-recognition observed by plants, bacteria release chemical signals to talk to each other.

Resource Five Activities

Activities

Creativity

1. Write a definition of ‘allelopathy’ in your own words.
2. Give an example of a transportation pathway which might be taken by a plant allelochemical.
3. Japanese knotweed releases allelochemicals into the soil. What do these chemicals do?
4. A bean plant, Vicia faba, is attacked by an aphid. The aphid sucks the sugar-containing sap from the bean plant’s phloem. How might the bean plant respond? Explain why this response would help the bean plant. Suggest how the growth of the bean plant may be affected.
5. Ethene, also known as ethylene, is a volatile organic compound. Suggest how it may be used commercially for bananas.
6. The diagram (left) is from a New Phytologist paper, ‘Kin recognition in rice (Oryza sativa) lines’. Look closely at the diagram; can you guess what is happening? Answer the below questions, A-E.



   a) What is the name given to this process?

   b) How do the rice plants respond differently when they recognise kin compared to a non-kin stranger?

   c) What effect does allantonin have on the roots of the non-kin plant?

   d) How might the above effect be detrimental to the non-kin plant?

   e) How might this benefit the kin-rice plants?

Link to full paper:
https://nph.onlinelibrary.wiley.com/doi/full/10.1111/nph.15296
Yang, Xue-Fang & Li, Lei-Lei & Xu, You & Kong, Chui-Hua. (2018). Kin recognition in rice (Oryza sativa) lines. New Phytologist. 220. 10.1111/nph.15296.

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Further Reading

Explore

Independent research

Watch this TED-ed video

[Can plants talk to each other? - Richard Karban]

Read this BBC article

http://www.bbc.co.uk/earth/story/20141111-plants-have-a-hidden-internet

Watch this YouTube video

[The Secret Social Life of Plants]

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