Fertilisers and food security

'Food security is the provision of sufficient amounts of safe, affordable, nutritious food that we need to underpin the health and wellbeing of all the human population across the globe' [Prof. Julie Fitzpatrick (Scientific Director, Moredun Research Institute); 2012].

Figure 1 *- The Edinburgh skyline.*

The world is facing a potential crisis in terms of food security. The challenge is to produce and supply enough safe and nutritious food in a sustainable way for a growing global population, which is projected to reach 9 billion by 2050 [1].

How might one visualise such a large increase in population? Recent estimates [2] suggest that by 2030 we will need to create 1000 cities, each the size of Edinburgh, to accommodate the predicted rise in population in Africa alone.

As population growth continues there is an increasing demand for 'sustainable intensification' - the need for greater food production without increasing the land used for agriculture. Globally there is a need to consider how we might improve food transportation and issues dealing with food waste [3].

Food security is a broad theme which runs through the new science courses in Scotland and a range of learning and teaching strategies to support curriculum delivery are under development both within SSERC (many of these are available on our website [4]) and through external agencies (see, for example, [5] and [6]). The purpose of this article is to introduce some of the resources which we in SSERC are developing/adapting to support learning and teaching about fertiliser use.

Fertilisers are used to improve plant growth - they encourage faster growth of plants and are used to maximise crop yield. Fertilisers are also used where plants are showing signs of nutrient deficiency such as leaf yellowing but healthy soil structure and pH are just as important as fertiliser application in the prevention of plant nutrient deficiencies. Fertilisers contain concentrated sources of nutrients which plants need in relatively large amounts.

Most fertilisers are based on the three major plant nutrients:

- nitrogen (N) - for green leafy growth;
- phosphorus (P) - for healthy root and shoot growth;
- potassium (K) - for flowering, fruiting and general hardiness.

In the following pages we explore both a practical and discussion activity to support learning and teaching about fertilisers.

Figure 2 *- Germinating mung beans (image taken from http://cf.ltkcdn.net/vegetarian/images/std/121613-425x282-Mungbeans.jpg).*

PRACTICAL ACTIVITY
Investigating Nutrient Deficiency in Mung Beans

(This protocol was adapted from one kindly provided by Roger Delpech of The Haberdashers' Aske's Boys' Schools, Elstree).

The aims of the activities involved in this practical are:

- to investigate how lack of chemical nutrients (nitrogen, phosphorous and potassium) affects the growth and development of mung bean plants;
- to identify mineral deficiency symptoms associated with lack of particular nutrients.

Background

Mung beans are native to India and grown extensively throughout the tropics as a food source. They are legumes and provide an excellent source of protein and potassium in the diet. They are also eaten as bean sprouts. In some countries mung bean plants are grown alongside rice in paddy fields as they have extensive roots which help retain soil and, being leguminous, they add nitrogen to soil.

Mung beans are cheap, reliable and easy to germinate (Figure 2). Germinated mung beans can be grown quickly in a range of water culture solutions - standard Sach's solutions can be used for this. Growth in distilled water makes a good comparison.

Within a few days learners will see differences in the growth and development of seedlings and can make comparisons and draw conclusions relating to mineral deficiency symptoms and requirements for healthy growth. The seedlings will grow for 10-14 days (Figure 3).

Time lapse photography can be used to capture images of seedling growth - an example of this is available on the SSERC website [4].

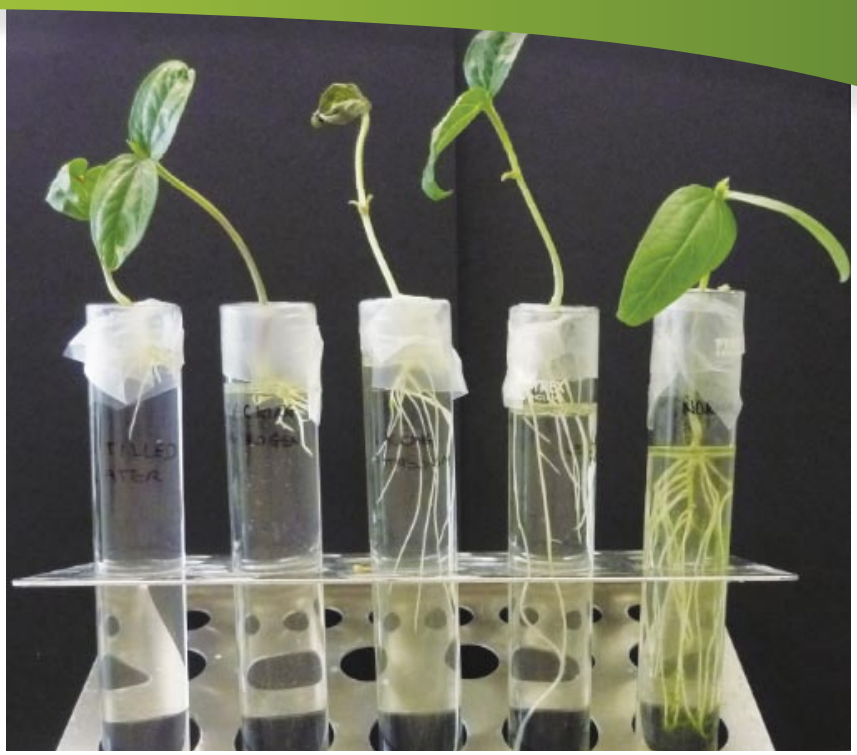

Figure 3 *- Mung bean seedlings growing in a range of nutrient solutions. From left to right the tubes shown are:*
- *distilled water;*
- *lacking P;*
- *lacking N;*
- *lacking K;*
- *standard Sach's solution.*

Preparation

Two days prior to setting up the investigation with culture solutions, place the mung beans in a flat dish, or tray. Each student (or group) will need 5 seedlings, so use enough beans to allow for the failure of some to germinate successfully. Moisten the beans (without soaking them) and cover loosely with muslin, or something similar, which will allow air to circulate. Place in a warm place for 1-2 days. Once small radicles (roots) appear the seedlings should be gently tipped onto paper towels. Students should select 5 seedlings that are at a similar stage of development.

Setting up the investigation

Materials

- 5 boiling tubes;
- test tube rack;
- Parafilm™ (or foil);
- scissors;
- marker pen;
- 5 germinated mung beans;
- a bright light source;
- a range of Sach's solutions (available from *Scientific & Chemical, Philip Harris, Timstar* etc.):
  - complete culture;
  - culture lacking nitrogen (-N);
  - culture lacking phosphorous (-P);
  - culture lacking potassium (-K);
  - distilled water.

Method

1) Label the test tubes with type of culture medium.
2) Fill each test tube with corresponding culture medium.
3) Cover each test tube with Parafilm™ (or foil).
4) Gently push down the centre of the Parafilm™ (or foil) in each test tube to make an upside down cone shape which will act as a 'well' so that the culture medium can be easily topped up.
5) Make a little hole in the centre of each well.
6) Carefully place a mung bean seed into each well and gently push the radicle through the hole into the culture medium. The seed should be on top of the Parafilm™ (or foil) and the radicle will be dipping into the liquid below. Top up with culture medium if necessary.
7) Place the test tubes in a rack and leave under bright light.

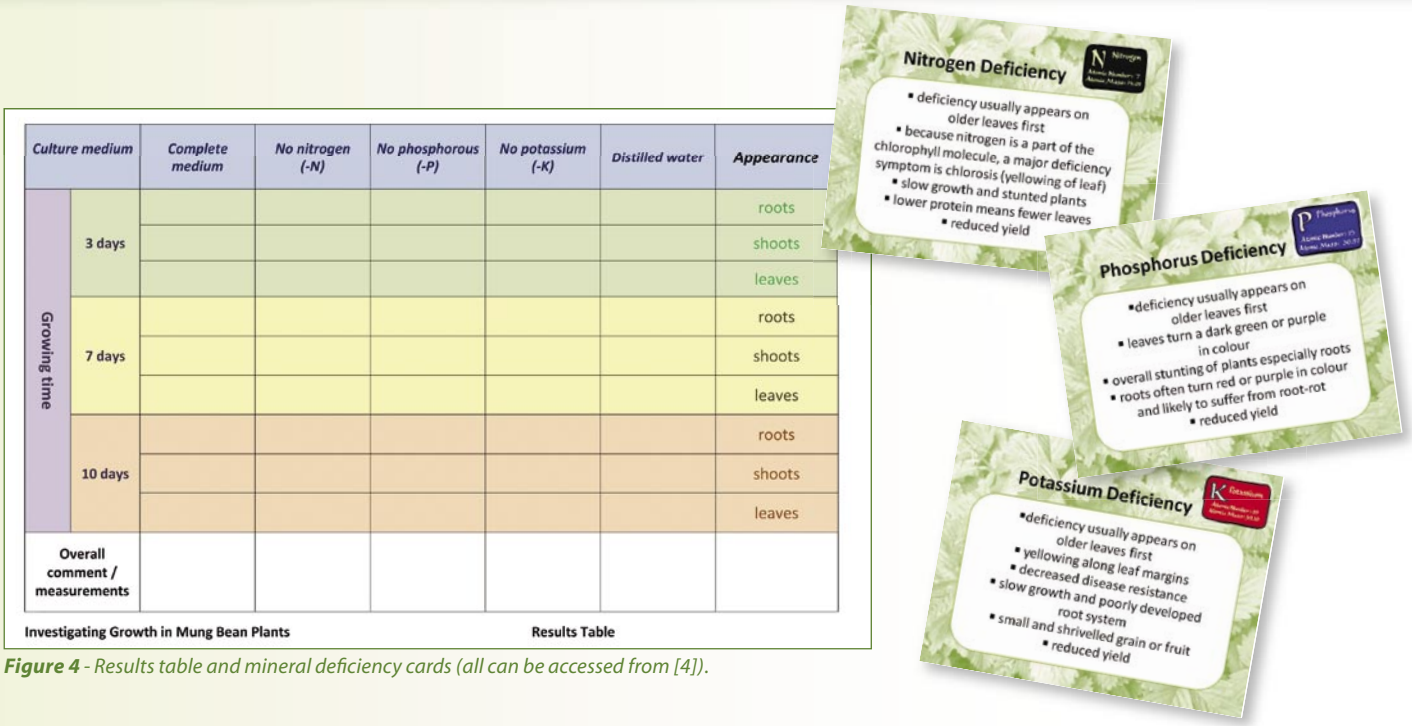

Figure 4 *- Results table and mineral deficiency cards (all can be accessed from [4]).*

Discussion

Pupils could be invited to make predictions about what might happen in relation to growth and development in each set of conditions.

Results and conclusions

The seedlings should be examined after 3, 7 and 10 days and comparisons between the growth in each culture medium can be made. A results table can be used to record results (an example table is provided (Figure 4) and is available on the SSERC website [4]).

Using the results of the investigation, together with the mineral deficiency help cards (Figure 4 & [4]), pupils can draw conclusions about mineral deficiency symptoms and why particular minerals are required for healthy growth and development.

Further suitable information can be found at http://www.allotment.org.uk/gardening/fertiliser/npk.

Additionally a pupil sheet 'Food Security and Fertilisers', provides background, questions and problem solving activities will shortly be available [4].

Discussion activity - designing a fertiliser

In addition to the practical activity we have created a discussion activity to support this aspect of the curriculum. The activity comprises a set of cards with characters and scenarios giving learners a context to help them to understand more about the decisions which have to be made when designing a fertiliser. Each scenario ends with a task to complete in small groups. There is a suggested website for each character/problem where learners might carry out further research. The activity highlights the idea that fertilisers are customised and that 'designing a fertiliser' to maximise crop production is complicated and depends on many factors. The activity introduces learners to Fred (the Scottish farmer) Risa (the Indonesian rice farmer) and Hermione (the horticulturalist); 3 story lines in the form of PowerPoint files are available from the SSERC website [4]. Each of these people has a story to tell, and issues to address, regarding fertiliser and other choices. The learners read the stories, use the background information, discuss the options and then offer advice to Fred, Risa and Hermione. The aim of the stories is to introduce learners to the importance of careful use of fertilisers and some of the hazards of over-use.

Figure 5 *- Sample slides from the discussion activity PowerPoint files.*

References

[1] The food security problem. Available on the Global Food Security website at http://www.foodsecurity.ac.uk/ (accessed July 12th 2013).

[2] United States Census Bureau offers a quick and easy method to view the most populous countries and areas of the world for any year between 1950 and 2050. Available at http://www.census.gov/population/international/data/idb/informationGateway.php (accessed July 15th 2013).

[3] The Royal Society (2009) Reaping the benefits: Science and the sustainable intensification of global agriculture. Available at http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/4294967719.pdf (accessed July 12th 2013).

[4] The SSERC website is available at www.sserc.org.uk. Please note that to access all resources on the website you will need to register and be provided with a log-on ID and password.

[5] Education Scotland (2013) Food Security - Advice and guidance for practitioners. Available at http://www.educationscotland.gov.uk/learningteachingandassessment/curriculumareas/publishedandplannedsupport/curriculumareas/sciences.asp (accessed July 12th 2013).

[6] I'm A Scientist Get me Out of Here (2013) Science Debate Kit: Food Security. A copy of the kit can be requested at http://www.debate.imascientist.org.uk/foodsecurity (accessed July 12th 2013).

[7] Time lapse software: *WebcamTimelapse* - a free tool for creating videos with a webcam. His can be downloaded to a laptop and used with the *Veho VMS - 001, 20-200 Magnification Digital Microscope*. (http://www.tnlsoftsolutions.com/timelapsehome.php). *iMotion HD* - a free *iPhone* app is available at https://itunes.apple.com/gb/app/id421365625.

[8] Education Scotland (2013) Sciences - Curriculum areas - Learning, teaching and assessment. Available at http://www.educationscotland.gov.uk/learningteachingandassessment/curriculumareas/sciences/index.asp (accessed July 16th 2013).

[9] SQA (2012). Course Unit Support Notes for new National Qualifications are available on the SQA website - http://www.sqa.org.uk/sqa/41328.html (accessed July 16th 2013).

Curriculum links

The Scottish curriculum has reflected the importance of food security by incorporating a strand in its new science courses. More detail is available in [8] and [9].

So, for example, delivery of a number of *CfE* level 2-4 outcomes would be supported by the activities described in this article:

- Through investigations and based on experimental evidence, I can explain the use of different types of chemicals in agriculture and their alternatives and can evaluate their potential impact on the world's food production - *SCN 3-03a*.
- Through investigating the nitrogen cycle and evaluating results from practical experiments, I can suggest a design for a fertiliser, taking account of its environmental impact - *SCN 4-03a*.

New National Qualifications

These activities support the following curricular statements from Biology and Chemistry:

National 4 Biology (Life on Earth):

4) *Fertiliser design and environmental impact of fertilisers*
   - Explore the use of natural and artificial fertilisers and the advantages/disadvantages of each e.g. cost, specificity, purity, NPK composition.

National 5 Biology (Life on Earth)

2) *Nitrogen in ecosystems*
   - Fertilisers supply nitrates to increase yield.

National 4 Chemistry (Chemistry in Society)

Fertilisers
- Percentage composition calculations can be related to the packaging of fertilisers.
- Design and prepare fertilisers using neutralisation reactions.
- Investigate the solubility of fertilisers and the potential environmental consequences associated with fertiliser use.
- Possible investigation into effectiveness of fertilisers: different school-made fertilisers could be compared by growing suitable plants.