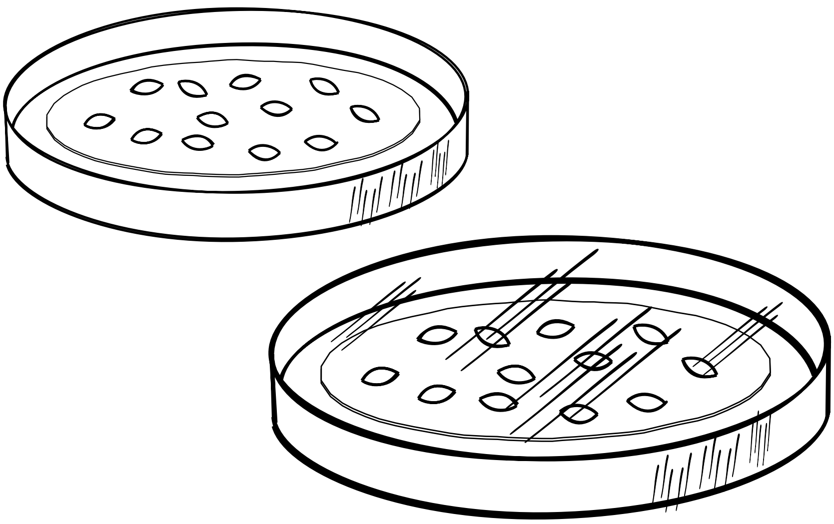
Science
through SEEDS

Teachers' Notes



IGER
INSTITUTE OF GRASSLAND & ENVIRONMENTAL RESEARCH

BRITISH SEED HOUSES

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In this pack

In this pack you will find:

- a series of student worksheets covering 11 different investigations suitable for 12-16 year olds.
- teachers' notes (including the answers to questions raised, graph and table examples, hints and tips and suggestions for alternative experiments);
- a glossary of terms
- two varieties of ryegrass (AberElf and AberLinnet) and one variety of white clover (AberHerald).

About the seeds

The seeds will remain viable for up to 12 months. There should be enough seed for a class of 30 students working in small groups to complete all the experiments.

The two ryegrasses have been selected to offer a good contrast. They have very different uses.

- **AberElf** is a top performing lawn **perennial ryegrass.**
- **AberLinnet** is a top performing **hybrid ryegrass** (produced by mating perennial and Italian ryegrasses). It is widely used for forage production (food for animals).
- **AberHerald** is a **white clover** variety which is also widely used in mixtures with grasses for both grazing directly by the animals and as conserved food (silage or hay).

All three varieties were bred at the **Institute of Grassland and Environmental Research (IGER)** at Aberystwyth in Wales. IGER's plant breeding programmes, which can take up to 20 years to produce a new variety, are funded by the Ministry of Agriculture, Fisheries and Food (MAFF), BBSRC and the company, **British Seed Houses Ltd.**

British Seed Houses have kindly provided all the seed in this pack. BBSRC thanks Simon Taylor - Sales Office Manager, Warrington Office for his support. British Seed Houses have offices throughout mainland Britain.

For further information on British Seed Houses products contact the Warrington Office on:
01522 868714

About the experiments

The experiments have been designed and trialed by the following team of plant scientists working at IGER, Aberystwyth: **Dr Mike Leggett, Dr Danny Thorogood**, and **Dr Judith Webb** with help and advice from the following educators; **Mr David Brigden** - University of Liverpool, **Mr Paul Stillman**, Head of Science at Shoeburyness County High School, **Dr Liz Lakin,** Environment Matters and Cheltenham and Gloucester College and **Mrs Jaquie Burt,** Lasswade High School and support from **BBSRC Schools' Liaison Service** and **British Seed Houses Ltd.**

The practicals are designed to help 12 - 16 year olds to explore the factors affecting plant growth; reproduction; variation and classification and adaptation. You will find that plants germinated for one experiment can often be used in subsequent experiments to cut down on preparation time and that indicators of the time needed to complete experiments are given and advice on likely outcomes and data presentation are given in the Teachers' Notes section.

In order to make full use of this pack, students should have reached level descriptions 4 to 5 of Science Attainment Targets 1 and 2 of the National Curriculum.

Further information

The BBSRC Schools' Liaison Service offers a range of free resources for all ages of students. For more information please contact:

The BBSRC Schools' Liaison Officer
The Biotechnology and Biological Sciences Research Council
Polaris House
North Star Avenue
Swindon SN2 1UH.

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Grass and clover as a teaching resource

Most of us see grass and clover plants every day, but we never really give them a second thought.

"Grass is just grass - it's all the same!" might be a commonly held belief but it's not true. Grasses (and legumes) come in all shapes and sizes. There is ample opportunity to discuss biological diversity, evolution, adaptation, food chains, genetics and breeding. You might start by asking students to consider the list below.

- Grasses (and legumes) can be annuals (completing their life cycle in a year) or perennials (continuing to grow year after year).
- Grasses (and legumes) can be inbreeders (pollinating themselves) or outbreeders (requiring pollen from a different plant of the same species).
- Some grasses (and legumes) are cold tolerant (i.e. survive severe frosts or prolonged snow cover) others are not.
- Some grasses (and legumes) will tolerate drought others will not.
- Some grasses produce large seeds (e.g. wheat, barley and oats) which we eat directly (e.g. bread, biscuits, breakfast cereals) or indirectly (e.g. by providing feed for cattle, chickens etc). Similarly, legumes are split into large and small seeded species, some of which we eat (e.g. peas, beans) and others which provide food for livestock (e.g. clover, lucerne).
- There are over 160 grass and legume species indigenous (native) to the UK. Of these, only about 10 are widely used for agriculture and amenity purposes (amenity being leisure and other useful non-agricultural uses such as sports pitches, gardens and parks).

Ryegrass

The ryegrass species (Latin name Lolium) are very important grasses, being widely used for both agricultural and amenity purposes.

Ryegrasses are:

- used to feed ruminant animals (cattle, sheep, goats) either grazed directly in the field or conserved as silage (grass and clover mixtures, cut , chopped up and placed in pits or wrapped in plastic bags, a bit like a covered compost heap) or hay;
- ideally suited to temperate climates like our own UK climate, providing high yields of high energy value forage (food) over a long growing season;
- bred for amenity use in lawns and sports pitches producing many small short leaves that tolerate close mowing and the wear and tear from football studs, trainers etc;
- are widely used as a mixtures with forage legumes to provide a balanced sward (field of a mixture of grasses and clover) for the ruminant animal.

Legumes

- Legumes such as clover are a good source of nutrients (they are especially rich in protein and minerals).
- Legumes have a symbiotic relationship with a bacterium called Rhizobium. Rhizobium bacteria cause nodules to appear on legume roots and can produce large quantities of nitrogen which the legume, and any plants around the legume, can use to grow.
- White clover (Latin name Trifolium repens) is the most widely used legume species and in combination with ryegrass produces a sward with a good protein/energy balance and enough nitrogen to produce high yields of forage for the ruminant animals.

Links to the Curriculum

National Curriculum: England and Wales

Science. Key Stage 3. Experimental and Investigative Science – all sections.

Life Processes and Living Things – specifically: 3. Green plants as organisms; 4. Variation, classification and inheritance.

Science. Key Stage 4. Experimental and Investigative Science – all sections. Life Processes and Living Things. Specifically: 3. Green plants as organisms; 4. Variation, classification and evolution.

Scottish Curriculum

Environmental Studies 5-14. P7 to S2. Science: Understanding Living Things and the Processes of Life – specifically: Variety and characteristic features and The processes of life.

Health and Safety

As with any experimentation, good laboratory practice should be followed for all the protocols detailed in this pack.

Experiment 6

Heating ethanol. Appropriate safety garments should be worn by all students. The use of a heat controlled water bath is desirable but where this is not available please ensure that students follow the directions given on their Starch Test worksheets.

Experiments 9 - 11

Hayfever suffers should take appropriate precautions when looking at the pollen producing structures of grasses.

Plant breeding

Clearly we need different grasses and clovers to provide us with varieties which will 'fit the bill' in terms of their use. We can either look for existing varieties which might be suitable or, better still, try to breed a variety which will be suitable. **For example** if we wanted a grass that would produce **lots of early growth in the Spring,** here are three ways we could tackle the problem.

Option 1: We might go to areas outside the UK (e.g. the Mediterranean) and collect plants which produce early Spring growth, then select those which perform best in UK growing conditions. However, we might find that such plants grow early but do not produce as much foliage in the UK as they do in their natural habitat (this is often the case).

Option 2: We might mate a variety that has early growth but produces very little foliage, with a variety which has a higher yield, but does not produce the early growth. Plant breeders call this mating 'crossing' or hybridising. By the careful selection of offspring (called the 'progeny') from such a cross, we could end up with a *high yielding, early growing, grass.*

A scientist gathering plants which might be used in breeding programmes in the U.K.

Breeders have used this second option for many years to produce grass and clover varieties with desirable characteristics such as high yields of seeds for food or tolerance to cold conditions.

Until recently options 1 and 2 were the only methods available to breeders. Over the last 20 years however techniques in molecular biology have enabled scientists and breeders to do much more. Scientists are now able to isolate single genes or groups of genes and transfer them between living things of the same species *and* of different species. This method of creating new combinations of genes is known by many names including genetic engineering and genetic modification but the most accurate term is **recombinant DNA technology.**

Option 3: Recombinant DNA technology has two main advantages over traditional breeding methods.

1. It is more precise. Instead of exchanging many thousands of genes when plants are crossed in the traditional way, recombinant DNA technology allows the selection of just one or a small number of desired genes and avoids the need for many generations of crossing and back crossing to retain desirable traits whilst eliminating undesirable traits.

2. It overcomes the species barrier. For example *bacterial* genes that code for toxins which kill certain insects can be inserted into plants to make the plants resistant to attack by that insect pest.

Natural selection and evolution

Hybridisation (the crossing of genetically different individuals) has been a key part in the evolution of most living things, and plants are no exception. Generally, natural hybridisation in plants only takes place between closely related species of the same 'family' or 'genus' (see glossary of terms) but occasionally, hybridisation occurs between species or genera which are quite distantly related. In each case, new gene combinations are present in the offspring which may give them some advantage over the parents. If the offspring have an advantage over the parents, it means that they may be better equipped to compete for food, water, light or space and so may be more likely to reproduce - passing on their beneficial characteristics to their own offspring. Over many millions of year this process, known as **evolution**, can lead to the creation of new species.

Teachers' Notes

Getting to know you - *introduction exercise*

Time period:
1 lesson

You might like to try the getting to know you exercise as a "starter", (or go straight to one of the main experiments). Try to get the students to come up with the ideas, with a little prompting if necessary (you will need a fairly accurate balance if you are going to weigh the seeds).

Q Do you think there will be any difference in germination between the seeds?

A Get the students to come up with ideas. Some answers will be provided as you go through the germination experiment below.

Q Touch seed from each species with your jumper– what do you notice?

A Some seed of each type will stick to the jumper, but the grass seed will stick better.

Q How do you think the seeds are scattered from the 'parent' plant?

A Local distribution is that they simply fall to the ground. They are generally dispersed over greater distances by getting stuck to the fur or muddy feet of animals and people.

Ask the students to count out 100 seeds of each type, and then weigh and measure them (millimetre graph paper is best for measuring).

Q Which seeds are largest and which smallest?

A The clover is smallest, then AberElf and then AberLinnet (see table below*)

Q Which seeds weighed the most and which weighed the least?

A See the table below for the results we obtained*.

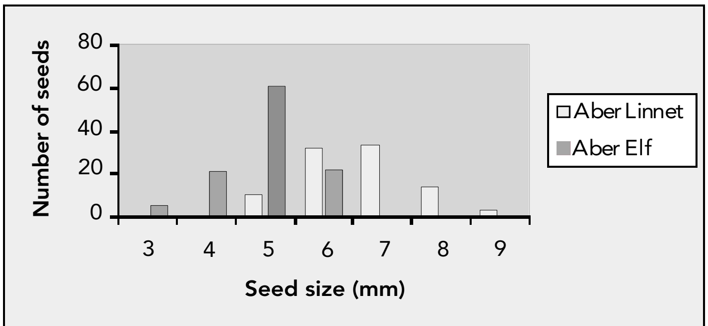
Q How can you count out lots of groups of seeds quickly?

A Count 100 seeds once and weigh. Then you can just weigh out the remaining batches of seeds.

Forage (grazing) grass	AberLinnet	4mm x 1mm	long and thin	100 seeds weigh 0.233g
Amenity (lawn) grass	AberElf	3mm x 1mm	long and thin	100 seeds weigh 0.134g
Clover	AberHerald	<1mm diameter	round	100 seeds weigh 0.062g

You will get slightly different results to these answers but the proportional differences should be the same.

If you have time, you can plot the different seed sizes as we did in a second experiment shown below.



If several groups of students undertake this, you can introduce the concept of **sampling errors**. By plotting the results, and looking at the high, low and mean, you can explain why it is essential to duplicate experiments, and show how the greater the sample number, the more accurate the overall result will become (assuming of course that you are applying the same criterion to each lot sampled)!

NOTES: Seed size like most biological characters can be affected by the environment in which the seed grows and also on the inherited characters of the seed. The combined effect of environment and genetics on biological characters of a population often creates a distribution with most individuals near the mean score with fewer and fewer individuals as you go to the extremes. The same pattern would be seen for example with distribution of height in a human population.

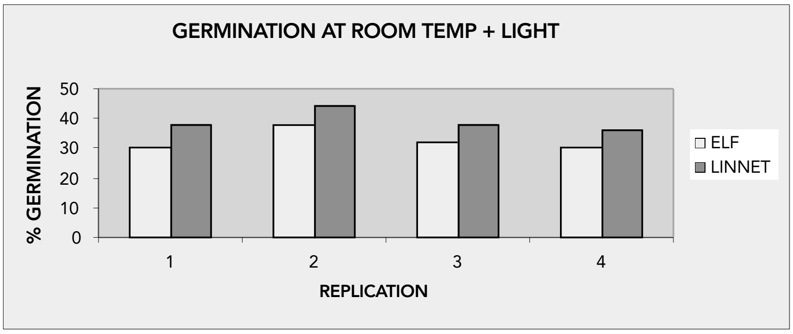
Germination tests

Time period to completion: 5-7 days

Experiment 1: Light and dark

Q Which grass variety showed the highest rate of successful germination?

A Linnet (See chart below).

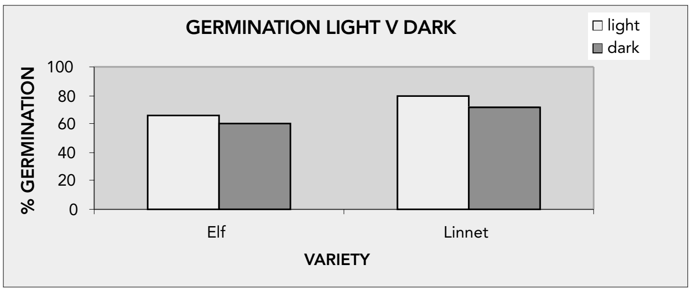


Q Can you think of reasons why the two seed varieties might germinate differently?

A We don't really know. However, germination % differences could be due to many factors both genetics based and environmental. Seed lots may vary because of age, growing conditions and weather at harvest for example. Remember, not all of the grass seed crop will be ripe when it is harvested, which can have an effect. There could be "built in" dormancy in some of the seed. A possible simpler answer could be that the greater surface area of the AberLinnet seed soaks up the water quicker.

Q Which seeds showed the highest rate of successful germination, those in the dark or those in the light? Why?

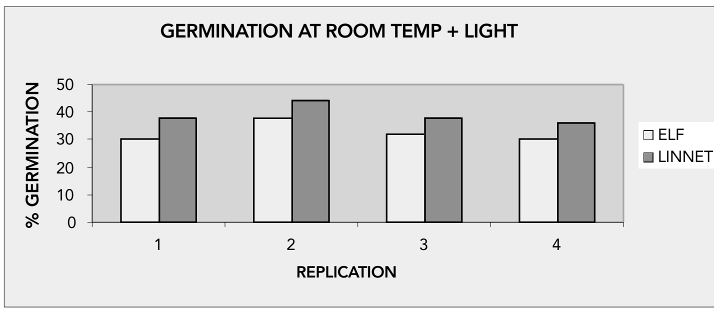
A See chart below. The most likely reason is that those in the light germinated better is that they were warmer. The silver foil would reflect the sun's heat.



NOTES: Deep in soil (in the dark) the seedling shoot has to use a lot of energy to reach the sunlight and begin photosynthesis. This could lead to a poor survival of seedlings and would impose selection pressure on the less fit seeds i.e. those with smaller endosperm's and hence energy for initial growth.

Experiment 2: Hot and cold

Tip **The seeds left at extremes of temperature will almost certainly not germinate, so after a few days, put them on the windowsill and record the numbers of seed that have germinated as often as you can until all or most have germinated successfully.**



Q Try to explain your results (ie why do you think the seeds did not germinate at these extreme temperatures, but did when placed on the windowsill?

A Every enzyme has a temperature at which it is most effective. Variations from this 'optimum temperature' will effect the enzyme's ability to function, and it is most likely that this is the reason that the seeds do not germinate in abnormally high or low temperatures. When restored to more normal temperatures, enzymatic processes function correctly and hence the seed will germinate.

NOTE: If the temperatures become too high or low, seed enzymes are denatured (lose their ability to function permanently) and the seed is killed. Some seeds can survive quite high temperatures because they have enzymes which are less prone to heat damage and/or a very protective seed coat.

Experiment 3; Clover colouring

Tip **If you prepare more seed than is needed at this point you can use it for experiment 8.**

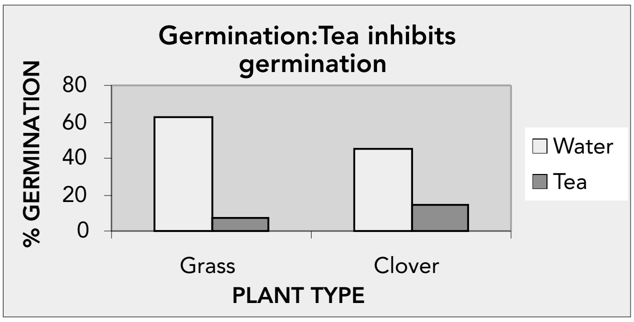
NOTE: The seed coat of clover contains chemicals especially **tannins** which have the effect of delaying germination if the concentration is high enough. It is interesting that germination of the grass was affected more than the clover, but we don't really know why.

Q Look at the clover seeds which have been given water. What can you say about the area on the blotting paper immediately around the seeds?

A Yellow-brown stain

Q How might this have happened (i.e. where do you think the yellow-brown stain comes from)?

A Seed coat (see note below).



Q Are there any differences in germination between the light and dark coated seeds? If so, what do you think might have caused these differences?

A It is unlikely that you will have observed a difference, But in some conditions, you may notice that the yellow clover seeds will germinate slightly faster than the brown ones.

Q What effect does the tea have on germination rates?

A Generally poor germination but tea inhibits germination. The table below (and in experiment 8), illustrates the results we recorded. (There will probably be some fungal growth on the seed, especially the grass, and fungal toxins can also reduce germination).

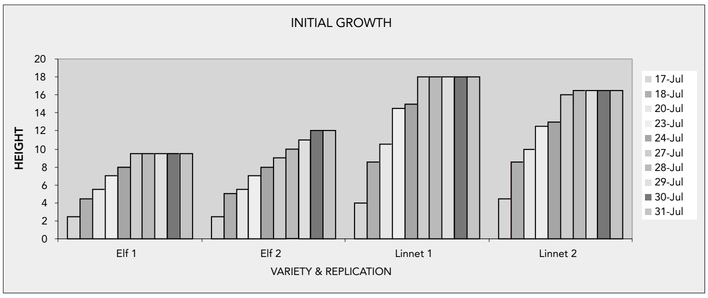
Q Where else are tannins found?

A Tea, coffee, wine, tree bark (especially oak).

	Grass	Clover
Water	22/35 (63%)	44/97 (45%)
Tea	2/30 (7%)	11/77 (14%)

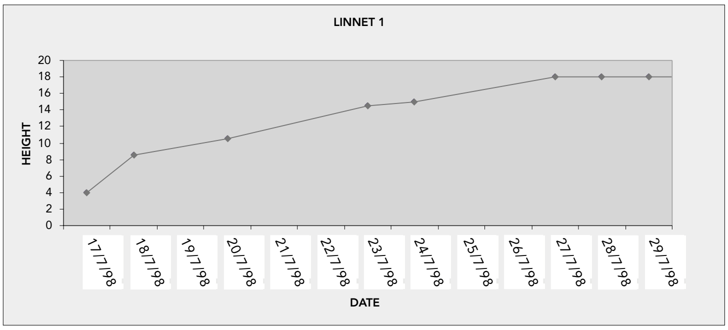
Experiment 4: Watching the grass grow

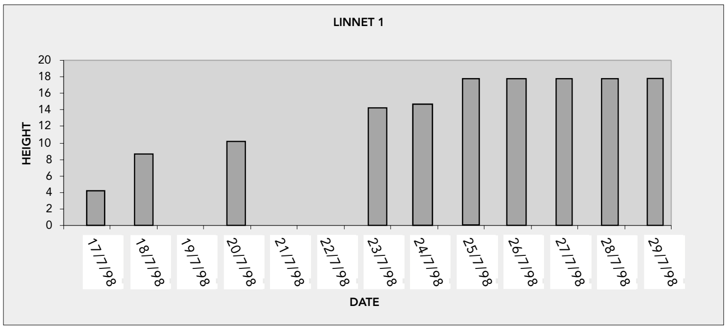
Hint **There is a more detailed experiment listed in the appendix which you might prefer to undertake.**



The growth rates (height x variety x time).

NB: *There is a lesson to be learnt in the sort of plot you use here. The bar chart above gives a general picture of the growth of the varieties, but growth is a continuous process not stepwise, so a line graph is a truer reflection of the actual growth "curve".*





Q What happened to the grass grown in the dark and why?

A As the seedlings grow, lack of light will cause them to etiolate (stretch up looking for light) and this may be reflected in taller growth. You may also observe that the seedlings become yellow due to lack of photosynthetic activity.

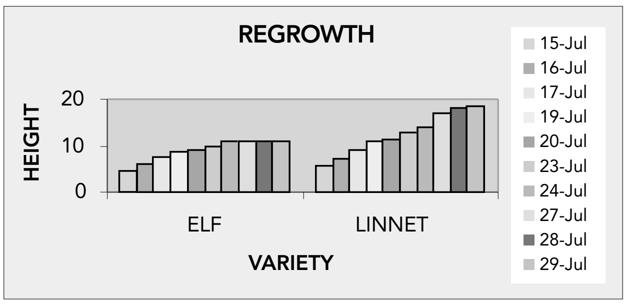
Q In your tests, which type of grass grown in the **light,** grew the tallest?

A The variety AberLinnet should be taller than AberElf. AberElf's short leaves which appear more rapidly than AberLinnet's produce a grass with lots of small leaves and hence a "carpet-like" surface ideal for rolling and bouncing balls and for running on. AberLinnet produces large leaves for feeding sheep and cattle.

Experiment 5: Watching the grass grow (regrowth)

Tip **When experiment 4 is complete, you can use the grasses for this experiment.**

Plot the growth rates (height x variety x time).



Q Is there any difference in the re-growth rates between the varieties? Do you think this is helpful or unhelpful? Why?

A The initial re-growth rates are similar but note that AberElf slows down sooner than AberLinnet. As an amenity grass, AberElf has been specifically bred **not** to produce vast quantities of herbage.

Experiment 6: Starch test

Tip **Potassium iodide solution. Put a half of a level teaspoon of potassium iodide into a beaker and add 25ml of water to dissolve it. Then add a fifth of a level teaspoon of iodine. Stir with a glass rod or swirl gently to dissolve. It should go very dark brown. Darker than a cola drink.**

Q What is the difference between the grass and clover leaves kept in the dark and those kept in the light after you have stained with iodine solution?

A The leaves of the grass and the clover that were kept in the light do not stain (they may go slightly brown). However, the clover leaves that were kept in the dark go black when treated with the iodine solution, whilst the grass leaves that were in the dark do not (they may appear light yellow brown). The black colouration in the clover leaves indicates the presence of accumulated starch.

Q What colour did the seeds go?

A Black.

Q What do the results from this experiment show?

A Clover leaves accumulate starch but grasses don't - yet the seeds of both grass and clover contain lots of starch.

Roots and shoots

In this section, you have the opportunity of introducing one of the best examples of a **symbiotic relationship** - that between the nitrogen fixing bacteria (Rhizobium) in nodules on the roots of the clover plants. Rhizobium is a gram negative bacterium that fixes nitrogen in association with roots of some higher plants, notably legumes of which clover is one example (others being peas and beans). The rhizobia form nodules on the roots of leguminous plants, and the nitrogen from the air is "fixed" by the bacteria catalysed by nitrogenase an enzyme that reduces nitrogen to ammonia. This is an essential stage in the nitrogen cycle and is the ultimate source of all nitrogen in living organisms. The oxygen-sensitive nitrogenase is protected by plant-produced leghaemoglobin (this is why older nodules are often pink in colour). You can also show that all plants do not grow in exactly the same way, some grow from the base of leaves and some from the tip of shoots or stolons.

Experiment 7: Roots and shoots

Part 1

Tip **When students draw the plants the differences they should pick up are: leaf shape, stolons in clover, upright growth versus horizontal growth, the presence of nodules.**

Q Which plant roots have bumps?

A The clover roots. They are called nodules and are most noticeable on older part of root near stolons, where they are larger and pink - less so towards root tip, where they can appear as small white bumps.

Q What do you think the bumps might be and how might they be caused?

A The nodules are caused by bacteria. Rhizobium bacteria are free living in the soil and in water (even tap water can contain Rhizobium) and of course in the nodules of clover plants and other legumes.

> **NOTE:** The higher the density of *Rhizobium* bacteria in the soil, the sooner the roots of legumes will nodulate, and you might expect a higher density of nodules per root.

Important: In experiment 7 (part 2) the students are made aware that the nodules are caused by *Rhizobium* bacteria. It is therefore advisable to keep the worksheets for part 2 back from the students until you are ready for your class to use them.

Part 2

If you have time and you feel the students are ready, ask then to devise their own Rhizobium exploration experiments. Alternatively use the **"Looking at *Rhizobia* "** students worksheets and teachers notes in the appendix.

Experiment 8: Which parts of the plants shoots actively grow?

Q Did the paper strips stay where you had placed them in relation to the top of the grass leaf or stolon tip.

A Grass grows from the base of the leaf, whilst clover grows from the stolon tip.

NOTE: The clover stolon actually grows horizontally rather than vertically as seen in the grass leaves.

Experiment 9: Plant classification

The features that all grasses have are:

1. Long strap-like leaves with veins running parallel
2. Leaves divided into flattened leaf blade and leaf sheath, which surrounds the stem.
3. Junction between blade and sheath characterised by a thin membranous structure called a ligule.
4. Sometimes there are claw-like structures called auricles (Latin auris = ear) at the junction as well.
5. Single non-branching stem.
6. Stem consists of nodes and internodes.
7. The nodes are solid throughout.
8. The internodes are hollow.
9. The structure of the flowers is also characteristic (see later section on floral structure and plant reproduction).

Experiment 10: Flowers and sex

Q What advantages do you think cross pollination might have over self-pollination?

A It ensures that 'new blood' (different genes) come into the next generation and prevents inbreeding depression (the accumulation of detrimental genes which over time will lead to a weak plant which can not compete with those which have been accumulating different genes from other plants).

Q How many anthers are there per floret?

A There are almost always three of these (a number which is commonly associated with monocotyledons and typical of all grasses).

Q What makes the anthers particularly suited to wind pollination?

A Anthers are quite large and are extended away from the florets on long slender filaments. The whole structure is called a stamen. The anthers are free to blow in the wind.

Tip **Once extended, the anthers will split at their ends to release large clouds of pollen into the wind. Hold a piece of paper under the flowering inflorescence and knock it lightly to release pollen.**

Q Grass plants produce a large amount of pollen. Why?

A To increase the chances of pollen grains reaching the ovule to effect fertilisation and seed development.

Part 2

Q What are the features, which help the grass stigma to catch pollen effectively?

A They are extruded from the florets to be exposed to the open air. Their branching structure gives them a large surface area for trapping pollen grains. You may see pollen grains attached to the stigma surface.

Discussion on the differences between wind and insect pollinated plants could wrap up a lesson on floral structure

Q Why are grass flowers so small and seemingly insignificant compared to some other flowers?

A Insect pollinated flowers develop secondary floral structures to attract insects, which ensure transfer of pollen from anther to stigma. Scented petals with colourful markings attract insects. Structures called nectaries contain nectar on which insects feed. Pollen is often sticky, has a complicated surface structure and clumps together to aid transfer on the surface of insects e.g. clover flowers are insect pollinated.

One extra question might be:

Q Do you think the adaptation of grasses to wind pollination is more primitive than adaptation to insect pollination?

A The truth is we are not sure. This could be a good point for classroom discussion. Some of the more primitive plants which are still living today (eg Conifers - cone bearing trees) are wind pollinated which makes one think that this is a more primitive pollination mechanism than insect pollination. In some ways it is a chicken and egg situation or rather when did the insects evolve in relation to the plants?

Experiment 11: Gone to seed

Grass inflorescences will quite happily flower, produce pollen to effect fertilisation when grown as cut stems in a jar of ordinary tap water. They will even produce seed after a period of time. You might ask the students to try and germinate some of these seeds. If they do they will have investigated all the life cycle of a grass plant.

Appendix 1

Leaf races

Leaf races can be used as an alternative growth experiment or a classification extension activity.

Tip **Students should be reminded of the need to make the test fair (e.g. grow ten seeds of each variety on the same reservoir and ensure other environmental variables (light, heat etc.) are the same for each variety.**

Tip **In the final analysis, the results of all the students could be pooled which should cancel out any bias shown by individual experiments.**

The graphs created by the students from their results should illustrate standard growth patterns typically found when measuring growth of parts of organisms, whole organisms or populations. The concepts of "lag phase" leading to "maximum growth rate" eventually reaching equilibrium when maximum size is reached (where the graph curves start to flatten off) are all illustrated.

- **Task:** Estimate the maximum growth rate of the first leaf of each variety by taking the steepest part of the curve and calculating the rate as leaf length/day.

  Result: **They will be about the same.**

- **Task:** Estimate the maximum leaf length of each variety i.e. where the curve flattens out. (Note: you may have to direct the students to extrapolate in the case of AberLinnet).

  Result: **AberLinnet has leaves as much as 50% longer than AberElf though actual measurements and differences will vary from experiment to experiment.**

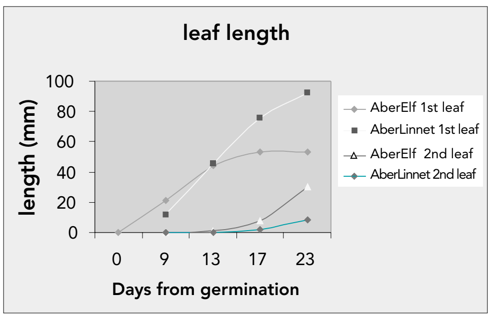
- **Task:** Estimate the time it takes to become fully expanded for each variety.

  Result: **As the growth rates are similar, AberLinnet will take longer to reach maximum expansion.**

NOTE: It may not be possible to determine the mean time for second leaf emergence if measurements are only being done on a weekly basis so the alternative would be to measure the time it takes from the start of the experiment to reach an average length of 5mm. Then, estimate the number of days from the beginning of the experiment it takes for the mean second leaf length to reach 5mm. AberElf's second leaf emerges before AberLinnet's.

You may find that AberElf's second leaf is longer than AberLinnet's on completion of the experiment. This is probably because it started growth earlier, and given similar (relative) growth rates it will remain bigger until maximum length is achieved.

If the experiment is continued for a longer period of time, you should observe that **AberElf has smaller leaves than AberLinnet and its second leaf will stop growing first. AberLinnet's second leaves will continue to grow, eventually overtaking AberElf's. Its maximum leaf length will be greater than that of AberElf's.**

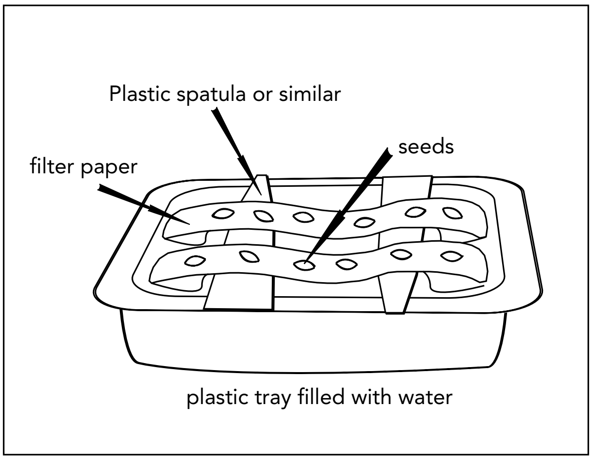


Q **Can you relate these growth patterns to the use these two ryegrass varieties are put to?**

A AberElf's short leaves which appear more rapidly than AberLinnet's produce a grass with lots of small leaves and hence a carpet-like surface ideal for rolling and bouncing balls and for running on. AberLinnet produces large leaves for feeding to animals.

Leaf races: Looking at the growth of the first two leaves of grasses

	Time check:
	4 weeks



Lesson 1

Working on your own or in pairs, set up equipment as shown in the diagram on the right to germinate 10 seeds of each of the two varieties of **grass** Consider the design of the experiment and the need to make it a fair test to compare the two varieties.

Tip **The reservoir will need to be topped up during the length of the experiment (4 weeks).**

Lessons 2, 3, 4.

- Observe the germination of grass seedlings.

The Angiosperm (Flowering Plant) Phylum is split into two Classes; **Monocotyledons** and **Dicotyledons.** **Monocotyledons** produce one seed leaf and have long, thin leaves. All grasses are Monocotyledons. **Dicotyledons** produce two seed leaves and have more rounded leaves. Clovers are Dicotyledons.

- **Task:** Carefully measure and record the length of emerging leaves trying not to damage them. At some time you will see the second leaf emerging from inside the first leaf and you could also measure the length of this and note when it emerges. **Use the score sheets below to record your results.**
- **Task:** Calculate and record the mean length of the leaves at the end of each week. Do not include seeds that have failed to germinate after four weeks when calculating your means.

The score sheets to record the heights of the 1st and 2nd leaves.

AberElf	1st leaf length			
	7 Days	14 Days	21 Days	28 Days
Seed 1				
Seed 2				
Seed 3				
Seed 4				
Seed 5				
Seed 6				
Seed 7				
Seed 8				
Seed 9				
Seed 10				
mean				

	2nd leaf length			
	7 Days	14 Days	21 Days	28 Days
Seed 1				
Seed 2				
Seed 3				
Seed 4				
Seed 5				
Seed 6				
Seed 7				
Seed 8				
Seed 9				
Seed 10				
mean				

Aber-Linnet	1st leaf length					2nd leaf length			
	7 Days	14 Days	21 Days	28 Days		7 Days	14 Days	21 Days	28 Days
Seed 1					seed 1				
Seed 2					Seed 2				
Seed 3					Seed 3				
Seed 4					Seed 4				
Seed 5					Seed 5				
Seed 6					Seed 6				
Seed 7					Seed 7				
Seed 8					Seed 8				
Seed 9					Seed 9				
Seed 10					Seed 10				
mean					**mean**				

- In the space below, draw a line graph to illustrate your results.

From this line graph:

- Estimate the maximum growth rate of the first leaf of each variety by taking the steepest part of the curve and calculating the rate as leaf length/day.

- Estimate the maximum leaf length of each variety i.e. where the curve flattens out. (You may have to extrapolate in the case of AberLinnet).

- Estimate the time it takes to become fully expanded for each variety.

- If possible, determine the mean time for second leaf emergence.

You may find that AberElf's second leaf is longer than AberLinnet's on completion of the experiment. This is probably because it started growth earlier, and given similar (relative) growth rates it will remain bigger until maximum length is achieved. You might like to predict what might happen if the experiment was continued for a longer period of time assuming that the second leaf behaves like the first for each variety.

My prediction:

Q Can you relate AberElf's and AberLinnet's growth patterns to the use that these two varieties are put to?

Appendix 2

Looking at *Rhizobium*

Looking at *Rhizobium*

Students should follow the directions on their Looking at Rhizobia worksheets which follow.

Optional work extensions: You can add an additional dimensions to this experiment as follows: Plant some seeds in peat (from a grow-bag) and others in sand, and water with clean tap water. You can then compare the results with those using the soil water described above.
Another good comparison can be made if you pull as many nodules as you can (we recommend 100+) off the clover plants, squash them 5mls of water, and water this mix onto seeds sown in Petri dishes as in experiment 3 and compare numbers of nodules formed.

Tip **Scoring the germination rate (i.e. appearance of root and shoot). Nodules are first apparent after about 14 days, but they are much more obvious after 21 days.**

The results we obtained from the germination and nodulation are given in the table below.

	Total number seeds grown	Total number of seeds germinated after 21 days	Presence/Absence of nodules after 21 days
Yellow/brown seeds & tap water	50	25	No Nodules present
Yellow/brown seeds & soil water	50	23	Nodules present*
Very brown seeds & soil water	50	26	Nodules present
Very brown seeds & tap water	50	20	No nodules present
Total **Germination %**	200 -	94 47%	

* In those plants where nodules formed, there were more than three nodules on each seedling.

Q Do all seeds germinate at the same rate or does colour of seed coat have an effect?

A No effect of seed coat colour.

Q Why do some seeds fail to germinate?

A Harder seed coat – less permeable to water. This can be considered to be an evolutionary adaptive mechanism which enables the seed to survive in the soil for a long time.

Q Do all the seedlings have nodules? Comment on your findings.

A The result here can be variable. Those plants which were grown in the soil water should have nodules because the soil contains free living Rhizobium bacteria. However, Rhizobium can also be present in tap water, so it is possible (though unlikely) that those grown in tap water will also have the occasional nodule.

Time check:
up to 21 days

You will need:

- ✔ about 100 clover seeds
- ✔ Petri dishes with lids
- ✔ blotting paper/filter paper
- ✔ J-cloth
- ✔ paper towels
- ✔ sticky tape
- ✔ funnel and beaker
- ✔ forceps
- ✔ water
- ✔ peat and garden soil (clover plants: optional)
- ✔ pots (10-15 cms diameter) and trays to place the pots in

Part 1

- Line four Petri dishes with filter or blotting paper labelling two as 'tap' and the others as 'soil' and adding your name or initials.

Tip **When you write on the paper remember to use a pencil rather than a pen.**

- Sow **25** clover seeds in each dish making sure you scatter them evenly.

Part 2

- Take some soil from around the roots of a growing clover plant, put it in a beaker and add 100 mls of tap water.
- Mix well and allow the soil particles to settle.
- Filter the "soil water" into a clean beaker through a clean J-cloth or similar.
- Repeat this filtering process until the water looks fairly clear. This filtered 'soil water' is called the **filtrate.**

Part 3

- To half the dishes of each colour add 10 mls of the 'soil water' filtrate.
- To the other half add 10 mls of tap water.
- Seal all the dishes with clear sticky tape to prevent them drying out and leave on the windowsill to germinate.

Part 4

- After 7 days, count the number of seeds that have germinated in each dish and record your results. Repeat this count after 14 days.
- After 21 days look carefully at the seedlings which have germinated. Do any of the seedling's roots have **nodules**? Record your results in the table below.

	Total number of seeds sown	Total number of seeds germinated after 21 days	Number of nodules after 21 days
Seeds with soil water			
Seeds with tap water			

Q Why do you think some seeds failed to germinate during your experiment?

A Do all the seedlings have nodules? Do all the samples have about the same number of nodules? Comment on your findings.

Appendix 3
The little helper

Data collection, tables, charts and graphs

The best way to collect data is by making a simple table so that you can enter the measurements you make each day or lesson. Below is an example of a table which has the number of days in one column, and the measurements you make (leaf length here) in the other.
In Table A, we have entered the length of the longest leaf as we measured it on the first day, which was 4cm. In Table B, we have entered the length of the longest leaf up to the twentieth day.

Day	Leaf length cm
1	4
4	
8	
12	
16	
20	

Table A

Day	Leaf length cm
1	4
4	6
8	8
12	14
16	16
20	16

Table B

Once you have completed your measurements, you can plot the data. First, draw the blank chart as shown in Fig. 1.

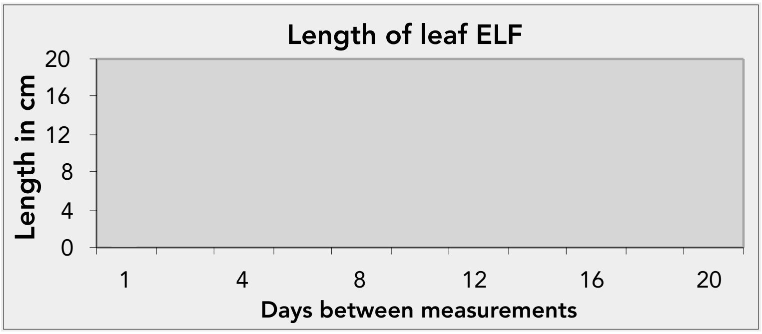


Fig 1.

Next you can plot the data as a bar chart by measuring the height of the leaves each day, and drawing a bar up to the measured height. In the examples below, we have added the data for day 1 which as you can see from the Tables above was 4cm (Fig. 2) and then for all twenty days (Fig. 3).

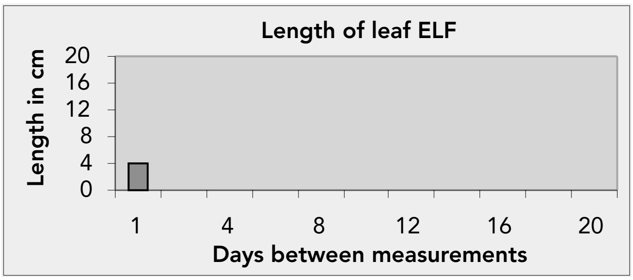


Fig 2.

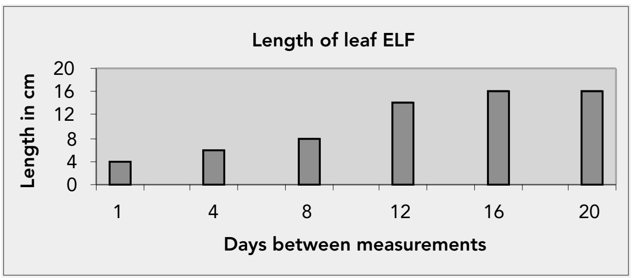


Fig 3.

Appendix 4

Teachers' pick and mix: an aid to lesson preparation

Experiment number	Topic	Anticipated timing	Comments
Introduction	Getting to know you	Parts 1 & 2: 1 Lesson	Self–contained activity
Experiment 1	Light and dark	•	Regular measurements at 1-2 day intervals for 1 week
Experiment 2	Hot and cold	•	Regular measurements at 1-2 day intervals for 1 week
Experiment 3	Clover colouring	•	Regular measurements at 1-2 day intervals for 1 week
Experiment 4 (Experiment 1 cont)	Watching the grass grow	• •	Regular measurements between 10-15 days Can use seeds from Expt 1
Experiment 5 (Experiment 4 cont)	Re–growth rates	• • • •	Regular measurements between 15-25 days Can use seeds from Expt 4
Optional extras Appendix 1	Leaf races	• • • •	Measured once a week for 4 weeks
Experiment 6	Starch test	2 Consecutive lessons 24h apart	Safety goggles needed
Experiment 7	Roots and shoots	Part 1: lesson Part 2: variable	Seasonal: May – June is best
Optional extras (Experiment 7 part 2) Appendix 2	Looking at Rhizobium	• • •	Observe after 2 and 3 weeks Can use seedlings from Expt 3
Experiment 8 (Experiment 7 cont)	Shoots	• • • •	Seasonal: May – June is best Can use plants from Expt 7
Experiment 9	Plant classification	1 lesson	Seasonal: May – June is best Precautions for hayfever sufferers
Experiment 10	Flowers and sex	1 lesson	Seasonal: May – June is best Precautions for hayfever sufferers
Experiment 11 (Experiment 10 cont)	Gone to seed	• • • •	Observe after 1, 2, 3 and 4 weeks Season: May – June is best Can use grasses from Expt 10

Key

1 week •
2 weeks ••
3 weeks •••
4 weeks ••••

Appendix 5

More Seeds

If you have a large number of students using the ***Science through seeds*** pack or you wish to use the pack again at a later date, you can request further packets of seeds from:

The School's Liaison Service
Polaris House
North Star Avenue
Swindon SN2 1UH
Fax: 01793 413382

Glossary of terms

Amenity grass	a grass used for leisure or other useful purposes
Amorphous endosperm	shapeless tissue surrounding the developing seed, which provides nourishment (food)
Anatomy	the physical structure of a plant or animal
Angiosperm	a major division of the plant kingdom, commonly called flowering plants
Annual	a plant which completes its life cycle within one year or less
Anther	the part of the flower where the male gametes (pollen) are produced
Auricle	a small claw or ear-shaped outgrowth at the junction of the leaf sheath and the blade of some grasses
Awns	bristles growing from the flowering parts of certain grasses
Cotyledons	the leaves contained inside a seed that feed the plantlet as it starts to grow
Crossing	hybridising (see hybrid)
Dicotyledon	a plant with two seed leaves
Dioecious	male and female gametes occur on different plants
Equilibrium	a stable condition; a balanced state
Family	a taxonomic (classification) term meaning a group of genera with similar characteristics
Fertilisation	the fusion of male and female gametes (e.g. pollen and ovum or sperm and egg) to produce a zygote (seed)
Floret	a small flower – often one of many making up the head of a composite flower
Forage	food for animals especially horses and cattle
Gamete	a sex cell containing exactly half the parental chromosomes and which is able to fuse with a cell of similar origin but of the opposite sex to produce a zygote
Genus	a taxonomic term meaning a group of species with similar characteristics (plural = genera)
Germinate	to cause seeds (or spores) to grow and develop
Hermaphrodite	a living thing which has both male and female organs, and produces both male and female gametes
Hybrid	a plant or animal resulting from a cross between two genetically unlike individuals
Inbreeders	to breed between closely related individuals
Indigenous	native to a country or area
Inflorescence	the part of the plant that consists of flower bearing stalks

Kingdom	a taxonomic term – five biological kingdoms are commonly recognised, these are the Plant, Animal, Fungi, Protista and Monera.
Leaf sheath	an enclosing structure surrounding part of the blade of the grass leaf
Legumes	plants which have a symbiotic relationship with a bacterium called Rhizobium, allowing the plant to produce nitrogen
Ligule	a thin membraneous structure at the inner junction between leaf blade and sheath
Monocotyledon	a plant producing seeds with one seed leaf
Monoecious	male and female gametes are on the same plant but present in different flowers
Morphology	the form and structure of an organism
Order	the taxonomic group into which a class is divided and which has one or more families
Outbreeders	mating between individuals which are not closely related
Ovule	a structure in seeds plants which contains female gametes and which develops into a seed after fertilisation
Pannicle	the stalk connecting spikelets to the stem of a grass plant
Perennials	a plant which survives more than one winter
Phylum classes	a taxonomic term; a group of plants or animals that contain one or more
Pollen	male sex cell contained inside pollen sacs in the anther
Progeny	the immediate offspring of a plant or animal
Protocol procedure	a formal procedure – in this context, the description of an experimental
Ruminant animals	animals with a rumen e.g. cattle, sheep, goats
Silage	fermented or composted grass used as an animal feed
Species	a taxonomic term; a group of organisms with similar characteristics which can breed with each other, but not with organisms of different species
Spikelets	the flowers of a grass plant
Stigma	the tip of the carpel. It has a sticky surface so that pollen grains will stick to it
Stolons	above ground vegetative structures which connect legume plants like clovers
Sward	a stretch of turf or grass
Symbiotic relationship	organisms of two different species living together for mutual benefit
Vascular system	vessels in a plant or animal which circulate fluids
Zygote	diploid cell (containing the complete parental number of chromosomes) resulting from the fusion of male and female gametes at fertilisation, which will grow to produce another adult individual.