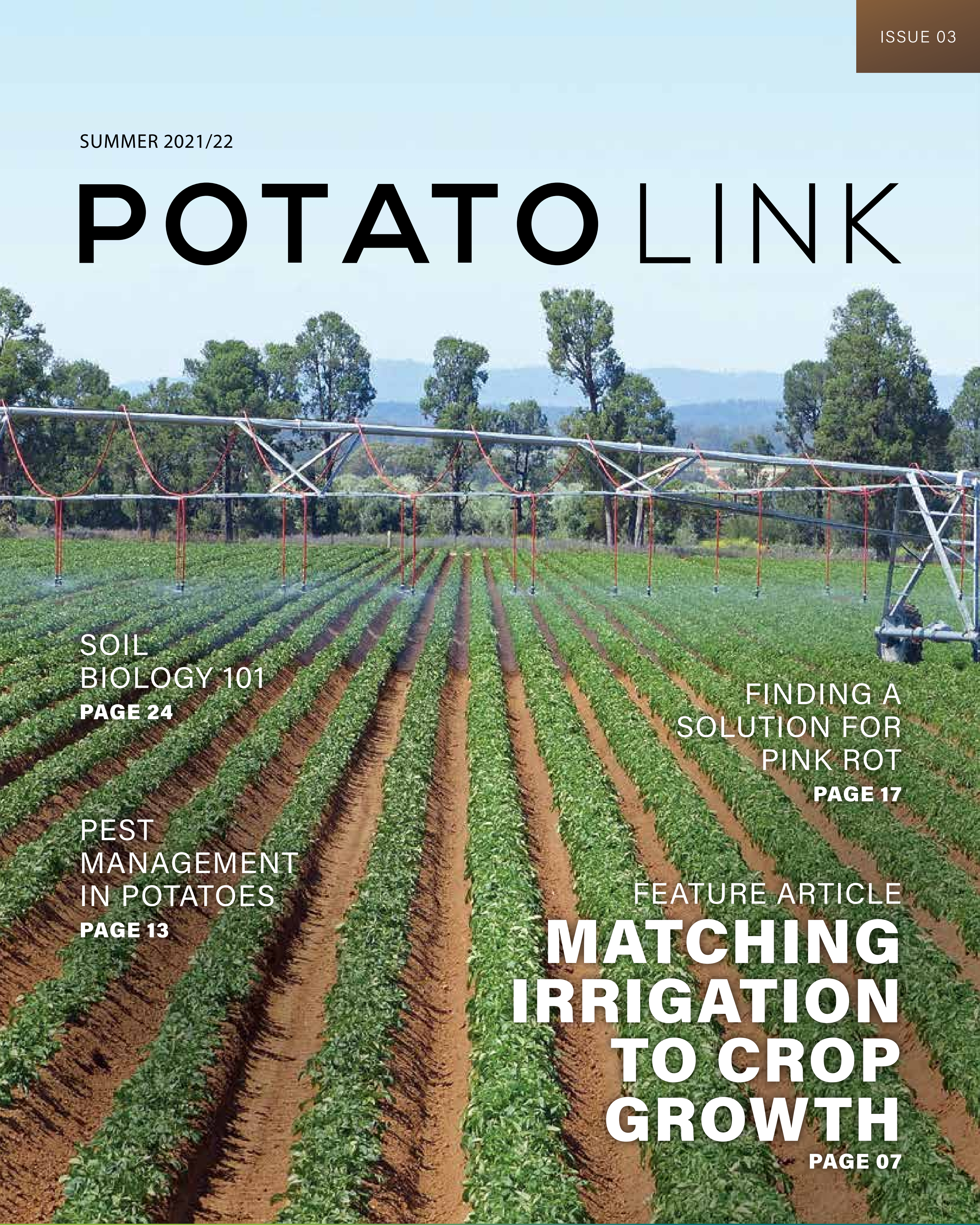
ISSUE 03

SUMMER 2021/22

POTATO LINK



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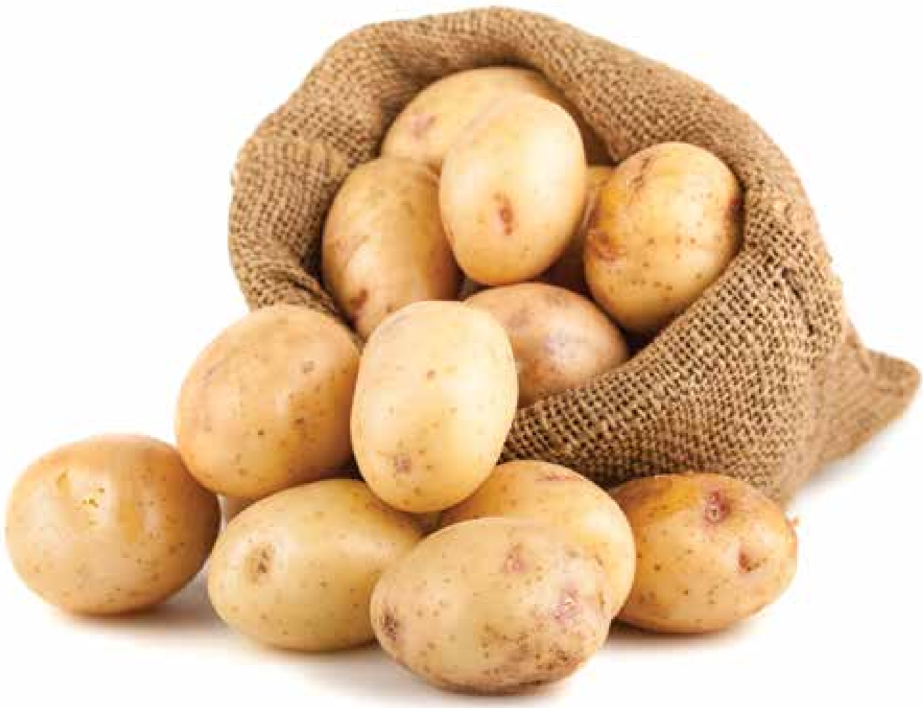

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POTATO LINK
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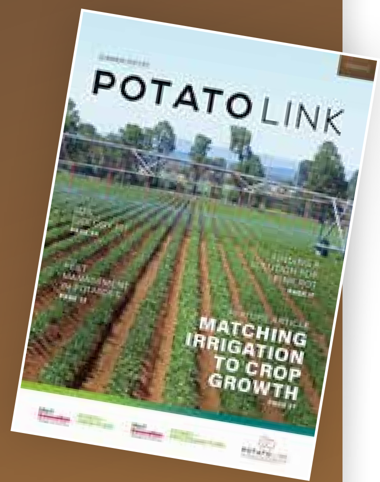

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Events guide

Project update from Peter O'Brien, plus our new program of webinars and workshops.

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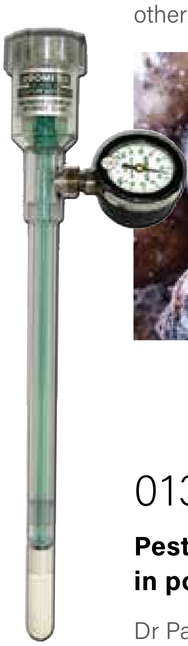
Matching irrigation to crop growth

Irrigation needs change as the potato crop grows. Moreover, yield and quality are more sensitive to water deficits at some stages than others



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Pest management in potatoes

Dr Paul Horne reflects on the succesful implementation of IPM on potato farms.

POTATO LINK
AUSTRALIAN POTATO INDUSTRY
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EVENTS GUIDE

Project update From Peter O'Brien

As we finally emerge from lockdowns the PotatoLink team is very much looking forward to increasing our face-to-face involvement with the potato industry. It will be great to finally leave our local government areas and engage directly with growers, advisers and processors through regional workshops, training events, field days and so on. Now that we feel more confident planning such events, they will soon be appearing through the e-news bulletin as well as on the potatolink.com.au website. Please keep a look out for these events and make sure you register so you don't miss any events near you.

Rain is creating havoc for many parts of the country trying to get crops planted. It has been a long time since we have had planting interrupted across the east coast and Tasmania as much as this.

Despite this, some demo sites are underway, with plantings often made at short notice due to the limited dry windows for getting out into the field.

In the coming months you will also see a number of webinars featuring international speakers. These will be focussed on important potato diseases. It's a great time to firm up these opportunities as our speakers go into the Northern hemisphere off season. As with field days and the like, these webinars will be promoted through the e-news and website on our calendar of events.

Remember you can watch any of our webinars you might have missed simply by visiting the Featured Resources section of the website. Or simply type in the topic you are interested in. For example, the recent masterclass on Soil Biology in potato production is now available, split into four parts for easy watching – or binge if you please!

We look forward to making real contact with you all in 2022.

EVENT	CONTACT / PRESENTERS	DATE AND TIME (AEDT)
F2F Growing right workshops – Getting a better crop stand, to optimise quality and yield		
Victoria, Potato virus management	Nigel Crump, with AusPICA	21 December 2021, 09:00 – 5:00 location TBD
Tasmania, Final crop management and canopy recovery	Frank Mulcahy	13 January 2022, 16:30 – 17:30, location TBD
SA (Naracoorte), Potato crop rotation and soil health	Peter Philp, in coordination with Bayer and SARDI (PredictaPt)	31 January 2022, timing and location TBD
SA (Parilla), Soil health workshop on calcium and salinity	Peter Philp, in coordination with Bayer	March 2022, timing and location TBD
Webinar – Cover crops		
Cover crops for fresh and processing potatoes	Kelvin Montagu, Darren Long	24 February, 12:00 – 13:00
Webinar – Disease series		
General potato diseases	Gary Secor (USA)	timing TBD
Black dot	Alison Lees (UK) and Len Tesoriero, TBD	timing TBD
Blackleg, and other bacterial diseases	Steven B Johnson (USA), TBD	timing TBD
Rhizoctonia diseases	Rudolf de Boer, Michael Rettke, TBD	timing TBD

MATCHING IRRIGATION TO CROP GROWTH

Dr Jenny Ekman reports

"Potatoes don't eat, they drink. Potatoes drink, but they don't swim."

F. Mulcahy

Potatoes are mostly water, packaged with starch plus various minerals, vitamins and other nutrients. While they are often regarded as being a high water use crop, they are more productive per megalitre of water than many other horticultural crops.

Potatoes have a relatively shallow root zone and are very sensitive to water stress. They are often grown on soils with low water holding capacity, which makes irrigation management difficult. Too much water increases disease and reduces quality, while too little water reduces productivity, yield and nutrient uptake.

Water is not necessarily free, and neither is distributing it across a paddock or pivot. The potential gains in yield and dry matter from managing water correctly are huge, so controlling and accurately managing irrigation should be a top priority for all growers.

POTATO DEVELOPMENT

Irrigation requirements change as the potato plant grows and matures (Figure 1). Understanding growth stage is therefore essential to understand the water needs of the crop. Physiological development of the potato plants is commonly divided into five stages;

Stage 1 – Establishment: Planting and emergence (20 to 35 days)

Stage 2 – Stolon initiation: Early vegetative growth and stolon development (15 to 25 days)

Stage 3 – Tuberisation: Tuber initiation at the end of the stolons (10 to 15 days)

Stage 4 – Tuber bulking: tubers fill and expand (30 to 60 days)

Stage 5 – Maturity: Tuber maturation and vine death (15 days or more)

Figure 1. Effect of water stress at different growth stages of potatoes. Derived from Obidiegwu et. al. 2015

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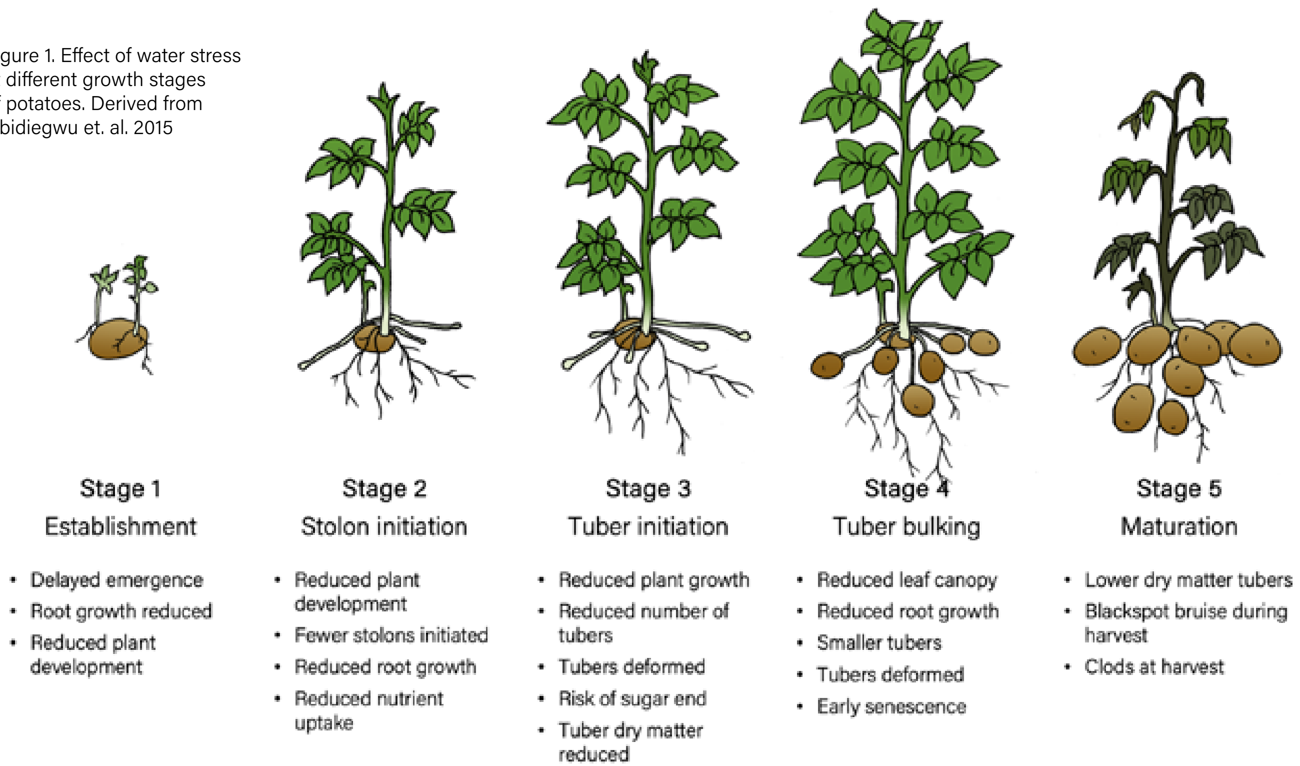

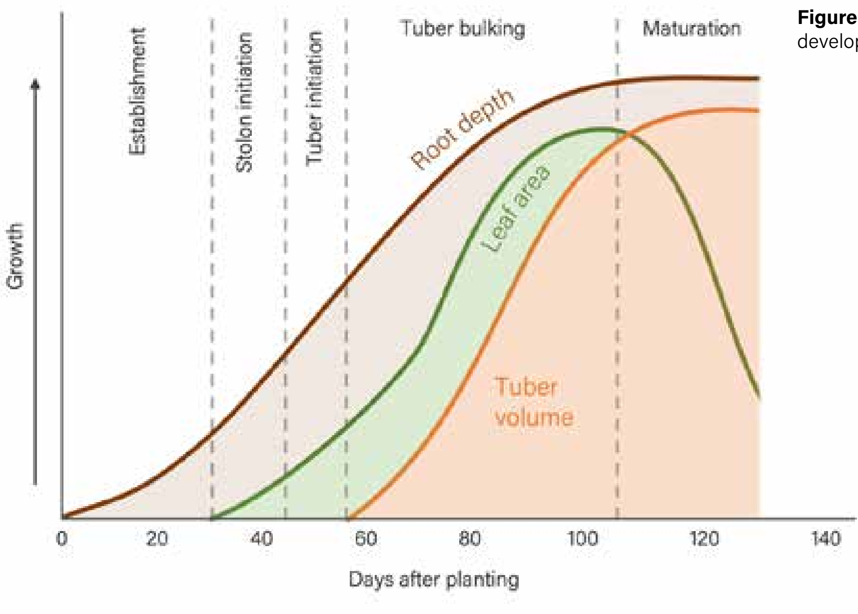

Figure 2. Potato plant development stages.

Potatoes are normally regarded as a cool-climate plant. It was once thought that photosynthesis by potato plants was almost completely inhibited at temperatures over 30°C. However, it is now known that this effect was mainly due to water deficits. In fact, potatoes can adapt to high temperatures (~40°C) and continue to photosynthesise, but only if adequate moisture is available[2].

WHAT IF PLANTS HAVE TOO LITTLE WATER?

The first physiological response to water stress is closure of the stomata (breathing holes) on leaves. Moisture inside the leaves evaporates through open stomata (Figure 3). While this cools the leaf canopy, keeping temperatures below the ambient air, it also results in moisture loss.

If the plant closes stomata to reduce moisture loss, carbon dioxide movement into the leaf is also reduced. This inhibits photosynthesis, limiting accumulation of starch and sugars. Potato yield and quality (e.g. specific gravity) depends on photosynthesis exceeding the everyday energy needs of the plant, allowing storage of excess carbohydrate in the developing tubers.

Water deficits also reduce the internal pressure which is necessary for cell expansion and growth. Leaf canopy and root growth can be significantly reduced. Although tuber development resumes when water becomes available, the disruption can result in deformed tubers with bottlenecks or pointed ends. It also increases the likelihood of tuber cracking (Figure 6).

It is well established that insufficient water at any stage will reduce yield. Overall, the penalties for under-irrigating are greater than those for over-irrigating (Figure 4). Moreover, avoiding moisture stress is more critical during some parts of the cropping cycle than others – as discussed on the following pages.

WHAT IF PLANTS HAVE TOO MUCH WATER?

Over-irrigation leaches nitrogen from the root zone. This reduces fertiliser use efficiency, potentially restricting plant growth as well as contaminating ground water. It also increases disease, often obvious in damper

Figure 3. Stomata control gas exchange between cells inside the leaves and the outside environment.

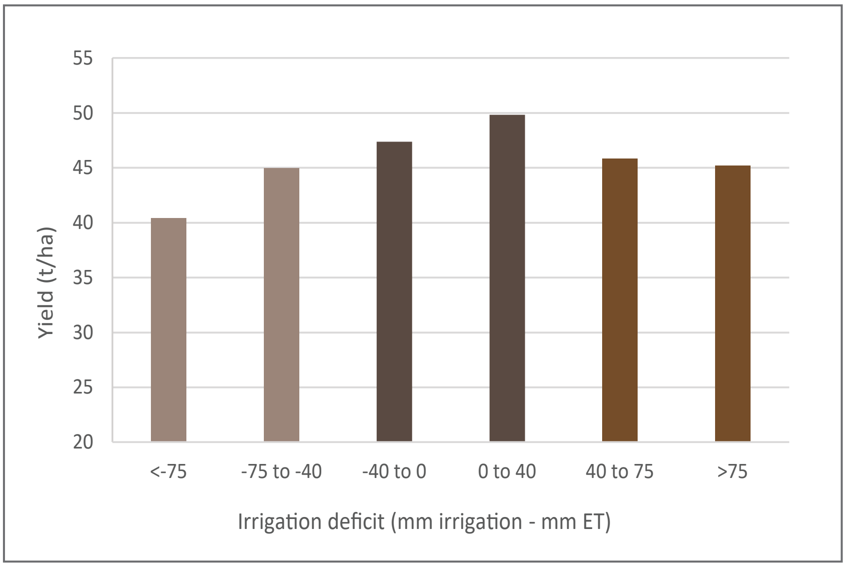

Figure 4. Total tuber yield as influenced by the difference between total irrigation and evapotranspiration (ET). Data from 45 commercial potato farms in Idaho (Stark, 1996[3]). *N.B. divide by 2.47 to convert to t/acre.*

patches of the paddock, and can have long term effects on tuber quality and storability.

Initial symptoms of anaerobic, waterlogged conditions are puffed lenticels on the tubers (Figure 5). If the soil profile remains fully saturated for more than 8-12 hours, anaerobic conditions can damage roots and tubers. This can cause "black heart" of the tubers, where the inner tissues collapse due to oxygen starvation (Figure 7). More than 36 hours of waterlogged conditions will also result in denitrification, or loss of soil nitrogen to the atmosphere.

Figure 5. Puffed lenticels on potatoes harvested from a wet area.

GROWTH STAGES AND IRRIGATION

Stage 1. Establishment

Ideally, soil moisture should be relatively high before planting. If this is the case, irrigation after planting may not be required. Some light watering to replace surface evaporation can be useful if soil moisture is marginal. In damp soil, the seed itself has enough internal water to support the developing sprout.

If soil moisture is too high, the saturated soil will restrict the rapid respiration rate of the sprouts. It can also potentially allow infection by soil-borne pathogens. For example, early dying has been linked to high moisture during emergence[4].

Excess soil moisture at planting can also increase seed piece decay and delay emergence, as soils remain colder for longer (e.g. for early spring plantings).

Stage 2. Stolon initiation

Although tubers have not yet started to develop during stage 2, water use increases as the leaf canopy expands. The leaf area index generally reaches around 50-80% row closure during this period, with increased transpiration as a result.

Water deficits during this period can reduce the number of stolons that form, as well as negatively affecting plant growth and maturation.

The most critical period for accurate management of irrigation is during stage 3 – tuber initiation and stage 4 – tuber bulking.

Stage 3. Tuber initiation

Water stress (and/or high nitrogen status) leading into this stage can delay tuber initiation by several weeks. The effects are often greatest for indeterminate varieties, increasing the length of the cropping cycle and potentially creating other issues. In contrast, some determinate varieties are relatively insensitive to water stress during this period and will mature normally.

Studies have certainly confirmed strong varietal effects. For example, water stress during early tuber initiation reduced yield by more than 50% for cv. "Luky" whereas cv. "Alpha" was not significantly affected[5].

Similarly, research in Western Australia found that yield and quality of cv. Russet Burbank (indeterminate) and cv. Delaware were significantly reduced by low soil moisture during emergence and tuber initiation, whereas cv. Cadima and cv. Kennebec (determinate) were less affected[6].

While irrigation deficits during tuber initiation can affect yield, it is the effects on tuber quality that are the most significant. Even short periods of dryness that do not reduce total yield can greatly affect tuber quality. Dumbbell shapes, cracks and other deformities all result from uneven soil moisture during tuber initiation and early development (Figure 6).

Another potential effect of water stress during tuber initiation and early bulking is the development of "translucent end" or "sugar end", especially when combined with high temperatures. Dry conditions mean that sugars produced by photosynthesis are not fully converted into starch in the tuber. The result is a colour gradient from the light tip to the dark stem end following processing (Figure 6).

Maintaining high soil moisture during tuber initiation and early bulking is essential for good dry matter. However, over-moist conditions during tuber initiation combined with cool conditions increases the risk of susceptible varieties developing brown centre or hollow heart (Figure 7).

Stage 4. Tuber bulking

Water stress during tuber bulking typically affects yield more than quality. These effects cannot be recovered; total yield will be reduced.

Maintaining a large, actively photosynthesising leaf canopy is essential for tuber expansion. The leaf canopy continues to grow during this period, reaching row closure near the end of stage 4.

Dry conditions interrupt shoot growth and hasten the decline of older leaves. Reduced photosynthesis slows tuber development.

The root system also expands during stage 4. Mature roots can access water up to around 50cm deep within the soil profile. However, as most roots remain within the top 30cm of the soil, plants are still susceptible to moisture stress.

Moreover, the relatively weak root system of potato plants means they are often unable to penetrate tillage pans or restrictive layers within the soil. Field traffic can cause soil compaction, which also limits penetration depth of roots.

Understanding the depth of root penetration is critical to managing irrigation volume and frequency during this growth stage. Varieties that have greater root branching, better root architecture and increased root depth are likely to be less sensitive to water deficits than those with less efficient root systems.

Tubers enlarge approximately linearly over time so long as environmental conditions are maintained.

All this means that potato plants' water requirements reach their maximum right when it is most critical to avoid water deficits[7].

It is also important to avoid excess irrigation during this stage as wet conditions increase disease, leach nutrients and may reduce dry matter.

Stage 5. Maturity

Irrigation needs drop as plants begin to die off during stage 5. Tuber growth rates decline, and skins start to mature and harden.

Translocation of nutrients from the leaves, stems and roots into the tubers leads to a small amount of further expansion, even as the tops die.

However, the soil should not be allowed to fully dry, as this can increase number and hardness of clods at harvest, as well as dehydrate tubers.

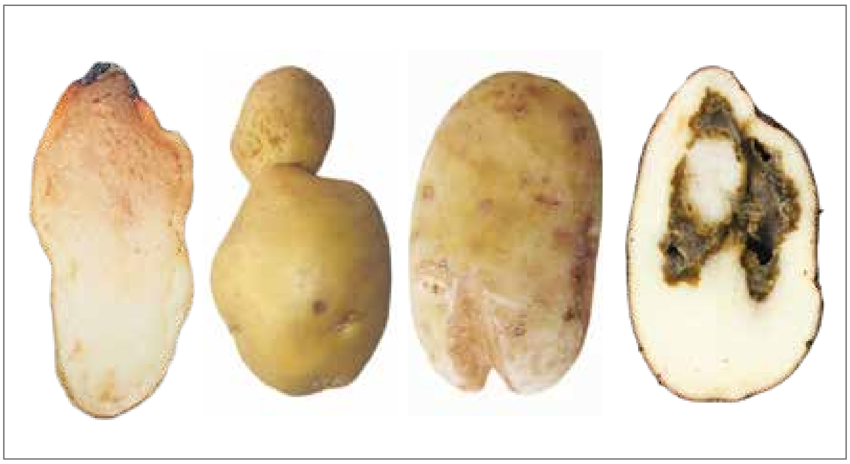

Figure 6. Disorders associated with dry conditions during tuber initiation and bulking include (from left) sugar end (M. Thornton, Uni Idaho); dumbbell (JM Gravouille, INRA); growth cracks (K Bouchek-Mechich, INRA) and internal heat necrosis (A Robinson NDSU).

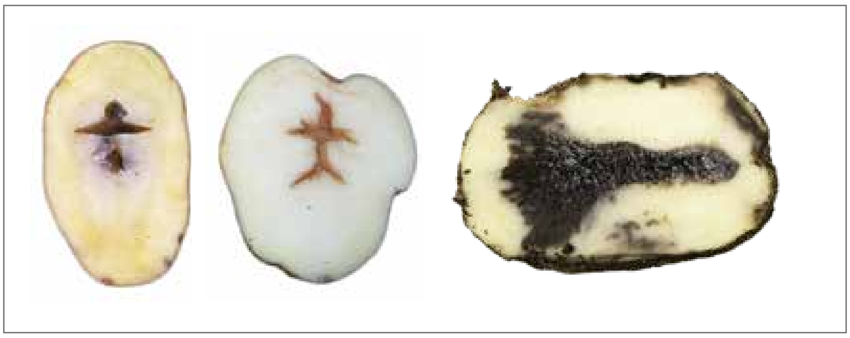

Figure 7. Disorders associated with too much water include (from left) brown centre (JM Gravouille, INRA); hollow heart (JM Gravouille, INRA) and black heart (A Robinson NDSU).

Dehydrated tubers are more likely to suffer bruising during harvest (Figure 8). Blackspot bruises are not visible externally, as the skin itself is undamaged. Instead, the damage is localised in the flesh, close to the vascular tissues. The damage is usually not visible straight away but develops 24 to 48 hours after harvest.

Excessive irrigation after the vines have died off increases risk from pythium leak (*Pythium* spp.) and pink rot (*Phytophthora erythroseptica*), as well as secondary infection by soft rots. It can also reduce tuber dry matter.

Wet conditions during harvest can lead to cracks and shatter bruise damage.

IRRIGATION METHOD AND FREQUENCY

The sensitivity of potatoes to soil moisture levels, combined with their shallow root system, means that irrigation needs to be applied before the crop is affected by water stress. Frequent irrigations have been found to result in higher yield and tuber dry matter compared to intermittent irrigation (Figure 9)[8].

Drip irrigation is frequently cited as the gold standard in irrigation for potatoes. Drip allows soil to be kept continually moist and avoids wetting leaves, thereby reducing foliar diseases. However, it is expensive and not compatible with current Australian growing practices.

Figure 8. Potatoes that are dehydrated at harvest are more susceptible to blackspot bruising (M Thornton, Uni Idaho).

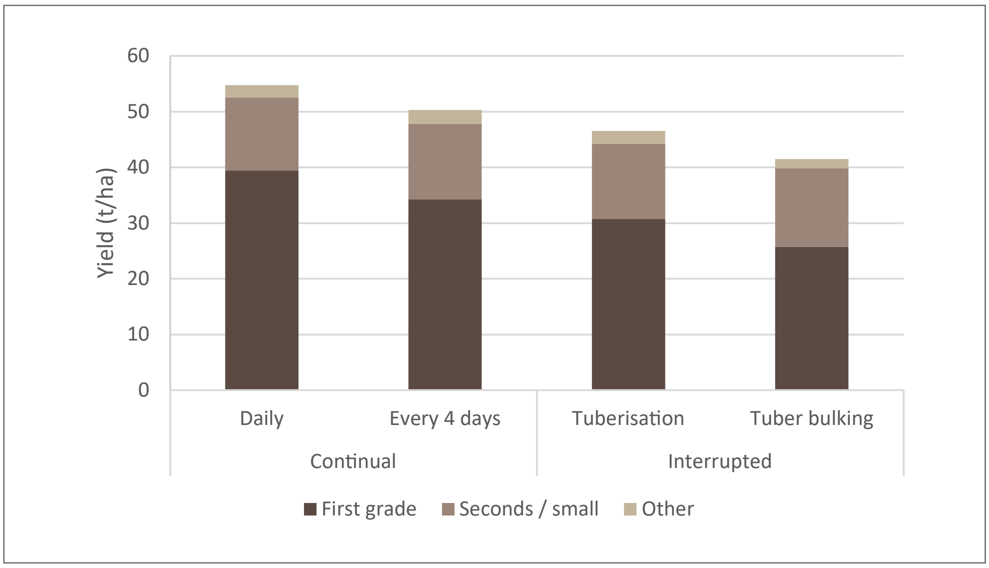

Figure 9. Effect of irrigation frequency (daily or every 4 days) and interruption during either tuber initation or tuber bulking, on average yield divided into grade 1, seconds and smalls (<114g) and waste. Derived from Miller and Martin, 1990[10].

Linear move and centre pivot are the next best options, followed by side-roll systems.

Furrow irrigation allows large and undesirable fluctuations in soil moisture content.

As sprinkler systems wet the leaves, it is often recommended that plants are not irrigated in the late afternoon or evening if leaves will remain wet overnight. Leaf wetness increases risk from diseases such as black scurf, common scab and early blight[9].

Large volume and infrequent irrigation events not only fail to maintain even soil moisture, they contribute to runoff, can pollute ground water with nitrates and are more likely to oversaturate soil than frequent irrigation. According to King and Stark[3], this is most likely with side roll and hand-move sprinkler systems, where soil water holding capacity and root depth may be overestimated.

MEASURING SOIL MOISTURE

See p12 for a comparison of different soil moisture sensors

Tensiometers

Tensiometers work like plant roots in that they measure the 'suction' required to extract water from the soil. Tensiometers are basically a sealed, water filled tube with a porous tip at one end and a pressure gauge (kPa) at the other. As the soil dries, moisture moves from the tensiometer into the soil, creating a partial vacuum in the tube. This is equal to the soil water potential (kPa). Fully saturated soil gives a reading of 0kPa, whereas -40kPa or less indicates the soil is dry.

To get reliable readings, the cylinder must be sealed against air leakage and there must be excellent contact between the soil and the porous tip.

Time domain reflectometry (TDR) sensors

These sensors measure volumetric soil moisture content. TDR sensors have two or three parallel metal rods. The time taken for an electromagnetic wave to travel from one rod to the other indicates soil moisture content.

TDR sensors are a well-established technology and widely used in agriculture to measure soil moisture. Small portable systems have been developed that allow data to be uploaded to a website, where it can be easily accessed.

The TDT (time domain transmissometry) sensor is a variation on the TDR. Instead of parallel rods, the sensor consists of a "U". TDT sensors are less portable than TDR but sample a larger soil volume.

Soil moisture capacitance sensors

Capacitance sensors also measure volumetric moisture content, but by measuring the charge time for a capacitor with electrodes separated by the soil. Fast charge times indicate high moisture contents. There are many brands available commercially, with associated equipment for transmitting and storing data.

IN SUMMARY

- **Too little** moisture affects yield more than **too much** moisture
- The effects of water stress vary at different crop growth stages
  - Tuber initiation and tuber bulking are the most critical times to get irrigation just right
  - Water stress during tuber initiation can have major effects on quality
  - Water stress during tuber bulking has the greatest effects on yield
- Too much soil moisture can increase disease and may reduce specific gravity
- Potato plants prefer small amounts of water often, avoiding water stress, compared to large, less frequent irrigation events
- There are lots of devices available to monitor irrigation and get soil moisture into the goldilocks zone: **Not too damp, not too dry, but.... Just Right!**

Figure 10. A tensiometer (Irrometer) and a, TDR sensor (Wildeye), two types of soil moisture probes

	Tensiometer	TDR	TDT	Capacitance
Accuracy	Variable	Very good	Excellent	Good
Cost	$150 – $500	$300 – $500 per sensor + comms	$300 – $500 per sensor + comms	$300 – $400 per sensor + comms
Life expectancy	5 years	10 years	10 years	5 years
Remote access?	Normally manual	Yes	Yes	Yes
Needs calibration by soil type?	No	No	No	No
Affected by salinity?	No	Yes but can be compensated	Yes but can be compensated	Yes but can be compensated
Sensing area	Small	Moderate	Moderate-large	Small
Notes	Easy to install and use, needs regular maintenance	Can be portable	Normally permanently installed	Requires good contact with soil

Table 1. Comparison of types of soil moisture sensors

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PEST MANAGEMENT IN POTATOES

By **Dr Paul Horne**

Dr Paul Horne is well known to many as the Director of IPM Technologies. His 5-year project "An IPM extension project for the potato and onion industries" has supported growers adopting IPM on farm, improving their pest management while reducing chemical use and costs. Now at its conclusion, Paul reflects on successful implementation of IPM on potato farms.

POTATO PESTS

Each agricultural crop has its own set of pests and potatoes are no different. The range of pests that Australian growers deal with varies a little between regions, but there are some that most have in common.

The main pest species in Australia are potato tuber moth and various aphids (as potential vectors of virus). Caterpillar species such as loopers and Heliothis (*Helicoverpa* species) can also be important, while several species of thrips are potential vectors of tomato spotted wilt virus (note that the seasonally abundant plague thrips does not vector TSWV). Soil-dwelling pests such as the larvae of African black beetle, whitefringed weevil and potato wireworm are very important in a few regions but absent in others.

The importance of these pests not only varies in importance by region but also by crop type. For example, aphids are of most concern to seed growers, while potato tuber moth is more important for growers wanting to harvest high-setting varieties in mid-summer. Thrips and TSWV are a concern in a few localities, where there are reservoirs of both the virus and species of thrips that vector it (particularly tomato thrips and onion thrips).

PEST CONTROL

So, what are the options for control of these pests, in whatever combination they occur? As with any crop, growers have three categories of options to select from:

- Biological controls (predators and parasitoids of the pests)
- Cultural controls (management methods that help encourage beneficial species or discourage pest populations)
- Pesticides

If growers choose to use all three in a compatible way, then that is integrated pest management (IPM).

Each species of pest has other insects that attack it. Some are extremely effective and can be relied upon to give substantial levels of control. Predators and parasitoids of aphids and potato moth include parasitoid wasps, brown lacewings, hoverflies, ladybird beetles and damsel bugs. They are particularly effective in providing a high level of control of these key pests, although at times they need some extra support from cultural and pesticide controls. These beneficial species occur naturally in all potato growing regions of Australia. They can reach extremely high levels in potato crops so long as broad-

Figure 1. Brown lacewing adult and larva (Photos IPM Technologies)

> *"We started using IPM just a few years ago, and now we are seeing much better control of potato moth and aphids. Our use of insecticides is much more precise and effective."*
>
> - Ben Hotchkin, Thorpdale, Victoria

Figure 2. Hoverfly adult and larva (Photos IPM Technologies)

spectrum insecticides are not applied. Pest thrips are attacked by other species of thrips, true bugs, mites and beetles.

However, it is more difficult to manage soil dwellers such as beetle larvae and wireworms. There are no really effective biological controls, so other techniques are needed – such as cultural controls.

Some cultural control measures are extremely important for reducing damage by insect pests. For example, certified seed, weed control (including control of self-sowns), rotation and isolation reduce the risk of virus transmission.

Potato tuber moth damage to the tubers can be reduced by ensuring there is fine soil tilth and large hills, rolling and using overhead irrigation.

Variety selection, time of planting and harvest can also help manage a range of pests and insect vectored diseases.

The third and final method of controlling pests is using chemical pesticides. Applying broad-spectrum insecticides before or immediately after planting will not usually reduce the impact of the beneficial species described above, as they will fly into crops only after they emerge.

However, application of these products to growing foliage will severely disrupt populations of beneficial species. This can induce 'pest flare', where populations of a particular pest (e.g. aphids) increases dramatically in the absence of competitors and predators.

Broad-spectrum insecticides can also be applied without disrupting beneficial species if sprayed at or after crop senescence (or when applying a herbicide to kill the plants).

However, if selective products are applied (e.g. for caterpillars or aphids) then the beneficial species and pesticides can work together, giving better control than either on their own. This is the "integrated" part of integrated pest management.

Over the last few years many growers around the country have switched to using IPM rather than relying on insecticide applications alone. Some have already told this story through articles in Potatoes Australia e.g. Victorian grower Wayne Tymensen [February/ March 2019], South Australian grower Pat Virgara ["Grower Success Stories" January 2019] and Kangaroo Island seed grower Peter Cooper [June/July 2017].

With few new chemicals coming on the market, increasing legal restrictions and costs associated with the ones still registered, and development of resistance among key pests, it makes sense to use all the tools in the toolbox – *and that means IPM.*

"We first met Paul and his team at a conference down south. At the time, pest numbers in the potatoes were un-manageable. We attended one of the workshops Paul and Angelica ran in the Lockyer and then they visited us on our farm to talk to us about our own pest management program. Since then, we have totally changed our approach to pest management. We have gone from a situation where pest numbers were out of control to now, where we are flat-out finding a pest in the crop. Our total pesticide usage is maybe 5% of what it was. And our agronomist tells us he feels sorry for all the beneficial insects in the crop because there is nothing for them to eat."

- Kerry Hauser, Hauser Farms, Lockyer Valley Qld

"The impression I get speaking to potato growers in my region is that they are comfortable with how they are managing pests in potatoes. Most of them are familiar with the IPM Technologies approach to pest management and have adopted this style of management for a number of years now. The impression I get is that pest management is "old hat" to them now – they don't view insect pests as a major problem anymore and they attribute this to the practice changes they have made through involvement in this project."

- Zara Hall, Industry Development Officer Southern Queensland

This project, , *An IPM extension program for the potato and onion industries (MT16009)* is funded by Hort Innovation, using the processing and fresh potato research and development levies and contributions from the Australian Government.

BRINGING BALANCE TO POTATO TUBER MOTH MANAGEMENT

Potato tuber moth (*Phthorimaea operculella*) is a pest of potatoes in many potato production regions around the world, including Australia and New Zealand. It has proved difficult to control with insecticides alone but can be effectively managed using biological and cultural controls with support from strategic use of insecticides.

- By **Dr Paul Horne**, IPM Technologies P/L

Potato tuber moth (*Phthorimaea operculella*) (PTM) is an important pest of potatoes in many countries, including Australia. The caterpillars can feed on a wide range of solanaceous plants, so can be serious pests of eggplants and tomatoes; in Queensland PTM is also known as tomato leafminer. Although there is a wide host range, potato (followed by eggplants), are the preferred hosts on which the female moths lay their eggs.

Larvae of PTM feed either on tubers of potato or within the leaves of potato plants (Figures 2 and 3). Leaf-mining activity makes them difficult to control with insecticides and control failures have been reported frequently. This is in part because of where they feed but also because of insecticide resistance.

Moreover, spraying the foliage may kill caterpillars but damage to tubers can still be serious. This is because moths can lay eggs on or near the soil surface, and the tiny caterpillars

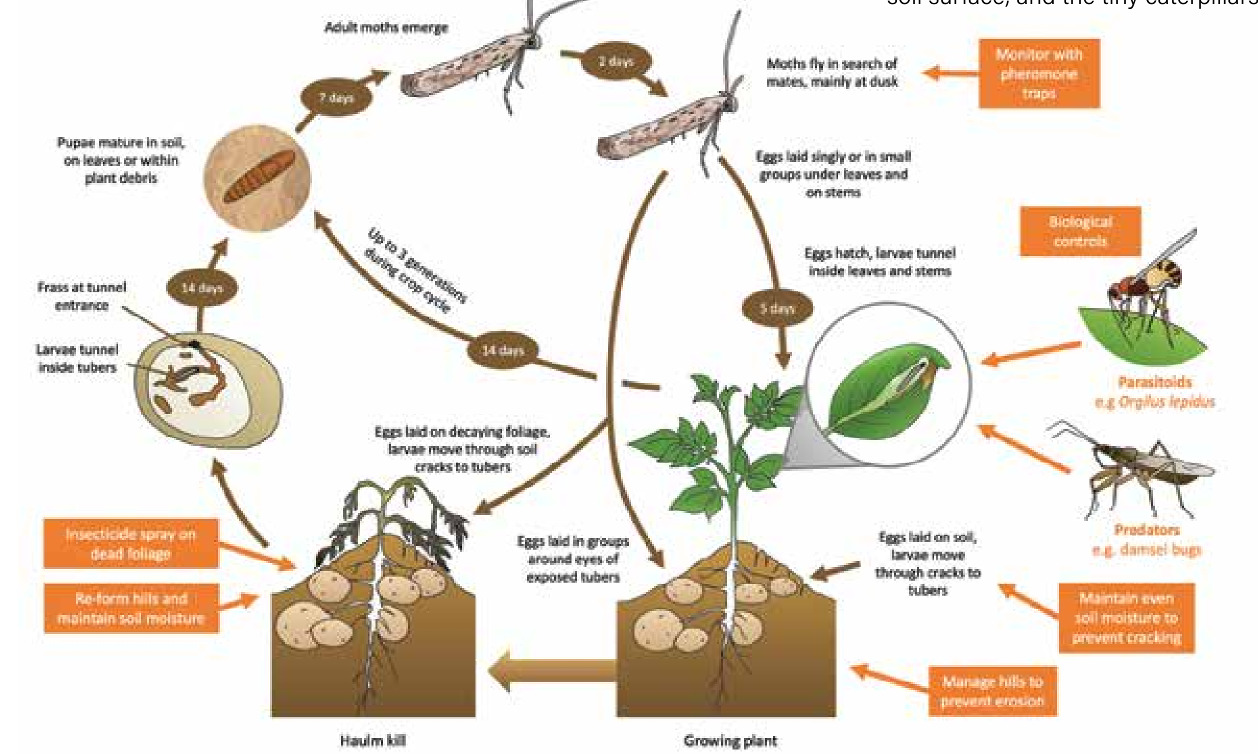

Figure 1. PTM lifecycle, indicating the approximate number of days for each stage under close to optimal conditions and potential control strategies (orange) at each lifestage. Note that speed of development and fecundity are highly temperature dependant. - Illustration J. Ekman

that hatch out can move onto tubers through cracked soil.

During the warmer months of the year potato moth eggs develop into adults in about four weeks. That means that three generations can develop in the life of a crop (Figure 1). Where plantings are made over several months, there can be many generations over the course of the year.

MANAGING THE MOTH

Instead of relying on insecticides, a better way to deal with this pest is to use its natural enemies (parasitic wasps and predatory insects) and some important cultural (management) methods.

If necessary, selective insecticides may be used during the growing period that don't kill the beneficial species. Broad-spectrum insecticides can be used at or after crop senescence to provide a chemical barrier over the tubers, as the beneficial species will no longer be present.

There are three species of wasps in Australia that parasitise and kill PTM caterpillars. Two species (*Orgilus lepidus* and *Apanteles subandinus*) produce one wasp from one caterpillar whereas the third (*Copidosoma koehleri*) produces around 50 wasps per caterpillar. Levels of parasitism on farms that have been using IPM for years are often above 80%.

The main predator of PTM caterpillars is the damsel bug, *Nabis kinbergii*. Other predators of importance in Australian potato crops are brown lacewings, *Micromus tasmaniae*, and hoverflies of several species. All these species occur naturally in potato growing regions of Australia and develop at the same rate as their caterpillar hosts.

Figure 2. PTM leaf mine - P. Horne

Figure 4. Adult PTM - P. Horne

A range of cultural control options to minimise damage by PTM are available to potato growers. Two key options are overhead irrigation and soil management. The aim here is to maintain an intact soil barrier over the top of the tubers, preventing access by caterpillars. So, a fine tilth without clods or cracks is ideal. Irrigation can be used to keep the soil barrier intact and to wash fine soil particles into centre-line cracks that might develop.

Related to this is variety selection. Deeper setting varieties will naturally have a potentially thicker layer of intact soil over the tubers. In some circumstances growers might want or need to plant a shallow setting variety. In this case they need to be aware that the risk of damage by PTM is greater and additional control measures may

Figure 3. PTM larvae developing inside a tuber and emerging to pupate - S.I. Rondon, Oregon State University

be needed.

Where cultural methods are not used and the biological controls are killed (by insecticides targeting PTM or other pests), then damage to tubers is likely. This is the situation in many other countries, including parts of New Zealand. Loss of control also occurs in hot conditions in Australia, where cracks in the soil or erosion of the hills allows larvae to access the developing tubers.

Using an IPM approach, which incorporates biological and cultural control options together with selective insecticides, is much more effective than cover-sprays alone. With less reliance on insecticides, the onset of insecticide resistance is reduced, so growers will have sustainable control options.

Most Australian potato producers are controlling PTM without over-reliance on cover sprays. With care it will remain so.

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MANAGING PINK ROT IN POTATOES

Pink rot, caused by P*hytophthora erythroseptica*, is an important disease worldwide. It is found widely in Australia, particularly in Tasmania, and can cause devastating losses both before and after harvest. Even if symptoms are not severe, its presence increases harvesting costs, as diseased tubers must be culled before storage or transport.

CURRENT MANAGEMENT OPTIONS

Pink rot is a potato specialist, in that it does not grow readily on other hosts. Despite this, long crop rotations are necessary due to production of long lived oospores. These can persist in the soil for up to seven years (Figure 1). Volunteer potatoes, and other Solanaceous hosts, must be scrupulously removed in order to break the cycle of infection.

The pathogen spreads rapidly in warm, wet soils through the movement of swimming zoospores. Improving drainage and soil structure to reduce the potential for waterlogging is therefore an important control strategy.

The fungicides Metalaxyl, Metalaxyl-M and Amisulbrom are currently registered for control (check for your

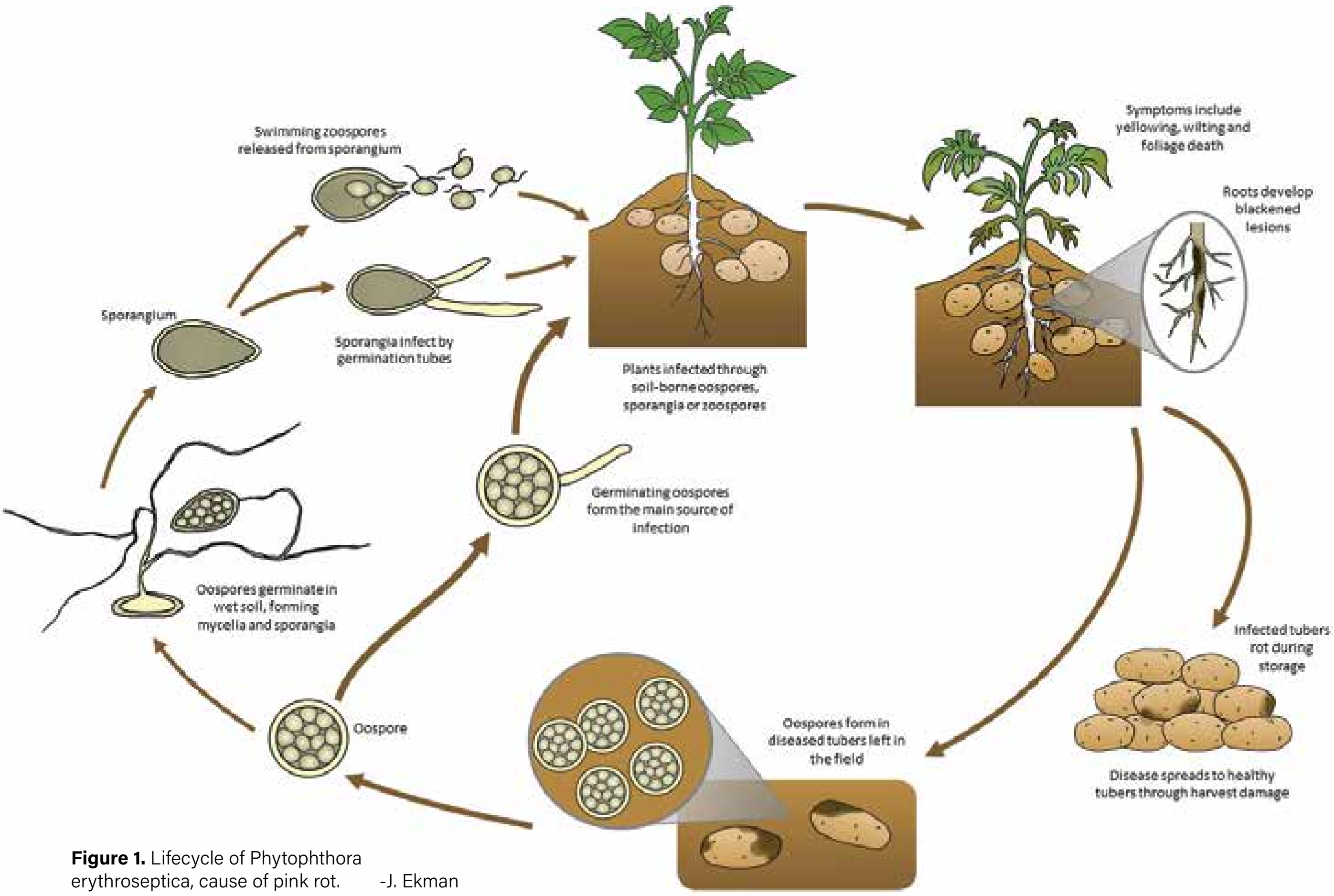

Figure 1. Lifecycle of Phytophthora erythroseptica, cause of pink rot. -J. Ekman

region, use according to instructions), but there are concerns regarding possible resistance.

In 2009, American research[1] indicated that calcium nutrition was important in suppressing the disease, with significant reductions in pink rot as plant calcium content increased.

The same team also determined that low pH amplified disease development, with an almost linear increase in the pathogen population between pH 5 and pH 8[2]. However, these trials were done using a hydroponic system, so it was unclear if these effects would be repeated under field conditions.

As a result, the potato industry together with Hort Innovation, have funded a project to examine these potential management strategies under Australian field conditions.

AUSTRALIAN PINK ROT RESEARCH

Dr Robert Tegg from the University of Tasmania is a research plant pathologist working on pink rot of potatoes. He is currently examining this issue through the project "Investigating soil pH and nutrition as possible factors influencing pink rot in potatoes (PT19000)."

The first year of trials are now complete. Eleven different sites were studied across four distinct regions: Sisters Creek, Devonport, Scottsdale and Epping forest. Six of the field sites included specific field trials with research strips of calcium amendments (Nanocal and/or Calciprill/OzCal). These were either pre-spread, applied in-furrow or surface sprayed.

Individual growers, as well as field officers, helped select and set up the trial sites. . Soil chemistry, pathogen levels, soil quality and disease outcomes were measured as were the relationships between these factors.

The objective was to assess whether the addition of calcium treatments impacted pink rot disease development and to also identify whether high levels of pink rot pathogen in the soil translated into increased disease in the crop.

SO, WHAT ARE THE RESULTS SO FAR?

Seven of the 11 sites suffered significant pink rot, with disease most severe in the NE regions. Unfortunately, according to Dr Tegg, "Calcium amendments failed to prove a silver bullet for control of pink rot, as benefits were negligible. However, there may be other benefits from increasing calcium". These could include tuber quality and pest resistance more generally.

Figure 3. Area where pink rot occurred in a field at Sisters Creek (left, - E. Blanchard, Simplot), and compacted zone along the bottom of the paddock that was expressing significantly more pink rot that the higher, non-compacted area (right, - R. Tegg).

Figure 4. Typical pink rot symptoms (left) and pink rot in combination with Spongospora galling and sclerotinia on the potato stem. Images taken in the field shown at right in figure 3. - R. Tegg.

The researchers did, however, find that soil quality and topsoil depth were good indicators of where pink rot was likely to appear within a paddock. Areas which were compacted, had thin topsoil or poor soil health were the most likely to suffer disease.

Similarly, other damage within the field, such as wind damage or stem canker, also increased the likelihood of pink rot. This makes sense, because if plants are stressed due to other factors, the opportunistic pink rot pathogen is more easily able to break through the plant defences and cause infection.

Another interesting discovery was that many of the cropping soils studied were highly acidic. Moreover, pH dropped by up to 0.6 units during the growing season, putting them into the sub-optimal pH 5 to 5.5 range.

"The PreDicta Pt test also provided some insights into the way the pink rot pathogen survives and proliferates in the soil" commented Dr Tegg. "Detection usually occurred mid-way through the growing season. Detecting the pathogen before planting was more difficult, probably due to its' sporadic distribution around the field as well as significant temperature and weather effects on the soil population".

NEXT STEPS?

Some complementary pot trials are currently underway. So far, these indicate that very high levels of calcium (>10 tonne/ha OzCal) are required to reach the efficacious levels recommended in the US studies (>7 – 7.5). Such high rates may not be practical commercially, particularly for red ferrosols. These soils are highly buffered, making it difficult to significantly modify pH.

The field work will also be repeated this coming season, with the aim of gaining a fuller understanding of factors that increase – or decrease – field incidence of pink rot.

For more information on the project please contact Dr Robert Tegg at robert.tegg@utas.edu.au

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This project, , *Investigating soil pH and nutrition as possible factors influencing pink rot in potatoes (PT19000)* is being funded by Hort Innovation, using the processing and fresh potato research and development levy and contributions from the Australian Government.

POTATO VIRUS Y

- flattening the disease curve

- By **Dr Nigel Crump**

The COVID-19 global pandemic means we are all aware of the need to suppress disease by "*flattening the curve*". That is, stopping the spread of COVID-19 throughout the population. It is now common to hear about the use of laboratory testing to identify known cases of COVID-19 in the population. We even understand the importance of genomic sequencing to identify the various strains of COVID-19, including delta.

The management of Potato Virus Y (PVY) shares similarities to COVID-19. Actions taken by the Australian Seed Potato Industry Certification Authority (AuSPICA) have resulted in the successful "flattening of the curve" for PVY and provided assurance of "clean" certified seed potatoes.

Just like COVID-19, PVY has several strains such as PVY^O, PVY^C and PVY^N. Around the world PVY is evolving and new strains of PVY are being discovered using genomic sequencing.

PVY is vectored by aphids feeding in the potato crop and PVY can be spread with infected seed lots.

SEED POTATO CERTIFICATION AND PVY

Potato seed certification programs aim to prevent or limit initial levels of virus in potato seed. Consistent with certified seed programs around the world, the Australian seed certification schemes limit the number of times a seed lot can be recertified to a maximum of five generations. The initial G0 minituber seed stocks are derived from pathogen-tested tissue culture material known to be free from virus (Figure 1).

PVY SYMPTOMS

Symptoms of PVY can vary across different potato varieties. In some varieties, the virus may show no visible symptoms. Alternatively, symptoms can range from very mild mosaic leaf yellowing to plant death or tuber necrosis. The impact of infection is therefore an interaction between potato cultivar and strain of PVY (Figure 2).

PVY STRAINS IN AUSTRALIA

Historically, Australia reported the PVY strains PVY^O, PVY^N, PVY^C, PVY^Z and PVY^D (1,2,3). A more recent study has shown Australian isolates belonged to the PVY^{NTN} strain. Sequence analysis of the whole genomes of three isolates suggested a single introduction of the PVY^{NTN} strain to Australia (4). PVY^{NTN} produces mild symptoms in potato, making them more difficult to manage through visual inspections. In addition to reducing yield, necrotic isolates may also cause external and internal

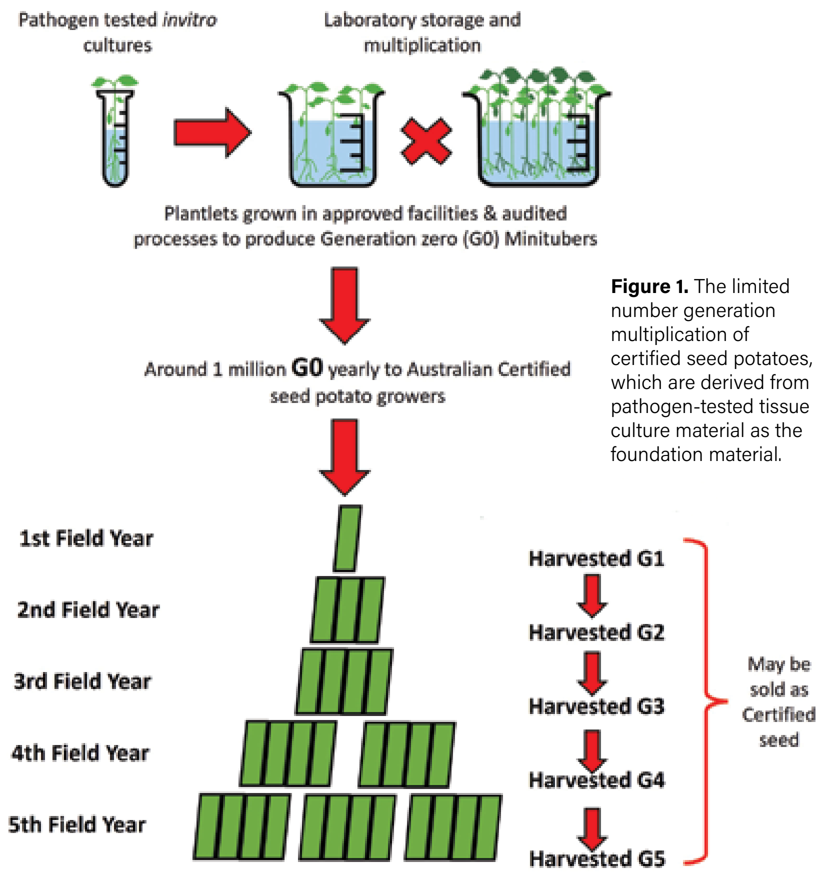

Figure 1. The limited number generation multiplication of certified seed potatoes, which are derived from pathogen-tested tissue culture material as the foundation material.

Figure 2. The symptoms of Potato Virus Y (PVY) in different potato varieties. - N Crump

a) foliage symtoms cv. Atlantic
b) tuber deformation on cv. Denal
c) tuber necrosis on cv. Atlantic

damage in tubers of susceptible cultivars, which is known as potato tuber necrotic ringspot disease (PTNRD).

PVY COST TO POTATO PRODUCTION

PVY is a potyvirus that causes significant economic loss in yield and quality of potatoes worldwide. A study in the US found that for every 1% of PVY in the seed, the yield of the subsequent crop was decreased by 0.18 t/ha, as PVY decreased marketable yield and tuber size (5).

In the US state of Idaho, which produces about 7.1m tonnes of potato worth US$1b annually, the losses due to PVY were valued at US$34m (6). It was estimated that 10% PVY infection in seed could decrease commercial crop returns by US$225–300 per hectare depending on the market sector.

In Australia, there has been no economic study on PVY. However individual crop losses of up to 90% have been reported when crops were grown from seed with high levels of PVY. If not effectively managed, PVY will have significant economic impact on the Australian potato industry.

FLATTENING THE CURVE ASSOCIATED WITH PVY

Until recently, seed potato crops were entirely assessed for PVY symptoms using visual inspections during the growing season. This became problematic as PVY strains that have very mild or no symptoms in foliage can therefore be missed by visual inspection.

In 2010, AuSPICA introduced mandatory leaf testing of all seed stocks, including all generations of certified seed potatoes that were issued with official certification labels. This involved the collection and laboratory testing of over 17,000 samples of leaves annually from around 2000 ha of seed crops throughout Victoria, South Australia and Northern New South Wales. This large surveillance program supplements the visual inspection of seed crops for certification, and – importantly – identifies seed lots that have shown no visual symptoms of PVY. The plants showing no symptoms can act as a reservoir for PVY to carry over between seasons.

The PVY surveillance program conducted by AuSPICA has been successful in mitigating the risk of PVY in certified seed potato crops. We have reduced the amount of seed crop rejection due to viruses, which includes PVY, from 7% in 2010/11 to 0.3% in 2021 (Figure 3). This surveillance has resulted in the flattening of the curve associated with PVY. This provides the Australian potato industry with high-quality certified seed that has the potential to achieve maximum yield and quality, without the adverse impact of Potato Virus Y.

SUCCESS IN RELATION TO THE SUPPRESSION OF PVY

Significant effort has been made by the entire seed potato industry to reduce PVY to extremely low levels. This should be celebrated by the whole industry. The use of laboratory diagnostics to support certification provides verification as to the quality of certified seed crops, especially in relation to PVY. Seed buyers have

Figure 3. Crop rejection due to presence of viruses (including PVY) as a percentage of the total crop area submitted to the AuSPICA seed potato certification scheme, from 2000 to 2021.

confidence in the extremely low levels of PVY in certified seed potatoes. Certified seed producers have greater awareness of PVY and have adopted integrated management strategies to mitigate PVY in seed crops.

NEW DIRECTIONS

AuSPICA has now adopted DNA-based diagnostics to detect PVY in potato leaves and tubers to ensure high-throughput testing capacity and more affordable tests are available.

New technology is available to sample insect populations and determine the presence of known insect vectors of PVY. This technology will provide growers with more information about the movement of aphids that can spread PVY and allow for more informed management decisions.

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Dear Spud GP

We have had a lot of rain lately, and now my leaves have gone curly! The plants also seem to have some sort of leaf blight.

Are they linked or are these two separate problems?

Wavy Dave

ASK THE SPUD GP

- By **Dr Len Tesoriero**

Dear Wavy Dave

Wet weather is generally favourable for a range of diseases and physiological disorders affecting leaves, stems and tubers. In this case it is probably wise to send a sample for laboratory testing as there are a few lines of investigation to determine if all the symptoms are related.

Leaf roll could be due to a virus infection by Potato leaf roll virus (PLRV) which is spread by some aphid species. There has been widespread aphid activity over the past spring so it would be important to also check for aphids on the plants. Unfortunately, potato aphid feeding can also cause leaves to roll in the absence of PLRV, so a laboratory test is required.

There are also several non-viral causes of leaves rolling. It can occur when sugars formed during photosynthesis are prevented from translocating away from the leaves, causing starch to accumulate. Some varieties are particularly prone to this. Excess nitrogen, and extremes in soil moisture, can also cause similar symptoms.

PLRV and a bacterium (a phytoplasma causing Purple Top in potatoes) only infect the phloem in the vascular tissue of potatoes. Phloem is responsible for movement of sugars produced in the leaves down to the tubers. This explains why these pathogens cause leaves to roll. As the name suggests, Purple Top is also accompanied by a red or purple discoloration towards the margins of emerging leaves.

The fungus *Rhizoctonia* can also reduce carbohydrate translocation, causing leaf rolling and sometimes leaf margin reddening. The disease infects the stolons, tubers and stem bases. It commonly forms a whitish growth at the stem base as well as typical brown lesions on the stolons. Both Purple Top and *Rhizoctonia* are often accompanied by formation of aerial tubers.

Finally, the symptoms on the older leaves could be early signs of infection by *Alternaria* species (which cause Early Blight, Brown Leaf Spot and Target Spot diseases), or possibly Late Blight (caused by *Phytophthora infestans*). Alternatively, wet weather can cause physical damage which can then be invaded by any number of environmental organisms leading to lesions and their premature senescence.

Contact the spud GP by emailing
info@potatolink.com.au

SOIL BIOLOGY 101 FOR POTATO GROWERS

Soil biology is a key driver for nearly all functions within the soil. Biological activity affects soil structure and aeration, nutrient cycling and availability, breakdown of organic materials, plant growth and disease.

Dr Jenny Ekman reports

Fungi, bacteria and other soil dwelling organisms are what build soil structure. Their activity creates the air pockets that allow potato plant roots and tubers to breathe. Those same spaces also allow water to infiltrate soil, holding it where it's available for plant growth. In contrast, structureless soils are likely to form a crust, so that water just runs off.

Tillage breaks down soil aggregates into smaller units. Regular tillage also tends to favour bacteria over fungi, as it breaks up the strands of fungal hyphae in the soil. Populations of larger soil dwellers such as nematodes, worms, insects and mites are also reduced by regular tillage.

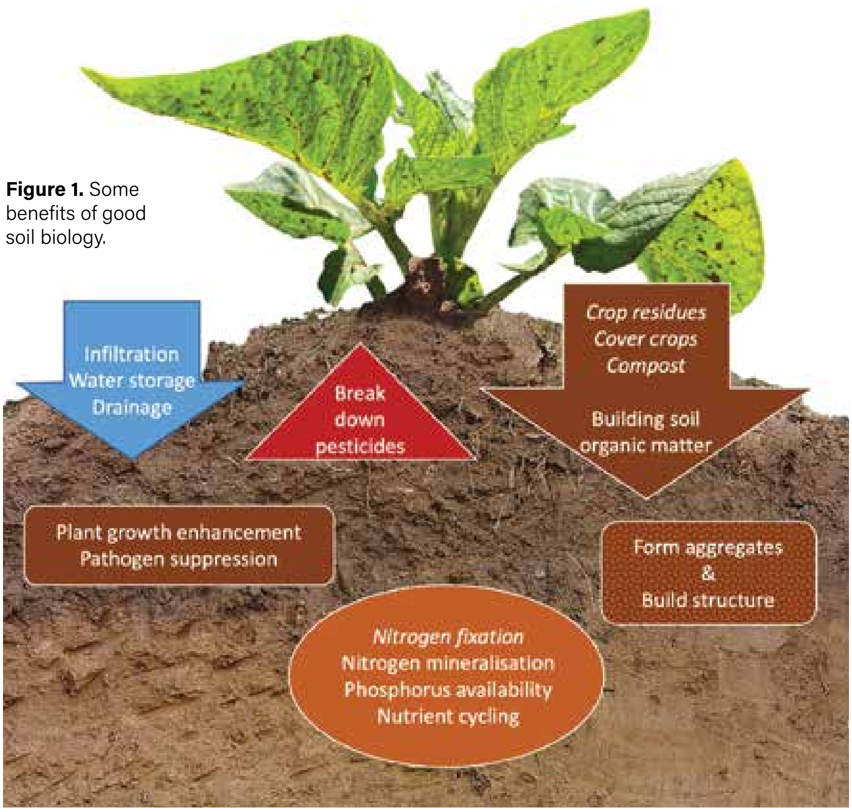


Figure 1. Some benefits of good soil biology.

SOILS TEEM WITH LIFE

Vegetable growing soils are rich in microbial life. There may be hundreds or even thousands of different species of bacteria, fungi and eukaryotes ('critters'). Even worn-out soils can still contain large numbers of different organisms.

Dr Kelvin Montagu has been examining the range of organisms present in soils used to grow vegetables and potatoes. "Soil from a potato farm in Forthside contained more than 500 species of bacteria, 200 species of fungi and 50 species of critters (e.g. nematodes, worms and springtails)".

"Even worn-out soils still have big microbial populations. For example, we worked on a farm in South Tasmania that was completely thrashed. Compared to some of the other farms we tested, there were a lot more species of bacteria than fungi present in the soil (Figure 2). This likely reflects regular cultivation. Despite this, significant populations of fungi and critters still remained, so the soil can be rehabilitated."

Soil biology means that when a potato seed sprouts, it is not into an empty space, but one already full of other inhabitants. As the shoot starts to grow into the soil, cells are shed from the root tips and exudates are

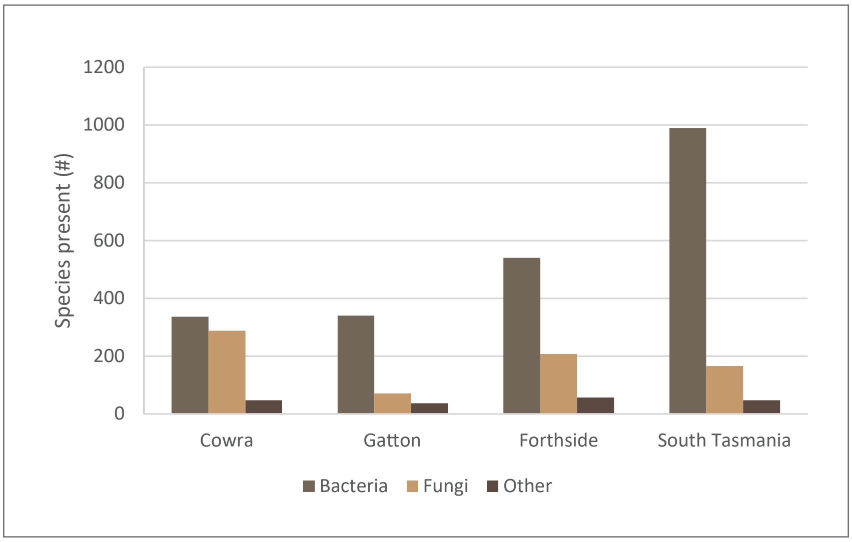


Figure 2. Number of species of bacteria and fungi and other phyla (e.g. nematodes, mites, insects) in soils used to grow potatoes and/or vegetables. - Data from K. Montagu

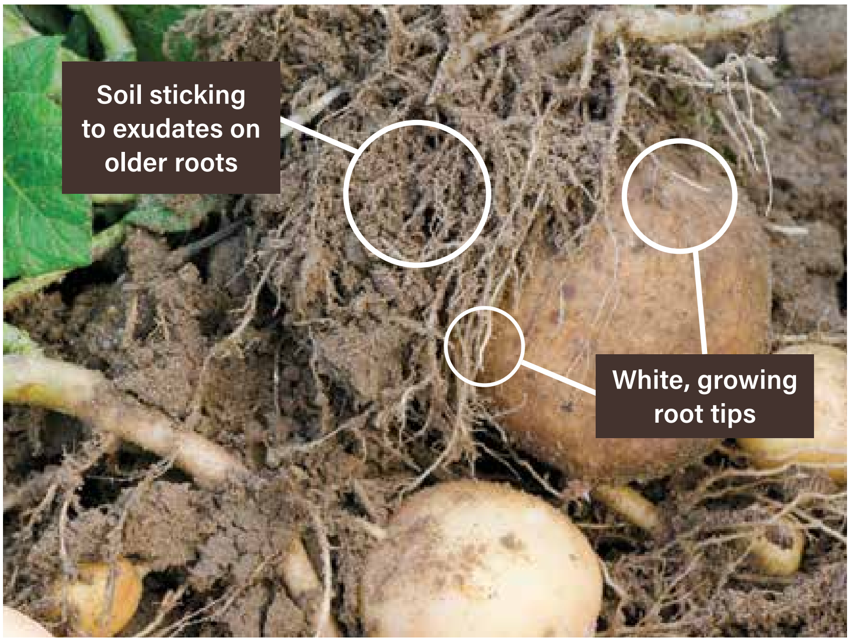


Figure 3. Roots and their surrounds are a biological hotspot

Figure 4.
Mycorrhizal fungi can help plants capture more nutrients from the soil. - UC ANR.

N.B. Mycorrhizae are not usually visible to the naked eye

released. These attract specific fungi and bacteria – which may be either beneficial or pathogenic.

After a few days of expansion the roots shed their fine hairs and form a waxy coating. Microbes become embedded in sticky compounds exuded from the surface, forming a barrier around the roots (Figure 3).

This means that beneficial organisms need to be already in the soil, ready to colonise the young potato plant right at planting. Otherwise, the young roots can be swamped by other organisms.

The benefits of mycorrhizal fungi to plants are well established. They improve moisture and nutrient uptake and can help to protect against disease.

Mycorrhizae live on carbohydrates produced by the plant. In exchange, they provide the plant with phosphorus and other nutrients from the soil (Figure 4).

Cultivation reduces natural populations of mycorrhizal fungi, which are often low in vegetable growing soils. Moreover, if the soil contains high levels of available phosphorus, the plant doesn't need its mycorrhizal partner, so the fungi may fail to establish.

HELPING THE GOOD GUYS

The two main things needed to activate soil biology are:

1. **Structure** – building them somewhere to live, with the right balance of air and water
2. **Food** – providing the raw materials needed to feed soil organisms

Bulk food includes crop residues, pasture (including roots) and cover crops incorporated into the soil. "These materials are like Weetbix for soil fungi, bacteria and earthworms. They use them as carbon sources as well as for the sulphur, phosphorus and other nutrients they contain" explains Dr Montagu. "Bulk feeding is incredibly important for improving soil structure. As bacteria and fungi feed on these materials they excrete the proteins and sugars that bind the soil particles together. Essentially, the microbes help build their own house."

Soil organic matter is a great indicator of soil health. Two of the best ways to increase soil organic matter are through use of cover crops and including pasture in the rotation.

It's possible to manage how quickly organic materials break down in the soil through crop selection, as well as manipulating the carbon:nitrogen ratio.

Dr Montagu gave the example for a cereal rye cover crop. "Terminating two weeks later than originally planned increased biomass from 7 t/ha to 9 t/ha as well as changed the C:N ratio from 30 to 45. The result was a much slower breakdown after incorporation into the soil."

"Wheat stubble has a C:N ratio close to 80, so it's really slow to break down. What's more, soil microbes may initially take nitrogen from the soil to help break down the stubble, making it unavailable to the plant. At the other end of the scale, a legume such as vetch has a C:N ratio of 15, so it breaks down extremely rapidly" explained Kelvin.

High C:N ratios favour fungi over bacteria. While fungi are slower, they convert more of the crop residue into soil organic matter, so effectively yield more soil organic matter for the same biomass inputs.

Soil microbes not only break down organic matter, but they are also vital to breaking down agrichemicals. Many chemicals would persist much longer in the environment if no biological activity is present. Essentially, the microbes use such chemicals as sources of nitrogen, carbon and other nutrients.

According to Dr Montagu "A side effect of repeated use of some agrichemicals is that you effectively select for microbes that feed on them. So they will be there in the soil, waiting for their next feed of metham sodium, or pre-emergent herbicide, or whatever.

The result is reduced chemical efficacy, because the biology breaks those products down so fast they aren't able to work."

Figure 5. Volunteer potatoes are a major issue, as they allow soil borne disease to persist. - R. Barrett.

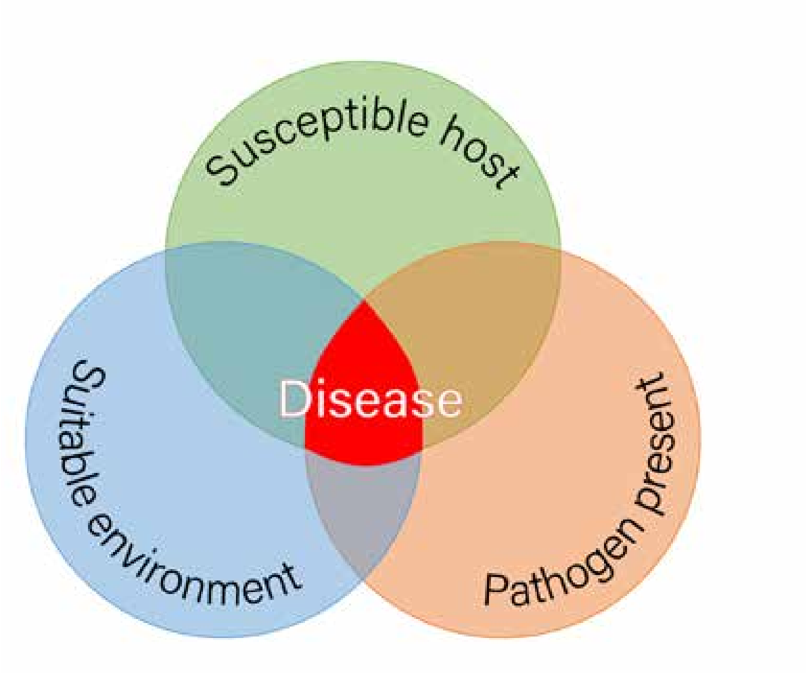


Figure 6. For disease to occur, the potato plant must be susceptible, pathogen present and environment suitable for infection – the classic "Disease triangle".

FIGHTING THE BAD GUYS

Just as the soil is rich in beneficial microbes, it is also inhabited by those that would do potatoes harm. Nematodes, bacteria, fungi, protists (such as powdery scab) and even viruses are ready to pounce on an unprotected potato plant and proliferate at its expense. Some are potato specialists (e.g. powdery scab and pink rot), whereas others have a broad range of hosts (e.g. *Sclerotinia*, *Rhizoctonia*).

Dr Calum Wilson is a plant pathologist and expert on soil-borne diseases of potatoes. "Most pathogens that multiply on potatoes die off if the

40 days | 68 days | 92 days

Figure 7. Breakdown of a ryegrass green manure crop in Cowra 40, 68 and 92 days after spraying out with glyphosate. - M. Hinderager.

potato or an alternative host is not there. This is the basis of crop rotation" states Dr Wilson.

"However, some diseases are good at surviving between potato crops, either by having a broad host range, or persisting on decaying organic matter. Certain pathogens form resting structures that can persist in the soil for years – powdery scab is particularly difficult to control due to this factor. Pathogens can also hitch a ride on contaminated seed, which is why clean seed is so important."

Volunteer potatoes are another big problem (Figure 5). According to Dr Wilson, volunteer potatoes are one of Tasmania's worst weeds; "if there are volunteer potatoes within the rotation, all you are doing is following a good potato crop with a bad one. That's why managing volunteers is critically important for disease control".

In general, poor soil biology favours infection. Poor soil structure reduces drainage and aeration, extending the time plants stay wet. Plants grown in non-biologically active soils are more likely to be stressed, making them susceptible to disease. Finally, low biological activity means there is less competition from other microbes compared to a soil with high organic matter. This can make it easy for the pathogen to persist and spread.

"Green manures, composts and cover crops all help improve soil biology, while tillage is frequently disruptive, especially to fungi," commented Calum. "Encouraging the beneficial soil microbes helps control the bad guys, as they will feed on them."

BALANCING SOIL BIOLOGY AND PLANT NUTRITION

Plants need nitrogen

Potatoes require balanced nutrients, and that includes a lot of nitrogen. Some varieties will use over 30kg of nitrogen a week during their early bulking stages, so that means somewhere between 150 to 300kg N/ha, depending on variety.

Estimating soil nitrogen requirements relies on three things:

1. **Available nitrogen within the root zone**
   - Requires strategic soil testing for inorganic nitrate and ammonium
2. **Soil organic carbon**
   - Estimate of in-season mineralisation
   - Test for organic matter, pH and CEC
   - Understanding the environment, including temperature, moisture and aeration in combination with soil biology

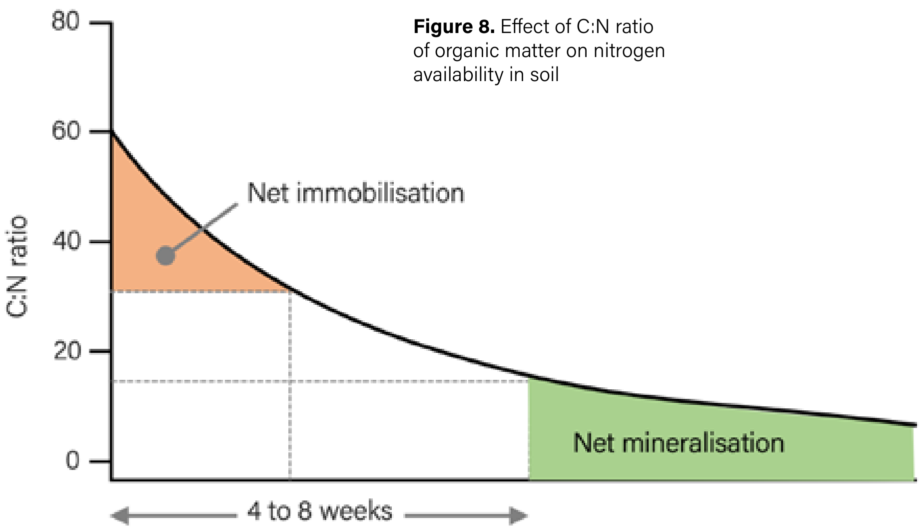


Figure 8. Effect of C:N ratio of organic matter on nitrogen availability in soil

3. **Previous crop residue**

- Estimate whether nitrogen will be tied up or released as crop residue degrades
- Amount of dry matter in the residue, its condition and position within the row
- Effects of climate and soil biological activity

Standard practice for soil testing is to sample the top 30cm. However, according to AHR agronomist Marc Hinderager, conducting separate tests of the top 0 – 15cm and 15 – 30cm gives far more information. "This is really useful if you're coming out of long-term pasture, or making decisions on whether to add soil amendments such as compost," suggests Marc.

NITROGEN IS UNLOCKED BY SOIL BIOLOGY

The conversion of organic nitrogen sources to nitrate depends on the activity of microbes in the soil. This process starts at around 5ºC, accelerates as it approaches 20ºC and peaks between 30 and 40ºC. Between 50 to 125kg N/ha can be mineralised annually from Australian soils, although ten-fold fluctuations are not uncommon.

"This means that soil tests are just a snapshot in time. It's important to consider this when estimating how much N the crop needs as the plants grow," commented Marc, "especially when considering breakdown of organic materials."

"For example, at our Cowra site we knocked down a green manure crop of ryegrass with glyphosate in mid-September. Ryegrass has a C:N ratio of 20:1. Combined with warm temperatures and 200mm of rain, this meant it was rapidly broken down by microbes (Figure 7)."

"By early December 60% of the organic N had been mineralised, effectively recycling 60kg N from the 100kg organic N contained in 2.5t/ha ryegrass residue. If the ryegrass had been incorporated, rather than left on the soil surface, it would have broken down around 10-15% faster".

At the same time as mineralisation is occurring, so is immobilisation. This is also driven by soil biology, in combination with temperature and moisture.

Crop residues with C:N ratios above 25:1 (like wheat stubble) will initially immobilise (tie up) soil inorganic nitrogen, making it unavailable to the plant (Figure 8). The factors that drive soil biology – temperature, moisture, aeration, pH and soil organic matter content – all influence the time taken to remobilise nitrogen, resulting in net mineralisation.

The biological activity within the soil can be estimated by measuring respiration. Microbes within the soil respire, absorbing oxygen and releasing carbon dioxide. The rate at which this is occurring reflects metabolic activity.

Sealing a portion of soil inside a container and measuring atmospheric changes provides an indicator of total microbial activity.

NITROGEN FROM LEGUMES

"As the price of fertilisers has increased, a lot of my farmers have been getting more interested in legumes," says Marc. "Legumes can fix around 20kg of N per tonne of dry matter, so long as good nodulation occurs. The roots can add another 35%. However, if the seed is harvested as a cash crop, that reduces fixed N to around 13kg/tonne".

Getting the right strain of Rhizobium bacteria is essential to get good nodule formation. Just as roots of potato plants signal to mycorrhizal fungi, so do the roots of legumes to Rhizobium.

Although Rhizobium are naturally present in soil, artificially inoculating seed with a good strain of Rhizobium will usually pay for itself. Commercial Rhizobium strains have been bred for effectiveness, and provide more reliable results than native Rhizobium in soil.

The total N fixed by legumes is also affected by soil nutrition. Good levels of molybdenum and a neutral pH help optimise results. Some research has indicated that phosphate and potash increase both the number of nodules, and the amount of N fixed (Figure 9).

Conversely, acid soils reduce N fixation for most legumes. Lupins are an exception, as they prefer acid soils.

Figure 9. Nodules on roots of legume - Neutrog Fertilisers

	Urea (CH_4N_2O)	Ammonium (NH_4^+)	Nitrate (NO_3^-)
Transformation in soil	Enzymes convert urea to ammonium.	Ammonium converted to nitrate by bacteria.	Bacteria convert nitrate to gas in warm, waterlogged conditions.
Plant available and efficiency	Can be taken up as a foliar. Limited availability (1-5 days) to roots due to rapid conversion to volatile ammonia by urease enzyme in soil.	Immobile in soil. Can be taken up directly. Potatoes prefer combination of ammonium and nitrate.	Mobile in soil (so can leach out). Can be taken up directly, potato plants.

Table 1. Biological processes and commercial fertilisers

High soil plant available N (>35kg/ha or 20ppm) will reduce N fixation by a similar amount; effectively, the rhizobia get 'lazy' if N is already abundant.

According to Marc, "Rhizobium species are the most proven biological product on the market. Peat inoculants should be kept cool and dry – in the refrigerator is good – and used as soon as possible after mixing with water to get best results. Just remember that some seed dressings and some chemical fertilisers can be toxic to them, so be careful of that".

NITROGEN FROM COMMERCIAL FERTILISERS

Nitrification is the conversion of NH_3 (ammonia) and NH_4^+ (ammonium) to NO_2^- (nitrite) and then to NO_3^- (nitrate). This mobilises nitrogen, turning it into the form most easily taken up by plants, but also potentially allowing it to leach into the environment. The process occurs rapidly in warm soils, so at 20°C a top dressing of ammonium sulphate will be converted to nitrate within a week.

Nitrification is driven by soil bacteria, including species of *Nitrosomonas*, which converts ammonia to nitrite, and *Nitrobacter*, which converts nitrite to nitrate. The bacteria are sensitive to low soil pH (pH<6), which is close to the optimum pH range for potatoes of pH 6.3 to 6.8. Managing pH is therefore essential to allow nitrification to occur.

Stabilised release fertilisers slow down nitrification by soil bacteria. This reduces nitrate leaching and emissions of nitrous oxide, making more nitrogen available to the plant and reducing the total number of top-dress applications required.

For more information on biological processes and fertilisers, a fact sheet is available on the Soil Wealth site at www.soilwealth.com.au/resources/fact-sheets/quick-guide-to-farm-nitrogen

WATERLOGGING SENDS NITROGEN BACK TO THE AIR

De-nitrification is the process by which nitrate is converted to nitrogen gas and lost from waterlogged soil. This process depends on soil bacteria and fungi – starved of soil oxygen, they utilise the oxygen in NO_3^-. De-nitrifiers are most common in the top layers of soil and active at above 15°C, especially if the soil remains waterlogged for 36 hours or more.

IN SUMMARY

A healthy soil is full of life. Bacteria, fungi, insects and larger creatures such as earthworms, all have a role to play in maintaining a healthy and productive soil. Biologically active soils will have better water infiltration and soil structure, improved nutrient management, and help potato plants resist the inevitable attack of soil-borne diseases.

Improving soil biology is not necessarily easy, especially given the tillage which is standard practice within commercial potato production. However, using suitable rotations, establishing cover crops, managing nutrition and avoiding soil becoming overworked or waterlogged can all help valuable soil microbes flourish.

As the silent workers in the field, they are well worth cultivating.

EYES ON THE WORLD

Recent advances in potato research and innovation

Transplanting hybrid potato seedlings at increased densities enhances tuber yield and shifts tuber-size distributions.

Van Dijk LCM., de Vries ME., Lommen WJM, Struik PC. 2021. Potato Research https://doi.org/10.1007/s11540-021-09522-z

WHAT'S IT ABOUT?

Diploid hybrid potato breeding is a new technology that allows faster production of new varieties with desirable traits.

Normal potatoes have four copies of every gene. Only one of these genes needs to work for the function to be expressed. The result is that potatoes have a lot of genes which do nothing, or may even have negative effects. As gene expression is unpredictable, this also means that crossing two varieties will not necessarily result in a hybrid with the desired traits.

New breeding techniques have produced self-fertile diploid potatoes, with two copies of each gene and stable traits. Crossing two of these lines results in an F1 hybrid. As only two copies of each gene are present, the characteristics are more predictable.

True potato seeds (TPS) are harvested when the F1 hybrid parent forms berries. A single gram contains 2,500 genetically identical TPS, allowing thousands of disease free seedlings to be produced from a single F1 hybrid parent.

TPS seedlings grown in the glasshouse are planted into the field. In contrast to plants grown from seed tubers, TPS seedlings form only one main stem. Plant density therefore equals stem density and may be manipulated to produce tubers in a preferred size range.

This Dutch study examined the effects of planting density of TPS seedlings on size and count of tubers. Densities ranged from 6 to 200 plants/m^2 grown in a flat bed system on sandy soil, and 3 to 50 plants/m^2 on a traditional ridge system with 75cm row spacings in clay soil.

WHAT WAS CONCLUDED?

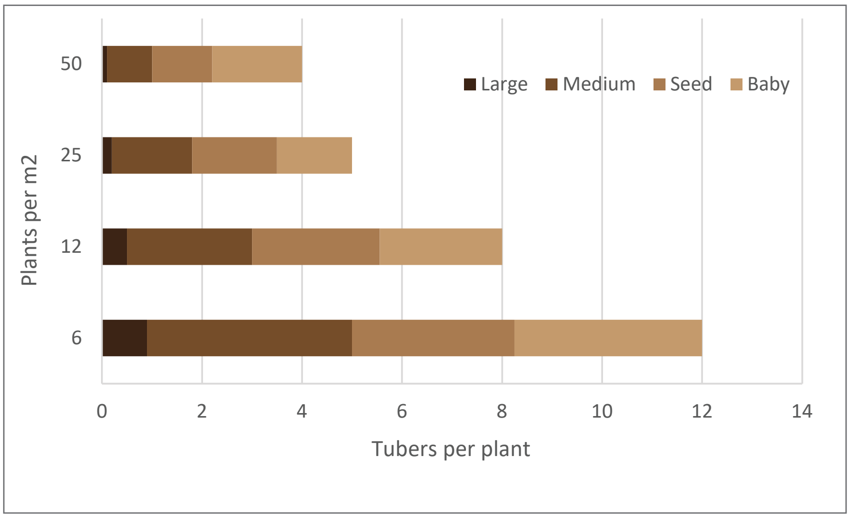
The highest tuber yields were 107 t/ha and 45 t/ha for the flat bed and ridge systems respectively. These were achieved with high planting densities, and correspondingly smaller tubers.

A maximum seed tuber (28-50mm) yield of 64 kg/ha was achieved planting 50 plants/m^2 on the flat beds. On the ridges, seed tuber yield was maximised at 25 plants/m^2.

Yields of large tubers (>50mm) were low, even at the lowest planting densities, and negligible in the ridge growing system.

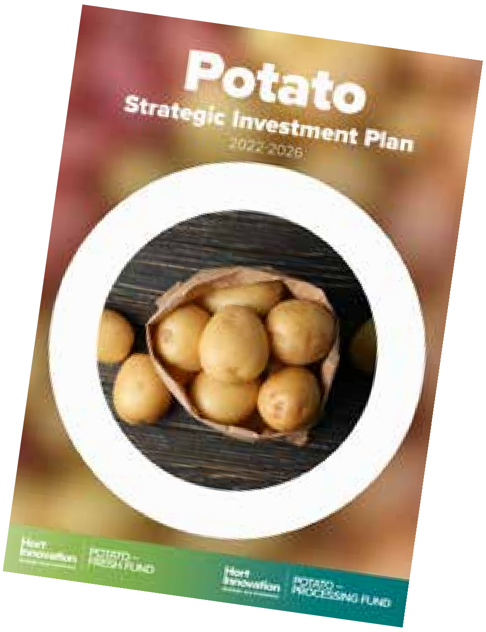
The researchers suggest that greenhouse derived seedlings may lack the capacity to lay down the carbohydrates needed for tuber bulking following tuber initiation.

However, it is concluded that this method may have commercial application in producing hybrid seed potatoes, or 'baby baker' ware potatoes. Further research is needed to determine how many seed production cycles would be needed to produce seed tubers that develop into plants with large size tubers.



Effect of TPS seedling spacing on the number and size of tubers per plant. Results shown for ridge system. Size ranges are large >50mm; medium 35-50mm; seed 28-35mm and baby 20-28mm. Data derived from van Dijk et al, 2021.

NEW POTATO INDUSTRY STRATEGIC INVESTMENT PLAN (SIP)



- By **Kim Saville**

Your levies working for you ... at a glance

The potato Strategic Investment Plan (SIP) 2022-2026 provides a 5-year roadmap to guide Hort Innovation's investment of both fresh potato and processing potato industry levies and Australian Government contributions, ensuring investment decisions are aligned with industry priorities.

Top priorities are to reduce the cost of production and improve the sustainability of production practices with effective management of pests, diseases, weeds and biosecurity threats. Growth in domestic and international consumer demand is also a focus for the fresh (non-processing) potato industry.

These are the strategies for the four key outcomes:

OUTCOME 1
Extension and capability

- Support industry best practices in biosecurity, precision input management, soil and plant health, and meeting quality expectations and trade development (for fresh potato industry)
- Engagement between industry, across potato and vegetable industry members and stakeholders, domestically and internationally
- Grow industry leadership through initiatives and training for the current work force, increasing horticulture as a career choice and bringing new people into the industry

OUTCOME 2
Industry supply, productivity and sustainability

- Improve productivity and sustainability through effective integrated pest and disease management (IPDM), weed control, soil health and cover crops
- Biosecurity preparedness and resilience, including surveillance and diagnostics
- Automation and emerging technology opportunities to support labour use efficiency, compliance and input management
- Prioritise the major crop protection gaps through a SARP
- Crop protection regulatory activities with the potential to impact plant protection product access, both in Australia and internationally
- Generate residue, efficacy and crop safety data to support applications to the Australian Pesticides and Veterinary Medicines Authority (APVMA)

OUTCOME 3
Create demand

- Increase domestic and international consumer demand for fresh, quality Australian potatoes
- Increase consumer demand in high value export markets
- Deliver an up-to-date export strategy and access to trade expertise for fresh potatoes
- Improve technical access to high value markets as identified within the export strategic plan

OUTCOME 4
Business insights

Increase fresh potato industry alignment with quality and brand-positioning opportunities driven by consumer insights

Use trade data to guide ongoing export development opportunities for fresh potatoes

You can access the [comprehensive potato SIP here](#).

Hort Innovation
Strategic levy investment
POTATO – FRESH FUND

Hort Innovation
Strategic levy investment
POTATO – PROCESSING FUND

POTATOLINK
AUSTRALIAN POTATO INDUSTRY EXTENSION PROJECT