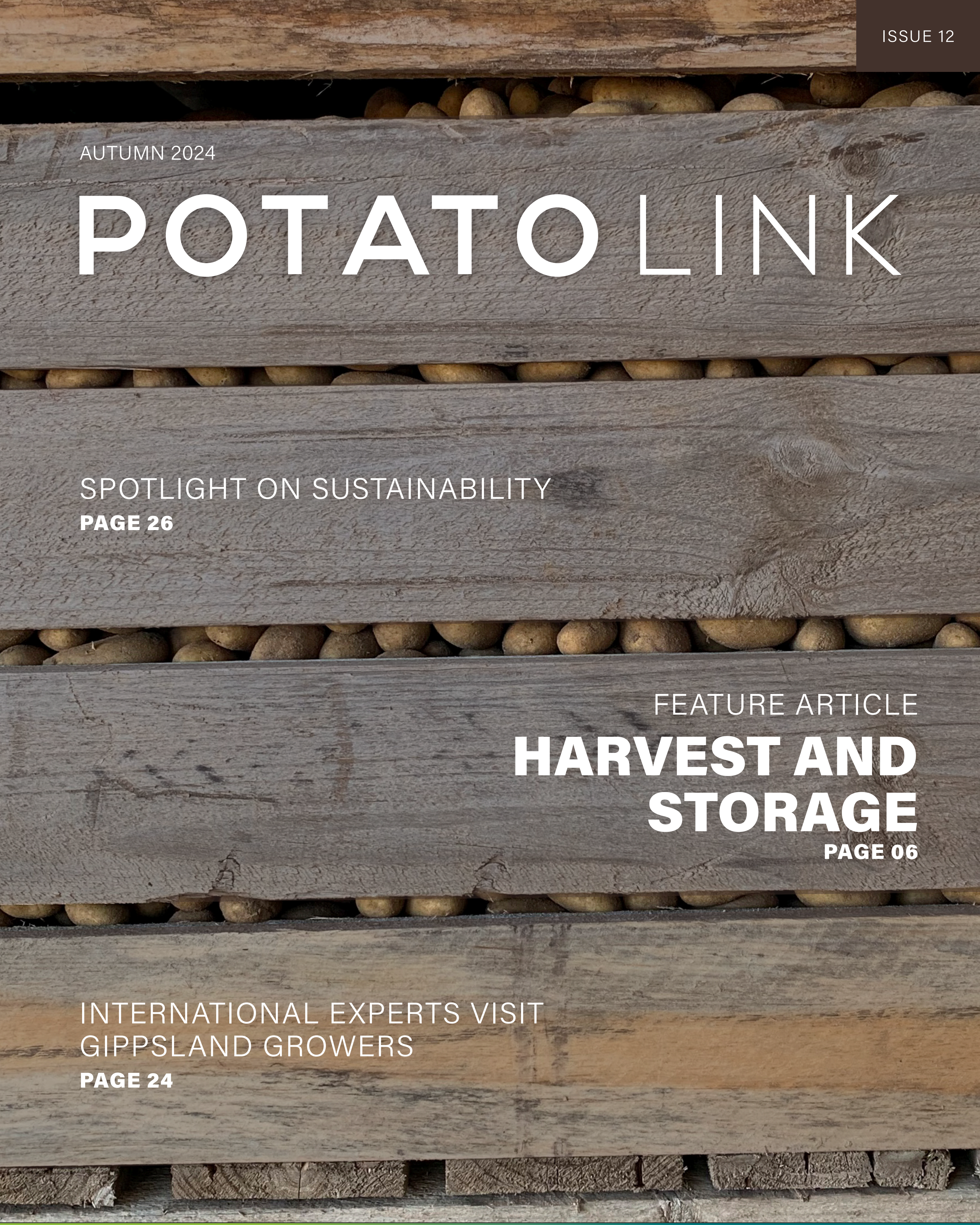
ISSUE 12



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AUSTRALIAN POTATO INDUSTRY EXTENSION PROJECT

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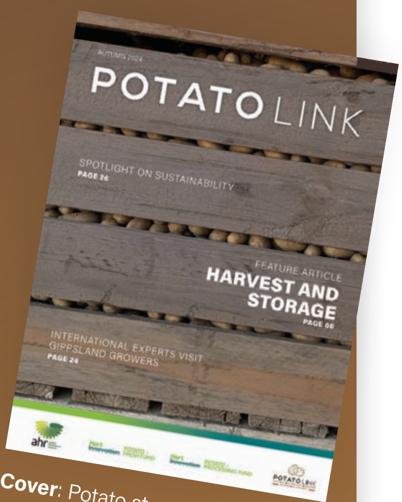

Cover: Potato storage, AHR archive

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FROM PETER O'BRIEN...

Welcome to the autumn issue of our publication.

We're delighted to present this collection of articles and features that we hope will engage and inform you on various aspects of potato growing.

PotatoLink postharvest expert, Dr Jenny Ekman, writes about the critical aspects of harvest and storage to ensure all the efforts of growing potatoes are not wasted.

In this issue, our new 'Spotlight on sustainability' section features just a few of the incredible efforts made to value add potato waste and we highlight the work of two agricultural engineers from Canada's Nova Scotia, who are working with industry to create innovative nutrient testing technology.

Our Assistant Editor, Ryan Hall, brings you highlights from the February PotatoLink event in Thorpdale, Victoria. For those who couldn't attend, his report will provide a glimpse into the proceedings and key takeaways.

We hope you enjoy diving into the diverse range of topics covered in this issue. Your feedback is always appreciated, so feel free to reach out with your thoughts and suggestions.

For those reading online, remember that getting a hard copy is easy. Just click the **link** to subscribe and have it delivered to your doorstep.

Happy reading!

Peter O'Brien, PotatoLink Project Coordinator

Send your feedback to info@potatolink.com.au

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HARVEST & STORAGE

POTATO HARVEST: WHERE YIELD GETS REAL

Harvest is where all the effort and expense that has gone into growing the crop finally comes to 'tuberition.' It is where money can be made or lost, and where the grower finally, conclusively, finds out what has been happening under their feet.

GROWING A GOOD CROP

A good harvest starts even before the potatoes are planted. This particularly means minimising the clods and rocks that can physically damage potatoes during harvesting, as well as acting as contaminants in the finished product.

Once the potatoes are growing, ensuring adequate nutrition and irrigation is an important part of preparing tubers for harvest day. For example, production factors that reduce the risk of bruising include:

- Moderate nitrogen fertiliser application (excessive nitrogen increases susceptibility to bruising, especially if applied late in the cropping cycle)
- Optimised levels of potassium
- High calcium – with a target of 250ppm tuber concentration
- Accurate irrigation, avoiding excessively wet or dry conditions

TERMINATING THE CROP

Vine kill is the first step in preparing the crop for harvest. It may occur when the crop is mature, or in response to market demand for a particular range of tuber sizes. Vine kill promotes tuber maturation and separation from the stolons, as well as removing plant material that would otherwise clog the harvester.

If vine kill is timed to meet market demand, growers may be tempted to allow the largest tubers to become oversize in the hope that more small tubers will reach the marketable range. However, larger tubers tend to be expanding faster than smaller ones, so this does not always work. Moreover, tubers can continue to expand slightly even after vine kill has occurred:

- If soil is dry, tubers are likely to only increase 1mm at most, regardless of kill method
- If soil is damp and vines are killed mechanically, tubers may increase by 1-2mm
- If soil is damp and vines are killed chemically, tubers may increase 2-3mm

Vine kill is usually conducted when the largest tubers from at least two-thirds of test digs have reached the maximum marketable size. Delaying further should only be considered if there is a good market for oversize tubers. To conduct test digs:

- Choose at least three locations within the crop, avoiding areas that look unusual or are growing poorly
- Conduct digs every 3–4 days once the largest tubers are within 10mm of maximum desired size
- Each dig should lift between 1-2m of the row (minimum three plants)
- Divide the tubers into appropriate size fractions and weigh each group to calculate percentage yield by size grade

Figure 1. Test digs should include at least three plants per location, and be repeated across the paddock.

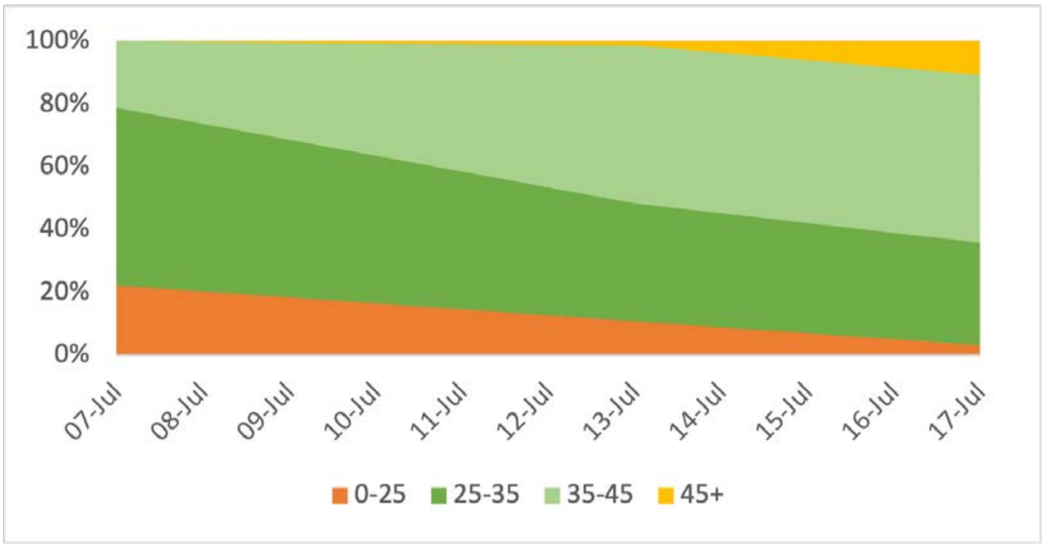


Figure 2. Example result from test digs for salad potatoes with a maximum marketable size of 45mm and optimum size grades of 25-35mm and 35-45mm. By 17 July, the crop was already passing optimum size. Data derived from summary by S. Wale, Teagasc.

Defoliation can be achieved using chemical, electrical or mechanical means.

Chemical

Chemical defoliants can provide a fast and efficient way to defoliate plants. Whatever product is used, it is essential to follow the label directions to avoid contaminating the tubers, soil or surrounding environment.

Diquat is commonly used for this purpose. Diquat acts by inhibiting photosynthesis. However, it is usually recommended to apply it under cloudy conditions, preferably later in the day. This is because the product works so fast when it is sunny that the plant tissue dies before the chemical can diffuse throughout the leaf.

One potential downside of rapid desiccation is the potential for vascular browning. To minimise risk, avoid applying defoliant when the soil is dry and plants are stressed.

For example, Syngenta recommends conducting a basic soil moisture test before application of diquat:

- Take a soil sample from the centre of the ridge (5cm below the deepest tuber)
- Gently squeeze into a ball
    - If it stays in a ball the soil is sufficiently moist
    - If it collapses the soil is too dry
- Repeat at several points across the paddock, particularly sampling in drier areas
- If the soil is too dry, delay application of diquat until after rain or irrigation

Figure 3. Terminated vines at the PotatoLink Ballarat demonstration site. April 2023.

As diquat is a contact herbicide, it is essential to use nozzles that provide good penetration into the crop canopy. Achieving good contact also means avoiding application if plants are dusty, as this forms a barrier on the leaves.

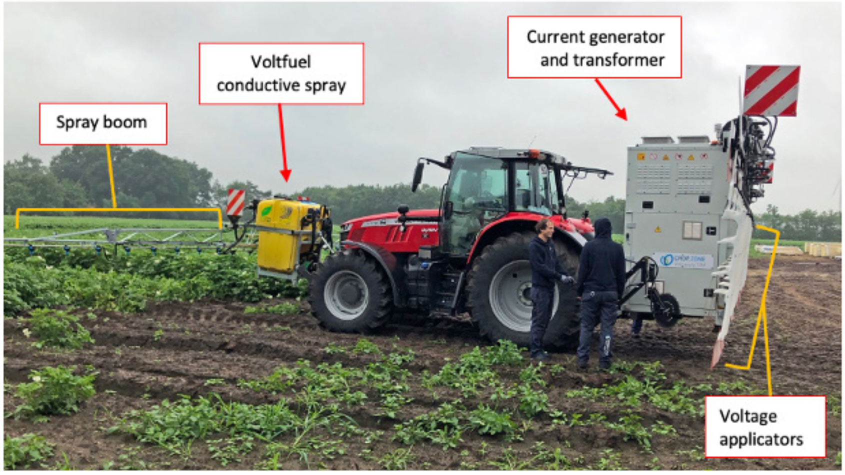
Although diquat is deactivated when bound to clay particles, it is highly residual in both soil and water. Regulation of diquat is increasing; it is no longer approved for use within the European Union, but is still registered in other countries including the USA and Australia.

Note that the herbicides Pyraflufen-ethyl and Carfentrazone-ethyl are used for crop-termination in Europe but are NOT registered for pre-harvest application to potatoes in Australia.

Whichever product is used, it is important to follow label rates. In some cases, a lower rate may be used first to remove the leaves. The second application then directly contacts the plant stems, optimising vine kill.

Electrical

The loss of chemicals in Europe has encouraged exploration of alternative crop termination methods. The CROP. ZONE system uses a combination of a conductive liquid and electrical current.



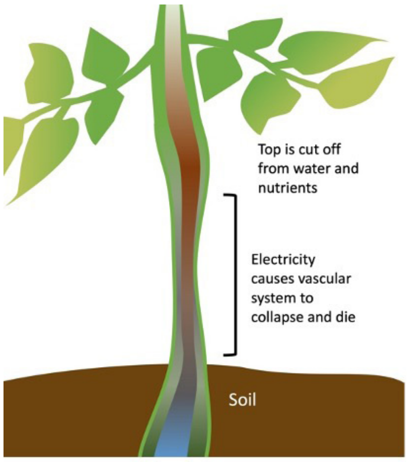


Figure 4. The CROP.ZONE system for vine termination combines an electrically conductive spray with voltage applicators, electrocuting the potato plants. This collapses the plant vascular system, starving the leaves of water and nutrients.

A 12m wide boom spray attached to the front of the tractor is used to apply "Volt.fuel" conductive liquid. This contains a spreader and dissolved solutes. The solution maximises electric conductivity between the applicator electrodes and the waxy, hairy, uneven surfaces of the plant leaves. Decreasing electrical resistance significantly reduces the voltage required.

Electricity is delivered using applicators attached to the rear of the tractor. This is most effective if the soil is relatively dry, as electricity will pass preferentially through the wet tissues of the plant vascular system. The current collapses the plant vascular bundles, stopping supply of water and nutrients to the plant leaves.

The system works best when applied to the crop twice in opposing directions. Unfortunately, the energy cost is estimated to be 5x higher than herbicides, and the 12m maximum boom width is likely to be limiting for larger growers. However, by reducing reliance on herbicides and avoiding impacts on soil biology, the system may meet sustainability objectives.

Mechanical

Mechanical methods of terminating the crop involve flailing and chopping. This may be combined with rolling to flatten the stems. Potential advantages of mechanical vine kill include speed and – possibly – a reduction in sprouting by remaining volunteer potatoes.

Speed can be important if growing seed or salad potatoes, where size specifications are relatively strict. Minimising the period between vine kill and harvest may also reduce incidence of black dot (*Colletotrichum coccodes*).

While chemical free, one key downside is the potential to spread disease. Mechanical methods break vines into tiny pieces. They then spread them around the paddock, along with any spores/oospores/bacteria that they might contain.

It is sometimes recommended to follow mechanical termination with application of a combined desiccant (e.g. diquat) plus a fungicide to prevent spread of diseases such as late blight. In this case, the cut stems should be left around 20cm long and the chemicals only applied once the leaf tissue has dried and exposed the cut stems (Wale, 2018).

Figure 5. This Grimme mechanical topper crushes and chops the plant haulm and deposits the trash in the interrow, leaving the plant stems exposed for further treatment. Image: R Halleron, Agriland.

SKIN SET

While tubers are still growing, their skins need to stay soft and flexible. Such soft skins are easily rubbed off (skinning) or wounded when handled.

Once tuber growth stops – whether naturally or at vine kill – the skin starts to harden and thicken. It also becomes more tightly attached to the flesh, protecting the underlying tissue. Good skin set is essential to reduce vulnerability to wounding and bruising, increasing storability of the tubers.

Complete skin set can take anywhere from one to four weeks, depending on variety and soil conditions. Skin set will take longer in cool, moist soil, yet still not achieve as good a result as that in warmer conditions. Also, if the crop is allowed to naturally senesce, the start (and finish) of skin set will vary between plants.

Potatoes that are to be processed immediately, or which are accessing a new market window, may sometimes be harvested before the skins set (green harvesting). Shelf life of such potatoes will be relatively short. For most end uses, it is important that harvest does not commence until the skins have properly set.

HARVEST

Once the skins have set, potatoes can be harvested. Avoiding damage during harvest is key to producing high quality potatoes with excellent potential storage life. Wounds and bruises inflicted during harvest detract from appearance, accelerate respiration and provide entry points for disease.

Factors that help reduce damage during harvest include:

Figure 6. Potato skins remain soft while growing, and are easily rubbed off if the tubers are harvested before the skins have hardened and set. Image: Arvalis JM Gravouille

Figure 7. Preparing the site well, and ensuring weather and soil conditions are right, will reduce the risk of damage occurring at harvest.

- The field is free of clods and rocks
- The crop has grown evenly throughout the paddock
- The soil is moist and tubers are normally hydrated
- Soil temperature is 12 – 18°C; soil temperatures below 5°C or above 25°C increase risk of bruising
- Tubers have lower dry matter, with small starch granules

The way the harvesting machine is operated will also have a major impact. The speed at which the harvester moves through the paddock needs to be adjusted according to crop yield and soil type.

Driving the harvester too slowly allows tubers to pile up, be caught by the haulm roller and pushed against the sides. Conversely, driving the harvester too fast means tubers roll and bounce around.

- Ensure the digging blade is angled correctly, so that tubers travel smoothly from the blade onto the primary conveyor
- Adjust drive speed so that the web is around 85% full
- Adjust web speed so that soil goes right to the top
- Use the minimum shaking and agitation needed to separate tubers from clods and soil
- Minimise drops and/or provide padding to reduce damage; potatoes should not drop more than 30cm when transferring between conveyors or from the boom conveyor to the bin, trailer or truck

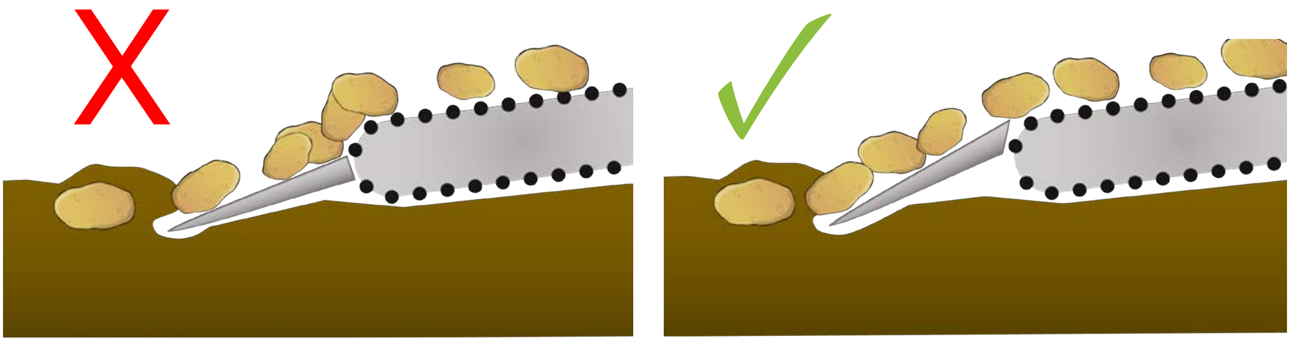


Figure 8. Ensure that the digger blade does not jam tubers into the primary conveyor, but delivers them smoothly onto the top of the chain.

BRUISING

Bruising can be roughly divided into two types - shatter bruises and blackspot. Shatter bruises are obvious. Damage is visible as cracks that can extend to the core of the tuber. These provide an easy entry point for rots and are visually unattractive. In contrast, blackspot bruises are internal, so more difficult to detect.

Potato skin is constructed from relatively small, corky cells that are good at resisting damage, so long as the skin has properly hardened off before harvest. However, the swollen, starch-laden cells that make up the underlying flesh are more fragile. Impacts can fracture the internal membranes of these cells, allowing the polyphenols (tyrosine) and enzymes (polyphenol oxidases) that are normally held separately inside the cells to mix.

The reaction between these compounds leads to the formation of melanin, the brown to black compound that makes bruises visible. The intensity of the colour that develops is directly related to the amount of substrate that is present. As the reaction is not instantaneous, bruises or 'blackspots' develop over at least 24 to 48 hours.

Bruise development is strongly variety dependant, with some varieties bruising more easily than others. Bruising is also more severe at low temperatures than warmer ones.

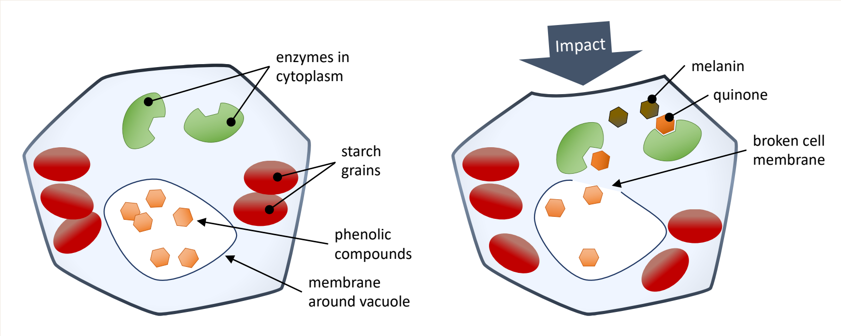


Figure 6. Intact potato cells (left) contain phenolic compounds and oxidising enzymes, kept separate by internal cell membranes. Impacts (right) can rupture this internal membrane, allowing mixing. Oxidation eventually gives rise to the dark compound melanin, visible as 'blackspot.'

For example, Dawson and Johnstone (2016) found that >50% of Nadine potatoes were bruised by a 50cm drop at 10°C, whereas drops less than 60cm did not cause any damage when the temperature was increased to 15°C. Moreover, while a drop of 80cm damaged virtually all Nadine potatoes (regardless of temperature), Ruby Lou was less susceptible. Approximately 20%/40% of Ruby Lou at 15°C/10°C were damaged by the same impact.

Impact recorders, such as the 'Smart Spud' or Techmark IRD (Impact Recording Device), can be used to identify points during harvesting with consistently high impacts. The device can be run again, after making changes, to confirm that impact intensity has been reduced. In the case of the IRD, the software includes a potato "damage boundary"; forces greater than this can potentially cause blackspot.

Figure 10. Impact recorders can be used to identify points on the harvester where consistently high impacts occur, then test ways to reduce these impacts.
Image: P. Morris, Techmark

EXPLORE THE TOPIC FURTHER BY CLICKING THE TITLE BELOW

FACTSHEET: Potato bruising and management

WEBINAR: Harvesting: Bruise prevention and grading

STORING SPUDS

Once the stress of harvest is over, potatoes need to be cured and cooled, especially if they are to be stored for any length of time.

WOUND HEALING (CURING)

While it is clearly better to avoid wounding potatoes in the first place, to some extent potatoes can heal or 'cure' themselves postharvest. Facilitating this natural process is critical if they are to be stored for any length of time.

The rate of curing is affected by temperature and relative humidity. Wounds heal faster above 15°C. However, warm temperatures increase the risk of storage rots, as well as increasing respiration rate and, therefore, internal temperatures.

Conversely, wound healing is very slow at temperatures below 10°C. While such low temperatures reduce the risk from diseases such as pink rot (*Phytophthora erythroseptica*) and watery leak rot (*Pythium* spp.), the slow rate of healing that results can allow other, opportunistic pathogens to take hold.

The optimal conditions for curing are therefore 5 to 10 days at 10 to 15°C.

Ideally, relative humidity (RH) should be kept at 85 to 90% during curing. If RH is over 90%, even small temperature changes are likely to result in condensation. Condensation restricts respiration by the healing tissues and increases infection risk. Maintaining good air movement is the best way of reducing the risk of condensation, especially if cool air is actively pulled through bins of potatoes; as air warms as it flows through the bins, rather than cools, no condensation will occur.

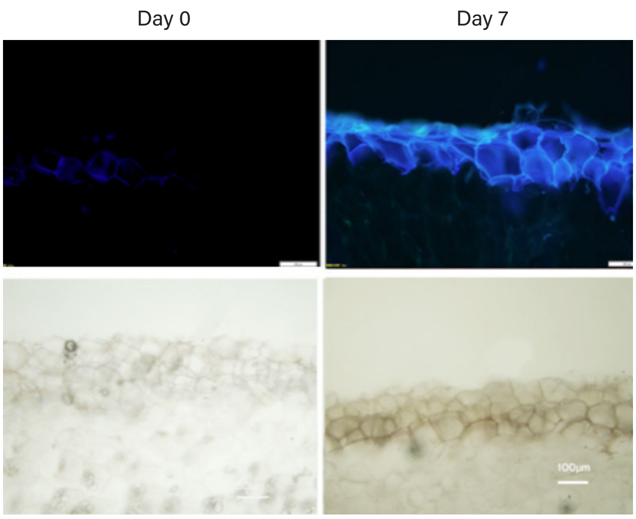


Figure 11. Cross section of freshly cut potato (left) and after 7 days curing (right). Top images use fluorescence to detect suberin; bottom images show lignification of cell walls. Image: Zhu et al., 2023.

Table 1.
Effect of temperature on wound healing. From Cunnington, 2019, ADHB Store Managers guide

Tuber temperature °C)	Initial suberisation (Days)	Suberisation complete (Days)
<5°C	7 to 14	21 to 42
10°C	4	7 to 14
20°C	1 to 2	3 to 6

The curing strategy will need to be adjusted if freshly harvested potatoes are wet. To reduce risk of rots, ventilation should be increased and relative humidity reduced, at least until the potatoes are dry.

While curing is an important step towards maintaining potato quality in storage, it should not be extended past what is needed. Curing is conducted at relatively high temperatures, so will accelerate ageing processes.

RESPIRATION

Stored potato tubers are **alive!** They can develop sprouts, produce chlorophyll, lose or absorb moisture, and continue to mature. All of this metabolic activity is fuelled by respiration.

Respiration breaks down stored carbohydrate reserves, consuming oxygen and releasing carbon dioxide, water and energy. While most energy is used by the cells, some is also lost as heat.

High respiration rates are associated with shortened storage life for many products. Moreover, as respiration produces heat and heat promotes respiration, a 'heat snowball' can develop, especially in poorly ventilated areas of the store.

Perhaps most importantly, high respiration increases the risk of high CO_2 building up in the storage environment. Ventilation rates need to match CO_2 production to avoid this occurring.

Effects of temperature

Respiration rates of potatoes are generally minimised between 3 and 8°C, and may show limited variation within this range. However,

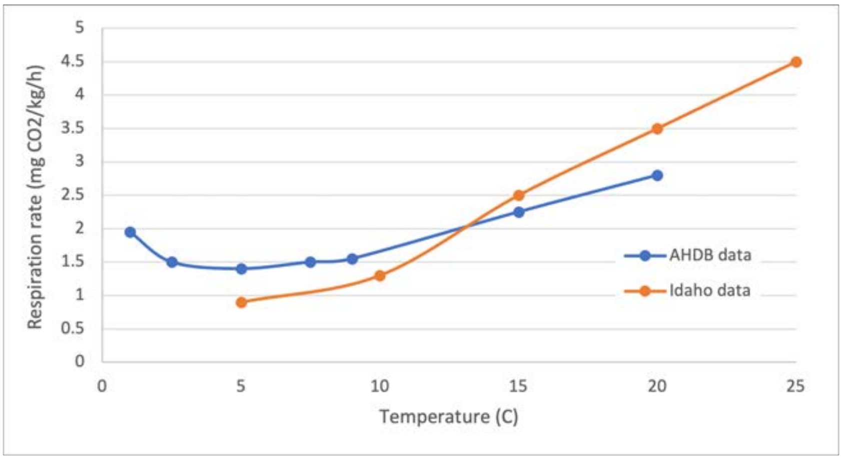


Figure 12. Effect of temperature on respiration rate of potatoes. Data derived from AHDB 2017 (average of five varieties including Russet Burbank and Maris Piper) and University of Idaho Extension 2024 (cv. Clearwater Russet).

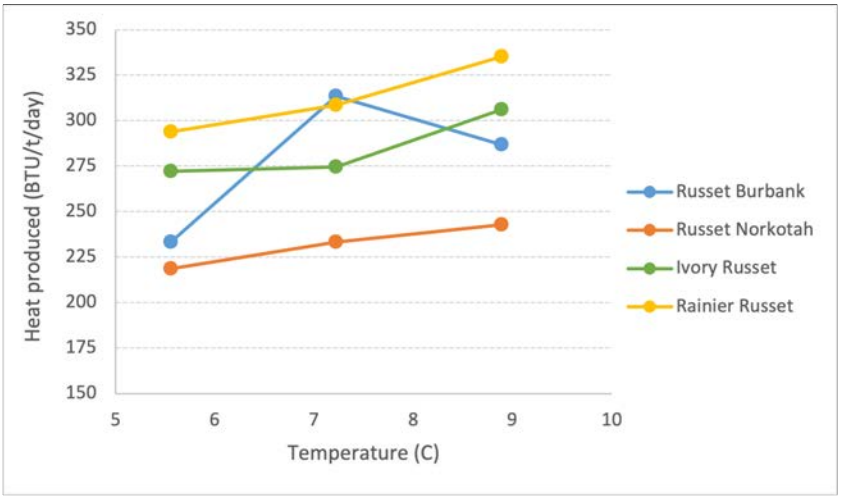


Figure 13. Average vital heat (BTU/t/day) generated by Russet potato cultivars treated with CIPC and stored for eight months at 5.6 to 8.9°C. Data derived from University of Idaho Extension (2024).

Figure 14. Blackheart can occur if internal tissues are starved of oxygen. Image: E. Banks, Ontario Potato Board.

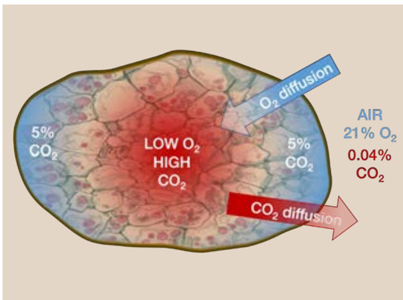


Figure 15. Limited gas diffusion between the external air and internal spaces inside potato tuber flesh means that significant gradients in CO_2 and O_2 are likely to occur, especially if respiration rate is high. For example, at 20°C the flesh immediately under the skin can contain 4 to 6% CO_2. The core may be even higher.

temperatures below 3°C can actually increase respiration rate – an indication that the potato is under stress (Figure 11). Temperatures higher than 10°C are associated with much higher respiration rates, doubling then tripling as potatoes approach ambient temperatures (20 to 25°C).

Respiration rate can vary between cultivars, by maturity at harvest, and with time in storage. After an initial decline, respiration generally remains fairly stable over several months of storage. They then tend to trend upwards as potatoes start to deteriorate. Rising respiration rates can sometimes be the first sign that stored products are starting to break down. For example, marked increases were commonly observed as potatoes kept at 15 or 20°C approached the end of storage life (AHDB, 2017). Damage (e.g. bruising) and sprouting also stimulate respiration.

Energy use in storage

The importance of respiration lies not just on its effects on ageing, but also its impact on the energy required to keep the storage room cool. According to the University of Idaho, a respiration rate of 1mg CO_2/kg/hour produces approximately 61.2 kcal/t/day energy, or 243 BTU/t/day heat.

This suggests that an increase in respiration rate from 1.0 to 1.5mg CO_2/kg/hour will increase the heat load on the cooling system to 364 BTU/t/day. This research also indicates that differences in respiration rates between varieties can change energy costs by 35% or more (Figure 13).

Cooling is essentially value adding with electricity. Although it may require more energy initially to cool potatoes below 7°C, this may be offset against lower energy costs once potatoes are cold. If potatoes warm back up, the value added is lost.

Ventilation

Preventing build-up of CO_2 is essential, especially during early storage.

One reason is that high CO_2 can stimulate production of ethylene. Both ethylene and CO_2 increase breakdown of starch into sugar thereby causing fry darkening and off flavours. High CO_2 can also result in 'blackheart', where the internal tissues blacken and die due to oxygen starvation

Potatoes are extremely susceptible to CO_2 damage because their dense structure limits gas diffusion into the internal flesh. This means there can be significant gradients between the inside and outside of tubers. For example, at 20°C, the outer tuber flesh of 'King Edward' potatoes contained 4 to 6% CO_2, compared to 0.04% in the ambient air (Banks and Kays, 1988). Accumulation of CO_2 is likely to be even greater at the tuber core, where the cells are most tightly packed (Gancarz and Konstankiewicz, 2007).

The threshold external CO_2 level that can cause damage varies between 1,200 to 5,000ppm (0.12 to 0.5%), and is likely to be affected by both respiration rate and tuber flesh density.

Increasing ventilation rates not only increases energy costs, but also, potentially, moisture loss and risk of condensation.

To minimise negative impacts of respiration:

- Harvest potatoes when mature; immature potatoes tend to have higher respiration rates
- Harvest when soil is cool to reduce cooling requirements
- Minimise harvest injuries
- Stimulate curing by keeping potatoes at 10 to 15°C after harvest
- Adjust ventilation rates so as to remove CO_2 generated by respiration;
  - » ventilation rates may be reduced as the potatoes cool to holding levels
  - » ventilation needs to increase if seed potatoes are warmed before unloading from storage

TEMPERATURE AND COOLING

Temperature is an extremely important factor in quality and storage life of potatoes. It is critical to ageing of stored seed, affects disease progression, and is key to sugar accumulation, sprouting and weight loss in ware and processing potatoes.

Once curing is complete, potatoes should be cooled as soon as possible. However, the ideal cooling method and storage temperature will vary with both cultivar and end purpose. It is critically important to avoid condensation on stored potatoes. This is very likely if bins of warm potatoes are simply placed directly into a cold room.

Cooling methods

One option to prevent condensation is to use positive pressure (forced air) to cool potatoes. Such systems use a powerful suction fan mounted into a plenum to pull cold room air through loaded bins or crates. Air is forced past individual potatoes, cooling the tubers much faster than passive room cooling. The air warms slightly as it moves through the product, so no condensation occurs.

Forced air systems are widely used for other horticultural products. Faster cooling rates mean that both total energy use and moisture lost by the product may be reduced.

Although not generally used for potatoes, forced air cooling should be considered if potatoes are harvested warm (>18°C) and/or wet. In this case, rapid removal of field heat is priority. Loading warm potatoes directly into trucks or shipping containers can easily end in disaster, with self-heating and disease rapidly destroying product quality.

The alternative to pressure cooling is to cool potatoes slowly, dropping the temperature gradually. The cold room air is set only 1°C to 4°C below the flesh temperature of the tubers, ensuring that dewpoint is not exceeded. This has long been standard practice for seed, processing and ware potatoes, with temperature reduced by 2 to 3°C weekly (approx. 0.5°C/day) until the potatoes reach the target temperature.

Effective storage

Maintaining good air movement around the bins or through a bulk load is essential during cooling, but remains important even once products have reached their ideal storage temperature. Well-designed stores have uniform airflow under normal operating conditions, preventing warm or cold spots developing. This may be achieved by adding air ducts or lateral outlets across the store.

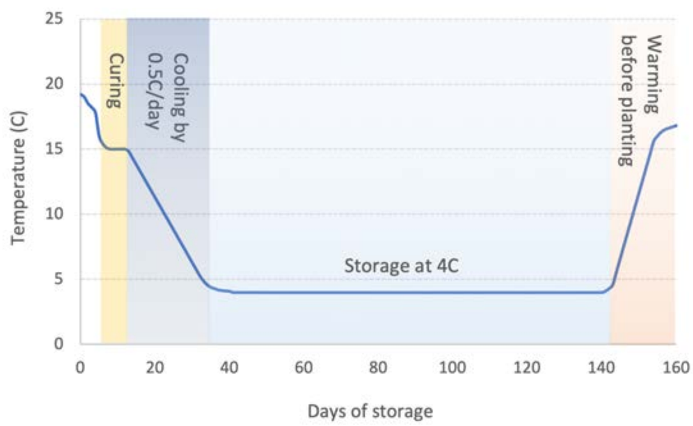


Figure 16. Recommended temperatures for seed potato curing, cooling and storage

A good store also needs to keep temperature stable, RH high, and include monitoring systems that can alert the grower if anything goes wrong.

In Australia's climate, getting the best possible insulation is a wise investment. Insulation works by trapping air in between layers of waterproof outer skin. Air is a poor conductor of heat – that's why puffer jackets are so warm! In contrast, water conducts heat very well. If insulation materials become wet, they will be ineffective.

Keeping floors, doors and walls properly sealed against moisture is an investment in infrastructure that will save energy costs and reduce internal temperature gradients.

- Always repair damage from forklifts or bins
- Check that door rubbers seal thoroughly
- Ensure seals between cold room panels are intact
- Keep the floor dry and sealed against moisture

Commercial systems are available which are designed specifically for storing potatoes. The Tolsma system (p17) is one example. A key benefit of using this technology is the timed ventilation that takes advantage of cool overnight air, providing energy efficiencies. Air refreshment can also be made through the 'Fresh Box', which pre-cools air in a heat recovery unit before using it to vent the room. This reduces CO_2 concentration without increasing room temperature. Automated temperature, atmosphere and humidity controls can be checked remotely, while a check-weigh system can be added to monitor weight loss in stored tubers.

All well designed rooms will provide good air movement, whether delivered above stacks of bins or through ducting on the floor of bulk stores. Air movement can be further improved by:

- Leaving gaps that allow the cool room air to circulate between stacks of bins
- Leaving gaps between bins and the cool room walls and ceiling
- Aligning pallet skids to airflow
- Ensuring the air intakes and cold air delivery system have clear space around them

Airflow can be checked using a hand-held anemometer. This is also a useful way to check that cold air is reaching all parts of the cold room. Adding flexible ducting or diffusers can help if airflow is limited.

Air temperature should be monitored at both the coldest and warmest parts of the room. However, it is the temperature of the potatoes, not the air, which is most important. Periodically checking the potato flesh temperature is an excellent way to double check the room is running well. Even simple, inexpensive temperature probes (such as those sold as kitchenware) can provide a reasonable result, especially if their calibration is checked (see breakout box below).

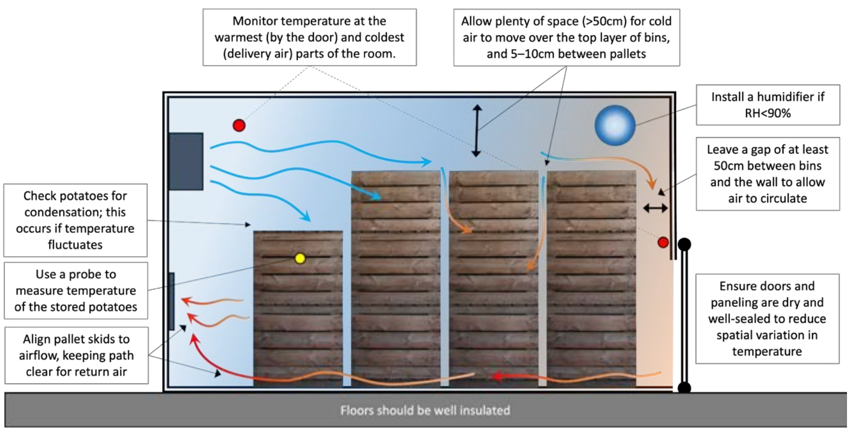


Figure 17. Cold storage rooms should be designed to allow cold air to circulate freely around the bins. For example, lleave gaps between stacks and around walls and consider how much air is reaching the far corners of the room. Monitor air temperature and humidity as well as checking flesh temperature of stored tubers.

PROBE CALIBRATION

The calibration of temperature probes can be readily checked using melting ice.

- Obtain some crushed ice or place ice cubes inside a double ziplock bag and smash with a hammer
- Place crushed ice in an insulated flask (e.g. a thermos, or double insulated container) with just enough water to cover
- Stir the water-ice slurry and allow to equilibrate for a few minutes
- Insert the probe into the slurry and stir gently
- Wait until the reading stabilises;
  - If it is 0°C, your probe is correctly calibrated
  - If it varies from 0°C then this figure needs to be added/subtracted
  - Record the correction (if any) and calibration date and sticker onto the probe for future reference

Typical temperatures used for long term storage are:

Use	Optimum storage temperature
Seed	3.5 – 4.5
Fresh market	3.5 – 7
Processed – Frying	7 – 10
Processed – Crisping	7 – 13

Cold temperatures and undesirable sweetening

Optimum storage temperatures vary between varieties. However, most varieties can suffer chilling injury if stored below 3°C.

Chilling damage does not cause obvious external symptoms, but the flesh can develop grey, discoloured areas that become more noticeable after cooking. Exposure to low temperatures can also reduce sprouting, making it particularly important to avoid temperatures below 3°C when storing seed.

Perhaps the most important impact of chilling temperatures is low temperature sweetening. This occurs due to conversion of starch into sucrose. As little as three days at 2°C can trigger significant accumulation of sucrose in some varieties. Some of this is further converted into the sugars glucose and fructose.

High levels of sugars result in undesirable browning when potatoes are roasted or fried. Not only do these compounds look unappealing and have a bitter taste, they include the probable carcinogen acrylamide.

Low temperature sweetening is due to a combination of both time and temperature. Risk differs greatly between varieties. For example, Figure 16, shows the difference in crisp colour of a variety highly sensitive to low temperature sweetening (Karaka) and one that is resistant (1021/1) after different storage periods.

In general, potatoes are most susceptible during the first two

Figure 18. Colour of crisps prepared from cold sensitive (Karaka) and resistant (1021/1) potato varieties processed immediately after harvest, following storage at 6°C for 1 or 4 months and following storage plus reconditioning for 10 days at 18°C. Image: Datir, 2011.

COOLING POTATOES

Some industry members have suggested that seed potatoes should be cooled slowly so as to avoid cold 'shock'. However, there is little evidence for this in published literature.

The PotatoLink team is therefore conducting a small trial growing seed potatoes (cvs Crop 77 and SIFRA) which were cooled fast or slow then stored for over six months in facilities with different levels of environmental control:

1. **Cooled rapidly** (approx. 1 hour) one week after harvest, minimal temperature fluctuations during storage at 4°C
2. **Cooled slowly** four weeks after harvest, with temperature reduced to 3.5°C over a two-week period, occasional temperature fluctuations during storage to maximum 5°C
3. **Cooled rapidly** (approx. 1 hour) three weeks after harvest, stored in a cool room fluctuating daily between 2°C and 5°C

An initial assessment of stem number and plant height was conducted four weeks after planting. While extremely preliminary, there was a trend to slightly taller plants with more stems when grown from Treatment 1 seed. Crop 77 plants grown from Treatment 3 seed were smaller and had fewer stems than those from other treatments, but the same difference was not found for SIFRA.

Full results and description of this trial will be included in PotatoLink winter edition.

Figure 19. Crop 77 (left) and SIFRA (right) plants grown from seed stored under three different protocols (1 to 3, as described above), pictured four weeks after planting

months after harvest. Sensitivity can be reduced by harvesting potatoes at correct maturity (not immature or overmature) and through stepped cooling – where the temperature is gradually reduced.

Sweetening can be reversed to some extent through post-storage conditioning at 16 to 20°C. By increasing respiration rate, easily accessed sugars are metabolised and reconverted into starch. The process generally takes around three to four weeks.

It is important to monitor sugar levels and processing colour frequently during this time, so as not to over-condition and reduce quality. For example, reconditioning can promote sprouting and disease development. Moreover, post-storage conditioning does not always work. Reversing low temperature sweetening is most difficult if tubers have been stressed in the field.

Long term storage at temperatures above 10°C can also trigger sweetening. In this case, accumulation of sugars is due to ageing. This type of sweetening cannot be reversed.

Irreversible sweetening was also thought to occur in response to high levels of CO_2. However, recent research has found no relationship between storage atmosphere and fry colour.

In ground storage

In Australia, particularly South Australia, ground storage is a common practice for managing year-round supply for the fresh market and extending the supply period for processors.

If storage time is less than four months, and temperatures are cool, ground storage can achieve similar, or even better, outcomes than harvesting then storing in cold rooms. Ground stored potatoes have undergone skin set without the skin damage and wounding that is virtually inevitable during harvest. In the case of fresh market potatoes, skin finish may actually be better when potatoes

COOLING AND VENTILATION SYSTEMS

Sophisticated and specialised systems can help take the guess work out of potato storage. Tolsma sells a number of systems designed to cure, cool and store potatoes. The drying wall shown below (Figure 20, left) is designed to dry and control the temperature of freshly harvested/cut seed potatoes. Once cured, potatoes are stored in the open space ventilation and cooling system (Figure 20, right). The unit blows cool air over stored potatoes, sucking it back through the bins in the air return. An inlet hatch within the unit opens to draw in outside air for cooling, drying and to vent CO_2 as needed. Outlet hatches equalise pressure when outside air is drawn in.

Sensors measure potato pulp temperature and weight loss as well as temperature and relative humidity inside and outside the store. The temperature and absolute moisture differential between outside and inside air is calculated to determine whether outside air is suitable for cooling and/or drying.

Figure 20. The Tolsma drying wall for curing freshly harvested/cut seed potatoes (left) and the Tolsma open space ventilation and cooling system (right). Images supplied by Tolsma.

have been ground stored instead of harvested and cold stored.

Depending on the dormancy characteristics of the variety, an in-crop application of a registered plant growth regulator (e.g. maleic hydrazide) may be needed to control sprouting. Timing is important, as early application can reduce yield whereas late spraying can be ineffective. Such products should always be applied according to label directions.

To be effective, ground storage also needs the right paddock conditions. Soil needs to be kept moist, but not wet, to stop tubers dehydrating. Regular, light irrigation can help reduce soil temperature during hot periods, maintaining more even conditions. This is because dry soils heat and cool easily, whereas moist soil is more stable.

Keeping soil moist also reduces the risk of wind eroding the hills. Erosion is more likely to become a problem as the vines die off and degrade. However, keeping the hills intact is essential to prevent tubers being exposed to the sun and, therefore, greening. Erosion and soil cracking also increase the risk from potato tuber moth. Caterpillars from eggs laid on dead haulms will crawl through soil cracks and burrow into the tubers below.

Once the vines are dead, weed seeds can germinate and grow in the moist soil. This can pose problems at harvest if not controlled early or managed. However, weeds do help protect the hills from erosion.

While it is important soil does not dry out, it is also important that soil does not stay wet. Wet or waterlogged conditions interfere with skin set, even if it has already occurred. Lenticels become swollen and risks from soil-borne diseases such as pink rot and bacterial rots massively increase.

Even under ideal conditions, ground storage can increase the risk of soil-borne diseases such as black dot, silver scurf and black scurf. Fresh market potatoes should not be ground stored in paddocks where there is high risk from these diseases.

Look out for more on anti-sprout agents in future editions of PotatoLink.

ACKNOWLEDGEMENTS

Much of the information presented here was sourced from the 2022 Australian Potato Growers Manual, specifically:

Chapter 4 – Harvest, by N Crump and N Malseed) and

Chapter 5 – Storage, by M Rettke and J Ekman

Hort Innovation project PT19003.

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Figure 20. Harvesting ground stored potatoes

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STORAGE DISEASES

When the potatoes have been harvested, graded and put into storage a great weight has been lifted. The spuds aren't going to be stuck in the ground due to late season rain. Grubs and bugs aren't going to start affecting the tubers, and it looks like most of the disease issues have been avoided. They're safe. Except there is another consideration, and that is storage diseases.

Most postharvest pathogens are weak organisms, incapable of penetrating a tuber's skin directly. Instead, they rely on wounds as entry points, especially in moist conditions, for example, condensation.

Decreasing the temperature of stored potatoes diminishes the risk. Typically, the colder the storage temperature, the slower the pathogen's growth. However, the temperature needed to completely halt pathogen growth is often lower than what's ideal for other quality parameters. Development of many of the diseases listed here virtually stops below 4.4°C, however temperatures this low may not be practical or advisable.

Lowering humidity levels also helps reduce the risk of disease, but can cause dehydration.

EXPLORE THE TOPIC FURTHER BY CLICKING THE TITLE BELOW

FACTSHEET: Pink rot

FACTSHEET: Black dot

WEBINAR: Dry rot

Australian Potato Growers Manual

SOURCES

- The Australian Potato Grower's Manual (2022)

SOFT ROT

(Pectobacterium spp., Dickeya spp.)

Soft rot bacteria can survive long periods in soil or on tubers without causing disease. However, periods of extended wetness can allow the bacteria to rapidly multiply and spread in the bacterial ooze created.

If rotten tubers are found at harvest, you should dry all other tubers as soon as possible to reduce further losses.

Temperatures below 10°C reduce the activity of soft rot bacteria, while spread virtually stops below 4.4°C.

Conversely, storage temperatures above 16°C and/or low oxygen levels will promote bacterial growth. The progression of soft rots can become extremely rapid as the temperature increases.

PINK ROT

(Phytophthora erythroseptica or P. cryptogea)

Storage temperature is critical to managing pink rot, with growth inhibited below 10°C. Temperatures below 5°C will inhibit the proliferation of pink rot. Depending how prevalent the disease is within the stored tubers, additional drying through ventilation with reduced humidity air may also be beneficial.

GANGRENE

(Phoma exigua var. foveata)

Gangrene primarily infects potato tubers through wounds. Fast and effective wound healing will limit its onset. Susceptibility increases during storage and the pathogen can continue to grow even at low temperatures. Keeping temperatures as low as possible in long-term storage will help slow the development and spread of gangrene.

BLACK DOT

(Colletotrichum coccodes)

Black dot infection occurs in the field. Infection can occur through the soil or when spores are washed off infected haulms onto the tubers below by irrigation or rain. Tuber symptoms reduce the marketability of washed potatoes grown for the fresh market.

The development of black dot symptoms on the skin of tubers is promoted by harvesting during hot conditions (>25°C). Rapidly cooling the harvested crop to 3.5°C or below will help to minimise disease severity. The severity of black dot symptoms increases at the temperatures used for skin curing (typically 10 to 15°C).

SILVER SCURF

(Helminthosporium solani)

Initial infection by silver scurf mainly occurs in the field. Moisture on the potato surface, caused by fluctuating temperatures and high relative humidity, allows spores to germinate and infect other tubers in storage. This makes avoiding condensation in storage critical.

Tubers should be stored at the lowest temperature possible, depending on market requirements. Maintaining lower humidity (<90%) will help control the spread of silver scurf by preventing spores from forming on any infected tubers.

PYTHIUM LEAK OR LEAK ROT

(Pythium spp.)

Pythium spp. mainly infects tubers through wounds caused during harvest. Rots then develop during storage, especially if the potatoes are wet due to condensation. As with pink rot, additional drying through ventilation with reduced humidity air may be beneficial if infection rates are low.

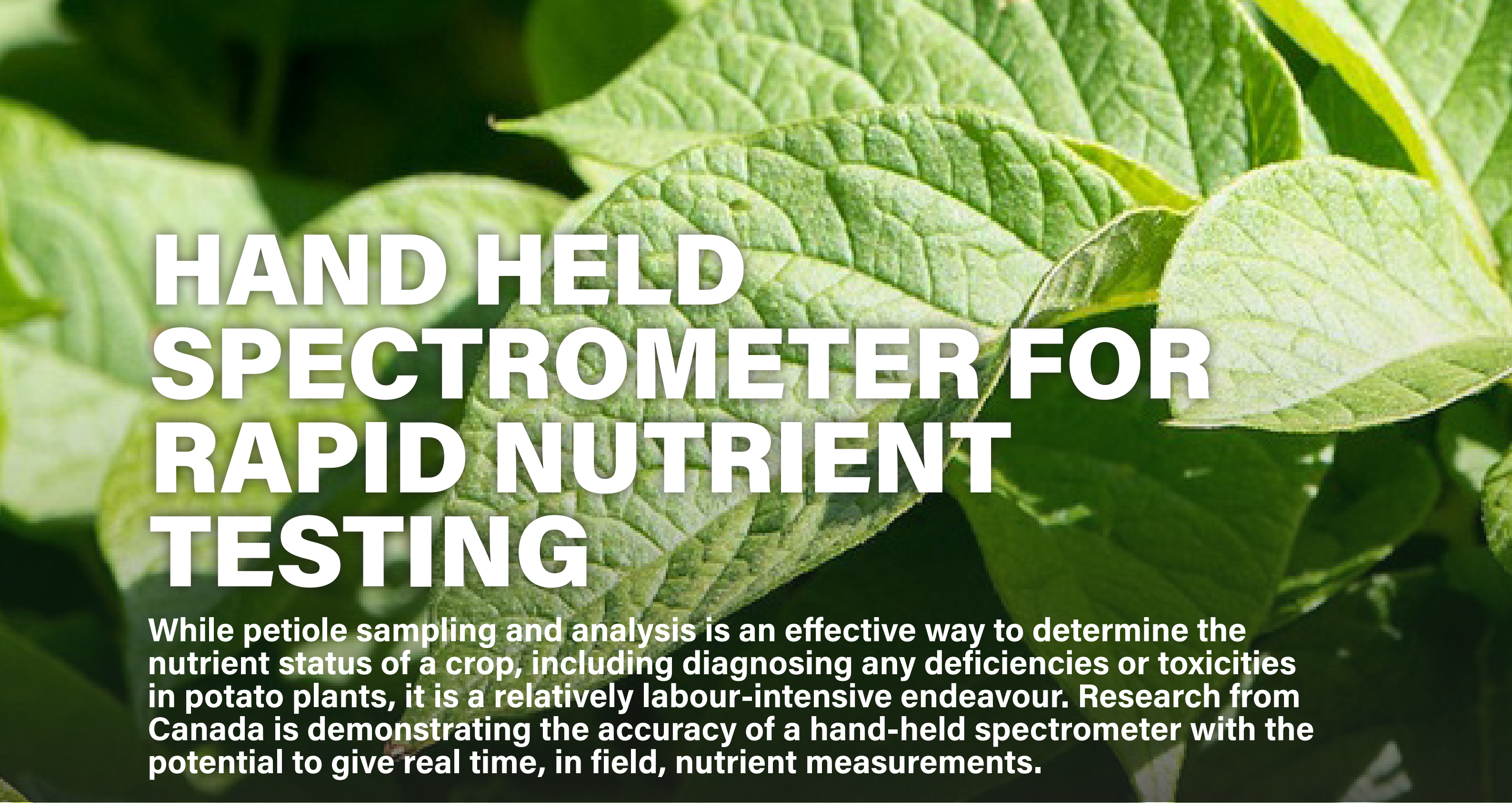
Temperatures below 5°C will inhibit development of leak rot. In contrast, storage at 16°C, or under warmer ambient conditions, will greatly increase progression.

FUSARIUM DRY ROT

(Fusarium spp.)

Fusarium infection usually occurs through wounds and the rot then expands within the tuber flesh. Susceptibility increases during storage.

If dry rot has been identified as a problem for a crop going into storage, fast and effective wound healing is required to limit onset. Storage temperatures below 8°C reduce disease progression while temperatures below 5°C greatly inhibit growth of this pathogen.



HAND HELD SPECTROMETER FOR RAPID NUTRIENT TESTING

While petiole sampling and analysis is an effective way to determine the nutrient status of a crop, including diagnosing any deficiencies or toxicities in potato plants, it is a relatively labour-intensive endeavour. Research from Canada is demonstrating the accuracy of a hand-held spectrometer with the potential to give real time, in field, nutrient measurements.

Regular petiole testing can assess the adequacy of fertiliser programs, diagnose deficiency or toxicity symptoms, and optimise fertiliser inputs. However, the process is time consuming, demands meticulous care and attention to detail, and results often take several days for analysis.

Compounding the issue is the sheer volume of petioles required for adequate sampling, often necessitating the collection of 40 to 50 specimens per sample for comprehensive laboratory analysis.

Standing hours in the field and searching for that all important fourth leaf may soon be a thing of the past, thanks to some new innovative technologies. Portable spectrophotometers and machine-learning algorithms are revolutionising real-time nutrient assessment in the field.

This new system enables rapid determination of petiole nutrient values, facilitating timely decision making for farmers. By leveraging historical data, these techniques offer the same valuable insights into nutrient status of a plant at a given time, without the laborious task of collecting and shipping samples.

Agricultural engineers, Associate Professor Ahmad Al-Mallahi and Reem Abukmeil (PhD candidate) from Dalhousie University in Canada, are pioneering efforts to redefine the relationship between spectral measurements and nutrient concentration. Their aim is to refine models to ensure the real-time nutrient measurements based on near-infrared spectroscopy (NIRS) are accurate.

THE CHALLENGE

The existing body of research has delved into various methods of assessing plant properties, including the use of ground-based and remote sensors. Ground-based sensors, employing vegetation indices, aim to estimate plant properties, while remote sensors detect stressed plants through electromagnetic wave reflectance data, such as the leaf area index (LAI). However, limitations persist with both sensor types, notably related to canopy reflectance issues caused by atmospheric and soil interference.

To mitigate these challenges, several studies have shifted their focus to leaf-level reflectance analysis to eliminate noise from atmospheric and soil interference. These studies correlate specific wavelengths to chemical analysis of leaves, providing a reference point for nutrient assessment. Different testing modes have been explored, ranging from intact analysis directly in the field to laboratory scanning of fresh removed leaves, and the analysis of dried and ground leaf samples.

Despite progress, challenges remain in predicting foliar nutrients other than nitrogen (N), with deficiencies often diagnosed through destructive methods. Additionally, while studies have successfully estimated leaf nitrogen, phosphorus (P), potassium (K), and micronutrients like iron (Fe) and manganese (Mn) in dried leaves, predicting other nutrients like copper (Cu) and zinc (Zn) remains unreliable.

Furthermore, while some research has explored the estimation of leaf NPK contents using specific wavelength ranges, the impracticality of spectral analysis over petioles persists due to their thin shape.

THE SOLUTION

The research of Dr Al-Mallahi and Ms Abukmeil aims to bridge the gap between leaf spectrum and petiole chemical testing, focusing on establishing correlations between the two. Recent studies have highlighted significant relationships between leaf reflectance and petiole nitrate-N, as well as correlations between petiole nitrate concentration, leaf protein content and chlorophyll content. However, there remains a lack of comparative studies between NIRS results from leaves and petiole chemical testing for nutrients other than N.

In light of these challenges, the overarching goal of their research is to investigate correlations between potato petiole chemical testing and leaf spectral data. This includes an examination of testing modes (dried or fresh leaves) to determine which yields higher correlations at a lab-based level. The analysis encompasses all macro and micronutrients investigated by farmers in Canada, with the ultimate aim of building validated robust models for nutrient assessment in potatoes.

RAPID AND ACCURATE

The research, which commenced in 2020, has now reached a level of first field deployment after expanding the data base to more than 350 samples. In one of the experiments, the researchers collected 45 samples of Russet Burbank potatoes from farms in New Brunswick, Canada, following the standard practice of taking the fourth leaf from the top of the plant for analysis. Each sample included 40 leaves, and data collection took place over five weeks from early July to mid-August 2021.

Spectral analysis was conducted on both fresh and dried leaves using a portable spectrophotometer. After scanning the fresh leaves, they were split in half, dried, ground into powder, and then scanned again. Statistical tests were performed to compare the spectra of fresh and dried leaves, assessing differences in variance and means. The results were analysed using statistical software to determine their significance.

Table 1. Comparison of approaches to assess the nutrients in potato plants in terms of sample size and time required to acquire the results.

Approach	Number of leaves removed per sample	Days to acquire results
Petiole chemical testing (current)	Up to 500	10-12*
Dried leaf lab spectroscopy (future)	20	4-5*
Fresh leaf lab spectroscopy (future)	20	2-3*
Dried leaf in-field spectroscopy (future)	10	1
Fresh leaf in-field spectroscopy (future)	1	0

* Approximate times

The study found that the spectral measurements of both fresh and dried potato leaves showed promising patterns. Peaks in reflectance were observed in the visible and near-infrared regions, with low reflectance in areas where water absorbs light. The reflectance peaks were consistent across fresh and dried leaves, with no significant differences between the spectral sets of leaves, indicating that it only takes one leaf to get an accurate measurement.

Overall, the findings suggest that spectral measurements of potato leaves, whether fresh or dried, provide reliable data for assessing nutrient levels in the plants.

HOW DOES THE SYSTEM WORK?

The sensing system works by connecting the handheld spectrophotometer, which serves as a proxy for assessing nutrient status, to the internet via mobile network. The leaf spectra is subsequently stored in a memory before sending them to a computational cloud. An embedded computational software, aimed at deriving petiole nutrient concentrations analyses the data. Finally, the nutrient values are provided as near real-time result to the end user through SMS messaging.

Dr Al-Mallahi and Ms Abukmeil will launch the sensing system in both fresh and dried modes in July 2024 at the Farms of the Future of McCain Foods in Canada. The launch will allow them to validate the performance of the estimation models and to evaluate the user experience of using rapid nutrient estimation to take informed decisions. This will be one step towards the wide spread of this new technology among potato growers across Canada and globally.

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SPOTLIGHT ON SUSTAINABILITY

Welcome to our new 'Spotlight on Sustainability' series, where we highlight the strides being made towards a greener future.

If you have a topic or question related to sustainability that you would like us to explore, don't hesitate to reach out. Alternatively, if you are doing some great work on your own patch that we could share, please write to us. We love highlighting grower stories!

In this first installment, we are dumpster diving into the world of potato waste. From cutting-edge research to products already on the shelves, our spotlight is on the many uses of potato waste.

Please email your story ideas to info@ahr.com.au

FROM SPUDS TO SOLUTIONS: REPURPOSING POTATO WASTE

Food waste is a hot issue in Australia, resonating with individuals across the country. Nobody likes to see resources go to waste. So what is being done?

Potato waste stems from various sources, from the rejected produce judged not perfect enough for 'Big Grocery', through to the waste generated through the manufacturing process in the form of peels, pulp, and rejects.

Reducing food waste not only addresses environmental sustainability issues, but also yields economic benefits. This symbiotic relationship between sustainability and profitability is increasingly recognised, driving initiatives globally.

Innovative solutions are emerging that convert potato waste into myriad useful products ranging from packaging, fuel and building materials. These developments highlight the creative problem-solving occurring worldwide to tackle the food waste challenge.

BIODEGRADABLE PLASTICS

The inspiring story of Australia's *Great Wrap* illustrates the outcomes possible when innovators and scientists work together to find solutions to complex problems. Plastic waste, along with climate change, are *the* complex problems of our time.

Through clever collaboration, entrepreneurial couple Julia and Jordy Kay teamed up with material scientists to convert potato waste into biodegradable plastic. This wrap is made from potato starch and polymers, using potato waste from food products such as fries and potato chips. With everyone keen to reduce their environmental footprint, biodegradable packaging is making headway into the market despite costing a little extra. With plans and funding to soon open their own biorefinery in Melbourne, the couple hopes that the cost of their clingfilm will soon match conventional plastic products.

Last year, the company launched the world's first biodegradable pallet wrap, available to Australian buyers now and soon to be exported.

Julia commented to *Business News Australia* that although the domestic cling wrap and the pallet wrap are similar, it took plenty of research and development for the pallet wrap to meet the tensile strength requirements for commercial customers.

"The new formula that we'll be launching is made from a combination of cassava and potato waste, and then we've developed a bioplasticiser made from used cooking oil," she said.

"That's been super incredible because we're using another type of waste, but it's also allowed us to get our pricing down to a point where we're

Great Wrap's potato starch pallet wrap. (Image: greatwrap.com.au)

comfortable we can compete with petroleum plastic."

Across in the USA, a company from Idaho has also turned to the state's beloved potatoes in a bid to reduce plastic waste.

BioLogiQ founders have developed plant based polymers that used within normal manufacturing processes. Their BioBlend XD products can be partnered with a range of other polymers, including polypropylene and high density polyethylene.

The system converts potato starch into natural resins. These can be blended with partner resins to produce everything from flexible films to hard plastic containers. BioBlends containing 5 to 40% plant based material are not only stable, but can increase material strength, allowing thickness to be reduced.

Inclusion of the BioBlend material also reduces the fossil fuel used. So polyethylene bags containing 25% NuPlastiQ were not only 30% thinner, but used 50% less fossil fuel to manufacture.

Although the blended films are still strong and durable, they provide microbes with relatively easy food sources as part of the matrix. This means they are more easily composted. For example, blends of 40% NuPlastiQ GP with LLDPE were 91 to 96% broken down (relative to pure cellulose) after approximately one year.

Perhaps next year, potato bags made (partly) of potatoes.

BIOENERGY

Biofuel from potato waste might be the white whale of many growers. Converting crop waste into fuel not only greatly reduces energy costs, but it is the ultimate closed-loop goal. While already used by some European farmers, it has yet to become a widespread viable solution for Australian growers.

As the world seeks alternative energy sources, potato peel waste is likely to play a role in biofuel production. The carbohydrates contained in potato peel can be readily converted into bioethanol through a combination of processes (saccharification, fermentation, and treatment that adds mould and yeast). Bioethanol is a renewable fuel that can be blended with petrol or used independently in vehicles. Studies are still in their early stages but moving fast towards efficiency and improvement, with

At Cavendish Farms on Prince Edward Island, digesters break down potato waste, producing biogas that fuels the boilers in the company's nearby French fry processing facility. (Image: Pat Martel/CBC)

researchers across the worlds addressing these challenges.

Meanwhile, researchers at the University of Prince Edward Island (UPEI) in Canada are pioneering a novel method for producing hydrogen from waste materials, offering a potentially more sustainable and cost-effective alternative to conventional hydrogen production techniques. Spearheaded by Yulin Hu, an assistant professor in the Faculty of Sustainable Design Engineering at University of Prince Edward Island (UPEI), the project aims to extract hydrogen from diverse waste sources, including used plastics and agricultural residues such as potato peelings.

The process uses a catalyst to break down the waste materials, releasing hydrogen gas. Currently, the research team at UPEI is working to refine the process and scale it up for industrial applications.

BUILDING MATERIALS

Bizarre as it sounds, British innovators have created strong materials based on potato waste.

Researchers at the University of Manchester have created a green alternative to concrete. Designed for space and known as 'StarCrete', it also shows great terrestrial promise.

This innovative material is twice as durable as conventional concrete. The researchers combined potato starch, salt and synthetic Martian soil to yield a concrete-like material, boasting a strength of 72 Megapascals (MPa), surpassing typical concrete's 32 MPa.

Calculations indicate that a 25 kg bag of dried potatoes contains enough starch to produce nearly half a tonne of 'StarCrete'.

Looking ahead, DeakinBio, a startup co-founded by Dr Aled Roberts, Research Fellow at The University of Manchester's Future Biomanufacturing Research Hub, is striving to refine 'StarCrete' for use on Earth. If successfully upscaled, 'StarCrete' could offer a greener alternative to traditional concrete production. Moreover, it can be fabricated in a standard oven or microwave, drastically reducing manufacturing energy costs.

Block of 'StarCrete', made from potato waste, salt and dust. (Image: designboom)

Staying in the UK, a London-based group have designed an eco-friendly alternative to conventional medium-density fibreboard (MDF) using potato waste. Their innovation, aptly named Chip[s] board, is derived from non-food-grade industrial potato waste, addressing concerns about toxic compounds commonly found in MDF.

Peelings are refined through various processes to create a binding agent, eliminating the need for toxic resins and chemicals. This agent is then applied to fibres including potato skins, bamboo, beer hops, and recycled wood, forming a composite that is heat-pressed into sheets suitable for manufacturing furniture and building materials.

So whatever your need - food, packaging, energy or shelter – potatoes can potentially provide it!

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AUSTRALIA'S -AWARD WINING GIN AND VODKA TURNING POTATOES INTO PROFITS

Ruby Daly checking out local delights at the WPC in Ireland in 2022

Tasmanian farmers the Daly family, frustrated that 20% of their harvest was wasted each year due to cosmetic imperfections, turned frustration into opportunity.

After extensive research, they decided to transform their second-grade potatoes into value-added products. Thus, Daly Potato Co. and Hellfire Bluff Distillery were born.

Daly Potato Co. received a boost from a Regional Jobs and Investment Packages grant, allowing them to establish a facility specialising in ready-made potato products. The venture not only uses the second-grade potatoes but also created 30 new jobs in the local area. Using their popular Nicola potatoes, Daly Potato Co. began producing potato salads, mashed potatoes, and pre-seasoned roasting potatoes, leveraging consumer trust in the variety.

The second venture, Hellfire Bluff Distillery, produces potato vodka and gin. With mentorship from UK-based Chase Distillery, Ruby Daly and her team perfected the recipe just in time for the launch at AgFest 2016.

Both ventures proved successful in achieving their key mission: providing a home for the 20% of second-grade potatoes that would otherwise go to waste. However, regulatory requirements proved challenging and costly to the Daly Potato Co.. The family found a solution by selling the processing function to Pure Foods Tasmania, while still ensuring that Daly Farm remained the sole supplier of second-grade potatoes.

Hellfire Bluff Distillery now consistently wins awards for their innovative spirits. Not only did the distillery pay off its initial investment, but it also became a significant purchaser of second-grade potatoes from Daly Farm.

Ruby Daly's insights underscore the importance of embracing risk, seeking expertise, and empowering the younger generation in agricultural innovation. The Daly family's efforts were recognised nationally when they won the Australian Farmer of the Year Award in 2019, a testament to their innovative approach and commitment to sustainability and community development

Here are Ruby's top three tips for value-adding:

1. Be willing to take a risk to value-add If you don't take a risk and try something new, second-grade or undervalued products will continue going to waste. There is profit in value-adding, so give it a try.

2. If you're not the right person for the job, find the right people to help If you have an excellent idea for a value-add but don't know how to get started, ask for the help of experts or consultants.

3. Let the younger generation have a go: Ruby has found that she has a skill for reading the market and staying ahead of trends. Susie and Gerard have encouraged Ruby's creativity, which has catalysed the distillery's success.

Read the full case study at Growing Country
https://growingcountry.com/case-studies/daly-farm-value-add-journey

INTERNATIONAL EXPERTS VISIT GIPPSLAND GROWERS

Growers from Gippsland, Victoria, welcomed visiting US scientists at a recent PotatoLink workshop. This unique opportunity, coordinated and facilitated by Dr Nigel Crump (PotatoLink and AuSPICA), merged an informal setting with globally acclaimed experts, presenting an unparalleled chance to acquire knowledge and insights into a range of topics, including diseases and their treatment and seed management.

Nothing beats the chance to hear new information direct from the source. This workshop gave Gippsland growers the chance to talk directly with international specialists, with questions asked and answered on both sides. Much of the discussion focussed on the specific concerns and challenges faced by local growers.

The following highlights some of the key issues raised in the workshop.

DISEASES

Verticillium wilt

Verticillium wilt is a major concern for growers in the region. A survey conducted some 15 years ago on potato crops across south eastern Australia (including Tasmania and SA) found that one-third were infected with the *Verticillium dahliae* pathogen. Fortunately, very few were infected with the potentially more serious *Verticillium albo-atrum* (Stagnitti, 2015).

Verticillium wilt has been identified as 'the most economically damaging disease in the mid-west (USA)' by Dr Andy Robinson, highlighting its global importance. Dr Nigel Crump characterises it as a 'sleeper disease', going relatively unnoticed in Australia.

Verticillium spp. can be synergistic with root lesion nematodes (*Pratylenchus* spp.), causing a syndrome known as 'Early dying disease'. While growers may notice dead plants in the field, early senescence is frequently attributed to other factors. However, Dr Crump warns that occurrence of verticillium wilt is increasing and growers need to be vigilant about this soil-borne pathogen.

Correct diagnosis of verticillium wilt is key to managing this disease. Symptoms include:

- Wilting of the plant leading to early dying of the crop
- Vascular browning inside stems (note other issues can also cause vascular browning, including blackdot disease (*Colletotrichum coccodes*) and desiccant herbicide)
- 'Flagging' or 'lone soldier plants,' where stems remain standing upright, but the leaves die. Typical early signs are for half the leaf to die while the other half remains green
- Vascular browning can extend to tubers when infection is severe
- Early die-offs, which may be dismissed as early crop death or other causes

Management involves targeting the

Symptoms of *Verticillium* wilt Images: Ontario CropIPM.

nematode population and/or the pathogen prior to planting. Longer crop rotations, that do not include alternative hosts of *Verticillium* spp., and use of resistant varieties, are key to control.

It is also worth considering green manures. Hort Innovation project PT09026 found that the effects of infection by *Verticillium* spp. on yield were greatly reduced when preceded by a green manure crop of millet. Green manure crops of sudangrass and corn have also provided positive results (Davis et al., 1996). Such effects are likely due in part to a general improvement in soil health, helping the potato plant to resist the onset of disease.

According to Dr Crump, biofumigation with mustard crops has also yielded good results. Key to success with such strategies is to include a high volume of green material, mulching it with immediate incorporation into the soil.

Soil fumigation with metham sodium) can reduce the amount of inoculum in the soil and may be a suitable strategy for some growers.

Late blight

Late blight (*Phytophthora infestans*) poses a significant threat, especially as the last three relatively wet years in eastern Australia are likely to have contributed to a build-up of inoculum. The disease is most prevalent in cool, moist conditions, especially if there are multiple consecutive days of damp weather.

Distinguishing between late blight and grey mould (*Botrytis cinerea*) is essential.

Late blight:

- Large, dark brown lesions on leaves and stems
- Lesions with a wet appearance
- May be masses of white spores on undersides of infected leaves

Grey mould:

- Dark brown, wedge shaped lesions with concentric rings
- Typically on leaflet tips or margins and confined by major veins

Volunteer potatoes can be sources of late blight inoculum between seasons.

Protectant fungicides act as barriers to infection and do not translocate within the plant. This means that new growth remains vulnerable to infection in between spray applications.

Dry rot

Fusarium dry rot (*Fusarium* spp.) presents a significant threat during storage. Dry rot typically requires a wound for entry, emphasising the importance of proper handling, curing and storage practices.

While fungicides are available, they are definitely not a substitute for good handling practices.

Avoiding condensation during storage is also important to prevent infection and spread. Positive ventilation to prevent condensation is particularly important during the first few weeks of storage.

Pink rot

While pink rot has similar external symptoms to pythium leak, it is characterised by the distinct pink colour that develops in lesions after 15 – 30 minutes of exposure to the air. The tuber can remain solid if no secondary soft rot bacteria are present.

Occurrence is influenced by soil pH (low pH = higher infection risk) and soil calcium levels. However, the group warned that while sap tests for calcium can be useful, results vary by test method. Also, calcium has limited mobility in plants, making tuber accumulation difficult to estimate.

Damage during harvest and condensation in the storage environment are likely to increase symptom development.

Blackleg

Various species that cause blackleg are present in different parts of Australia. This can impact the symptoms observed. In Australia, blackleg can be broadly separated into two groups: new and old.

'New' blackleg – *Dickeya dianthicola*, *Pectobacterium brasiliense, Pectobacterium parmentieri*

'Old' blackleg: P*ectobacterium atrosepticum, Pectobacterium carotovorum* (common soft rot)

Blackleg, whether the older Pectobacterium or the newer Dickeya, presents different symptoms depending on the season and conditions.

Key points:

- *P. atrosepticum* (old blackleg) causes stems to rot from the outside-in
- *D. dianthicola* and *P. parmentieri* (new blackleg) cause internal blackening, with the stems rotting from the inside-out
- Symptoms of new blackleg tend to develop at warmer temperatures, with the infection potentially remaining asymptomatic in cool conditions
- Mandatory testing for *D. dianthicola* in Australia has helped to reduce occurrence


Fusarium dry rot (left) and backleg (right). Images: PotatoLink

TREATMENTS

Fungicide resistance

Fungicide resistance is a major international issue. There is evidence of resistance developing in several key potato pathogens including late blight, target spot (*Alternaria* spp.) and pink rot.

The status of fungicide resistance in Australia is relatively unknown.

A combination of different modes of action can prove beneficial in minimising the risk of resistance development, particularly when switching between chemical groups. However it is crucial to ensure that these combinations do not have antagonistic effects on plant growth.

Key points:

- Always read and adhere to label instructions when using agricultural chemicals
- Use the specified application rate, timing, purpose and method
- Avoid using the same chemical group for in-furrow and foliar applications
- Healthy, well nourished plants are generally more resilient against diseases
    - For example, plants with poor nutrition are more vulnerable to target spot infection

SEED MANAGEMENT

Key points:

- Ensure knives are sharp when cutting seed, as healing is slower when blunt blades are used.
- Seed tubers that are pre-cut 2-3 weeks before planting should be warmed and exposed to good airflow; this will facilitate effective wound healing before planting
- Dust treatments can be effective but it is essential they are applied in ways that protect worker safety
- Application of seed coating chemicals in-furrow at planting has proven ineffective.

Determining the physiological age of seed presents challenges. However, bringing some seed out of storage and allowing it to sprout can provide some information. A warm environment will make this happen more quickly.

- Fewer sprouts = fewer stems but more large tubers
- More sprouts = more stems with more smaller tubers
- Optimum seed age depends on the intended use of the crop, whether fresh consumption or processing

Hort Innovation POTATO – FRESH FUND

This project has been funded by Hort Innovation using the potato – fresh research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Hort Innovation POTATO – PROCESSING FUND

This project has been funded by Hort Innovation using the potato – processing research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

EXPLORE THE TOPIC FURTHER BYCLICKING THE TITLE BELOW

FACTSHEET: Pink rot

FACTSHEET: Late blight

WEBINAR: Late blight

FACTSHEET: Blackleg

Q: *If individual products within Group 7s start to fail or gain resistance, will all Group 7s lose effectiveness?*

A: *No, not necessarily. Different modes of action within Group 7 fungicides mean that if one product fails or encounters resistance, others may still remain effective.*

Q: *Can old chemistry become effective again against resistant strains?*

A: *Sometimes, although it's not always the case. While there may be instances where older chemistries regain effectiveness against resistant strains, this outcome is not guaranteed. It depends on various factors, including the specific resistance mechanisms involved.*

Q: *Does application of lime have an influence on incidence of scab?*

A: *No, liming does not cause or control scab*

Q: *Is resistance localised in certain areas or spread across states?*

A: Initially, resistance may be localised in specific areas. However, over time, it tends to spread beyond these regions and become more widespread across states.

Q. *Are there rapid tests to test for resistance?*

A. *No*

EVENT COORDINATOR

Dr Nigel Crump is a potato crop specialist with extensive experience working in the Australian potato industry. Nigel is the General Manager for the Australian Seed Potato Industry Certification Authority (AuSPICA), an industry-based organisation that operates the seed potato certification Scheme in South Australia, Victoria and northern New South Wales. Nigel also oversees the day-to-day operation of the Toolangi Elite business which produces G0 potato minitubers and tissue culture plantlets. Nigel holds adjunct roles including Deputy Chair of the UN Economic Commission specialised section on seed potatoes. Recently, Nigel was appointed as a director of the World Potato Congress Inc.. His research interests include international projects in Vanuatu, Ethiopia, Indonesia and New Zealand. Nigel is a PotatoLink regional representative for eastern Victoria and key contact for the seed potato sector.

SPEAKERS

Dr Andy Robinson is an Associate Professor and Extension Potato Agronomist at North Daktoa State University / University of Minnesota. He works with potato growers on the agronomics of potato production, cultural management of potato, herbicide use and misuse in potatoes, and variety development.

Dr Mike Thornton is a professor of plant science working on potatoes and onions for the University of Idaho. His research program focuses on agronomic management practices with an emphasis on evaluation of new varieties, management of in-season pest problems, and reduction of bruising together with other factors that reduce quality and storability.

Dr Jeff Miller is the principal field investigator and owner at Miller Research. He has previously worked as the potato pathologist at the University of Minnesota and the University of Idaho. He conducts research on pest management in potatoes focusing on fungal diseases including Rhizoctonia canker and scurf, early blight and brown spot, late blight, powdery scab, white mould, Fusarium dry rot, pink rot, black dot, Verticillium wilt, and silver scurf.

Dr Brad Geary is a professor of plant health at Brigham Young University (BYU), Utah, a position he has held for over 20 years. Prior to BYU, he worked as an assistant professor of potato production at the University of Idaho. Dr Geary's current research interests include potato diseases associated with the soil, soil health, and biological control. Specific areas of research include silver scurf, black dot, the soil microbiome, and use of *Streptomyces* as a biological control.

EYES ON THE WORLD

RECENT ADVANCES IN POTATO RESEARCH AND INNOVATION

Polymer coated urea in 'Russet Burbank' potato: Yield and tuber quality

Taysom, T.W., LeMonte, J.J., Ransom, C.J., Stark, J.C., Hopkins, A.P.
Am. J. Potato Res. (2023). 100:451-463.

WHAT IS IT ABOUT?

It is often said that you need to spend money to make money, and potatoes are no exception. High productivity relies on high nutrient availability, particularly nitrogen (N). This is partly due to their relatively shallow, inefficient root system.

Getting fertiliser into the soil when and where it is needed is a constant challenge. Too little and growth is impaired. Too much and plants develop more canopy than tubers, with the excess N polluting groundwater and/or volatilising into the air.

To overcome this issue, growers may apply 25 to 40% of the total crop N requirements at or before plant emergence. The remainder is applied incrementally during the growing season, either as broadcast fertiliser or fertigation through irrigation. Both increase costs. Nitrogen for fertigation is typically more expensive than broadcast products. Conversely, mechanical spreading uses time and fuel and may damage a developed crop canopy.

Controlled or slow-release sources of N can potentially improve the synchronisation between plant development and availability of nutrients in the soil. Polymer coated urea (PCU) consists of granulated urea with a thin polymer coating. The rate of release depends on soil temperature together with coating thickness.

There have been many studies comparing PCU with traditional N sources for potato production. In all cases yield was similar or increased. However, previous studies were done in relatively high rainfall areas with good soils. This study was conducted in the Pacific Northwest USA, a semi-arid climate with relatively sandy soils - this makes it more analogous to the conditions in some Australian growing areas.

WHAT WAS DONE?

Three commercial grower properties were used for the trials. Four main treatments were applied at each property: control (no added N); PCU applied pre-emergence; urea applied pre-emergence; urea split applied four times over the growing period (50:16.7:16.7:16.7%). Nitrogen was applied at 33, 67, 100 or 133% of the University of Idaho recommended rate for each site. Once plants reached commercial maturity, vines were killed and 6m plots harvested. Tuber size, grade, internal quality and total yield were recorded.

Idaho potatoes (Image by Henry Gartley from Pixabay)

WHAT WAS FOUND?

While yield was reduced in the control (no added N) treatment, differences between the rates of N were generally not significant, so the data was combined.

Yield from PCU was significantly higher than the split applied urea at two of the three locations and significantly higher than urea applied at emergence at one location. Overall, both marketable yield and US No. 1 grade yield were increased by application of PCU compared to the urea based treatments. The proportion of potatoes that were small (114-170g), medium (170-284g), large (284-397g) or extra-large (>397g) was relatively unaffected by the N application method. However, there was a clear increase in small potatoes in the unfertilised controls. Specific gravity and physiological disorders were unaffected by N fertilisation.

The study demonstrates that application of PCU at emergence provides an efficient source of N for Russet Burbank potatoes grown with low rainfall in sandy, calcareous alkaline soils. While PCU is more expensive than urea, this may be offset by lower application costs, particularly where split applications are difficult to achieve.

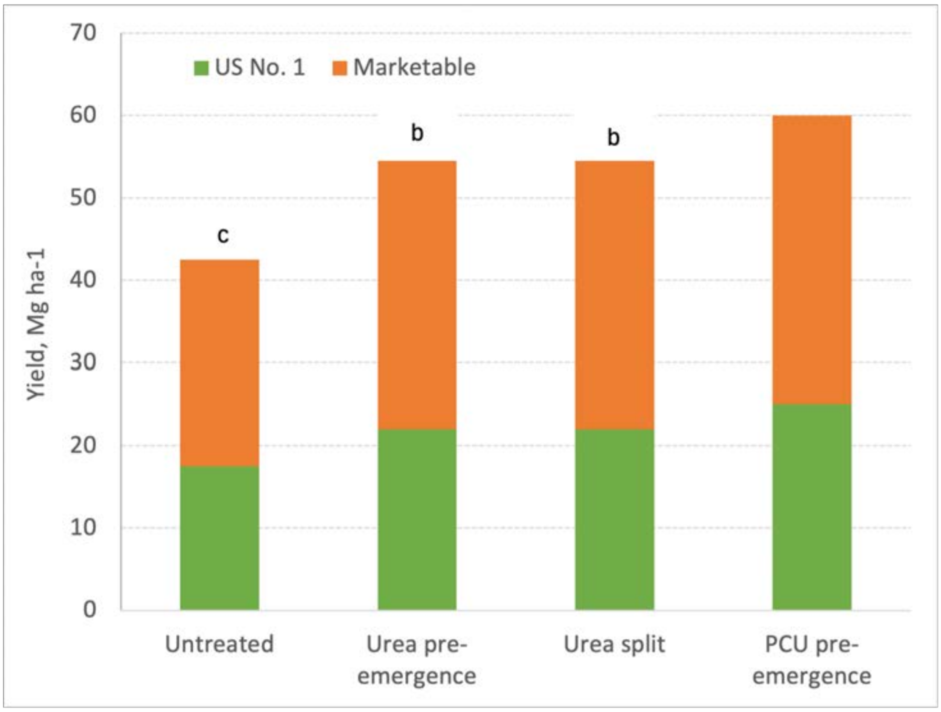

Figure 1. Yield of US No. 1 and marketable Russet Burbank potatoes, averaged across three locations and four N rates for different N sources (urea applied pre-emergence, urea split over 4 applications and polymer coated urea (PCU)) relative to an untreated control. Letters indicate values that are significantly different ($p<0.05$). Derived from Taysom et al, 2023.

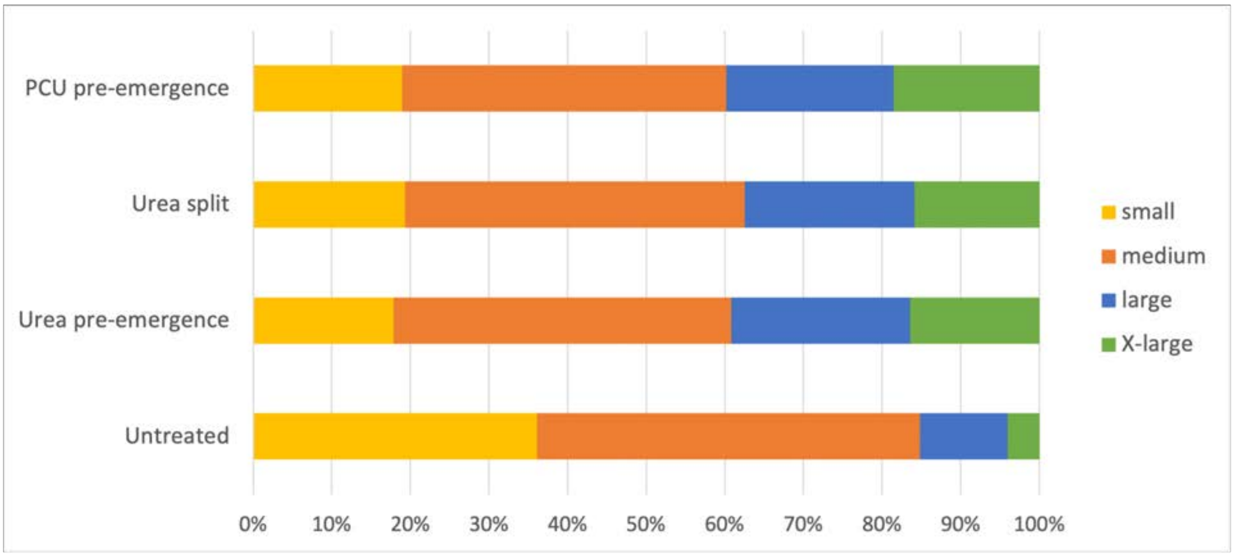

Figure 2. Proportion of yield of US No 1 grade potatoes falling within each size grade being small (114-170g), medium (170-284g), large (284-397g) or extra-large (>397g). Data averaged across three locations and four N rates for different N sources (urea applied pre-emergence, urea split over 4 applications and polymer coated urea (PCU)) relative to an untreated control. Derived from Taysom et al, 2023.

DISPATCH FROM ... SOUTH AUSTRALIA

Touring across 1400km with US expert Dr Phillip Wharton and AuSPICA's Dr Nigel Crump

Potato Link arranged a series of workshops in the southeastern potato-growing regions of Australia focusing on potato diseases and viruses. The workshops featured presentations by Dr Phillip Wharton from the University of Idaho and Dr Nigel Crump from AuSPICA.

The workshops, coordinated by regional rep and extension partner Peter Philp, were delivered across multiple towns including Ballarat (Vic) and Mount Gambier and Murray Bridge (SA), as well as visits to growers in the southeast South Australia and Mallee regions.

Dr Wharton shared insights into potato diseases prevalent in Idaho and southern Australia, focusing on their life cycles and management strategies to minimise crop loss and improve yield and quality. Meanwhile, Dr Crump empahsied the importance of clean seed and discussed trends in disease and virus occurrences in Australia.

Discussions with growers in Ballarat and Mount Gambier centered on diseases thriving in cool, wet conditions, particularly late blight, black leg, and other bacterial diseases caused by Pectobacterium species. Dr Wharton highlighted the importance of hygiene and precise seed cutting practices, particularly seed handling, temperature control, and the use of appropriate products to prevent disease transmission during seed cutting operations.

A visit to Buckley Innovative Farming in Mingbool, South Australia, provided insights into exemplary crop management practices, with Terry

Dr Wharton, Dr Crump and Terry Buckley inspecting FL 1867 roots stolons and soil health on Terry's farm in South East South Australia (photo PS Wharton)

Buckley showcasing a healthy crop of FL 1867, attributed to optimal soil management resulting in well-aerated soil and robust crop growth free from disease.

Meetings in the Mallee and Riverland production areas, specifically in Parilla, Loxton, and Murray Bridge, focused on black dot, pectobacterium diseases, and target spot. Dr Wharton highlighted the importance of understanding disease life cycles and their interaction with crops, alongside other factors influencing crop susceptibility.

The Murray Bridge meeting brought together a diverse group of stakeholders, including growers, industry suppliers, agronomists, and advisors. Dr Wharton's discussion on potato fungicide sensitivity studies emphasised the need for resistance management strategies, exemplified by the recommendation to tank mix systemic fungicides with protectant fungicides for effective disease control.

During their time in the Mallee, Dr Wharton and Dr Crump explored rotation crops used with potatoes, and the importance of managing black dot and other soil-borne diseases through informed crop and weed rotation decisions. Dr Wharton also highlighted black leg as an example of a secondary pathogen often following primary infections by pathogens such as *Fusarium* spp.

Dr Wharton's presentation of a Potato Disease Calendar, illustrating disease life cycles overlaid on the potato crop's life cycle and infection window, captured growers' interest.

UPCOMING EVENTS

- World Potato Congress, 23-26 June https://tcc.eventsair.com/world-potato-congress-2024/
- There are tentative plans for a roadshow in September in Mt Gambier, Loxton and Murray Bridge. Keep up with PotatoLink social media and e-bulletins for details closer to the date

CONTACT

For more information about PotatoLink activities in South Australia, contact Peter Philp peterkphilp@hotmail.com

POTATOLINK BULLETIN

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HORT INNOVATION PROJECTS

Project name	Code	Lead organisation	Description	Fund	Start and end date
Potato industry minor use program	PT16005	Hort Innovation	Used to submit renewals and applications for new minor use permits for the potato industry	Fresh & Processing	Ongoing
Australian potato industry communication and extension project (PotatoLink)	PT20000	Applied Horticultural Research	Supports growers in adopting improved practices on-farm and communicating new information, research and technology	Fresh & Processing	08/12/2020 – 30/11/2025
Management strategy for serpentine leafminer, *Liriomyza huidobrensis*	MT20005	Queensland Department of Agriculture and Fisheries	Delivering targeted R&D specifically for serpentine leafminer in response to the incursions detected in late 2020	Multi fund including Fresh & Processing	19/03/2021 – 30/11/2023
Regulatory Support & Response Co-ordination	MT20007	AKC Consulting Pty Ltd	Provides key information regarding domestic and international pesticide regulation	Multi fund including Fresh & Processing	30/06/2021 – 01/07/2024
Consumer behavioural data program	MT21004	Nielsen	Provides regular consumer behaviour data and insight reports, through the Harvest to Home platform (www.harvesttohome.net.au)	Multi fund including Fresh	20/01/2022 – 20/11/2026
Feasibility/scoping study: Surveillance and diagnostic framework for detecting soil-borne pathogens in vegetable industries	MT21016	NSW Department of Primary Industries	Examining the potential to develop a national surveillance and diagnostic framework for soilborne pathogens of vegetable crops including potatoes	Multi fund including Fresh & Processing	11/10/2022 – 31/08/2023
Generation of data for pesticide permit applications in horticulture 2022	ST22001, ST22003 and ST22004	Agreco, Eurofins Agroscience Services and Kalyx	The generation of pesticide residue, efficacy and crop safety data to support label registration and minor use permit applications and renewals made to the APVMA	Multi fund including Fresh	16/05/2022 – 15/12/2025
People development strategy for the vegetable, potato, onion, and banana industries	MT22002	RMCG	Building a People Development Strategy to guide future investment in building capacity and capability within a range of industries including potatoes	Multi fund including Fresh & Processing	12/12/2022 – 01/07/2023
Horticulture trade data	MT22005	IHS Global	Provides Hort Innovation with a subscription to the Global Trade Atlas Database	Multi fund including Fresh & Processing	14/12/2022 – 01/12/2025
Horticulture Impact Assessment Program 2020/21 to 2022/23	MT21015	Ag Econ	Evaluating impact of our R&D investments, providing insights into the type and magnitude of impacts that are being generated across the company's strategic levy programs	Multi fund including Fresh & Processing	2021-2023


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