‘Save your Spuds’ Activity

Teaching notes

This activity introduces plant diseases and the different types of microorganisms that infect plants. The activity focuses on potato late blight disease; its importance and the difficulties farmers face in controlling the disease.

The main activity is the ‘Save your Spuds’ board game, where students play out the benefits and costs of growing blight resistant versus susceptible potatoes, and spraying fungicides to protect against potato blight disease.

There is also an optional extension activity, where students use resources to write a letter to a potato farmer and discuss the pros and cons of growing GM potatoes, which are resistant to potato late blight.

KS3 Biology Curriculum (June 2014) Links

This activity provides resources and activities to help teach about the following areas of the GCSE curriculum.

Health, disease and the development of medicines
Communicable disease

- Explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals and plants.
- Show understanding of how infectious diseases are spread in animals and plants: (to include a minimum of one common infection, one plant disease, and sexually transmitted infections in humans including HIV/AIDS).
- Explain how the spread of infectious diseases may be reduced or prevented in animals and plants.

Scottish Science National 5 Curriculum Links

This activity provides resources and activities to help teach about the following areas of the Scottish Science National 5 curriculum.

Life on Earth (Curriculum support notes).
5 Human impact on the environment

- A) Increasing human population requires an increased food yield. Research GM crops, monoculture and intensive farming.
- E) Biological control may be an alternative to the use of pesticides. GM crops may be an alternative to the use of fertilisers.

Scottish Higher Curriculum Links

This activity provides resources and activities to help teach about the following areas of the Scottish Higher curriculum.

Course Support Notes for Higher Biology Curriculum.
Sustainability and Interdependence

- C) Plant and animal breeding by manipulation of heredity: for improved plant crops, improved animal stock, to support sustainable food production. Investigate resistance of potato varieties to *Phytophthora infestans*.
- D) Crop protection: (i) Weeds, pests and disease populations compete with crops reducing productivity. (ii) Control of weeds, pests and diseases by cultural means. The advantages of plant protection chemicals which are selective or systemic. Protective applications of fungicide based on disease forecasts are often more effective than treating a diseased crop. Case study on the control of weeds, pests and or diseases of agricultural crops by cultural and chemical means. The use of pesticides may also result in a population selection pressure producing a resistant population.

Aims and Objectives

- To learn about the challenges associated with producing food.
- To learn about how plant diseases affect our ability to produce enough food.
- To use the ‘Save your Spuds’ Power point and board game to learn in detail about the plant disease potato late blight: its impact, how the pathogen infects, disease symptoms, disease resistant varieties, use of fungicides and effects of weather conditions.
- To evaluate the difficulties farmers face in weighing up the benefits and costs of growing blight resistant potatoes and spraying fungicides.
- Extension activity: to learn about GM technology enabling the production of blight resistant potato.

Summary of this activity

- 5 mins: Starter questions to get students thinking about plant diseases and their importance.
- 20 mins: Powerpoint presentation (Appendix 1) introduces key plant disease concepts and focuses on potato late blight disease.
- 10 mins: Students use the Potato Late Blight Information Sheet (Appendix 2) and Game Information Sheets (Appendix 3) to brainstorm what they have learnt about: potato late blight, fungicides and plant resistance to the disease.
- 20 mins: Students play the 'Save your Spuds' game.
- 15 mins: Students write Farmer Guidelines to explain what they've learnt.
- Extension: Students use resources to write a letter to a potato farmer discussing the pros and cons of growing GM potatoes, which are resistant to potato late blight.

Background Reading

Food security

Today the world is faced with a huge problem; how to produce enough food for everyone. It's not just enough to produce calorie-rich food. To be healthy we also need food to be nutritious; rich in vitamins and minerals.

Already there are approximately 900 million people living in extreme hunger and many more who are not getting enough vitamins and minerals[1]. The global population is set to rise from 7.2 billion in 2014 to 9.6 billion in 2050[2]. With an extra 2.4 billion people to feed, we'll need to grow much more food. To produce enough food, it's estimated that global agricultural production needs to increase by 60% from 2005 – 2050[3]. Food costs are already increasing; in 2008 a price spike lead to increases of 130% for wheat and 74% for rice and causing riots in 36 countries[4]. As food gets progressively more expensive, there is an increased likelihood of food riots and global unrest.

Damage by plant pests and pathogens

Currently up to 40% of crop yields are lost to pests and diseases[5]; these include insects, fungi, bacteria, viruses and other plant pathogens.

Potato late blight

Potato late blight is a devastating disease caused by the fungus-like (oomycete) pathogen: *Phytophthora infestans.* In 1845-57, *P. infestans* destroyed the staple crop of the Irish population: the potato. This resulted in the death of over 1 million people and the emigration of another million. The two million lost accounted for 25% of the Irish population at the time. The Irish population has still not recovered. The mass exodus helps to explain why there are Irish pubs and people all over the world.

Present research shows that the *P. infestans* strain (HERB-1), which caused the famine is likely to now be extinct. The active strains today are increasingly common and aggressive and *P. infestans* is still a threat to global food security causing worldwide losses of potatoes exceeding $5 billion annually.

Control of potato late blight

Farmers can try to avoid the disease by removing and destroying infected potato tubers and planting disease free seeds. However, successfully removing all *P. infestans* from a previously affected farming area is very difficult and expensive.

Fungicides

Fungicides can be used to prevent infections. The choice of fungicide depends on the strains of *P. infestans* that are found locally. As spraying is expensive, farmers often use weather forecasts to help predict when they should spray fungicides.

Unlike the majority of human medicines, to be effective fungicides must be applied before the disease occurs and usually before the pathogen has infected the plant. Fungicides can only protect new uninfected growth from disease. To protect potatoes against *P.infestans*, they often need to be sprayed multiple times during the growing season. This is to protect newly emerged parts of the plant, and to replenish fungicide which has been lost due to chemical and UV light breakdown and wind and water erosion.

Late blight resistant potatoes

Farmers can also grow late blight resistant potatoes, which have molecular receptors that recognise the *P. infestans* pathogen. Once they plant has recognised *P. infestans,* its immune responses prevent it from infecting and causing disease. Susceptible potatoes lack the receptors and are not able to recognise *P. infestans*. This means the pathogen is able to infect and cause disease.

Potato blight resistant potatoes tend to be more expensive than susceptible potatoes. This is because, developing resistant potatoes is an expensive process; it can cost plant breeders around £1M and around 10 years[6] to bring a new potato variety to market. As well as having potato late blight resistance, commercial potatoes need to also have many other desired features, such as: a high yield, size, taste, appearance etc.

There are many *P. infestans* strains and so it's difficult to produce a potato which is resistant to all strains. *P. infestans* populations are able to rapidly adapt and evolve. And so, by the time a new potato blight resistant variety has been developed, the *P. infestans* population may have already developed the ability to overcome the disease resistance.

GM potato
Researchers are hoping to use GM technology to speed up the breeding process. A genetically modified commercial potato has been created by introducing two resistance genes from a wild potato variety, which can resist late blight. This way only the desired resistance genes are introduced, without changing other characteristics. At the moment, the GM potato is not permitted to be grown commercially in the UK. However it is due to be grown in the U.S., where it is likely to be commercially available in a few years[7].

It's hoped that developing both GM and non-GM resistant potatoes could help boost profits for farmers by reducing potato crop losses and the need to spray fungicides.

1. Starter Questions

To get students thinking about plant diseases and their importance, ask them:

- Do they think plants can get diseases?
- Have they ever seen a diseased plant? If so, where and what were the symptoms?
- Why do they think plant diseases are important?
- What impact do they think plant diseases have on our global food security and forests?

Key points: Try to get students to think about where they may have seen plant diseases. For example they will have noticed that fruit goes mouldy, which is very often due to the fungus *Botrytis cinerea.* They may have also seen the fungus rose black spot in their gardens, or cankers on tree trunks in the park which are caused by bacteria.

Explain that plant diseases have a massive impact on the amount of food farmers produce and transport to feed the global population. Plant diseases also affect our forests, woodland and natural areas. For example ash dieback is currently threatening UK ash trees, which form a major part of our landscape.

2. Powerpoint Presentation

Go through the Powerpoint presentation (Appendix 1) to explain the different types of microorganisms that infect plants and why they're important. Explain that in this lesson they will be focusing on one very important plant disease: potato late blight. Give students copies of the Potato Late Blight Information Sheet (Appendix 2) and Game Information Sheets (Appendix 3) to give them key information.

3. Brainstorm

Ask students to brainstorm everything they have learnt about: potato late blight, fungicides and resistance. The key concepts to reinforce are:

- Potato blight is a devastating disease, which can rapidly wipe out potato crops and this can cause famine.
- Its life cycle is affected by the weather and the ideal conditions are warm and very humid.
- Farmers use fungicides to protect their crops, which are beneficial when there's a high disease risk but costly when there's a low disease risk.
- Farmers can also grow blight resistant potatoes, which can help prevent disease but are more expensive than susceptible potatoes.

4. Play the Save your Spuds game

Explain to the students that they are now going to become potato farmers. They need to make decisions about whether they want to buy resistant or susceptible potatoes and whether they want to spray fungicides or not. These decisions will affect how much of their yield is lost to potato late blight disease. They are competing against the other players in their group, who are also potato farmers. Who ever makes the most profit wins!

Students play the game using the Calculations Table (Appendix 4). We recommend a group size of 4 -5 players. The aim is to grow a crop of potatoes and make as much money as possible from the crop. Note: you may want to use calculators of this activity.

I. Resistant vs. susceptible potatoes
Each student must decide whether they want to grow resistant or susceptible potatoes. Resistant seed potatoes cost £3000 for 5 tonnes and susceptible seed potatoes cost £2000 for 5 tonnes.
If there is a high disease risk, students would benefit from investing in resistant potatoes, but if there's a low disease risk, the cheaper susceptible potatoes will help to boost profits.

II. Spin the 'weather wheel'
Students take turn to spin a pen on the Weather Wheel (Appendix 5), which gives a forecast and disease risk for May. Note: when a student spins the wheel, this gives the risk for all students. Students write whether the risk in the row marked 'Weather' on their Calculations Table.

III. Fungicides: to spray or not to spray
Using this disease risk, each student must decide if they want to spray fungicides. For example if there is a 'Low Risk', they would benefit financially from not spraying fungicides, whereas if there's a 'Very High Risk', they would benefit

from spraying fungicides. Each time they spray it costs £350.

IV. Enter yield loss for May, June and July
Students then use the Yield Loss Table (Appendix 6) to write in their Calculations Table what percentage of their potato crop has been lost to potato late blight disease in May. They repeat these steps II, III and IV for June and July.

V. Total yield loss
Students then calculate the total percentage of their yield that has been lost and write this in their Calculations Table.

VI. Total spent on seed potatoes and fungicides
First students calculate and enter in the table: the total amount of money the student spent on fungicides and the total percentage of their potato yield lost.

VII. Yield loss in tonnes/hectare
Students need to work out how much this yield loss is in tonnes/hectare. They do this by multiplying their total yield loss by 0.5. Note that this is because 50 t/ha is the ideal yield and therefore: 50 t/ha = 100%, (50/100) = 0.5 = 1% of the ideal yield, therefore multiplying by 0.5 gives yield loss in t/ha.

VIII. How much yield remaining
Students then work out how much of their yield is left by subtracting their yield loss t/ha from the ideal yield of 50t/ha.

IX. Initial Income
Students calculate how much their initial income is by multiplying by 200. Note this is because we are using the market price £200 per tonne of potatoes.

X. True Income
Students calculate their true income by subtracting from their initial income, the total money they have spent on their seed potatoes and fungicides spraying.

XI. The student with the highest profit wins!

For example:
• A student chooses to grow resistant potatoes, which cost £3000.
• They spin the pen on the weather wheel and get a 'Low Risk' of potato late blight in May, and decide not to spray fungicides. This equates to a yield loss of 4%.
• They spin the pen on the weather board for June and get a 'Very High Risk' of potato blight, and decide to spray fungicides (£350). This equates to a yield loss of 15%.
• They spin the pen on the weather board for July and get a 'Medium Risk' of potato blight and decide to spray fungicides (£350). This equates to a yield loss of 7%.
• In total they have sprayed fungicides twice, costing them £700.
• In total they have lost 26% of their yield (4% + 15% + 7%).
• To calculate this in tonnes/ha, they multiply 26% by 0.5 = 13 t/ha.
• To calculate how much of their yield is left, they subtract the yield loss of 13 t/ha from the ideal yield of 50 t/ha, which gives a total yield of 37 t/ha.
• To calculate how much their yield of 37 t/ha is initially worth, they multiply by £200, which gives £7400.
• To calculate their true income, they subtract the cost of the resistant seed potatoes and fungicide sprays: £7400 - £3000 - £700 = £3700.

Please note: In some cases students may actually lose money. This demonstrates how difficult it can be to make profit when there is extremely high risk of potato late blight.

Class Discussion
Ask the students what they have learnt from playing the game. Have they noticed any trends, e.g. generally did the players who bought resistant or susceptible seed potatoes make more profit from their crop?

Summary teaching notes

Complex situation
Explain that in reality farmers are faced with a very complex situation. Each crop is affected by many different pests and pathogens. For example, as well as the oomycete pathogen *P.infestans*, fungi, bacteria, viruses, nematodes also cause a range of potato diseases, many of which can not be controlled by fungicides. Other crops, such as wheat are also affected by a diverse range of diseases.
In addition, the amount of yield lost to pests and disease varies across different geographical locations and farming practices. For example, yield losses in Romania are estimated to be between 6 - 40%, compared to 25 - 75% in the Republic of Cameroon, Africa [8].
As weather conditions are likely to alter with climate change, scientists are now working hard to predict how climate change

will impact on plant pathogens and the plant diseases they cause. This is enormously complex and difficult to predict. It is therefore essential for the next generation of plant pathologists to be trained so that they can research plant diseases and to attempt to control damage to crops.

5. Write Farmer Guidelines

Ask students to write set of guidelines to help other potato farmers. They should think about what they have learnt about when it's best to grow resistant or susceptible potatoes, and when it's best to spray fungicides. They may also want to include other things they have learnt, such as potato late blight symptoms etc.

6. Extension Activity

Students use the resources below to read about the genetically modified (GM) potato, which has recently been developed. Students write a letter to a potato farmer to tell them about the research. Students are free to write about whatever they think is important. They can include information about: how the potato was created, why it was created, how it might benefit potato farmers and what their personal opinions are of genetically modified crops.

Extension Resources:

- BBC: Genetically modified potatoes 'resist late blight'
- Farmers Guardian: Scientists develop blight resistant GM potato
- Elevating crop disease resistance with cloned genes.
- GM potato to reduce agrochemicals

7. Appendix Resources

1. Power Point Presentation (Link).
2. Potato Late Blight Information Sheet (Link).
3. Game Information Sheets (Link).
4. Calculations Table (Link).
5. Weather Wheel (Link).
6. Yield Loss Table (Link).

8. References

The data used in the game has been adapted from data in the paper: Fungicide application and host-resistance for potato late blight management: benefits assessment from on-farm studies in S.W. Uganda. By the authors:
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2. World population prospects: the 2012 revision, highlights and advance tables (2013). United Nations, Department of Economic and Social Affairs, Population Division. Working paper ESA/P/WP.228.
3. Alexandratos, N., and Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.
4. The cost of food: Facts and Figures. BBC News (2008): http://news.bbc.co.uk/1/hi/world/7284196.stm.
5. OECD–FAO Agricultural outlook 2012–021. OECD Publishing and FAO (2012).
6. 'Conventional potato varieties resist PCN and blight'. Farmers Weedly (09/04/2014).
7.'Field trial of late blight resistant potatoes Q&A'. The Sainbury Laboratory site (27/08/2014).
8. 'Social Impact and Economic Importance of Late Blight'. Global Initiative on Late Blight (22/09/2014).

9. Contact

We would really like to hear your feedback on this activity. Please get in touch: outreach@bspp.org.uk and visit: bspp.org.uk/society/education for more resources.