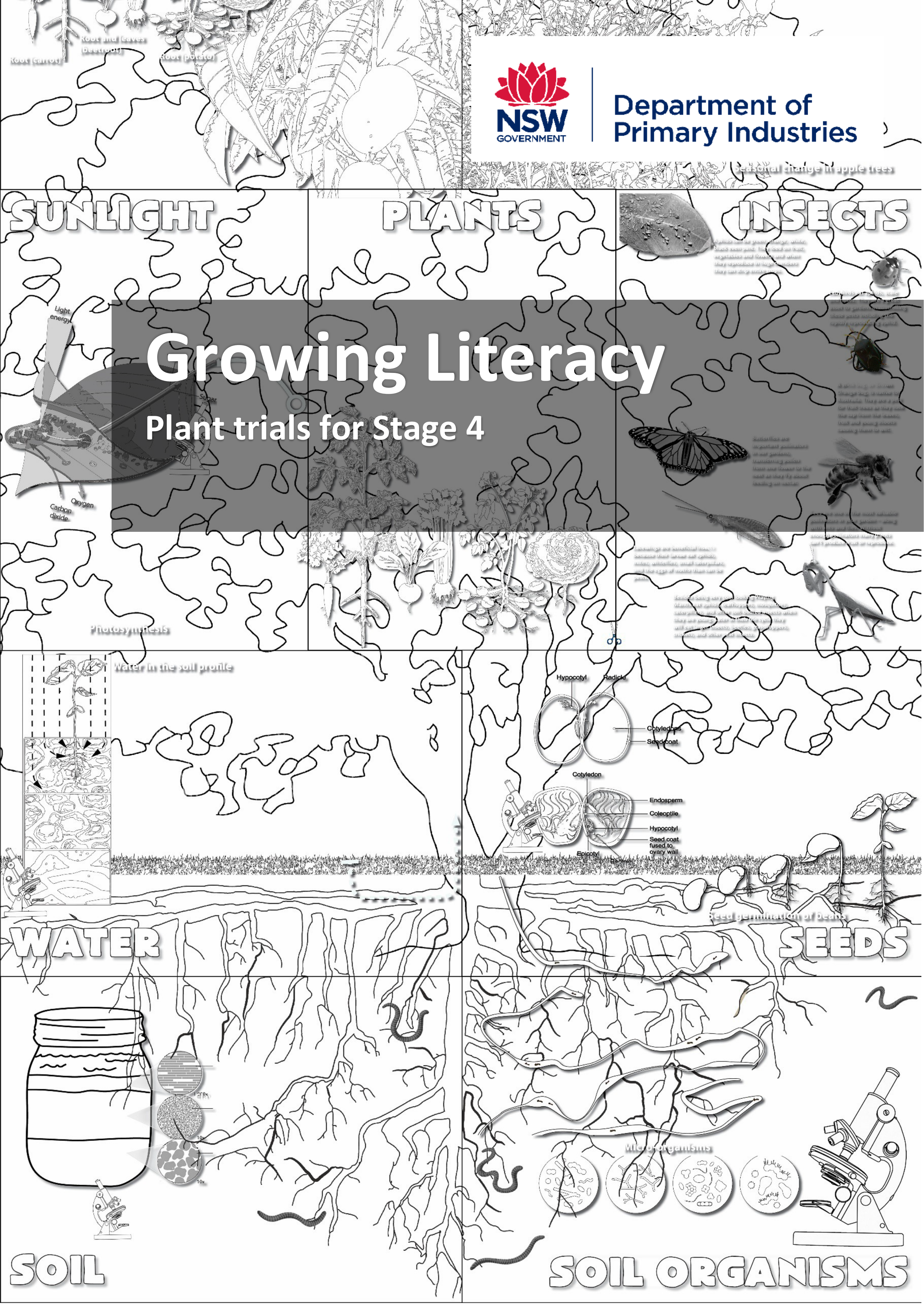
NSW Government
Department of Primary Industries

Growing Literacy

Plant trials for Stage 4



Plant growth trials

To accompany AgPatch: growing literacy posters for secondary schools and Plant structure and function poster and worksheets.

Conducting a series of plant trials while students are completing the AgPatch: growing literacy workbook, enables them to observe the impact that changing growing conditions (the variables in the trials) can have on plant growth – and therefore food production. This hands-on learning will help students apply their learning and give them a better understanding of the challenges faced in plant production.

Planning for and setting up trials provides a good opportunity for students to understand the role of science and the scientific method in research.

Student scaffolds, syllabus outcomes, and suggested experiment ideas are included in this document.
Prior to completing this booklet, it is recommended teachers brush up their Experimental design and Scientific process knowledge and skill by reading the NSW DPI Schools Program publication 'Experimental Design and analysis'.

Good experimental design and fair tests

You may have heard or used the term 'fair test' in junior science when carrying out investigations. Carrying out a fair test uses the principles of experimental design.

Good experimental design involves following a well-planned protocol, which manages factors to ensure reliable results. The results should be unaffected by bias or the influence of any external factors not being investigated. Good experimental design follows the scientific method and allows researchers to make conclusions that relate to the wider population.

Badly designed experiments can lead to incorrect conclusions, wasted time and scientific resources. Conversely many experiments can be improved with better experimental design.

Elements of good experimental design

When you carry out a scientific experiment, many different factors can affect the outcome and experiment results. These factors are called variables. Types of variables:

- Independent variable- the factor changed on purpose in the investigation. An independent variable is changed in an experiment to see what effect it has on the dependent variable. Examples include temperature, light intensity, and soil type.
- Controlled variables- factors that are kept the same. For example, if you are testing different fertiliser rates on plant growth, factors that are kept the same (controlled variables) include temperature, location, number of plants, plant type, soil, light, water. This is also called standardisation.
- Dependent variable- responses measured in an investigation e.g. weight, length, yield, micron, number of leaves. The dependent variable changes in response to the independent variable, for example, crop yield is dependent on the rate of fertiliser applied.

Good experimental design requires that only ONE factor (variable) changes in any experiment - the independent variable. All other variables are kept the same (controlled variables). If this is not that case the results could be attributed to a range of factors.

Treatments- are the different manipulations of the independent variable to determine its effect on the dependent variable. For example, in a trial investigation light colour effects on plant yield. The independent variable is light colour. The dependent variable is plant yield. The treatments are the different light colours. For example,

Light colour treatments on plant yield
Treatment 1- blue light
Treatment 2- red light
Treatment 3- green light
Treatment 4- yellow light
Treatment 5- purple light
Control Treatment- natural sunlight (white light)

In simple animal and plant trials at the school education level, the fundamental features of good experimental design are:

- Randomisation- random allocation of treatments to the experimental units being tested.

Replication- living things all naturally vary even if they are treated the same way (called natural variability). Replication is having multiple experimental units for the same treatment to reduce the chances of natural variability influencing the results.

- Standardisation- involves controlling all experimental variables other than the one under investigation.

- Inclusion of a control treatment- the control treatment does not experience the independent variable. The control treatment provides the baseline for comparison of the independent variable treatment effects.

These four features allow for meaningful results to be captured, valid comparisons to be made and reliable conclusions to be formulated.

More information about fair tests and what you can expect of your students in planning this investigation is in the skills continuum of the 'NSW Science and Technology syllabus (2017)'.

For greater detail on Experimental Design and the Scientific process check out the NSW DPI publication 'Experimental Design and analysis'.

Learning activities

Go to "Fair test" to conduct a virtual greenhouse experiment and investigate the effects of different variables on tomato, lettuce and pea plant growth. Complete questions 1)-6).

1. Identify six variables which are kept the same or standardised in the tomato plant experiment (controlled variables).

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2. Define the purpose of a control treatment in the experiment.

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3. In valid experimental design, identify the maximum number of variables which should be selected for an experiment and explain why.

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4. Identify the four possible independent variables in this experiment.

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5. Identify the results measured in all the experiments (dependent variables).

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6. Use this check list to identify if this investigation followed good experimental design.

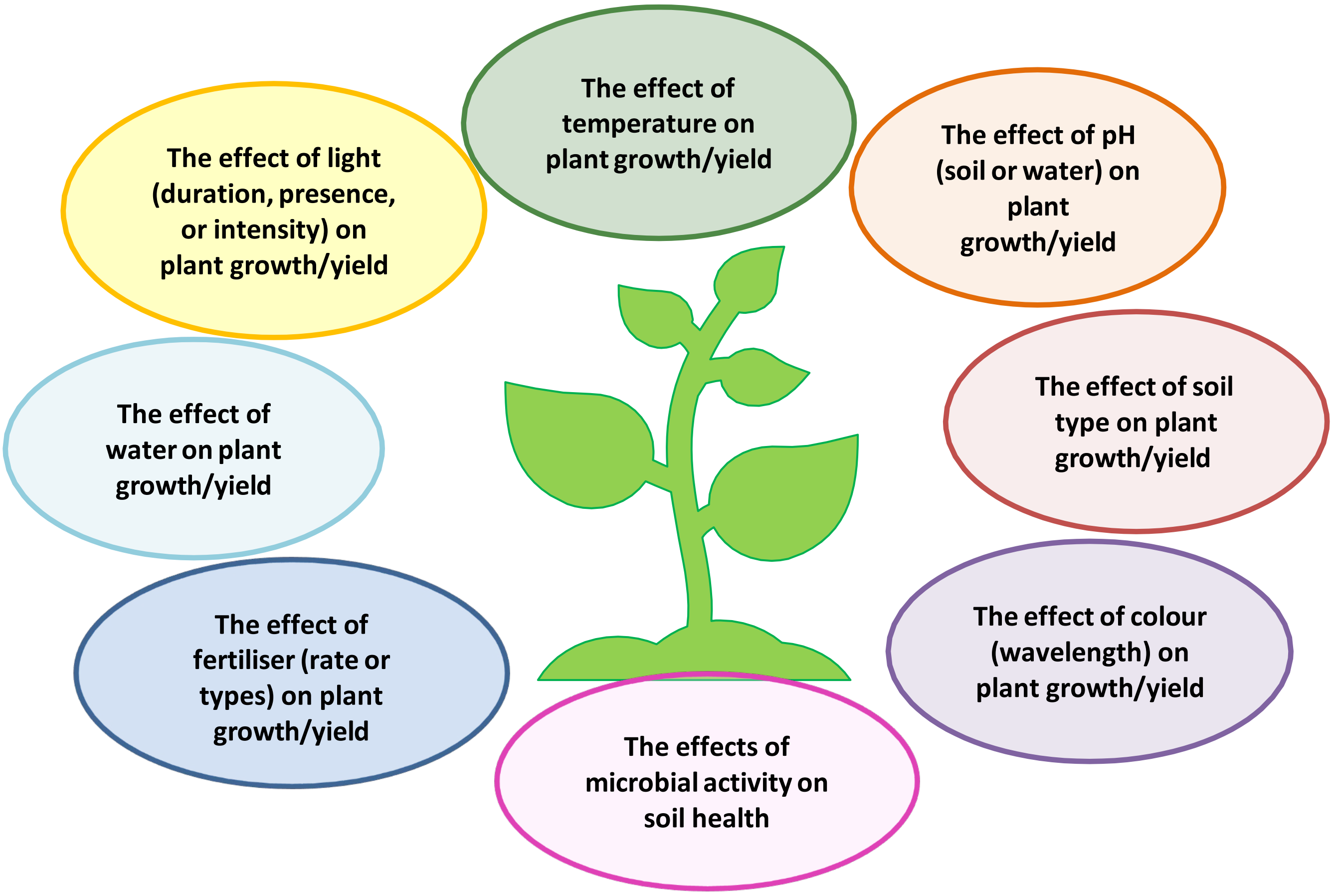
- ☐ Includes a control treatment?
- ☐ Includes replication?
- ☐ Includes randomisation?
- ☐ Includes standardisation?
- ☐ Experiment is repeatable and gives similar results to the original experiment when repeated?
- ☐ Follows a clearly defined method?
- ☐ Attempts to standardise all external factors which may influence the experiment?
- ☐ Variables within the experiment clearly identified (for example, independent and dependent variables)?
- ☐ Collects sufficient data (results) for an average to be determined and conclusion made?

Plant growth and germination trials

Planning your own experiments

It is suggested students conduct a range of plant growth trials to facilitate deep learning of the factors required for plant growth.

Suggested investigations include:



These investigations assess some of the factors that affect plant growth.

Each investigation must be carried out separately following principles of good design.

With these experiments, you can either give your students a clear goal and experimental procedure to follow, or you can encourage your students to create their own hypotheses and design experiments to test them. Students could work in groups to design and conduct their own individual experiments and inquiries. These skills align with NSW Science Years 7-10 syllabus Working Scientifically stage 4 outcomes (see Appendix 4 - NSW syllabus outcomes).

- Use the Experimental design scaffold (Appendix 1) to help plan and carryout your experiments.
- Use the Experimental report scaffold (Appendix 2) to help write up a

scientific report.

- For links for ideas of possible experiments go to Appendix 3- Experiment ideas.

The following experiments model good experimental design following the scientific method. It is suggested all student's carry out at least one of these experiments prior to conducting their individual investigations. If only carrying out one experiment- Experiment 1 is most appropriate for Stage 4 learners and Experiment 2 for Stage 5 learners.

Students should break into groups and all perform the following experiments to allow for concepts of replication, standardisation, randomisation, inclusion of a control treatment and statistical analysis to be performed. Teachers point out and discuss the aspects of good experimental design in the experiments to strengthen student understanding.

Example experiment 1 - How does salt affect seed germination?

Background: Soil salinisation is one of the major factors of soil degradation. Soil salinisation can occur due to naturally occurring salts in the soil profile accumulating near the soil surface in the plant root zone or from water being added to the soil with high salt content (e.g. irrigation).

Plant species vary in how well they tolerate salt-affected soils. Some plants will tolerate high levels of salinity while others can tolerate little or no salinity. The relative growth of plants in the presence of salinity is termed their salt tolerance. A high salt level interferes with the germination of seeds. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of high concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant roots. Keep in mind not all salts are the same. This experiment deals with sodium chloride (NaCl) common table salt and a common salt in agricultural soils which causes salinity.

Aim: Do different concentrations of salt (NaCl) in water affect the germination of radish seeds?

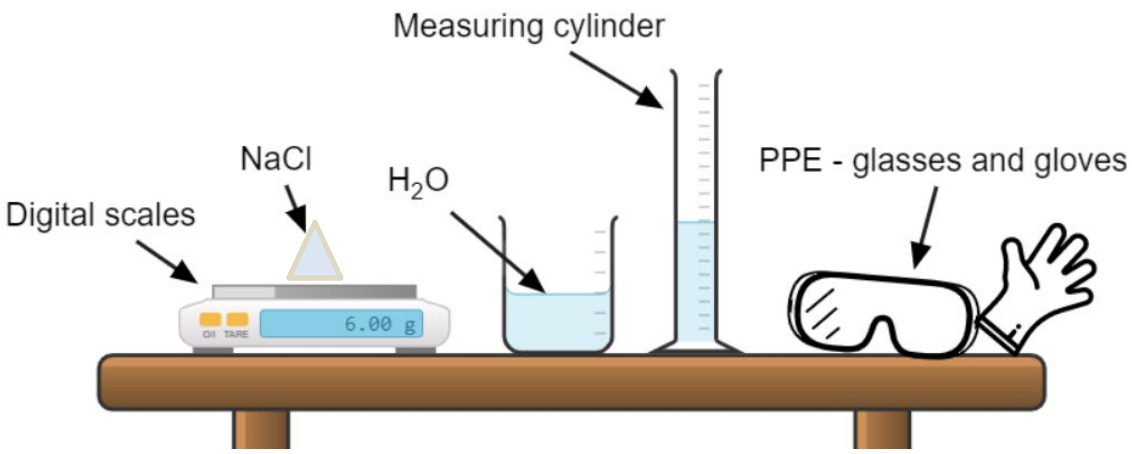
Hypothesis: The more salt added to the water, the fewer seeds will germinate. The radish seeds will not germinate in a solution with more than 12g (≃ 2 teaspoons) of salt in 250mL (cup) of water.

Materials:

- 5 petri dishes (substitute Ziplock bags)
- 500 radish seeds of a single variety
- 5 filter papers or cotton wool
- Tap or rain water (tap water is the control)
- Distilled or deionised water
- Table salt (NaCl)
- Digital scales
- 5 beakers (substitute cups)
- Measuring cylinder (substitute measuring cup)
- 5 stirring rods (substitute teaspoon)
- Tape
- science journal and pen, or computer document to record results

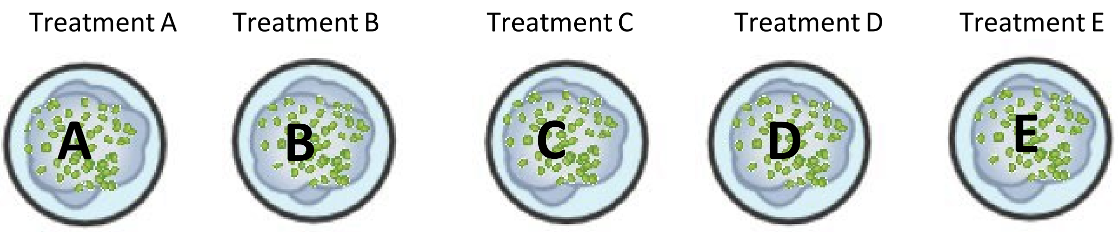
Method:

1. Take five separate beakers/cups. Label them A - E. Use a measuring cylinder to measure the liquids and digital scales to measure the salt. Fill them as follows:



- Solution A: 250ml tap/rainwater (control treatment)
- Solution B: 250ml distilled water
- Solution D: 250ml. distilled water with 6g (≃1 teaspoon) of table salt. Stir with a fresh stirring rod to dissolve the salt.
- Solution F. 250ml distilled water with 12g (≃2 teaspoons) of table salt. Stir with a fresh stirring rod to dissolve the salt.
- Solution H. 250ml distilled water with 18g (≃3 teaspoons) of table salt. Stir with a fresh stirring rod to dissolve the salt.

2. Take 5 petri dishes label the top and bottom of each dish with the letter of the solution to be used in each one (A through E).
3. Place a coffee filter in each petri dish.
4. Pour 5ml (one tablespoon) of solution on the filter in the petri dish with the same label, make sure it soaks the whole coffee filter.
5. Divide the 500 seeds into groups of 100. Randomly assign 100 seeds on the filter of each petri dish. Make sure the seeds are scattered evenly over the filter paper.
6. Tape up the petri dish to prevent gas exchange.
7. Place all 5 treatments (petri dishes) at room temperature out of direct sunlight (seeds don't need light to germinate and light can cause fungus to grow. This simulates industry growing conditions).



8. Observe the petri dishes daily. Record the number of seeds that have germinated in each treatment and any other changes in the seeds or apparatus.

Safety Procedures: Wear safety glasses to prevent possible saltwater splash to eyes, and gloves to prevent bacterial transfer to the seeds.

Results: (Includes tables and graphs)

Add more columns for days if required

Calculate the average germination % using data from all groups in the class. Add all germ % ÷ by number of replicates (class groups)

Treatment	Days 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Germination total	Mean number of days until germination	Germination %	Average germination %
A																							
B																							
C																							
D																							
E																							

Add daily seeds germinated

Add daily germination rates ÷ Number of days

(Total seeds germinated ÷ total seeds ×100)

Graphs:

Use this space to create a bar graph illustrating the average (mean) number of days it takes a seed to germinate for all treatments including the control treatment.

- *x*- axis = independent variable (Saltwater concentration)
- *y*- axis = dependent variable (average germination rate (days))

Always remember to label the axis, include units, and add an appropriate scale and title.

Diagrams:

Use this space to include scientific diagrams or images you have captured. Check with your teacher for their preference.

Discussion: (Use Appendix 2- Experimental report scaffold to assist developing a discussion and conclusion)

These are specific questions about the experiment, which may include:

- Is the hypothesis supported or disproved? (Whether your prediction was right or wrong)
- Your ideas of why your results came out the way they did.
- What problems were encountered?
- How could the experiment be improved?
- What errors were made?
- What experiment would you do next to get more information?
- The importance of your experiment to real-world problems.

The discussion should be written in past tense.

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Conclusion:

This is a short statement directly stating the results in relation to the aim.
This should be written in past tense.

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Questions *(Answers p15)*

a) What is the independent variable?

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b) What is the dependent variable?

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c) What is the control treatment in this experiment and why?

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d) How is standardisation carried out in this experiment? (list the controlled variables)

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e) How is replication carried out in this experiment?

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g) How is randomisation carried out in this experiment?

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h) How could experimental design be improved?

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i) Do you have to use radish seeds? Why or why not?

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j) Do you need a lot of seeds to see how salt affects seed germination? Is it okay to use about four seeds in each petri dish?

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Answers

a) What is the independent variable?

The concentration of saltwater is the variable.

b) What is the dependent variable?

Germination rate of radish seeds

c) What is the control treatment in this experiment and why?

The control treatment in this experiment is treatment A- 250ml rain or tap water. It is a control treatment as no independent variable is being administered (no salt concentration) and it represents industry practice

d) How is standardisation carried out in this experiment (list the controlled variables)

- same plant variety
- all apparatus is the same
- growing medium and sowing depth are the same
- use of scientific equipment to improve accuracy of results
- all procedures for set up are the same
- controlled location
- control environmental factors- temperature, light, oxygen, moisture, grow medium

e) How is replication carried out in this experiment?

In this experiment replication of treatments is carried out by having multiple class groups carry out the experiment which replicates the treatments and allows for an average to be determined. It is also carried out by having a large sample population of 500 seeds (100 seeds all being observed for germination rate in each treatment).

f) How is randomisation carried out in this experiment?

1000 seeds are allocated for each replicate. 100 seeds are randomly selected and randomly allocated to each treatment (A-E).

g) How could experimental design be improved?

For a junior science experiment the experimental design here is adequate. In industry, it would be essential to have a greater number of replicates and treatments to gain more accuracy in results, along with the use of other statistical analysis testing e.g. ANOVA. Randomisation would also be carried out differently using randomised block designs etc.

h) Do you have to use radish seeds?

No, radish seeds were used as they are a temperate species and easily grown in many locations Australia wide. They have a quick germination period of 3-10 days. Other plants could be easily substituted.

i) Do you need a lot of seeds to see how salt affects seed germination? Is it okay to use about four seeds in each petri dish?

You must have replication within any experiment to compile enough data to make meaningful statistical analysis. Replication in this experiment is achieved by all groups completing the investigation then comparing results between groups. Using only fewer seeds per treatment would not be advisable as result could be due to natural variability and not the treatments.

j) How often you water the seeds, if at all?

Check each petri dish each day to make observations and check the filter paper (growing medium) is moist but not wet. If you see there is some dryness, then add just enough water (from the original solution) to moisten the filter paper again. The number of germinating seeds will change the amount of water needed. Keep your water concentrations in covered containers so that you don't need to make any more of them. The containers need to be covered so that they don't evaporate and cause the salt concentrations to increase.

k) What is the link between lack of germination and plant death?

If the seeds don't germinate, then they can't produce a full-grown plant. Another way to do this experiment is to water full-grown plants with different concentrations of saline water.

Example experiment 2 – Cotton strip comparative test for soil microbial activity

Background: Decomposition is the process of organic matter breakdown and transformation to smaller forms that can be used by plants for growth. Decomposition is carried out by decomposers- soil fauna (worms, nematodes etc.) and microorganisms (mainly fungi and bacteria). Inorganic compounds are not easily broken down by decomposers.

These decomposers, along with climate (temperature, moisture, humidity, sunlight) and organic matter present in the soil, are the primary regulators of the decomposition process.

Decomposers are important for soil health nutrient cycling and carbon sequestration (carbon storage in the soil).

As soil microorganisms are microscopic, it is hard to determine their populations in soil. One way is to measure the amount of total decomposition of organic matter (cotton strips and grass cuttings). The organic matter is used as a food source for fungi and bacteria. The more they break down (decompose) the material, the more microbial activity there is in the soil.

Aim: To examine microbial activity of different soils, by measuring the percentage of decomposition of organic matter.

Hypothesis: The cotton strips and grass clippings will decompose at different rates in different soils. Soils with higher microbial populations will have the greatest amount of decomposition. The growing medium vermiculte/perlite (which is a weathered mineral) will have the least amount of decomposition.

Materials:

- 120g unbleached calico material
- 120g of grass clippings
- 120g nylon material
- 36 inorganic mesh pouches (approx 5x5cm) (eg organza, fruit/nut bag mesh or fine fishing net.

- Bucket (10L) of vermiculite or perlite (growing medium attainable from hardware store)
- Spade
- Digital scales
- Class set of Permanent textas, scissors and rulers
- Science journal and pen, or computer document to record results
- School/paddock map
- 36 x pots (capacity approximately 2L)
- 6 x 10L buckets

Pre- experiment preparation- Buy unbleached calico from a material shop. Rinse the calico in cool water to remove manufacturer's stiffener, then dry. Unbleached calico is the least treated/processed cotton fabric available.

Safety note: Soils contain bacteria and fungi, be careful with hygiene, wear gloves and a mask to prevent inhalation.

Method:

Pouches

1. Take 120 g of calico material.
2. Use scissors to shred/cut material into small slithers of material (approximately the size of grass clippings).
3. Take digital scales.
4. Weigh 10 g of shredded calico.
5. Place this into a gauze pouch.
6. Label as Calico using permanent marker.
7. Repeat steps 1-6 for eleven more pouches of shredded calico.
8. Repeat steps 1-7 for grass clippings and nylon separately – grass clippings do not need to be cut/shredded.

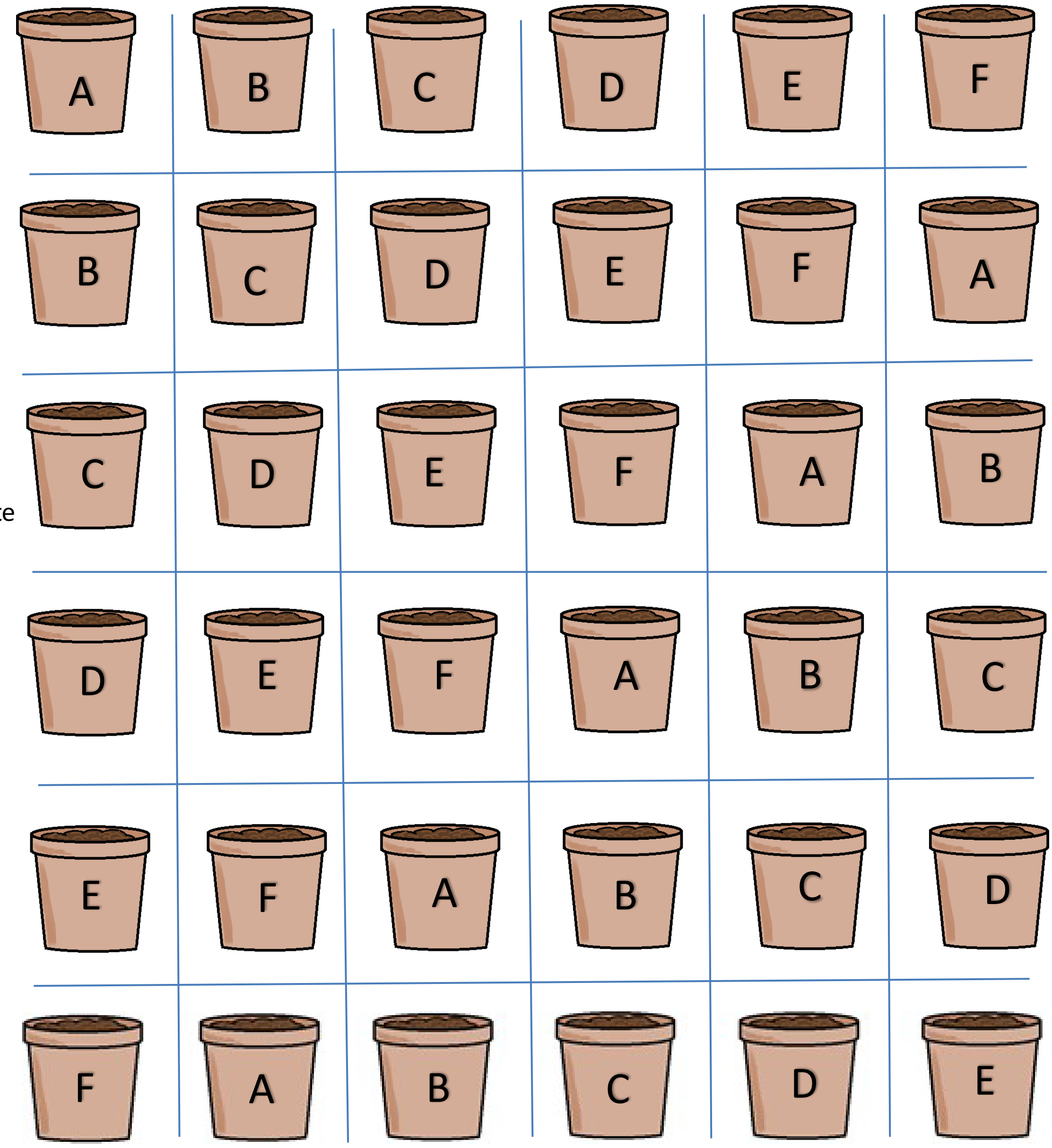
Site selection and sampling

9. Select (at least) 5 locations around your school site to investigate soil microbial activity. The sites could be known areas that you are interested in investigating (e.g. places with a different soil type, limited plant growth, water logging, etc. Mark locations A-E on your school/paddock map or in your workbook.
10. Go to site A
11. Use a spade to dig a 50cmx50cm square of top soil approximately 20-30cm deep.
12. Take a bucket, label with site location A using a permanent Texta.
13. Collect all soil that has been dug up from the site to fill the labelled bucket. Include any organic matter and debris that might be mixed amongst the soil sample or on the soil surface in the area you are sampling. Collect approximately 10L (bucket full) of soil.
14. Break up and thoroughly mix soil sample to a crumbly texture in the bucket. Use mask to reduce risk of soil microbe inhalation.
15. Repeat steps 9-14 for each site B-E.
16. Make up a 10L bucket of moistened perlite/vermiculite to product directions. Label sample F. (Control treatment).

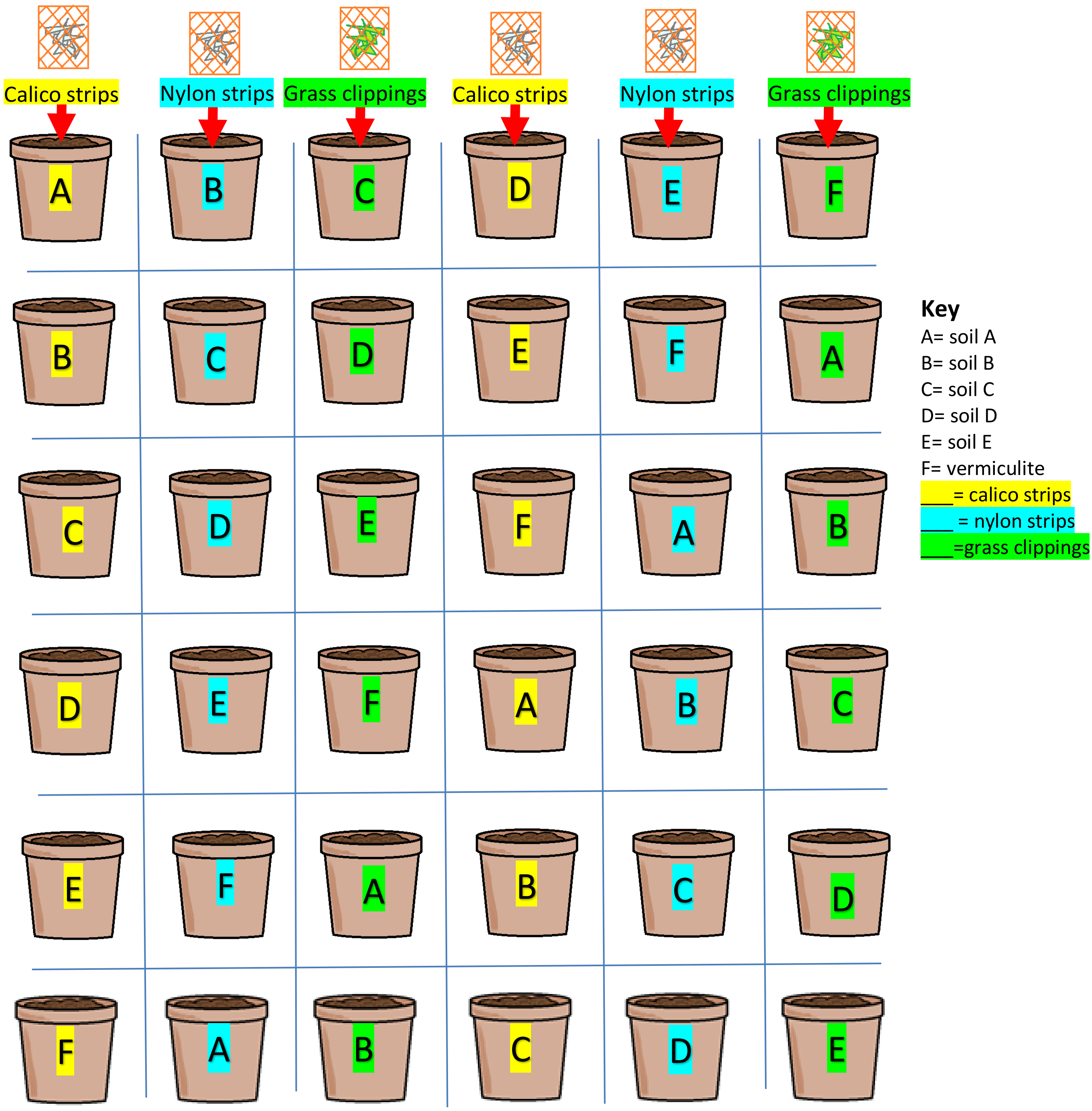
Experiment layout

17. Label five pots A
18. Take soil sample A. Use digital scales to weigh 1.5 kg soil sample and place it into the matching pot.
19. Repeat step 18 for all six Sample A pots
20. Repeat steps 17-19 for Samples B-F.
21. Set up pots in the one area using the diagram and key on the following page.

Key
A= soil A
B= soil B
C= soil C
D= soil D
E= soil E
F= vermiculite



22. Take the 30 gauze pouches of materials. Use the following key and diagram to match treatments.
23. Take one pot and one gauze pouch. Scrape 1cm soil at the top of pot to the side. Lay gauze pouch horizontally and backfill soil. Ensure the pouch is fully covered with soil.
24. Repeat step 24 for each pot separately.



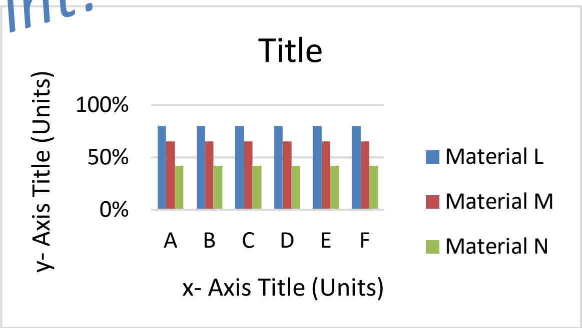
Results capture

25. Leave the pots for one month. Keep pots moist throughout this period.
26. Remove a gauze pouch from a pot by carefully scraping back the top 1cm layer of soil.
27. Observe pouch contents.
28. Carefully remove any material from the pouch.
29. Weigh contents using digital scales.
30. Record results in the following table.
31. Repeat steps 26- 30 for each gauze pouch separately.

Results:

Treatment (soil sample)	Materials									Total average decomposition (g) /Soil type
	Calico			Grass clippings			Nylon			
	Final weight (g)	Average final weight (g)	Average % decomposed	Final weight (g)	Average final weight (g)	Average % decomposed	Final weight (g)	Average final weight (g)	Average % decomposed	
A										
B										
C										
D										
E										
F- vermiculite/ perlite										

Hint!



Graphs:

Use this space to create a bar graph illustrating the average (mean) decomposition percentage of each material in each soil

- *x*- axis = independent variable (soil sample)
- *y*- axis = dependent variable (average % decomposed)

Always remember to label the axis, include a key, include units, add an appropriate scale and title.

Diagrams:

Use this space to include scientific diagrams or images you have captured. Check with your teacher for their preference.

Discussion: (Use Appendix 2- Experimental report scaffold to assist developing a discussion and conclusion)

These are specific questions about the experiment, which may include:

- Is the hypothesis supported or disproved? (Whether your prediction was right or not?)
- Your ideas of why your results came out the way they did.
- What problems were encountered?
- How could the experiment be improved?
- What errors were made?
- What experiment would you do next to get more information?
- The importance of your experiment to real-world problems e.g. waste and recycling, mineral cycles, soil health, importance of organic matter in soil.

The discussion should be written in past tense.

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Conclusion:

This is a short statement directly stating the results in relation to the aim.
This should be written in past tense.

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Questions *(Answers p24)*

a) What is the independent variable?

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b) What is the dependent variable?

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c) What is the control treatment in this experiment and why?

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d) How is standardisation carried out in this experiment? (list the controlled variables)

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e) How is replication carried out in this experiment?

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f) How is randomisation carried out in this experiment?

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h) How could experimental design be improved?

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i) What happens if the pots dry out?

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j) When is the best time of year to carry out this experiment?

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Answers

a) What is the independent variable?

The soil type.

b) What is the dependent variable?

Percentage of decomposition of each material for that soil type.

c) What is the control treatment in this experiment and why?

The control treatment in this experiment is treatment F- vermiculite or perlite (whichever is used) with nylon. It is a control treatment because vermiculite and perlite do not have any microorganisms present - they are a processed inorganic growing medium. Therefore, microbial breakdown of the nylon (synthetic material) should not occur. Vermiculite allows for comparison of results.

d) How is standardisation carried out in this experiment (list the controlled variables)

- Location and other environmental factors controlled e.g. sunlight, oxygen, temperature, moisture, humidity
- All apparatus and equipment are the same
- Use of scientific equipment to improve accuracy of results
- All procedures for set up and testing are the same

e) How is replication carried out in this experiment?

In this experiment replication of treatments is carried out by having multiple class groups carry out the experiment which replicates the treatments and allows for an average to be determined. It is also carried out by having replication of treatments within the experimental design.

f) How is randomisation carried out in this experiment?

Soil samples are randomly allocated within the experimental setup. No pots being side by side. No replicate has the same order. This set up minimises possible bias, and factors like edge effects.

g) How could experimental design be improved?

For a junior science experiment this experimental design is adequate. In industry, it would be essential to have a greater number of replicates and treatments to gain more accuracy in results, along with the use of other statistical analysis testing e.g. ANOVA. As well, randomisation would be carried out differently using randomised block designs etc.

h) What happens if the pots dry out?

Water is required by all living things including microbes. If the pots dry out- the bacteria and fungi may die. Pots should be moistened each week to prevent full drying out. Add the same amount of water to every pot in the experiment to facilitate standardised procedure.

i) When is the best time of year to carry out this experiment?

Environmental factors essential to decomposition include moisture, heat and a food source. If it is too hot, cold, wet or dry- the microbial population in the soil samples may become dormant or die. If you are carrying out the experiment outdoors- the best times would be Spring- early summer, or late Summer- early Autumn. The experiment could be carried out year-round in a controlled environment e.g. classroom.

Appendix 1 - Experiment design scaffold

Follow the steps below to ensure correct experimental design is used when completing and planning an investigation.

Planning

- ☐ Formulate a problem or question to investigate
- ☐ Research the problem or question to identify findings in the area and find methods you can use for your investigation
- ☐ Decide on the treatments that you are going to use, make sure you include a control treatment
- ☐ Formulate a hypothesis. Make *sure* you state the consequences and reasoning for the hypothesis

Identify variables

- ☐ List the dependent variable c List the independent variable
- ☐ Consider an adequate size for your experiment. Ensure there are enough replicates for a meaningful statistical analysis.

Sampling

- ☐ Identify and describe how you will randomly select your sample

Randomisation

- ☐ Identify and describe how you will randomly allocate treatments to experimental units

Replication

- ☐ Describe how you will carry out replication of treatments. Provide a diagram.
- ☐ Will the number of replicates you have chosen, give meaningful statistical results?

Standardisation

- ☐ Identify how you will carry out standardisation in terms of all samples receiving the same conditions. Consider factors such as water, sunlight, time, feed, nutrients, soil type, shade, predation, interference and nutrients etc.
- ☐ Identify how you will standardise the method for setting up, carrying out and collecting results from the investigation (Quality Assurance)

Inclusion of a control treatment

- ☐ Does your investigation require a control treatment?
- ☐ If yes, identify the control treatment and explain why it is needed in the investigation
- ☐ Formulate a detailed methodology

Doing

- ☐ Measurement and method strictly followed.

Include detailed descriptions, images, photos, tables etc. for results capture

- ☐ Collection and recording of data
- ☐ Identify statistical analysis methods used (such as mean, median and mode)
- ☐ Present data in an appropriate form (e.g. graphs, table)
- ☐ Make conclusions from your findings
- ☐ Did your results reflect your hypothesis?

Reporting

- ☐ Write a full experimental report using the following titles: aim, hypothesis, materials, methodology, results, discussion and conclusion, references. Provide appropriate detail.

Appendix 2 - Experimental Report Scaffold

Students could use this scaffold to structure their experimental report write up. The titles in blue should be included in the report. The text in the boxes give a guide of what to include in each section.

Title:

- Name for you report. Relates to what you are investigating.

Aim:

Purpose of the experiment. Written in terms of the effect the independent variable has on the dependent variable.

- Independent variable:
- Dependent variable:

Hypothesis:

Statement prediction the outcome of the experiment. An example could be 'increasing the amount of nitrogen fertiliser applied will increase the yield of wheat'

Materials:

Comprehensive and full list of all material and equipment used throughout the experiment

Method:

Describe what you did. It must be in:

- Past tense e.g.,' Measured in 10ml of water' or '10ml of water was measured'
- Point or numbered form
- Passive voice (what was done rather than what you did) e.g., 'The circuit was set up' rather than 'I set up the circuit'

Diagrams: (optional)

These should be labelled and drawn in pencil. At times they may be used instead of a written method.

Results: (tables and graphs)

Table: This is a record of what was observed and/or measured during the experiment.
Graphs: select the correct graph.
Include: title, labelled axis with units, key, add an appropriate scale.

- *x*- axis = independent variable (Salt water concentration)
- *y*- axis = dependent variable

Discussion:

These are specific questions about the experiment, which may include:

- Is the hypothesis supported or disproved? (Whether your prediction was right or not?)
- Your ideas of why your results came out the way they did.
- What problems were encountered?
- How could the experiment be improved?
- What errors were made?
- What experiment would you do next to get more information?
- The importance of your experiment to real-world problems.

The discussion should be written in past tense.

Conclusion:

This is a short statement directly stating the results in relation to the aim.
This should be written in past tense. For example, the aim of the investigation was achieved, and it was found that light is required for photosynthesis to occur. This was evidenced by starch present in leaves exposed to light. The results support the hypothesis.

Appendix 3- Experiment ideas by topic

Investigation area	Examples
	• Easy plant experiments for the classroom - https://www.plt.org/educator-tips/easy-plant-science-experiments-for-the-classroom/ • Size vs. depth: The relationship between the size of a seed and it's ideal planting depth - https://www.sciencebuddies.org/science-fair-projects/project-ideas/PlantBio_p005/plant-biology/seed-size-planting-depth • May the best plant win! Experiment with genetically modified seeds - https://www.sciencebuddies.org/science-fair-projects/project-ideas/Genom_p020/genetics-genomics/genetically-modified-seeds
The effect of water on plant growth/yield	• How does the amount of water affect plant growth? - https://www.scienceprojects.org/how-does-the-amount-of-water-affect-plant-growth/ • Plant growth experiment - http://www.stat.ualberta.ca/statslabs/casestudies/files/plant15.pdf
The effect of light (duration, presence, direction or intensity) on plant yield/growth	• Plants on the move! Experiments with phototropism -https://www.sciencebuddies.org/science-fair-projects/project-ideas/PlantBio_p041/plant-biology/plants-movement-phototropism#background • Experiments on Photosynthesis for High School - https://www.biologydiscussion.com/experiments/photosynthesis-experiments/experiments-on-photosynthesis-for-high-school/56430 • Experiments to show the factors required in photosynthesis- light and carbon dioxide - https://www.biotopics.co.uk/plants/psfac2.html • The effect of different light intensities on the rate of photosynthesis - https://www.ozarktigers.org/cms/lib011/MO01910080/Centricity/Domain/489/Coursework%20Sample%20A%20marked.pdf
The effect of colour (light wavelength) on plant growth/yield	• Effect of light colours on bean plant growth - http://www1.udel.edu/MERL/Outreach/Teacher%27s%20Guide/2.%20Effects%20of%20color%20on%20plant%20growth%20TE.pdf • How light affects plant growth - https://www.education.com/science-fair/article/light-affects-plant-growth/
The effect of temperature on	• How does temperature affect plant growth? - https://www.scienceproject.com/projects/detail/intermediate/IB015.asp

plant yield/growth	• The effects of freezing on plant growth - https://www.education.com/science-fair/article/effects-freezing-plant-life/
The effect of fertiliser (rate or types) on plant growth/yield	• Growing, growing, Gone! An experiment on Nitrogen fertilisers - https://www.sciencebuddies.org/science-fair-projects/project-ideas/PlantBio_p012/plant-biology/nitrogen-fertilizers-plant-growth • Too much of a good thing? Study the effect of fertilisers on algal growth - https://www.sciencebuddies.org/science-fair-projects/project-ideas/EnvSci_p054/environmental-science/effect-of-fertilizers-on-algal-growth
The effect of pH (soil or water) on plant growth/yield	• How does PH level affect the plant growth? - https://www.scienceprojects.org/how-does-ph-level-affect-the-plant-growth/ • How does the pH of water affect the growth of plants? - https://wna.works/sciencefair/c10scn-how-does-the-ph-of-water-affect-the-growth-of-plants/
The effect of soil type on plant growth/yield	• Growing plants on Mars - https://www.sciencebuddies.org/science-fair-projects/project-ideas/SpaceEx_p028/space-exploration/growing-plants-mars#summary • Plant Growth in Different Soil Types - https://www.iowaagliteracy.org/Article/Plant-Growth-in-Different-Soil-Types
The effect of soil decomposers on plant growth/yield or soil health	• Soil your undies Challenge- University of New England- https://www.unediscoveryvoyager.org.au/soilyourundies/ • Earthworm castings – The ideal proportion in soils for young garden plants - https://www.sciencebuddies.org/science-fair-projects/project-ideas/PlantBio_p002/plant-biology/earthworm-castings-gardening

Appendix 4 -NSW syllabus outcomes

Science Years 7-10 Syllabus

Outcomes	Content
Questions and predicting	
SC4-4WS identifies questions and problems that can be tested or researched and makes predictions based on scientific knowledge Related Life Skills outcome: SCLS-4WS	WS4 Students question and predict by: a) identifying questions and problems that can be investigated scientifically (ACSIS124, ACSIS139) b) making predictions based on scientific knowledge and their own observations (ACSIS124, ACSIS139)
Planning investigations	
SC4-5WS collaboratively and individually produces a plan to investigate questions and problems Related Life Skills outcome: SCLS-5WS	WS5.1 Students identify data to be collected in an investigation by: c) identifying the purpose of an investigation d) proposing the type of information and data that needs to be collected in a range of investigation types, including first-hand and secondary sources e) locating possible sources of data and information, including secondary sources, relevant to the investigation WS5.2 Students plan first-hand investigations by: a) collaboratively and individually planning a range of investigation types, including fieldwork, experiments, surveys and research (ACSIS125, ACSIS140) b) outlining a logical procedure for undertaking a range of investigations to collect valid first-hand data, including fair tests c) identifying in fair tests, variables to be controlled (held constant), measured and changed d) describing safety and ethical guidelines to be addressed WS5.3 Students choose equipment or resources for an investigation by: a) identifying suitable equipment or resources to perform the task, including safety equipment and digital technologies b) selecting equipment to collect data with accuracy appropriate to the task (ACSIS126, ACSIS141)
Conducting Investigations	
SC4-6WS follows a sequence of instructions to safely undertake a range of investigation types, collaboratively and individually Related Life Skills outcome: SCLS-6WS	WS6 Students conduct investigations by: a) a. collaboratively and individually conducting a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125, ACSIS140) b) assembling and using appropriate equipment and resources to perform the investigation, including safety equipment c) selecting equipment to collect data with accuracy appropriate to the task (ACSIS126, ACSIS141) d) following the planned procedure, including in fair tests, measuring and controlling variables (ACSIS126, ACSIS141) e) recording observations and measurements accurately, using appropriate units for physical quantities f) performing specific roles safely and responsibly when working collaboratively to complete a task within the timeline

	g) assessing the method used and identifying improvements to the method (ACSIS131, ACSIS146)
Processing and analysing data and information	
SC4-7WS processes and analyses data from a first-hand investigation and secondary sources to identify trends, patterns and relationships, and draw conclusions Related Life Skills outcome: SCLS-7WS	WS7.1 Students process data and information by: a) summarising data from students' own investigations and secondary sources (ACSIS130, ACSIS145) b) using a range of representations to organise data, including graphs, keys, models, diagrams, tables and spreadsheets c) extracting information from diagrams, flowcharts, tables, databases, other texts, multimedia resources and graphs including histograms and column, sector and line graphs d) accessing information from a range of sources, including using digital technologies e) applying simple numerical procedures, e.g. calculating means when processing data and information, as appropriate WS7.2 Students analyse data and information by: a) checking the reliability of gathered data and information by comparing with observations or information from other sources b) constructing and using a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS129, ACSIS144) c) identifying data which supports or discounts a question being investigated or a proposed solution to a problem d) using scientific understanding to identify relationships and draw conclusions based on students' data or secondary sources (ACSIS130, ACSIS145) e) proposing inferences based on presented information and observations f) reflecting on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected (ACSIS131, ACSIS146)
Problem solving	
SC4-8WS selects and uses appropriate strategies, understanding and skills to produce creative and plausible solutions to identified problems Related Life Skills outcome: SCLS-8WS	WS8 Students solve problems by: a) using identified strategies to suggest possible solutions to a familiar problem b) describing different strategies that could be employed to solve an identified problem with a scientific component c) using scientific knowledge and findings from investigations to evaluate claims (ACSIS132, ACSIS234) d) using cause and effect relationships to explain ideas and findings e) evaluating the appropriateness of different strategies for solving an identified problem
Communicating	
SC4-9WS presents science ideas, findings and information to a given audience using appropriate scientific language, text types and representations Related Life Skills outcome: SCLS-9WS	WS9 Students communicate by: a) presenting ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS133, ACSIS148) b) using appropriate text types in presentations, including a discussion, explanation, exposition, procedure and recount c) using a recognised method to acknowledge sources of data and information d) constructing and using a range of representations to honestly, clearly and/or succinctly present data and information including diagrams, keys, models, tables, drawings, images, flowcharts, spreadsheets and databases e) constructing and using the appropriate type of graph (histogram, column, sector or line graph) to express relationships clearly and succinctly, employing digital technologies as appropriate

Agricultural Technology 7-10 Syllabus

Outcomes	Content
Core A: Plant Production 1	
AG5-11 **designs, undertakes, analyses and evaluates experiments and investigates problems in agricultural contexts**	• conduct a controlled agricultural experiment based on a plant-related hypothesis, for example: – sowing density – fertiliser application – plant yield • plan and undertake procedures in the management of a plant enterprise (ACTDEP048, ACTDEP050) • work collaboratively to perform plant enterprise management activities (ACTDEP050, ACTDEP052)
Core B: Agricultural Systems and Management	
AG5-11 **designs, undertakes, analyses and evaluates experiments and investigates problems in agricultural contexts**	• design and conduct a controlled agricultural experiment, for example: (ACTDEP049) – the effect of irrigation on a plant enterprise – soil testing to determine the influences on plant growth – compare the growth rates of yabbies fed on different diets
Planning investigations	
AG5-12 **collects and analyses agricultural data and communicates results using a range of technologies** AG5-14 **demonstrates plant and/or animal management practices safely and in collaboration with others**	• draw conclusions from evidence and the analysis of data, for example: (ACTDEP051) – identify fertilisers for optimal plant growth – identify optimal irrigation systems • formulate a solution to an agricultural issue (ACTDEP048)