Targeted amelioration in Mallee sands to maximise crop water use

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Take home messages

- Across the Southern region research trials which target physical constraints (without significant repellence or subsoil toxicities) have demonstrated positive first-year responses to deep ripping ranging from 0.2t/ha to 1.2t/ha, with an average gain of 0.6t/ha.
- While most trials demonstrate multiple years benefit from ripping, yield penalties have been evident following consecutive drought years in 2018 and 2019, which appear to be greater in soils ripped deeper (60cm versus 30cm).
- Across project trials with water repellence and where subsoil toxicities are not present, spading treatments show an average annual yield response of +0.8t/ha.
- Although spading remains the more effective amelioration approach on repellent sands, inclusion-ripping has shown smaller benefits that persist over multiple years.
- Reliable and effective inclusion of topsoil is strongly influenced by operating conditions (e.g., moisture, operating depth and speed), but enhancements to design alongside and operation set-up could improve inclusion-ripping outcomes.
- When considering amelioration of sandy soils in low rainfall environments, it is useful to estimate the yield gap and evaluate seasonal risks that could limit the size and longevity of benefits.

Background

Uptake of amelioration practices to improve the productivity of sandy soils in the Southern region has gained strong momentum in recent years. These practices include deep ripping which aims to shatter hard or compacted layers, and deep ploughing and spading which aim to mix and dilute repellent or hostile layers, and/or incorporate topsoil into bleached deeper layers. Additionally, inclusion-ripping, deep ploughing and spading practices offer opportunities to incorporate amendments or fertilisers into the profile to improve soil condition or nutrient supply. Amelioration practices invariably incur an upfront cost ranging from around $60/ha (e.g. shallow ripping) to several hundred dollars depending on the machinery running costs, work rate, depth of operation, and amendments applied. First year responses are often positive but return on investment can require benefits over multiple seasons. Multi-year benefits can be challenging in a water limited environment with high seasonal variability, or where amelioration effects may be short-lived. The impact of the quality of soil and amendment mixing and/or inclusion is often not considered.

Building on previous amelioration trials (PIRSA New Horizons est. 2014, Trengove et al. 2015), CSP00203 research aims to improve the diagnosis and management of primary soil constraints across deep sandy soil in the Southern region's low-medium rainfall environment. Including 10 research trials (5 years) and 18 validation trials (3 years) the research project is working to define which sandy environments and amelioration treatments are more likely to provide strong return on investment, and where environmental risks or short-lived effects are likely to limit potential benefits.

CSP00203 research and validation trial overview

A range of research experiments have been established across the Southern region low to medium rainfall environment with estimated yield gaps of between 1.9 - 5.2t/ha, or greater in higher rainfall environments (Table 1). Sites are categorised according to the primary soil constraints identified. Research experiments were established between 2014 and 2019 and include a range of deep ripping and/or ploughing approaches, with/without additional amendments (fertiliser, N-rich hay, chicken manure, clay). Research experiments are supported by validation trials established in 2019-2020 which aim to evaluate responses more broadly across sandy environments. All trials monitored the impact of amelioration on crop growth and yield. Research trials include more intensive measurements to understand the impact of amelioration on crop water use and soil constraints over time.

This paper discusses findings relating to deep tillage practices (ripping, spading) alone, without including responses to incorporation of amendments. Findings report the range of yield responses to deep tillage for: a) sands without water repellence issues where physical constraints have been targeted through ripping-based practices; b) water-repellent sands where approaches have focused on spading and/or inclusion ripping to disrupt repellent layers and physical constraints. All sandy sites are considered to have inherently low biological fertility with topsoil (0-10 cm) organic carbon contents of between 0.3% and 0.7%.

Table 1. Summary of research and validation sites targeting a range of different constraints including the long-term growing season rainfall (mm), an estimated yield gap (t/ha, based on water limited potential minus current attainable yields), an indication of the target soil constraints, and an overview of the deep tillage practices and amendment treatments.

Research Site_Yr Established		**GS Rain** (mm)	**Yield Gap** (t/ha)	**Amelioration** (focus treatments for this analysis)	**Validation Trials** ***(est 2019, 2020)***
Physical constraints and low inherent nutrition (*plus acidity)					
Bute 2015	Yorke Pen.	298	3.0	Deep ripping approaches including depths between 30 - 60 cm aiming to overcome	Telopea Downs, Kooloonong, Buckleboo Karkoo, Walpeup, Monia Gap.
Bute 2018		298	3.0		
Yenda* 2017	NSW	252	3.3		
Lowaldie 2019	SA Mallee	235	3.5		
Ouyen 2017	VIC Mallee	213	3.0		

Carwarp 2018		174	2.5	physical constraints	
Waikerie_2018	SA Mallee	157	1.9	through shattering.	
Water repellency, physical constraints and low inherent nutrition (*plus acidity)					
Cadgee* 2014	Upper SE	410	6.2	Mixing (spading) and	Warnertown, Kybunga,
Brimpton 2014	Eyre Pen.	377	5.3	inclusion ripping	Tempy, Karoonda, Mt.
Murlong 2018		251	3.7	(Murlong) aiming to	Damper, Younghusband,
Karoonda 2014	SA Mallee	235	3.5	disrupt repellent layers and physical constraints.	Sherwood, Malinong

Results and discussion

Ripping deep sands with physical constraints - shattering to maximise root exploration

Yield responses to ripping across seven research trials (2017-2020) and two validation trials with physical constraints are summarised in Figure 1. Except for one non-responsive site, all sites demonstrated a positive response to ripping in the first year (Figure 1b). Yield gains ranged from 0.2t/ha to 1.2t/ha, with an average gain of 0.59t/ha. These responses are similar to those reported by Dzoma *et al.* (2020) across five site x years at Loxton, Peebinga and Buckleboo. The non-responsive example is the only project site with severe subsoil acidity (Yenda, NSW) which has shown larger responses to nutrition compared to physical interventions (ripping 30cm, deep sweep tine) over four years of monitoring. Seasonal conditions at Yenda have been unfavourable including consecutive drought years and frequent frost events.

Across the remaining trial sites responses in years after the ripping treatments demonstrate an average yield gain of 0.3t/ha, but also include a higher incidence of yield penalties of up to -0.6t/ha. All observed yield penalties relate to the 2019 season and represent a consecutive year of dry seasonal conditions. Ripping responses in the more favourable 2020 season show benefits ranging between 0.3t/ha and 0.9t/ha at responsive sites, including those that suffered penalties in 2019.

Cumulative yield responses across seven multi-year research trials are summarised in Figure 2. Three sites (Bute'15, Lowaldie, and Ouyen) demonstrated cumulative gains over multiple seasons, while three did not (Bute'18, Carwarp, Waikerie). Response variability highlights the importance of understanding where responses are driven by seasonal risks and where soil constraints have not been adequately ameliorated for long-term effect. At two lower rainfall sites established in 2018, small positive responses to ripping in the first year (decile 1) were negated by yield penalties in the second year (decile 1). Second year penalties were larger in deeper ripped treatments (60cm compared to 30cm) despite physical constraints extending beyond 30cm depth. After three years, there was no cumulative yield benefit which highlights risks in environments where consecutive drought years can limit profile re-charge. While the ripping effects at these low rainfall sites (Carwarp, Waikerie) have had small positive gains in two seasons out of three, it will require positive responses in the 4th year to achieve an overall positive return on investment. In these Mallee environments, early positive responses in a particular season are often, but not always, a guide to future cost:benefit performance.

Despite being geographically close, cumulative yield gains from ripping at Bute'18 (a bleached grey sand) have been limited compared to responses at the Bute'15 trial (a red sand, Trengove *et al.* 2018). Comparison of these two trial sites under a similar rainfall environment emphasises the driving role of sand type and the nature and severity of constraints. Soil characterisation indicates contrasting physical constraints and subsoil properties (e.g. presence of kaolinite clay, calcite, silica, and iron). Physical constraints in sandy soils can result from physical processes alone (e.g. tight packing of particles to give a high bulk density) or from chemical processes which bind or cement particles together as the profile dries. Further research is underway to identify the causes and behaviour of subsoil settling and/or cementing in these sandy environments and its potential role in limiting long-term effects of amelioration.

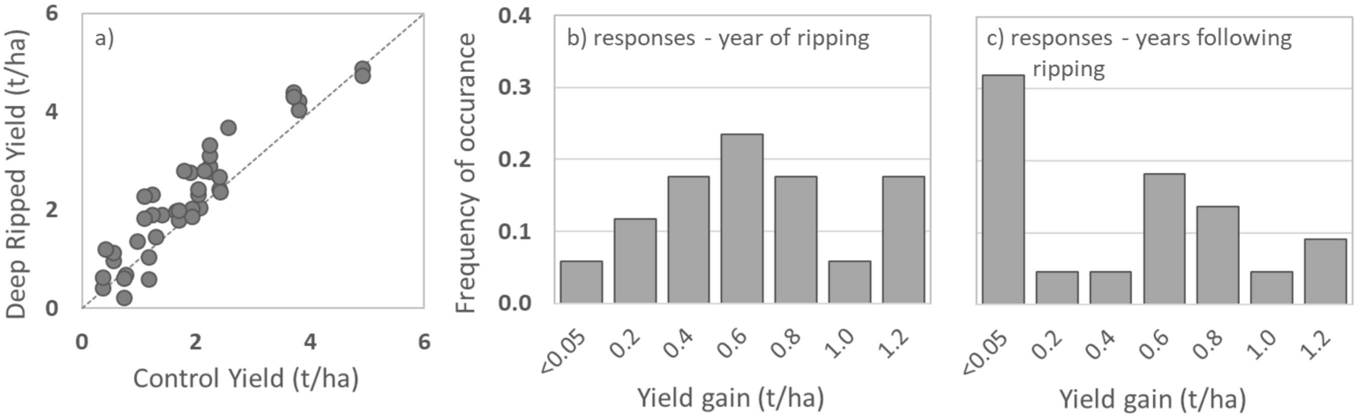

Figure 1. Annual crop yield (t/ha) responses to deep ripping in sands where physical issues are considered dominant including: a) biplot demonstrating unmodified control yields against deep ripped yields; and frequency distributions of yield gains (ripped yield – control yield) in the year of ripping (b) and subsequent years following ripping (c) across CSP00203 trial sites. Data represent treatment averages from seven research trials (multiple years, *n=4*) and two validation trials (single year, *n=3*) with a total of 40 response years.

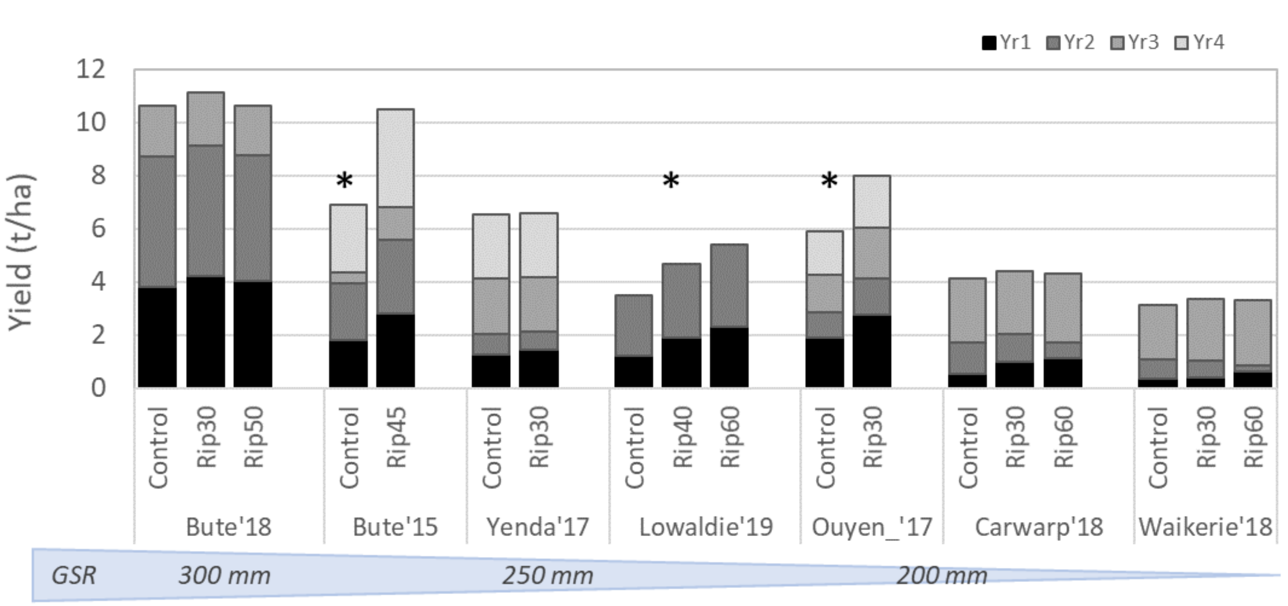

Figure 2. Cumulative yield responses (t/ha) across seven research sites (site & year of establishment) in unmodified (control) and ripped treatments (rip depth cm). Data are averages of four field

replicates, with * indicating significant (P<0.05) cumulative gains. Sites are ordered according to longer-term average annual rainfall. All sites have inherently low fertility and physical constraints.

Water repellent sands – mixing to maximise water capture and root exploration

Early research trials led by PIRSA (New Horizons 2014-2018) demonstrated that spading can have long-term yield impact on water repellent sands with physical constraints, providing subsoil chemical toxicities are not present. Five years of monitoring two research sites (Karoonda, Brimpton Lake) showed ongoing establishment, biomass, and/or yield gains. At Cadgee, where physical constraints were less evident but severe subsurface acidity was present, detrimental effects to spading continued for multiple years. Amelioration strategies of acidic soils is reported by Hughes at Adelaide GRDC Grains Research Update 2021.

Within the current project a fourth research site at Murlong and seven validation trials continue to improve our understanding of amelioration responses in repellent sands (Figure 3a), including comparing spading and alternative deep tillage practices (Figure 3b). Where subsoil toxicities are not present, these trials report an average annual yield response of +0.8t/ha, including examples of substantial gains (+1.8t/ha), as well as neutral responses in some seasons (Figure 3a).

Spading offers long-term benefits on repellent sands, but practical challenges include trafficking and managing seed depth for successful crop establisment, and erosion risk. One-pass operations to simultaneously spade and seed, when conducted into a moist profile, can have advantages including minimising erosion risks, securing uniform crop establishment and increasing flexibility of when spading might be implemented within the crop rotation.

While spading is the most effective approach to mix and dilute repellent layers, alternative deep tillage practices can offer some benefit by disrupting water repellent layers, or by overcoming co-occuring physical constraints to root growth. Comparison of spading to inclusion ripping at a severely repellent sand at Murlong demonstrate intermediate benefits from inclusion ripping (Figure 3b). A cumulative three-year benefit of 2.9t/ha was achieved from spading under a wheat (+1.4t/ha), barley (+0.9t/ha), and vetch (+0.6t/ha) rotation. Inclusion ripping provided cumulative gains of +1.4t/ha and 2.2t/ha at 30cm and 40cm depths, respectively.

Although inclusion ripping may appear an attractive option, topsoil inclusion and crop response variability alongside elevated running costs pose challenges for reliable return on investment. Trials on sandy soils in Western Australia and South Australia showed higher draft requirements (+24% to +40%), reduced workrate (-24%), and extra fuel use (+3.7L/ha) with baseline inclusion ripping compared to ripping alone (Parker *et al.* 2019). Engineering research using simulation modelling indicates opportunities to optimise the design of inclusion plates which may improve reliability. Field validation (Ucgul *et al.* 2019) demonstrate how effective depth and quantity of inclusion can be increased by lengthening the plates. A trial conducted on a repellent sand at Young Husband in 2020 produced yield benefits of 0.75t/ha from inclusion-ripping with modified 600mm plates, over and above deep ripping alone (3.9 t/ha) where the untreated control yield was 2.8t/ha. While effective inclusion of topsoil is strongly influenced by operating conditions (e.g., moisture, operatiing depth and speed), opportunities exist for this amelioration approach through design modification alongside optimising machinery set-up and operation.

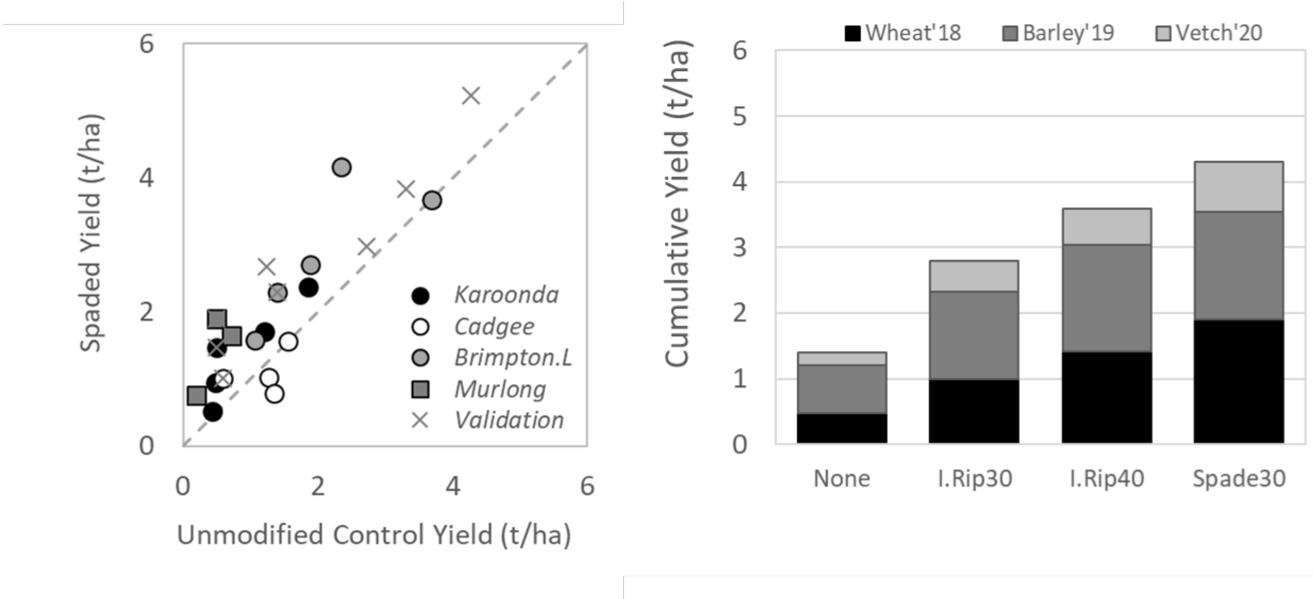

Figure 3. Yield responses in water repellent sands including: a) comparison of unmodified control yields and spaded yields at multi-year research trials (different symbols) and first year validation trials (X); b) cumulative crop yield (t/ha) responses in a severely repellent sand (Murlong) including the unmodified control, inclusion ripping to 30cm or 40cm (I.Rip30, I.Rip40) and spading (spade30).

Conclusion

Although CSP00203 research trials demonstrate that yield responses can be highly variable in the seasons following amelioration of sandy soils, the majority of responses were positive. Many trials demonstrate ongoing positive effects for more than three seasons after implementation, while some demonstrate limited responses due to poor seasonal conditions or where subsoil constraints have not been adequately overcome. All sites across the Southern region which target physical constraints (without significant repellence or subsoil toxicities) demonstrated positive first-year responses to deep ripping ranging from 0.2t/ha to 1.2t/ha. While most trials produced multiple years benefit from ripping, yield penalties were evident following consecutive drought years in 2018 and 2019, with greater penalties in soils ripped deeper (60 cm versus 30 cm). These results demonstrate that early positive responses to soil amelioration in a particular season are not always an indicator of future cost:benefit performance.

In trials with water repellence, spading treatments showed an average annual yield response of +0.8 t/ha. Although spading remains the more effective amelioration approach in repellent sands, inclusion-ripping has shown smaller benefits that persist over multiple years. Reliable and effective inclusion of topsoil is strongly influenced by operating conditions (e.g., moisture, operating depth and speed), but design and operation set-up enhancements could provide opportunities to improve inclusion-ripping outcomes. Central to cost effective amelioration of sandy soils in the Mallee environment is identifying and prioritising the primary soil constraints and implementing appropriate practices that improve soil condition for enhanced root exploration and water use for multiple season benefits.

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Useful resources

GRDC Deep Ripping Factsheet
(https://grdc.com.au/__data/assets/pdf_file/0028/91756/grdc_fs_deepripping_lr.pdf)

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