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POTATO LINK AUSTRALIAN POTATO INDUSTRY EXTENSION PROJECT

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POTATO LINK
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Slugs in potato crops

The recent wet spring and summer has provided ideal conditions for slugs to build up their numbers.

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Using legumes to supplement nitrogen

The world may be easing its way into post-pandemic normality, however latest market research shows that this will have limited impact on the historically high prices of nitrogen and imported fertilisers for Australian farmers.

024

Managing herbicides and herbicide injury

While visiting Australia, Professor Andy Robinson took time out of a busy schedule to take part in our Ballarat workshop and field walk. Professor Robinson is a highly regarded extension agronomist and academic from North Dakota State University and the University of Minnesota. During his visit he also presented a webinar on chemical weed control and herbicide injury.

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Regional rep dispatch - Tasmania

Our new magazine segment Regional Rep Dispatch, turns the spotlight on what is happening in the main potato growing regions of Australia, including any topics of interest, concerns, and events in different parts of the country.

SPECIAL FEATURE: SEED POTATOES

As every vegetable grower understands, all good crops start with good seed, and potatoes are no exception. However, potato tubers, unlike many other seeds, need a considerable care and attention to optimise results. Seed potatoes, themselves a perishable input, power the young plants for their first 40 days and account for about 30% of the total cost of production. Understanding what they need, and why, is of great value.

By Paulette Baumgartl

EXPLORE A TOPIC FURTHER

Our special extended feature on seed includes information on age, diseases, storage, cutting, treatment, and certification. Some topics have been extensively covered in previous editions of this magazine or elsewhere; look for this symbol for links to articles, webinars, and fact sheets.

SEED AGE

At any one time the seed tuber has two ages: its chronological age and its physiological age. Chronological age is, as the name suggests, a time marker, usually from harvest. Physiological age reflects the life the tuber has led since harvest.

The physiological age of seed will influence how a potato crop will perform (Table 1). Growers can effectively manipulate the physiological age of seed potatoes according to growing conditions and desired outcome. For example, seed growers may prefer older seed that yields many smaller tubers, whereas growers producing processing potatoes may favour younger seed so as to produce larger tubers.

Young seed	Old seed
Slow emergence	Rapid emergence
Fewer stems / hill	More stems / hill
Low tuber set	Higher tuber set
Longer tuber bulking period	Shorter tuber bulking period
Long tuberisation period	Uniform tuber set
Larger tubers at harvest	Smaller tubers at harvest
More foliar growth	Less foliar growth

Table 1. Characteristics of old tubers versus young tubers (Adapted from Bohl, Nolte, Kleinkopf and Thorton; Struik (2007))

Many factors effect physiological age, including:

- Depending on cultivar, seed **dormancy** may vary from a few weeks to several months.
- **Growing conditions** of the seed. Crop stress due to high temperatures, low moisture, poor nutrition, frost, or disease pressure increase ageing.
- **Mechanical damage and bruising** of the tubers increases seed respiration rate and accelerates ageing.
- **Cold storage temperatures** reduce respiration rate and therefore ageing. Avoid fluctuating temperatures due to low ventilation rates.
- **Respiration rates of cut seed** rise during healing, increasing physiological age. Providing optimal conditions for rapid curing after seed cutting minimises ageing and disease risk.

EXPLORE FURTHER

For a deeper dive into the topic of seed age, read more in Issue 1 of PotatoLink Magazine: **http://bitly.ws/BFzD**

To read more about diseases, access the fact sheets here: **https://potatolink.com.au/factsheets**

To watch webinars about diseases, access here: **https://potatolink.com.au/webinars**

DISEASES AND DEFECTS OF SEEDS

Potato seed tubers can be an important source of disease inoculum, and, when present, can cause substantial reductions in yield or quality in the subsequent crop under the right environmental conditions.

Some diseases are more likely to cause significant losses than others. Diseases, such as ring rot, late blight, and leafroll (net necrosis) (Figure 1), are carried on or in the seed, and have the potential to spread very quickly through the crop. Tubers infected with such diseases need to be safely discarded. Other diseases, including rhizoctonia black scurf and pythium leak, have limited secondary spread from the tuber (other sources of inoculum are usually more concerning) and are less serious.

Importantly, the absolute losses resulting from specific tuber problems will depend upon environmental conditions and disease management practices. The most important aspect of disease management in potato production is the use of certified seed potatoes (see break out box on page 12).

Table 2 provides a useful summary of typical tuber diseases, physical symptoms and risks.

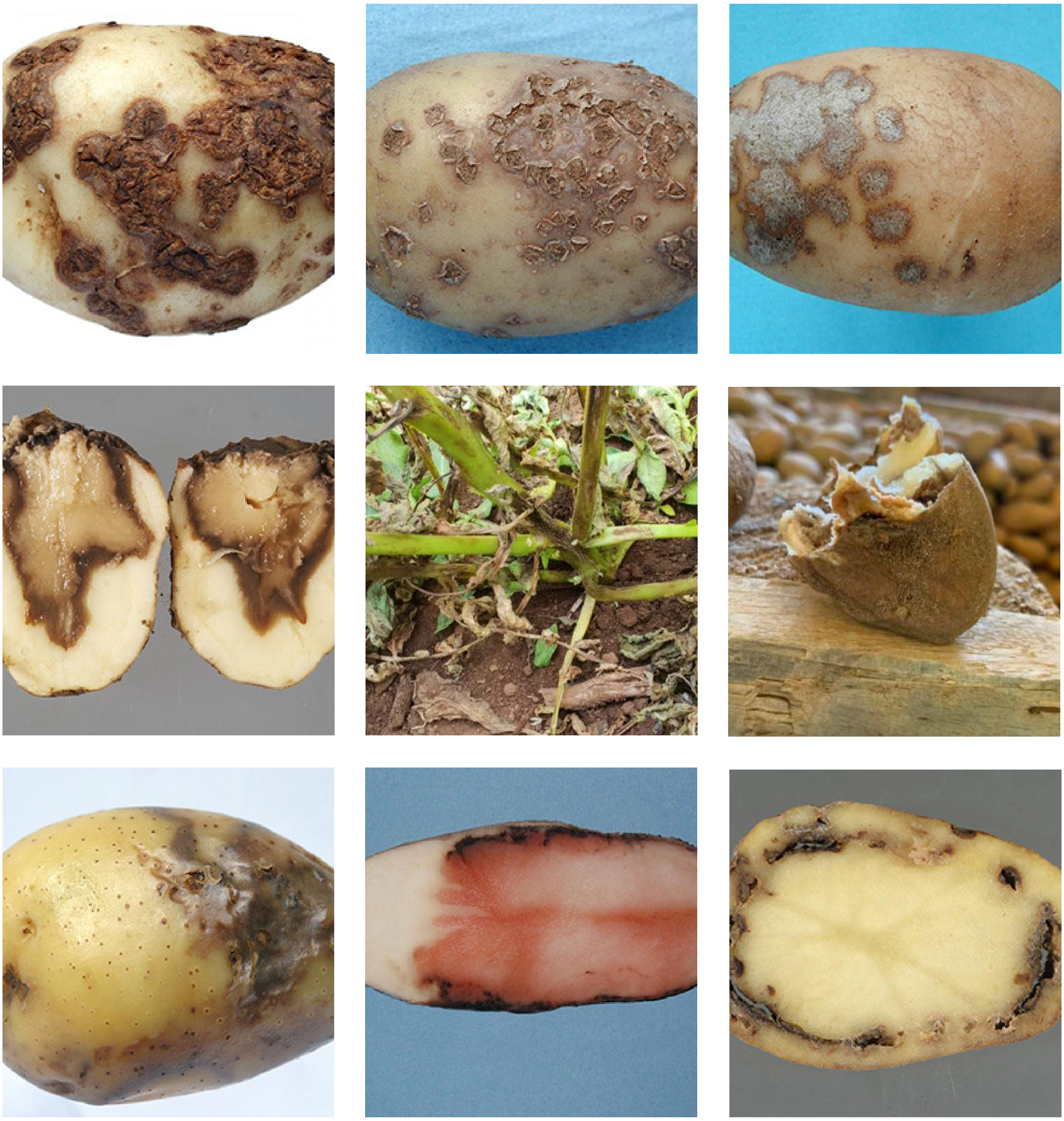

Figure 1. From top, left to right: common scab, powdery scab, silver scurf, soft rot, blackleg, fusarium rot, late blight, pink rot, ring rot (Source: Agriculture and Horticulture Development Board (AHDB) potatoes archives website).

Disease or defect	Source of pathogen or disorder			Diagnosis & location on/ in tuber	Spread within storage[1]	Other comments
	Soil	Seed	Other			
Common scab	✓	✓		External, general	No	
Powdery scab[2]	✓	✓		External, general		See footnote 2
Rhizoctonia	✓	✓		External, general, must wash	No	
Silver scurf[3]	✓	✓		External, general, must wash		See footnote 3
Bacterial soft rot	✓	✓	✓	External general; internal general	Yes	Other sources are from cull piles and irrigation water
Blackleg	✓	✓		External, stem end; cut internal stem end and longitudinal	No	
Early blight	✓	✓		External, general; internal, make shallow cuts through lesions	Yes	
Freezing and chilling			✓	External, general; internal, stem end and cross section	No	
Fusarium rot	✓	✓		External, general; internal, cut through lesions	No	
Late blight		✓	✓	External, general; internal, cut through lesions	Yes	Other sources include cull piles and volunteers
Mechanical injury			✓	External, general; internal, cut through damaged area	No	
Pink rot	✓			External, stem end, eyes, lenticels; cut internal, turns pink	Yes	
Ring rot*		✓	✓	External skin cracks; cut internal, near stem end	No	Other sources of inoculum include volunteers, equipment, and containers
Root knot nematode	✓	✓		External, general; internal, cut tangential	No	
Black heart	✓	✓		Cut internal, longitudinal	No	Caused by lack of oxygen under certain field conditions, in storage, and in transit.
Black spot			✓	Cut internal, stem end half or on shoulder	No	Deep piles contribute to problem
Fusarium wilt	✓	✓		Cut internal, through stem end, only in xylem	No	
Leaf roll virus		✓	✓	Cut internal, cross section	No	Insect transmission from infected plants in cull piles and volunteers
Verticillium wilt	✓	✓		Cut internal, extends through vascular ring	No	

Table 2. Summary of important potato tuber disease and defects (Source: Cornell College of Agriculture and Life Sciences https://www.vegetables.cornell.edu/pest-management/disease-factsheets/detection-of-potato-tuber-diseases-defects/summary-of-important-aspects-of-20-potato-diseases-and-defects/)

[1]Refers to tuber-to-tuber spread. Some of the diseases and disorders will progress within affected tubers in storage but will not spread to healthy tubers.

[2]Powdery scab is caused by the pathogen *Spongospora subterranea*. It is not directly spread by tuber to tuber contact in the store. Spore balls, also called cystori, are produced by the powdery scab pathogen and can survive in soil for lengthy periods and the inoculum load can carried on the surface of tubers in infested soil or shed dust. Powdery scab is primarily a soilborne disease and does not develop in the potato storage.

[3]Silver scurf of potatoes is caused by the fungal pathogen *Helminthosporium solani*. The disease occurrence can be promoted in store with free moisture on the tuber surface. In the store, spores of *H. solani* can be spread in air. In addition, the spores of the fungus can be spread in contaminated shed dust coating tubers with inoculum load.

* Not recorded in Australia, and listed as a zero-tolerance disease in seed certification scheme conditions.

SEED STORAGE

Potato tubers are living, breathing, organisms. Keeping this in mind, the particulars around how to keep them happy during storage make a lot more sense.

Potato seeds respire, 'sweat' and convert starch to sugars to use as energy. How much they do any of these things depends on the environment in which they are stored. Are they a little high maintenance? Perhaps. But the correct storage conditions are not complicated. Maintaining them ensures that money invested into quality seed is not wasted.

TEMPERATURE AND RELATIVE HUMIDITY

Note the following key considerations:

1. Maintain uniform temperatures and high (85% to 95%) relative humidity (RH) during storage. **WHY:** Low RH leads to dehydration and shrinkage.
2. Avoid temperature fluctuations by setting maximum and minimum points close together. **WHY:** Fluctuations can reduce the RH in the room and result in condensation on the tubers. The fungi and bacteria that cause breakdown in storage flourish under wet conditions, so seed must be kept dry.
3. Minimise spatial variation within the room to keep humidity high and temperature uniform. Replace leaky insulation and avoid frequent door opening.
4. Ensure potatoes are stacked in a manner that allows air to circulate. **WHY:** Even at 4°C, seed potatoes are still respiring and producing heat. This heat needs to be removed by the cold room air; if the air cannot circulate over and under the bins, hot spots will develop.
5. When warming up or cooling down, change temperatures gradually over several days.
6. Temperature management is most important as the tubers reach the end of their natural dormancy. For example, trials in the Netherlands found that yield was reduced if seed stored at 4°C was warmed to 16°C for more than six weeks before planting. Yield was less affected if seed were stored at 16°C for the same period before cooling to 4°C (Struik et al., 2006).

However, the best results were achieved when tubers were kept continually at 4°C throughout storage.

OXYGEN

Seed potatoes are, like humans, sensitive to the concentrations of O_2 and CO_2. If CO_2 levels are too high, potatoes are unable to respire normally. As little as 4,000ppm CO_2 (0.4%) can reduce seed vigour after planting. In severe cases, lack of air inside the centre of the tuber leads to black heart.

EXPLORE FURTHER

Watch more: Dr Jenny Ekman, Maarten van Delden, and Dr Nigel Crump discuss the importance of correct seed potato storage, optimal storage conditions and management of physiological age.
http://bitly.ws/BFAk

Read more: Click here for the seed storage and physiological age factsheet.
http://bitly.ws/BFAy

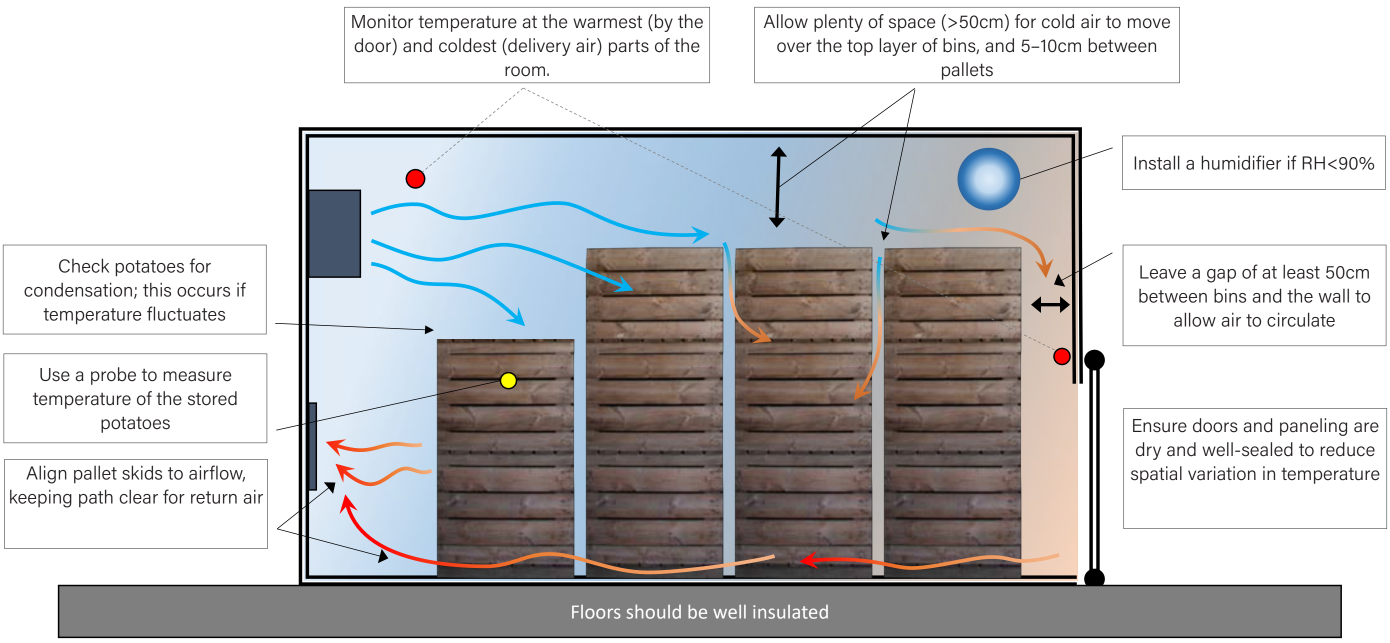

Figure 2. Cold storage rooms should be set up to allow the cold air to circulate around the bins; leave gaps between pallet stacks and the walls, align pallet skids to airflow; leave clear space for the return air intake. Temperature should be monitored and condensation checked in different parts of the room as well as in the stored seed (Source: J. Ekman)

TREATMENT AND HANDLING OF SEED

SEED CUTTING

With seed costing up to 30% of the total cost of potato production in Australia, seed cutting is a common practice.

As well as cost savings, cutting offers several advantages. Properly cut and cured seed, if held for three or four weeks, will overcome dormancy for some varieties. Careful cutting that results in uniform sized pieces with consistent numbers of eyes can improve uniformity of emergence. Cutting is particularly useful for varieties that have slow seed curing ability, such as Atlantic and Kennebec.

Seed cutting: age and temperature

1. Young or middle-aged (physiologically) seed is best suited to cutting, as cutting will further age the seed as it heals.
2. Young seed can be cut up to one month before planting. However, if the seed has already sprouted, this time should be reduced to 2 weeks.
3. Middle-aged seed that has not sprouted can be cut up to two weeks ahead of planting. Middle-aged seed that has sprouted and been de-sprouted is considered old and therefore not suitable for cutting.
4. The temperatures at which to cut and then hold seed varies with physiological age and sprouting.
   - Potatoes shouuld be warmed prior to cutting over approximately 10 days.
   - The younger the seed, the higher the cutting and holding temperatures.
   - Young seed can be cut and held at about 10°C.
   - Older seed should not be warmed or held above 7°C.
   - If the seed has already sprouted, warm to 10°C and cut as soon as the temperature is reached.
5. Carefully consider the effects of temperature and timing on physiological age. Keep in mind that warming, cutting, and holding will all advance physiological age.
6. Remember, pre-cutting is not for all seed.

Cut potatoes will be particularly sensitive to the soil into which they are planted. Delayed emergence, slow, uneven establishment and reduced plant stands are all symptoms of planting seed in soil that may have been either too cold, too wet or too dry. Recently cut seed will be particularly vulnerable to infection and dehydration if planted into an unfavourable environment.

Seed cutting: size

The clear objective is to create pieces that fit into the planter and provide uniform stands. Mechanical cutters may not always be perfect, but can handle large volumes of seed, cutting the tubers into two or four pieces.

The size of a potato seed piece affects early plant vigour a great deal. Larger seed pieces usually emerge faster than smaller ones.

Ideally, cut seed tubers into blocky pieces about 50g in size. Discard poorly cut seed pieces, such as slivers or slabs (Figure 3). Remove seed pieces ripped or torn by dull knives.

Each seed piece should have at least one eye. For varieties with poor eye distribution, such as Atlantic and Shepody, consider cutting seed pieces closer to 55g each.

Also use larger seed pieces (55 – 70g) for Russet Burbank and similar varieties. Adjust planting distances for

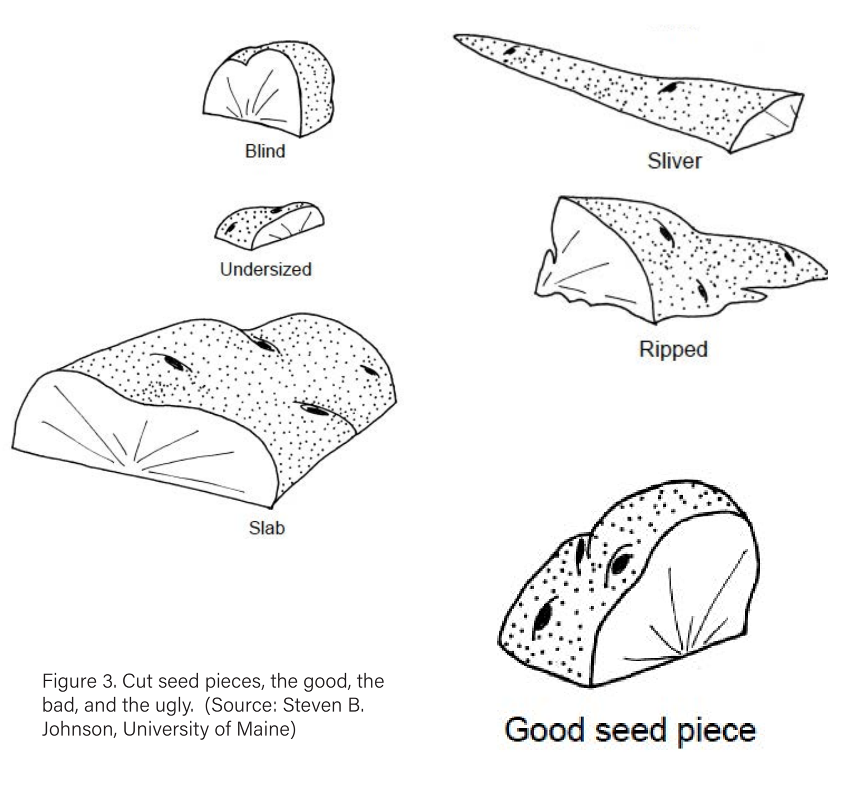

Figure 3. Cut seed pieces, the good, the bad, and the ugly. (Source: Steven B. Johnson, University of Maine)

such large pieces, allowing each extra space to grow.

Higher total yields are generally associated with larger seed pieces, but at some point, the seed piece size will not result in increased yield.

Bruise problems are more likely with very large seed pieces, especially at warmer temepratures. Excess bruising increases the risk of seed decay and accelerates ageing.

If cutting very large seed, also note that each piece will have a relatively large cut surface area. More stored energy will be used for wound healing, leaving less to support new plant growth. Emergence will likely be slowed, and plants will be less vigorous. A good rule is to keep the number of cut surfaces per tuber to a minimum.

Undersized seed pieces can contribute greatly to the number of doubles or triples planted. Oversized seed pieces can cause skips and are also prone to fall out of the planter.

To assess the seed cutting operation, count out 100 seed pieces and weigh them. If aiming for 50g per piece, no more than 10 pieces should be less than 30g or more than 70g. For most planters to run smoothly, at least 70 percent of the seed should be in the 43 – 85g range.

Other key points

1. Seed tubers should not be washed.
2. Do not try to salvage diseased potatoes or those that are breaking down.
3. Grade out bent or very rough tubers for hand cutting.
4. Size seed potatoes before cutting:
    - Less than 50g should not be planted
    - Between 50-100g should be planted whole
    - Between 100-150g should be cut into two pieces
    - Between 150 – 300g should be cut into three pieces
    - Greater that 300g should be cut by hand or not used at all
5. Keep the number of cut surfaces to a minimum to reduce bruising during handling and planting.
6. Seed pieces should have 2-3 eyes.
7. Disinfect all equipment before each seed cutting session and between seed lots.
8. Calibrate the seed cutter daily and between lots.
9. Keep the seed cutter knives sharp and straight to prevent ripping the potato surface. Ripping provides an ideal area for disease organisms to attack the seed.

CURING AND HANDLING CUT POTATO SEED - STEP BY STEP

The curing process takes between six to 10 days when the following steps are followed:

1. Cure cut seed optimally around 15 degrees and with high humidity and good ventilation.
2. Do not pile more than 1.8m deep - good air circulation will keep the temperature uniform and prevent build up of carbon dioxide and ethylene, which interferes with wound healing.
3. Relative humidity levels of 85 – 95% promote healing and prevent dehydration.
4. If there is too much air flow and not enough humidity, a thin skin may form on the cut surfaces. This thin layer is not enough to provide wound protection and can be easily sloughed during handling.

Care in handling cut potato seed is perhaps the most underrated aspect of commercial potato production. Cut potato seed is much more easily bruised than whole potatoes of similar weights. The most vulnerable areas of the seed pieces are the edges of the cut surfaces. Very small impacts can damage cells on the edges of the cut seed. These damaged areas make it easy for pathogens to infect the seed piece. Damaged cells may not heal.

As already noted, there is increasing recognition that optimising emergence and growth means minimising bruising to both seed-tubers and seed pieces. These are effectively baby plants; they need to be handled gently.

TREATING THE SEED: FUNGICIDES AND OTHER ACTIVE INGREDIENTS

Sourcing high quality, certified seed is an investment worth protecting. Seed treatments are therefore an important component of the overall disease management program.

Properly treated seed will provide a better, more uniform plant stand. However, more is not always better, as high concentrations of some products can be phytotoxic. Conversely, inadequate coverage may not provide good control.

Dust formulations are preferred for cut seed. If using a liquid, remove any diseased tubers before treatment to avoid spreading pathogens. As liquid formulations can inhibit wound healing, cut seed should ideally be fully cured before treatment.

Treatment will not be effective on seeds already diseased.

Determining which product to use will depend on a number of factors, including site history and other testing data that is supplied with the certified seeds. It is always a good idea to discuss requirements with a local agronomist.

THE VALUE OF CERTIFIED SEED

The adage 'rubbish in, rubbish out', succintly summarises the importance of buying good seed.

In 2013, The Australian Seed Potato Council (ASPC) was established to provide a collaborative framework involving the four respective State-based seed potato Certification Authorities, which includes the Department of Agriculture and Food Western Australia (DDLS Seed Testing and Certification), Australian Seed Potato Certification Authority (AuSPICA), Crookwell Seed Potato Growers and the Tasmanian Institute of Agriculture (TIA).

Certified seed potatoes underpin the security of the national potato industry. Seed certification provides some certainty that the investment made on seed is a good one, ensuringe that the seed potatoes meet quality standards set by the authority.

The benefits of potato seed certification are numerous and include:

- Avoiding spread of disease and maintaining tuber quality.
- Ensuring the genetic purity of potato varieties.
- Upholding common terminology.
- Creating uniform national labeling for both domestic and export certified seed potatoes, and uniform guidelines for seed production.

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MANAGEMENT OF POTATOES UNDER WET CONDITIONS

Many parts of Australia have seen Dorothea Mackellar's famous poem writ large across the landscape over the past few years. Three successive La Niña seasons have left prime potato growing areas waterlogged. Farmers more used to managing drought now find themselves with a suite of new challenges.
By Paulette Baumgartl

KEY POINTS

- Plant cover crops/green manure to improve soil physical properties that can better cope with wet conditions
- Ensure hills are stable and water can drain away in furrows. Reassess furrows following heavy rain
- Closely monitor nutrient levels, particularly in sandy soils, or if sub-soils are waterlogged
- Check moisture content of soil at different levels. A shovel is your best friend!
- If soil moisture below 25cm is at field capacity, the root system will be severely impacted
- Make sure hills are staying in place
- Avoid harvesting when soil conditions are wet; this will save soil structure and machinery

While flooding rains provide much needed relief to parched catchments and water tables, too much rainfall has consequences that are numerous and complex for potato growing. Challenges for growers are evident at every stage, from managing seed, planting, crop management and storage.

PRE-PLANTING

COVER CROPS AND PREPARING THE SOIL

Waterlogged soils are bad news for potato plants. Although we cannot control the weather, with some preparation we can create conditions that are better adapted to extreme wet conditions.

When soil is saturated, it cannot drain properly. The excess water inhibits the movement of oxygen into the soil, and thus the soil ecosystem quickly becomes anaerobic (Figure 1).

With a relatively shallow root system, potatoes have a very low tolerance to waterlogging and anaerobic conditions. Obviously, waterlogging cannot always be prevented, but improving drainage of water away from the crop and improving the soil's physical structure will help when the rains set in.

The many benefits of cover crops and green manures to soil health are widely known. These extend to helping soils prepare for a deluge by promoting a good physical structure through the addition of organic matter

Waterlogging in Ballarat, Feb 2023 - J Ekman to the soil. The extra organic matter improves drainage and optimises the amount of oxygen in the soil pores. Organic matter also increases the field capacity of soil, which is the amount of water the soil can hold before the air pockets fill with water and become waterlogged.

Organic matter from cover crops helps improve the physical properties, and thus the soil's ability to cope with excess water in a number of ways by:

- 'Gluing' particles together to form soil aggregates, creating a more porous soil structure.
- Acting as a sponge to absorb water and making it available to plants, slows down saturation, reducing the risk of waterlogging.
- Improving aeration by creating channels for air and water exchange. This is important for soil microorganisms, which are critical for soil health.
- Creating voids following decay: larger organic debris, for example roots and stems from green manure decay, leave an empty space, improving soil structure.

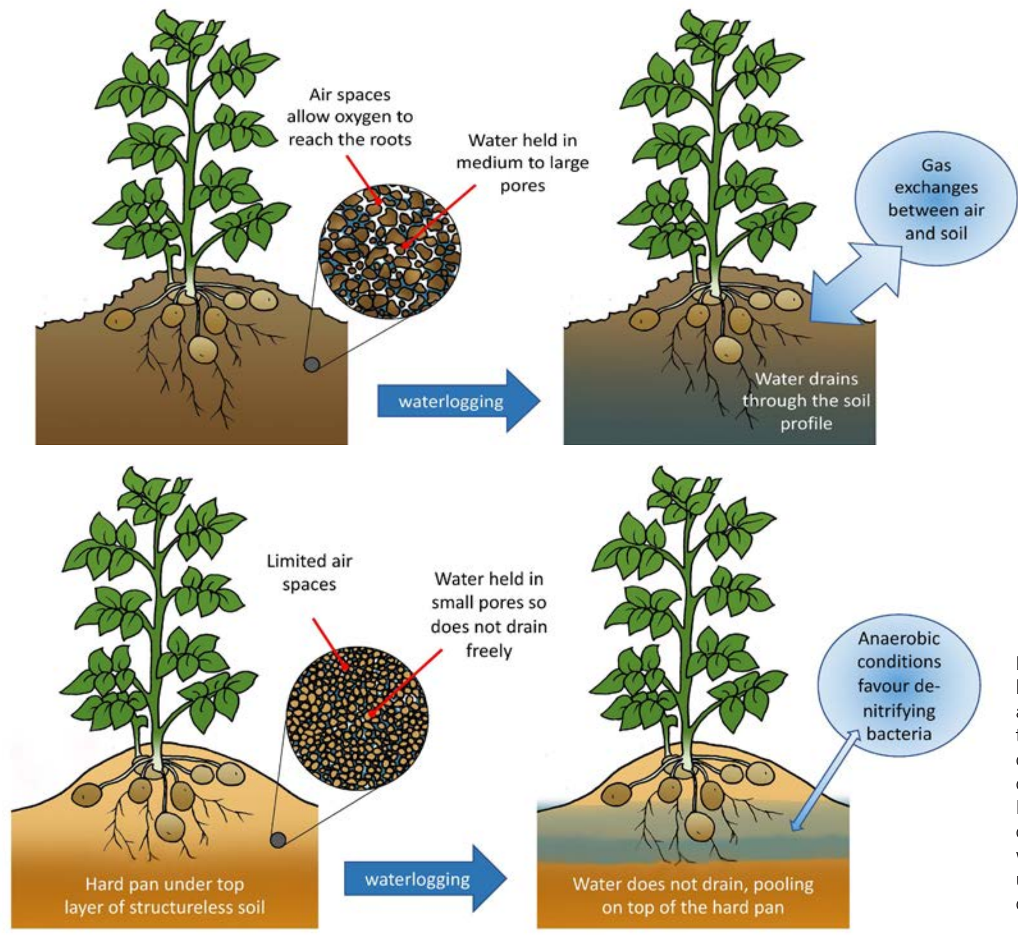


Figure 1. Top - good, healthy soils have a higher resistance to excess water and can maintain healthy conditions for longer. Bottom - poor soils can quickly become waterlogged, leading to unfavorable, anaerobic conditions.

Most soils, especially those with a high clay content, become compacted and slump after heavy rainfall and local flooding. This can form a crust, preventing oxygen and water penetrating the soil. Driving on the cropping area while the soil is very wet will result in further compaction and potential damage to expensive machinery.

However, once the paddock has dried, a light cultivation can be used to break up the crust to allow water and oxygen to penetrate. Care should be taken during cultivation not to cause further damage the soil structure.

Waterlogged ares are more prone to disease - T. Walker

SEEDBED PREPARATION

When a wet season is forecast, particular care needs to be taken when hilling potatoes. Potato seed pieces should be grown in hills of moist, weed free, stone free, friable soil, usually about 25-30cm high.

For soils that are prone to waterlogging, a bed former can be used before planting. This eases the planting operation by creating stable furrows and raised beds. These assist water flow and aeration through the hills. If a deluge occurs after hill formation, it is worthwhile checking the hills for damage and reconstructing if necessary. It is equally important to ensure that existing hills are not capturing water and preventing effective drainage.

Drainage can be either natural or artificial. Many areas have some natural drainage; this means that excess water flows from the farmers' fields to swamps or to lakes and rivers. Natural drainage, however, is often inadequate and artificial or man-made drainage is required.

There are two types of artificial drainage: surface drainage and subsurface drainage.

Surface drainage is the removal of excess water from the surface of the land. This is normally accomplished by shallow ditches, also called open drains. The shallow ditches discharge into larger and deeper collector drains. In order to facilitate the flow of excess water toward the drains, the field is given an artificial slope by means of land grading.

Subsurface drainage is the removal of water from the rootzone. It is accomplished by deep open drains or buried pipe drains.

i. Deep open drains

The excess water from the rootzone flows into the open drains. The disadvantage of this type of subsurface drainage is that it makes the use of machinery difficult.

ii. Pipe drains

Pipe drains are buried pipes with openings through which the soil water can enter. The pipes convey the water to a collector drain.

Waterlogging can lead to nutrient deficiencies - Daniel Geisseler, UC Davis

Buried pipes cause no loss of cultivable land and maintenance requirements are very limited. The installation costs, however, of pipe drains are likely to be higher due to the materials, equipment and skilled manpower involved.

DURING CROP GROWTH

MANAGING NUTRITION

Heavy rainfall and flooding can lead to nutritional deficiencies, especially in sandy soils.

If significant rain events occur after the crop has been planted, nutrient levels need to be closely monitored through regular soil and tissue testing.

Elements such as nitrogen and potassium are readily leached from the soil. Fertiliser applications should be adjusted to make up for shortfalls. Rates should be increased with caution though, as over application adds unnecessary cost and pollutes the environment.

Soils containing clay have a higher CEC so leaching is less of a problem. However there are other risks, including denitrification. The anaerobic conditions in wet soils favour denitrifying soil bacteria; these microbes convert nitrates into nitrogen gas, reducing available soil nitrogen.

MANAGING WEEDS

Pre-emergent herbicides are an important tool. If a dry window of 48 hours can be relied upon, these products can be highly effective.

Post-emergent herbicides need to be used with caution and are not generally recommended when wet conditions have reduced the growing season. Herbicides easily burn new potato leaves, damaging the ancillary parts of the leaves where important hormones for root growth are formed. While the potato leaves can recover, below the ground the root growth has been stunted. Recovery can take a week or more. If wet conditions have already shortened the growing season, even one lost week will have a significant impact on yield and quality.

In general, applying chemicals in the right conditions can be hard in wet years. If possible look out for a dry window to apply pre-emergent herbicide.

MANAGING PESTS AND DISEASE

Very wet weather clearly increases the risk of fungal disease, including late blight, pink rot, and powdery scab.

Mild growing conditions also create a heavy but soft potato canopy, increasing the risk of foliar disease. Observe your crop carefully (potentially using a drone) and remove infected plants to reduce the spread of disease. Powdery scab, for example, will make itself known at around day 20 after planting.

Although it is difficult to keep fungicide applications on schedule during wet conditions, they are vital to prevent spread and entry of disease. To ensure the best outcomes, consider the following:

- Adhere to correct rates and concentrations to reduce risk of resistance.
- Speak to your local agronomist to ensure timely application.
- Prevention and not cure is the key. Where late blight was last year, it will most likely be present this year. Be swift, take early action.
- Inform yourself on the latest, approved products.
- Ensure hills and furrows are well managed.
- Check spray nozzles are calibrated and oriented correctly.

OTHER PROBLEMS

Lenticels are the pores in the skin of a potato tuber that allow gas exchange between the internal tissues and external atmosphere.

Under waterlogged conditions tubers struggle to get enough oxygen to support normal respiration. In response, the lenticels swell into puffy, corky white growths. This is not only unsightly, but makes infection easier for a range of fungal and bacterial pathogens.

If the soil remains waterlogged for an extended period, plant health will suffer. The roots are restricted and may die, crops become stressed and nutrient uptake is reduced. The air between soil particles is displaced by water, eventually leading to plant death due to lack of oxygen. It may seem counter-intuitive, but waterlogging can lead to wilting, as the oxygen starvation kills the roots and vascular system blocks.

Even after the sun comes out, problems may persist, as damaged root systems struggle to keep up with demand from an oversize leaf canopy.

Puffed lenticels on waterlogged potatoes - R. Hall

HARVESTING AND POST-HARVEST CONSIDERATIONS

When harvesting the crop following the challenges of a wet season, the best advice is to understand the variability in your crop and identify problematic areas.

Some important considerations when harvesting in wet conditions:

- If you know an area has disease present, avoid placing the potatoes in a storage facility.
- Keep everyone informed. Buyers and processors need to know about issues. Talk to customers and discuss issues with your local agronomist.
- If the potatoes are stored by the processing company, it is vital they know about and can anticipate potential problems.
- If soft rot is suspected, delay crop harvest and let soft rot run its course, which should take approximately two weeks.
- Potato tubers normally contain air spaces, which allow gas to diffuse for respiration but also provide some 'cushioning' of impacts during harvest. These are reduced when potatoes are fully turgid (i.e. the plant cells are full with water), increasing the risk of bruising during harvesting.
- Waterlogged soils are heavy and can break expensive machinery.
- Waterlogged but otherwise 'valuable' soils can be sticky and leave the farm via machinery.

EXPLORE FURTHER

Watch more in these PotatoLink webinars:

Pink rot with Dr Robert Tegg.
http://bitly.ws/BFB7

Late blight with Professor Steven Johnson and Dr Rudolf de Boer
http://bitly.ws/BFBa

Common scab with Dr Tonya Wiechel.
http://bitly.ws/BFBj

Panel discussion on managing potatoes in wet conditions with Peter O'Brien, Peter Philp, and Tim Walker.
http://bitly.ws/BFCh

Read more about soil test reports in this PotatoLink factsheet:

http://bitly.ws/BUKX

SOURCES

https://www.fao.org/3/r4082e/r4082e07.htm

Panel discussion: Managing potatoes in wet conditions Peter O'Brien, Peter Philp, and Tim Walker

SLUGS IN POTATO CROPS

The recent wet spring and summer has provided ideal conditions for slugs to build their populations. As soils start to dry out during Autumn, slugs will seek moisture in soils and crop residue. Potato crops become targets for slug attacks, with the potato tuber providing an ideal harbour for this serious pest.

In recent years, slugs have emerged as a significant pest group in Australian agriculture. Potato tubers, rich in starch and with high water content, are attractive to slugs. The rasping mouth parts of slugs can penetrate the tuber. Feeding creates a cavity that increases risk of disease.

For both processing and fresh crops, the presence of slugs in tubers can result in load rejection and significant financial loss.

While these slug species differ in appearance, they can coexist in the same area. Accurate identification is essential for effective control. Incorrect identification can mean that controls miss peak activity, or are applied to non-pest species, allowing the real problem to persist.

Perforations and holes caused by slugs - potato-tuber-blemishes.com

THE UNUSUAL LIFECYCLE OF SLUGS

Slugs are hermaphrodites. That is, they have both male and female sexual parts.

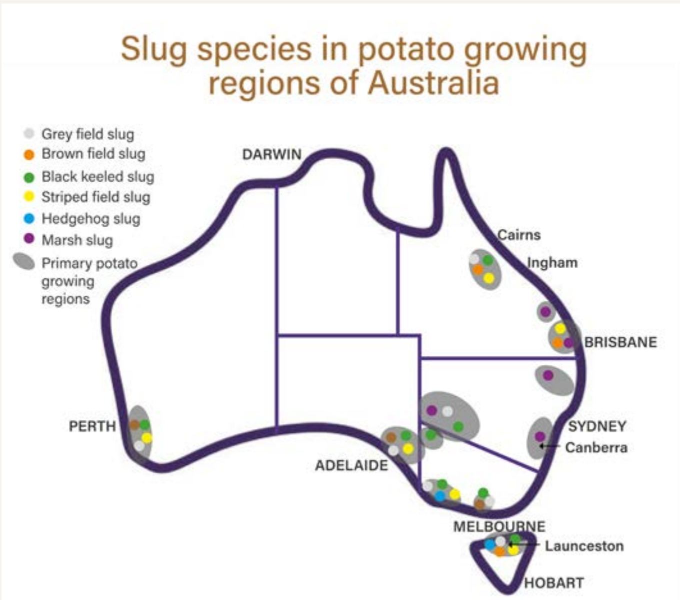
Unlimited by a biological gender, any two individuals can mate and both then lay eggs. The breeding period occurs when moisture and temperature conditions are suitable, which is generally over winter and spring.

Slugs will lay eggs in clutches into moist soil over one to two month periods. The ideal soil temperature for egg development is between 10°C and 16°C for grey field slugs. Neonates hatch from the eggs within three to six weeks. These initially grow slowly, but accelerate as they develop into juveniles, especially given damp conditions and plenty of food. Temperatures ranging between 4°C to 21°C are suitable to many species.

The juveniles can become as large as adults, reaching sexual maturity after 10 to 40 weeks, depending on the species and conditions.

One intriguing aspect of slug development is that development times vary between individuals hatched from the same clutch. Within a population, there are both slow and quick breeders. This staggered breeding is believed to be an adaptation to survive difficult conditions.

Adult slugs can survive dry conditions by hiding under the top layer of soil and lowering their metabolism. They re-emerge once the subsurface wets up, which generally occurs after 75 to 100 millimetres of rain. However, emergence is often staggered, another adaptation to variable conditions.



Distribution of common slugs in Australia's potato growing regions

Along with plant damage, slugs leave a silvery, slime trail in their wake, caused by a secretion of mucus. Slugs a ravenous feeders, and can kill seedlings.

Factors which may cause a slug infestation include:

- A nearby crop, or weedy and grassy areas nearby
- Long grass in drains
- Wet areas from leaking irrigation
- Following a pasture crop
- Minimum tillage
- Wet, moist weather

The control of slugs is best achieved by adopting effective Integrated Pest Management (IPM) strategies (Table 1). Sampling, for example using slug mats, should the first step in any control program to determine the location, population and species present.

Cultural practices	Biological control	Chemical control	Physical barriers
Reduce soil moisture (if practical and suitable); remove weeds that provide favourable habitats; use trap crops to keep slugs and snails away; cultivate weed free strips between crop and headland to prevent migration; keep gully lines clean.	Birds, rats, frogs, and lizards feed on slugs and snails. Carabid beetles and native earwigs also feed on slugs.	Chemical baits are effective when used with cultural practices at those times when the populations have not reached damaging levels. Bait choice is important. Small, even sized pellets/granules will give a better coverage, increasing the likelihood of slugs and snails finding the baits	A protective border can be used to prevent the movement to crops. Lines of sawdust, ash, lime, and copper sulphate are effective barriers but efficacy is often reduced on wetting.

Table 1: IPM for the control of slugs (adapted from https://ausveg.com.au/biosecurity-agrichemical/crop-protection/overview-pests-diseases-disorders/slugs-and-snails/)

COMMON SLUGS FOUND IN AUSTRALIA (IMAGE CREDITS, WIKIMEDIA)


Grey field slug (*Deroceras reticulatum*); 50mm long. PEST: Yes (all crop types)


Brown field slug (*Deroceras invadens*); 30mm long. PEST: Yes (all crop types)


Black keeled slug (*Milax gagates*); 50mm long. PEST: Yes (all crop types)


Striped field slug (*D. nyctelius, Ambigolimax valentianus*); 70mm long. PEST: No


Hedgehog slug (*Aron intermedius*); 20mm long. PEST: Yes (wheat and pasture)


Marsh slug (*Deroceras laeve*); 25mm long. PEST: Yes (all crop types)

SOURCES

Nash, M. 2022. Slugs in crops: The back pocket guide. GDRC

https://ausveg.com.au/biosecurity-agrichemical/crop-protection/overview-pests-diseases-disorders/slugs-and-snails/

https://www.potato-tuber-blemishes.com/Symptoms/Pitted-or-raised-symptoms/Slug-holes

https://ahdb.org.uk/knowledge-library/how-do-slugs-damage-crops

USING LEGUMES TO SUPPLEMENT NITROGEN

The world may be easing its way into post-pandemic normality, however latest market research shows that this will have limited impact on the historically high prices of nitrogen and imported fertilisers for Australian farmers. By Paulette Baumgartl

According to Rabobank's 2022 Fertiliser Affordability Index Report, despite predictions that the global price of fertilisers will fall in the coming months, Australian farmers will enjoy no such reprieve.

Contributing to these high prices are Australia's heavy reliance on imported fertilisers, unpredictable bulk freight rates, ongoing currency and interest rate challenges, and domestic freight and logistics constraints.

With prices of urea still hovering around $1300-$2000/tonne, understanding alternative, cheaper ways to add nitrogen to the soil is more important than ever.

THE BIOLOGY OF 'CHEAP NITROGEN'

The many benefits of cover crops are well-documented. When legumes are part of the cover crop, the benefits extend to adding atmospheric nitrogen, of which there is an abundance, to the soil.

The process of fixing nitrogen from the atmosphere into the soil is called biological nitrogen fixation (BNF). This process occurs when legume plants form symbiotic (i.e., mutually beneficial) relationships with nitrogen-fixing bacteria, such as rhizobia, which live in root nodules.

TIPS TO GET THE MOST NITROGEN OUT OF YOUR LEGUME COVER CROP

- If nitrate levels are low in the soil, select and grow a vigorous legume cover crop; the more biomass grown, the more nitrogen fixed and added to the soil.
- Add the right rhizobium inoculant for your selected cover crop to ensure maximum results. Sow within 24 hours of inoculation.
- If nitrate levels are too high, a mixed crop can remove nitrate form the soil, paving the way for effective fixation from legumes, which provides better long-term results.
- The timing of the cover crop is important to ensure nitrogen is available when the potatoes need it most.

In this process, the bacteria convert atmospheric nitrogen (N_2) into a plant available form, for example ammonia (NH_3) or nitrate (NO_3). By way of thanks, the plant then provides the bacteria with energy in the form of sugars produced through photosynthesis (Figure 1). Once the nitrogen has been fixed, it is available for the plant.

EXPLORE FURTHER

Watch the recent webinar *Legumes in rotation with potatoes - an alternative nitrogen source*. In this webinar, Dr Kelvin Montagu and Peter O'Brien discuss the principles of using legumes as an alternative nitrogen source, the importance of legume inoculants and considerations for best results in rotation with potatoes.

http://bitly.ws/BS77

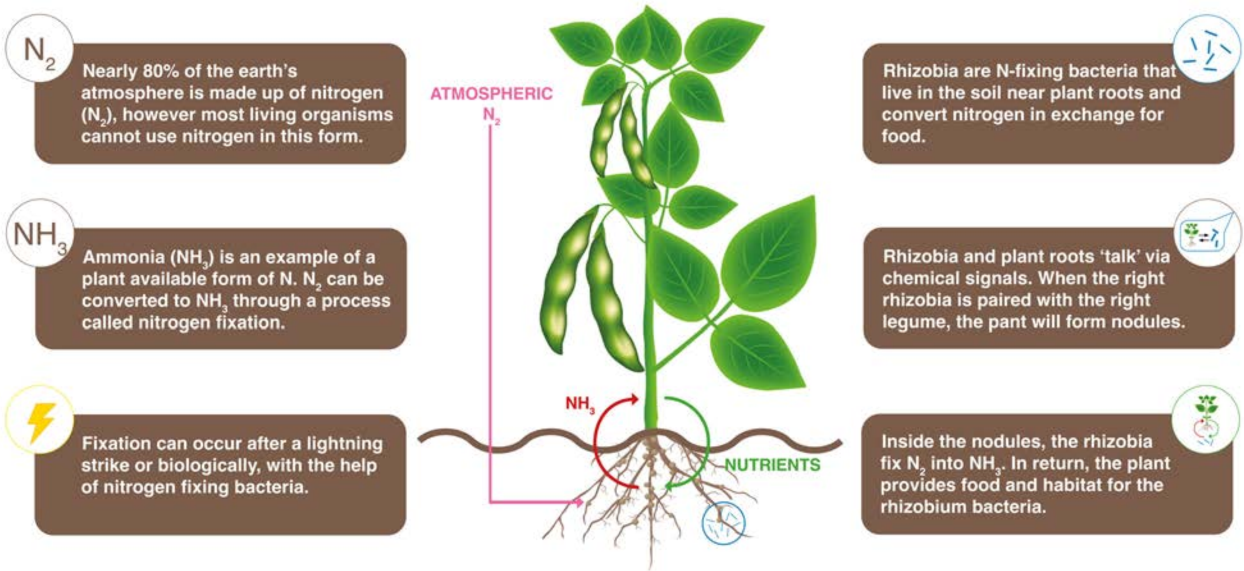


Figure 1. Converting atmospheric nitrogen to plant available nitrogen through biological fixation. (Based on figure from https://xitebio.ca)

COVER CROPS, BIOMASS, AND NITROGEN

Potatoes are a nitrogen-hungry crop. The nitrogen budget in a crop cycle depends on many factors, including yield, soil type and how much in-crop nitrogen fertiliser was used, and whether cover crops are part of the crop cycle on the paddock.

While all cover crops add some nitrogen to the soil, legume cover crops are the big contributors, owing to their ability to fix nitrogen. On average, for every tonne of shoot biomass grown, approximately 20kg of nitrogen will be added. A good legume cover crop with the right inoculant can produce 8-10 tonnes of shoot biomass, which equates to 160-200kg of nitrogen added. Cover crop roots can add a further 30-100kg of nitrogen.

Which cover crop is best will depend on local factors, including soil type and climate. For help with choosing the right legume for your area, the *Cover Crops for Australian Vegetable Growers* poster provides a handy overview.

Cover crop mixes add less nitrogen and sometimes this is the preferred option when growing a potato crop, particularly in soils with high soil nitrate levels. Plants, like humans, will favour the easy option, so if free nitrogen is available in the soil, legumes are less likely to make the effort to enter a partnership with rhizobium bacteria to create nitrogen.

Before selecting a cover crop, it is worthwhile to conduct a soil test to determine nitrate levels:

- At nitrogen levels of 50kg per ha (to 30cm), the legumes will add lots of nitrogen.
- At nitrogen levels above 200kg per ha, the legume will not add much nitrogen.

In soils with high nitrogen levels, a mixed cover crop of a sunn hemp, sorghum and tillage radish for summer, or oats and vetch mix for winter, could be a good option. The cereal and broadleaf species will recover and store the nitrogen, while 'forcing' the legume to fix its own nitrogen.

The nitrogen stored in the biomass can be later re-released when the crop is terminated and left as green manure.

WHEN TO GROW A COVER CROP

Generally, it is best to grow a legume cover crop prior to the potatoes. Although legumes can host some diseases, for example grey mould, this rarely presents a major problem.

As the nitrogen demands of the crop vary at different stages, controlling the amount of available nitrogen is important. Too much in the first few stages can delay tuber initiation and cause some internal defects; conversely too little in stage 4 will have an impact of tuber bulking.

Matching nitrogen supply to the nitrogen demand requires systematic soil and tissue testing, both before and during a season. Understanding the movement and release of N from legume biomass (or other forms of biomass) is also useful.

There are three important factors to consider about nitrogen and potatoes:

1. Potatoes require most nitrogen during stage 3.
2. Too much nitrogen before tuber initiation (growth stage 2) can delay initiation.
3. Potassium must also be present during the middle growth stages. Excess nitrogen with limited potassium is associated with reduced specific gravity, an important consideration for processing potatoes.

Therefore, terminating a legume cover crop in summer, six weeks prior to planting an indeterminate potato variety (some varieties are not impacted by too much nitrogen) is not advisable as there would be too much nitrogen still present at stage 2.

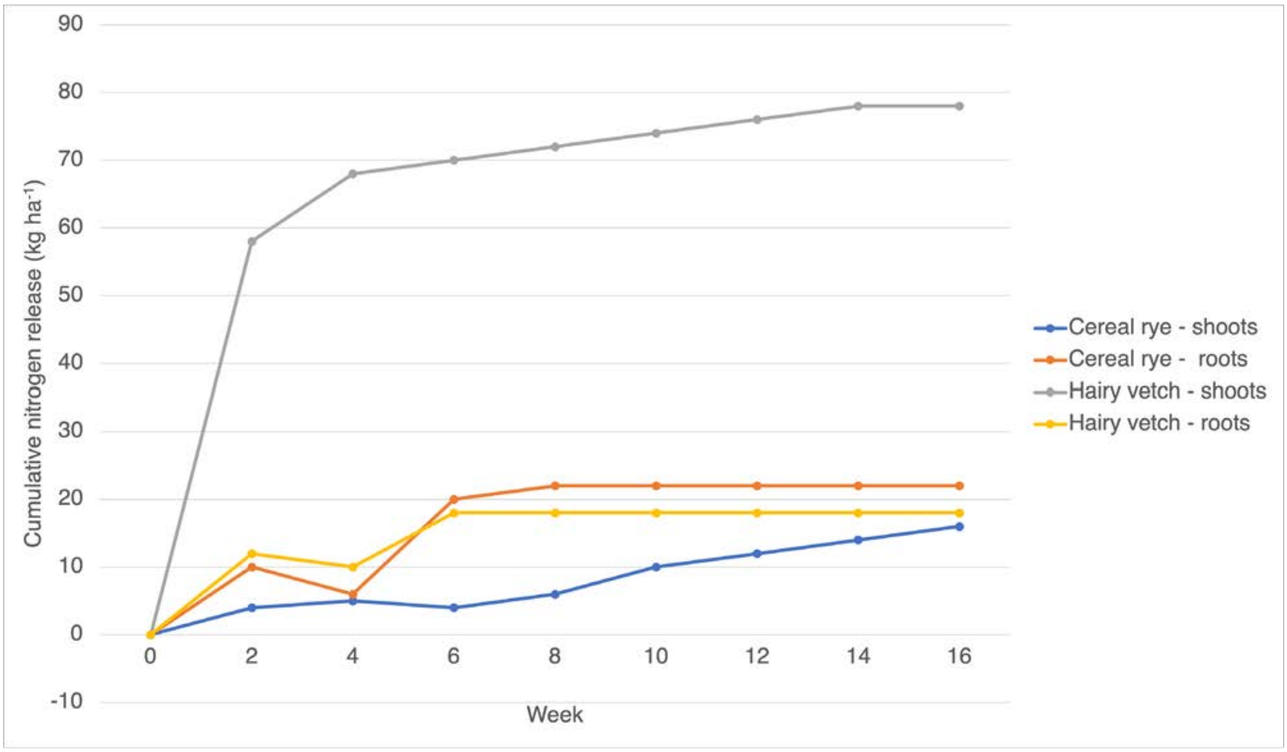


Figure 2. Estimated cumulative nitrogen release of cereal rye and hairy vetch residual biomass over 16 weeks of decomposition with potato growth stages. (Based on Sievers and Cook, 2018)

However, if it was terminated and left to dry out (no rain or no irrigation), the release would be timed in a way that would be suitable for potato growth, i.e., the residual cover crop would not start releasing nitrogen until the potatoes were planted and irrigated.

Figure 2 illustrates some results from an American study showing the release of nitrogen from different cover crop biomass residues, following termination with herbicides. Rate of decomposition is effected by the carbon:nitrogen ratio - cereal rye biomass residues decompose much slower and may also immobilise N as it has a higher C to N ratio than vetch. However, although a cover crop like hairy vetch contains more N and releases it more quickly, the rapid, early release may not suit potatoes.

THE IMPORTANCE OF ADDING THE RIGHT RHIZOBIA

Rhizobium bacteria do much of the heavy lifting in fixing nitrogen, and if they are not present in the soil, the legume cover crop cannot do its job.

Compatible, effective rhizobia must be present before nodulation and N fixation can occur. When a legume is grown for the first time in a particular soil, it is unlikely that the correct rhizobia will be present. Therefore, the rhizobia must be supplied in a highly concentrated form as inoculants.

Each species of legume has a specific strain of rhizobium that it needs for this process. To ensure adequate plant growth, it is important to inoculate legume seed at planting with the correct strain of rhizobium. A number of reliable resources are available to help select the right rhizobium.

The Australian Inoculant Research Group (AIRG) curates a selection of suitable rhizobia for inoculant products. These products have a green tick and have been independently tested for Australian farming conditions.

Currently there are 42 strains covering over 100 species and cultivars of grain and pasture legumes approved by the AIRG and the National Rhizobium Steering Committee.

Usually a seed supplier can provide the right rhizobium when purchasing legume seed.

It is also important to sow the seed within 24 hours of inoculation.

Morgan field pea - K. Montagu

Sunn hemp - K. Montagu

Lupin - D Long

EXPLORE FURTHER

Download the *Cover crops for Australian vegetable growers* poster - **http://bitly.ws/BULf**

Read more about the AIRG and the list of inoculants -**http://bitly.ws/BULg, http://bitly.ws/BULj**

SOURCES

Sievers, T. and Cook, R.L. (2018), Aboveground and Root Decomposition of Cereal Rye and Hairy Vetch Cover Crops. Soil Science Society of America Journal, 82: 147-155. https://doi.org/10.2136/sssaj2017.05.0139

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MANAGING HERBICIDES AND HERBICIDE INJURY

In February we had the pleasure of meeting Professor Andy Robinson and welcoming him, in person, to the PotatoLink project. While visiting Australia, Professor Robinson took time out of a busy schedule to take part in our Ballarat workshop and field walk. Professor Robinson is a highly regarded extension agronomist and academic from North Dakota State University and the University of Minnesota. Before heading our way, he presented a webinar on chemical weed control and herbicide injury. By Paulette Baumgartl

WATCH THE WEBINAR

This article summarises key points from Prof Robinson's webinar regarding best management for weeds and how to recognise the difference between herbicide injury and diseases or defects in your potato crops. The webinar is available to watch any time via the PotatoLink website. at this link: **http://bitly.ws/BFEY**

When no pre-emergent herbicide has been applied, a post-emergent treatment is the only option - A. Robinson

WEED CONTROL TOOLBOX

Potato growers have many options to control weeds, from prevention and cultural management to mechanical and physical weed control, and chemical and biological methods. With so many choices, the key to success is knowing which method to use, and how to combine them for maximum impact.

As the name suggests, **prevention and cultural management** are all about growing potatoes in a way that inhibits weed growth. This includes factors like row width, canopy closure, water and fertiliser management.

Creating shade and reducing weed space promotes potato growth and can reduce the volume of herbicides needed for chemical weed control. Likewise, taking care not to transfer seeds from one area to another can help prevent the spread of weeds (as well as disease).

Mechanical and physical weed removal also play a role. Each pass across a field disrupts the soil and prevents weed growth. Hilling can also be an opportunity to remove weeds.

Chemical weed control, or herbicides, is the primary method used by most potato growers. Herbicides facilitate reduced tillage (which is good for maintaining soil structure), can target specific weeds, and are effective for treating large acreage.

Choosing the right herbicide requires careful consideration of factors including variety sensitivity, the weed spectrum present, timing, and cost.

Timing is particularly crucial when using herbicides. Pre-emergent herbicides provide a window of 3-5 weeks for weed control, giving potato plants time to grow, form a canopy and prevent weed emergence. But the effectiveness of pre-emergent herbicides can be impacted by weather conditions, often beyond the grower's control.

Also note that slow growing weeds need a slower acting herbicide, i.e., a herbicide with lower water solubility. Conversely, if quick action is required, a herbicide that dissolves quickly in water is more suitable.

PRE-PLANT (KNOCKDOWN) HERBICIDES

Knockdown herbicides, as the name suggests, are applied just prior to planting and designed to work rapidly. They can also be useful in reducing a seedbank.

Glyphosate remains a popular choice in Australia but can cause herbicide injury if mismanaged.

Table 1 highlights the man advantages and challenges of the typical knockdown herbicides used in Australia.

Herbicide - Active (trade name)	Targets	Advantages	Challenges
Glyphosate (Round up*)	All weeds - burndown, good for pre-plant, can be a problem during growth	▪ Translocates ▪ Low water volume ▪ Adjuvants can be added to improve results ▪ Good on grasses ▪ Can withstand sunlight and warm temperatures ▪ Low cost	▪ Weed resistance ▪ Potential damage to potato plant
Paraquat and diquat (Gramaxonae, Spray seed)	All weeds	▪ Kills on contact ▪ High volume of water needed ▪ Herbicide resistance low	▪ No contact, no kill ▪ Injury to plant ▪ Sunlight is needed ▪ Human safety

Table 1. Common pre-plant (knockdown) herbicides used in Australia (Source: A. Robinson). Always refer to directions on the label
*Or other generic herbicides with the same active ingredient.

PRE-EMERGENT HERBICIDE

Pre-emergent herbicides prevent germinated weed seedlings from becoming established.

For maximum efficacy, several factors should be considered:

- As they require 10-20mm of water to activate, if no rainfall is expected irrigation is required.
- Incorporating the herbicides through tillage or water can also improve their effectiveness.
- Timing is paramount: apply before weed seeds germinate.
- With the right knowledge, tank mixing herbicides can expand the weed control spectrum.
- Soil factors, including pH, organic matter, texture, and moisture need to be considered before application to ensure optimal results.

Metribuzin injury - A. Robinson

Wrinkly leaves caused by herbicide injury from metolachlor - A. Robinson

Table 2. Common pre-emergent herbicides used in Australia (Source: A. Robinson). Always refer to directions on the label

Herbicide - Active (trade name)	Targets	Advantages	Challenges
Metribuzin (Sencor, Mentor)	Broadleaves, grasses	▪ Good general weed control ▪ Water soluble ▪ More active in soils with pH > 7.5, low organic matter, stressed plants	Foliar: symptoms can be severe when applied when plant metabolism is slowed, or within 3 days after periods of cool, wet, or cloudy weather. Can affect sensitive cultivars, can cause venal chlorosis.
Linuron (Linex)	Blackberry, nightshades, broadleaves	▪ Great on fat hen ▪ Good on nightshades ▪ 1/12th as soluble as metribuzin – needs more water to activate but lasts a lot longer. ▪ Late PRE herbicide treatment ▪ Tank mixes well with metribuzin and S-metolachlor	▪ Linuron binds to OM, will be less effective (don't use in high OM soils) ▪ Limited weeds controlled ▪ Cost
Metobromuron (Soleto)	Broadleaves	▪ Good control of many small-seeded broadleaves	-
EPTC (Eptam)	Nut grass, broadleaves	▪ Incorporation is key - fertigate, tillage	▪ Cost ▪ Photodegrades so needs to be tilled in immediately
Metolachlor, prosulfocar (Boxer gold)	Grasses, Nightshades, Fat Hen, Redroot Amaranth, Toad Rush	▪ Ideal for resistance management ▪ Versatile ▪ Good compatibility with other herbicides	Irrigation or rainfall is required to a depth of 3 to 5 cm and should occur within 7 days of application.

Table 2 (over page) highlights the main advantages and challenges of the typical pre-emergent herbicides used in Australia.

POST EMERGENT HERBICIDES

Most post emergent herbicides fall into two categories, **graminicides and desiccants**.

Graminicides target weedy grasses and should be used on weeds less than 15 cm tall (Table 3).

- Use the full label rate, as a reduced rate will lessen efficacy and could lead to herbicide resistance.
- Add an adjuvant to help break the barrier on the leaf surface and get more herbicide in the plant.
- Use a high volume of water to achieve good spray coverage on leaves.

Trade name	Active	Targets
Fusilade*	Fusilade	Grasses
Select, Clethodim*	Clethodim	Grasses

Table 3: Common **grass herbicides** used in Australia (Source: A. Robinson).
Always refer to directions on the label.
*Or other generic herbicides with the same active ingredient.

Trade name	Active	Targets
Reglone	Diquat	Potato foliage
Spray Seed**	Paraquat + diquat	Weed destruction

Table 4. Common **desiccants** used in Australia (Source: A. Robinson).
Always refer to directions on the label.
**DO NOT use SPRAY.SEED® 250 for potato haulm desiccation.

Desiccants prevent specific functions within the plant, such as interfering with photosynthesis or disrupting cell membranes. The internal structure collapses and the plant dies, drying out almost as rapidly as if it had been burned (Table 4).

Glyphosate is not considered a 'true' desiccant, as plants take weeks, rather than days, to die.

AN INTEGRATED, COMBINED APPROACH IS ALWAYS BEST

As every grower knows, an integrated approach usually yields the best results. Timely application of herbicides appropriate to the specific needs of the crop and the weed pressure it is under is a useful tool.

Combining this with good cultural management practices, such as crop rotation and cover cropping, is the best way to reduce weed pressure and avoid herbicide resistance.

HERBICIDE INJURY

Herbicide injury can cause a variety of problems for potato growers, including reduced stand, slow canopy closure, damaged leaves, malformed tubers, reduced yield and quality, and unacceptable accumulation of contaminants in the tuber.

There are three main ways herbicide injury can occur: **soil carryover, foliar exposure,** and **seed contamination.** Common modes of 'unwanted herbicide transport' include drift (Figure 1), tank contamination (tank and/or boom not cleaned out properly), misapplication, volatisation, or sometimes even a broken hose.

SOIL CARRYOVER

Microbial decomposition, together with UV light and other environmental factors, generally breaks down herbicides in soil.

However, if conditions are too cold, dry or wet for microbial activity, or hard pans are present that trap herbicide within the profile, then some products can persist. Herbicides can also potentially be released from treated materials that have not broken down before planting.

Signs of soil carryover include slow emergence, pruned or brown roots, stunted plants, shortened stolons, and early tuber set or malformation.

If large areas or whole fields show symptoms, this can indicate contamination via a sprayer (tank contamination).

FOLIAR EXPOSURE

Herbicides can also cause damage through foliar exposure. This can occur via particle drift, inversion, contamination of spraying equipment, volatilisation, misapplication, contaminated water, and more.

Symptoms of foliar exposure include leaf injury and tuber cracking or malformations. The specific symptoms vary depending on the herbicide's mode of action. These can include twisting of leaves and stems, cupped leaflets, wrinkled leaflet margins, misshapen tubers, yellowing of youngest leaves, and elongated and wrinkled leaflets.

Herbicides that translocate within the plant can potentially damage both the leaves, especially young leaves, and the underground tubers (Figure 2).

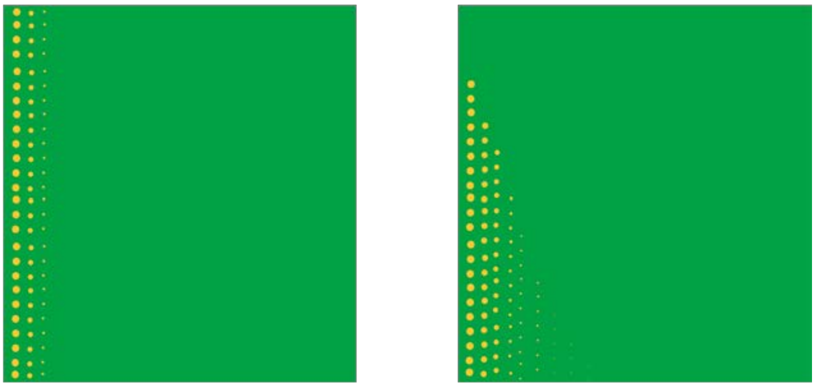

Figure 1. Typical patterns caused by herbicide drift (Source: A. Robinson)

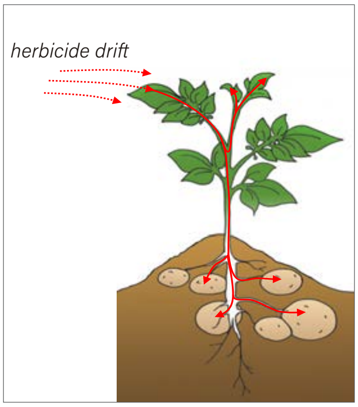

Figure 2. Translocating herbicides can cause chemical build up in tubers (Source: A. Robinson)

Contact herbicides will affect what they touch, including both young and old leaves equally.

In addition to direct damage, herbicide injury increases plant stress, which can result in tuber cracking or malformations in tubers.

GLYPHOSATE DAMAGE

Glyphosate is a commonly used herbicide with wide benefits in agriculture. However, it can have negative effects on crop growth and development if misused. Accidental exposure to glyphosate can cause yellowing of new leaflets, stunting of plant growth, and reductions in plant height and leaf size.

These effects can be particularly pronounced at higher application rates, where leaves can become chlorotic and necrotic.

The often subtle effects of glyphosate drift, or other herbicide injury, can make identification challenging, even for experienced experts. Patterns in the field can provide some helpful clues: if symptoms are present throughout the field, the issue may be related to nutrient deficiencies. However, if only the edges of the field are affected, herbicide drift may be the culprit (Figure 1).

In addition to its effects on foliage, glyphosate can have negative impacts on tuber development during the early bulking stages. Exposure can result in smaller, irregularly shaped tubers that have folds, cracks, knobs, and 'elephant hide'. Even minute amounts of glyphosate can cause significant damage to tuber development, ultimately leading to reduced yields and lower quality crops.

Glyphosate can also leave residues in seeds. These affect seed germination and plant growth. When seeds are contaminated with glyphosate residues, typical symptoms include erratic and slow emergence, bending and twisting of leaves, multiple stems from a single eye, and "cauliflower" or "candelabra" formations of stems with no dominant growing point.

IS IT HERBICIDE INJURY OR SOMETHING ELSE?

Identifying herbicide injury in plants is not always straightforward as many other causes have similar symptoms.

In potatoes, high turgor pressure and rapid tuber growth can cause cracking, while drought stress and fertility stress can cause discoloured leaves. Potato virus Y can cause mosaic patterns, small leaflets, and wavy leaf margins.

To properly diagnose whether it is herbicide injury or something else, consult your local agronomist, take samples and test, test, test. It is essential to document the symptoms immediately and collect multiple samples for laboratory analysis.

Prevention is always better than cure. It is crucial to check previous herbicides used in the field, communicate with neighbouring farmers about sensitive crops, and work closely with seed growers to ensure seed is clean.

Proper tank cleanout procedures and training for spray system users are essential. Herbicides should always be kept separately to other pesticides in clearly labelled containers.

WHAT TO DO IF YOU SUSPECT HERBICIDE DAMAGE ON A LARGE SCALE?

If you suspect herbicide injury has occurred, it's important to document it immediately because symptoms may decrease over time, making it more difficult to capture. A laboratory analysis is also necessary. When sampling, take multiple leaves and/or tubers and use clean gloves and an unused bag. Comparing affected and non-affected areas is also recommended, as is sampling multiple intensities of damage.

Chain of custody is also essential, especially if the issue becomes litigious. Chronological documentation of the individuals who take custody of the sample should be maintained, and a third party can be used to verify when and where samples were taken.

After sampling, gently clean the samples if necessary and store refrigerated. Samples need to be kept cool and preferably shipped overnight to the laboratory. Information on how to sample and get tests for herbicides can be found at **z.umn.edu/injury.**


Left: Edge of fields or lower point in field – herbicide residues accumulate in low spot causing carry over. Right: Tank/boom contamination - A. Robinson


Left: Two seed lots, one with glyphosate contamination in seed and one with no contamination. Right: 'Cauliflower sprouts' due to glyphosate exposure - A. Robinson


Left: Fluorescent green foliage from glyphosate drift on a seed paddock. Right: Extremely malformed tubers - A. Robinson


Left: Uneven irrigation can also cause malformed tubers - J Ekman. Right: Diseases and fertility deficiencies can display symptoms similar to herbicide injury - A. Robinson

KEY POINTS

- Pre-emergent herbicides usually require 10-20mm of water to activate.
- Incorporate pre-emergent herbicides through tillage or water for improved effectiveness.
- Apply pre-emergent herbicides before weed seeds germinate.
- Tank mixing herbicides can expand the weed control spectrum.
- Consider soil factors such as pH, organic matter, texture, and moisture, adjust rates and application timing accordingly.
- While herbicides are extremely useful tools, especially when used within an integrated approach, accidental exposure can significantly reduce potato yield and quality.
- Herbicide injury can occur through soil carryover, foliar exposure, and seed contamination.
  - Soil carryover can cause slow emergence, pruned or brown roots, stunted plants, shortened stolons, and early tuber set or malformation.
  - Foliar exposure can occur due to particle drift, inversion, contamination of spraying equipment, volatilisation, misapplication, contaminated water, and more.
  - Symptoms of foliar exposure include leaf injury and tuber cracking or malformations, which can vary depending on the herbicide's mode of action.

GLYPHOSATE DAMAGE:

- Glyphosate can cause yellowing of new leaflets, stunting of plant growth, and chlorotic and necrotic leaves.
- Glyphosate exposure can result in smaller, irregularly shaped tubers with folds, cracks, knobs, and 'elephant hide'.
- Even extremely low levels of contamination can have a significant impact on tuber growth, quality and yield.
- Glyphosate residues in seeds can cause erratic and slow emergence patterns, bending and twisting of leaves, multiple stems from an eye, and enlarged stems.

FACTORS THAT CAN MIMIC HERBICIDE INJURY:

- Environmental stress, nutritional imbalance, diseases, and genetics; drought stress can reduce plant growth; irregular soil moisture can result in cracked and deformed tubers; nutrient stress can cause leaf discolouration.
- High turgor pressure and rapid tuber growth can cause early cracking and larger cracks.
- Potato Virus Y can cause mosaic effects on leaves, wavy leaf margins and deformed tubers.

WHAT TO DO IF YOU SUSPECT HERBICIDE DAMAGE ON A LARGE SCALE?

- Document symptoms immediately because they may decrease over time.
- Sample multiple leaves and/or tubers, compare affected and non-affected, and sample multiple intensities of damage.
- Chain of custody is important if this becomes litigious.
- Clean and store samples properly and ship them to a laboratory.

HOW TO PREVENT HERBICIDE INJURY:

- Check previous use of potentially persistent herbicides or bioassay soil.
- Communicate and cooperate with neighbours.
- Follow tank cleanout instructions and have specific herbicide-only equipment.
- Train spray applicators to ensure spray drift does not occur.
- Keep herbicides separately from other pesticides.

SOURCES

Information for this article has been sourced from the webinar "Herbicide damage and weed management in potatoes" (Professor Andrew Robinson)

https://potatolink.com.au/resources/webinar-recording-herbicide-damage-and-weed-management-in-potatoes

POTATOLINK MAGAZINE

ATTENTION ALL POTATOLINK ENTHUSIASTS!

After eight issues of co-publication with *Potatoes Australia*, we're excited to announce that PotatoLink magazine is branching out as a stand-alone publication.

We will continue our commitment to delivering the latest in R&D extension, tech updates, and scientific explanations of all things spud-related.

To keep receiving a printed copy of PotatoLink magazine, please scan the QR code and subscribe today!

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Wondering when the next in-person event will be held in your area? Looking for a factsheet or an update on a demonstration site? Or want to join the next webinar?

For all this and more, subscribe to our monthly newsletter.

The PotatoLink Bulletin is a free e-newsletter emailed to subscribers each month and is brimming with information. The bulletin provides a platform for growers to stay up to date on upcoming events and resources delivered by PotatoLink or other industry groups and projects.

EACH ISSUE INCLUDES

- Upcoming events – webinars, regional in person events, online training and conferences
- New resources – PotatoLink magazine, factsheets and case studies
- Updates from our demonstration sites
- Event reviews for all those who missed out
- General info, project updates and more

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REGIONAL REP DISPATCH TASMANIA

We are excited to introduce our new magazine segment *Regional Rep Dispatch*.

Each issue we will provide a spotlight on what is happening in the main potato growing regions of Australia, including topics of interest, concerns, and events in different parts of the country. This new segment will be an excellent addition to the PotatoLink magazine and encourage our readers to stay tuned for future updates from our regional representatives.

Our first dispatch comes from Tim Walker in Tasmania.

EVENTS

Earlier in the year, over 40 Tasmanian growers and other industry members took the opportunity to join Professor Andy Robinson (North Dakota State University, US) and the PotatoLink team for a field walk in North Motton, Tasmania.

Topics included herbicide and weed management, and the similarities and differences of the American and Australian potato systems.

The event was a great opportunity for the industry to get out, meet, talk, and tour a fantastic potato crop.

Attendees at the field walk

LATE SEASON ISSUES

Weather: crops looking good, but will the yields be decent?

The weather in Tasmania has resulted in late plantings for much of the industry, which will result in difficulties obtaining yields similar to earlier plantings as sunlight becomes limited later in the year.

Oxalis weed: come clean, go clean.

Oxalis, a weed with a similar appearance to red clover, is becoming a problem on a few properties in Tasmania. If ignored, the problem can become severe and have an impact on yield and harvesting. Potato operations significantly spread the weed by disrupting and moving the bulbs.

Oxalis is easily spread and can quickly get out of control.

To bring some focus to this challenge and make farmers aware of the weed and the importance of quick action, PotatoLink held an event in late March in nearby Gawler. Topics included identification tips, management strategies, and the potential severity of the weed.

In the meantime:

- Consult your agronomist for control options and be aware of biosecurity on farm.
- Do not ignore the problem. Ensure biosecurity protocols are updated - the best way to manage Oxalis is to prevent it.

Early senescence: Leaf tip blackening?

Noticing some unusual leaf tip blackening and early senescence in potatoes, Tim sent away some samples for pathological analysis.

Results currently only show the normal pathology expected for dying potatoes, with no clear indicator of what could be causing the black leaf tips.

This raises a few questions, including whether the issue has environmental causes, and if interventions make sense in a cost/benefit analysis context.

EXPLORE FURTHER

AUSVEG has several biosecurity resources for potato growers
http://bitly.ws/BURT

Soilwealth factsheet on oxalis management
http://bitly.ws/BURW

For more information about PotatoLink activities in Tasmania contact Tim
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Photo by Jenny Ekman