Hort Innovation

Final Report

Impact of Groundwater Quality on Management of Centre Pivot Grown Potato Crops

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Project code:

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Content

Summary

Australia grows on average 1.3million tonnes of potatoes per year, which accounts for 40% of all vegetable production. The state of South Australia is the largest producer of potatoes in Australia, growing 385,000 tonnes annually, comprising 80% of Australia's fresh market potatoes. Potato production across the major growing regions of the state is however challenged with salinity, with saline irrigation water sources and variable soil salinity limiting crop potential. While the true cost to potato production is unknown, crop yield in some areas may only achieve 50% (PotatoesSA).

This project undertook detailed assessments of both fresh and processing potato production across three of the major potato growing regions of South Australia; the Mallee, the Northern Adelaide Plains and the South East/Limestone Coast. While irrigation water quality and variability were the primary focus, the application of this water to soils and the ensuing site conditions during crop growth through to harvest, were monitored closely in order to determine the impact of water quality on crop production for each region.

Irrigation water quality was variable between regions, with major groundwater systems driving regional water quality (WaterConnect). Within regions, local bore water quality did vary, but was consistently saline with conductivity levels (ECw) ranging between 1.7 & 3.9dS/m. Sodium and chloride were dominant salts, with levels two to eight times above upper desirable threshold levels for potatoes.

The application of these highly saline irrigation water supplies to crops not only impacted directly on potato health with yellowing of plant leaves and scorching of leaf tips, but also resulted in the addition of salts to soils, where root zone salinity levels increased throughout the crop life, and soil structure declined.

Additional to the impacts of salinity and nutrient availability on potato management, inherent soil variability within centre pivot irrigation systems and the presence of hydrophobic sands, combined with the increasing occurrence of long periods of heat stress, created additional challenges for growers to achieve optimal potato production.

From these identified limitations to potato production across South Australia, trials were conducted to address management options that would provide growers with tools and techniques to maximise productivity and profitability. Understanding irrigation water quality, what salts cause high conductivity levels, and what salts are applied in fertiliser programs formed the foundation of all trial work.

Alternative fertilisers low in chloride and high in soluble calcium, nitrates, sulphates and phosphorus, were trialed to improve the flushing of chloride and sodium, and resultant uptake of nutrients that are otherwise unavailable in highly saline conditions. Alternative biological products were also trialed to boost plant productivity, such as mycorrhizal fungi to assist with nutrient and moisture uptake, and improved resistance to potential disease pressure. A soil conditioner was also trialed to improve water infiltration and uniformity of wetting within the rootzone of plants in hydrophobic sands.

All trials yielded positive results, presenting cost effective opportunities for fresh and processing potato growers to improve potato production across the major growing regions of South Australia. The outcomes of this project will also contribute to the broader potato industry, raising skills and awareness of growers across Australia, assisting with longer-term productivity goals and competitiveness in overseas markets.

Keywords

Salinity; salts; potato production; groundwater quality; irrigation water quality; fresh market potato industry; processing potato industry; nutrient availability; hydrophobic soils.

Introduction

Salinity across Australia has been well documented over the years, with agriculture and related practices within most states detrimentally affected. In South Australia the loss of agricultural production to dry-land salinity alone is estimated at $47 million per annum. Similarly, salinity threatens groundwater districts and communities that rely on irrigated farming, which coincide with South Australia's major potato growing regions. South Australia is the largest producer of potatoes in Australia, growing more than 385,000 tonnes of potatoes annually, however optimal yield and quality of potatoes is often limited due to salinity. In some areas, yields achieved are down as much as 50%.

Salinity not only limits current production potential, but the ongoing sustainable production of potatoes under future climate projections where warmer and drier conditions are likely, is also compromised. As importation of potatoes is not a desirable outcome for South Australia, a more in-depth look at salinity and how it impacts potato production was necessary.

Intensive horticultural production and increasing expansion of agriculture into more marginal soils, will continue while world populations continue to grow. Therefore, we need to become smarter and more efficient, at producing food in these conditions. In order for South Australian growers to maximise yield potential across both fresh and processing potato markets, this project first aimed at gaining a thorough understanding of baseline soil and water salinity levels across three major growing regions, combined with current grower practices, to determine the greatest limiting factors to production. Understanding these constraints, would then enable management options to be tailored for growers within each region, facilitating the most desirable practice change necessary for positive lifts in yields and quality, while minimising costly inputs.

While site conditions and natural resources varied across the three regions, the common underlying factors contributing most to sub-optimal production were highly saline irrigation waters, variable soil types, non-wetting sands and uneven watering of mounds, heat stress, and resultant nutritional imbalances. Unfortunately, there is little that can be done to address the poor-quality irrigation water used for potato production. While there are treatment options available, these are not cost effective and would be very difficult for growers to implement. Therefore, managing the soil, water and nutrient environment within the root zone of the developing tubers is the most ideal way to maximise crop quality and yield in these saline environments.

Trials implemented during this project addressed the conditions that commonly lower tuber quality and potato yields. Soil conditioners, biological products, and high quality fertilisers were trialed with growers, providing encouraging results that show cost effective management options can lift yields in saline environments.

Methodology

The broad aim of this project was to develop and deliver effective management strategies for the sustainable and profitable production of potatoes under compromised conditions within major potato growing regions of South Australia. The Northern Adelaide Plains, the South East Limestone Coast and the Mallee were the primary regions chosen to undertake this work, with growers of both fresh market and processing potatoes represented.

The first stage of this project focused on the collection of extensive baseline site data across eight potato varieties of the three regions involved. Given varying planting and harvest times, a staggered approach to data collection was implemented between each region. Data collected during Year 1 included:

A) Irrigation water samples. Three samples were collected per season where possible, including irrigation season start, mid-season and end of season, in order to determine possible changes in salt loads that may occur. All irrigation water samples were submitted to AgVita Analytical for analysis using the AquaSure test for irrigation waters.

B) Soil sampling. On site soil pits were dug to determine characteristics such as depth of soil, soil structure and texture prior to site establishment. The number of pits assessed was based on general site variability including topography and visual changes in soil type, along with guidance on soil textural variability depicted in EM38 induction maps. The presence of shallow perched water tables, particulate organic matter, hydrophobicity and presence of macro soil fauna was also assessed.

Plate 1. Soil pits dug in the Mallee and the South East, used to determine soil characteristics across pivots.

Composite soil sampling for detailed soil nutrient analyses was also undertaken prior to site establishment. All soil samples were submitted to AgVita Analytical for complete Express Soil testing which includes a full suite of macro and micro nutrients along with many other soil fertility indicators.

Soil DNA testing was also undertaken to determine baseline risks for pathogens and pests that may influence potato quality and yield. Soil samples collected were submitted to SARDI for Predicta Pt analyses.

Soil samples were also collected and submitted to Microbiology Laboratories Australia for analysis of soil microbial composition including fungi and bacteria, their diversity and population densities.

C) Soil solution sampling. Solusamplers were installed at each site, using Sentec solusamplers. Solusamplers were installed in a nested design, at 20cm, 30cm and 40cm depth. These depths were chosen in order to determine salinity levels in soil solution surrounding the developing potato tubers, and potential increases in salts, or movement of salt at each depth throughout the life of the crop. Solusamplers were installed following the completion of all site mounding practices.

Plate 2. Solusampler installation in the Mallee.

D) Plant sap sampling was undertaken regularly at key crop growth stages in order to assess nutrient uptake, particularly salts, by plants at the time of sampling. Plant petioles were collected and submitted to AgVita Analytical for Nu-test sampling where 15 major and trace elements were reported on.

Dry tissue testing of potato tubers, peel and flesh, was also conducted in order to assess the total amount of nutrients taken up by the tubers. While there is currently little information or baseline data for the Australian potato industry, minimum desirable levels of calcium are recommended for improved storage quality.

E) Final assessments of yield, including quality, quantity and specific gravity for processing potatoes, were assessed prior to commercial harvest. Assessments were conducted by lifting four 3m strips of potatoes. For each strip, plant and stem numbers, tuber numbers and weights, and tuber quality were assessed and measured. From this data, estimated potato yields could be calculated, along with an assessment of common tuber blemishes occurring at each site. Yield data was calculated using the following yield estimation process.

1. Row spacing was measured, and metres of row per hectare calculated as follows, using 0.8m row spacing as an example:
   1ha = 10,000sqm/0.8 m (row/ha)
   1ha = 12,500m of row/ha
2. 3m of row = 3/12,500 ha
   = 0.00024ha
3. Yield = tuber weight(kg)/0.00024
   =kg/ha

F) Statistical analyses used were Paired T tests for trials with two treatments, and One-Way Anova with Tukey Pairwise Comparison for means separation for trials with more than two treatments. Error Bars shown in all graphs are standard error bars. Statistical Analyses conducted by TRAP Services.

G) Return on Investment (ROI) for each trial was calculated by multiplying the increased yield of treatments above that of the Control yield, by the expected $/T to be gained for each grower's product. The $/T gained was then divided by the cost of the product/ha, providing a $ return on investment. This ROI does not take into account any other costs associated with product application.

H) Overarching these data sets, broader scale mapping and assessment was also undertaken. Electromagnetic Induction surveys were conducted where possible in order to spatially map soil textural and conductivity zones. This data provided guidance to key soil sampling areas, and also provided an indication to growers of spatial variability that would most likely coincide with crop productivity and yield.

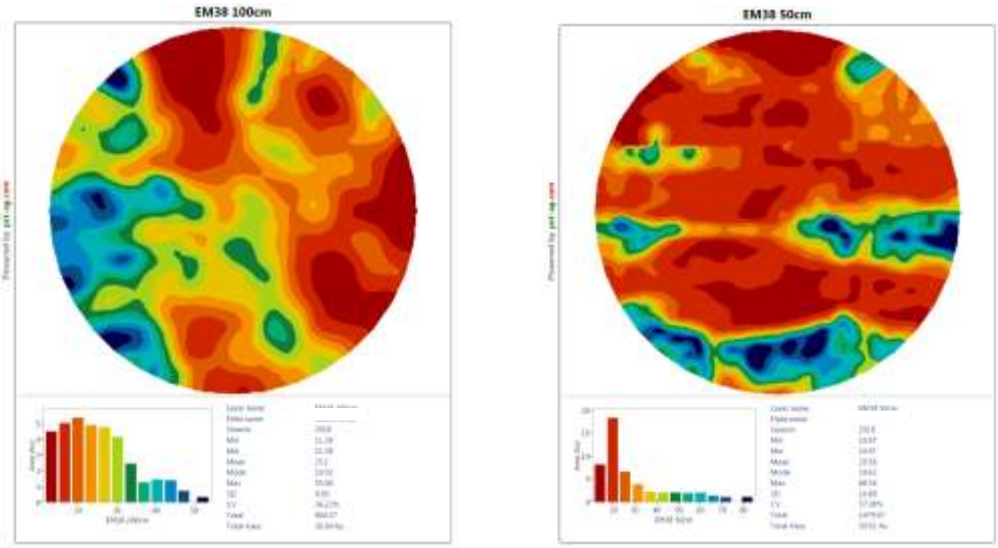

Figure 1. Examples of EM 38 survey results averaged over 50 and 100cm depths, displaying site variability.

I) Satellite imagery for each region was also purchased through 'iek base', a new CSIRO based platform primarily aimed at monitoring plant vigour throughout the season. Plant vigour, modelled from NDVI (normalised different vegetation index) captured data, was introduced to growers where crop vigour could be viewed for the entire pivot, highlighting areas of differing productivity. Growers were provided with personalised access to their crop data throughout the season following introductory sessions on 'iek base' use and data interpretation.

Other relevant site data that may have influenced site management, such as regional groundwater systems, local well data and broad scale soil mapping, was sourced through state government web sites such as AgInsight and Water Connect.

The analysis of data collected throughout the first stage of this project, combined with grower liaison, was then used to determine the major limiting factors influencing potato production within each region, and the formulation of specific trials to address them.

Four areas of research were defined for Stage 2 of this project. This included:

1. Improving infiltration of irrigation water through targeted management of non-wetting soils;
2. Re-addressing crop nutrition through regular monitoring and appropriately adjusted fertiliser programs;
3. Reducing salt accumulation within the root zone through improved salt leaching;
4. Improved provision of stress relief through soil amendments and use of specialised products.

(It is important to note that all trials were established within commercial potato crops, and as such, no on-site replication occurred for treatments applied. Areas treated were appreciable within each pivot or paddock, with four replicant areas sampled from within each treatment for the Mallee and South east trial, and three replicants sampled for all Northern Adelaide Plains trials due to time limitations).

1. Two trial sites were established to assess methodologies for improving infiltration of non-wetting soils, one in the South East for processing potatoes and one in the Mallee for fresh market potatoes. Transformer, a soil conditioner consisting of natural cold pressed orange oil, formulated with a special blend of surfactants, was chosen for these two trials, a product that was compatible with herbicides and fungicides typically used in potato production, and therefore more easily incorporated into current grower programs.

   Three application methodologies were trialed and compared against an untreated control area for each site as shown in Figure 2, including;

   1. Broadscale fertigation application pre plant – Rate 10 litres per hectare
   2. Infurrow application at planting - Rate 2 litres per hectare
   3. Combined fertigation and infurrow application – Rate total 12 litres per hectare
   - https://www.oroagri.com/

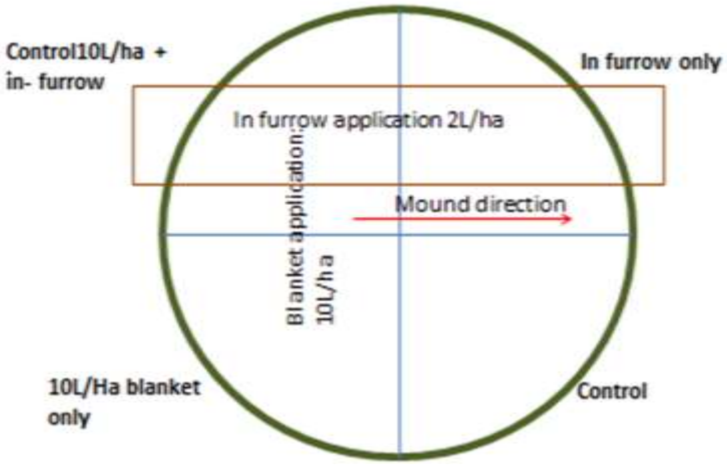

Figure 2. Trial design for product application methodologies to assess improvements to irrigation water infiltration of non-wetting soils.

Data collected at each trial site included the same suite of tests and assessments (A to G) as detailed for Year 1. Satellite Imagery for year 2 trials however utilised free online NDVI imagery via DataFarming.

2. Crop nutrition, improved salt leaching and the use of soil amendments and specialty products were combined within grower trials, with one site established in the South East for processing potatoes, and three sites in the Northern Adelaide Plains for fresh market potatoes. This included aspects of the 2nd, 3rd and 4th areas of research.

Specific products trialed included:

Calcium thiosulphate (Thiocal) – A quality liquid fertiliser that supplies readily available calcium and sulphur for plants in a solution that is significantly more soluble than gypsum. The readily available calcium not only enhances nutrient uptake in saline environments, but also acts as a soil amendment that assists with leaching harmful salts from the root-zone and improving soil structure in highly saline environments. Calcium thiosulphate is an excellent substitute for chloride based fertilisers, such as muriate of potash (MOP).

- Application rates: Approximately 20-50L/ha – site dependent
- https://www.campbellsfert.com.au/product/product-type/liquid-fertilisers/thiocal/

Arbuscular Mycorrhizae Fungi (EndoPrime) – a biological soil enhancement product that contains four high performing mycorrhizae species plus humic acid, a biostimulant, to assist with nutrient uptake.

- Application Rate: 150g/ha applied in-furrow at planting
- https://www.sumitomo-chem.com.au/endoprime

Arbuscular Mycorrhizae Fungi (Mycogel) – a water soluble biological inoculant that contains *Rhizophagus Irregularis* (*Glomus spp*) (5x107 propagules/litre) formulated in sterile gel. Mycogel also contains hyphae and secondary metabolites for immediate colonisation and enhanced plant function.

- Application Rate: 1litre/ha applied in-furrow at planting
- https://sustainablefarming.com.au/products/?wpv-product-range=soil-health

Mycorrhizae fungi colonise plant roots, with hyphae extending out into the root-zone well beyond the capability of the actual root hairs. The symbiotic relationship established between mycorrhizae and plant roots then facilitates improved uptake of nutrients and moisture otherwise inaccessible to plant roots. Mycorrhizae fungi also produce enzymes that help to release nutrients that can bind to soil particles and otherwise be unavailable, such as soil phosphorous in alkaline soils. Mycorrhizae fungi also form structures in plant roots called vesicles, which are believed to store both nutrients and water which may assist with overcoming heat stress in the potato growing regions in South Australia.

Liquid ammonium polyphosphate (Iperen IPE) – is a unique formulation containing 3.5 % nitrogen (w/v), 17.8% phosphorus (w/v) in the form of pentoxide (P_2O_5), and zinc 2.1%. IPE improves phosphate and micronutrient availability for plants, and is importantly very low in sodium and chloride, highly suitable for use in saline environments. IPE helps to improve nutrient use in both alkaline and acidic soils, and assists with both plant root and shoot growth.

- Application Rate: 10 litres/ha applied in-furrow at planting
- https://www.vaniperen.com/products/iperen-ipe-liquid/

Micronutrients (Brexil Mix and Brexil MN) – Brexil Mix and Brexil Mn are uniquely formulated trace elements from Valagro, supplying readily available nutrients to plants, assisting with plant health and productivity with combined low environmental impact. Brexil trace elements are combined with LSA, a natural substance that improves penetration efficiency and absorption at the cellular level. The formulation and function of Brexil trace elements should enhance uptake in saline environments and improve plant performance with overall reduced inputs.

- Application Rates: 1kg/ha foliar application
- https://www.valagro.com/en/products/farm/

Site assessments and data sets collected for these trials generally included the same suite (A-G) as detailed for Year 1. Some minor variations did apply.

Communication

Due to the confidentiality required of all data collected, specific documented case studies and field days could not be undertaken.

Planned regional workshops and information sessions near completion of this project could not be undertaken at the time due to the COVID-19 global pandemic and federal imposed travel restrictions. As an alternative means of raising awareness and improving grower monitoring and management techniques to lift potato production, a series of fact sheets were developed, promoted and distributed via several social media outlets and web sites of; AusVeg, EEMuir & sons, Serve-Ag, Soil Wealth and Integrated Crop Protection and Potatoes SA. The Salinity and

Potato Production Fact Sheets composed four parts:

1. Monitoring for improved management
2. Know your salts to better manage potato nutrition
3. Managing hydrophobic soils in potato production
4. Organic sol amendments, biologicals and biostimulants

Four Webinars were also conducted to further promote project outcomes, based on the Fact Sheet series. Webinars were delivered towards the end of the project, in collaboration with the Soil Wealth team, with webinar recordings available on the Soil Wealth web site (https://www.soilwealth.com.au/resources/webinar-recordings/)

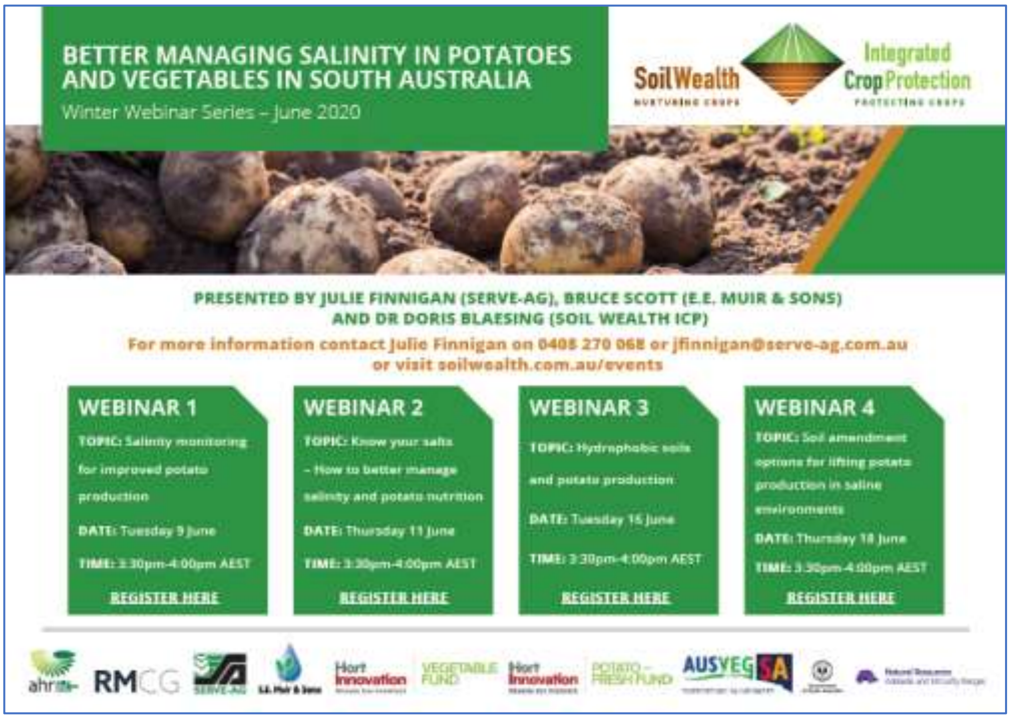

Plate 3. Salinity and Potato Production Webinar Flyer.

Outputs

Milestone status reports

Timely submission of detailed MERI Plan (Appendix 1).

Seven monthly milestone reports were generated and submitted on time throughout the duration of this project.

At the conclusion of year 1 and the Stop/Go Milestone, a detailed proposal was also submitted to the Project Reference Group, outlining proposed management options to trial during years 2 & 3 of the project (Appendix 2).

Specific project outputs (No links or attachments due to confidentiality)

Regular on-site liaison/discussions occurred with all growers involved in the project. Results were shared and discussed as they were generated, and additional to this, confidential grower summary reports were provided at the completion of each season. Due to confidentiality, these individual grower reports are not attached to this final report.

Thomas Foods Potato Grower Group – Evening presentation, titled "Green manuring and soil health management". Gawler, South Australia, July 24th, 2017.

Project Communication

The confidentiality requested by growers participating in this project limited the ability to publicly promote project activities and outcomes among the wider community during delivery. In particular, this impacted on planned grower case studies and field days. In order to honour grower confidentiality, minimal communication of project outcomes involving participants or their properties, were agreed upon.

Two interviews and subsequent publications did occur early in the project via Michelle De'Lisle, writer/journalist with AUSVEG, and approval from the Project Reference Group (Appendix 3).

- December 15, 2017. AusVeg Grower Success Stories - Real results from the Potato R & D Levy. Tim Heysen, Breaking New Ground.
- July 2018 Potatoes Australia. Understanding the Impact of Groundwater on Potato Crops.

In early March 2020, the Covid-19 pandemic and associated travel restrictions imposed immediate limitations to planned presentations of project outcomes during the final six months of the project. This resulted in the development and production of four fact sheets, all part of a series titled 'Salinity and Potato Production' (Appendix 4). Digital and print versions were produced, titled:

1. Monitoring for improved management
2. Know your salts to better manage potato nutrition
3. Managing hydrophobic soils in potato production
4. Organic soil amendments, biologicals and biostimulants

These fact sheets detail the major limitations faced by potato growers within South Australia, how best to implement monitoring, and a range of management options that will assist growers to improve tuber quality and yields, and can be found in full in Appendix 4.

Four Webinars were also developed and presented to further promote project outcomes, based on the Salinity and Potato Production Fact Sheet series. Webinars were delivered in June 2020 in collaboration with the Soil Wealth and Integrated Crop Protection Team, with webinar recordings also made available on the Soil Wealth web site.

The production of the fact sheet and webinar series will provide a long-lasting legacy of the project outcomes for growers of both processing and fresh market potatoes across Australia to access. Additionally, while the focus was on potato producers, there are many tips and take-home messages that will assist all vegetable growers to better understand and manage salinity.

AUSVEG Weekly Update – Tuesday June 2, 2020

AUSVEG Weekly Update – Tuesday June 9, 2020

Webinar links

https://www.soilwealth.com.au/resources/webinar-recordings/

https://www.soilwealth.com.au/resources/webinar-recordings/salinity-and-potato-production-part-1-of-4-monitoring-for-improved-management/

https://www.soilwealth.com.au/resources/webinar-recordings/salinity-and-potato-production-part-2-of-4-know-your-salts-to-better-manage-potato-nutrition/

https://www.soilwealth.com.au/resources/webinar-recordings/salinity-and-potato-production-part-3-of-4-managing-hydrophobic-soils-in-potato-production/

https://www.soilwealth.com.au/resources/webinar-recordings/salinity-and-potato-production-part-4-of-4-organic-soil-amendments-biologicals-biostimulants/

Webinar Number	Web site Registrations	Attendees
1	45	26
2	42	19
3	44	20
4	45	18

Registrations represented a good mix of growers and advisors, however attendees on the day was generally dominated by advisors and consultants, with a few growers and processors. This was to be expected as it is often difficult for growers to attend meetings, and would usually watch the webinars later at a time more convenient to them. This does however, influence the result of some of the poll questions asked during the webinars. For example, I would expect advisors to undertake more testing, and be more aware of the salts in fertilisers such as MOP.

Webinar Poll results

Question	Yes	No	Response rate	Comment
Do you test your irrigation water quality?	8	3	42%	2 of the 3 No's were growers
Do you work with hydrophobic soils?	5	4	45%	>50% do, therefore area for increased awareness & demo
Do you conduct SAP tests?	6	1	37%	Majority yes, pleasing but mainly consultants
Do you use MOP?	1	8	47%	Unexpected result, did not reflect grower usage during project
Do you use compost?	7	6	72%	Great to see, definitely a growing trend
Do you use biologicals/biostimulants?	5	7	67%	Surprising level of adoption, likely reflecting role of those responding

Fact sheet links

https://www.soilwealth.com.au/imagesDB/wysiwyg/FactSheet1-SalinityandPotatoProduction-MonitoringforImprovedManagement-V4CMYK.pdf

https://www.soilwealth.com.au/imagesDB/wysiwyg/FactSheet2-Knowyoursaltstobettermanagepotatonutrition-RGB.pdf

https://www.soilwealth.com.au/imagesDB/wysiwyg/FactSheet3-SalinityandPotatoProduction-Managinghydrophobicsoilsinpotatoproduction-V4CMYK.pdf

https://www.soilwealth.com.au/imagesDB/wysiwyg/FactSheet4-Organicsoilamendmentsbiologicalsbiostimulants-RGB.pdf

Plate 4. Collation of Salinity and Potato Production Fact Sheets produced.

An additional Zoom presentation titled; Salinity, Crop Nutrition and Irrigation Management in SA Vegetable Crops, was also conducted in partnership with AusVeg SA - Jordan Brook-Barnett, Doris Blaesing (RMCG) and Ivor Gaylard (SWAN Systems). This presentation, held on 24 June 2020, had approximately 15 registrants from SA involved in vegetable and viticulture production in saline systems.

Advisory Committee Meetings

1. Advisory Committee Meeting, Mt Gambier. Monday March 20th, 2017.
2. Advisory Committee Meeting, Mount Gambier. Tuesday July 11th, 2017
3. Advisory Committee Meeting, Mount Gambier. Tuesday January 30th, 2018.
4. Advisory Committee Meeting, Mount Gambier. Wednesday June 13th, 2018.

Outcomes

Results obtained during Year 1 of data collection from the three potato producing regions, showed similarities across a number of key data sets. A detailed summary is provided in Appendix 5. These results shaped the direction of trials implemented in years 2 and 3, ensuring that key limiting factors for potato production in salt affected regions, were addressed with the aim of increasing tuber health and quality. While it was quickly recognised that water quality could not be easily or cheaply addressed, management options focusing on improving soil moisture and balanced nutrient uptake were prioritised.

Year 2 trial results.

Improving infiltration of irrigation water through targeted management of non-wetting soils.

Results from the infiltration trials established in the Mallee and South East, showed that initial soil wetting was improved through the broadscale application of Transformer via fertigation or spray rig prior to planting. Following initial trepidation from growers based on past experience with other products and the general unknown that accompanies trialing new products, their on-site observations were very positive including:

- Ease of use and handling.
- Extremely limited chemical exposure due to natural orange oil composition.
- Observed rapid infiltration of product applied broadscale to soil surface compared to untreated areas.
- Marked decrease in wind erosion to areas receiving broadscale application.
- Reduced erosion and slumping of potato mounds.
- Improved harvesting condition of soils.

Trial assessment data and harvest results that accompany these observations include:

- Improved uniformity of water penetration in mounds, with little to no 'dry pockets' as observed in untreated control areas, demonstrated in Plate 5.

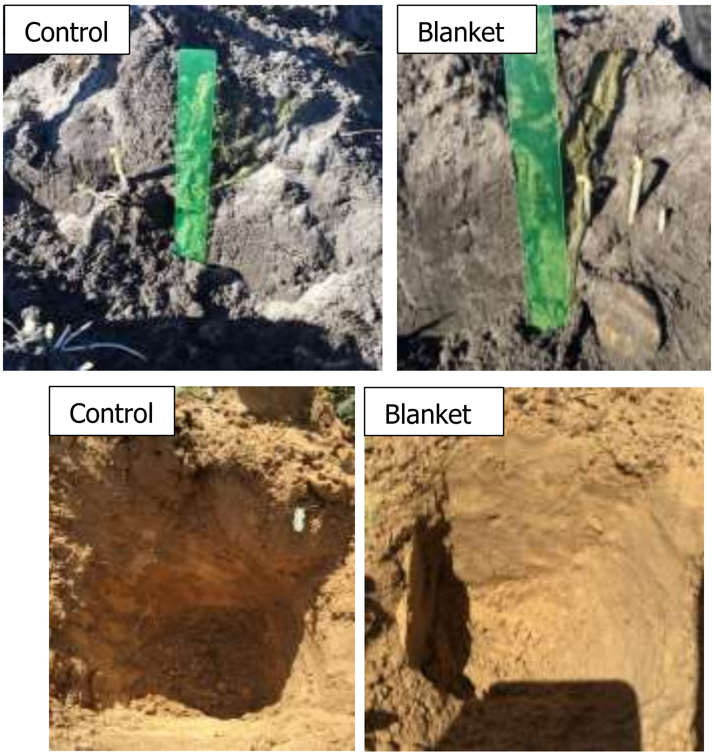

Plate 5. The presence of dry pockets and uneven water penetration in untreated controls (L) compared to more uniform wetting in broadscale blanket applied treated areas (R).

- Improved root development of seedlings at early hook stage treated with Transformer, compared to control areas as seen in Plate 6. The root system of the combined Blanket and In-furrow treatment seedling is clearly more vigorous, and the seedling vigour of both Blanket treated seedlings is greater than the In-furrow and Control plants.
- Continued improved root development of plants treated with Transformer (Plate 7).

Plate 6. Increased root mass and general plant vigour in treated areas compared to control.

Plate 7. Vigorous fibrous root development of Transformer Infurrow treated plants (L) compared to Control (R).

There was a significantly reduced (P=0.000) occurrence of total processing tuber blemishes typically associated with irregular watering of potato mounds during tuber development and growth, for all treatments compared to the control. Figure 3 shows the average percentage of blemishes for each treatment compared to the Untreated Control by size class.

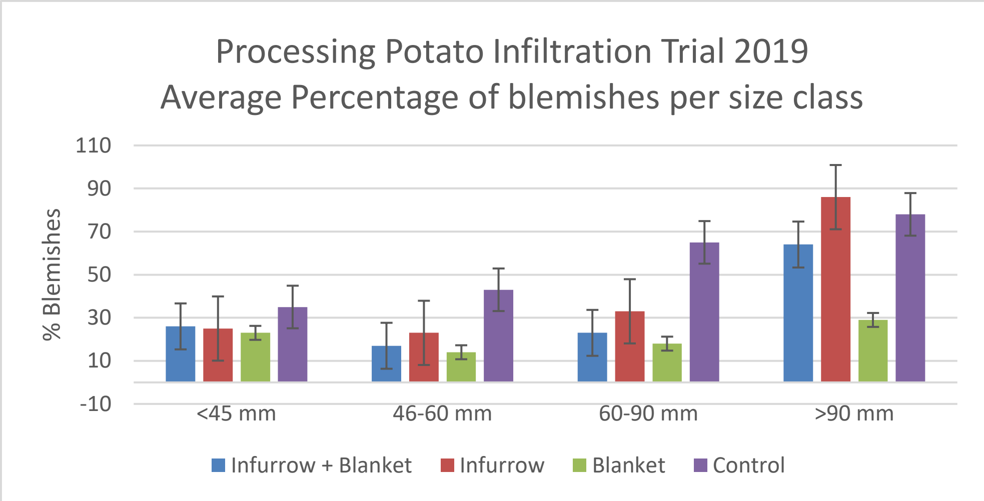

Figure 3. Reduced tuber blemish numbers for Blanket application of Transformer across all size classes.

The total number and weights of processing tubers were not significantly different between the different treatments, however total yield of marketable potatoes (Total yield minus total yield of tubers with blemishes) was significantly greater (P=0.027) in the Blanket treatment compared to the Control (Figure 4).

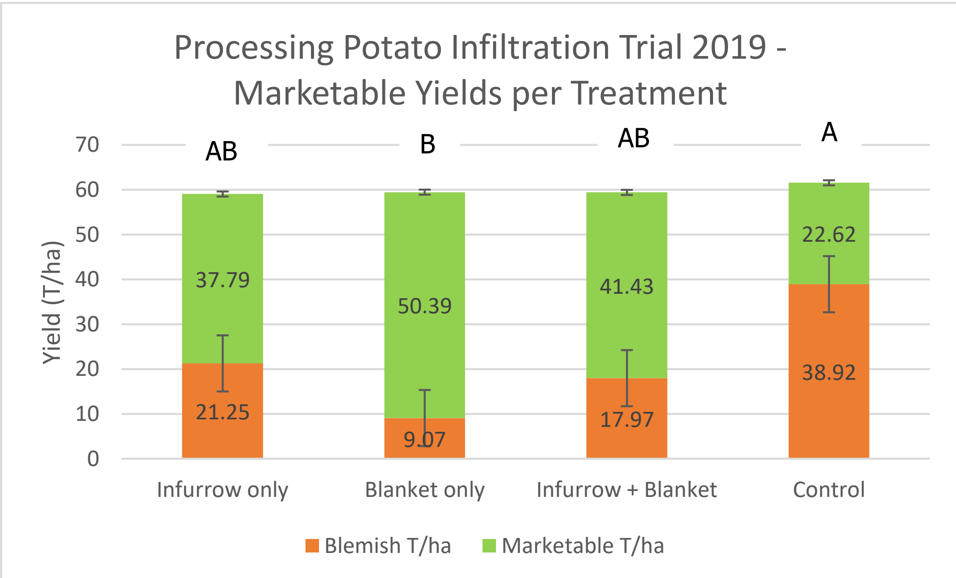

Figure 4. Marketable yield of processing potatoes by Transformer application methodology compared to untreated areas.

The ratio of tubers numbers with blemishes per treatment type was similar for fresh market potatoes, however there was no statistical difference detected between treatments (P=0.154). Marketable yields between treatments were not statistically different either (P=0.079), however the In-furrow and In-furrow and Blanket treatments did yield approximately 3T/ha above the control (Figure 5).

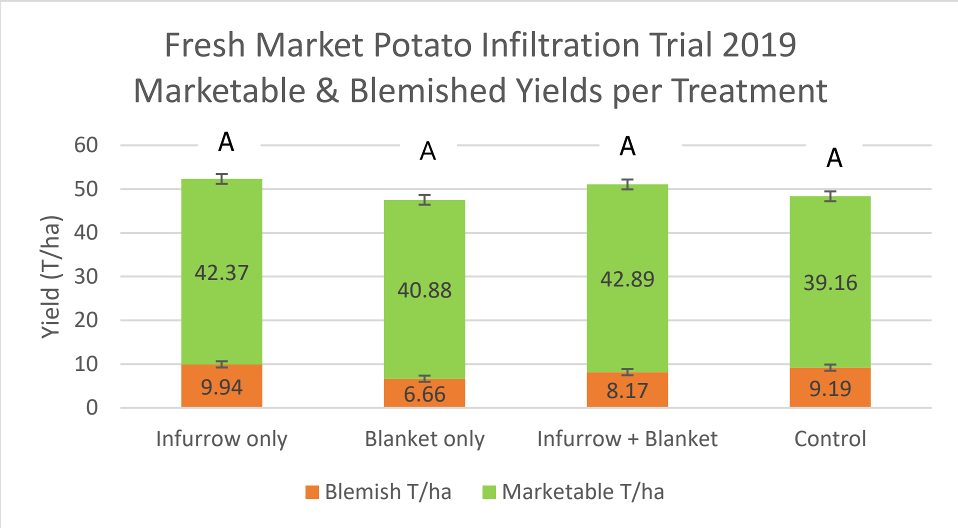

Figure 5. Marketable yield of fresh market potatoes by Transformer application methodology compared to untreated areas.

Blanket treatments for both fresh and processing potatoes resulted in less green and blemished potatoes, most likely a result of reduced wind erosion occurring to mounds and tuber exposure. The In-furrow treatment as a minimum, is a cost-effective means of improving root zone moisture and yield for fresh and processing potatoes.

In the South East, 4% of processing tubers from the Blanket treated areas were green, compared to the Untreated Control where 13% of tubers counted green. This equated to an additional 3.54T/ha of marketable potatoes, providing a return on investment to the grower of 5:1.

In the Mallee, the In-furrow treatment returned the best return on investment for growers at 24:1, compared to the Blanket treatment at 2.6:1.

Soil moisture data collected from each treatment area during crop growth, provided Volumetric Water Content (%) information from the potato mounds in the Mallee trial site. This data was collected using Time Domain Reflectometry (TDR 150), where salinity (EC) above 2dS/m may attenuate the signal and affect the accuracy of the results. It is important to note that EC readings in the Mallee were all under 0.5dS/m, therefore accuracy of VWC readings should be within the product specified (+/- 3.0%). Readings taken from the top, middle and base of the mounds were averaged for each visit from week 1 through to week 15 just prior to harvest. From Figure 6 it can be seen that from week 1 through to week 5, the control had a greater average VWC, but this consistently decreased after week 5 through to week 13. The blanket and in-furrow blanket treatments did however generally maintain moisture content over this period with the least fluctuation, highly important for even growth during the tuber bulking stages. This data helps to support the reduction in blemishes measured under treatment compared to the control site. Importantly, this tool was trialed as a cost-effective and easy to use tool, to measure multiple points for salinity and water content.

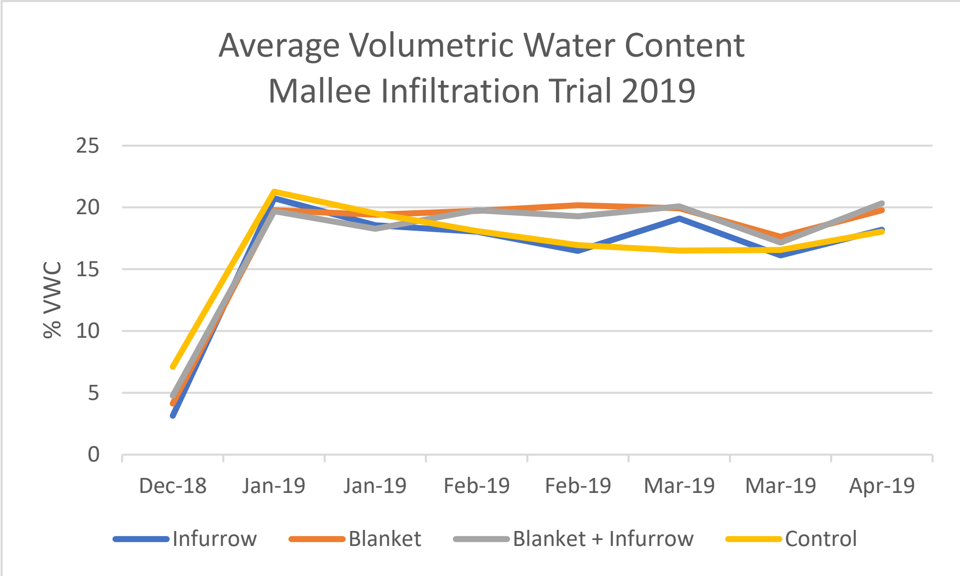

Figure 6. Averaged volumetric water content measured within mounds during crop growth.

Variability in results between the two regions is likely attributable to inherent site variability for both trial sites, including soil textures, site topography, soil salinity and irrigation water quality. The methodology of application for the Blanket treatments was also different, due to the inability to fertigate the product within the Mallee.

Final yield results would be greatly influenced by nutrition programs applied by the grower. Early trial harvest estimates indicated higher likely yields for both fresh and processing potatoes than were actually achieved. It is believed that current standard nutrition rates were insufficient to sustain continued tuber growth. Therefore, higher yield potential may be possible if nutrition inputs are increased, or changed to better suited products, to match the increased growth and development of the root systems.

New trial data from the Northern Hemisphere indicates that blanket application of Transformer at 5L/ha will return similar results to those achieved in this trial when applied at 10L/ha. Therefore, increased yields with double the return on investment are possible.

Crop nutrition, improved salt leaching and the use of soil amendments and specialty products were combined within grower trials, with one site established in the South East for processing potatoes, and three sites in the Northern Adelaide Plains for fresh market potatoes.

ThioCal

Given the high levels of sodium and chloride in most soils tested, and associated uptake of chloride and other plant nutritional imbalances, the application of calcium thiosulphate was trialed to assist with the flushing of harmful salts from the root zone. Thiocal is a liquid fertiliser providing readily available calcium for plant uptake. At 7.5% calcium and 100% solubility, for every 100L/ha, 7.5kg of calcium is available for plant uptake, compared to 1.2kg of available calcium per 2.5T/ha of gypsum. While gypsum has long been a common amendment for combating saline soils, research is showing that liquid calcium products are now far more effective in providing calcium for immediate uptake by stolons.

By improving the calcium and sodium balance, the uptake of potassium is also greatly improved. Along with the nutritional benefits of liquid calcium, soil structural improvements are gained. With increased available calcium within the soil profile, this assists with the replacement of sodium ions from the surface of soil colloids with calcium, thereby reducing soil sodicity and associated dispersion of soil particles, and assisting with soil structure, aeration and drainage. This improvement in soil structure further aids the exchange of air, nutrients and moisture.

The thiosulphate present in Thiocal also assists with the release of calcium typically bound in soils high in calcium carbonate. Soil bacteria oxidise the thiosulphate, producing sulphuric acid which then dissolves lime into gypsum and available calcium.

Thiocal was introduced to growers and applied to both processing and fresh market potatoes.

In the South East, despite best intentions, product application timing was late. This once off application resulted in negligible results and no further product applied. However, grower determination to observe first-hand the potential benefits from Thiocal, applied the product on a nearby potato crop grown under very similar conditions. The crop was at week 12 at time of application. Table 1 shows the plant sap analyses for both treated and control areas. While sodium uptake levels remain very similar, potassium, phosphorous and calcium levels are more balanced. Pleasingly, chloride uptake has decreased by 28%, and nitrate levels although they remain low, have increased by 29%. From this one application, there is an improved overall balance in both major nutrients and trace elements. Given the measured increases in soil salinity experienced from season start to end from ongoing inputs of sodium and chloride in irrigation waters, the regular use of Thiocal would result in ongoing more balanced nutrition for the crop.

Key	Near optimum			Optimum			Low			High			Very High		
29/01/2019	Analyte (ppm)														
Date	Ammonium	Nitrate	P	Sulphur	K	Ca	Mg	Boron	Moly	Copper	Iron	Mn	Zinc	Sodium	Chloride
Treated	27.4	4150	188	68.82	8166	820.7	513.2	0.69	0.131	5.44	1.6	4.64	0.97	173.42	6650
Control	21	2940	108.3	44.97	7005	1319.9	1055.1	0.65	0.198	2.87	0.93	4.86	0.48	159.74	9150

Table 1. Plant SAP results for Thiocal treated and Untreated Control plants in the South East. (Source of Scale based on AgVita NuTest Analysis report, specific to crop type and growth stage).

Soil solution data collected from the different areas of the trial pivot was aimed at determining movement of sodium and chloride within the rootzone during crop growth. Figure 7 shows the sodium and chloride levels measured at 30cm depth, from sites with high and low conductivity and treated and un-treated with Thiocal. Site details are as follows. Site A: mapped high conductivity/ control, Site B: mid conductivity /control, Site C: low conductivity/treated, Site D: High conductivity/treated. This clearly shows the increase in sodium and chloride over a 12week growing period in the South East, beginning at levels that are quite acceptable, and increasing to toxic levels late tuber bulking. High and mid conductivity zones show increasing trends as expected, however treated areas show a surprising change in chloride and sodium levels at the 4th measurement, at which point the 'higher conductivity zone' levels for chloride and sodium rise at a much lower rate than those in the low conductivity zone. Given only one application of Thiocal, the cause behind this is unclear.

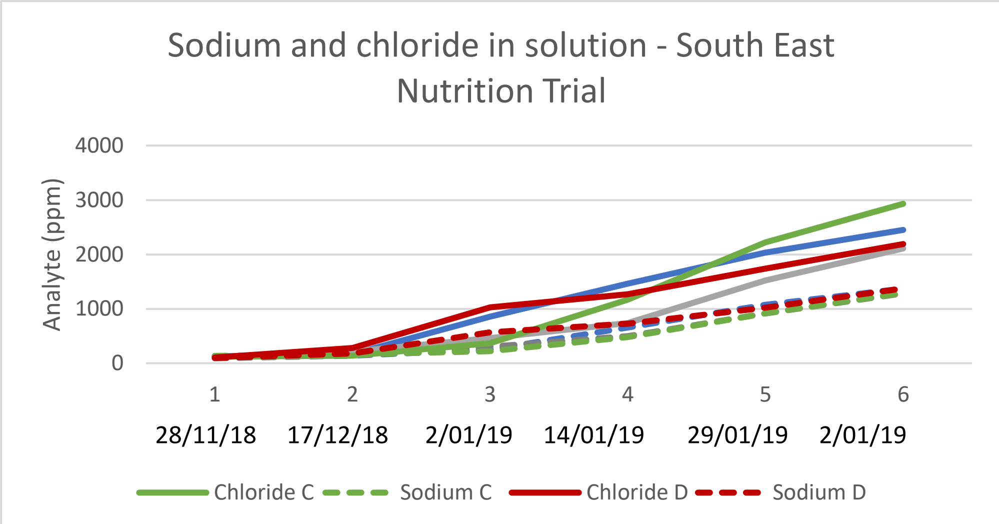

Figure 7. Sodium and chloride soil solution levels measured over time in areas of high and low conductivity.

Final trial harvest results unfortunately would not truly reflect the application of Thiocal, but more so site variability given the one late application. For this site, the Thiocal treatment had statically more tubers in total than the Control (P=0.024), however total tuber weights and yields were not significantly different. This is largely due to the Control having significantly higher tuber weights in the 60 to 90 size class compared to the Thiocal treatment. The Control treatment did have significantly higher (P=0.017) blemished tuber weights compared to the Thiocal treated area (Figure 8). Blemished tubers largely consisted of green, misshapen and Rhizoctonia affected tubers, as seen in Plate 8. While the types of blemishes are more related to drying and wetting during growth, the application of Thiocal can assist with soil condition, thereby aiding the movement of water and nutrients within the root zone. The Thiocal and Brexil treated area did have less blemished potatoes, but this was not significantly less (P=0.355) than the Control. Similar to the Thiocal, the single application of Brexil Mix and Brexil Mn, applied to address the low level of trace elements measured in plant SAP, would have had minimal impact on final yield.

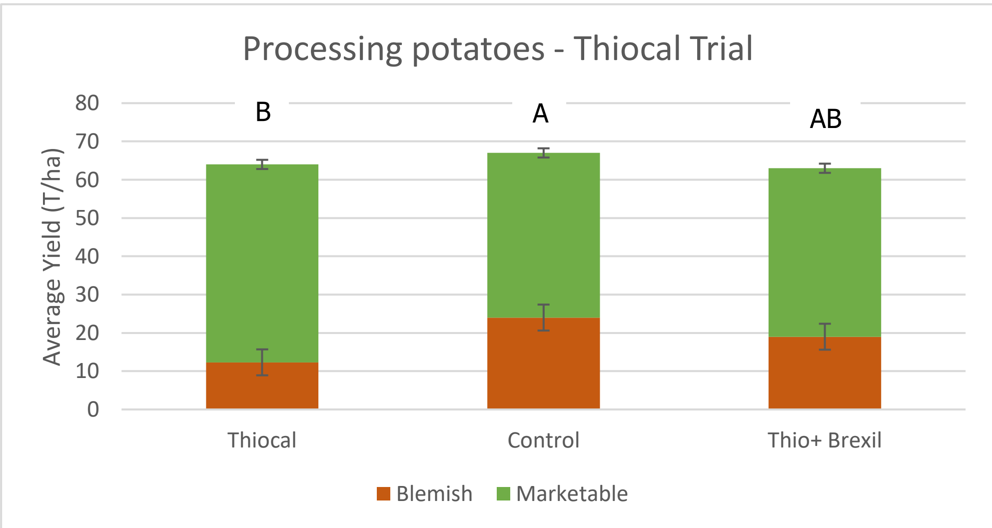

Figure 8. Average marketable and blemished tuber yields for processing potatoes in the South East.

Plate 8. Misshapen tubers; knobs, cracks and swollen eyes, often resulting from drying and wetting of the soil profile.

In the Northern Adelaide Plains, yield results for Thiocal treated fresh potatoes compared to the grower standard Control, revealed no significant differences (P=0.493) as seen in Figure 9. Final yields were slightly higher in the Control treated plot, with counted blemishes minimal and the same for each treatment. Site conditions appeared similar across the board (Plate 9). The control had sandy loam over a heavy compacted clay base at 40cm, and the treated area was a sandy clay loam over a heavy, blocky clay sub soil at 35cm. By mid-August, soils were very wet, with many areas in the treated area sitting waterlogged, particularly where pivot wheels disrupted natural flow, as seen in Plate 10. Subsequent searching of historical satellite photos revealed the treated area had undergone major transformations 13 years prior, where old roads and buildings had once occupied the area, the likely cause for such drainage issues compared to the control area. The waterlogged conditions in the Thiocal treated area is believed to have played a role in the lower yields, conditions that are not conducive to healthy plants or productive tuber growth.

Three applications of Thiocal (25L/ha) were recorded during the trial, once late July, late August and the last in mid-September.

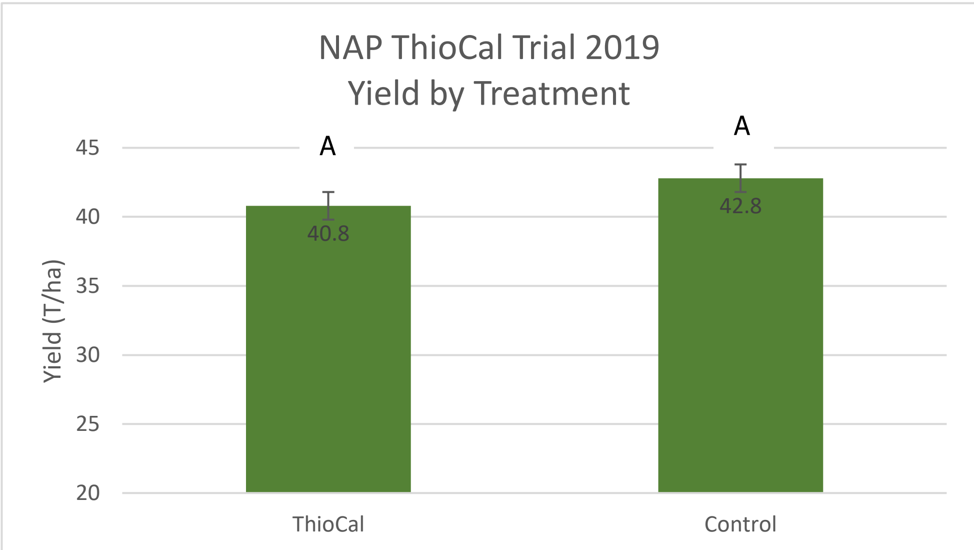

Figure 9. Trial harvest average yields for Treated and Untreated control fresh market tubers

 

Plate 9. Control (L) and Thiocal Treated area (R)

Plate 10. Waterlogged soils in October, showing stressed plants late in the season in the treated area.

The soil solution data tracked for 30cm depth is presented in figure 10. This shows contrasting data to that expected for the two areas, where Thiocal applications occurred between points 1 and 2, 3 and 4, and again between 5 and 6. The soil solution data from the Untreated area has lowered markedly, whereas the Treated area remained fairly consistent with a minor downward trend throughout the crop. This may be reflective of the inability to actually flush salts from the rootzone of the treated areas due to the waterlogging, whereas the control areas may have seen some flushing of salts from the winter rains.

Broadly speaking plant SAP test results were very similar across the two sites, with most analytes near optimum or optimum, indicating good nutrition management under the conditions. Chloride levels were quite good in both Treated and Untreated areas, and similar levels of nitrate for both. Sodium levels are marginally higher in plants from the untreated areas, with sap sodium levels more optimal under treatment with Thiocal.

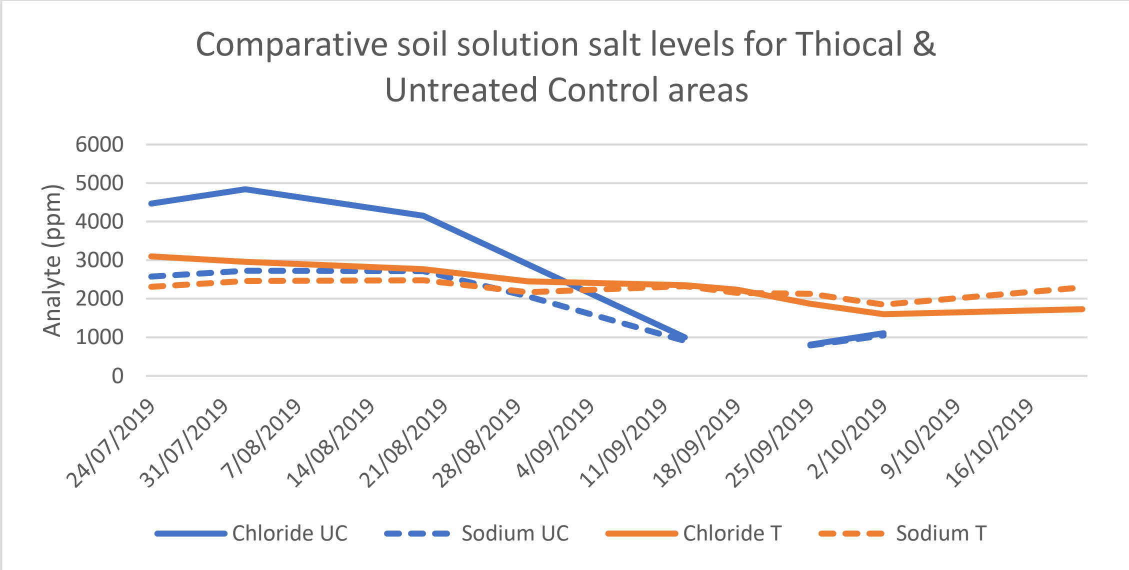

Figure 10. Comparative sodium and chloride soil solution levels measured at 30cm depth, for Thiocal Treated (T) and Untreated control (UC) sites.

Conductivity was also measured on site using a portable FieldScout TDR150 Soil Moisture Meter, where multiple measurements were taken within the top, middle and the base of mounds. Some of these averaged results are presented in Figure 11, from pre and post treatment applications. While conductivity consistently increased with depth in the mounds, it also showed a consistent decrease in conductivity for the post treatment assessment at each depth compared to the two pre-treatment measurements.

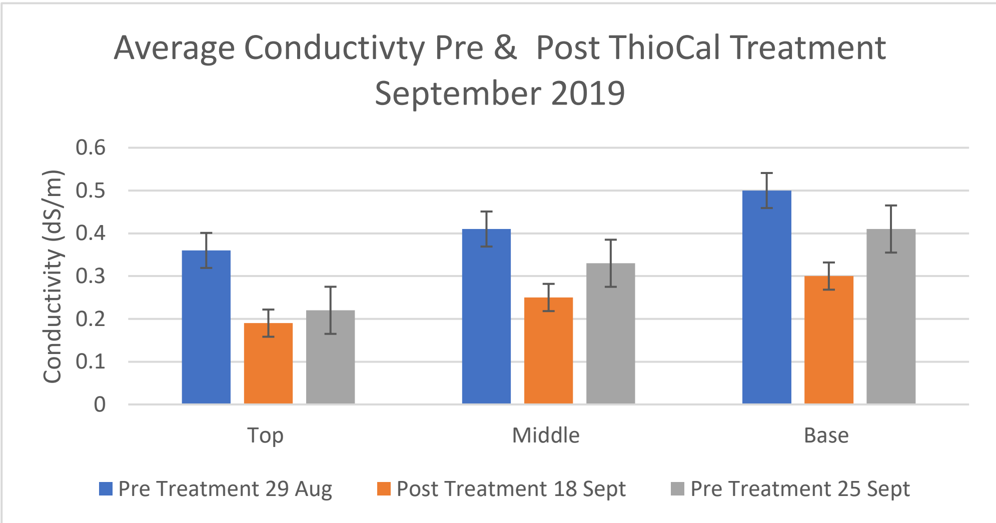

Figure 11. Rootzone Average Fieldscout conductivity levels from pre and post treatment dates.

Key	Low			Near Optimum			Optimum			High			Very High		
	Analyte (ppm)														
Date	**Ammonium**	**Nitrate**	**P**	**Sulphur**	**K**	**Ca**	**Mg**	**Boron**	**Moly**	**Copper**	**Iron**	**Manganese**	**Zinc**	**Sodium**	**Chloride**
T 1	128	5850	341	147	6548	260	219	0.34	0.25	0.49	18.36	3.22	2.33	81	1465
T2	17.5	7000	178	87	7656	456	269	0.59	0.05	0.38	0.88	3.86	1.42	144	3960
T3	8.7	8100	164	83	10614	736	393	0.84	0.02	0.39	0.81	8.35	1.81	196	5200
UT1	41.3	7200	318	162	6495	402	219	0.32	0.03	0.43	6.93	3.82	1.96	76	1435
UT2	12.2	7800	188	102	7874	620	293	0.71	0.02	0.56	2.23	6.63	1.79	192	3875
UT3	6.4	6200	89	95	9030	908	409	0.75	0.02	0.35	1.09	8.52	2.07	212	5950

Table 2. Plant SAP test results for Thiocal Treated and Untreated Control plants in the Northern Adelaide Plains. (Source of Scale based on AgVita NuTest Analysis report, specific to crop type and growth stage).

In summary, the Thiocal trial in the Northern Adelaide Plains did not show any clear benefits in yield or reductions in salt levels from the treatments applied as a result of underlying site conditions that resulted in waterlogging of the treated area only. While this is disappointing, it is a good example of where prior EM38 mapping would have been incredibly beneficial for trial planning and layout, and provided the grower with a better understanding of potential productivity and areas at risk of waterlogging and salinity.

Mycorrhizal treatments

In saline environments, the ongoing balance of nutrients and their uptake can be very challenging. In particular, high sodium can prevent the uptake of potassium, and the availability of phosphorous can also be very limiting in alkaline soils. Two mycorrhizal products were trialed in the Northern Adelaide Plains for two different varieties of fresh market potatoes, in order to determine if the addition of mycorrhizae can improve overall yield.

It is important to note that both trial sites, treated and untreated, were also treated with Viva, a biostimulant that assists with improved rhizosphere efficiency, improved vegetative-productive balance and improved yields. Given the standard Viva application across mycorrhizal treated and untreated control areas, any differences in results between mycorrhizal treated and untreated areas is believed to be attributed to the actions of the beneficial fungi only.

Trial 1 looked at the Sumitomo product EndoPrime, a mycorrhizal product containing 4 different strains of endo-mycorrhizae and a highly soluble humic acid. Trial 2 looked at Mycogel by Sustainable Farming Solutions, a water-soluble biological inoculant containing one strain of mycorrhizae in sterile gel, along with hyphae and secondary metabolites for immediate colonisation and enhanced plant function. Both products were applied in-furrow at planting, and are compatible with Amistar, a commonly used fungicide in potato production.

Results from both trial sites revealed increases in yield for treated areas compared to those untreated, albeit not significantly different, as seen in Figures 12 and 13. Trial 1 shows that Endoprime provided an overall increase in yield of 6.3T/ha, or 3.5T/ha of clean tubers, although this was not significantly different to the Control (P=0.472). The Endoprime treated tubers were on average larger than the Control, whereas the Control did produce more tubers of less size. In the 40-75g class size, the number of Control tubers was significantly higher (P=0.041), and the average tuber weights were significantly higher (P=0.014) by 10g on average, compared to the treated area. In contrast, for the 75-250g class size, there were more tubers in the Control area, although the treated tubers were heavier on average, but not statistically different. For the 250-850 size class, only treated tubers reached this growth class, with significantly more tubers (P= 0.026), and significantly greater weights (P=0.038). Return on investment (ROI) for Endoprime at this site was calculated at 33.9 to 1 (See Page 8 for calculations).

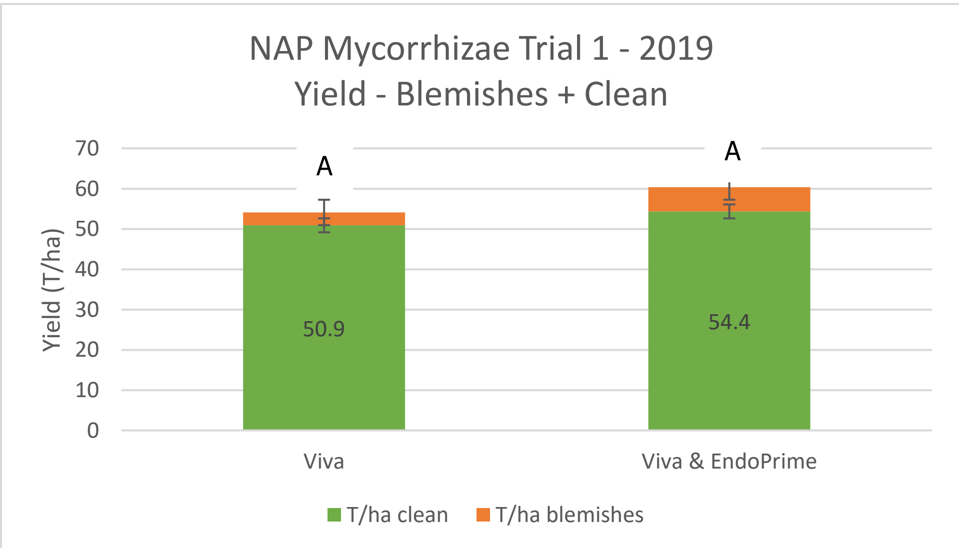

Figure 12. Yield data for fresh market potatoes treated with EndoPrime mycorrhizal product.

Trial 2 results show that Mycogel provided an overall increase in yield of 1.5T/ha, as seen in Figure 13. Average weights of tubers by size class were not significantly different. Average tuber numbers however, were greater in all size classes for the area treated with Mycogel as seen in Figure 14. This increase in size was significant (P=0.027) for the 40-75g size class only. ROI for this product was 2.75 to 1 (See Page 8 for calculations).

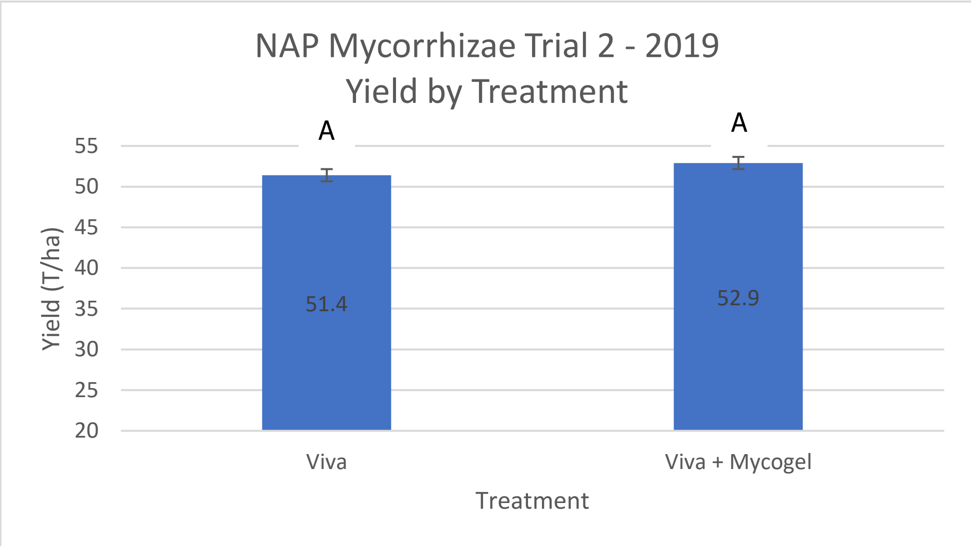

Figure 13. Yield data for fresh market potatoes treated with Mycogel mycorrhizal product.

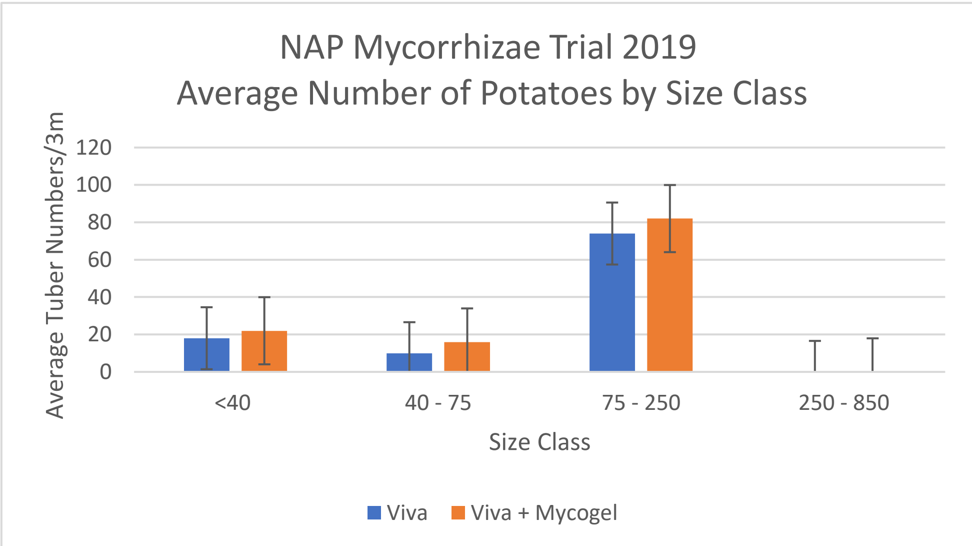

Figure 14. Average total number of tubers per 3m sample by size class for potatoes treated with Mycogel.

Dry ash test results from the tubers at both sites did reveal an increase in phosphorous and potassium compared to each site control. Mycogel had an increase in phosphorous of 0.01% and potassium 0.06%, and the Endoprime an increase in phosphorous of 0.04%, and potassium 0.12%. The Endoprime treated tubers also saw a pleasing drop in chloride of 0.1%. While these increases are merely comparative measured figures, the increases in P and K were desired outcomes from the use of these products.

Both mycorrhizal products trialed within the Northern Adelaide Plains provided returns on investment for growers with increased yields, and increased uptake of phosphorous. The Endoprime provided a much greater return on investment for growers, and the increase in tuber size was consistent with results provided by the product supplier and recent trials conducted in fresh market potatoes in Tasmania.

The Mycogel provided a smaller increase in yield and return on investment, however this yield increase was due to more tubers within each size class. Increased yields and returns on investment in fresh market potato production, can be achieved through the use of mycorrhizal products in saline environments. However, growers should be mindful of the variety of potato grown, and where the potential lifts in yield are achieved, such as increased tuber sizes or increased tubers numbers. These results will no doubt vary according to site variation, potato variety and individual grower nutrition programs.

Liquid ammonium polyphosphate (Iperen IPE)

The final trial established within the Northern Adelaide Plains was to assess the use of a liquid phosphorous product, IPE, a unique formulation containing 3.5% nitrogen (w/v), 17.8% phosphorus (w/v) in the form of pentoxide (P2O5), and zinc 2.1%. IPE is promoted to improve phosphate and micronutrient availability for plants, and being very low in sodium and chloride, is highly suitable for use in saline environments. Given the alkalinity of many soils in the Northern Adelaide Plains and the associated inability of plants to access phosphorous, trial results were looking for improved phosphorous uptake and increased yields compared to grower standards.

IPE was applied in-furrow at planting at a rate of 10litres/ha, to a red variety of fresh market potato. Soils across the two sites were fairly uniform, with sandy clay to 40cm depth where there was a mixed red/brown compacted base. Soils were slightly sodic, showing hard setting cracking surfaces along the mounds as shown in Plate 11.

Plate 11. Hard setting surfaces in the IPE treated soils and salt crystals noticeable on soil particles.

Plants during growth showed limited visual differences, however king tubers within the IPE treated area became slighlty larger from mid season onwards (Plate 12). This trend continued through to harvest, with final yields for the treated area 5.5T/ha greater than the grower control, as seen in Figure 15. Although final trial harvest yields were greater (13%) for the IPE treated area, no significant differences were detected between the two treatments (P=0.594). The IPE treated area produced more tubers in the 75-250g size class (Figure 16), and tuber weights were larger in both the 40-75g and 75-250g size classes (Figure 17), but again these increases were not statistically significant.

A second treatment was also established and monitored at this trial site (Treatment A), however due to the grower failing to provide product details and rates, this treatment was not analysed further with results. While treatment A did yield higher than the Control, this difference was not statistically different from either the Control or IPE treatment.

Plate 12. Tuber comparison five weeks prior to harvest, IPE (L) and Untreated Control (R).

Tuber dry ash analyses revealed the same levels of sodium and chloride between Treated and Control areas, however levels of phosphorous and potassium were actually lower in the Control areas. Nitrate nitrogen was however higher in the IPE treated tubers. These nutritional differences between tubers may be a result of the increased tuber numbers and size produced, without any additional fertiliser applied over the IPE. With adjusted fertiliser programs to take into considration the increased number of tubers produced, this may again enhance final tuber yield for growers.

The increase in yield gained for this trial over the grower standard, provided a ROI of 95 to 1, a well priced product providing improved yields for high quality fresh market potatoes. This return on investment is high due to the low cost of product per hectare to apply, and the estimated value of this fresh market potato per tonne. The type of yield gains must be considered by the grower however, to ensure desirable tuber size and weights for each fresh market or processing variety, are targeted.

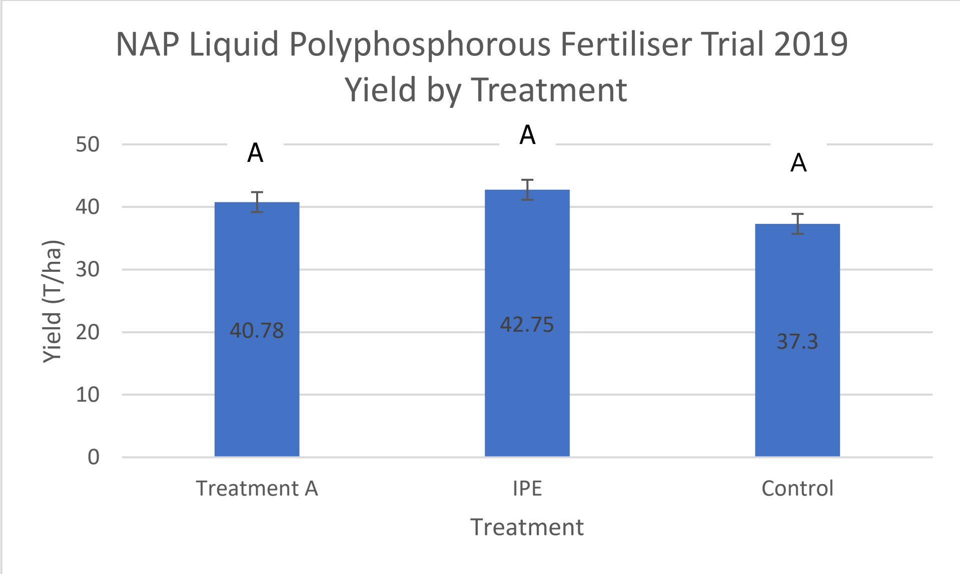

Figure 15. Trial harvest yield comparison between IPE Treatment, Treatment A and Control.

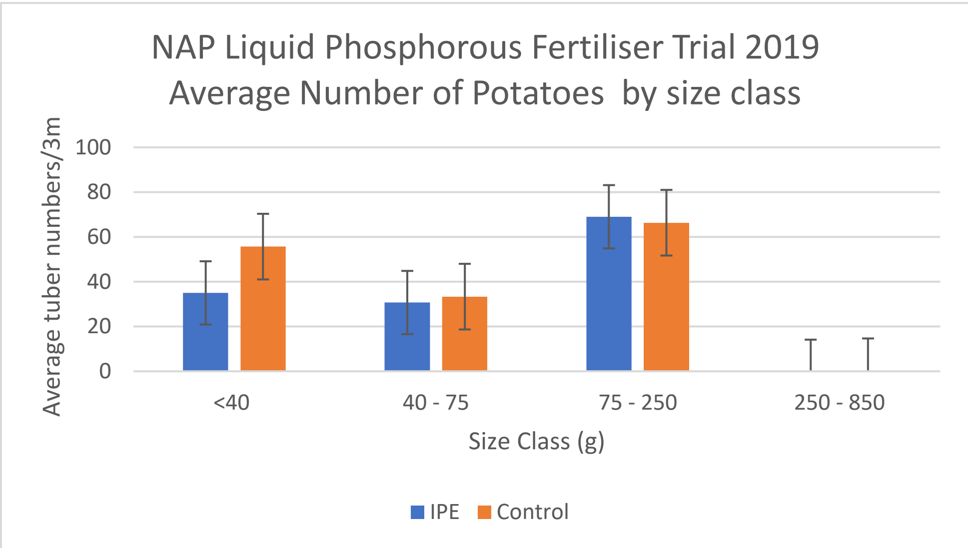

Figure 16. Average number of tubers for each size class in Treated and Control areas.

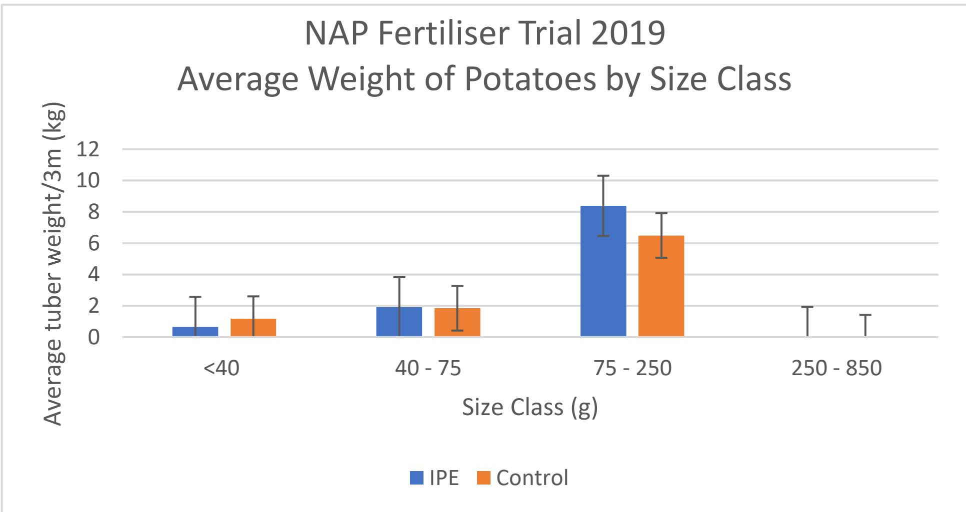

Figure 17. Average weight of tubers for each size class in Treated and Control areas.

Monitoring and evaluation

From January 2017 through to June 2020, the overall performance of this project was well executed, and broadly completed on time. Flexibility was built into the project timeframe following initial acceptance of the Request For Proposal (RFP), in order to accommodate the seasonal production of fresh and processing potatoes across the three major growing regions of South Australia. The first twelve months of pure data collection for eight potato growers, was therefore completed over an 18month period, to allow for all regional data collection, collation and presentation to the Hort Innovation and the Project Reference Group (PRG).

At the conclusion of this 18month period, or 12month Stop Go Milestone, the data and subsequent proposal for implementation of targeted management options was presented to the PRG. Review of this proposal was a lengthy process, with acceptance taking two months. In general, the timing of project milestones and activities was often in conflict with on-ground activities occurring in the three potato growing regions. This did impede the ability to undertake some planned assessments, where sufficient time prior to crop establishment was compromised. Similarly, exposure to climatic variation and extremes also impacted slightly on the ability for some activities to be undertaken or completed on time, such as rainfall and waterlogged soils. All milestone reports were completed and submitted on time.

Internal staffing did change throughout the course of the project, mostly reflected in the agronomists planned to undertake the in-field crop assessments. This changing of internal staff did not greatly impact on the delivery of the project. All staff employed were regularly updated with project progress and delivery across the three regions, and fully equipped with the necessary knowledge and tools to undertake all project activities.

The engagement of project stakeholders/growers is always aimed at those with a keen interest to learn and have active involvement in trial work. On the whole this project did engage with interested and eager clients, however during the first year it became very clear that confidentiality was a major concern for growers. The unexpected withdrawal of one grower from the Mallee was very surprising, as confidentiality of data was made very clear to all participants and this concern was not expressed during initial meetings and discussions regarding confidentiality. However, this did lead to a complete review of communication methodologies, and removal of any grower case studies and field days. No data from the first year would be released, and years 2 & 3 trial data would maintain grower confidentiality at all times.

The desire from some growers for confidentiality also imposed barriers to fully understanding 'standard grower practices'. Limited information was made available regarding fertiliser/chemical programs adopted, particularly from the larger producers involved in the project.

Staff changes within grower businesses also provided challenges, in regard to both communication and execution of activities. For one particular grower, this created significant interruptions to communication at the time of site assessments and crop establishment. While site assessments were still completed, site location details and access were made incredibly difficult, and further crop establishment information was withheld sufficiently so that the implementation of planned crop trials could not be done without greatly compromising trial outcomes. In this instance, it was decided that the risk of generating poor trial outcomes was too great, and therefore the site was removed.

All data collection for each site was broadly completed as planned for irrigation water, soil, plants, and broader scale site assessments. The planning and execution of Electromagnetic Induction Surveys were often difficult to undertake prior to site assessments. Climatic conditions provided challenges, with waterlogged soils in the South East, and fire risk in the Mallee, both limiting access for mapping. Despite this, these regions had all planned EM surveys completed, whereas the Northern Adelaide Plains had no EM surveys completed due to continued cropping and limited access to ground prior to crop establishment. A limited number of other tests, such as irrigation water or sap samples were missed across the multiple sites, due to a number of reasons, such as inability of grower or agronomist to collect, spray application etc. Submitted Milestone reports and individual grower reports summarised completed data bases for each site.

For many other criteria assessed, there were more tests conducted and data collected than originally planned. For one grower, additional irrigation water tests were run in order to determine the feasibility of the 'magnetic ring' to remove salts from the irrigation water. For other sites, significantly more soil solution tests, express soil tests, soil pit assessments and detailed tuber inspections were conducted than originally planned.

The data collected during the course of this project has enabled practical management solutions to be identified. By undertaking studies within three of the major potato growing regions, with several growers in each region, a thorough understanding was gained of grower practices, their current knowledge of salinity, soil and water salinity changes that occur during production, and the major barriers largely preventing improvements in potato quality and yields. Applied management options trialing amendments to improve a balanced nutrient uptake and more efficient watering of hydrophobic soils, showed that cost effective solutions can be applied to current production systems providing good returns for growers.

The implementation and adoption of monitoring and management activities is varied among growers. This project has highlighted to many growers, those directly engaged in the project and many others indirectly, the need to monitor more regularly. Many grower programs were developed some years ago, built on sound R & D at the time. A time when significant government funds were being invested in national salinity awareness. However, many of these programs have not changed since, albeit potato varieties and environmental conditions have changed. As a result, with minimal focus on salinity, the perceived need to test and monitor diminished significantly. Grower surveys revealed that irrigation water may be tested as infrequently as once every 10 years, sap tests not conducted by all growers, few growers undertook Electromagnetic Induction surveys, and no growers we worked directly with had utilised NDVI imagery to assist with crop management. In particular, there was a very poor understanding of the role of chloride in salinity, and the salts, particularly chloride, being applied with commonly used fertilisers such as muriate of potash. With a heightened awareness of the impact of salinity within the broader potato industry, this project has provided growers with simple solutions to adopt to better manage the salinity within their production systems. Using hydrophobic soils as an example, a large proportion of growers within South Australia battle to wet their soils and maintain uniform water penetration during crop growth, having tried numerous products over the years with minimal success. This project was able to introduce a new product that effectively improved the wetting up of hydrophobic soils, and provided returns on investment with improved quality and yield. This project has reminded many that salinity is a natural part of the Australian environment, and with the increasing need to provide food to a growing population, we need to better understand and manage the natural resources we work with. Responses and feedback following the webinar presentations in June, suggest that growers in many agricultural industries from across Australia, are desiring solutions to assist with production in saline environments.

Planned project communication activities changed dramatically following the heightened sensitivity of growers to confidentiality of site data. Limited project communication occurred within the first twelve months during which time project activities were directed at broadscale data collection to identify the major constraint's to potato production within the salt affected growing regions. During years 2 and 3 and the implementation and execution of planned trials, grower confidentiality was again imperative, so the development of grower case studies and running of field days were removed from project communication activities. While individual growers were visited and results from their trials discussed, any other grower group meetings were not possible due to travel restrictions imposed by the Covid-19 pandemic. As an alternative means to promote trial results and raise awareness among the broader potato community, a series of four fact sheets and associated webinars were developed, presented and promoted using a range of communication channels.

Improvements to project outcomes may have been possible with the selection of grower involvement from smaller businesses where there is a greater link between management and activities on the ground. The ability to extract information from larger producers was incredibly difficult, or non-existent, and the lag in communication also provided barriers to the timely adoption of some activities. The concern among some local growers where confidentiality may be breeched, and the level of competitiveness underlying the willingness to share information or not, also impeded some project progress. Supplier competitiveness has also been an underlying barrier to the adoption of some trials or acceptance of information provided in some areas. Grower allegiance to certain providers, at times provided an instant barrier to alternative management strategies and/or products.

Over the three-year project, total project expenses were above the forecast budget. A number of project items were underspent, generally reflecting several changes in project activities. For example, not all EM38 surveys were conducted due to time limitations, and satellite service providers changed to ensure ease of use and grower adoption beyond the life of the project. Similarly, travel costs were slightly less than budgeted for, primarily due to travel restrictions over the last six months of the project, a result of Covid-19 enforced restrictions. In contrast, other budget items were over spent, including laboratory testing, crop monitoring equipment and installation of crop monitoring equipment. Hours allocated to project management, site assessments, and agronomy were also over budget.

In summary this project has been effective in achieving the desired outcomes. However, limitations to the project's success may have been overcome by working with potato growers from affected areas around Australia. With many agricultural areas of Australia detrimentally affected by salinity, conducting this project nationally would have introduced a range of growers with different backgrounds, agronomists and suppliers, which may have minimised the confidentiality aspects, created more grower discussion, and generated more interest in trialing new products.

Recommendations

Twenty years ago, the Australian government invested significant funds into salinity mapping and basic salinity management programs. Much of this however was focused on dryland salinity, and pasture and tree management. Since this time, there has been significant growth in intensive horticulture, with greater areas of land undergoing management change, and particularly the addition of irrigation. This is leading to changes in soil health, local groundwater conditions and in some areas, increasing salinity. As a result, there is an increasing need to not only raise awareness of soil and water salinity again, but to focus on intensive irrigated horticultural practices, particularly potatoes and vegetables. A strategic program focusing on getting the basics right first, will lead to greater efficiencies across the board.

The Northern Adelaide Plains due to the intensive production of fresh market potatoes, short rotations and inherent salinity of soils and water may well be at higher risk moving forward compared to the Mallee and South East where longer rotations and winter rains offer significant relief from salinisation. However, all regions would benefit from the following recommendations.

- *Promote monitoring programs of soil and water salinity to raise awareness of the impact of high chloride and sodium levels in irrigation water.*
    - Most growers communicated with during the project did not regularly test their irrigation water, and had no understanding of potential salt loads or how quality may vary over time. Limited understanding of irrigation water quality results in the inability to manage crop nutrition effectively.
    - Promote the adoption of EM technology to assist growers understanding of soil variability better, facilitating strategic testing and management of soils and crop nutrition.
- *Recommend the removal of chloride based fertilisers in potato nutrition programs.*
    - There remains a large number of growers utilising muriate of potash fertiliser, unaware of the high levels of chloride it contains. In saline environments, most irrigation waters are high in chloride, thereby placing crop health and yield at risk of toxicity and other associated nutrient imbalances caused from high salinity levels.
- *Promote regular plant SAP testing in nutrition programs.*
    - Grower discussions revealed a lack of awareness of the importance of soil nutrition and plant available nutrients in saline environments. The ability to undertake sap tests and accurately determine plant nutrient uptake compared to soil nutrient levels, would greatly assist improved nutrition programs.
- *Recommend an awareness raising program focused on managing hydrophobic soils.*
    - From grower discussions, there appears to have been many products trialed in past years to manage hydrophobic soils that were great failures. This has led to a reluctance to try new products for fear of experiencing the same costly troubles. This attitude is however prohibitive to grower productivity and longer-term improved environmental outcomes, given that new technology and products as demonstrated in this project, has led to increased yield quality of fresh and processing potatoes.
    - A large proportion of growers' struggle with the difficulty of 'wetting-up' hydrophobic soils and maintaining uniform moisture levels within the root zone of developing tubers. This is costly in many ways, ultimately leading to greater water use, increased quantities of salts added to soils and poor crop quality.

- Recommend further trials/regional demonstrations with Transformer applied broadscale using fertigation at rates of 5L/ha to determine if ROI and yield improvements are similar to results when applied at 10L/ha.
- Implement further trials to look at the use of Transformer combined with other products, biologicals, high quality fertilisers etc., to assess the potential efficacy of heightened product performance in fresh and processing potato production.

- *Recommend the use of cover crops and composts to improve overall soil condition*
    - Increasing soil organic matter will address the longer-term management of saline, sodic and poorly structured soils. While not all grower programs currently allow time for cover crops, the addition of composts is the next best thing which will over time, greatly improve the structure and function of cropping soils.
    - The Northern Adelaide Plains may be better suited to regular inputs of compost, being easier to apply within tight rotations and more readily available.
- *Recommend the use of quality fertiliser products which provide readily available nutrients to assist in plant health and nutrient uptake, and general soil condition.*
    - The dollar value of a bag of fertiliser understandably plays a significant role in budgeting for potato production. However, this upfront cost can be so misleading if the efficacy of the product in saline environments is minimal, and final pack-out is compromised.
    - The combined application of Thiocal or other similar calcium thiosulphate products, with effective soil conditioners like Transformer, may greatly aid the structural integrity and nutrient and moisture availability for developing tubers.
- *Promote the use of biological products such as EndoPrime, that have shown improved yields with extremely good ROI.*
    - The investment and development of biologicals and biostimulants in recent years is staggering. There are many good products on the market, and when chosen carefully to address specific crop management issues, they can provide lifts in tuber quality and yield. The inclusion of more sustainable production methods is becoming more desirable from growers and consumers alike. However, the efficacy of such products will be limited if general soil health and nutrient balance is not firstly managed.
- *It is recommended that the development and implementation of any future trials be targeted with smaller growers compared to the larger corporate businesses.*
    - There is no doubt that potato producers across fresh and processing potato growing regions in South Australia are all keen to identify the most cost-effective ways forward to lift potato quality and yield, particularly in areas with saline soil and irrigation waters. The chain of command and resultant communication channels between management and staff on the ground however, does provide a large degree of difficulty when implementing trials and seeking information. With smaller growers, there is a far greater ability to communicate across all levels, and particularly in a timely manner. General unwillingness of many to share information was counterproductive to project outcomes.

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WaterConnect
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Government of South Australia

Intellectual property, commercialisation and confidentiality

Confidentiality for growers became apparent during the early stages of Year 1, where one grower chose to remove his business from further project involvement soon after the initial site investigations were undertaken and solusamplers were installed. Despite the confidentiality agreements shared and discussed prior to project engagement, there was a perceived risk to grower IP. Understandably, confidentiality was a high priority for most growers, which then shaped the direction of project communication plans moving forward. Grower case studies and field days planned for years 2 and 3 to showcase trial outcomes were discarded, choosing to utilise grower forums and meetings to share project outcomes with heightened grower confidentiality instead.

With the Covid-19 outbreak in early 2020, this further changed the direction of project communication, where the generation of fact sheets and presentation of webinars was chosen as a preferred means of communicating general project outcomes across the main trial areas. Growers of fresh market and processing potatoes, as well as processors, agronomists and consultants from across Australia, now have the ability to easily tap into project outcomes and trial results, hopefully leading to an improved knowledge of salinity monitoring and management, and various options for improving crop nutrition and yields in saline environments.

Acknowledgements

There are many people who have contributed to the success of this project, from RFP development, through to grower engagement, site assessments, data analysis, fact sheets and webinars. Spread widely across two states, a massive thanks to everyone.

Firstly, I need to acknowledge and thank all of the participating growers who agreed to be involved in this project. The time you have volunteered to assist with trial establishment and discussions is greatly appreciated, as is the ability to utilise your farms and crops for this project.

The Project Reference Group, again consisting of local potato growers, has also given much time over the years to assist with project guidance and ensuring we stayed on track with delivering appropriate and timely outputs and outcomes. Many hours were spent preparing for and attending meetings, which I thank you so much for. It is never easy to leave the farm for extra-curricular activities such as this!

I would also like to thank the regional agronomists from EEM who assisted with all fieldwork. The hours spent on the road getting to sites, and the time spent undertaking crop assessments, data collection and harvesting, was paramount to this project's success.

Other EEM and Serve-Ag staff have also assisted with this project, including statistical analysis, purchasing and installation of solusamplers, proof reading documents, budget estimates etc. Thank you all.

Product suppliers have also provided a wealth of information and support throughout this project, ensuring all questions and enquiries were addressed sufficiently, along with assistance during trial establishment and trial harvests. Thank you.

Staff at AgVita also deserve thanks for their timely processing of samples, and enduring willingness to provide testing services that suit client's needs.

Many thanks to RMCG and the Soil Wealth/ICP team for your assistance with the promotion and delivery of fact sheets and webinars. A last-minute change to project communication made so much easier with your help.

Last but not least, thank you to Hort Innovation staff, Processing and Fresh Potato Levies and the Australian government for funding this project.

Appendices

Appendix 1. Project MERI Plan

Appendix 2. Year 2 work plan

Appendix 3. Project related published articles

Appendix 4. Fact Sheets

Appendix 5. Summary of Year 1 key data sets from the Mallee, the South East and the Northern Adelaide Plains.

Appendix 1

Project MERI Plan

Monitoring, Evaluation, Reporting and Improvement (MERI) Plan

Impact of groundwater quality on management of centre pivot grown potatoes

Project No: PT16001.

January 2017

Julie Finnigan

Serve-Ag Pty Ltd

Contents

Introduction

MERI planning relates to the continuous cycle of Monitoring, Evaluation, Reporting and Improvement of planned project work. This MERI plan provides a framework for:

- checking to see if our project is on track
- deciding whether our project has achieved its goals
- examining what differences our project has made
- promoting/communicating how successful our project is,
- minimising risk to the project and
- identifying what aspects of our project could be done better next time around.

This MERI plan will provide a clear guide for the project steering committee, project staff and industry stakeholders as to what our project aim is, the activities undertaken to achieve this aim, when activities are to be completed by and by whom, and the methods by which we can evaluate the success of each activity. This MERI plan will also facilitate the identification of areas for improvement to project design and activities, with the longer-term view of broader application of project activities for potato growing regions across Australia.

Scope

This project aims to develop and deliver an effective management strategy for the sustainable and profitable production of potatoes under compromised conditions within major potato growing regions of South Australia.

This project, funded by HIA using R&D levies from the Australian Processing Potato and Australian Fresh Potato Industry levies and funds from the Australian Government, is being delivered by experienced staff from Serve-Ag Pty Ltd and E.E. Muir & Sons. This project officially started on January 3,2017, and will run for the duration of three years assuming all milestones are delivered according to the plan.

The dominant users of this plan will be HIA, the Project Steering Committee, Project staff, and relevant industry stakeholders including regional potato growers engaged in demonstration trials.

Program Logic

The following Program Logic (Table 1) outlines the major inputs required for this project, the activities and outputs that detail the work we plan to undertake, and the results and outcomes we hope to achieve across the short, medium and longer-term timeframes. This Program Logic has provided the foundation for key monitoring and evaluation questions to be developed.

Table 1 - PT16001 Program Logic

Inputs	Activities	Outputs	Shorterm Outcomes	Intermediate Outcomes	Longterm Outcomes
HIA Funding **Processing & Fresh Potato Levy Funding** **In-Kind Funding** **Consultancy & Agronomy Staff** **Julie Finnigan** **Peter Hoek** **Steve Coventry** **Matt Wetherall** **Heinrich VDW** **Josh Dennis** **Danny Schoenmaker** **Stakeholder clients within the Mallee, South East & Southern Murraylands**	Careful Budgeting of Project Funds Project planning & ongoing monitoring & evaluation Comprehensive soil & water testing within each region Comprehensive crop nutrition sampling Regular on-site visits & client liaison Development of extension material Regional information sessions Regional field days	Comprehensive site databases Media releases/interviews Extension material & project newsletters Regional information sessions x3 Regional field days x 6 Regional case studies produced x 6 Project updates produced Cost/benefit analyses Six monthly milestone reports Final project report	Raised awareness within local potato growing regions Comprehensive regional site databases produced Yield & quality data from Y1 monitoring Understanding of regional key limiting factors Establishment of demonstration trials	Yield & quality data from implemented trials Tailored nutrition & soil amendment programs produced Tailored management scheduling determined Raised awareness of recommended management options within the potato industry	Development & delivery of an effective management strategy for the sustainable & profitable production of potatoes under compromised conditions within major potato growing regions of Sth Australia Increased yields across the potato growing regions of Sth Australia Improved monitoring & management practices implemented across the broader Australian potato growing regions

Evaluation

Both broad and key evaluation questions have been identified and outlined in the following table. From these questions, project progress can be regularly tracked throughout the duration of the project, therefore providing opportunity to make adjustments and improvements to project design if and when required. See Table 2 for Key Evaluation Questions.

Table 2 - PT16001 Key Evaluation Questions

PT16001 - Key Evaluation Questions									
Evaluation	**Monitoring**						**Evaluation**		
Broad Evaluation Questions	What do we want to know? (Key Evaluation Question)	How will we know it? (Indicator)	Where will the data come from? (Data source/method)	Who will capture the data? (Person responsible)	When will the data be captured? (Timeframe)	Estimated Cost?	Who will be involved?	How will it be reported?	When will the evaluation occur? (Timeframe)
Internal Staffing	Did we allocate the correct staff for the project?	Committed staff, delivering milestones on time	Milestone reports	JF	6 monthly	Admin	SAG & Muirs	Milestone reports	Annually
Broader Industry Stakeholders	Did we engage with the most appropriate clients for the project?	Committed clients eager to participate	Milestone reports	JF	Ongoing	Reporting	Steering Committee	SC Meetings	Annually
Budget	Did the project operate within budget?	All activities completed within budget	Independent audit reports	JF & SD	Ongoing	Admin Reporting	Sandra Dale	Financial Audits	Annually
Data collection	Was all soil & water data collected as planned for each site?	Completed databases for each site	Milestone reports	JF, SC, MW, HV	At specified times within the cropping schedule of each region	Admin Reporting	Steering Committee	Milestone reports	6 Monthly
	Did all crop nutrition sampling occur as planned for each site?	Completed databases for each site	Milestone reports	JF, SC, MW, HV	At specified times within the cropping schedule of each region	Admin Reporting	Steering committee	Milestone reports	6 monthly

	Has the data collected enabled practical management solutions to be identified?	Analysis of data sets for each region	Milestone reports	JF,SC, MW, HV	Annually, post Year 1	Admin Reporting	Steering Committee, SC, MW, HV, JF	Stop/go Milestone	Annually
Communication	Did all planned communication activities occur?	Transcripts, articles, photographic evidence, media releases,	Milestone reports	JF	6 monthly	Admin Reporting	JF & Steering Committee	Milestone reports	6 monthly
	Were communication methods appropriate & effective? Did we reach the desired audience?	Questionnaires and surveys	Field day questionnaires, Facebook poll's?	JF	6 monthly	Admin Reporting	JF & Steering Committee	Milestone reports	Yr 2, after 1st planned extension activity
Reporting	Were Milestone reports written well and on time?	Acceptance of reports by HIA	HIA	BK	6 monthly	Admin Reporting	Steering Committee	Milestone reports	Annually
Implementation & Adoption	Are stakeholders engaging in monitoring activities?	Stakeholder liaison	Milestone reports	JF		Admin Reporting			Annually
	Have applied management options been effective?	Implemented demonstration trial results	6 monthly reports	JF, SC, MW, HV & stakeholders		Admin Reporting			Yrs 2 & 3
Improvement	What areas of this project could we implement more?					Admin Reporting			Yr 3

Communication Plan

For this project to be successful, effective and efficient communication is imperative across the broader potato growing industry. A communication plan has been developed, Table 3, which outlines the major channels, methodologies and extension activities that will be employed throughout the duration of the project. All communication will follow the HIA Publication Guide, and will target key stages of the project.

Table 3 – Communication Plan

PT16001 - Communication Plan

Communication Channel	Details	Dates	Contact	Contact Details		Comments
AusVeg	Weekly Update Potatoes Australia Regional Updates Vegetables Australia Spud casts ICP/SoilWealth project	On-going, when opportunities arise		info@ausveg.com.au Gordon Rogers/RMCG	(03) 9882 0277	Identify opportunities and avenues for publications with Steering Committee
Potato Industry Extension Program	Extension activities Stakeholder forums	Yearly plan developed	Bianca Cairns	HIA & Arris arris.com.au/potato-extension/ arris.com.au/potato-extension/stakeholders	(for extension service providers). (for stakeholder registration & extension ideas registration	Discuss opportunities to link into plan Discuss opportunities with Steering Committee & HIA Discuss opportunities with Steering Committee & HIA
Media	ABC Country hour Stockjournal (SA) FB? Twitter?	On-going - when opportunities arise	Rosie James Rosie James	silvia.brunialti@fairfaxmedia.com.au SAG / HIA SAG/ HIA	Phone: 08 8394 5150	When pertinent to project activities When pertinent to project activities Check for permission with HIA & Steering Committee

Training Sessions	Solusampler set up & monitoring Potato Grower Groups	Year 1 Yrs 1,2 & 3	Josh Dennis Peter Hoek	SAG Muirs	Training with agronomists & growers Create questionnaire to use as benchmark for learnings?
Field Days	Mallee South East Southern Murraylands	Yrs 2 & 3 Yrs 2 & 3 Yrs 2 & 3	SC & MW SC & HV SC		1 in Yr 1, 1 in Yr 2 1 in Yr 1, 1 in Yr 2 1 in Yr 1, 1 in Yr 2 Create questionnaire to use as benchmark for learnings?
Case Studies	Mallee South East Southern Murraylands	Yr 3 Yr 3 Yr 3			2 case studies 2 case studies 2 case studies
Project staff and regional stakeholders	Regular site visits regular phone & email contact	On-going On-going			
Reporting	HIA - as per contract	6 monthly	Brenda Krantz		
MERI Review	Project evaluation	Annually	Steering Committee		Or more frequently where possible

Managing Risk

A risk management matrix has been developed for this project, identifying major risks, assessing their likely impact on project progress and actions that can be taken to minimise these risks and their associated costs to project progress. Table 4 details this project's risk management strategy, where regular review throughout the duration of the project will help to ensure that uncertainty does not impact negatively on project goals.

See Table 4 for Risk Management Matrix.

Table 4 PT16001 Risk Management Matrix

Risk Description		Impact of Risk	Risk Rating	Risk Likelihood	Change	Date of Review	Mitigation Actions	Responsible Persons for Mitigation	Costs	Timeline for mitigation
Staff retention	Internal	Delay to project progress	M	L		On-going		JF, PH	Administration costs	Immediate
		Loss of project knowledge	H	L						
		Leave / Holidays	L	L		Monthly	Review leave register monthly			Prior
	Clients	Delay to project progress	M	M		On-going	Key obligations outlined at project start			Immediate
		New staff disinterested	H	L			Key obligations outlined at project start			
Client loss from Project	Illness / Incapacity	Impaired site access & data retrieval	H	L		On-going	Key obligations outlined at project start	JF, SC, MW, HV		Prior
Working in isolation	Personal safety	Personal Safety/injury	M	L		On-going	Maintain OH&S safety familiarisation	JF,SC, MW, HV, PH	Internal costs	Prior
		Vehicular breakdown/accident	H	L			Maintain vehicle fleet maintenance			Prior
		Limited mobile reception	L	H			Confirm site safety/induction processes			Prior
							Provision/wearing of flack jackets			Immediate
							122 safety/emergency number awareness			Immediate
							Staff check in at end of day when travelling			Immediate
							UHF 2 way radio where appropriate			Immediate
							SAG/Muirs Internal Policies adhered to			Prior
Communication	Remoteness	Delay caused to knowledge transfer	H	L		On-going	Project staff recognition & proactive management applied		Internal costs	Immediate
							Sharing of itineraries			Immediate

Communication	Remoteness	Delay caused to timing of on-site management actions	H	L			Key obligations outlined at project start			Prior
	Media	Deadlines missed	M	L		On-going	Plan communication events	JF, HIA		Prior
		Media don't show	L	M						Immediate
		Incorrect interpretation of information supplied	H	L			Ensure articles are written well & checked prior to submission			Prior
Sample loss/quality loss	Unrefrigerated	Complete loss of data	H	L		On-going	Ensure car refrigerators work	SC, MW, HV		Prior
	Lost in transit	Poor sample quality & unreliable data	L	L			Correct sampling procedures	SC, MW, HV, JF		Prior
		Incorrect sampling time	L	L			Label all samples correctly	SC, MW, HV, JF		Prior
	Postal delays	Sample quality compromised	L	M			Timely postage of samples	SC, MW, HV, JF		Prior
Catastrophic environmental events	Flood	Crop damage/loss	H	L		On-going	Watch for weather alerts & plan accordingly	Clients	Project	Prior
	Fire	Crop damage/loss	H	M						Prior
	Wind	Crop damage/loss	H	M						Prior
	Heatwave	Crop damage/loss	H	M						Prior
	Frost	Crop damage/loss	H	M						Prior
	Insects/diseases	Crop damage/loss	M	L			Insect alerts & weekly agronomy scouting			Prior
Equipment failure	Irrigators	Insufficient watering & poor growth	M	L		On-going	Ensure appropriate maintenance &	Clients	Clients	Immediate
		Crop loss & compromised yield & quality	M	L			Regular equipment inspections			Immediate
	Solusamplers	Loss of/inadequate data	M	L			Regular equipment inspections	SC, MW, HV, JF	Internal	Immediate
	Computers	Loss of data	M	L			Regular back-ups/maintenance	SC, MW, HV, JF		Prior
	Car refrigerators	Sample spoilage	M	L			Regular inspections	SC, MW, HV		Immediate
	Security of water	Crop losses & poor yield quality	M	L		Yearly	Annual planning with clients	JF, SC, MW, HV		Prior
Late supply of equipment	Supplier issue	No stock	L	M			Clear and advanced planning	JF	Project costs	Prior

	Delivery	Loss in transit	M	L			Tracked postage	JF		Immediate
Sub Contractors to project	Timing Quality	Missed data collection Compromised data sets	H L	L L			Constant communication	JF		Immediate Immediate
Seed quality	Disease Physiological age	Compounded compromised data	M M	L L		Pre-plant	Quality check at supply	SC, MW, HV & clients		Prior Prior
Inadequate Funding	Compromised activities Funding redirected Poor budgeting Increase in costs	Year 2 activities compromised Year 2 activities compromised Time management Fuel price increase	H H M M	L L L L		6 monthly milestones	Milestone evaluations Annual audits/reviews Monthly monitoring of staff timesheets Monthly budget checks, annual audits	Steering Committee St, SD & JF JF & PH JF	Project/ Internal Costs	Immediate Immediate Prior At review
Steering Committee	Inability to gain full attendance at meetings	Delayed outcomes	M	L		6 monthly milestones	Skype meetings Provide advance notice to members	Steering Committee JF	Project costs	Prior Prior

*Risk rating: H = High, M = Medium, L = Low

Appendices

Appendix 1

Site Data Collection Notes/Check list

Client Details

Client:		**Date:**	
Region:			
Address:			
Property Name:			
Pivot name:			

Pivot Details

Criteria	Comment
GPS data	
Landscape Photos	
Soil Pit photos	
Topography:	
Aspect:	
Other Miscellaneous:	

Pivot Site Assessment Notes

Indicators	Comment
Soil moisture	
Soil structure	
Uniformity with depth?	
Soil compaction	
Gravels	
Particulate organic matter	
Root penetration	
Earthworms (juvenile)	
Earthworms (adult)	
Other soil fauna	
Irrigation infiltration?	
Weeds?	
Signs of surface salts?	
Samples collected for pathogens?	
Samples collected for microbiology?	

Horticulture Innovation Australia SERVE-AG E.E. Muir & Sons

Appendix 2

Site History information

Client Details

Client:		**Date:**	
Region:			
Address:			
Property Name:			
Phone:			
Fax:			
Email:			

Pivot Details

Pivot Name:	**Comment**
Pivot Size (ha):	
Pivot History - Current	
Previous 1 year	
Previous 2 years	
Previous 3 years	
Previous 4 years	
Previous 5 years	

Pivot Performance

Indicators	**Comment**
Does the paddock perform well?	
Is paddock performance uniform?	
What yields do you normally gain?	
Are there weed problems?	
Are there pest problems?	
Are there disease problems?	
Does the paddock compact easily?	
Are there soil wetting issues?	
How often do you test your soils?	
How often to you test your irrigation water?	
Do you normally conduct sap testing?	
Have any significant events occurred that may impact on soil health?	
What do you believe is your main constraint?	
Any other concerns?	

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Appendix 3

Site History information / Change Analysis

Client Details

Client:		**Date:**	
Region:			
Address:			
Property Name:			
Phone:			
Fax:			
Email:			

Pivot Details

Pivot Name:	**Comment**
Pivot Size (ha):	
Pivot History - Current	
Previous 1 year	
Previous 2 years	
Previous 3 years	
Previous 4 years	
Previous 5 years	

Pivot Performance

Indicators	**Comment**
Has communication been satisfactory?	
Have you implemented any management changes over the past 12 months?	
Have project test results collected from your property helped with potato management?	
Are you likely to conduct your own soil, water & plant tests after this project?	
Have applied management options been effective?	
How could we improve the efficacy of this project?	
If there was more funding available, how would you spend it?	

Horticulture Innovation Australia

SERVE-AG

E.E. Muir & Sons

Appendix 4

		January				February				March			
		Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Office Work				Start up meeting with HIA		Committee Meeting No. 1?							
			Merri, project logic & Risk management						Finalise project planning	Project planning completed & submitted			
				300 word project start communication									
			Collation of all data collected										
Field Work	Mallee			Revisit Mallee clients and confirm participation	Plant testing to begin according to each sites plant dates								
					Conduct Grower Interviews								
						Installation of solusamplers							
					Initiate CSIRO imagery contracts								
	South East Clients			Begin Liaison with SE Clients						Revisit SE clients & confirm participation		Initiate CSIRO imagery contracts	
	Southern Murray-lands			Begin liaison with Southern Murray-lands clients						Revisit Southern Murray-lands clients & confirm participation		Initiate CSIRO imagery contracts	

Appendix 2

Year 2 Work Plan

Project title:

Impact of Groundwater Quality on Management of Centre Pivot Grown Potato Crops

Project code:
PT16001

Stop Go Milestone:
Requested Project Plan Years 2 and 3

Project leader:
Julie Finnigan

Delivery partner:
EE Muir & Sons Pty Ltd trading as Serve-Ag

Report author:
Julie Finnigan

Project overview year 1:

Through Hort Innovation funding to assess the impact of groundwater quality on management of centre pivot grown potatoes, Serve-Ag and E.E. Muir and Sons employees assessed a wide range of factors inclusive of soil, irrigation water and plant health across three major potato growing regions of South Australia. The three regions were the Northern Adelaide Plains, the Mallee and the lower South East Limestone Coast. Within each region, three growers were chosen to work with, inclusive of 7 potato varieties from both the processing and fresh markets.

Groundwater forms the primary source of water used for irrigation across the potato production regions of South Australia. Each region sources water from different aquifers, which to a great degree sets the water quality parameters for growers. While regional variations were evident, the common issue for all irrigation waters was high levels of sodium and chloride, combined with very high levels of bicarbonate and hardness, up to five times the desirable limit for any of these criteria. This groundwater quality not only creates in-crop management issues for plant nutrition and soil chemistry, but also becomes problematic for growers with the development of scale, or salt deposits within irrigation lines. High iron levels in the water can also lead to the growth of iron loving bacteria (chemotrophic iron oxidising bacteria) that can also block irrigation pipes and nozzles.

Water quality, combined with inherent site variability; depth of sand to clay, topography, hydrophobic properties, and climatic stresses, lead to compounding management issues that limit the current level of potato production, quality and uptake of variable rate irrigation.

Summary of groundwater impact:

- Scale build-up within irrigation lines: major barrier to the adoption of variable rate irrigation
- Application of high salt loads to crops and soils throughout potato season
- Accumulation of salts within the soil profile
- Soil variability leads to uneven watering and development of perched water tables
- Hydrophobic soils exacerbate irrigation inefficiencies and management of soil moisture
- Low soil carbon and often poor levels and diversity of beneficial soil biology inhibit the ability of soils to flush salts, and plants to gain optimum nutrient efficiencies
- Poor soil quality, combined with waterlogging, creates conditions conducive to soilborne diseases to flourish
- Heat stress, combined with salt stresses and uneven watering decreases the ability of potato varieties to perform at optimal levels
- Combined impact was found to lower potato productivity through disease, poor tuber set, and salt stress impacting on plant nutrition
- Crop nutrition was often based on past R & D, limiting the potential of current varieties to perform optimally

Addressing water quality prior to application:

Irrigating with high bicarbonate and saline water can increase pH, lead to the precipitation of calcium and magnesium carbonates, and increase sodium absorption onto clay particles. Furthermore, scaling of irrigation lines and solenoids can occur, creating blockages and barriers to the adoption of VRI technology.

Reverse osmosis (RO) and the direct injection of sulphuric acid are current practices that have been implemented by some horticultural businesses within the South East. Neither of these treatment options is truly viable for the potato industry, due to costs, ease of handling toxic chemicals and the flexibility required to move these systems from pivot to pivot to suit most current potato rotations. For some growers who have permanent pivots and irrigate year-round, systems for direct injection for sulphuric acid could be set up, however attention to detail would be required to test irrigation water more frequently, and to ensure correct doses are injected to gain a sufficient level of neutralisation of the bicarbonate.

In the search for a more user friendly and cost-effective method of achieving neutralisation of the irrigation water, there are a number of products that may assist in the prevention of scale build-up in irrigation lines. Such products include: Ferti Acid from Van Iperen, Hortipray MKP Anticalc from Prayon, PeKacid from ICL Fertilisers, and Transformer from Oro Agri. These products may help to clean irrigation systems and buffer bicarbonates to varying degrees however, if current corrosion is present, true prevention of scale build-up is not likely to occur. For some products, determination of the dosing rates required is also unknown.

While this line of R & D to address poor water quality prior to application is highly desirable, it does not fall within the scope of this project. Significant time would be required to undertake more detailed scoping of products, followed by lab and infield trialing to determine correct dosing rates prior to implementation on a commercial scale.

Therefore, the following project plan aims to address the implications of irrigation water quality applied and associated in-crop soil health, plant stresses and nutrition management to facilitate improved plant performance and potato yields of processing and fresh potatoes.

Proposed plan years 2 & 3

In-field crop and soil management to minimise the impact of poor irrigation water quality:

Based on the data collected throughout year 1 of this project, feasible management strategies have been identified to help overcome groundwater quality issues for potato production. These are focused on the basics of soil health encompassing physical, chemical and biological attributes, improving irrigation efficiencies and in-crop nutrition management. Collectively, addressing potato production through this connected system approach will improve the ability of crops to function optimally where only poor irrigation water quality is available, and therefore set the foundation for ongoing productivity and growth of the potato industry.

Practical trials for implementation in years 2 and 3 of this project address key limiting factors for each of the three project regions, and include:

1. Improving infiltration of irrigation water through targeted management of non-wetting soils
2. Re-addressing crop nutrition through regular monitoring and appropriately adjusted fertiliser programs
3. Reducing salt accumulation within the rootzone through improved salt leaching
4. Improved provision of stress relief through soil amendments and use of specialized products

General outline:

Given the regional variations and constraints identified in year 1 of the project, it is recommended that in years 2 & 3, trials be implemented across all three regions, encompassing the South East, the Mallee and the Northern Adelaide Plains (NAP). Anticipated seasons:

South East	Sept – April 18/19
Mallee -	Nov – May 18/19
NAP -	April – Nov 19

To enable dedicated focus on trial work in partnership with selected growers, it is recommended that the number of sites assessed be lowered in order to increase the level of detail within each captured.

Trial 1, that focus be directed on the Mallee and the South East, where the presence of hydrophobic soils is more common, one pivot in each region.

Trials 2 and 3 will be assessed jointly, where detailed site assessments and focused in-crop agronomy will be conducted in close partnership with the grower/manager and agronomist. One pivot from each of the three regions will be assessed.

Trial 4 will be conducted across each of the three regions, as strip tests within pivots for Trials 2 and 3.

Methodology

1. Improving infiltration of irrigation water through targeting management of non-wetting soils

The presence of non-wetting soils across the potato growing regions of South Australia, poses inefficiencies in irrigation application and often overwatering to 'wet the soil profile' prior to planting. This is a widespread issue for potato growers particularly within the Mallee and South East regions. Savings can be made in the volume of water applied, the power spent in applying excess irrigation water, and the prevention of overwatering lower lying areas, with the application of Transformer, a proven soil conditioner with Orowet technology. Overseas research and limited trials already conducted in the Mallee, have shown increased yields, and improved uniformity of potato growth through the application of Transformer in-furrow, at a rate of 2-3litres/ha. This provides a uniformly wet area within the potato mound, improving nutrient uptake, minimising waterlogged conditions, and thereby minimising the potential for soilborne diseases to flourish. While there are similar products on the market, such as Aqua Boost, the orange oil in Transformer also serves as a biostimulant, aiding tuber growth and resultant potato yields, showing beneficial levels of soil bacteria and fungi post application. For some potato growing areas where hydrophobic soils require between 3 and 5 irrigations to wet the soil prior to working, one application of Transformer through the irrigation system, of 10litres/ha, may also provide sufficient wetting of hydrophobic soils to occur after just one irrigation pass.

Therefore, suggested trial methodology would include two steps:

1. Apply Transformer via irrigation to 1/2 of each pivot at season start.
The ability of Transformer to wet the soil profile following the first irrigation will then be compared to standard practice through the assessment of soil wetness and uniformity within the soil profile down to 40cm. EM38 data if available will guide sampling locations, combined with topographical variability. Two pits within each 'zoned area' will be assessed, encompassing treated and control areas.

2. Apply Transformer in-furrow over 2 to 3 passes, intersecting step 1, perpendicular to application.
The assessment of Transformer to improve uniformity of soil wetting within furrow will be measured through the assessment of plant and tuber growth fortnightly throughout the crop cycle, along with step 1 results.

Furthermore, final estimates of potato yield will be conducted within treated and non-treated areas to compare tuber uniformity, sizes, disease pressure and yield. Photographic evidence will be captured, along with objective soil moisture levels using FieldScout TDR 150 soil moisture meters.

2. Re-addressing crop nutrition through regular monitoring and appropriately adjusted fertiliser programs, &
3. Reducing salt accumulation within the rootzone through improved salt leaching

Crop nutrition was managed in varying ways across the 8 growers and 7 potato varieties assessed in year 1. The use of sap or dry ash tests was generally found to be quite low, as was the testing of soil solution and soil moisture throughout the crop cycle. The application of nutrition management for optimum potato yields moving forward can only be done efficiently with regular testing to ensure the right products are applied at the right time, and in the right place. Moving into Year 2 trialing, it is recommended that the management of one pivot be conducted in close partnership/collaboration with a grower from each region. Monitoring will determine on site management, where each site presents its own in-situ variabilities. This may relate to the removal of MOP fertiliser to reduce additional chloride applications, the replacement of older fertiliser blends with compound fertiliser's to improve nutrient availability and uptake, the timing of fertiliser application to improve early uptake of calcium for example, or the addition of trace elements to address the low level of trace elements found in many SAP test results. Nutrition may also be aided via the application of products such as Retrosal, Thiocal or AquaCal, which helps to flush sodium from the soil and generally increase the absorption of other nutrients in saline environments. These products will be assessed in strip treatments, measuring the effectiveness against control areas and the movement of nutrients through the soil profile using solusamplers

The initial identification of growers and resultant discussions regarding crop management will broadly determine management options up-front, while in-crop sampling will refine management throughout the season. The assessment of soil, water, soil solution and plant nutrition, combined with trial harvest results within treated and control areas will provide results regarding the efficacy of the management applied.

General crop nutrition costs will be covered by growers; however, trial products will be supplied through the project and 'in-kind' support from EE Muir & Sons. Costs of production and yield within each of the trial pivots, will be compared to traditional grower costs and yields of neighbouring pivots with similar potato varieties.

For these pivots, site assessment criteria will remain the same as year 1, focusing on

A) Water; irrigation water quality and soil solution within the soil profile
B) Soil; chemistry, structure, texture, pathogens and pests
C) Plant; SAP, Dry Ash, disease pressure and tuber development
D) Yield; quality, quantity, SG's (processing) and peel calcium levels (fresh market potatoes).

Recommended modifications to monitoring will include additional dry ash testing, increasing from 1 to 3 tests to include key growth stages, and installing an additional solu-sampler at 50cm in order to measure potential leaching of salts in relation to applied management practices. Overarching data sets of EM38 and satellite NDVI imagery will also be undertaken where possible. It is important to note that project timing and site conditions can greatly affect the ability of EM38 data to be collected.

4. Improved provision of stress relief through soil amendments and use of specialized products

Heat Stress
One of the biggest constraints to potato production, particularly within the Mallee, is heat stress. It is not uncommon for temperatures to sit at 40 degrees Celsius for weeks at a time. Overcoming heat stress is commonly

targeted with irrigation applications throughout the day, and again of an evening to actually provide moisture to the tubers. One product that has been used with success to date is Megafol, a Valagro product that stimulates plant growth and reduces plant stress through various amino acids, proteins, betaines and vitamins. While the trialing of this product cannot be predicted ahead of time, it is aimed to trial 1 strip within each pivot of the project to illustrate potential efficacy, and associated costs to growers ahead of a predicted heat wave. Photographic evidence of crop tolerance to heat will be captured at each site.

Soil microbial composition
Plant stress in harsh conditions may also be exacerbated by poor soil microbial populations. Beneficial soil biology was generally found to be quite poor for most of the pivots assessed during year 1, particularly within the Mallee and the NAP. This was in part due to poor soil condition; low carbon, poor structure and drainage etc. Healthy soil biology is important for plant health and nutrient uptake, where beneficial bacteria and fungi assist nutrient transfer around plant roots. Products such as Serenade Prime by Bayer (beneficial soil bacteria), when applied in furrow at rates of 5-7litres/ha, have resulted in increased potato yields in Tasmania and Queensland, and also improved size and quality of potatoes in WA. (Cost of product is approximately $80/ha, however yield gains between 15-26% are achievable compared to standard practice.) The application of Serenade Prime, or a similar product, trialed within the Mallee in particular, may well help to improve yields against standard practice.

Data also suggests that specific soil bacteria (heterotrophs) can play an important role in plant nutrition when irrigation water contains high levels of bicarbonate. The application of elemental sulphur to soils can help to lower pH and keep calcium and magnesium in suspension. However, the acid producing effect of the added sulphur is generated from the interaction of soil biology, gram negative bacteria, on the sulphur. Therefore, improved levels of gram-negative bacteria would be required to assist with this means of coping with poor irrigation water quality.

Some potato varieties assessed in year 1 were found to generate poor tuber set. This again may be due to poor diversity and populations in beneficial soil biology. Viva, a root stimulant product from Valagro, has been found to increase tuber set in potatoes, thereby providing the ability to lift potato yields close to half a ton/ha. Cost is approximately $125/ha. This improvement in yield has been attributed to polysaccharides, vitamins and humic acids, combined with amino acids, and proteins, improving rhizosphere efficiency and improved vegetative and productive growth balance.

Using soil microbiology test results as a guide, it is recommended that either of these products be trialed within each regional pivot, to assess the efficacy of the product to boost beneficial soil microbiology and potential gains in yield. Yield assessments comparing treated area to control will provide guidance regarding cost effectiveness of product to the potato industry.

Cover cropping and soil health
In an ideal world, improved soil structure and biology would be gained through the use of cover cropping. Cover crops, particularly biofumigants, have shown increased yields in potatoes across various soil types, along with improved diversity and balance of beneficial soil microbes and decreased levels of pathogens. Within the Mallee such management may be difficult to implement, however encouragement of cover cropping in the Northern Adelaide Plains and the South East should be easier to adopt, creating improved soil conditions immediately prior to potato crops. In Tasmania, increased processing potato yields of up to 9ton/ha has been achieved with biofumigants compared to traditional rye grass, along with 10% increases potato numbers for preferential size classes. Additional to this, weed pressure was lowered and improved soil water holding capacity decreased volume of irrigation water applied. ($275/ha to establish, potential returns of $5000/ha). Biofumigation is effective on all soil types however greater efficacy of ITC release is gained in sandy soils over heavier clay soils due to less adsorption occurring on clay particles.

Communication

On completion of project trials and collation of all results, Year 3 will finally focus on the development of relevant extension materials to promote identified beneficial monitoring tools and management practices throughout the broader potato industry. While irrigation water quality poses limitations to potato productivity, it is firmly believed that in-crop management of in-situ soil parameters, physical, biological and chemical, linked with careful irrigation and regular monitoring of crop nutrition, will lead to increases in potato yield and pack-out for both the fresh and processing varieties. Guiding growers through new tests, technology and products focusing on holistic soil, water and crop management practices will be the first step in achieving cost effective outcomes.

Extension material generated will focus broadly on monitoring and management practices and the associated cost/benefits. Specific case studies will however be avoided, in order to maintain grower confidentiality. Presentation of project results will also be delivered through relevant industry forums and regional potato grower groups.

Appendix 3

Published project news articles

TIM HEYSEN

BREAKING NEW GROUND

It's only early days, but Tim Heysen is excited about boldly going where no potato grower has gone before.

Together with growers in the south east, southern Murraylands and the Mallee regions of South Australia, the Kalangadoo grower is playing a small part of an extensive three-year project examining the effect of groundwater on nine varieties of potato crops.

The project *Impact of groundwater quality on the management of centre pivot-grown potato crops* (PT16001) is a strategic levy investment under the Hort Innovation Fresh Potato and Potato Processing Funds. It is being coordinated by E.E. Muir & Sons, trading as Serve-Ag.

It will include studying site and plant conditions to see how they affect the growth and health of plants, but the long-term goal is to increase productivity and profitability across the state by implementing proven practices.

IT'S ABOUT EXAMINING EACH PIECE OF THE JIGSAW PUZZLE AND PUTTING IN PLACE THE BEST PRACTICES AND STRATEGIES ... FOR THE ULTIMATE AIM OF CREATING HIGHER YIELDING CROPS

In Tim's case at Kalangadoo, about 50 kilometres north of Mount Gambier, the project is studying his Ranger Russet and Innovator potatoes, which he usually sells to McCain.

"The issue with our groundwater here is it is having many dissolved salts, including sodium chloride, in the water and pumping it out of an underground aquifer," Tim said.

"Our aim is to find the magnitude of the problem in the area, then suggest changes or solutions to what can be done. It's an exciting prospect because no one has previously tried to quantify how bad the issue is, and any knowledge we acquire is to be shared with other growers."

Its expected outcome is an improvement to sustainable irrigation management and water efficiency at a local and regional level. The project will also assist growers in making well-informed decisions as to what, when and how much fertiliser to use as part of an integrated management plan.

DIGGING DEEP

The obvious focus would be the groundwater's interaction with soil and in turn, the potatoes, Tim said.

Other variables could include the depth of clay, soil issues, fertiliser practice (such as what works best and when) and irrigation management, such as whether frequent small applications of watering reaps premium results or if fewer applications of large volumes of water is preferential.

There's also the matter of growers and their individual practices – some only grow a summer crop, planting in October or November and harvesting from February to May. Others in northern areas of the state generally plant in August and also in February.

DETAILED PLAN

The complexity, scope and detail into which the project will delve is what sets it apart as a strategic levy investment.

Tim said a project officer would monitor water quality through the season at the various farms, where it would be business as usual for participants.

"In South Australia we've all been dealing with a less-than-ideal water scenario, but this is about us all taking our product to the next level," Tim said.

"It's about examining each piece of the jigsaw puzzle and putting in place the best practices and strategies, and then sharing that information for the ultimate aim of creating higher yielding crops."

Tim said it may be up to three years before definitive findings can be made, but he was confident the methodical process would unearth better and more efficient methods of growing potatoes.

SUMMARY

- Project PT16001 is a three-year project that will examine the effect of groundwater on nine varieties of potato crops located across South Australia.
- In collaboration with a project officer and other growers, Tim Heysen from Kalangadoo will study how his Ranger Russet and Innovator potato crops can be better managed.
- The project is likely to improve sustainable irrigation management and water efficiency at a local and regional level, and will assist growers to make well-informed decisions.
- *Impact of groundwater quality on the management of centre pivot-grown potato crops* is funded by Hort Innovation using the fresh potato and potato processing research and development levies and contributions from the Australian Government.

Hort Innovation

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UNDERSTANDING THE IMPACT OF GROUNDWATER ON POTATO CROPS

A new project examining the effect of groundwater quality on nine varieties of potato crops located across South Australia has just completed its first year. Serve-Ag Technical Agronomist and Project Lead Julie Finnigan spoke to *Potatoes Australia* about the findings.

In South Australia, the loss of agricultural production to dry-land salinity is estimated at $47 million per annum. Similarly, salinity threatens groundwater districts, and communities that rely on irrigated farming overlap with South Australia's major potato growing regions.

National average potato crop yields are around 40 tonnes per hectare; however saline- and groundwater-affected areas such as the Mallee in South Australia may struggle to achieve half of this tonnage. To improve potato yields in these marginal areas, it is essential to understand current conditions and practices in order to identify practical and cost-effective management practices that may be recommended to facilitate change.

A project is currently underway to identify regional groundwater variability within three major potato growing regions of South Australia including the Mallee, the South East and the Northern Adelaide Plains. It aims to understand how this, combined with specific site conditions, affects the growth and health of potato plants and associated quality and yields.

Impact of groundwater quality on management of centre pivot grown potato crops (PT16001) is a strategic levy investment under the Hort Innovation Fresh Potato and Potato Processing Funds. It is being coordinated by E.E. Muir & Sons, trading as Serve-Ag.

A GROWER FOCUS

Serve-Ag Technical Agronomist and Project Lead Julie Finnigan is working with both fresh and processing potato growers on this project. She said it was initially designed to run for one potato growing season but this could be extended.

"Upon review of the data and recommendations provided, a further two years may follow where implementation of recommended management practices or nutritional programs may be trialled," Ms Finnigan said.

"Ultimately this project hopes to outline the major limiting factors to potato production across the three regions, with the ability to provide practical solutions to overcome or manage these constraints whereby production can be lifted with minimal cost for growers in South Australia. Beyond South Australia, if the project is successful, a similar approach could be used Australia-wide for all potato growing regions in marginal soils and/or with salt-affected irrigation water supplies."

Three growers within each of the three regions were approached to be involved in this project.

For each grower, a set range of data is collected which focuses on irrigation/groundwater quality; soil nutrition and physical parameters; and plant nutrition and health.

"On top of this, current irrigation and fertiliser management practices are discussed with growers to help identify potential areas for change that will help lead to increases in potato yields," Ms Finnigan said.

"All data collected is confidential, so while no specific details will be promoted, potato growers and the wider industry will benefit from regional summaries and the identification of key monitoring and management practices that will flag areas of potato production that could be addressed to help maximise yields and pack out."

All growers across the three regions have now completed their first year of monitoring and assessment.

"While a final first year summary report is yet to be completed, we are seeing regional variations across water quality and site conditions that do affect potato production," Ms Finnigan said.

"As such, tailored nutritional management strategies will be recommended to help maximise plant health and tuber development that should help to increase potato yields. The use of satellite imagery and EM38 mapping has also helped to identify site variability and areas that may be at risk of production loss. General recommendations outlining best monitoring and management practices will provide generic options for many growers to follow."

While this project will enhance the knowledge of local potato growers and provide them with the latest tools and resources to better manage their crop productivity, there will be wider benefits for the industry.

"The results of this project will also contribute to the Potato Processing Strategic Investment Plan vision, through longer term improvements to Australia's productivity and competitiveness in overseas markets," Ms Finnigan said.

"This in turn should help to lower costs via improved strategic management, collectively assisting to lower the ever-increasing level of imports."

INFO

For more information, please contact Julie Finnigan on 03 6391 4650 or at jfinnigan@serve-ag.com.au

This project has been funded by Hort Innovation using the fresh potato and potato processing research and development levies and contributions from the Australian Government.

Project Number: PT16001

Appendix 4

Fact Sheets.

Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Australia grows an average of 1.3 million tonnes of potatoes per year, accounting for 40 per cent of all vegetable production. Sixty per cent of potatoes grown are for processing (crisps, frozen food products) with the remaining forty per cent for fresh market supply.

The state of South Australia is the largest producer of potatoes in Australia, growing 385,000 tonnes annually and 80 per cent of Australia's fresh market potatoes.

1. **Monitoring for improved management**
2. Know your salts to better manage potato nutrition
3. Managing hydrophobic soils in potato production
4. Organic soil amendments, biologicals & biostimulants

This fact sheet is the first in a series of four offering tools, tips and management options for potato growers in Australia affected by salinisation.

This first fact sheet outlines the causes of salinity followed by key assessments and tests that will better inform your management decisions.

What is salinity?

Salinity is the saltiness of soil and water. Salinity naturally occurs in soils and water in many agricultural regions of Australia, known as Primary Salinity. Since colonisation, Australia's natural landscape has changed with clearing taking place for agriculture, the introduction of irrigation, and widespread urbanisation. This has led to Secondary Salinity. With many salts highly mobile, landscape and hydrological changes have moved salts, concentrating them in lower lying or lower slope areas, sometimes raising saline groundwaters or even creating perched saline water tables.

The impact of salinity

Salinity affects the major agricultural areas of South Australia with dryland salinity in the state accounting for an estimated production loss of nearly $50 million. Salinity does impact yield and quality of fresh and processing potatoes, but the true cost to production is still largely unknown. In other areas of Australia, potato yields have been reduced up to 30 per cent, reducing grower profits up to 45 per cent.

The sustainable and profitable production of potatoes requires efficient use of resources and inputs to suit specific site conditions and crop varieties. In order to maximise production and packouts, and reduce costs, you need to understand the systems you are working in and the major factors which limit production. This includes soil variability, irrigation water quality, salinity, sodicity and heat stress. Site conditions can change region to region but also vary between growers, so baseline assessments and ongoing monitoring can be critical in understanding what influences productivity.

The major potato producing areas of South Australia also coincide with areas that are affected by salinity (Figure 1).

Hort Innovation SERVE-AG

This project has been funded by Hort Innovation, using the Australian Processing Potato Industry and Australian Fresh Potato Industry research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Monitoring for improved management

1

Figure 1: Major potato growing regions in South Australia (Adapted from: Potatoes SA).

Identifying salinity

It is not always possible to visually identify salinity ahead of establishing your crop. Sometimes it's only after irrigation water is applied that salt crystals, leaf tip burning, stunted plant growth or poor crop yields become apparent. Other in-crop symptoms may include moisture stress from induced drought like conditions and soil structural decline, all resulting from imbalances of salts in soil and water.

Testing soil and irrigation water supplies ahead of crop establishment will confirm the presence and severity of salinity. Additional in-crop testing of soil, water and plants will help identify potential changes in salt levels and appropriate management practices to apply.

Salinity units of measurement

Many units of measurement are used to express salinity so ensure you check the unit of measurement for any soil or irrigation water test before making key management decisions. The most commonly used unit is dS/m.

1dS/m = 100mS/m = 1mS/cm = 670ppm = 1000uS/cm

How saline irrigation water can affect crops

Potato plants are moderately sensitive to saline irrigation water and it can affect your crop in the following ways:

- **Direct application and contact with the crop, particularly on hot sunny or windy days can scorch the plant leaves.** Scorching of the leaves will directly affect the ability of the plant to photosynthesise, decreasing plant health or at worst, cause plant deaths.
- **The application of saline irrigation water to your potato crop may increase soil salinity levels.** This is highly dependent on both soil type and the irrigation leaching fraction. Well drained soils will accumulate less salts than heavier or poorly drained soils, but with increasingly efficient water applications and less leaching, salts build up within the root zone. Increases in soil salinity can then lead to nutritional imbalances, decreases in water uptake and poor crop health and yields.

Table 1 can be used as a guide to understand potential crop losses that may occur for differing salinity levels, and how soil texture can also influence irrigation water salinity threshold for potatoes grown in different soil types.

Salinity of irrigation water resources in South Australia's potato growing regions generally tested between 1.7 and 3.9dS/m, with some exceptionally higher than this. This would impact crop quality and yield, and also add significant quantities of salt to the soils applied. For every 1ML of water tested at 1dS/m, up to 600kg of salt per hectare could be applied.

The total volume of salt that could be applied to soil during one potato crop: 5ML/ha of irrigation water applied at 1.7dS/m would be close to 1T of salt applied to that hectare of land.

ECw threshold for crops growing in (dS/m)			ECw threshold for crop losses (dS/m)		
Sand	Loam	Clay	10%	20%	50%
3.2	1.8	1.1	1.7	2.5	3.9

Table 1: Tolerance levels of potatoes to salinity in irrigation water.

2

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Monitoring for improved management 1

Monitoring irrigation water quality

Test your water frequently

- Use multiple tests throughout your irrigation season to identify fluctuations in salinity levels. Irrigation water, no matter its source can vary in quality from year-to- year, or throughout any one season.

Time your sampling

- Time your samples as events such as significant rainfall and hot evaporative conditions can change the salt loads in river systems and dams impacting the quality of your water.
- Irrigation water from groundwater sources can vary according to the depth of the aquifer tapped into, or for many areas of South Australia and Murray Darling Basin, the age and recharge capacity of the aquifer can influence water quality.
- While seasonal changes to irrigation water salinity sourced from groundwater resources is less common, locality of bores may still influence changes over the shorter term. In-crop testing for one grower in the Limestone Coast region, revealed an increase in irrigation water salinity from 1.6 to 2.46dS/m, mostly attributable to rises in sodium and chloride.

Testing options

- Use an approved laboratory at least twice a year to understand your irrigation water quality and for a complete breakdown of nutrients and salts present throughout your irrigation season.
- Regularly use a hand-held conductivity meter to get an immediate understanding of irrigation water conductivity levels and what further action is required.
- Calibrate and take good care of personal meters to ensure the collection of more consistently reliable results.

Monitoring soil salinity

Given the significant investment required to establish a potato crop, soil testing is a relatively small investment to help maximise your return on this investment. It is crucial to understand the variability of salinity within your crop, including the area affected and the severity of salt. This will guide your management response in order to maximise growth under different conditions and optimise crop health and yield. This may include fertiliser selection and application or irrigation scheduling.

Where to test

Collect and test soil from areas of your paddock that perform differently. Your knowledge of soil types and previous performance of crops will guide this, as can the use of technology such as Electromagnetic Induction (EM) surveys.

In-field soil testing options

For each area identified for soil testing, it is important to test the soil from within the root-zone of your potato crop. Typically, composite samples that consist of 12 – 20 soil cores should be collected from similar areas of your paddock, such as one composite sample from the sandy ridges and one from the lower lying heavier soils. This soil is then thoroughly mixed together and a subsample of this used for testing.

Testing the nutrient composition of your soil is best conducted by a reputable independent laboratory. These tests will not only provide you with an 'EC value', but provide you with a complete nutrient analysis and breakdown of the different salts present, which is critical for appropriate nutrition management. Be sure to check the units of measurement used as different laboratories may use different testing procedures and report using different units of measurement. Assistance from your local agronomist may help with the interpretation of soil tests.

Once you have a thorough knowledge of your soil salinity, a hand held salinity meter can provide you with a quick in-field assessment of electrical conductivity (EC1:5), by simply mixing one-part soil with five parts distilled water.

Such in-field tests may help you monitor change over time, or highlight areas of higher or lower salinity although should not replace laboratory testing.

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Monitoring for improved management 1

Understanding soil test measurements & crop tolerances

Similar to irrigation water, potatoes have a range of tolerance levels to soil salinity as shown in Table 2. One of the most common tolerance tests for potatoes is based on saturation extract levels (ECse), gained from laboratory testing the EC of a soil paste extract.

This type of salinity test removes any effect that soil texture has on results, compared to soil water solution tests such as an EC1:5, which does. Therefore, to convert your EC1:5 test result to a comparable ECse level, it is important to apply a conversion factor applicable to your soil type.

Soil test results for a sandy soil in South Australia yielded an EC1:5 of 0.113dS/m. Using the conversion factor of 17 for a sandy soil as listed in Table 3, a comparable ECse of 1.9dS/m is gained and less than 10 per cent crop loss could be expected. In comparison, another site with light clay soils had an EC1:5 of 0.433dS/m. Applying the conversion factor of 8.6 to this gives an estimated ECse of 3.73dS/m, where crop losses of nearly 20 per cent could be expected.

ECse threshold for crop losses (dS/m)		
10%	20%	50%
2.5	3.8	5.9

Table 2: Estimated salinity threshold levels for potatoes.

Soil texture	Conversion factor
Sand	17
Sandy loams	14
Loams	9.5
Clay loams and light clays	8.6
Medium and heavy clays	6.7

Table 3: Soil texture conversion factors for calculating ECse values from EC1:5 results.

Electromagnetic Induction surveys

Electromagnetic Induction (EM) surveys are a quick and effective way to measure conductivity within pivots or paddocks to identify salinity locations or 'zones'. The surveys are non-invasive, collecting data by submitting electrical signals into the soil profile. The conductivity is averaged over two depth profiles, 50cm and 100cm.

Figure 2 shows an example of a pivot in South Australia that has variable topography and soils, captured spatially using EM38 technology. Higher sandy ridges are typically the red areas measuring the lowest conductivity. Soil sampling and testing from within each major zone provides increased confidence in understanding the baseline salinity across your pivot. An EM survey is a good initial step for large cropping regions, or when embarking on developing new ground.

EM38 data does not readily change from year-to-year, so can also assist with predicting how your soils may react to differing climatic conditions. In wetter years, the drier deep sandy areas are likely to perform well, where in comparison, the lower lying shallow soils are likely to lay wet, and potentially accumulate more salts. Conversely, in drier years, the deep sandy areas will be very difficult to wet up and maintain moisture during a potato crop, while the lower lying areas will generally perform better with more uniform moisture.

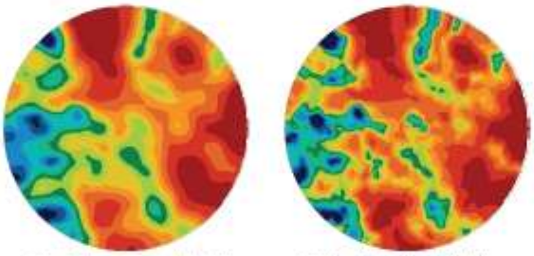

Figure 2: Electromagnetic Induction surveys at 100cm (L) and 50cm (R) depths, showing the spatial variation in soils and likely areas of salinity.

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Monitoring for improved management 1

Monitoring soil moisture & solution

In-field monitoring of soil solution is an easy and effective means of understanding root-zone soil moisture levels, along with nutrients and their concentration. There are a multitude of sensing and sampling tools available for this, all varying in functionality and price. Some units are better suited for irrigation monitoring and scheduling, while others monitor soil solution nutrients – both can be effective tools to assist with salinity management.

Soil moisture sensors provide objective information, remotely monitoring soil moisture within the root-zone of a crop at multiple depths. Through strategic placement of sensors, irrigation management practices can be monitored and assessed.

With saline soils, such irrigation management decisions are highly important to ensure sufficient water is applied to help flush salts down from the root-zone and prevent shallow watering and drying when salts are more likely to accumulate.

Some sensors can also monitor pH and EC, or at best a limited range of nutrients. However, to thoroughly understand the nutrients available in the soil solution, other soil moisture monitoring technology would be more appropriate. There are many different units on the market so select a unit that suits your purpose, fits within your budget and importantly, a system you have the time to monitor.

Figure 3: Extracting soil water from installed solusamplers in fresh market potatoes of South Australia.

Soil solution monitoring within potato crops in South Australia was recently conducted using Sentec solusamplers, chosen for their ability to draw and collect available soil water surrounding each unit, that can be extracted and later tested for nutrient analysis (Figure 3). When installed at varying depths, the resultant data can show the presence and movement of salts within the root-zone of your crop, and how this may vary with applied management or irrigation, or over the longer term, from start to end of your crop.

Sodium and chloride levels within the root-zone of potato crops across South Australia were often found to increase during one irrigation season. Highest levels were mostly measured at 40cm depth, a likely result of salt flushing.

Similar increases in root-zone salinity were measured in the nearby Angus Bremer region of South Australia using Full Stop devices (Thomson 2008).

Plant sap testing

Sap testing is a very quick and accurate test for monitoring crop nutrition. Plant petioles submitted to suitable laboratories can provide results in 24 hours, permitting early detection and correction of potential nutritional imbalances, either deficiencies or toxicities. Sap testing can be critical for the management of salinity where timely flushing of salts, via irrigation or the application of remedial products and fertilisers, is crucial for crop productivity.

When and where to sap test

Typically, one sap sample consists of 20-30 petioles from the youngest fully expanded leaf, collected from 20-30 plants. Be sure to collect one separate sample from each representative area of your paddock, such as the lower lying heavier soils and the upper slope sandier soils. Check sampling procedures and specific preparation and transport instructions from your preferred laboratory to ensure your samples arrive in the best possible condition for testing.

Throughout the potato crop, there are key growth stages where sap testing is recommended, starting in the early vegetative/ pre tuber stage, through to early tuber development and later tuber bulking. A regular sampling program will provide key nutritional information to assist with nutrient management for optimal growth. When multiple varieties of fresh and processing potatoes are being grown, sap testing can be the key to nutritional management and performance.

Sap testing can also be used strategically to measure salt mitigation management practices. For example, it can show the effectiveness of applied practices to lower chloride and sodium levels, and ensure a balanced uptake of all other nutrients.

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Monitoring for improved management 1

Precision Agriculture – other useful salinity monitoring tools

Normalised Difference Vegetation Index (NDVI) – Plant vigour

Satellite imagery or drone flights that can capture spatial plant vigour information is another useful tool for assisting with crop monitoring. Plant vigour measured using NDVI technology can identify areas of your paddock that may not be performing optimally, well before the eye can detect such differences. The earlier that declines in crop vigour can be detected, the earlier corrective measures can be put in place to avoid costly crop losses.

Crop vigour may vary across your paddock for any number of reasons, such as a broken spray nozzle applying too much water, patches of healthy growing weeds, variable soil types responding to irrigation differently or due to nutritional imbalances. Whatever the cause, the early visual differences picked up through NDVI, allow for early management to be applied.

Figure 4 shows an NDVI image captured using satellite imagery, of a potato crop in SA, week 5 (L) and week 15 (R). The blue areas show the greatest plant vigour, while the red areas show the least plant vigour. At week 5, the higher sandy areas are least productive, most likely due to moisture stress, compared to the lower lying areas where moisture at the time was more readily available. At week 15, plant vigour is changing, and becoming more variable with combinations of low-lying saline areas and upper slope sandy areas showing poor plant vigour. NDVI data coupled with EM baseline data can be powerful tools to assist with proactive crop management, particularly over larger areas.

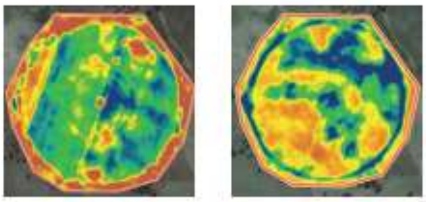

Figure 4: Satellite NDVI imagery taken at week 5 (L) and week 15 (R) of a potato crop in SA.

Elevation data and drainage

Free-draining soils are imperative for effective salinity management when irrigation water is highly saline. When drainage is impeded due to heavy sub soils for instance, highly mobile salts will accumulate. Affected areas often increase in size and severity. This can lead to nutrient imbalances, coupled with waterlogging and very poorly performing crops.

Elevation data captured with most EM surveys and guided tractors can be used to improve the drainage design within your paddock. Drains installed, either surface or deep, within a millimetre of accuracy will ensure the most effective movement of water across your paddocks.

pH gridded mapping

pH gridded mapping is a relatively new geo-referenced and guided type of soil assessment, where pH (CaCl2), phosphorus (Colwell or Olsen), potassium (Colwell) and/or exchangeable-cations are tested and assessed in a grid pattern to determine variability across a paddock. Combined with EM38 data, it can be very effective for defining soil textural and chemical conditions over large cropping areas from which targeted and effective nutritional management can be prescribed and applied.

pH gridded mapping trials in South Australia found that the generated soil management and nutrient zones assisted with prescription rates of fertiliser, amendments and irrigation, minimising overall production costs for potato growers.

Online resources

There is a wealth of free information about the natural resources within your local region. The various data sets available will provide you with general soil and water information from which more detailed on-farm assessments can be guided. Information is available through most state government agricultural and natural resources websites.

- **AgInsight South Australia** have a free online resource where you can search and layer multiple spatial maps of interest including: soil types, surface textures, groundwater depth, irrigation areas, water table induced salinity, rainfall and pan evaporation levels.
- **WaterConnect South Australia** provides free regional information for all groundwater resources. Detailed groundwater data is available for observation networks and wells within prescribed areas or NRM regions. Drill dates, well depths, sampling dates, standing water levels, yield and limited chemistry are all available, along with spatial maps displaying their locations.

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Salinity and potato production

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Nutrients play a vital role in the optimal production of fresh, processing and seed potatoes. Where imbalances exist, it can lead to a multitude of issues from general poor shape, size and skin blemishes, to storage quality, frying properties and flavour.

Applying the right nutrients at the right time and in the right quantity will help to reduce inputs while maintaining or increasing yields. Regular monitoring and assessments of your natural resources will facilitate sustainable potato production.

1. Monitoring for improved management
2. **Know your salts to better manage potato nutrition**
3. Managing hydrophobic soils in potato production
4. Organic soil amendments, biologicals & biostimulants

This fact sheet is the second in a series of four on salinity and potato production in South Australia. 'Know your salts' takes an in-depth look at salinity and the salts that affect both plant health and soil structure, and guide potato nutrition.

Although these fact sheets focus on potato production in salt affected regions of South Australia, the information can be applied to other salt affected regions of Australia.

Salinity in South Australia

Landscapes and soils across South Australia range from deep sands to shallow sands over light clays and are all affected by salinity to varying degrees. Salinity not only affects the soil but can also affect the irrigation water applied.

While sodium and chloride are the main reason for a decline in productivity in many parts of Australia, South Australia's groundwater resources used for irrigation is hard and high in sodium, chloride and bicarbonates. This provides multiple challenges for optimal potato production. Irrigation water supplies measured across the three major potato growing regions show salt levels often four to five times above upper desirable limits for potatoes.

The application of highly saline irrigation water to potato crops not only directly impacts potato plants but can also add salts to the soil profile. Salt accumulation within soils affects nutrition and can also directly affect soil structure impacting on potato emergence, growth and harvest.

Irrigation and cropping can exacerbate salinity in prone areas so it is paramount to know your salts and where they exist for optimal nutrition and irrigation management.

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Know your salts to better manage potato nutrition **2**

Test results – What salts are what?

For optimal potato nutrition, it is important you understand the salts in your cropping system and their levels in the soil, water and plants. All nutrients must be in balance for plants to function at their best. Only one element in excess, such as sodium, can cause deficiencies in others such as calcium and potassium. Here are the important salts and how they can affect potato quality and yield.

Chloride

Chloride is one of the most soluble anions of salt which can have a major impact on potato production.

Irrigation water high in chloride applied directly to potato crops using an overhead form of irrigation, can scorch the plant leaves where browning on the leaf edges quickly becomes evident (Figure 1).

For potato production areas, scorching of the leaves during irrigation on hot windy days increases the likelihood and severity of scorching that will occur. With the onset of climate change and higher summer maximum temperatures, the risk of scorching only increases. Scorching of plant leaves reduces the health of the plants due to impaired photosynthesis, akin to damaged solar panels, with overall decreased leaf growth and area.

Figure 1: Yellowing of plant leaves and scorching of leaf tips, early signs of salt stress in young potatoes.

Measuring salinity

- Electrical conductivity (EC) is the most common unit of salinity measurement used for soils and water.
- ECw and ECse values classify the severity of salts, along with determining the tolerance of crops to salts.
- The EC value is a measure of all dissolved salts present, which may include the cations sodium, magnesium and calcium, and anions chloride, sulphate, carbonate and bicarbonate. These salts vary in their level of solubility further complicating salinity and EC readings.

Upper chloride levels in irrigation waters were measured in the three potato growing regions in South Australia including the Mallee (382ppm), South East (554ppm) and Northern Adelaide Plains (898ppm). All measured well over the upper desirable limit of 200ppm.

Elevated soil chloride levels above 200mg/kg decreases plant health and vigour as the plant roots are unable to absorb water and other nutrients efficiently. Chloride directly competes with nitrate, preventing the uptake of nitrate by plants. With the application of extremely high chloride levels in irrigation water, the potential for chloride toxicity in the plants is high, along with accumulation within the soil.

Soil chloride levels were measured across the three major potato growing regions, with the highest levels observed in the Northern Adelaide Plains at 209mg/kg. The other two regions had significantly lower chloride levels, <100mg/kg, however results showed chloride increased from the start to the end of each potato irrigation season.

Chloride levels in plant sap tests also varied region to region. The Mallee and the South East observed some of the highest increases in chloride, often doubling or tripling in levels from start to season end, with levels up to five times greater than the upper desirable range.

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Know your salts to better manage potato nutrition 2

Sodium

- Sodium is the most soluble salt of the cations and collectively with chloride can be very damaging to plant health and productivity.
- For irrigation water the upper desirable level for sodium is 74ppm.

The three potato growing regions showed variability with sodium levels in irrigation water ranging from 140ppm as the lowest recorded level in the Mallee, through to 608ppm in the Northern Adelaide Plains – eight times greater than the upper desirable limit.

- High soil sodium levels can lead to nutritional imbalances, as well as poor soil structure, increasing potential compaction, decreasing porosity which in turn impedes water infiltration and decreases the ability of plant roots to function properly.

Soil sodium levels varied between regions from the start to end of the season and between the sands and clays. The upper desirable range for soil sodium is 90mg/kg. At the start of the season, the majority of sites had sodium levels well below 90mg/kg (10 – 34mg/kg), apart from some of the higher clay-based soils that ranged from 85 – 145mg/kg. End of season accumulation levels ranged from two to six times greater that start of season levels.

- Sodium levels are typically measured as Exchangeable Sodium Percentage (ESP).

Soils with elevated ESP >6% are referred to as sodic. Sodic soils can be highly dispersive, losing structure quickly when wet and forming hard setting crusts on the soil surface when dry. The high proportion of sodium relative to other cations enables the sodium to remain bound to the clay particles, but displaces other cations. This weakens the bond between the soil particles, resulting in dispersion and poor soil structure.

Plant sap sodium levels generally varied throughout the season regardless of region, most likely due to individual management practices combined with inherent site conditions. Elevated sodium levels in soil solution can lead to imbalances in plant calcium and potassium. Deficiencies in plant calcium can lead to reduced strength in cell walls, reduced resistance to various diseases and decreased storage capacity of tubers. Potassium deficiencies add to reduced disease resistance and inefficient uptake of nitrogen, can impact specific gravity of tubers and generally lead to poor plant health and reduced yield.

Figure 2: Salt scalding and the accumulation of salts on the tops and sides of potato mounds in South Australia.

Figure 3: Surface crusting of a potato mound with salt crystals formed just below the surface.

Calcium

- Calcium is a very important nutrient required for healthy potato production, playing a significant role in early cell division and growth through to tubers approximately 5mm in size.
- Research has shown that for calcium to reach the developing tubers, it can only be absorbed via the stolons, and therefore must be present in a highly available form during early cell division. In this regard, calcium is unlike other nutrients, only moving upwards through the plants, not downwards from the leaves.
- For healthy potato production, you need to minimise the effects of excess sodium on soil nutrition and structure, ensuring healthy root growth with the correct balance of available nutrients.
- Typical liming agents used to adjust pH will not provide sufficient available calcium, and instead growers should be sourcing quality products with highly available calcium to the developing stolons.

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Salinity and potato production

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Know your salts to better manage potato nutrition 2

Other water quality issues

pH

- Alkalinity of soil and water is very common in potato growing regions of South Australia.
- Alkalinity of soils is caused by the presence and weathering of calcium carbonate rich parent material. This is typically seen in drier regions that experience uneven rainfall events.
- Irrigation water with a pH above 7 is considered alkaline.
- Irrigating with alkaline water that is high in carbonates can increase soil sodium levels due to the relatively insoluble nature of calcium carbonates present, effectively removing the calcium availability from solution.
- pH of soils and water can reflect the salinity and sodicity of soils, creating both nutrient imbalances and poor soil structure.

Hardness

- Water hardness relates to high levels of dissolved calcium and/or magnesium salts, along with other cations such as iron, manganese, aluminium and zinc.
- The classification of water hardness is based on levels of calcium carbonate, with most South Australian waters testing Hard to Very Hard, 2.5 to 5 times greater than the upper desirable limit of 100mg/L.
- Irrigation with hard water can lead to increased sodium accumulation within the soil, and sometimes calcium deposits can lead to blocked irrigation equipment.
- Hard water used in irrigation is a key factor in reducing the adoption of variable rate irrigation due to the blockages that can readily occur.
- High iron levels in irrigation water can lead to the build-up of iron loving bacteria in irrigation lines and nozzles, creating blockages and potential inefficiencies in the application of irrigation water to crops.

What salts are in fertilisers?

Fertilisers play a significant role in managing salinity in potato crops, with all fertiliser materials varying in their relative salt content and solubility. Muriate of potash, potassium chloride, is one fertiliser that can add further chloride to saline systems with already high chloride levels. Since chloride can be quite toxic to potatoes, the use of other potassium fertilisers, albeit slightly more expensive, may end up saving you money in the long-term.

Quality liquid fertilisers such as calcium thiosulphate, can supply readily available calcium and sulphur for plants in a solution that is significantly more soluble than gypsum. The timely application of calcium thiosulphate to both processing and fresh market potato crops in South Australia has assisted with flushing chloride and sodium from the root-zone of tubers, reducing plant chloride levels up to 30 per cent.

With chloride competing with nitrate for plant uptake, the application of potassium nitrate or magnesium nitrate will assist with nitrate uptake in saline environments compared to traditional ammonium-based fertilisers such as urea.

Organic amendments such as compost may also contain salts, so if you are applying composts to your potato crops and soils, make sure you request a nutrient analysis prior to application to avoid adding further salts.

Irrigation management

Irrigation water is essential for potato production to occur but there are few cost-effective ways to change the quality of this water. In some agricultural regions, 'shandying' highly saline irrigation water with fresh water can assist with lowering salt loads. Unfortunately, this option is rarely available in South Australia.

Some regions rely on wastewater for irrigation, which can also be highly saline, and when stored in on-farm dams can become exposed to potential evaporation during hot summer days, further increasing salts.

Irrigation management and scheduling can assist with salinity management within the root-zone of potatoes. Ensuring potato mounds remain wet helps to prevent the drying and wetting patterns that lead to evaporation and accumulation of salts within the root-zone. Regular irrigation assists with pushing or flushing the harmful salts down and away from the developing tubers, helping to balance nutrients.

Amending irrigation water quality ahead of application is not a cheap or easy process. However, the salts within the root-zone can be managed more easily and cost effectively if we monitor and measure regularly. Management options will be discussed in more detail in the following two fact sheets.

4

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Salinity and potato production

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1. Monitoring for improved management
2. Know your soils to better manage potato nutrition
3. Managing hydrophobic soils in potato production
4. Organic soil amendments, biologicals & biostimulants

The state of South Australia is the largest producer of potatoes in Australia, growing 385,000 tonnes annually and 80 per cent of Australia's fresh market potatoes.

This fact sheet is the third in a series of four on salinity and potato production in South Australia.

In this fact sheet, we explore the impact of hydrophobic soils on potato production and options for growers to assist with their management to improve potato yields.

Hydrophobic soils in South Australia

Soils can vary in the major potato growing regions of South Australia, ranging from deep sands through to shallow sands and loams over light clays. This variability not only occurs within each region, but also on a much smaller scale in individual pivots.

Growers say a major limitation to potato production is the sands being cropped and their hydrophobicity, or inability to wet easily. Hydrophobic soils repel water due to waxy organic compounds that coat the soil particles, often leading to run-off from the mounds before it can infiltrate to where the plant roots require it (Figure 1). This can lead to excessive quantities of irrigation water being applied in order to wet soils sufficiently prior to sowing. Sandy soils are most susceptible to water repellency.

Figure 1: Irrigation water pooling inter-row having run-off from the potato mound

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The effects of hydrophobic soil on potato production

Poor water infiltration and mound degration

The application of excess irrigation water in South Australia is costly to growers. Irrigation water needs to reach the root-zone of plants to make every dollar count. Nearly all irrigation water supplies in South Australia are saline, so every megalitre applied is adding salts to the soil, and potentially scorching plants along the way.

Rising temperatures in Australia are adding further stress to the system. Temperatures in excess of 40 degrees during summer greatly impact potato production. This makes it even more difficult to keep soil moist for developing tubers, or the ability to flush salts from the root-zone.

The inability to maintain soil moisture levels in hydrophobic sandy soils also leads to significant slumping and degradation of potato mounds. This can be seen in Figure 3 during the early stages of growth. This loss of mound structure and blowing of sands can cause physical damage to emerging plants, but more importantly, has been found to significantly decrease marketable crop yields by 30 per cent through elevated numbers of green potatoes for both fresh and processing markets.

Figure 2: Examples of tuber damage and skin blemishes occurring in fresh and processing potatoes from uneven watering

Figure 3: Wind blown sands and degraded potato mounds occurring in deep sandy soils of the Mallee

Tuber damage

Tuber damage can come in many different forms, a result of uneven water penetration – whether too much or too little received by the tubers. Misshapen tubers are a common result, as are retained stolons and 'lady shaped' tubers, growth cracks, and raised and burst lenticels (see Figure 2). Raised and burst lenticels can then become wounds or points of entry for disease to occur. While misshapen or blemished tubers directly affect fresh market crop yields, more severely affected processing tubers may also lead to reductions in crop yield. Common scab can also result from insufficient soil moisture levels during early tuber development, particularly in light sandy soils.

Minimising the risk of tuber damage and associated decreased yields from hydrophobic soils is achievable with applied soil management practices.

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Cost effective management options for hydrophobic soils

Cover cropping and the inclusion of green manures is by far the preferred long-term method for managing hydrophobic soils.

This method requires you to increase soil organic matter levels and soil biological diversity by adding green manure crops into your rotation. The inclusion of green manure cover crops requires forward planning to ensure you have sufficient time to grow your crop, the resources and equipment for establishment, termination and incorporation, sufficient water allocation to irrigate your cover crop, and importantly the most suitable cover crop to deliver timely results without hosting potential diseases or pests. A great long-term option, but not always feasible or cost effective for growers.

> Sandy soils by nature can respond very quickly to the addition of organic matter. Soil carbon levels increase, soil resilience improves and subsequent crop yield will improve.

Another method is to add composts to help increase soil organic matter levels. For composts to be cost-effective, a local source is required to reduce transport costs. It is crucial you understand the nutrient analysis of local composts to ensure you are not adding additional harmful salts to your soil.

Short-term options

While long-term options to address hydrophobicity may not be viable for many areas in South Australia, a short-term option is through the use of soil wetting products and practices. There is a plethora of products on the market, so the key is to understand how they work and how best each may suit your situation.

Claying

Adding clay to sandy soils is one management practice that has been used to increase soil surface area and minimise the water repellency of soils. In highly sandy soils, significant quantities of clay could be required to reduce the impact of hydrophobicity, adding substantial costs on top of those to establish a crop. While claying may contribute to some long-term benefits, sandy sites are still likely to succumb to wind erosion and uneven watering within potato mounds.

Gels and crystals

Gels and granules can be added to the soil to store water, increasing the water holding capacity of your soil. Such gels have the capacity to store large volumes of water, increasing the immediate quantity of water available to your crop, potentially increasing the time required before the next irrigation. However, once these granules and gels dry out, they will no longer assist with holding water within your root-zone. Importantly, these products will not help to alleviate the hydrophobicity of your soil, and you must first be able to sufficiently water your soil to gain this result.

Soil Wetting Agents

Soil wetting agents assist with water penetration of hydrophobic soils by effectively stripping the waxy residues from sandy soils, lowering surface tension of the water and allowing penetration through pore spaces. The key is to find a suitable product that is safe and easy to use, along with being cost effective.

Which products & practices?

There are many products and practices that can assist with the management of water repellent soils but it is important to understand their mode of action and select your management option accordingly. Ensure the product you select is backed by strong research and development.

Product price can vary so look at the upfront cost compared to rates of application required per hectare and examine whether the product can be introduced cost effectively into current production systems.

Many other input costs and savings could also be gained when water repellency management is applied, such as:

- Cost savings from reduced water volumes applied to wet soils up
- Reduced costs in fuel or power to run irrigator pumps
- Reduced volumes of harmful salts added to soils
- Likely improved efficacy of herbicides and fungicides applied given improved uniformity of wetting assisting the uniformity of distribution of products.

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Salinity and potato production

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Managing hydrophobic soils in potato production 3

Soil conditioner product trial

Recent trials in South Australia looked at the effectiveness of a soil conditioner that combines natural cold pressed orange oil with a special blend of surfactants to help improve infiltration and uniformity of wetting with the root-zone.

The results of the trial were encouraging, with growers immediately commenting on the rapid infiltration of irrigation water where the soil conditioner had been applied compared to control areas. Where the product had been applied using fertigation over the sands prior to planting, these treated areas were also observed to resist blowing in strong winds. A positive early sign that sandy potato mounds may hold better.

This product was chosen above others to trial for a number of reasons:

1. Overseas research showed improved water infiltration of challenging hydrophobic soils for periods up to eight months. The longevity of the product performance in soils would enable growers to benefit from improved water penetration throughout the root-zone for the life of the crop. This would assist with plant emergence through to improved quality of yields.
2. This soil conditioner was compatible with herbicides and fungicides typically used with potato production, assisting growers with ease of application and incorporation into current programs. Furthermore, the natural composition of the product was greatly appealing for both handlers and consumers of potatoes.

Published research results from South Africa showed similar increases in quality and yield for potatoes grown using this soil conditioner in hydrophobic soils.

Differing methodologies of product application were trialled, including: broad scale application prior to planting using fertigation and sprayrigs, in-furrow application at planting, and combinations of the two. All methods of product application resulted in increased yields compared to untreated areas, as seen in Figure 4 with processing potatoes. Increased yields were a result of improved potato quality, greatly minimising tuber defects and blemishes associated with uneven watering of hydrophobic soils.

The two most common blemishes observed in control areas were greening and raised or burst lenticels, strongly suggesting that the application of this soil conditioner did assist with improved water penetration as well as uniform watering within the root-zone of the tubers. In particular, this sandy site with blanket application benefited from a reduction in green potatoes close to 30 per cent compared to the control.

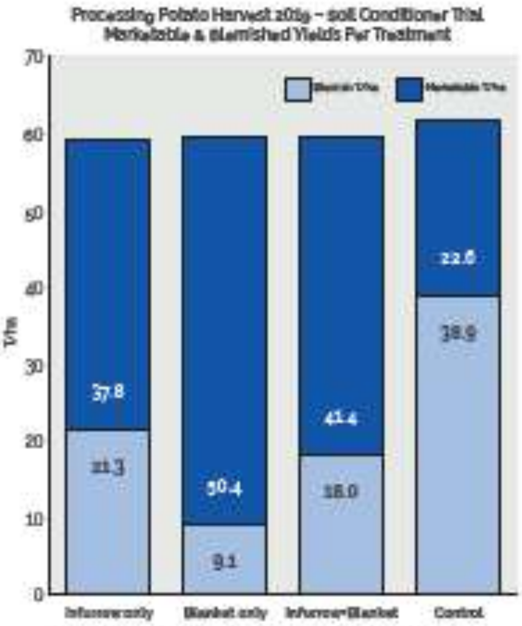

Figure 4. Marketable and blemished yields of processing potatoes in sandy hydrophobic soils treated with soil conditioner.

While raised or burst lenticels would not usually be rejected for processing potatoes, the reduction in skin blemishes for fresh market potatoes is highly desirable. Burst lenticels are also future points of infection, so improving uniformity of water penetration and re-wetting of hydrophobic soils would help to lower the risk of disease occurring in tubers. The reduced incidence of all blemishes associated with inefficient water penetration achieved in this trial, highlights the efficacy of the soil conditioner applied in improving water penetration and availability to tubers in hydrophobic soils.

Similar results were gained in trials with fresh market potatoes, collectively showing that soil conditioners can be very effective at improving water penetration and uniformity of wetting in hydrophobic soils.

4

Hort Innovation

References and further reading
Water Repellent Soils Case Study | Water Repellency Fact Sheet, Shepherd J, Hoyle F and Murphy D, (2020) | Soil conditioner trial product information

Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Organic soil amendment, biological and biostimulant products vary greatly in terms of what they actually are and how they function. The applicability of any product to your situation should be based on what your specific barrier or limitation to improved crop health and yield is, how each product functions, and choosing a reputable product that addresses such issues.

1. Monitoring for improved management
2. Know your soils to better manage potato nutrition
3. Managing hydrophobic soils in potato production
4. Organic soil amendments, biologicals & biostimulants

This is the final fact sheet in a series of four for potato growers exploring monitoring and management options to overcome many soil and water constraints.

With a growing interest in the area of soil health and the wide range of products available, this fact sheet explores organic soil amendments, biologicals and biostimulants to help growers understand what these products are and how they work.

Soil amendments, biologicals & biostimulants

In recent years soil health has become more of a buzz word, with soil more widely recognised as a living medium, not just the physical and structural resource we manage for food and fibre production. Soil hosts a living zoo, full of bacteria, fungi, protozoa, and larger macroinvertebrates such as beetles and earthworms. The more we explore soil health, the more we realise that diverse soil biology can be very beneficial to crop productivity.

Soil management practices, such as cultivation practices, irrigation, cover crops, chemical inputs combined with climate conditions such as heat and rainfall influence the overall health of soils; the chemical, physical and biological components.

Organic soil amendments, biologicals and biostimulants, provide a new suite of natural inputs to assist with feeding and stimulating beneficial soil fauna, improving the condition of their habitat, and ultimately improving the health and function of plants more naturally.

Heavily cropped soil repairing with Brassica cover crop

This project has been funded by Hort Innovation, using the Australian Processing Potato Industry and Australian Fresh Potato Industry research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Organic soil amendments, biologicals & biostimulants 4

What are these products & how do they work?

Organic soil amendments

The term organic soil amendment encompasses a broad range of composts, compost teas, manures and biosolids, and other crop wastes such as plant mulches. Soil amendments are generally used to improve overall physical properties such as structure, aeration, drainage and water retention, and must be mixed thoroughly within the root-zone for best results. Organic soil amendments available to growers will be highly dependent on region and proximity to product supplies, so for some this may not be a viable option.

Organic soil amendments can contain decomposing material from plants, animals or both, but always contain carbon along with nitrogen, phosphorous, potassium and sulphur. Trace elements may also be present, along with the potential for beneficial microbes. However, composts do vary greatly in their nutrient status and not all would be suitable for application in saline environments. For example, some composts and biosolids contain heavy metals or pesticide residues, or have elevated levels of harmful salts which should be avoided for potato production. The safest option when purchasing soil amendments is to ask your supplier for a nutrient test before you invest.

Amendments can assist with improving soil health but results vary according to your soil type, rates of product applied, breakdown rates, irrigation and other fertiliser inputs as examples. Know what you are applying and how it may influence your cropping system.

Biologicals

Biological soil improvement products typically contain either beneficial fungi or bacteria. The number and diversity of fungal and bacterial strains within these products varies, as does the inclusion of substances such as humic acids, yeasts, and other microbial exudates that may improve their effectiveness.

Trichoderma

Trichoderma are one type of beneficial fungi which can assist with disease suppression. The fungi are soil dwelling and feed on dead and decaying organic matter. Trichoderma are generally fast growing, and importantly form symbiotic relationships with plants. For example, *Trichoderma harzianum* is a beneficial fungi that grows within the rhizosphere of plant roots and feed on excess nutrients not used by the plants. The fungal growth in the rhizosphere, the very thin layer surrounding plant roots, can then help provide a physical barrier to fungal pathogens present in the soil. Trichoderma also release enzymes that help to break down the cell walls of fungal pathogens, such as Rhizoctonia, Pythium and Sclerotinia. Some strains of Trichoderma have been found to help solubilise phosphorous bound to soils, a common feature of the alkaline soils in South Australia.

This is where a Trichoderma could assist by naturally accessing nutrients that would otherwise be unavailable to plants.

Trichoderma Harzianum
Source: Wikipedia

Mycorrhizae
Source: Soilhealth.com

Mycorrhizae

Mycorrhizae fungi are another type of beneficial fungi that colonise the root systems of plants. There are seven major types of mycorrhizae, however just one of these form relationships with 80 per cent of plants including potatoes - arbuscular mycorrhizae.

Arbuscular mycorrhizae fungi form structures within plant roots called vesicles. These vesicles are oval shaped and are believed to assist with storing nutrients and moisture, which may reduce the severity of prolonged periods of heat, and increase drought tolerance of plants. As such, potato cropping in areas that suffer long periods of heat stress during the summer months may find arbuscular mycorrhizae fungi beneficial in a number of ways.

Arbuscular mycorrhizae extend out into the root-zone colonising plant roots with hyphae, well beyond the capabilities of actual plant root hairs. This improves nutrient and moisture uptake from areas otherwise inaccessible by the plant roots themselves. Mycorrhizae fungi also produce enzymes that encourage nutrients to release, which can bind to soil particles.

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Salinity and potato production

Impact of groundwater quality on management of centre pivot grown potato crops

Organic soil amendments, biologicals & biostimulants 4

The effects of a mycorrhizal product were examined in recent fresh market potato trials in the Northern Adelaide Plains of South Australia. It looked at one product that contained four key strains of arbuscular mycorrhizae, plus a humic acid aimed at further enhancing the uptake of nutrients.

Figure 1 shows that an increase in yield of 6.3 T/ha was achievable in fresh market potatoes, providing substantial returns to the grower for their investment. The greatest gain in potato yield from this mycorrhizal product was measured in the size class 75-250g, where the average weight of potatoes was greater than in un-treated areas.

Bacillus subtilis

Bacillus subtilis is a naturally occurring beneficial bacterium commonly found in soils, water and decomposing plant material. Research has shown that certain strains of *Bacillus subtilis* applied to the root-zone of plants colonise the rhizosphere of plant roots, helping to provide a barrier to fungal pathogens and assist with the prevention of resulting diseases. Similar to beneficial fungi, beneficial bacteria also release a complex mix of chemicals that ultimately enhance plant nutrition and can assist with moisture uptake and retention.

Tasmanian processing potato trials using *Bacillus subtilis* applied in furrow, have repeatedly shown improved yields averaging 10T/ha.

Biostimulants

Biostimulants are a relatively new range of agricultural product that are applied to plants or soils to improve crop yields and quality. They consist of a very diverse range of compounds, substances, micro-organisms and formulations.

Biostimulant products are created based on research and development conducted with plants that in nature exhibit significant qualities and coping mechanisms for overcoming natural, and often daily, environmental stresses. The genetic and molecular processes of such plants are studied in great detail, with key performing compounds isolated and refined into specific products to help improve plant performance.

Biostimulants stimulate natural plant growth, helping to improve the overall vigour of plants. Biostimulant products can assist with the production of both fresh and processing potatoes in saline environments as specific products have been developed to target and improve particular areas of plant function. This includes improved absorption of nutrients, improved root growth, increased photosynthetic activities, improved growth in saline conditions and assisted recovery from stress such as heatwaves or severe frosts.

When incorporating biostimulants into your program, be sure to fully understand what each product is designed to assist with and follow application instructions carefully. It is important to note that biostimulants do not replace fertilisers or crop protection products, but when applied correctly, can greatly improve their performance.

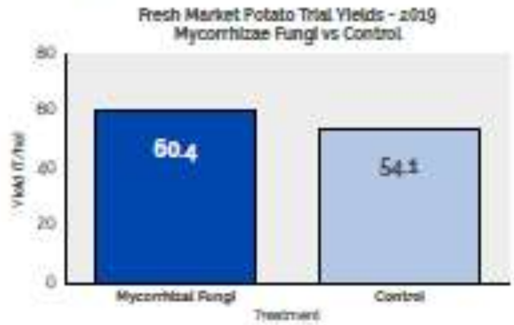

Figure 1 Fresh market potato yield comparing Mycorrhizae fungi treatment to control

How do I know if a product is right for me?

Trial products for yourself using your own farm as a research tool and against your standard practices so that benefits can be observed and measured over part paddocks or along strips. The results you gain will vary depending on soil types, crop variety and other climatic stresses so try not to make decisions on just one trial.

Measure your crop yields and record visual differences to help you determine the potential benefits to be gained from these products. Soil tests can also be submitted to specific laboratories that undertake testing for microbial populations. This will provide you with a breakdown on diversity and population densities, and what it all means for your soil health. While these tests are relatively new, it will provide baseline information of your soil biology which can be monitored over time. The tests will highlight the potential changes that different crop management practices or seasonal fluctuations may induce.

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References and further reading

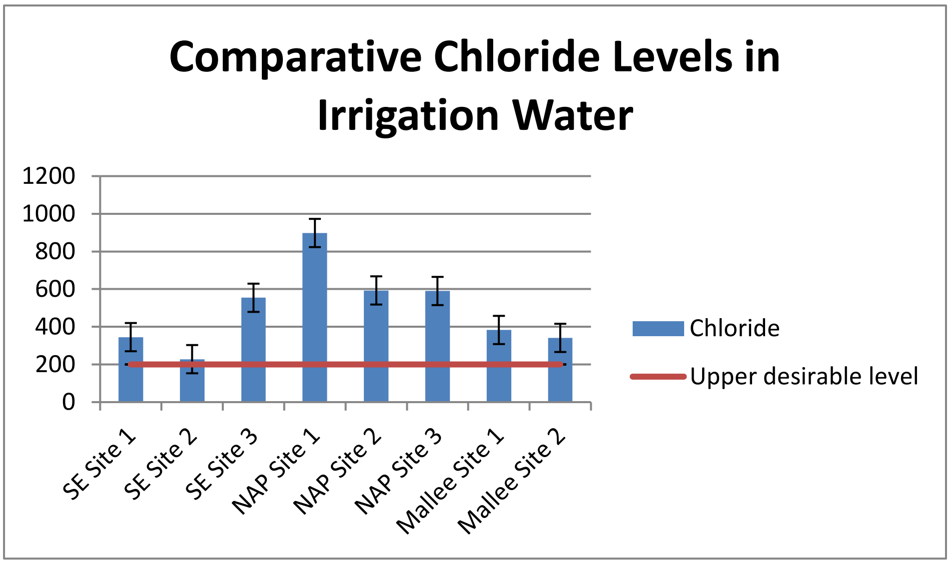
Appendix 5

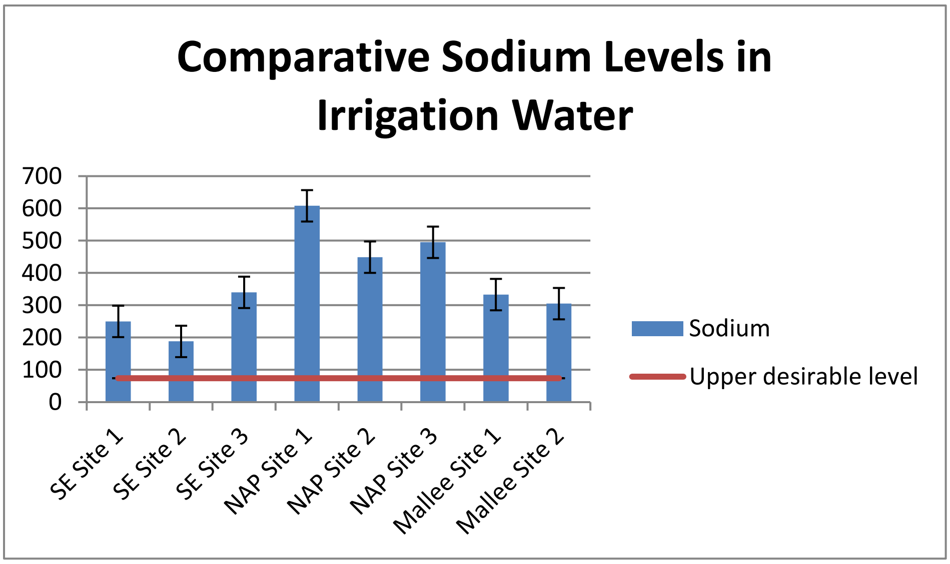
Summary of Year 1 key data sets from the Mallee, the South East and the Northern Adelaide Plains.

Irrigation water.

Irrigation water supplies were generally highly saline, with elevated chloride and sodium levels. Graphs 1 and 2 display the variability in chloride and sodium levels across the eight sites assessed, with all sites except one, well above the upper desirable levels recommended for irrigation. Irrigation waters in the Northern Adelaide Plains measured the greatest concentrations of sodium and chloride, with the South East measuring the least. Irrigation water supplies in the Northern Adelaide Plains differ to the traditional groundwater resources used in the other regions, where recycled water is predominantly used, stored in holding dams prior to application.

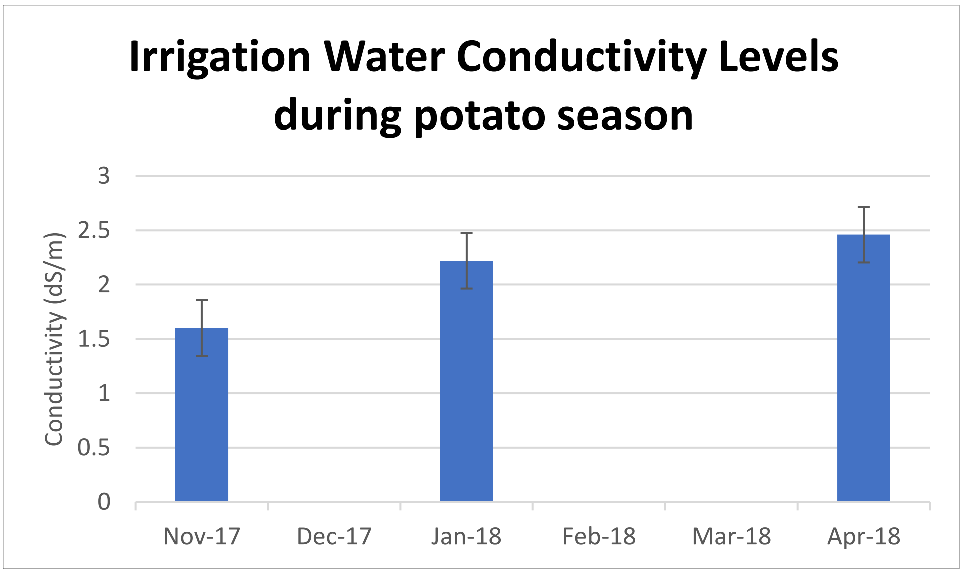
Graph 1. Irrigation water chloride levels measured across the potato growing regions of South Australia.





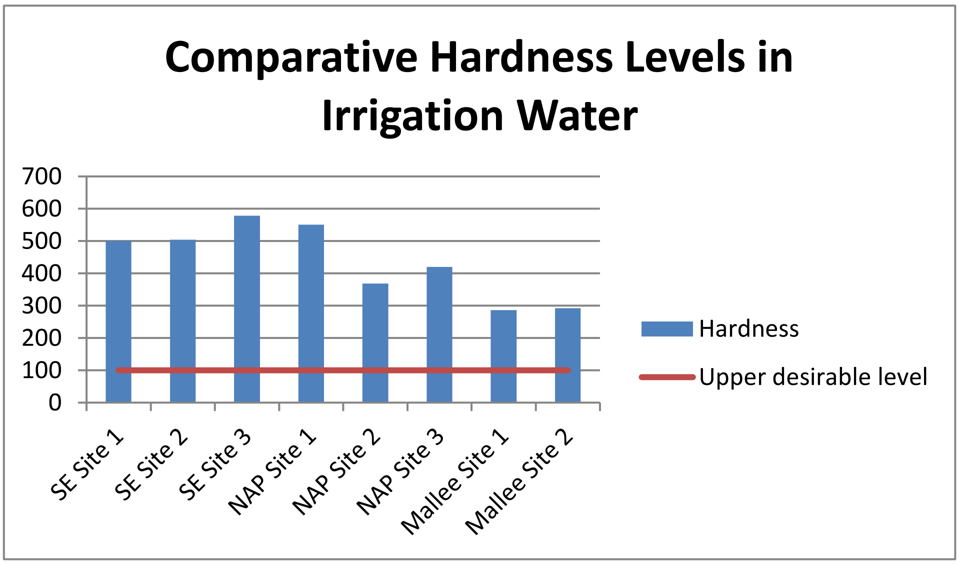
Graph 2. Irrigation water sodium levels measured across the potato growing regions of South Australia.

During year 1, additional water tests conducted within the South East, also showed that salinity levels increased for one grower from start to end of season, as seen in Graph 3. The start of season conductivity level falls just below the upper threshold level where a 10% crop loss could be expected. Throughout crop growth, it can be seen that the conductivity level of the irrigation water continues to rise, reaching 2.5dS/m, at which level a 25% loss in crop could be expected. This rise in irrigation water conductivity was primarily a result of increases in sodium and chloride, and was generally unexpected for the grower. A decline in plant health was however noticeable in an area defined with high conductivity and lower slope.



Graph 3. Irrigation water conductivity results for one site within the South East.

Additional to these harmful salts, irrigation waters were commonly hard and alkaline, adding further constraints to cropping and irrigation management.



Graph 4. Irrigation water hardness levels measured across the potato growing regions of South Australia

The hardness of irrigation water is defined by the levels of dissolved calcium carbonate, and generally contain dissolved calcium and magnesium salts, along with zinc, iron, manganese and aluminium. While sodium and chloride can affect both plant health and soil structure, hard irrigation water affects soil structure, creating indirect issues for plant health. Hard water used in agriculture can also lead to blockages in irrigation equipment through the build-up of calcium deposits. The hardness of irrigation water supplies was found to be a limiting factor for many growers in the adoption and implementation of variable rate irrigation practices. High soluble iron levels in irrigation water can also lead to growth of iron loving bacteria and additional blockages of irrigation equipment, although this was not raised as an issue by growers.

Several growers interviewed stated that they did not test their irrigation water supplies regularly. Given this lack of testing, combined with the high salinity levels measured across the potato growing regions assessed, led to increased testing scheduled for year 2 of the project, with early, mid and end season tests desirable.

Soil condition

Soil condition was assessed via a number of parameters, which collectively showed great variability within pivots, and between sites and regions. Information accessed via AgInsight and Water Connect web sites provide the following general site information.

The South East sites are characterized by generally shallow groundwater depths, ranging between 2 – 5m depth with long-term average conductivity levels of 1.5ds/m. Soils are variable, with sandy texture contrast soils or shallow soils over limestone in the south of the region, through to soils formed on relic coastal dunes with shallow soils on calcrete and deep sands in the northern areas. Land potential for potatoes varied from Class 5 – Low potential, to Class 2 – Moderate to High potential.

The areas of the Mallee were characterized by much deeper groundwater systems, ranging from 20 – 500m deep, with long term average conductivity levels of 2.5dS/m. Soils are variable, consisting of dunal swales with deep bleached sands and shallow sandy loams over poorly structured red clays. Land potential for potatoes range from Class 3 – moderate potential, to Class 5 – Low potential.

The Northern Adelaide Plains was generally characterized by shallow groundwater systems, with groundwater depth ranging from 2 – 5m in some areas through to 20m depth in others. Many areas of the Northern Adelaide Plains fell in regions not currently mapped for soils however, soil types were typically sandy loams over red clays, calcareous subsoils. Land potential for potatoes was not available for several sites, however for some sites this was classed moderate (Class 3) to moderately high (Class 2).

EM38 survey results showed great variability in apparent conductivity for the three sites assessed within the South East during Year 1. Unfortunately, the Mallee and the Northern Adelaide Plains could not be assessed due to time limitations between start of project and site preparations in readiness for planting.

Mapped data showed spatial changes in elevation, slope, depression, aspect, landscape change, landscape change zones, and importantly apparent conductivity. Figure 3 shows EM38 Conductivity results for three South East sites, each displaying great variability within the top 50cm of the soil profile, most indicative of the root zone conductivity to be experienced by the crop. These apparent conductivity results reflected both elevation, soil texture, moisture and depth, and soil EC1:5 results.

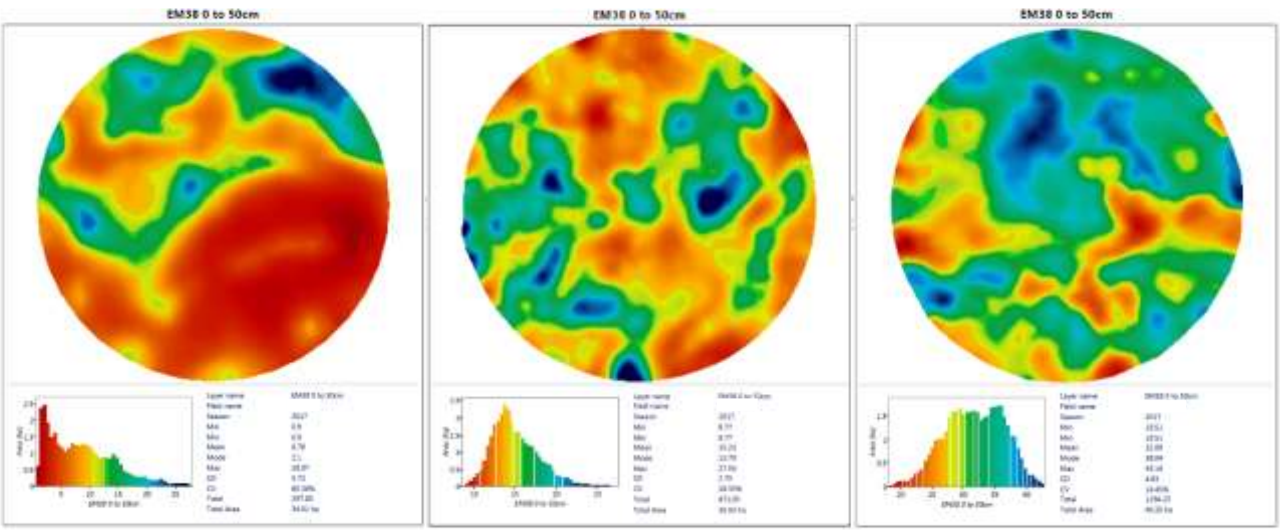


Figure 3. Apparent conductivity variability within pivots and between pivots within the South East.

The darker blue areas generally reflect lower slope, shallower soils where higher conductivity levels were, and in contrast the red areas are upper slope sites with deeper sands, greater flushing potential and typically lower conductivity. Importantly, while the colour scale indicates in-site variability, the colour scales are relevant to each site only, so it is critical that actual measured levels are referred to, and direct colour comparisons are not drawn between sites. The total area of each conductivity zone also varied greatly within and between pivots. The pivot to the left in Figure 3 had relatively little area affected by the higher salinity levels, compared to the pivot on the right, which had a much greater total area affected by higher salinity. From these three sites it can be seen that both spatial variability and severity of the apparent conductivity differ widely for growers, creating challenges for salinity and irrigation management for potato production.

Ground truthing of conductivity maps was conducted for each pivot, where soil pits were assessed within the different conductivity zones. Plate 5 shows soil variability across the many sites, where depth of sands varied greatly, and for some sites, groundwater perching over heavier shallow subsoils also occurred.

While EM38 mapping of all sites in Year 1 was not possible, the assessment of soil pits guided by landscape change and slope and AgInsight maps, generally revealed similar conditions. The Mallee soils were influenced by dunal swales with upper slope deep sands and lower slope shallow sands over heavier sub soils. The soils of the Northern Adelaide Plains were however less variable in both topography and soil texture, predominantly loamy sands over heavier red clay sub soils.

Plate 5. Soil pits reflecting variable soil conditions and perched watertables, experienced across different sites.

Soil Nutrient testing showed variability across the three regions, with sodium and chloride levels generally increasing from start to end of season for most sites (Figure 4). The South East soils were all slightly acidic pre plant, with ECse levels ranging between 2.1 and 3.7dS/m, above the average rootzone threshold of 1.7dS/m, with potential crop losses ranging between 10 and 25%. Post-harvest testing revealed increased pH levels, with minimal change in ECse levels. Sodium and chloride levels however, increased for all three sites. Pre plant levels were all well below upper threshold levels, with post-harvest levels up to 11 times higher and generally above the upper desirable levels.

The Mallee soils pre plant, were both alkaline, with ECse levels well below the threshold for potatoes, ranging from 0.7 to 1.3 dS/m. Post-harvest testing revealed increases in salinity with ECse levels between 1.9 and 2.5dS/m, and sodium and chloride levels elevated, but remaining within or near upper desirable limits.

The Northern Adelaide Plains soils pre plant, were all alkaline, with ECse levels all sitting at 4.4dS/m. Post-harvest sampling measured slight increases in alkalinity, slight increases in ECse levels, and increases in sodium and chloride levels by 2 to 3 times, all well above the upper desirable limits.

The increases in sodium and chloride across the three sites was influenced by both soil type and associated likeliness of leaching or accumulating, and the salt levels of the applied irrigation waters. Results generally indicate that soils across the three regions utilised for potato production are variable, have great potential to accumulate salts where sands are shallow and lie over heavier subsoils. Mallee soils are less likely to accumulate salts compared to the Northern Adelaide Plains due to larger areas of deeper sands and current 4-5 year cropping rotations. The South East showed the ability to accumulate harmful levels of salts within one season, however the 4 to 5 year cropping rotation in this region also allows the flushing of salts to occur with winter rains and general grazing of pastures. The Northern Adelaide Plains however does have predominantly heavier soils, and began the cropping season with higher sodium and chloride levels and continued accumulation throughout the potato crop.

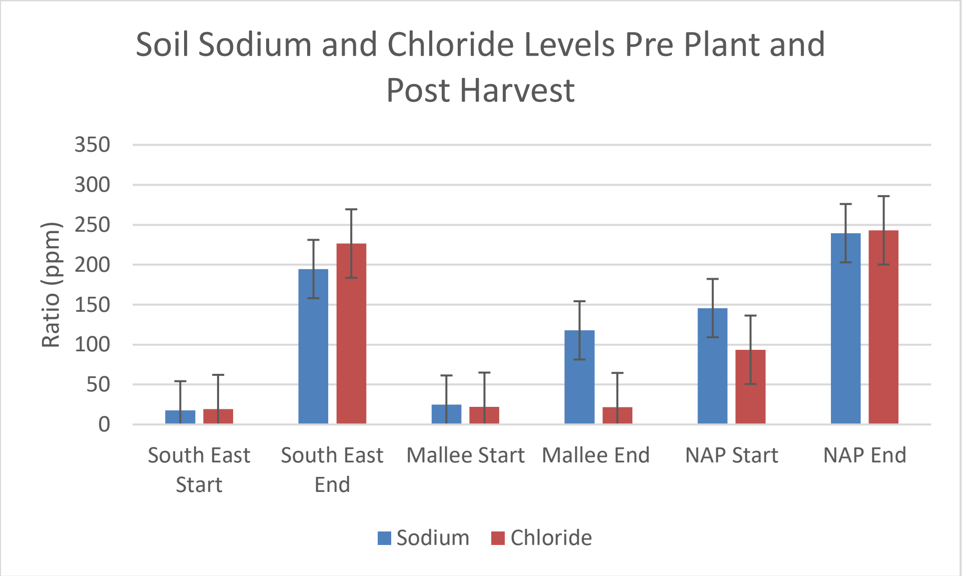
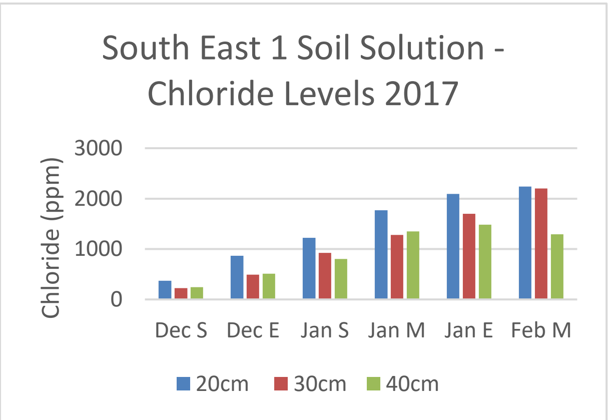
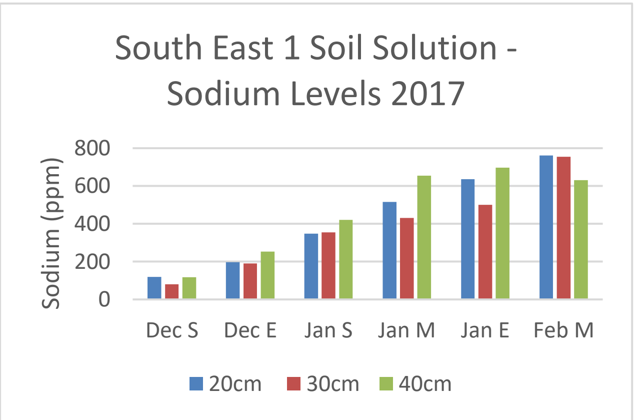


Figure 4. Regional examples showing increases in sodium and chloride following a season of irrigation

Soil solution results were measured across all sites throughout the potato crop. Installation generally occurred following the last scheduled hilling event, to ensure depth of installation was consistent. Sodium and chloride levels were well above the threshold for potatoes, which would have impacted on plant nutrient and moisture uptake, combined with less than optimal yields achieved at harvest.

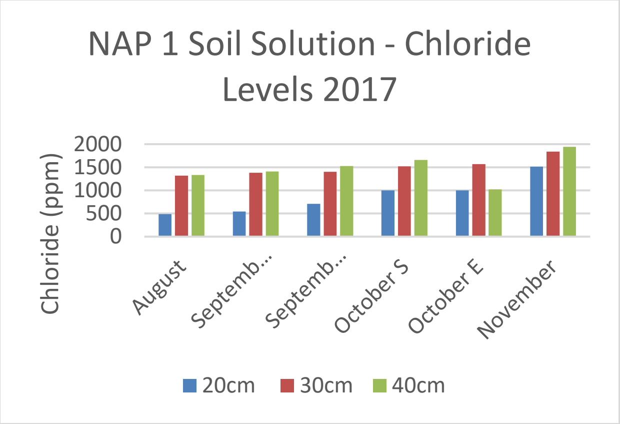
For the South East, very clear increases in sodium and chloride were measured throughout the potato season, occurring for each depth. Both salts were present at levels well above the upper threshold for potatoes, which would have influenced nutrient and moisture uptake increasingly during tuber growth.

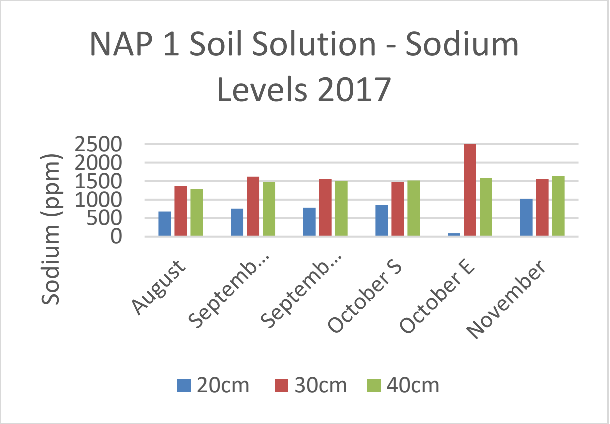




Figures 5 and 6. Chloride and sodium soil solution levels from one site representative of the South East.

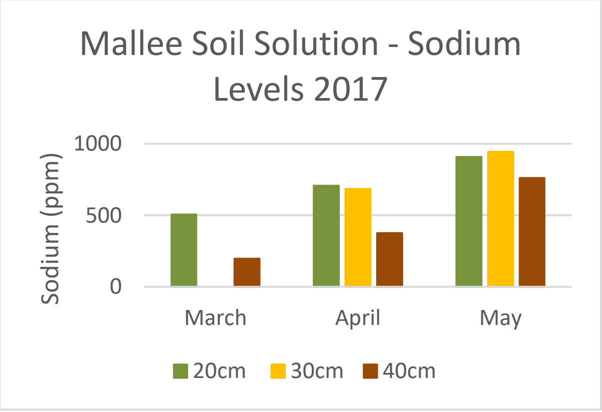
In the Northern Adelaide Plains, soil solution results varied between sites, but generally increased from season start to end as indicated in Figures 7 and 8. Both sodium and chloride levels were exceptionally high, also increasing with increasing depth. October sodium levels are an anomaly, and unexplained.

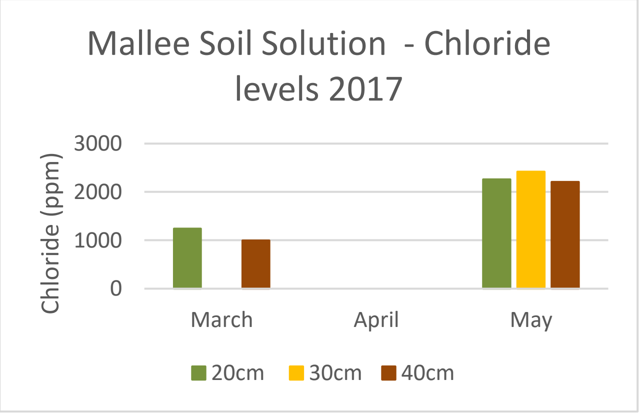




Figures 7 and 8. Chloride and sodium soil solution levels from one site in the Northern Adelaide Plains.

Within the Mallee, sodium and chloride levels increased from season start to season end, for all three depths assessed. For one site, the ability to extract soil solution was very limited, potentially due to the drying of the soil profile. Figure 9 shows higher sodium in the upper two depths compared to 40cm, with final levels nearing 1000ppm. Chloride levels showed a similar pattern (Figure 10), doubling from season start to end.





Figures 9 and 10. An example of Mallee soil solution sodium and chloride levels measured at different depths

Predicta Pt sampling was conducted at the start of the season for each region to determine potential disease risk, or population densities for pathogens that can lead to potato diseases and blemishes. Once again results varied between sites, and also between regions. This is likely to reflect soil type and textures, along with soil management activities, such as the use of chemical fumigants ahead of potatoes. Two sites in the Northern Adelaide Plains had no detection of pathogens. While this cannot state that no pathogens were present at all, it does indicate the likely chemical fumigation treatment of these soils which kills most living organisms.

In the Mallee, low levels of *Pratylenchus neglectus* were detected at both sites. *Rhizoctonia solani* AG 2.1 and 3, were both present in low to medium population densities for one site, while the other instead had low to medium disease risk detected for powdery scab (*S.subterranea*) and Black dot (*C.coccodes*).

In the South East, the presence and diversity of pathogens was much greater. One site had little diversity, with only a medium disease risk of Root Knot Nematode, and low to moderate population density of Verticillium dahlia. The other two sites were at much greater risk of disease, both with medium to high risk of powdery scab and black dot. Additionally, these sites hosted low to high population densities of *Rhizoctonia solani* 2.1, *Verticillium dahlia* and *Streptomyces txtA gene*, *Pratylencus crenatus, Pratylencus negectus* and *Meloidogyne hapla* were at low and medium population densities, and Root Knot Nematode disease risk was low to medium.

Key microbe groups were also analysed for each site at early planting. Results in many ways reflect the pathogen diversity across the regions, although common microbial analyses for all sites stated poor or limited nutrient accessibility and cycling, low disease and drought resistance and poor aeration of compacted soils. Diversity and balance of microbes was generally fair to good in the South East, fair to good in the Mallee and fair to poor in the Northern Adelaide Plains. Mycorrhizal fungi levels and fungi to bacteria ratios were generally fair to poor, however levels in the South East for two sites were more pleasing.

SAP testing

Potato petiole samples were regularly collected for SAP analyses. Results again show trends within each region, although variations do occur, most likely a result of in-crop nutrition management.

The South East test results generally showed high to very high levels of sodium and chloride. Nearly all trace elements were below optimum for all sites, while phosphorous, potassium and sulphur were also generally low. Calcium and magnesium levels were however generally high, broadly reflecting soil and irrigation water quality.

Both Mallee sites had consistent high levels of chloride, which reflected in lower levels of nitrate. Sodium differed between the two sites, being very high for one and moderate to high for the other. Where sodium was very high, many other elements were also very high, such as sulphur and magnesium, and trace elements molybdenum, zinc and boron. Where sodium levels were lower, most other elements were near optimum, although copper was low, and phosphorous and sulphur were trending high.

For the Norther Adelaide Plains, sodium and chloride levels were generally managed well, reflecting in adequate levels of both nitrate and potassium throughout the season. Calcium levels were low for two sites during early tuber development, combined with low levels of trace elements. Phosphorous levels were generally good, but were low for one site during the last 6 weeks of tuber bulking.

Other influential site conditions

In discussion with growers, along with general site observations, extended periods of extreme heat were causing difficulties in some regions, particularly the Mallee, in providing sufficient irrigation water to maintain adequate soil moisture levels for the tubers. Pivots at times were operating day and night, to relieve heat stress during the day and provide essential soil moisture to the root systems during the night. Such conditions would exacerbate salinity stress to plants from direct contact of salts applied during hot windy days, decreasing plant health and function, but also leading to the addition of further harmful salts to the soils.

Combined with this heat stress, a number of sites assessed across the three regions were observed to suffer from hydrophobicity, where the sands repel water and are extremely difficult to wet and maintain uniform rootzone moisture levels. Plate 6 highlights the inability to wet soils, showing powder dry sands under a thin wet crust following water application. The implications from this inability to easily wet and maintain soils during potato production, can lead to increased costs of production via higher water use, diesel costs, addition of salts to soils.

Plate 6. Hydrophobic sands of the South East South Australia.