KIT 1.7

Reduce the impacts of soil salinity and sodicity on plant water uptake to improve grain yield and stability

Impact	**Growers are able to correctly identify soil salinity and sodicity constraints that impact yield and have access to cost-effective options for reducing the impact of those constraints.**
Summary	• Growers understand the impact of saline and sodic soil constraints on yield and yield stability. • Growers have access to cost-effective management options for saline and sodic soil constraints. • Growers understand the whole-of-farm business implications of implementing management options to overcome those constraints.

OVERVIEW

There is much already known regarding the impact of soil sodicity and salinity on plant water uptake and the resulting yield limitation these soil constraints create. It is estimated that sodicity represents a missed annual yield potential to the Australian grains industry of $1.3 billion and salinity $0.3 billion (Orton et al. 2018). Diagnosis of these constraints is problematic because of the large extent of spatial variability and the varying degree of impact this has across growing regions, farms and paddocks. Management is difficult because these constraints do not occur in isolation but rather are influenced by a range of interacting environmental impacts. There is also a gap in individual grain grower's understanding of the impact of sodicity on their cropping area and the extent to which this is causing economic loss. This lack of understanding has resulted in growers placing a lower priority on overcoming these constraints as they do not clearly understand the potential return on investment (ROI) of mitigation.

Sodicity and salinity are known constraints to cropping soils, reducing crop productivity that impact plant available water (PAW) across much of the Australian grain industry (Dang et al. 2008). Our analysis indicates that of the two soil constraints addressed by this strategy, sub-soil sodicity has the greatest overall impact. Sodic soils have an excess of sodium which causes soil dispersion. Soil swelling and dispersion is a physical barrier to plant development by restricting root growth which in turn limits plant access to water, aeration and nutrients. Sodic soils are also highly susceptible to erosion. Saline soils have high electrical conductivity and high chloride concentrations which are toxic for many crop species. The excess levels of dissolvable salts, principally sodium (Na^+) and chlorides (Cl^-), in saline soils chemically impact plant growth in the subsoils by reducing rooting depth, increasing osmotic potential and chloride toxicity.

The estimates of the cost to grain growers of these two problems is high. Soil sodicity is estimated to affect 26.3 million ha of agricultural land generally and cost grain growers $1.3 billion/annum in lost production. Soil salinity is estimated to affect 9.3 million ha and cost growers $270 million/annum, mainly in Western Australia. Reducing the impact of both could improve root growth and water uptake to increase yield.

Grain growers seem largely unaware of the true impact of these constraints on their farms as both constraints currently require laboratory work to diagnose spatially at paddock level. The high cost of field mapping makes it challenging for growers to evaluate the potential return on investment of any outlay on amelioration options. Whilst there have been many research investments to determine surface amelioration options the potential impact of methods for sub-surface amelioration are not well understood.

Some level of genetic tolerance to salinity in some crop species is known however genetic tools to enhance plant performance in sodic soils has not been identified. Plant breeders are focussed on yield with no strong market impetus to concentrate on traits which could assist in combating sodicity, such as increasing the plant's ability to punch through soil crusting at emergence.

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A number of key assumptions underpin this KIT strategy. Reducing the impact of sodicity and salinity will be considered in the operational context of broader overall farming system decisions. This strategy recognises that potential high cost amelioration will require a whole of farming systems analysis, requiring evidence of strong financial drivers.

The scope of this strategy includes site specific and spatial diagnostics, including understanding the data gap as it impacts individual crop management decisions. All potential amelioration options have been considered within scope of this strategy i.e. chemical, organic and mechanical. Also, under consideration are potential genetic solutions.

Economics and logistics of various amelioration options, for example freight on gypsum and the costs of placing ameliorants at depth, were considered within scope and it was determined that extension and demonstration should focus on understanding the complexity and economics of sodicity and salinity.

The use of pasture in the crop rotation as a potential ameliorant was considered in scope however the performance of livestock on these pastures was not considered as being within scope. Also noted as being outside of scope are catchment and farm planning as much work has already been done in this space via initiatives such as previous Landcare projects.

FUTURE RD&E FOCUS

SCOPE – Understanding of saline and sodic soil constraints

Improved salinity and sodicity diagnosis options and tools are identified and developed. The mechanisms by which salinity and sodicity impact yield and yield stability are better understood.

To better understand saline and sodic soil constraints growers require improved salinity and sodicity diagnosis options and tools. This will lead growers to a closer understanding of the mechanisms by which salinity and sodicity impact yield and yield stability.

Investment Outcome 1.7.1 – Growers and researchers have access to field diagnostic tools that efficiently and effectively estimate the severity of salinity and sodicity and their impacts on yield and yield stability.

In-field diagnostic tools - which are affordable and readily available will enable growers to gain an understanding of the area and degree of soil sodicity and salinity at various depths across their paddocks. This understanding will assist growers with decisions such as crop choice, amelioration options and the relative benefits, if any, of undertaking amelioration. Combined with digital mapping, diagnostic tools may also inform variable rate and depth delivery systems and thereby enable growers to economically treat multiple constraints in one pass.

Sodicity and salinity reduce the crop plant's ability to take up water. Field diagnostic tools to measure plant available water in real time, combined with data from a constraints diagnostic tool will enable growers to assess the full impact of these constraints and thereby determine the potential yield response from a range of amelioration options. The capacity for grain growers to accurately calculate potential return on investment (ROI) is the key to grower's ability to consider their amelioration options. If amelioration is to be funded by debt this calculation will also provide a debt funding framework.

Investment Outcome 1.7.2 – Growers and researchers have knowledge of the causes of salinity and sodicity and their impact on yield and yield stability.

At present grain growers are largely unaware of the area and extent of sodicity and salinity on their farms. In some instances, there is an anecdotal understanding of on-farm sodicity and salinity limitations however growers are largely simply living with these constraints. Sodicity management can be further complicated by having other accompanying constraints such as acidity or salinity and these limitations need to be considered. In order to ensure the saline constrained areas do not increase, growers need a comprehensive understanding of how and why both this constraint originated and what can be done to lessen future impact.

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SCOPE – Management options for salinity and sodicity

Management options to raise yield in saline and sodic soils are identified and developed.

Growers require further management options for salinity and sodicity and an understating of how these may be employed on their own farm.

Investment Outcome 1.7.3 – Growers understand current options to overcome salinity and sodicity.

Previous research has led to some knowledge regarding the management of soil sodicity and salinity, however further extension, communication and demonstration is warranted to increase growers' understanding of the potential benefit of amelioration (Page et al. 2008). To assist growers to understand the current options available to overcome salinity and sodicity there is value in building advisory capacity for the Australian grains industry in diagnosing and understanding soil constraints and management options.

Much is known surrounding the impact of salinity on crop growth and yield due to the presence of salt in the root zone. The current focus being on managing water movement down the profile and salt leaching below root zones especially for sensitive species and cultivars. Further extension of this work is warranted combined with the ability to fully understand the return on investment of land management practices across paddocks to reduce salinity.

Whilst GRDC know that increases in crop yield on sodic soils are possible through the traditional soil ameliorant treatment of applying surface gypsum it is less well known how long this treatment lasts, its effect when applied at various depths and how it may be effectively applied at depth, particularly in no-till farming systems. The current range of known ameliorants requires full characterisation for their relative effectiveness, cost, ease of application and impact.

Investment Outcome 1.7.4 – Growers have access to new cost-effective and novel options for dealing with salinity and sodicity.

Whilst there are some known soil amelioration options to address sodicity and salinity GRDC are yet to fully explore the use of novel amelioration options from other industry sectors such as mining and manufacturing and the newly developing recyclables sector. Exploration of amelioration options currently employed by sectors other than agriculture should also assist in identify potential pathways to market. Exploration of novel amelioration options and/or re-engineering of the soil should also consider the potential impacts on the whole farming business and farming systems.

Whilst some novel amelioration options have been proposed, further work is required to understand the potential impact of these. These novel options include, but are not limited to, the impact of treating sodic soils with acidifying agents, such as elemental sulphur or sulphuric acid. It would be worthwhile to understand how organic amendments on their own, or in combination with gypsum, affect crop yields and how acid producing biological processes can be incorporated into farming systems to help acidify alkaline sodic soils to thereby release calcium from calcium carbonate to improve soil structure. Also, to be considered is the development of novel methods of delivering ameliorants in formats such as pelletisation, emulsifiable concentrates and /or nanoparticles should be considered as well as biological amelioration methods.

To ensure chemical or organic ameliorants are cost-effective further RD&E is required on ensuring operational logistics, such as freight and the cost of various application techniques, are considered in the assessment of potential options. Options designed specifically to deliver a range of amelioration materials for mixing at depth is also required. Any machinery options will need to be energy efficient and therefore cost effective.

SCOPE – Integration of solutions to salinity and sodicity in farming systems

The enduring economic implications and risks of different options to overcome salinity and sodicity in a whole-of-farm business context are better understood.

Growers wish to better understand the integration of solutions to salinity and sodicity in their farming system and the enduring economic implications and risks of different options to overcome salinity and sodicity in a whole-of-farm business context, including the implication of doing nothing.

Investment Outcome 1.7.5 – Growers have knowledge of the enduring economic benefits and risks of different options to overcome salinity and sodicity.

There is a current knowledge gap regarding the potential economic benefit of the various approaches to amelioration of sodic and saline soils and their ongoing return on investment. As discussed above an improved ability to fully diagnose the extent of grower's sodicity and salinity will enable an informed calculation of the economic benefit, if any, of the various treatment options. This will enable growers to assess the risk of not treating these constraints versus the potential increase in yield and profitability of a whole of farm amelioration strategy across seasons. Cost calculators should include the expense of - constraint diagnosis by paddock, amelioration "product", freight and cost of application or land re-engineering against the expected duration of effectiveness.

Investment Outcome 1.7.6 – Growers have access to tools to assess the whole-of-farm business impact (including on capital value) and risks of different options to overcome salinity and sodicity.

If GRDC view soil as a grain grower's primary capital asset, soil amelioration can therefore be viewed as a capital expenditure rather than an annual cropping cost to be accounted for in single year gross margin calculators. Improved knowledge of the impact on yield combined with an economic assessment tool will enable growers to undertake clear analysis of the yield gap and the potential gain over time if sodic and saline soils are treated with ameliorants or the landscape or part of the landscape structure is changed. Such tools may also be useable by industry (finance sector) to justify the capital expenditure of amelioration options. At present there is limited understanding by growers and the finance sector surrounding the full impact of undertaking soil amelioration to improve grain production and subsequently the potential impact on land value. Do practices such as ameliorating for sodicity and salinity constraints deliver long term productivity benefits or reduce the risk of long-term decline? What, if any, is the impact of this on the capital value of the farm business? What is the risk of doing nothing?

Investment Outcome 1.7.7 – Growers have access to crop types and farming systems to optimise yield and profitability on soils where salinity and sodicity constraints have been addressed.

Soil constraints such as sodicity and salinity do not occur in isolation and are likely to have mixed responses over time. Further understanding of the true impact of these constrains on a range of different farming systems is required.

Changing the soil condition to address sodicity or salinity will alter the response of crops differentially within a given farming system. Investment in managing soil sodicity and salinity may not provide the same benefit to all farms in the same manner. It is important to understand the impact of these changes on yield across the system in a whole-of-farm economic sense over time.

Further evaluation of the genetic traits that perform best on constrained soils will assist growers to optimise yield. Some research has already been conducted on the relative impact of salinity on some cereal germplasm however, there is a need for further exploration to identify suitable genetic traits for other crop types such as canola, pulses and sorghum (Xu, D. et al 2012, Spiegare et al. 2017, Asif et al. 2019). Noting that Australian plant breeders are motivated by market demand, as perceived by the seed companies, it is thought that an improved understanding of the degree of impact and economic cost to the grain industry will encourage breeding companies to develop robust, high yielding varieties that thrive in saline environments. Whilst GRDC have knowledge of some genetic traits that provide saline tolerance in certain plants, there is an opportunity to improve this somewhat limited knowledge by enhancing tools for phenotyping. As researchers find further traits and diversity, and GRDC are able to demonstrate value by testing in a range of environments, it is expected that this will translate into breeding programs thereby closing the gap between research and industry.

The complexity and diversity of Australia's sodic soils has limited the efforts of researchers and breeders to find genetic solutions to this constraint. A better classification of sodic soils, with an understanding of what the major driver is for the yield gap in each "sodic soil", may assist in focusing these efforts. In the past breeders and pre-breeders have largely selected for individual stresses such as boron toxicity, high pH and salinity and have incorporated greater levels of tolerance sequentially over time. Many of the most successful and widely adapted varieties developed by breeders for the southern and western grain regions have some level of tolerance to one or more of the constraints associated with sodic soils.

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