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).

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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.

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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 ($EC_{1:5}$), 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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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.

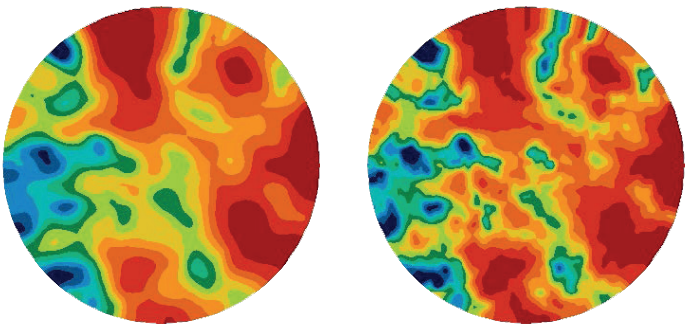

Figure 2: Electromagnetic Induction surveys at 100cm (L) and 50cm (R) depths, showing the spatial variation in soils and likely areas of salinity.

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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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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.

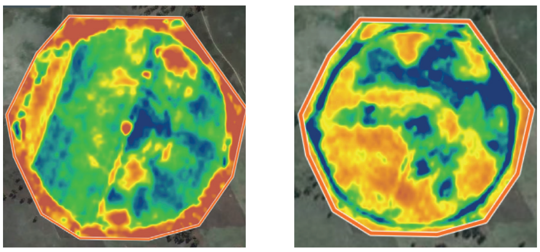

Figure 4: Satellite NDVI imagery taken at week 5 (L) and week 15 (R) of a potato crop in SA.

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.

References and further reading
Potatoes SA | Precision Mapping in Potatoes – Does it tell us anything we don't already know? PIRSA (2019) | AgInsight South Australia | WaterConnect | Enviro Data SA – NatureMaps | Introducing practical tools and an implementation framework to manage the salt applied in irrigation water, Thomson, T. (2008), 2nd International Salinity Forum, Adelaide SA.