Stage 6 Agriculture

## Plant breeding teacher resource 2

This unit is the second of a three part series about plant breeding in agriculture. Resource 2 guides students through traditional plant breeding methods and the reasons why new plant varieties are developed for agricultural production. Tissue culture, mass selection and hybrid breeding are plant breeding techniques focussed on in this resource.

## Outcome

**H2.1** describes the inputs, processes and interactions of plant production systems.

[Agriculture](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/technologies/agriculture-syllabus) Stage 6 Syllabus © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2013.

## Delivery strategies

This resource is adaptable for teachers to use with online platforms such as Google Classroom. Links to the videos and websites could be posted for students to access during learning at home. The activities and questions could be set as classwork documents within Google Classroom that the students complete and submit for a grade or feedback. Alternatively, students could receive the activities and questions as worksheets to complete and submit at a later date.

## Section one:

Students are introduced to the reasons why plant breeding is important in agriculture and being looking at breeding methods using tissue culture.

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| Focus area | HSC Plant/animal production, Managing plant production and experimental analysis and research in plant/animal systems. |
| Content | * Outline plant breeding systems and their genetic basis including selective breeding, hybridisation and genetic engineering. * Explain how plant breeding is used to develop new varieties to improve product quality, yield and environmental adaptation. * Outline the impact of research on agricultural experiments. |
| Resources | * [Plant breeding – flowering plants: introduction](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-flowering-plants#plant-breeding-flowers-introduction) (video duration 0:50) * [The Royal Botanic Garden](https://www.rbgsyd.nsw.gov.au/Science/Australian-plantbank/Our-collections/Plant-journeys/Tissue-culture-and-beyond) - tissue culture |
| Activities/questions | 1. Outline the aims of plant selection and breeding? 2. Outline the role that tissue culture plays in modern plant breeding programs. |
| Suggested answers | 1. The main aims of plant selection and breeding are:    * Increasing production    * Improving quality    * Resistance to pests and disease    * Producing varieties suited to particular soils or climates    * Producing varieties that are resistant to lodging    * Producing novel or exotic varieties. 2. Tissue culture involves propagating a complete new plant from a small piece of tissue, such as a terminal bud, in a sterile agar medium containing plant nutrients and hormones.   By changing the concentration of nutrients and hormones the tissue can be induced to form roots and shoots. The plants produced through tissue culture are “clones” of the original plant material, meaning they have identical genotype to the original plant.  The principal uses of tissue culture in modern plant breeding are:   * + Allows rapid multiplication of new genotypes, leading to much faster evaluation and testing of new plant varieties developed by plant breeders   + Allows utilisation of technologies such as anther culture and embryo rescue   + Propagation of some plant varieties for commercial production, for example kangaroo paws. |

## Section two:

Students discover the characteristics of plants that plant breeders select for and look in depth at the plant breeding method of mass selection.

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| Resources | * [Traditional techniques](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-flowering-plants#traditional-techniques) (video duration 2:14). * [Breeding traditional tomatoes](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-flowering-plants#breeding-traditional-tomatoes) (video duration 1:58). * [TAMU plant breeding – mass selecting cotton](https://www.youtube.com/watch?v=LgaN_aUdk58) (video duration 3:20). |
| Activities/questions | 1. Describe (provide characteristic and features of), in your own words, the method of plant breeding known as mass selection. 2. Use a two columned table to outline what you think the advantages and disadvantages of mass selection would be. 3. Explain why and/or how crossbreeding has played a role in developing new plant varieties. 4. List using dot points, some characteristics of wild plant species that may make them valuable for inclusion in cross breeding programs. |
| Suggested answers | 1. Mass selection involves growing crops from seed, selecting the best performing plants (based on their appearance and yield) and retaining seed from them. The seeds from these selections are grown again and the process of selection and replanting repeated. This process is continued for many generations. 2. Advantages:  * Seed is cheaper due to natural pollination and the use of mechanical harvesting * It can be done by anyone.   Disadvantages:   * Plants sill show variation in habit, flower colour, maturity, size (especially those of cross pollinating species) * Genetic improvement can be slow  1. Cross breeding allows genes from a closely related plant to be transferred to an existing plant variety. Hence it allows new genotypes to be created. Plant breeders have used this technique to combine the desirable characteristics of two or more varieties, for example yield, disease resistance or quality characteristics into a new variety. 2. Some characteristics of wild species that may make them valuable for inclusion in cross breeding programs include drought tolerance, disease resistance, resistance to insect damage, salinity tolerance, heat tolerance and tolerance to water logging. |

## Section three:

Students learn about developments and technologies used in plant breeding to create new varieties of plants for agricultural production.

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| Content | * Outline plant breeding systems and their genetic basis including selective breeding, hybridisation and genetic engineering. * Explain how plant breeding is used to develop new varieties to improve product quality, yield and environmental adaptation. * Outline the impact of research on agricultural experiments. |
| Resources | * [Recent technologies](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-flowering-plants#recent-technologies-breeding-plants) (video duration 2:45) * [Recent developments](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-flowering-plants#recent-developments-tomato-breeding) (video duration 3:09) |
| Activities/questions | 1. Describe the characteristics that may be required to be incorporated into tomato varieties into the future. 2. List two technologies that may be used to speed up the genetic improvement process in plant breeding. |
| Suggested answers | 1. Characteristics that may be required to be incorporated into tomato varieties into the future include drought tolerance, heat tolerance, resistance to insect attacks and pathogens. 2. Examples of technologies that may be used to speed up the genetic improvement process in plant breeding include:    * Identification of genetic markers    * Another culture    * Ovule culture    * Somatic embryogenesis    * Embryo rescue |

## Section four:

An in depth look at the double haploid method of breeding of wheat plants and its advantages.

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| Resources | [Wheat breeding techniques](https://education.nsw.gov.au/teaching-and-learning/curriculum/tas/tas-curriculum-resources-7-12/tas-11-12-curriculum-resources/plant-breeding-wheat#wheat-breeding-techniques) (video duration 3:30). |
| Activities/questions | 1. Draw a flow chart, showing step by step, the accelerated genetic improvement through the process of breeding double haploid plants. Remember that flow charts have arrows between each step to show the process in order. 2. Outline the main advantages of double haploid breeding. |
| Suggested answers | 1. Emasculation of the target wheat plant – pollination of the target wheat plant with maize pollen – a wheat embryo starts to develop – the wheat embryo is rescued and placed on growing media – haploid (sterile) wheat plant grows on media – haploid wheat plant is transplanted to a pot and treated with colchicine – chromosome number is doubled by colchicine – double haploid wheat plant (fertile). 2. Plants selected from double haploid breeding always breed true and cultivars that are produced by double haploid breeding can be release three to five years earlier than conventional breeding. |

## Section five:

Students are introduced to the concept of seed banks and why geneticists keep ancient varieties of plants safely locked away.

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| Content | * Outline plant breeding systems and their genetic basis including selective breeding, hybridisation and genetic engineering. * Explain how plant breeding is used to develop new varieties to improve product quality, yield and environmental adaptation. * Outline the impact of research on agricultural experiments. |
| Resources | * [Banking on our future](https://www.abc.net.au/gardening/factsheets/banking-our-future/9436110) (video duration 7:58). * The Royal Botanic Garden - [The Australian plant bank](https://www.rbgsyd.nsw.gov.au/science/australian-plantbank) |
| Activities/questions | 1. Explain why plant breeding centres aim to maintain a wide variety of genotypes, including those of the ancient relatives of modern plant cultivars. 2. Describe how these genetic resources may be kept. Consider how seeds, parts of plants and whole plants are stored. |
| Suggested answers | 1. Different varieties (genotypes) of cultivated crops, including the ancient “wild” relatives from which they were domesticated, contain a plethora of genes that relate to characteristics such as disease and pest resistance, grain and fruit quality, water use efficiency, salinity, tolerance, soil acidity tolerance, temperature tolerance and nutritional value of seeds and fruits. These genes can be very useful in the development of new varieties for future use, particularly those that relate to pest and disease resistance and to adapting to changed environmental conditions like soil salinity, lower rainfall and higher atmospheric temperatures. Hence plant breeding centres aim to maintain these genotypes so that they can access the genes within them into the future. 2. These genetic resources can be kept by:    * Seeds are stored in specially designed storage facilities    * Vegetative plant parts are stored in cryogenic tanks    * Living specimens are grown in an arboretum. |

## Section six:

Students examine why new plant varieties are continually being researched and developed.

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| Resources | [Plant breeding solves problems](https://www.youtube.com/watch?v=mtVtpO7FOaA) (video duration 6:15) |
| Activities/questions | 1. Account (identify components and the relationship between them) for the need for plant breeders to continually supplement and/or replace currently grown varieties of crops. |
| Suggested answers | 1. New plant varieties are needed for the following reasons:    * The world’s population is growing rapidly. To meet the demand for food and fibre into the future more productive crops are needed. This includes crops that can be grown in marginal areas with limited water and extremes of climate and crops that have decreased growing seasons so that multiple crops can be produced each growing season.    * Plant varieties that are currently disease resistant may become susceptible to diseases sue to mutations that occur in the plant pathogens which cause them. Hence breeders must continually be developing new disease resistant plant varieties.    * Plant varieties that have features that decrease their susceptibility to insect attack can reduce the need for pesticide use. This can lead to decreased costs of production and contribute to environmentally sustainably practices.    * As the world’s climatic and soil environments change new varieties adapted to these changed conditions must be developed in order to maintain or improve current levels of productivity. |

## Section seven:

Students take an in depth look at the development of hybrids and how they impact agricultural enterprises.

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| Content | * Outline plant breeding systems and their genetic basis including selective breeding, hybridisation and genetic engineering. * Explain how plant breeding is used to develop new varieties to improve product quality, yield and environmental adaptation. * Outline the impact of research on agricultural experiments. |
| Resources | * [Hybrid plant breeding](https://www.youtube.com/watch?v=JVIya94rekM) (video duration 1:40) * [George Shull explains hybrid corn and heterosis](https://www.youtube.com/watch?v=XQj8POXZEZo) (video duration 3:23) * [F1 hybrid fact sheet](https://www.thompson-morgan.com/f1-hybrid-what-is-it) |
| Activities/questions | 1. Outline the development of hybrid varieties of one crop of your choice. You might like to use a flow chart to show the sequence of the steps involved in the breeding program. 2. Discuss (give points for and/or against) the widespread use of hybrid varieties in modern farming. Use a table to present your answer. |
| Suggested answers | 1. Hybrid maize production.    1. Inbreeding of two open pollinated varieties over 4-5 generations, selecting for particular desired characteristics such as disease resistance, grain quality or drought tolerance. Inbreeding is achieved by covering the silks before they emerge, collecting the pollen from the same plant and manually transferring it to the silks. The cobs are left to develop then the grain is harvested and planted. The inbreeding process is continued for 4-5 generations.   Result is two distinct types of small, low yielding plants (called inbreds) which are true breeding for the selected characteristics. These will enable the inbreds to pass these characteristics onto their offspring.   * 1. Crossing the two inbred lines. This is achieved by de-tasselling the female line and allowing the pollen from the male line to pollinate the silks.   2. Harvest hybrid seeds and use to plant commercial crops. The grain is harvested and used for human or animal food. If this generation is planted the offspring will not be as uniform and will not yield as well. Thus, new hybrid seed must be purchased at a high cost each season. This high cost of hybrid seed is a result of the long period of time taken to produce it and the low yield of the parent plants. A double cross hybrid is produced by starting with four open pollinated varieties, producing four inbred lines. A similar process as for single cross hybrids occurs, with the two single cross hybrids being crossed to produce double cross hybrid seeds for commercial crops.  1. Advantages of hybrid varieties include:    * Hybrid varieties usually have higher yields than open pollinated varieties. This characteristic is known as heterosis or hybrid vigour.    * Individual hybrid variety plants are very uniform with little variation between plants in terms of size, shape, maturity time. This makes them very suitable for mechanical harvesting and assists in marketing of outputs.    * Hybrid varieties usually have high disease resistance.   Disadvantages of hybrids include:   * + Cost of seed very high (10-20 times that of traditional open pollinated varieties).   + Farmers must purchase new seed every year as seed kept from a hybrid variety and resewn will begin to show significant variation amongst the plant population.   + The genetic uniformity of the plants leaves the entire population vulnerable to new diseases for which they are not resistance or to a mutation of a disease for which they are not currently resistance.   + Loss of genetic resources (biodiversity) will occur if steps are not taken to maintain “gene banks” of traditional varieties. |

## Section eight:

Resources for teachers to assist students when answering questions and suggested past HSC exam questions for formative assessment at the end of the section.

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| Focus area | HSC Plant/animal production, managing plant production. |
| Related material/activities | * Scaffolds can be used to assist students in breaking down a question based on the HSC verb. [Scaffolds for key works](http://home.kooee.com.au/mulhearn/HSC%20VERBS.pdf) provides eight, simple to use scaffolds that can be added to the activities/questions in this focus area. * [Past HSC exam](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/resources/hsc-exam-papers) questions can be used as formative assessment at the end of topics/sections, using the features on your chosen online platform such as Google classroom can collect and store data on student performance. Sample exam questions could include the following:   1. 2015 HSC examination, agriculture. Question 25 a.   + Explain, using examples, why plant breeding programs are necessary in Australian agriculture.   1. 2015 HSC examination, agriculture. Question 25 b.   + Explain the advantages and disadvantages of using hybrid plant varieties.   [Agriculture HSC exam paper 2015](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/resources/hsc-exam-papers) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2015. |