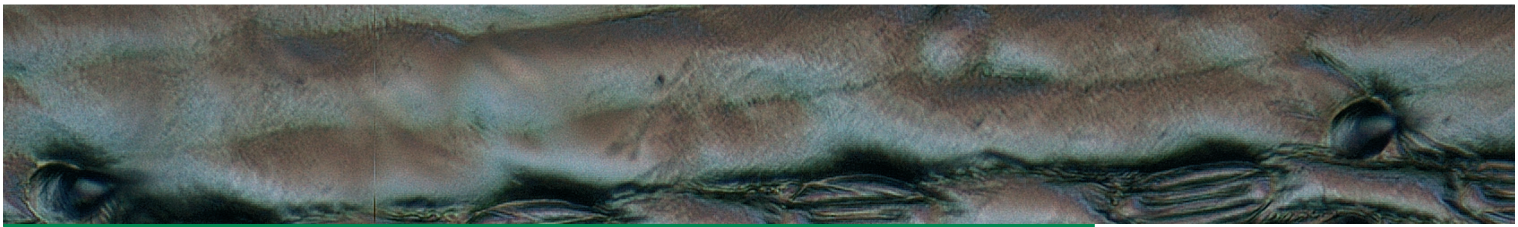
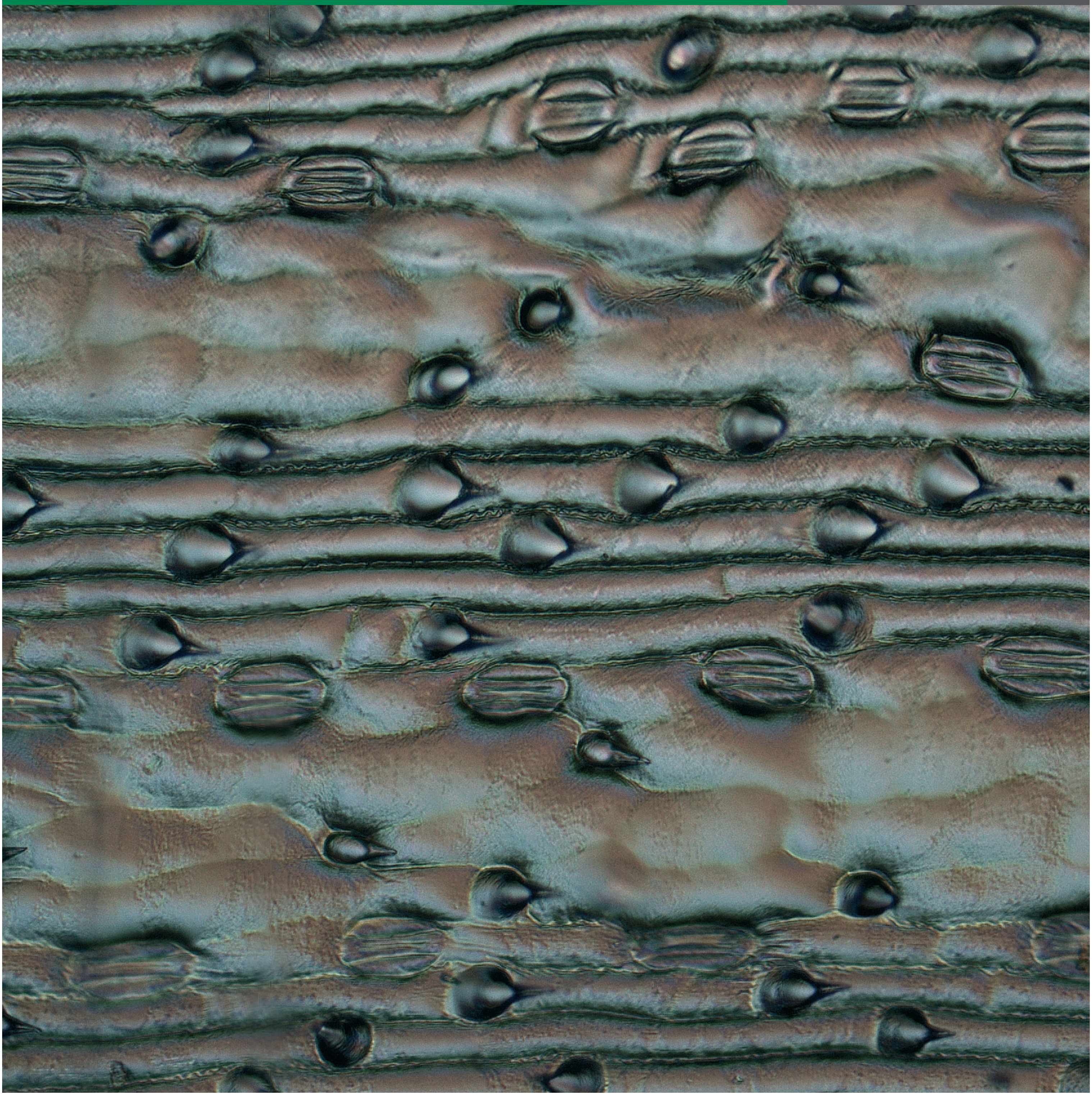


THE SCIENCE OF STEMS, STOMATA AND SUSTAINABILITY

HOW MODERN SCIENCE IS HELPING PRODUCE MORE FOOD IN A CHANGING CLIMATE

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

A TEACHING UNIT FOR YEAR 11 SCIENCE STUDENTS



About the GRDC

The GRDC

The Grains Research and Development Corporation is a statutory authority established to plan and invest in research, development and extension (RD&E) for the Australian grains industry.

Its primary objective is to drive the discovery, development and delivery of world-class innovation to enhance the productivity, profitability and sustainability of Australian grain growers and benefit the industry and the wider community.

Its primary business activity is the allocation and management of investment in grains RD&E.

GRDC Vision

A profitable and sustainable Australian grains industry, valued by the wider community.

GRDC Mission

Create value by driving the discovery, development and delivery of world-class innovation in the Australian grains industry.

GRDC Values

- We are committed and passionate about the Australian grains industry.
- We value creativity and innovation.
- We build strong relationships and partnerships based on mutual trust and respect.
- We act ethically and with integrity.
- We are transparent and accountable to our stakeholders.

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Title: The science of stems, stomata and sustainability – How modern science is helping produce more food in a changing climate
Project Code: AGC00001
Authors: AgCommunicators
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Contents

1.0 Teaching the science of grains

The Grains Research and Development Corporation has invested in the development of a suite of user-friendly grain education resources and initiatives for students, teachers and families.

These resources have been developed with teacher and researcher input and have been designed following a comprehensive survey of more than 340 teachers throughout Australia.

In each of our curriculum linked resources we have worked to incorporate a range of lesson plans which explore the latest science, technology, engineering, mathematics, nutrition, research and innovation in the Australian agricultural industry. You can use these resources as a unit or select components to complement your teaching plan.

Using an investigation and inquiry based approach students will touch, try, taste and even smell the science of the Australian grains industry. It provides an ideal and relevant teaching context to engage students in food production.

Specifically, resources are available to address the food and fibre curriculum descriptors in geography, science, home economics and agriculture.

We hope you have fun teaching with these resources. Please contact us for more information.

Kind regards
The GRDC Education Team

2.0 Learning outcomes and curriculum links

About the science of stems, stomata and sustainability

Understanding plant physiology is imperative to the success of plant breeding and growing great grain crops in Australia. How plants utilise water from their environment can influence how well a plant survives in a tough growing conditions such as a drought. For example, how plants take up water from the soil, transport it to the leaves and use it for photosynthesis and leaf cooling and how it is lost through transpiration.

Tougher and higher yielding varieties, with better ability to withstand drought, are the focus of many grain research centres. Using molecular biology approaches, it is possible to identify plants with 'tough' genes and traits. The size and shape of the stomata, root structure and function and leaf waxiness are all traits associated with better survival.

This resource will explore a range of modern plant breeding principles which underpin the development of improved cereal crop varieties. The ultimate goal is to develop new crops which farmers are able to successfully grow and reap to sustain our expanding population. The better suited or adapted they are; the more yield or food they will produce. Students will also gain an understanding of how weather systems and climatic variation can impact on plant growth and performance.

Learning outcomes

In reflecting on the past and present climatic challenges for grain farmers in Australia, students will look at the relationship between weather, plant growth and development, grain production and the internal physiology of plants. Students explore these challenges using analytical, investigative and communication skills. They will be engaged through critical thinking activities and investigation based practicals.

Curriculum focus

Students should be able to:

- Communicate their understanding of how internal systems of multi-cellular organisms like plants are dependent on each other and the surrounding environment.
- Reflect on the challenges faced by Australian grain farmers and how scientific research has responded to this.
- Explore the processes of the internal system of a plant, communicating understanding of scientific concepts through observational records and explanation of findings.

Australian curriculum content descriptions

Science inquiry skills

Conduct investigations, including microscopy techniques, real or virtual dissections and chemical analysis, safely, competently and methodically for the collection of valid and reliable data (ACSBL032).

Science as a human endeavour

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043).

Scientific understanding

Multicellular organisms

In plants, gases are exchanged via stomata and the plant surface; their movement within the plant by diffusion does not involve the plant transport system (ACSBL059).

In plants, transport of water and mineral nutrients from the roots occurs via xylem involving root pressure, transpiration and cohesion of water molecules; transport of the products of photosynthesis and some mineral nutrients occurs by translocation in the phloem (ACSBL060).

3.0 Teaching unit content and overview

This resource contains a range of curriculum-linked lesson plans which teachers can cut, paste and utilise as they see fit. Our team work to develop resources which are interactive, fun and fit into your busy teaching schedule. The table below summarises the wide modes of engagement strategies – science experiments, exploring critical and lateral thinking and investigation. You can use some of these lesson plans or all. Whatever you do, we hope you have fun teaching your students about plant and grain science.

	Introduction	Reflect on the history of growing grains in Australia with a particular focus on the challenges presented by climate (weather systems such as el nino, la nina, plus cyclic droughts and frosts).
	Brainstorm	Why would wheat brought from England not survive well in Australia? Ask students to think about the difference in weather between the two countries.
PAGE 8	**4.0 Insight** History of Australian cropping	This section provides an overview of the history of growing grains in Australia. It is then followed by an insight into the response to drought over a timeline. This resource from the ABC provides an interactive timeline of drought in Australia. **http://www.abc.net.au/news/rural/specials/drought-timeline/#0**
PAGE 11	**5.0 Activity** Climate, weather systems and cropping	Ask students to explore the Bureau of Meteorology website (www.bom.com.au) to gain an overview of rainfall and drought in Australia and discuss this in comparison to the areas in which grain is grown.
PAGE 12	**6.0 Activity** Plant breeding for drought tolerance	Explore plant drought response and suitability to the environment. Provide students with three different plants in real or picture form and ask them to discuss the benefits of the phenotypes/traits of each plant which would enable them to suit a specific environment.
PAGE 15	**7.0 Insight** Transporting water and food inside a pant	Students are to learn about water movement through a plant by understanding the role of xylem and phloem and processes of osmosis and transpiration. Ask students to openly discuss, draw diagrams and complete the table of keywords to differentiate learning. This video provides a simple overview of the role of xylem and phloem in plants. 'Transportation in Plants', 7ActiveStudies, **https://www.youtube.com/watch?v=bvPM6sfidY4**
PAGE 18	**8.0 Practical** Xylem and Phloem	Students will use a pulse plant to look at the structure of a stem. Ideally, teachers could source three different grain and pulse plants for students to compare. This practical provides opportunity for the concepts of dicot and monocot plants to be reintroduced or introduced as grain plants are typically monocots and pulse plants are typically dicots.

PAGE **20**	**9.0 Practical** Observing transpiration	1) Students will need to be provided with plastic cups, cardboard, blue tac, water, scissors and a timer. Provide students with a cutting from a grain or legume plant (otherwise, any other plant with leaves). 2) Students will need a seedling or a mature age potted grain or pulse plants (otherwise, any other plant). Alternatively, students can set the whole practical up if provided with pot, soil, grain plant, water, measuring jug, measuring scales and a timer. **Ensure that when students are watering their plants they do no lose water through splashing or from dribbling out the bottom. Instruct them to measure out enough water relative to the size of the plant and water slowly.* **In combination, these two small practicals can be extended into a science investigation report for assessment.*
PAGE **22**	**10.0 Insight** Stomata	Students are introduced to the role of stomata in the exchange of gases and loss of water. Get students to brainstorm about the environments that particular plants grow well in. **Decreased stomata on the leaf surface means less evaporation.* **Smaller stomata which stay closed for longer periods mean less water evaporates.* For introduction, there are many good videos available including: Stomata, TutorVista, **https://www.youtube.com/watch?v=lImgFYmbAUg&noredirect=1**
PAGE **24**	**11.0 Practical** Stomata leaf peel	In this practical students can conduct a simple procedure which will allow them to see stomata. Students will need to be provided with the leaves from different species of plants (ideally two different species of crop plant), microscope slides, a microscope, clear nail polish and sticky tape. **Ensure that students use the nail polish in a well ventilated area. Face masks can be worn.* Students will need to provide annotated drawings of what they see and answer the questions which require them to critically think about the way in which these stomata work.
PAGE **27**	**12.0 Activity** Estimating potential grain yield	This final activity puts students in the shoes of a grain grower. Students are to compare the physiological attributes of two varieties of plants. Secondly, they are to calculate the potential yield of each variety, using the soil evaporation, water-use efficiency averages and crop supply. Students have been supplied with the estimated evaporation for each soil type to complete the table and equation. Visit the Bureau of Meteorology website. Select the state > Monthly Statistics. Calculate the rainfall over the growth period of wheat by adding the Mean Rainfall for each month. Alternatively, use the following totals Dubbo – 316mm, Esperance – 481mm, Stawell 376mm

4.0 INSIGHT
History of Australian cropping

The father of Australian plant breeding:
William Farrer, circa 1890 (Wikimedia)

Wheat was brought to Australia in 1788 by first fleet colonists and was planted in experimental plots at what is now the Sydney Botanic Gardens. These varieties performed poorly as they were not adapted to the harsh Australian growing conditions. As a result, the young colony almost starved. Subsequently, botanists used conventional breeding techniques to develop new varieties which suited Australian conditions.

Brainstorm

Why would wheat brought from England not survive well in Australia?

Did you know?

FATHER OF AUSTRALIAN PLANT BREEDING

From 1882, pioneer plant scientist William Farrer started to formulate plans for producing improved wheat varieties. He began selecting individual plants with superior qualities such as disease resistance or increased yields. He then expanded to utilise foreign wheat and worked to cross-fertilise the suitable parent plants to produce better offspring. In his early years he used hairpins to transfer the pollen from one plant to another in his crosses until he was able to source forceps!

The use of cross-breeding to improve wheat was then only being attempted in Europe and America, so Farrer relied on overseas correspondence for his information. William Farrer's work resulted in new wheat varieties which were hardier and less pest and rust susceptible. This, and an increasing farm mechanization in the years following the Second World War, led to wheat becoming Australia's single most valuable agricultural product. (State Library NSW, 2015).

You might have seen William Farrer recognised on the Australian $2.00 note. This was in recognition of his plant breeding efforts, in particular the release of Federation wheat which was distributed in 1903. This variety had improved quality and yield plus reduced susceptibility to plant rust which is a windborne wheat disease. The release of Federation resulted in Australia's wheat yields tripling over a 20-year period – an amazing achievement.

Federation wheat, circa 1910 (NSW State Records)

Wheat farming in South Australia, circa 2013 (AgCommunicators)

Over the past 50 years in particular, plant breeders using modern plant breeding technologies have developed improved varieties which produce more grain, have improved disease resistance, better quality attributes and can tolerate a range of growing conditions.

Did you know?

Plant breeding plus modern wheat agronomy and improved technologies have helped Australian wheat farmers achieve great things... In fact, if we look at wheat production in Western Australia, for example, farmers grow about four million hectares of wheat each year. From this area, the grain produced increased from two million tonnes 20 years ago to seven million tonnes today! This productivity growth rate is higher than the world average (GRDC Wheat Grow Notes).

While modern varieties have far greater tolerance to drought than their early counterparts, breeding for drought tolerance remains a top priority of many plant breeders.

Brainstorm

What technologies have helped Australian farmers produce more grain?

In Western Australia since the 1990s, the area sowed to wheat has remained at about four million hectares.

Interpret

Look at this graph representing the area of land used for growing wheat in WA and the amount of grain produced within this area.

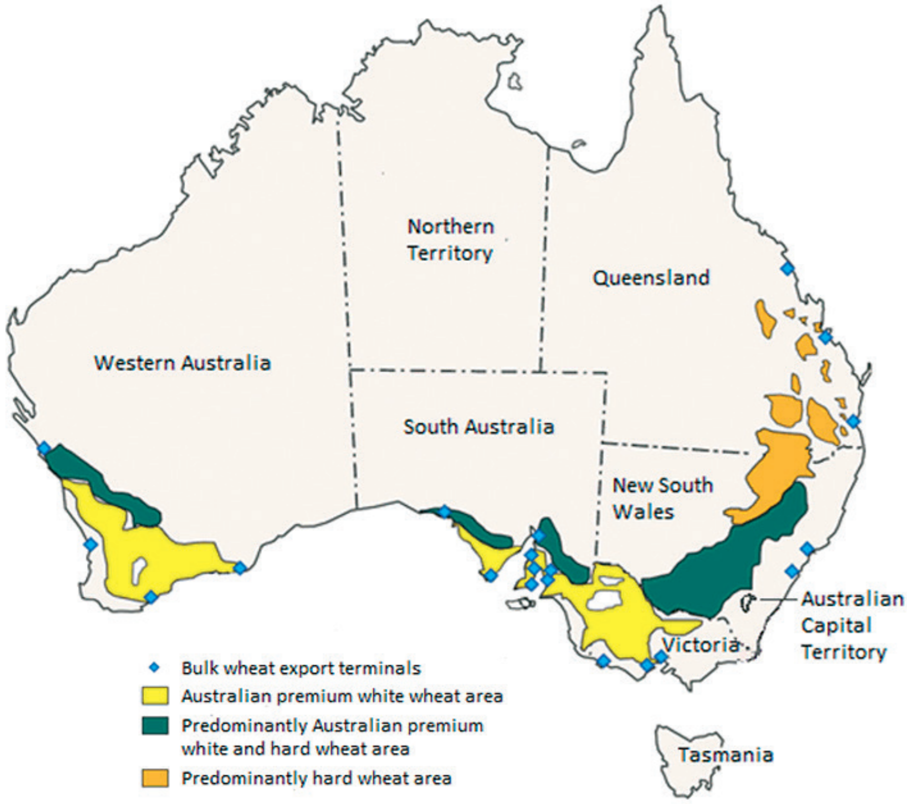
Western Australian wheat area and production 1980-2014 (WA Department of Agriculture and Food (2015))

How has the amount of grain produced in this area changed?

Despite the trend you see here, what might cause the fluctuations?

5.0 ACTIVITY
Climate, weather systems and cropping

Most wheat cropping in Australia relies on rainfall because there is no option for irrigation or it is too expensive for larger scale grain farms. This is why Australian grain growers regularly check weather updates from the Bureau of Meteorology. Farmers need the rain to fall at the right time and in the right place.



Source: ABARES, 2012

Brainstorm

Where would you grow crops in Australia?

Activity

1. Visit the Bureau of Meteorology website (www.bom.gov.au) and select 'Agriculture'.
2. Using the 'Forecast Rainfall' tab, look at the current predictions across the nation.
3. Secondly, research drought maps and review the regions affected by drought.
4. Compare these to the map below which shows areas where grains are grown – the Australian wheat belt.
5. Discuss your findings

6.0 ACTIVITY
Plant breeding for drought tolerance

Unfortunately, the weather does not go according to plan each year with Australian farming areas being plagued by periods of low rainfall, hot weather, dry winds and drought. In these conditions, plants can struggle to grow, survive and reproduce.

The acute water shortage makes a period of drought one of the most challenging for grain growers. A drought is defined by monitoring the daily rainfall for three months or more. If the rainfall is within the lowest 10 per cent of previous records, this is a period classified as drought. In 2006, drought resulted in wheat yield being 60 per cent lower than the national average (ACPFG, 2007).

Some plants are better able to cope with drought than others. How they respond is complex and dependent on their genes.

Essentially, the ability of a plant to cope with drought is determined by what strategies they use to cope with lack of water. Farmers not only need to choose the right location to farm, but they need to choose the right variety of plant (crop) to grow in their region. The crop plant needs to have the right traits to grow, survive, reproduce and set seed.

Choosing or selecting the right variety of plant can be tough. There are different types of cereal crop plants and then different varieties within those types. For example:

Durum wheat – which is used for pasta production.

Barley – which is used to make beer and confectionery. production.

Oats – which are used to make porridge.

Did you know
there are about 100,000 genes in a wheat plant – and more than 1000 of those genes are involved in the drought response.....

Did you know
there are about 30,000 genes in a barley plant – and more than 1000 of those genes are involved in the drought response.....

In a drought-prone area, many farmers might choose to grow wheat or barley. They would refer to a 'cereal variety guide' and look for the variety which is best suited to their annual rainfall, disease pressures and soil type.

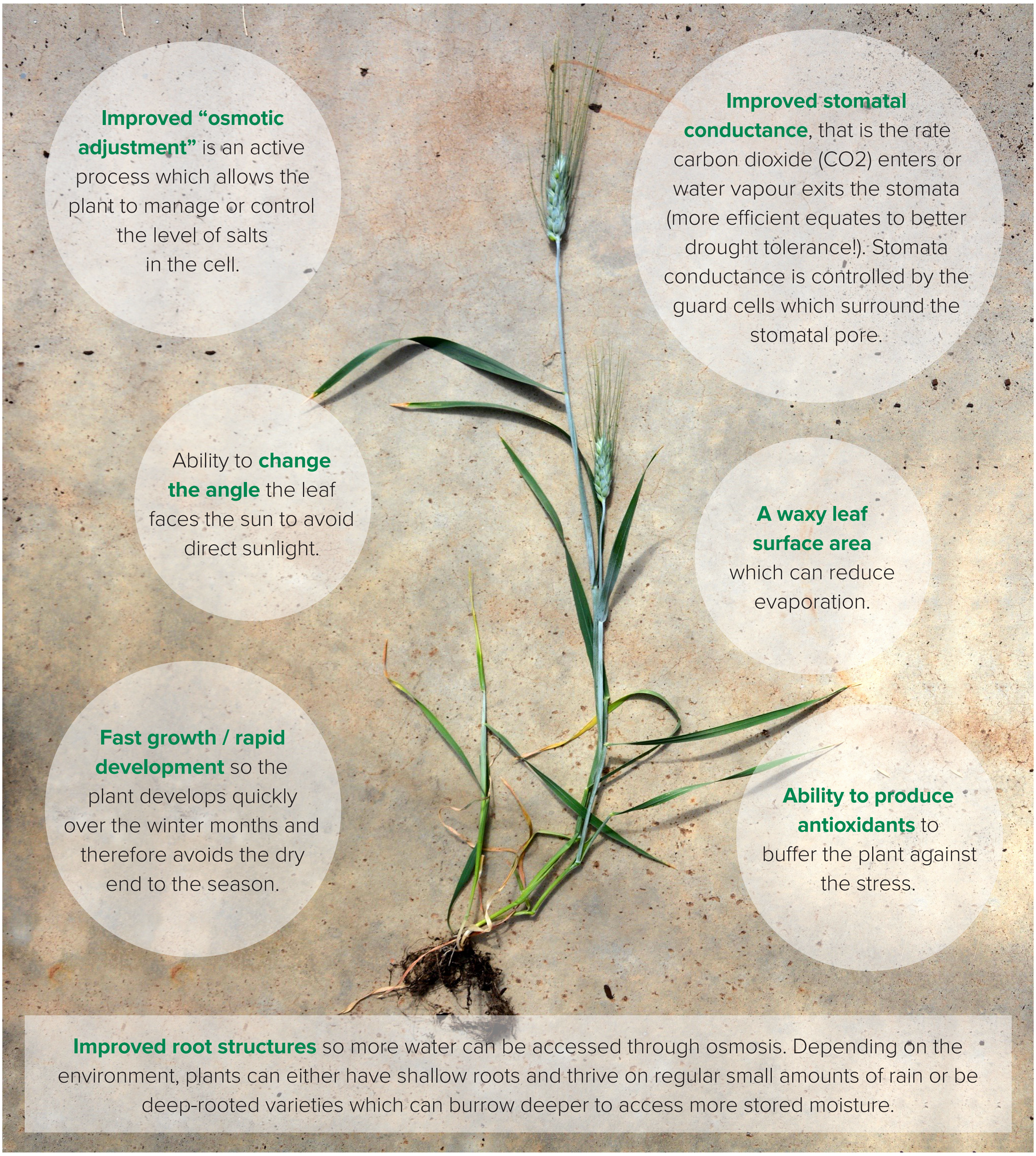
Focus on wheat

Some wheat plants are more drought tolerant than others. Research scientists have identified that drought tolerant plants:

- May produce specialised sugars in the leaves to help buffer the plant from stress.
- Are able to change the angle the leaf faces the sun to reduce direct exposure.
- Have better root traits to assist in water uptake.
- Have stronger photosynthetic traits.
- Have a waxy leaf layer which helps minimise evaporation and reflect the sun's rays.

These are just some of the response factors which exist in different wheat varieties. In fact there are more than 100,000 genes in a wheat plant and more than 1000 are activated in response to drought!

For a plant to survive in a drought environment it must have the successful combination of several advantageous traits.



So how do we know which plants have the genes involved in drought tolerance?

The easiest way to do this is grow them and watch how they perform.

This visual assessment involves observing traits we can see and measure - it is called phenotyping.

ACTIVITY

Look at the three different plant varieties - cactus, a fern and a wheat plant - and make a list of all the different traits you can see and measure. You will be assessing the plant's phenotype.

PLANT	OBSERVATION NOTES

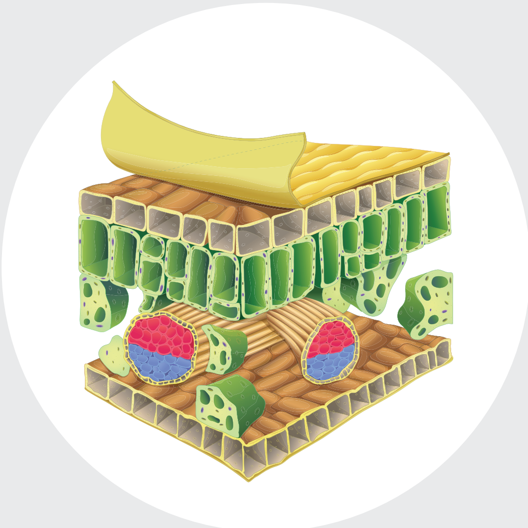
Can you measure 1000 different traits which might make each one tolerant or intolerant to drought?

7.0 INSIGHT
Transporting water and food inside a plant

Water movement throughout a plant is essential to its ability to grow, survive and reproduce. In a farming system, growers are keen for the plant to utilise every millimetre of water. From a scientific point of view, they want to offer farmers a variety which has the best adaptive traits possible.

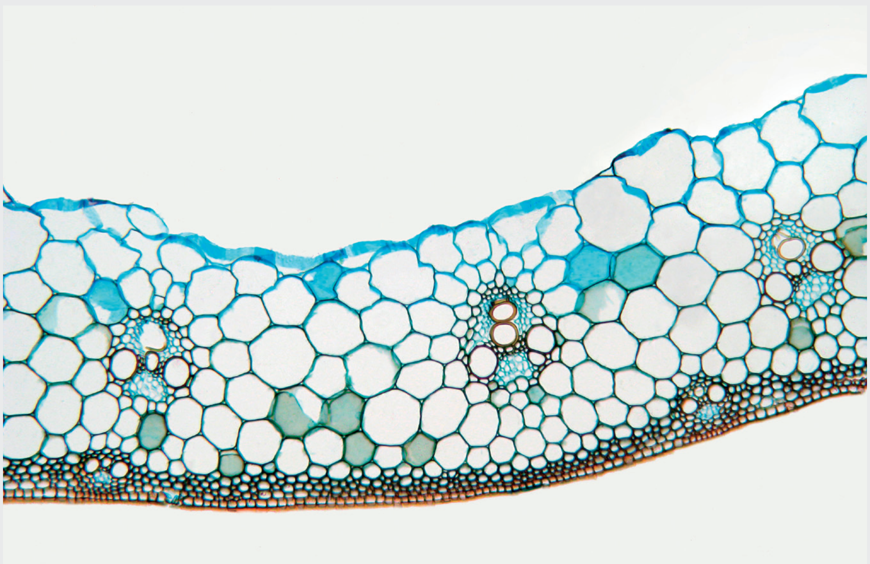
Let's investigate how a plant transports water.

Inside the stem of a plant are two transport systems: the 'xylem' which transports water and mineral nutrients and the 'phloem' which transports food. When a crop is watered by irrigation or rain, the water moves into the soil where it becomes available for plants. From here the roots of the plant can take up the water and move it to other parts of the plants, including its leaves through the xylem. When sunlight hits the chloroplast within the leaf, it creates food for the plant through photosynthesis. This food is transported around the plant by the phloem.



Xylem: Water carrying tubes which transport water, mineral salts and raw materials from the roots up into the plant. Transport vessels with thick cell walls connect the root stem to the leaves to ensure water flow. Water moves into the plant from the soil through osmosis and moves through the plant due to pressure.

Phloem: Food carrying tubes which transport the energy molecules created by photosynthesis to the rest of the plant. Long, circular cells which make up the phloem transport the products of photosynthesis which include carbohydrates and sucrose. This process of moving energy around the plant is called translocation.

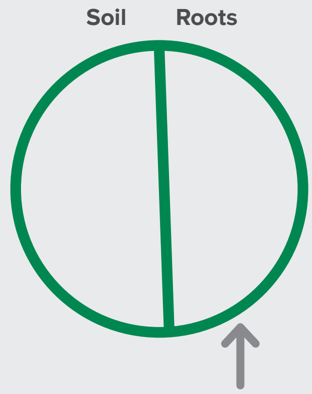


Wheat stem: Light micrograph of a section through the stem of wheat (Triticum aestivium). The circular structures (orange and green) are vascular bundles which consist of xylem (larger circles, orange) and phloem (smaller circles, green) tissues. Xylem transports water and mineral nutrients from the roots throughout the plant and phloem transports carbohydrate and hormones around the plant. Magnification: x100 when printed 10 centimetres wide.

Osmosis

Plants collect water from the soil through their root hair cells using a process of osmosis. The root hairs of a plant are hypertonic to the surrounding soil. Hypertonic means that the root hairs have a lower water molecule concentration than the soil. To even this out, water molecules from the soil will move along a concentration gradient into the root cells. The water then diffuses into the xylem, travelling through this vessel until it moves into the surrounding cells via osmosis again.

The concentration difference between the xylem and the phloem causes osmosis inside the plant. As the plant produces more energy molecules through photosynthesis, these feed into the phloem. The phloem then becomes more concentrated and it becomes hypertonic. Osmosis forces water from the xylem to the phloem. This water flow helps the energy molecules move around the plant.



Roots are hypertonic because they have lower water molecule concentration.

Transpiration

Water is lost from plants through an evaporation process called 'transpiration'. As water reaches the spongy mesophyll cells of the leaves through the xylem, evaporation causes the water to enter the space behind the stomata. From here, in the process of transpiration, water is lost from the plant as it diffuses into the surrounding air.

Activity

Draw your understanding of xylem, phloem, transpiration and osmosis within a plant. Annotate your drawing.

Keywords

Summarise your understanding of the following terms

XYLEM	
PHLOEM	
OSMOSIS	
TRANSPIRATION	

8.0 PRACTICAL
Xylem and phloem

Although grain and pulse plants have different anatomical characteristics, they possess similar xylem and phloem structures. Let's take a closer look at these features under the microscope. You are to create a cross section of the stem of a pulse plant, staining its cells so they are clearer under the microscope.

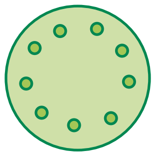
Materials

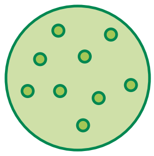
- Pulse plant e.g. green field peas or faba beans
- Razor blades
- Forceps
- Clean slides and cover slips
- Toluidine blue stain
- Beaker with water
- Pipette
- Petri dish with a very shallow amount of water
- Spatula

Method

1. Wet the razor blade.
2. **Take caution using a blade. Keep your fingers away from its edge. Ensure to safely put the razor blade away when not being used.*
3. Cut a portion of the stem. In a smooth motion, cut the portion slowly to create very thin cross-sections of the stem.
4. Using a spatula put all of the thin cross-sections into the petri dish of water so they do not dry out.
5. On a clean slide, place a droplet of the Toluidine Blue Stain.
6. Again using the spatula, select one of the thinnest cross sections and place in the drop.
7. Carefully place the coverslip over the top of the stain, avoiding trapping bubbles.
8. Take a look at the cells of the cross section under the microscope and record your observations.

As pulse plants are dicots, the vascular bundles inside the stem will appear in a ring. Grain plants are monocots, meaning the vascular bundles appear scattered throughout the stem.





This is one structure that should be readily observed.

Make notes about other structural characteristics of the stem you observe.

Record your observations

Date of observation ______________________

Stain ______________________

Sample ______________________

Lighting intensity (If applicable) ______________________

Magnification:

Magnification:

9.0 PRACTICAL
Observing transpiration

Transpiration is the process by which plants lose water. Plants collect water from the soil through their root hairs via a process of osmosis. The water then travels up through the plant to the leaves where it is lost as the water diffuses into the surrounding air.

1. Explore the concept of transpiration by creating a controlled environment by which this process can be monitored and measured.

Equipment

- 2 x clear plastic cups
- Square of cardboard
- Small cutting of plant
- Blue tac
- Water
- Scissors
- Timer
- Pen

Method

1. Make a hole in the centre of the cardboard big enough for the stem. Put the stem of the cutting through this hole and seal the remaining space with blue tac.
2. Fill one cup with water and mark the water level with a pen. Put the bottom of the cutting in the water and place the second cup over the top of the leaves of the plant.
3. Place in the sun and observe for 20 minutes.
4. Record your observations.

What type of plant did you use as a sample?	
How long did you observe the plant for?	
Predict what percentage of water was taken up by the plant in this time	
Explain what you observe, including how your sample is going through the processes of osmosis and transpiration.	

2. Measure the rate of transpiration by monitoring the weight of a plant

Equipment

- Pot
- Soil
- Plant
- Water
- Measuring jug
- Scales
- Timer

Method

1. Plant your sample seedling/mature plant in a pot.
2. Weigh your potted plant and record as weight one.
3. Measure out an exact amount of water which is suitable for the size of your plant and pot – you want to ensure that no water splashes or dribbles out. Water slowly.
4. Leave your plant for 30 minutes to an hour.
5. Weigh your potted plant again and record as weight two.

WHAT TYPE OF PLANT DID YOU USE AS A SAMPLE?	
Weight (include units) **Weight one**	
Amount of water	
Weight two	
Time between weight one and weight two	

Calculation

Ensure that units are consistent (g or kg)

The amount of water lost is represented by 'c'.

Weight 1 Weight 2 = b

+ amount of water

= a

Equation b - a = c

Now calculate the loss as a percentage

c / amount of water = d x 100

= %

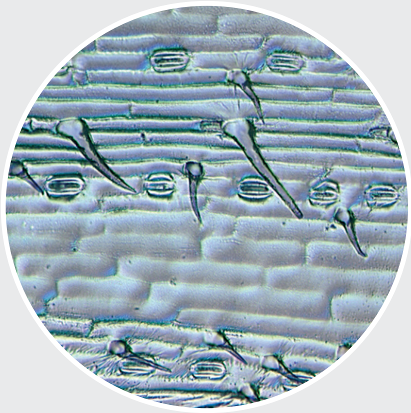
Show your working out

What are some potential sources of error?

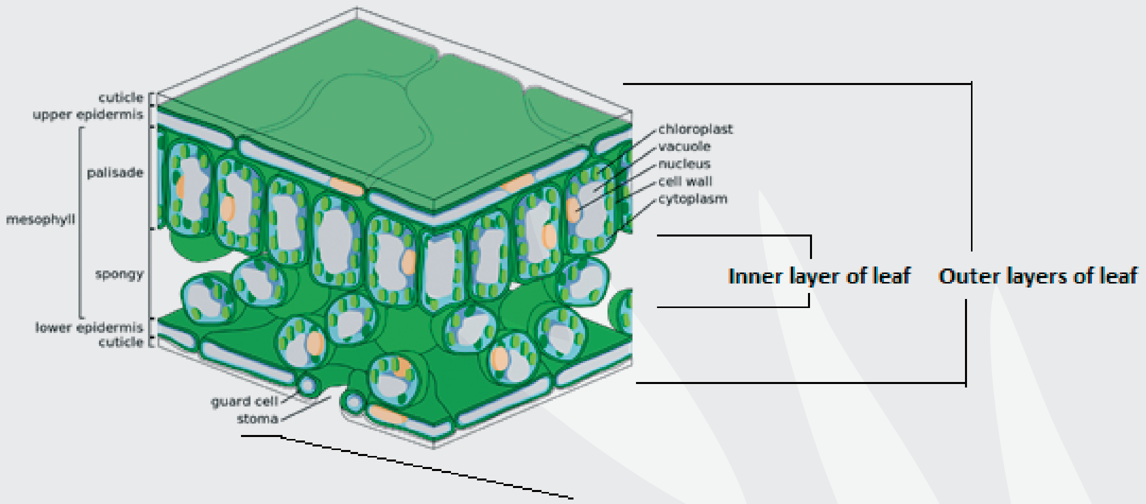
10.0 INSIGHT
Stomata

On the outer layer of the leaf of a plant are microscopic holes called 'stomata'. Stomata control gas exchange and water loss by opening and closing. They are of particular interest to plant breeders because plants with smaller or fewer stomata tend to have lower levels of evaporation.

Stomata are important for the process of photosynthesis, where the plant uses the energy of the sun to convert carbon dioxide (CO_2) and water to glucose in order to feed itself while producing oxygen as a bi-product. The stomata allow carbon dioxide to enter the plant and release oxygen to leave the plant into the atmosphere.



ACPFG, P.Thomelin, P.Kalambettu 2015



**Stomata are small hole in the surface of leaves which allow the exchange of gases like CO2 and O2. Generally, more stomata can be found on the underside of a leaf as this limits water lose from evaporation.*

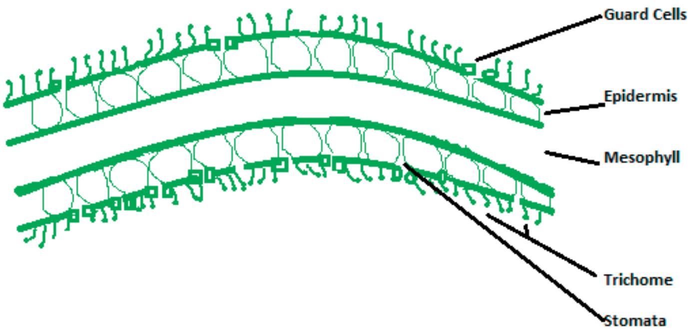
Source: Wikimedia

Stomata facts

Opening and closing of the stomata are controlled by the expanding and contracting action of two guard cells (they are shaped like jelly beans!).

As a general rule, the stomata open during the day to allow for the free movement of gases into and out of the leaf. At night, when photosynthesis does not take place, the guard cells close the stomata to minimize water loss. Guard cells also close when a plant is dehydrated to reduce water loss.

The number and type of stomata can tell you a lot about the environment in which the plant lives. A high number of stomata indicate fast growth and wet climates while lower numbers can indicate lower rates of photosynthesis and growth or adaptations for dry conditions.



Brainstorm

What plants do you know that grow well in specific environments?

11.0 PRACTICAL
Stomata leaf peal

Many farmers rely solely on rainfall for crop production – they do not have irrigation. However, the Australian wheat belt is characterised by periods of drought or low water availability.

Solution:

Plant breeders work to breed better crop varieties using modern plant breeding technologies. Plant breeders must investigate the many different mechanisms plants use to deal with water stress.

Your task:

Compare the epidermal cellular structures (such as stomata) from the leaves of different wheat varieties. Suggest which might be best for a low rainfall environment.

Method

Take a leaf from the three different varieties provided.

1. Carefully paint a thin layer of nail polish over a small area of the underside of the leaf. Allow the nail polish to dry completely.
2. Once dry, take a piece of sticky tape and carefully place it over the nail polished area of the leaf. Smooth down, then gently and slowly peel the tape off (note the sticky tape will pull the nail polish off of the leaf, taking with it the epidermal layer of cells).
3. Place the sticky tape sample onto a clean microscope slide. Label the slide with the name of the variety.
4. Examine under the light microscope at 400X.
5. Draw and label what you observe using the images provided to help you label the cells.
6. Follow procedures with the other leaves provided and do a leaf peel for the top and bottom of the leaf so you can compare the difference.
7. Complete the questions and activities provided on your worksheet.

Records and observations

1 Draw the cells you see in the leaf peel for each variety.

Be sure to draw and label any points of difference between the varieties and between the top and bottom of the leaf. Clearly label the stomata, guard cells and any other organelles you see.

TOP OF THE LEAF		
Variety 1:	Variety 2:	Variety 3:
UNDERSIDE OF THE LEAF		
Variety 1:	Variety 2:	Variety 3:

2 Were the guard cells open or closed? ______________________

3 What does this mean (i.e. explain how stomata work and the role of the guard cells in gaseous exchange)?

4 From the average number/400X microscopic field, calculate the stomata per mm^2 by multiplying by eight.

5. **Which variety had the most stomata? What do you think this means for the ability of the variety to survive in a drought situation?**

6. **Explain why the lower epidermis of a leaf has more stomata than the upper epidermis?**

7. **What time of the day are stomata most likely to be open?**

8. **What gases move in and out of the leaf stomata?**

9. **Which variety would you grow in a low rainfall / drought environment and why?**

12.0 ACTIVITY
Estimating grain yield

Throughout this topic we have discussed grain yield and a plant's ability to produce grain when stressed. We know that there are traits a plant has to tolerate drought. In this final activity, your task is select a premium plant.

Meet your plants

Plant one characteristics include:

- Large stomata
- Non waxy leaf
- Non hairy roots

Plant two characteristics include:

- Small, spaced stomata
- Waxy epidermis
- Hairy roots

If the both plants were to be planted in a low-medium rain-fall areas, which plant is likely to produce more grain? Explain your answer

In southern Australia, a nifty model known as the French-Schultz approach can be used to provide growers with a benchmark of their crop yields based on the amount of moisture available to the crop.

Equation for potential yield (kg/ha)

= WUE (kg/ha.mm) x (crop water supply (mm) – estimate of soil evaporation (mm))

	PLANT ONE	PLANT TWO
Wheat 'water-use efficiency' (WUE): WUE is calculated by scientists and farmers when wheat varieties are trial grown and varies significantly between varieties.	14kg/ha.mm	20kg/ha.mm

The following areas have differing average rainfall totals for the growing season (April to October) and different soil types.

For different soil types, the estimated soil evaporation amount is different.

To find out the crop water supply, look on the Bureau of Meteorology for average rainfall in your area for the months of April to October (add the total for each month together). **www.bom.gov.au**

SOIL EVAPORATION (MM)	
SANDY	90
CLAY	130
AVERAGE	110

The area of Clare in South Australia has been used as an example of how to calculate potential yield using this French-Schultz approach.

ESTIMATE OF SOIL EVAPORATION AND CROP WATER SUPPLY	SOIL TYPE	SOIL EVAPORATION (mm)	CROP WATER SUPPLY: RAINFALL TOTAL APRIL TO OCTOBER (mm)
Clare, South Australia	CLAY	130mm	489mm
Dubbo, New South Wales	CLAY		
Esperance, Western Australia	SANDY		
Stawell, Victoria	AVERAGE		

Example

Clare, South Australia

Equation for potential yield (kg/ha)

= WUE (kg/ha.mm) x (crop water supply (mm) – estimate of soil evaporation (mm))

Potential yield of plant one	Potential yield of plant two
14 X (489 – 130) = 5026 kg/ha	20 X (489 – 130) = 7180kg/ha
In Clare, in an area which has predominantly clay based soils, the variety plant two will produce approximately 2000kg of grain per hectare more than the variety plant one.	

DUBBO, NEW SOUTH WALES	
Plant one	**Plant two**
If you were a grain grower, which plant would you select as your crop and why?	

ESPERANCE, WESTERN AUSTRALIA	
Plant one	**Plant two**
If you were a grain grower, which plant would you select as your crop and why?	

STAWELL, VICTORIA	
Plant one	**Plant two**
If you were a grain grower, which plant would you select as your crop and why?	

What would be the economic, social and environmental impacts of breeding and growing these two different varieties? Summarise in two paragraphs.

13.0 Good reads

'Australian Grain Note: Wheat', 2012, Australian Export Grains and Innovation Centre, http://www.aegic.org.au/media/20167/australian_grain_note-wheat_web.pdf

'Timeline: droughts and Australian drought policy 1895 – 2014', ABC Rural, 2014 http://www.abc.net.au/news/rural/specials/drought-timeline/#1

GRDC GrowNotes (2016) downloaded at http://www.grdc.com.au/Resources/GrowNotes

14.0 References

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'Plant Structure and Development Lab Manual', University of Rhode Islands, 2015, http://www.uri.edu/cels/bio/plant_anatomy/bio311.pdf